Topical Rev. Notes

CONTENTS

TOPIC 1 Physical Quantities, Units and Measurement

Objectives

Candidates should be able to:

(a) show understanding that all physical quantities consist of a numerical magnitude and a unit
(b) recall the following base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K), amount of substance (mol)
(c) use the following prefixes and their symbols to indicate decimal sub-multiples and multiples of the SI units: nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G)
(d) show an understanding of the orders of magnitude of the sizes of common objects ranging from a typical atom to the Earth
(e) state what is meant by scalar and vector quantities and give common examples of each
(f) add two vectors to determine a resultant by a graphical method
(g) describe how to measure a variety of lengths with appropriate accuracy by means of tapes, rules, micrometers and calipers, using a vernier scale as necessary
(h) describe how to measure a short interval of time including the period of a simple pendulum with appropriate accuracy using stopwatches or appropriate instruments

NOTES..

1.1 Physical Quantities and SI Units

1. Physical quantities consist of:
   (a) Numerical magnitude – denotes the size of the physical quantity.
   (b) Unit – denotes the physical quantity it is expressing.

2. Physical quantities can be classified into:
   (a) Basic quantities

Basic Quantity	Name of SI Unit	SI Unit
length	metre	m
mass	kilogram	kg
time	second	s
thermodynamic temperature	kelvin	K
amount of substance	mole	mol

   (b) Derived quantities – defined in terms of the basic quantities through equations. SI units for these quantities are obtained from the basic SI units through the equations.

Example 1.1

Density = $\frac{\text{Mass}}{\text{Volume}}$ (Unit for mass: kg, Unit for volume: m^3)

Therefore unit for density = $\frac{\text{kg}}{\text{m}^3}$ = kg/m^3

3. (a) Units of measurements: SI units are used as standardised units in all measurements in the world. SI is the short form for "International System of Units".
   (b) Other Units:

Length	Mass	Time
1 km = 1000 m	1 kg = 1000 g	1 h = 60 min
1 m = 100 cm	1 g = 1000 mg	1 min = 60 s
1 cm = 10 mm		

4. Examples of some derived quantities and their units:

Derived Quantity	SI Unit
area	m^2
volume	m^3
density	kg/m^3
speed	m/s

A complete list of key quantities, symbols and units used for the O Level examination can be found in the syllabus.

1.2 Prefixes, Symbols and Orders of Magnitude

1. Physical quantities can be very large, like 23 150 000 000 m, or very small, like 0.000 000 756 m. Writing down such numbers can be time consuming and error-prone. We use prefixes to indicate decimal sub-multiples and multiples of the SI units to make writing such numbers easier.

2. Some prefixes of the SI units are as follows:

Prefix	**Multiple**	**Symbol**	**Factor**	**Order of Magnitude**
Tera	1 000 000 000 000	T	10^{12}	12
Giga	1 000 000 000	G	10^{9}	9
Mega	1 000 000	M	10^{6}	6
Kilo	1000	k	10^{3}	3
Deci	0.1	d	10^{-1}	–1
Centi	0.01	c	10^{-2}	–2
Milli	0.001	m	10^{-3}	–3
Micro	0.000 001	μ	10^{-6}	–6
Nano	0.000 000 001	n	10^{-9}	–9
Pico	0.000 000 000 001	p	10^{-12}	–12

The ones in bold are specifically required in the syllabus.

Example 1.2

(a) 0.000 0031 m = 3.1 μm = 3.1×10^{-6} m

(b) 0.000 000 0012 s = 1.2 ns = 1.2×10^{-9} s

3. When measurements are too large or too small, it is convenient to express them in standard form as follows:
   $M \times 10^{N}$
   M lies in the range of: $1 \leqslant M < 10$
   N denotes the order of magnitude and is an integer.

4. Orders of magnitude are often being used to estimate numbers which are extremely large to the nearest power of ten.
   E.g.
   (a) Estimate the number of strands of hair on a person's head.
   (b) Estimate the number of breaths of an average person in his lifetime.

5. The following tables show how the orders of magnitude are used to compare some masses and lengths.

Mass/kg	Factor
Electron	10^{-30}
Proton	10^{-27}
Ant	10^{-3}
Human	10^{1}
Earth	10^{24}
Sun	10^{30}

Length/m	Factor
Radius of a proton	10^{-15}
Radius of an atom	10^{-10}
Height of an ant	10^{-3}
Height of a human	10^{0} ($10^{0} = 1$)
Radius of the Earth	10^{7}
Radius of the Sun	10^{9}

Example 1.3

Find the ratio of the height of a human to that of an ant.

Ratio of height of human to that of an ant = $\dfrac{10^{0}}{10^{-3}} = 10^{3} = 1000$.

1.3 Scalars and Vectors

1. A scalar quantity – has only magnitude but does not have direction.
   E.g. mass, distance, time, speed, work, power.

2. A vector quantity – has both magnitude and direction.
   E.g. weight, displacement, velocity, acceleration, force.

Example 1.4

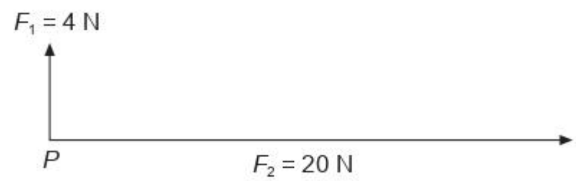
The velocity of a particle can be stated as: "speed of particle = 2.0 m/s and it is moving at an angle of 30° above the horizontal".

1.4 Addition of Vectors

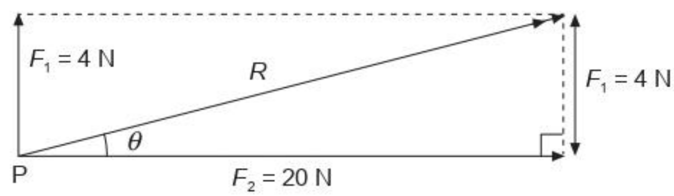
1. Involves magnitude and direction.

Example 1.5

Find the resultant force R at point P due to F_1 and F_2.



Method 1: Trigonometric Method



Using Pythagoras' Theorem:

$R = \sqrt{(F_1)^2 + (F_2)^2}$

$R = \sqrt{4^2 + 20^2} = \sqrt{416}$

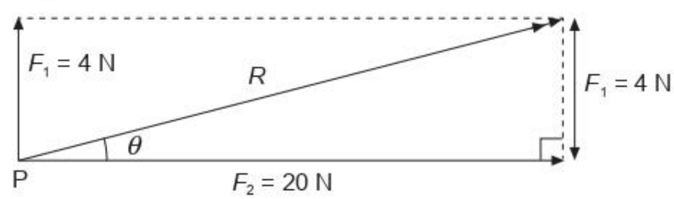
$R =$ 20.4 N

R is at an angle θ above the horizontal

$\tan\ \theta = \dfrac{F_1}{F_2} = \dfrac{4}{20} = \dfrac{1}{5}$

$\theta = 11.3°$

Method 2: Graphical Method



(Not drawn to scale)

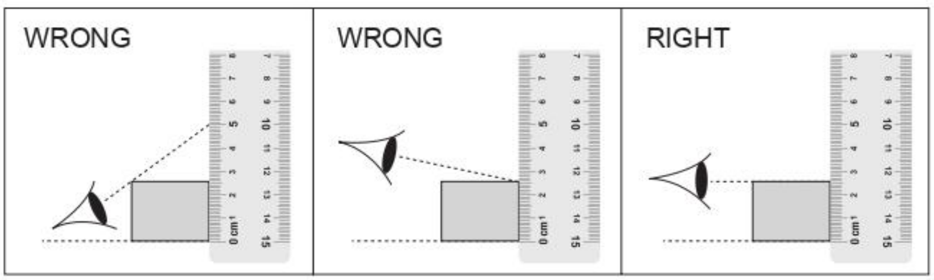
Step 1: Select an appropriate scale
E.g. 1 cm to 2 N.
Step 2: Draw a parallelogram of vectors to scale.
Step 3: Measure the diagonal to find R.
Step 4: Use the protractor to measure angle θ.

1.5 Measurement of Length

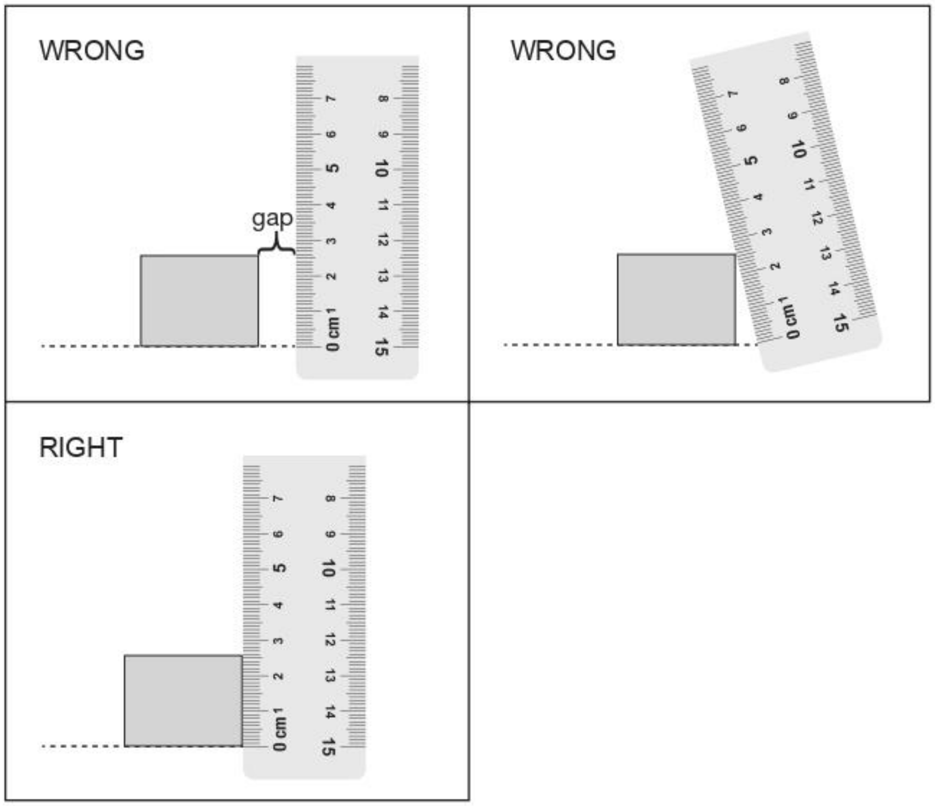
1. Choice of instrument depends on the degree of accuracy required.

Range of length, *l*	Instrument	Accuracy	Example
$l > 100$ cm	Measuring tape	± 0.1 cm	waistline of a person
5 cm < l < 100 cm	Metre rule	± 0.1 cm	height of an object
1 cm < l < 10 cm	Vernier calipers	± 0.01 cm	diameter of a beaker
$l < 2$ cm	Micrometer screw gauge	± 0.001 cm	thickness of a length of wire

2. How parallax errors can occur during measurement:
(a) incorrect positioning of the eye



(b) the object is not touching the marking of the scale
(for measuring tape and metre rule, ensure that the object is **in contact** with the scale)



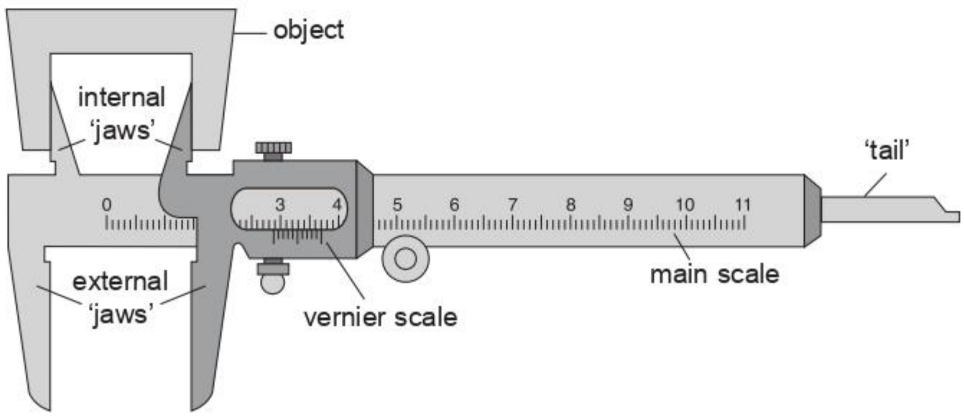
3. A measuring instrument can give precise but not accurate measurements, accurate but not precise measurements or neither precise nor accurate measurements.

   (a) Precision is how close the measured values are to each other but they may not necessarily cluster about the true value. Zero errors and parallax errors affect the precision of an instrument.

   (b) Accuracy is how close a reading is to the true value of the measurement. The accuracy of a reading can be improved by repeating the measurements.

4. **Vernier calipers**

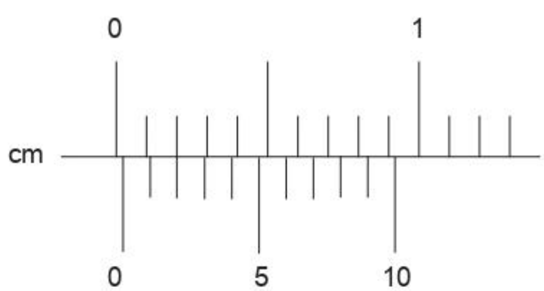
A pair of vernier calipers can be used to measure the thickness of solids and the external diameter of an object by using the external jaws. The internal jaws of the caliper are used to measure the internal diameter of an object. The tail of the caliper is used to measure the depth of an object or a hole. Vernier calipers can measure up to a precision of ±0.01 cm.



Precautions: Check for zero error and make the necessary correction.

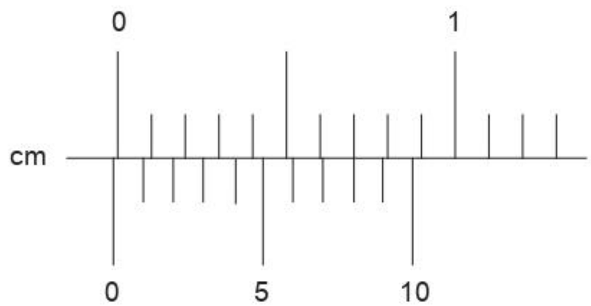
Example 1.6

(a) Positive zero error:



Zero error = +0.02 cm

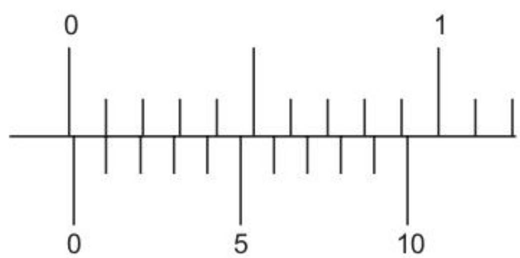
(b) Negative zero error:



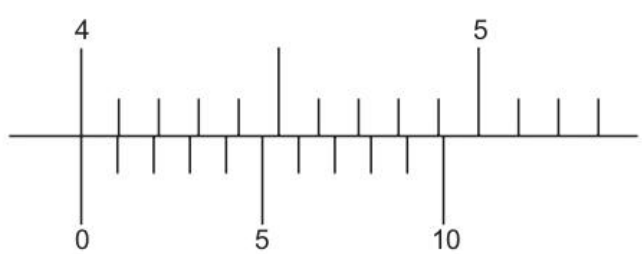
Zero error = –0.02 cm

Note: In (b), the pair of vernier calipers is built with an existing zero error. There is a negative reading without any object between its jaws. The vernier scale is pushed 0.02 cm to the left.

Example 1.7
When the jaws of a pair of vernier calipers are closed, the vernier caliper reading is as shown.



When the same pair of vernier calipers is used to measure the diameter of a beaker, the vernier caliper reading is as shown.

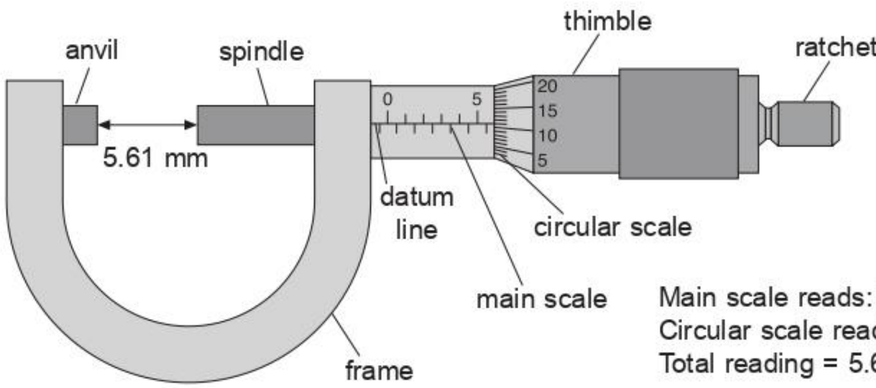


What is the diameter of the beaker?

Solution

Zero Error = +0.01 cm
Reading = 4.00 + 0.01 = 4.01 cm
Actual reading = 4.01 − 0.01 = 4.00 cm

5. Micrometer screw gauge

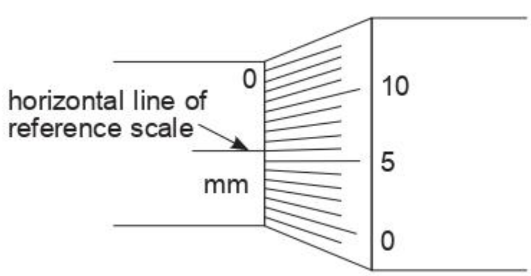


Main scale reads: 5.50 mm
Circular scale reads: 0.11 mm
Total reading = 5.61 mm

Precautions:
(a) Ensure that the jaws of the micrometer screw gauge are completely closed by turning the ratchet until you hear a ‘click’ sound.
(b) Check that the ‘0’ mark of the thimble scale is completely in line with the horizontal line of the reference scale. If not, there is zero error.

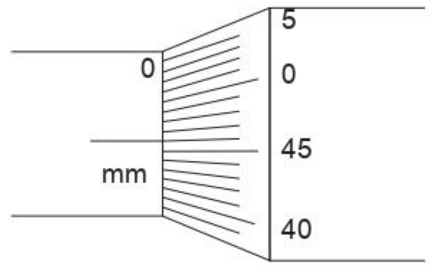
Example 1.8

(a) Positive zero error: ‘0’ mark is below the horizontal line



Zero error = +0.06 mm

(b) Negative zero error: '0' mark is above the horizontal line



Zero error = –0.04 mm

Example 1.9

A micrometer screw gauge is used to measure the thickness of a plastic board. When the jaws are closed without the plastic board in between, the micrometer reading is shown in Fig. (a).

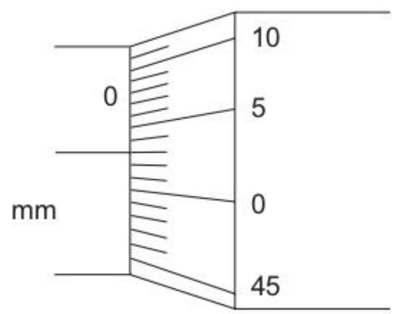


Fig. (a)

With the jaws closed around the plastic board, the micrometer reading is shown in Fig. (b).

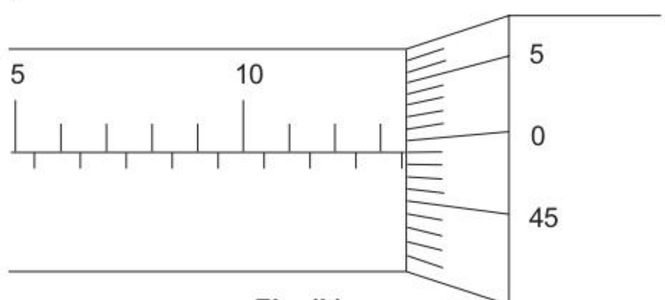


Fig. (b)

What is the thickness of the plastic board?

Solution

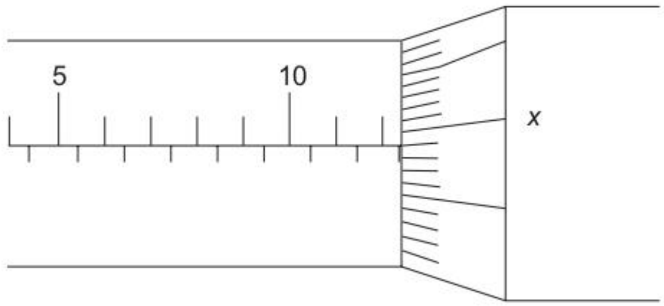
Zero error = +0.03 mm

Reading = 13.5 + 0.49 = 13.99 mm

Actual thickness of plastic board = 13.99 – (+0.03) = 13.96 mm

Example 1.10

The micrometer reading as shown in the figure is 12.84 mm.



What is the value of x on the circular scale?

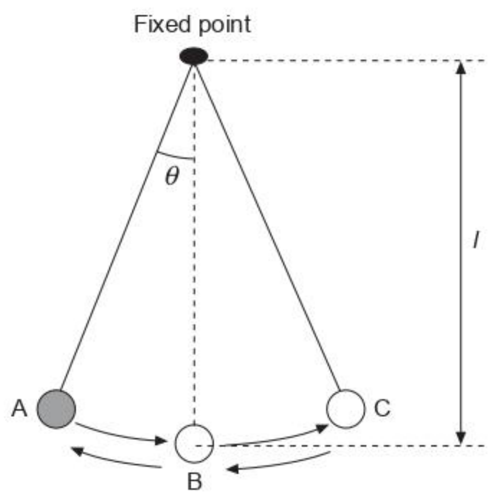
Solution

Reading = 12.5 + reading on the circular scale = 12.84 mm

Reading on the circular scale = 12.84 – 12.5 = 0.34 mm

Since the marking x is 1 mark above 0.34 mm, the value of x is 35.

6. Period of oscillation of a simple pendulum.



(a) (i) One oscillation – One complete to-and-fro movement of the bob from point A to B to C and back to A.

(ii) Period, T – Time taken for one complete oscillation.

(iii) Amplitude – The distance between the rest position of the bob (point B) to the extreme end of the oscillation (either point A or point C).

(b) Steps to find the period of oscillation:
Step 1: Take the total time for 20 oscillations.
Step 2: Repeat **Step 1**.
Step 3: Take the average of the two timings.
Step 4: Divide the average in **Step 3** by 20 to obtain the period.

(c) The period of the pendulum, T, is affected only by its length, l, and the acceleration due to gravity, g.

$$T = 2\pi\sqrt{\frac{T}{g}}$$

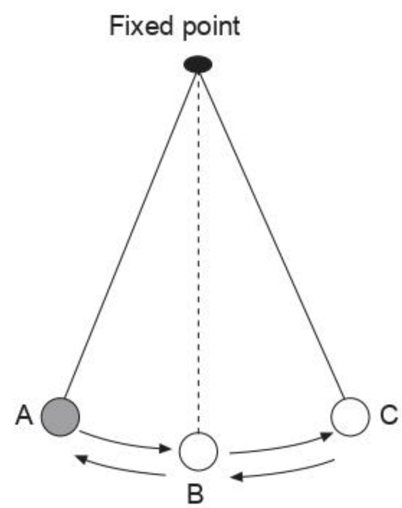
T is not affected by the mass of the pendulum bob.

Example 1.11

A pendulum swings backwards from B to A and forwards to C passing through B, he middle point of the oscillation. The first time the pendulum passes through B, a stopwatch is started. The thirtieth-time the pendulum passes through B, the stopwatch is stopped and the reading taken is 25.4 seconds. What is the period of the pendulum?

Solution

$$\text{Period} = \frac{\text{Total time taken}}{\text{Number of oscillations}} = \frac{25.4}{15} = 1.69 \text{ s}$$



TOPIC 2 Kinematics

Objectives

Candidates should be able to:

(a) state what is meant by speed and velocity
(b) calculate average speed using *distance travelled / time taken*
(c) state what is meant by uniform acceleration and calculate the value of an acceleration using *change in velocity / time taken*
(d) interpret given examples of non-uniform acceleration
(e) plot and interpret a displacement-time graph and a velocity-time graph
(f) deduce from the shape of a displacement-time graph when a body is:
   (i) at rest
   (ii) moving with uniform velocity
   (iii) moving with non-uniform velocity
(g) deduce from the shape of a velocity-time graph when a body is:
   (i) at rest
   (ii) moving with uniform velocity
   (iii) moving with uniform acceleration
   (iv) moving with non-uniform acceleration
(h) calculate the area under a velocity-time graph to determine the displacement travelled for motion with uniform velocity or uniform acceleration
(i) state that the acceleration of free fall for a body near to the Earth is constant and is approximately 10 m/s^2
(j) describe the motion of bodies with constant weight falling with or without air resistance, including reference to terminal velocity

NOTES...

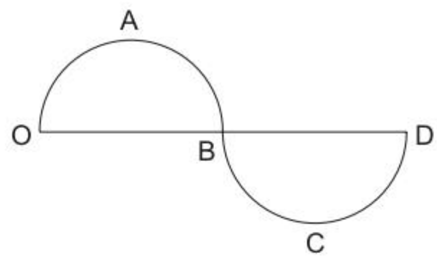
2.1 Distance vs Displacement and Speed vs Velocity

1.

Scalar	Vector
Distance	Displacement
Speed	Velocity

Example 2.1

A car travelled from point O to D along the curved path OABCD.



The distance travelled by the car is OABCD.

The displacement of the car from point O is OD (to the right of O).

2. When measuring/ calculating the displacement of an object, one has to include its starting point.

Example 2.2

Wrong: "The displacement of the bus is 500 m." (*500 m from where?*)

Right: "The displacement of the bus from point A is 500 m in the backward direction." or "The displacement of the bus from point A is –500 m (taking the forward direction as positive)."

3. (a) The formula for calculating speed is

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

(b) $\text{Average speed} = \dfrac{\text{Total distance travelled}}{\text{Total time taken}}$

(c) Velocity is the rate of change of displacement of an object from a fixed point (displacement per unit time).

(d) $\text{Average velocity} = \dfrac{\text{Resultant displacement from a fixed point}}{\text{Total time taken}}$

The average velocity v_{avg} of an object moving through a displacement (Δx) along a straight line in a given time (Δt) is:

$$v_{avg} = \frac{\Delta x}{\Delta t}$$

where $\Delta x = x_{final} - x_{initial}$

$x_{initial}$: Initial displacement from starting point

x_{final} : Final displacement from starting point

2.2 Acceleration

1. Acceleration is the rate of change of velocity.

2. $a = \frac{\Delta x}{\Delta t} = \frac{v - u}{\Delta t} =$ where v is the final velocity, u is the initial velocity and Δt is the time taken.

3. Acceleration is a vector quantity. (You need to give both the magnitude and direction when writing down the answer.)

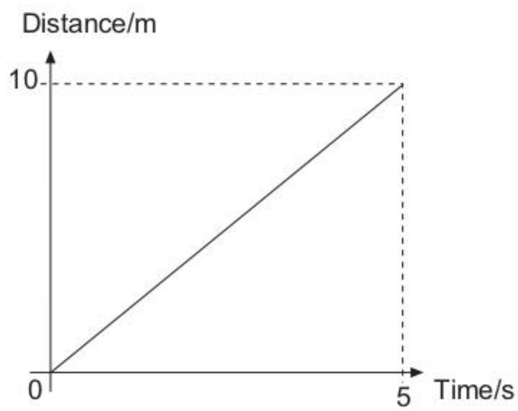
2.3 Graph of Distance vs Time

1. The distance-time graph of a moving object along a straight road is used to find its speed.

2. The gradient of the graph gives the speed of the object.

Example 2.3

Object moving at uniform speed



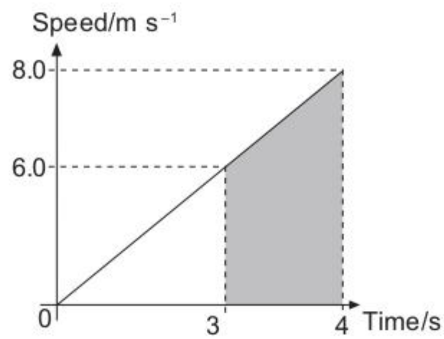
$$\text{Speed} = \frac{10 - 0}{5 - 0} = \frac{10}{5} = 2 \text{ m/s or } 2 \text{ m s}^{-1}$$

2.4 Graph of Speed vs Time

1. The speed-time graph of a moving object along a straight road is used to find:
   (a) Acceleration (Using the gradient of graph)
   (b) Distance travelled (Using the area under the graph)

Example 2.4

Object moving with uniform acceleration:



Acceleration = $\frac{8.0 - 0.0}{4 - 0}$ = 2 m/s^2 or 2 m s^{-2}

Distance travelled from t = 0 to t = 4 s

$= \frac{1}{2}(4 - 0)(8.0 - 0.0) = 16$ m

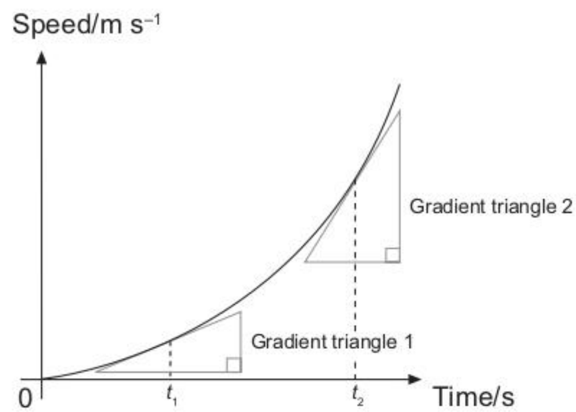
Distance travelled from t = 3 to t = 4 s

$= \frac{1}{2}(4 - 3)(8.0 + 6.0) = 7$ m

2. For an object moving with constant acceleration, the speed-time graph is a sloping straight line. A constant acceleration means that speed is increasing at a constant rate.

2.5 Interpret Other Speed-Time Graphs (Non-Uniform Acceleration)

1. Increasing acceleration:



Notice that the gradient of the graph becomes steeper.

The gradient of triangle 2 is larger than the gradient of triangle 1.

(Gradient gets more and more positive).

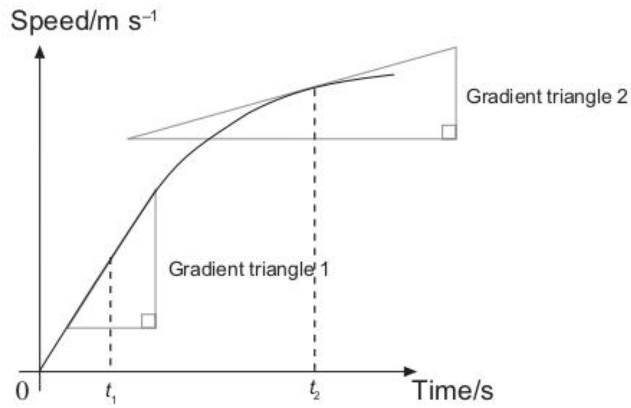
The **speed is increasing** with **increasing acceleration** (increasing rate).

At time = t_1, acceleration = a_1.

At time = t_2, acceleration = a_2.

$a_2 > a_1$

2. Decreasing acceleration:



Notice that the gradient of the graph becomes less steep.
The gradient of triangle 2 is smaller than the gradient of triangle 1.
(Gradient gets less and less positive).
The **speed is increasing** with **decreasing acceleration** (decreasing rate).
At time = t_1, acceleration = a_1.
At time = t_2, acceleration = a_2.
$a_2 < a_1$

2.6 Acceleration Due to Free-Fall

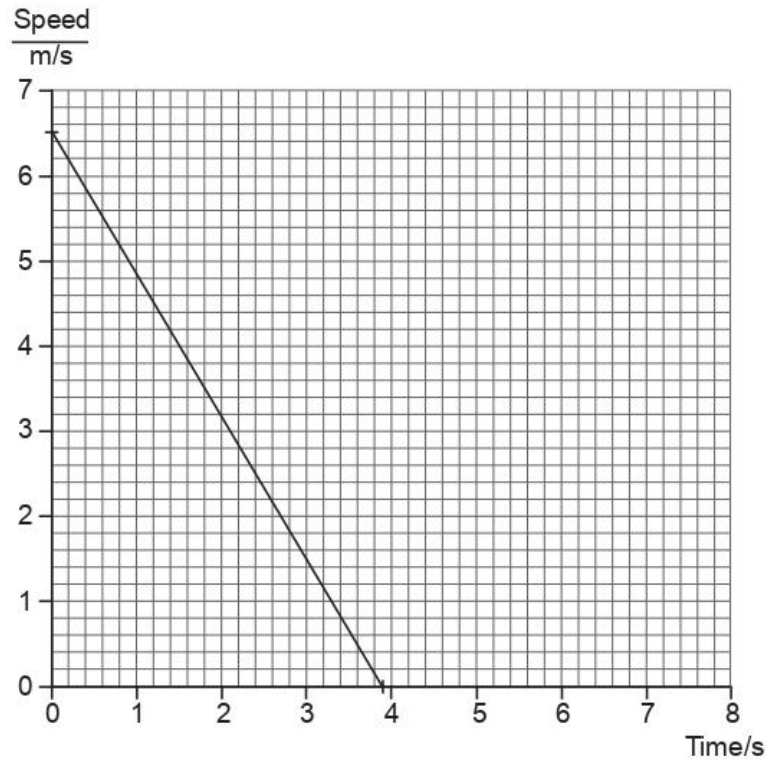
Near the surface of the earth, the acceleration of free fall for an object is constant and is approximately 10 m/s^2. When an object drops from the top of a building, its speed will increase from 0 m/s uniformly at a rate of 10 m/s per second.

2.7 Effect of Air Resistance

1. In real life, a falling object will encounter air resistance on Earth, unless it is moving in a vacuum.
2. Air resistance acts against the motion of the object increasingly to reduce its downward acceleration (NOT SPEED) to zero.
3. When the air resistance increases till it is equal to the weight of a falling object, the acceleration of the object is zero.
4. With zero acceleration, the object will continue falling downward at a constant velocity.
5. The constant velocity of the object is known as “terminal velocity”.

Example 2.5

An astronaut standing on the Moon's surface throws a rock vertically upwards. The figure shows the speed-time graph of the rock where at t = 0 s, the rock just leaves the astronaut's hand. Air resistance on the Moon can be neglected.



(a) (i) What is the time taken for the rock to reach its maximum height?

(ii) What is the total distance travelled by the rock when it returns to its initial position?

(iii) Find the acceleration of the rock.

(b) The rock is then brought back to the Earth's surface and the astronaut repeats the same action as on the Moon. Determine whether the speed-time graph of the rock, when it is thrown on Earth, will be different. Explain your answer.

Solution

(a) (i) From the graph, the time taken for the rock to reach its maximum height is 3.90 seconds.

(ii) Total distance travelled = 2 × area under the graph

$$= \left(\frac{1}{2} \times (6.50 - 0.00) \times (3.90 - 0.00)\right) \times 2$$

$$= 25.4 \text{ m (to 3 s.f.)}$$

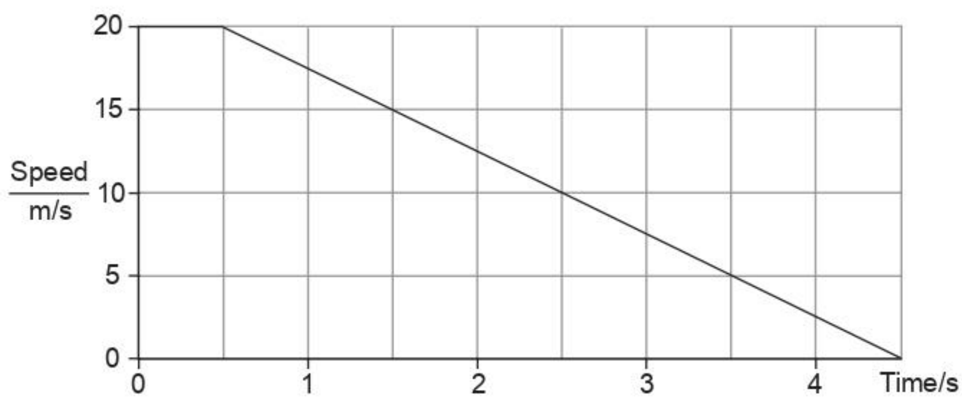
(iii) Acceleration of rock = $\dfrac{6.50 - 0.00}{0.00 - 3.90}$

$$= -1.67 \text{ m s}^2 \text{ or } -1.67 \text{ m s}^{-2} \text{ (to 3 s.f.)}$$

(b) The speed-time graph of the rock on Earth is different because the speed of the rock decreases as it falls from a height. This is due to air resistance. The speed of the rock is decreasing at an increasing rate. The deceleration of the rock increases as the speed decreases. Hence, the gradient of the speed-time graph is steeper initially and becomes gentler after some time. The sketch of the speed-time graph is a curve and not a straight line.

Example 2.6

The graph shows the speed of a car from the time the driver saw an obstacle on the road and applied the brakes till the car came to a stop.



(a) How long did it take the driver to begin applying the brakes after seeing the obstacle?

(b) Calculate the distance travelled
   (i) before the brakes were applied,
   (ii) while the brakes were being applied.

(c) Calculate the average speed of the car.

Solution

(a) The speed remains at 20 m/s for the first 0.5 seconds, so the driver took 0.5 seconds to begin applying the brakes after seeing the obstacle.

(b) (i) Distance travelled before braking

$= 20 \times 0.5$

$= 10$ m

(ii) Distance travelled while the brakes were being applied

$= \frac{1}{2} \times 20 \times (4.5 - 0.5)$

$= 40$ m

(c) Average speed of car $= \frac{\text{Total distance travelled}}{\text{Total time taken}}$

$= \frac{10 + 40}{4.5}$

$= \frac{50}{4.5}$

$= 11.1$ m/s or 11.1 m s^{-1} (to 3 s.f.)

TOPIC 3 Dynamics

Objectives

Candidates should be able to:

(a) apply Newton's Laws to:

(i) describe the effect of balanced and unbalanced forces on a body

(ii) describe the ways in which a force may change the motion of a body

(iii) identify action-reaction pairs acting on two interacting bodies (stating of Newton's Laws is not required)

(b) identify forces acting on an object and draw free body diagram(s) representing the forces acting on the object (for cases involving forces acting in at most 2 dimensions)

(c) solve problems for a static point mass under the action of 3 forces for 2-dimensional cases (a graphical method would suffice)

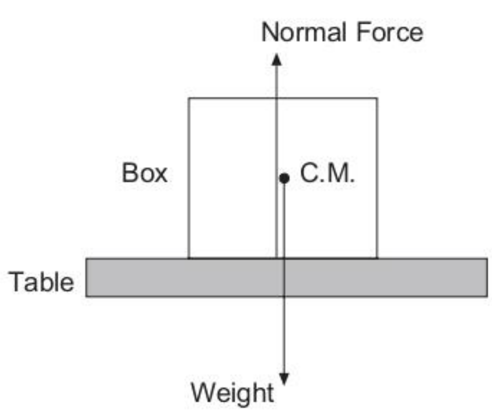
(d) recall and apply the relationship *resultant force = mass × acceleration* to new situations or to solve related problems

(e) explain the effects of friction on the motion of a body

NOTES..

3.1 Forces

1. A force (SI unit: Newton, symbol: N) is a push or a pull exerted on a body by another body, i.e. an object resting on a table will have a contact force (normal force) acting on it upwards. This force is equal to its weight.



Note:
1. The Normal Force and Weight arrows are of the same length but in opposite directions.
2. Normal Force arrow starts from the base of box (contact between the box and the table top).
3. Weight starts from the centre of mass of the box, C.M. (indicated by the black dot).

2. Effects of a force on a body:
   (a) Increase/ decrease speed of a body (accelerate/ decelerate)
   (b) Change direction of a moving body

3. Newton's First Law:
   A body will remain stationary or in continuous linear motion unless acted upon by a resultant force.

4. Newton's Second Law:
   Resultant vector sum of forces on body is given by:

$$\boxed{F = ma}$$

   where m is the mass of the body and a is the acceleration of the body in the direction of F.

5. Newton's Third Law:
   For every action, there is an equal and opposite reaction.

3.2 Balanced and Unbalanced Forces

1. Balanced forces: If resultant $F = 0$ N, the body is either stationary or moving with constant velocity.

   Example 3.1
   A parachutist falls to the ground at terminal velocity when his weight is equal to the upward force acting on him due to air resistance. Hence, the resultant force acting on him is zero, i.e. his acceleration is zero.

2. Unbalanced forces: If resultant $F \neq 0$ N,
   (a) a stationary body will start moving,
   (b) a moving body will change its velocity.

3.3 Friction

1. Friction is the force which opposes motion when objects slide over each other. For a moving object, the friction on the object acts in the direction opposite to its motion.

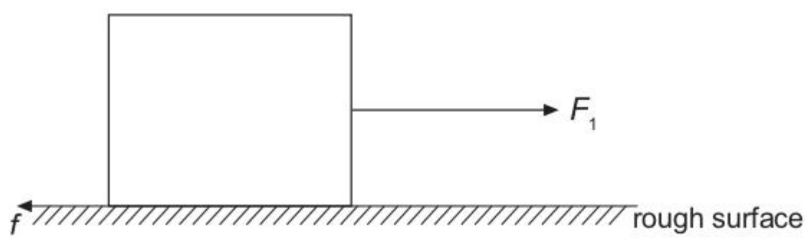
2. Advantages of friction:
   (a) Walking on roads.
   (b) Friction in brake pads and wheels of cars and bicycles.

3. Disadvantages of friction:
   (a) Wears down moving parts of machines.
   (b) For an object moving on a rough surface, more energy is needed to move the object as compared to moving on a smooth surface.
   (c) For an object moving on a rough surface, energy is required for the object to maintain a constant speed. Otherwise, it will slow down and come to a stop.

4. Ways to overcome friction:
   (a) Use lubricant (i.e. graphite or oil) for moving parts of machines.
   (b) Use ball-bearings between moving surfaces.
   (c) Make sure moving parts of machines have very smooth surfaces.

Example 3.2

An object weighing 50 N lies on a rough surface. A constant F_1 force of 12 N acts on the object. The frictional force f acting on the object is 2 N. Find the acceleration of the object. (Take acceleration due to gravity to be 10 m/s^2.)



Solution

Vertically, resultant force = normal force – weight = 0 N

Horizontally, resultant force $R = F_1 - f = 12 - 2 = 10$ N

(Object will only accelerate on horizontal plane)

Mass of object $= \frac{50}{10}$ kg

$= 5$ kg

Using formula:

$F = ma$

$10 = 5a$

$a = 2$ m/s^2

(Object is accelerating at 2 m/s^2 to the right, i.e. in the direction of F.)

Example 3.3

An object moves in a circular path at a constant speed. Is the object accelerating?

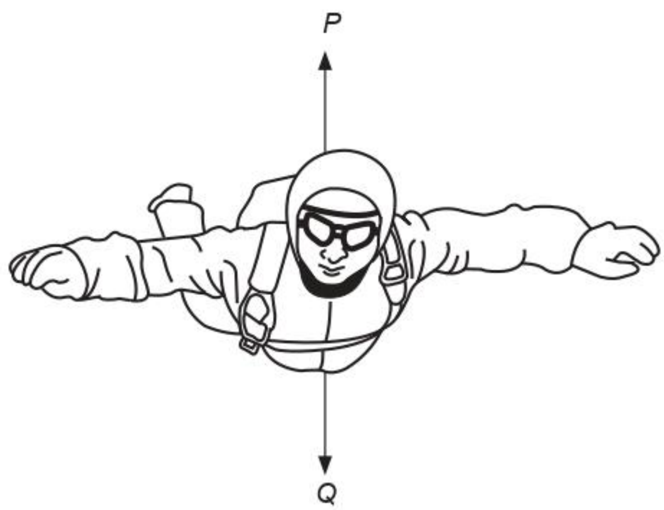
Solution

Yes. Its velocity keeps changing (because direction keeps changing), hence there is a resultant force causing the change. Resultant force acts towards the centre of the circle.

Example 3.4

A skydiver of mass 60 kg falls from rest vertically downwards at a constant velocity.

The figure shows the forces, P and Q, acting on him.



(a) Identify the forces P and Q acting on the skydiver.

(b) Explain why P is acting upwards.

(c) When the skydiver starts to fall from rest, the forces P and Q are unbalanced.

  (i) Find P and Q at t = 0 s.

  (ii) Find P and Q when the velocity of the skydiver is uniform.

  (iii) Describe, in terms of the forces acting on the sky diver, why the velocity of the skydiver increases before reaching terminal velocity.

Solution

(a) P is the air resistance on the skydiver and Q is the weight of the skydiver.

(b) Air resistance opposes the motion of the skydiver. Since the skydiver is falling vertically downwards, the air resistance acting on him is in the upward direction to oppose his motion.

(c) Take all forces acting downwards as positive.

(i) $P = 0$ N

$Q = mg = 60 \times 10 = 600$ N

(ii) When the velocity of the skydiver is uniform, he has reached terminal velocity. The resultant force acting on him is 0 N.

$Q - P = 0$

$P = Q = 600$ N

(iii) As a result of unbalanced forces, there will be a non-zero resultant force acting on the skydiver, and it is acting vertically downwards. By Newton's 2^{nd} Law, the skydiver is accelerating downwards. Hence, the velocity of the skydiver increases before it reaches terminal velocity.

TOPIC 4 Mass, Weight and Density

Objectives

Candidates should be able to:

(a) state that mass is a measure of the amount of substance in a body
(b) state that mass of a body resists a change in the state of rest or motion of the body (inertia)
(c) state that a gravitational field is a region in which a mass experiences a force due to gravitational attraction
(d) define gravitational field strength, g, as gravitational force per unit mass
(e) recall and apply the relationship *weight = mass × gravitational field strength* to new situations or to solve related problems
(f) distinguish between mass and weight
(g) recall and apply the relationship *density = mass / volume* to new situations or to solve related problems

NOTES

4.1 Mass

1. Defined as a measure of the amount of substance in a body. (SI unit: kilogram, symbol: kg)
2. The magnitude of mass depends on the size of the body and the number of atoms in the body.
3. Mass is a scalar quantity.

4.2 Inertia

1. Defined as the resistance of the body to change in its state of rest or motion due to its mass.
2. To overcome inertia of a body, a force has to be applied.
   This force is dependent on the body's mass.

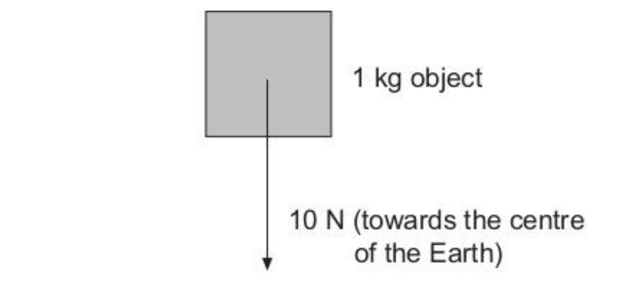
4.3 Gravitational Field Strength

Defined as the gravitational force acting on a body per unit mass.

	Gravitational Field Strength
Earth	$10\ \text{N kg}^{-1}$
Moon	$1.6\ \text{N kg}^{-1}$

Note:
These are approximate values for points close to and on the planets' surface.

i.e. on Earth, a force of 10 N is pulling on a 1 kg falling object.



Note:
Since the resultant force on object is 10 N (weight), the acceleration of the object is (by Newton's 2nd Law) $10\ \text{m s}^{-2}$.

4.4 Weight

1. Defined as the gravitational force W acting on an object of mass m.
2. When a body falls, its gravitational force (weight) can produce an acceleration, g (the acceleration due to gravity).
3. Using Newton's 2nd Law of $F = ma$, we have $W = mg$.
4. Comparison of weight and mass:

		Mass	Weight
1.	definition	the amount of substance in a body	the gravitational pull acting on a body
2.	depends on location	no	yes
3.	measured by using	beam balance	spring balance
4.	unit	kilogram	Newton

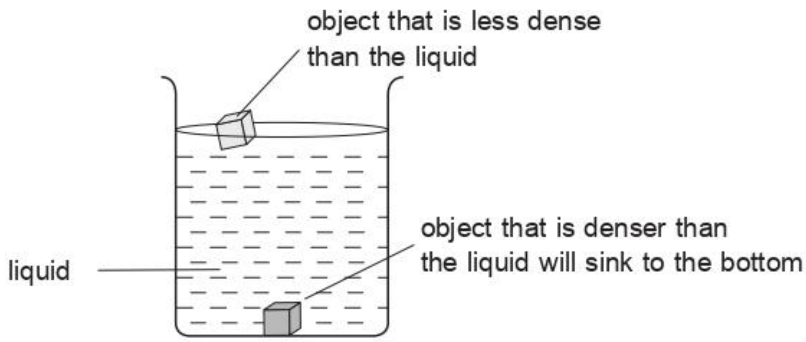
4.5 Density

1. The density of a body, ρ, is defined as its mass, m, per unit volume, V.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$
$$\rho = \frac{m}{V}$$

2. SI Unit: kg m^{-3}

3. For an object to float in a liquid, the object has to be less dense than the liquid. As such, if an object is denser than the liquid, the object will sink in the liquid.



TOPIC 5 Turning Effect of Forces

Objectives

Candidates should be able to:

(a) describe the moment of a force in terms of its turning effect and relate this to everyday examples
(b) recall and apply the relationship *moment of a force (or torque) = force × perpendicular distance from the pivot* to new situations or to solve related problems
(c) state the principle of moments for a body in equilibrium
(d) apply the principle of moments to new situations or to solve related problems
(e) show understanding that the weight of a body may be taken as acting at a single point known as its centre of gravity
(f) describe qualitatively the effect of the position of the centre of gravity on the stability of objects

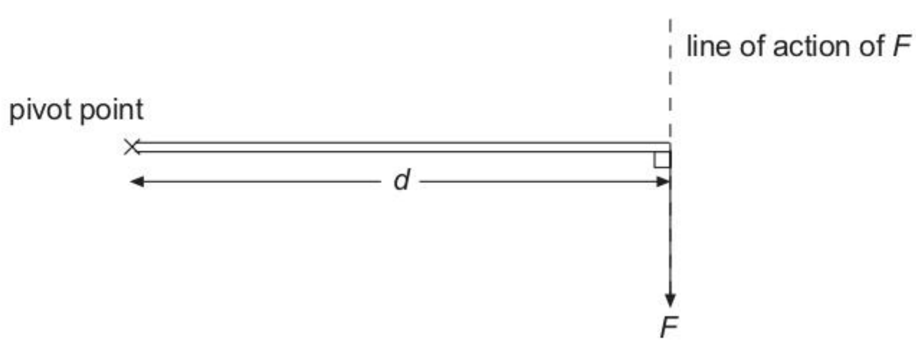
NOTES..

5.1 Moment of a Force

1. Moment – the turning effect of a force about a pivoting point
2. Moment of force = $F \times d$

   F: Force

   d: perpendicular distance of line of action of F from pivot



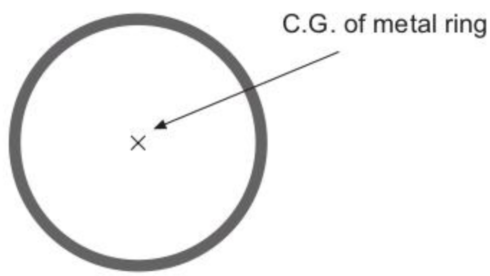
3. SI unit of moment: N m

4. Conditions for object to be in equilibrium:
   (1) The sum of moments about any point is zero. (Principle of Moments)
   (2) The vector sum of forces on object is zero.

5. Principle of Moments:
   For an object in equilibrium, the sum of clockwise moments about any point is equal to the sum of anticlockwise moments about the same point.
   (Resultant moment = 0 N m)

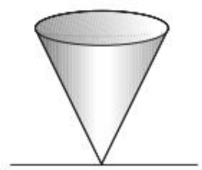
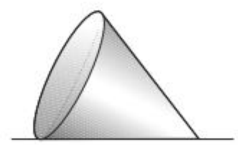
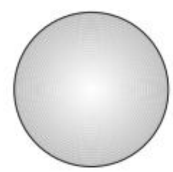
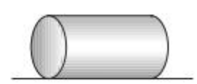
5.2 Centre of Gravity (C.G.)

1. The C.G. of an object is the point where the whole weight appears to act on.
2. The C.G. will not change regardless of how the object is orientated.
3. The C.G. can lie outside an object.
   E.g. C.G. of a metal ring is in the middle of the circle.



5.3 Stability

1. Stability – the ability of an object to retain its original position after being displaced slightly.

	Stable	**Unstable**	**Neutral**
Base Area	Large	Small	1 line of contact or point(s) of contact with surface
Height of C.G.	Low	High	–
Slight displacement from equilibrium position	Return to original position	Topple over	Stay in new position
Example	 Cone resting on its base  Cylindrical shape, resting on its base (large base)	 Cone at its vertex  Cylindrical shape, resting on its base (small base)	 Cone resting on its side  Sphere  Cylinder resting on its side

2. The stability of an object can be improved by:
   (a) Lowering its C.G. (Add weights to the object's lower part).
   (b) Increasing the base area of the object.

TOPIC 6 Pressure

Objectives

Candidates should be able to:

(a) define the term pressure in terms of force and area
(b) recall and apply the relationship *pressure = force / area* to new situations or to solve related problems
(c) describe and explain the transmission of pressure in hydraulic systems with particular reference to the hydraulic press
(d) recall and apply the relationship pressure due to a *liquid column = height of column × density of the liquid × gravitational field strength* to new situations or to solve related problems
(e) describe how the height of a liquid column may be used to measure the atmospheric pressure
(f) describe the use of a manometer in the measurement of pressure difference

NOTES...

6.1 Pressure

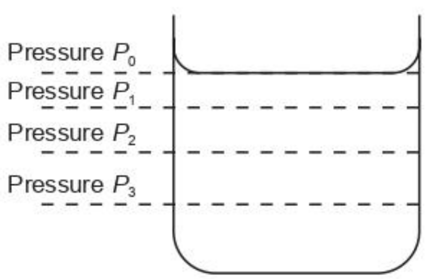
1. Pressure is the force acting per unit area.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

2. SI unit: Pascal (Pa) or N m^{-2}

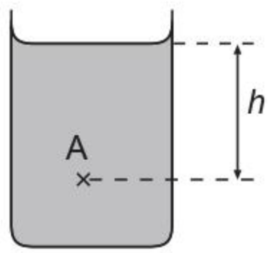
6.2 Liquid Pressure

1. An object immersed in a uniform liquid will experience a pressure which depends only on the height of the liquid above the object.



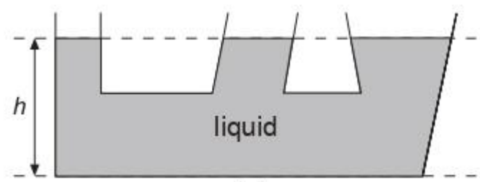
P_0: Atmospheric pressure
Pressure increases with depth: $P_0 < P_1 < P_2 < P_3$

2. Pressure at point A due to the liquid, $P = \rho gh$



Pressure at point A = $P_0 + \rho gh$
P_0 – Atmospheric pressure

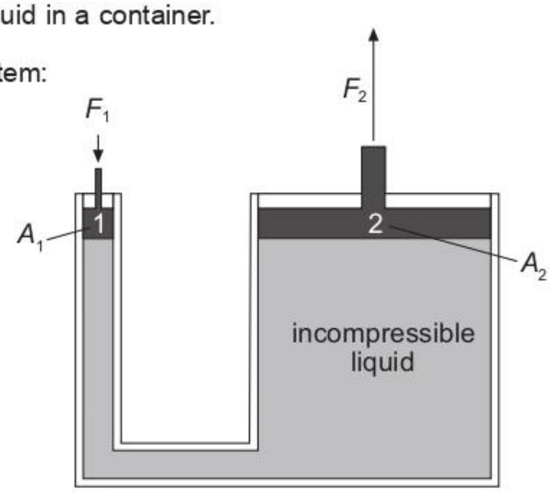
3. When a liquid is at equilibrium, the pressure is the same at any point along the same horizontal surface. Thus the liquid in the container settles at a common height, *h*.



container

6.3 Transmission of Pressure in Hydraulic System

1. Pressure can be transmitted in all directions if it is exerted on an incompressible fluid in a container.
2. Components of a hydraulic system:
   - Container with two openings
   - A press
   - A piston
   - Incompressible fluid



Hydraulic System

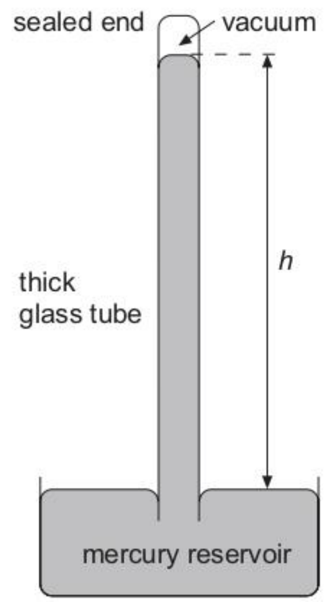
3. In the above figure, if the two pistons at '1' and '2' have the same area, then the force F_1 exerted on one piston will have the same magnitude as F_2 at the other piston.

4. If the area A_1 is smaller than area A_2, then the force exerted at '1' will produce a larger force at '2'.

$$\text{Pressure} = P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

5. Thus we can use a hydraulic system to lift heavy objects.

6.4 Atmospheric Pressure

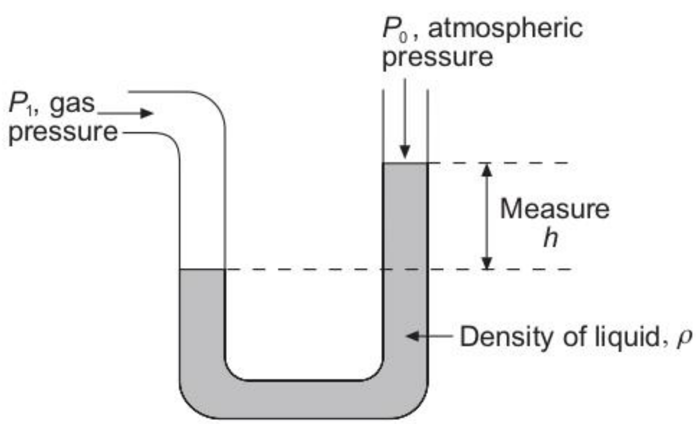


Mercury Barometer

1. Defined as the force per unit area exerted against a surface by the weight of air above that surface.
2. Instrument to measure atmospheric pressure: mercury barometer
3. At sea-level, h = 760 mm.
   Atmospheric pressure recorded as 760 mm Hg.
4. Even if the tube is tilted, h will still remain the same unless it is brought to a different level where the atmospheric pressure is different.

6.5 Manometer

1. The manometer is an instrument that is used to measure gas pressure.
2. Gas pressure, $P_1 = P_0 + \rho gh$ where h – difference in height.



Manometer

TOPIC 7 Energy, Work and Power

Objectives

Candidates should be able to:

(a) show understanding that kinetic energy, potential energy (chemical, gravitational, elastic), light energy, thermal energy, electrical energy and nuclear energy are examples of different forms of energy
(b) state the principle of conservation of energy and apply the principle to new situations or to solve related problems
(c) calculate the efficiency of an energy conversion using the formula efficiency = energy converted to useful output / total energy input
(d) state that kinetic energy $E_k = \frac{1}{2}mv^2$ and gravitational potential energy $E_p = mgh$ (for potential energy changes near the Earth's surface)
(e) apply the relationships for kinetic energy and potential energy to new situations or to solve related problems
(f) recall and apply the relationship *work done = force × distance moved in the direction of the force* to new situations or to solve related problems
(g) recall and apply the relationship *power = work done / time taken* to new situations or to solve related problems

NOTES

7.1 Energy

1. Different forms: kinetic energy (*KE*), elastic potential energy, gravitational potential energy (*GPE*), chemical potential energy, thermal energy.
2. SI unit: Joule (J)
3. Principle of Conservation of Energy: The total energy in a system remains constant and cannot be created or destroyed. It can only be converted from one form to another without any loss in the total energy.

7.2 Gravitational Potential Energy (*GPE*) and Kinetic Energy (*KE*)

1. Take the surface of the Earth to be the reference level ($GPE = 0$).
   GPE of an object of mass m at height h above surface:

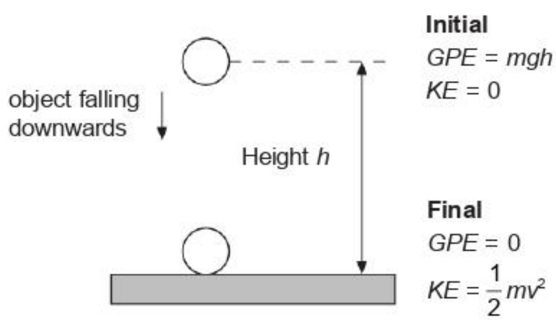
$$\boxed{GPE = mgh}$$

2. *KE* of a moving object of mass m, with a velocity v is

$$\boxed{KE = \frac{1}{2}mv^2}$$

Example 7.1

For a free-falling object of mass m, its gravitational potential energy is converted into kinetic energy. Take ground level as reference level ($GPE = 0$).



Apply the Principle of Conservation of Energy and assuming there is no air resistance:

Total energy at height h = Total energy at ground level

$$mgh = \frac{1}{2}mv^2$$

Velocity of object, $v = \sqrt{2gh}$

Note: The total energy of the object is constant throughout its fall, not just at the two positions used in the above calculation.
($GPE + KE$ = Total energy = Constant)

7.3 Work

1. Energy is required for an object to do work.
2. Defined as the product of applied force (F) and the distance moved (s) in the direction of the force.

$$\boxed{W = Fs}$$ Unit: J

3. No work is done if the applied force F does not displace the object along the direction of the force.

7.4 Power

1. Defined as the rate of work done.

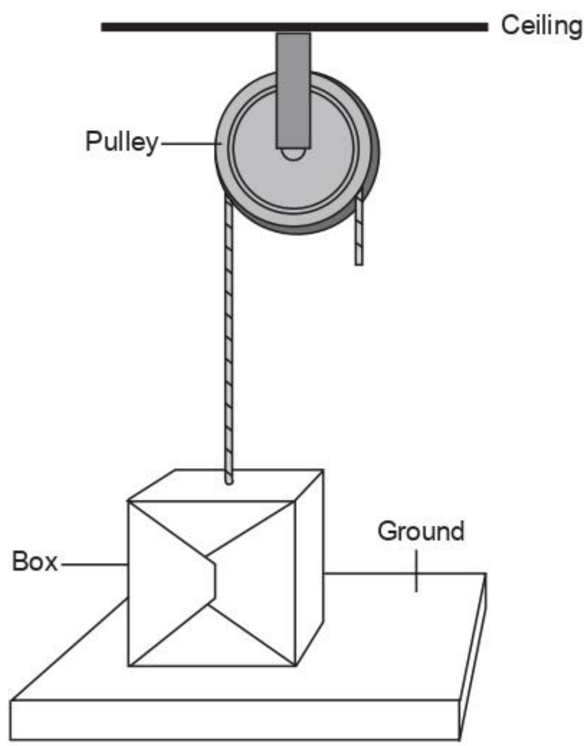
$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

2. SI unit: Watt (W) or J s^{-1}
3. Efficiency of an energy/ power conversion:

$$\text{Energy} = \frac{\text{Energy converted into useful output}}{\text{Total energy output}} \times 100\%$$
$$= \frac{\text{Useful power output}}{\text{Total power output}} \times 100\%$$

Example 7.2

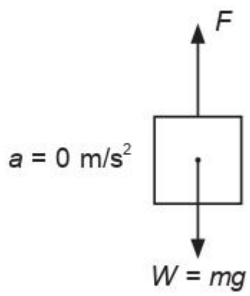
A box with a mass of 30 kg can be lifted by a light rope threaded through a smooth pulley.



(a) If the box is lifted at a constant speed from the ground to a height of 2.0 m in 4.0 s, what is the power required?
(b) If the box is lifted with a constant acceleration of 1.5 m/s^2 from rest to a height of 3.0 m above the floor, what is the power required?
Take g, the gravitational field strength as 10 N/kg.

Solution

(a) Draw a free body diagram of the box and identify all the forces acting on it.



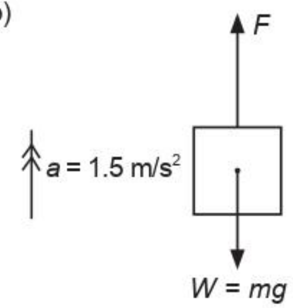
F – Applied force
W – Weight of the box
R – Resultant force on the box
s – Displacement of the box from the ground

Take forces acting upwards to be positive.
Using Newton's 2nd Law,

$$F - mg = 0$$
$$\therefore F = mg$$
$$= (30)(10)$$
$$= 300 \text{ N}$$

$$\text{Power required} = \text{rate of work done}$$
$$= \frac{Fs}{t}$$
$$= \frac{300 \times 2.0}{4.0}$$
$$= 150 \text{ W}$$

(b)



F – Applied force

W – Weight of the box

R – Resultant force on the box

Take forces acting upwards to be positive.
Using Newton's 2nd Law,

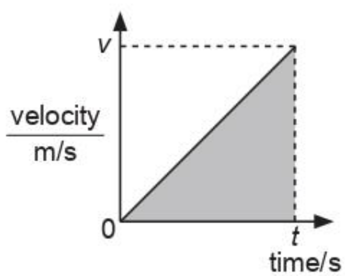
$F - mg = ma$

$F - 300 = 30 \times 1.5$

$F = 45 + 300$

$F = 345$ N

Sketch the speed-time graph of the box to obtain the time taken for the box to move to a height of 3.0 m above the ground.



t – time required for the box to reach a height of 3.0 m.

v – final velocity of the box

From the graph, we can obtain the velocity (gradient of graph) and the total displacement of the box.

Gradient of velocity-time graph,

$$a = \frac{v - u}{t} = \frac{v - 0}{t}$$

$$1.5 = \frac{v}{t}$$

$$v = 1.5t \text{ ------ (1)}$$

Area under the graph (shaded) = Displacement s of box from the ground

$$s = \frac{1}{2} \times \text{Base} \times \text{Height} = \frac{1}{2} \times t \times v$$

$$s = \frac{1}{2} vt$$

$$\frac{1}{2} vt = 3.0 \text{ ------ } (2)$$

Substitute (1) into (2):

$$\frac{1}{2}(1.5t)t = 3.0$$

$$\frac{3}{4}t^2 = 3.0$$

$$t^2 = 4.0$$

$$(t - 2.0)(t + 2.0) = 0$$

$$t = 2.0 \text{ s (since } t > 0)$$

$$\text{Power required} = \frac{345 \times 3.0}{2.0}$$

$$= 518 \text{ W (to 3 s.f.)}$$

TOPIC 8

Kinetic Model of Matter

Objectives

Candidates should be able to:

(a) compare the properties of solids, liquids and gases

(b) describe qualitatively the molecular structure of solids, liquids and gases, relating their properties to the forces and distances between molecules and to the motion of the molecules

(c) infer from Brownian motion experiment the evidence for the movement of molecules

(d) describe the relationship between the motion of molecules and temperature

(e) explain the pressure of a gas in terms of the motion of its molecules

(f) recall and explain the following relationships using the kinetic model (stating of the corresponding gas laws is not required):

   (i) a change in pressure of a fixed mass of gas at constant volume is caused by a change in temperature of the gas

   (ii) a change in volume occupied by a fixed mass of gas at constant pressure is caused by a change in temperature of the gas

   (iii) a change in pressure of a fixed mass of gas at constant temperature is caused by a change in volume of the gas

(g) use the relationships in (f) in related situations and to solve problems (a qualitative treatment would suffice)

NOTES...

8.1 States of Matter

The 3 States of Matter

	Solid	Liquid	Gas
Volume	Definite	Definite	Indefinite (Takes the shape and size of container)
Shape	Definite	Indefinite (Takes the shape of container)	Indefinite (Takes the shape of container)
Compressibility	Not compressible	Not compressible	Compressible

	Solid	Liquid	Gas
Arrangement of atoms/molecules	1. Closely packed together 2. Orderly arrangement 3. Held together by large forces	1. Closely packed in clusters of atoms or molecules 2. Atoms/ molecules slightly further apart compared to particles 3. Held together by large forces	1. Atoms or molecules are very far apart and occupy any given space 2. Negligible forces of attraction between atoms/ molecules.
Density	High (Usually)	High	Low
Forces between atoms/ molecules	Very strong	Strong	Very Weak
Movement of atoms/ molecules	Can only vibrate about fixed positions	Able to move pass each other and not confined to fixed positions	Move in random manner independent of each other and at high speed.

Common mistakes:

1. Some substances, such as carbon dioxide, are commonly known to be in gaseous state at room temperature. However, this does not mean that the carbon dioxide molecules move in random motion.

   (Check its state (temperature): solid or gas, etc.)

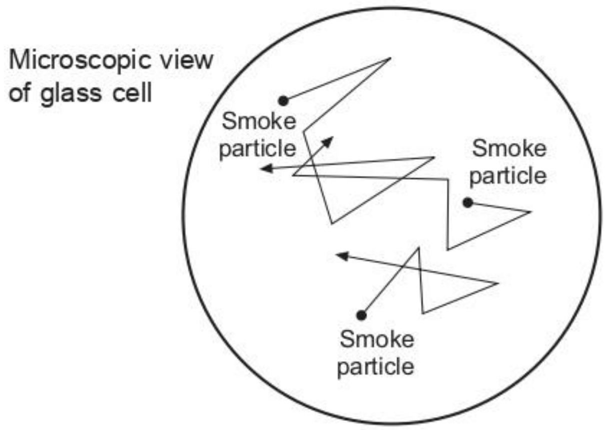
   E.g. Dry ice is a solid which consists of carbon dioxide molecules in an orderly arrangement.

2. ***Not all*** solids have high density, i.e. “ice” is a solid consisting of water molecules arranged orderly in an open hollow structure. Hence, its density is lower than water (liquid) and it can float in water.

8.2 Brownian Motion

The random and irregular motion of gas and liquid molecules.

Experimental observation (using microscope): Smoke particles in a sealed glass cell move about randomly and irregularly, because of bombardment by air molecules in the cell.



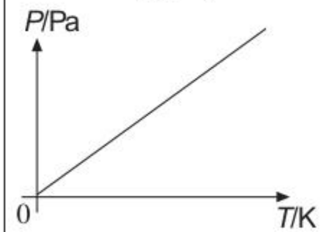
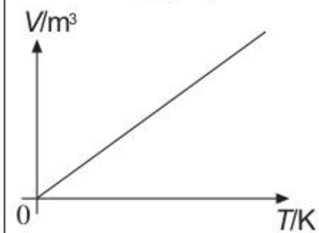
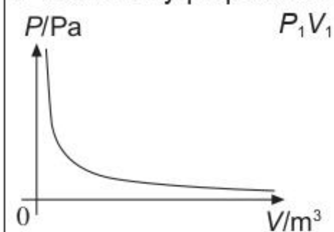
Smoke particles moving randomly

8.3 Pressure of Gas

1. In a sealed container, gas can exert pressure on the walls of the container.
2. The large number of molecules move at high speed, colliding against the container's walls and exerting a force against the wall when they bounce off the walls.
3. The force per unit area exerted by the molecules on the wall is the pressure of the gas on the wall.
4. Gas pressure increases when the
   (a) number of molecules in the container increases,
   (b) speed of molecules increases,
   (c) molecules have larger mass.

8.4 Relationship between Pressure (*P*), Volume (*V*) and Temperature (*T*)

1. For a constant mass of gas:

	P	***V***	***T***	***Relationship***
1.	Increase	Constant	Increase	*P* is directly proportional to *T*.  $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
2.	Constant	Increase	Increase	*V* is directly proportional to *T*.  $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
3.	Increase	Decrease	Constant	*P is* inversely proportional to *V*. $P_1V_1 = P_2V_2$ 

Example 8.1

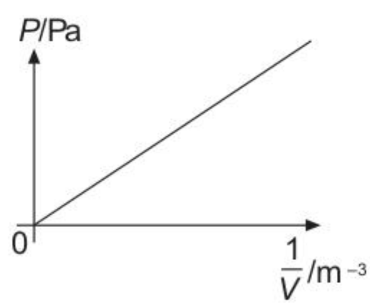
To get a linear graph that shows *P* is inversely proportional to *V*, rearrange the equation:

$P_1V_1 = P_2V_2 = \text{constant}, k$

$$P_1 = \frac{k}{V_1}$$

Sketch the graph of *P* against $\frac{1}{V}$:

y-axis (*P*), *x*-axis $\left(\frac{1}{V}\right)$, gradient = *k*



TOPIC 9 Transfer of Thermal Energy

Objectives

Candidates should be able to:

(a) show understanding that thermal energy is transferred from a region of higher temperature to a region of lower temperature
(b) describe, in molecular terms, how energy transfer occurs in solids
(c) describe, in terms of density changes, convection in fluids
(d) explain that energy transfer of a body by radiation does not require a material medium and the rate of energy transfer is affected by:
  (i) colour and texture of the surface
  (ii) surface temperature
  (iii) surface area
(e) apply the concept of thermal energy transfer to everyday applications

NOTES...

9.1 Types of Heat Transfer

1. 3 types of heat transfer: Conduction, Convection, Radiation
2. Transfer of thermal energy is ***always*** from a high temperature region to a low temperature region (Temperature gradient).

	Conduction	Convection	Radiation
Medium	Solids Liquids Gases	Liquids (fluid) Gases (fluid)	Vacuum*
Process	1. Vibration of atoms/ molecules 2. Movement of free electrons (if any, i.e. metals) For solids, their atoms/molecules are in fixed positions	Movement of atoms/ molecules in the form of convection by currents set up by density change in parts of the fluid being heated.	Infrared waves (no medium required)

* Radiation does not require matter to transfer heat, but radiation can travel through matter (through several thousands of metres in air or a few metres in common solids).

9.2 Conduction

1. A direct contact between media is necessary.
2. Metals are the best solid conductors because of their free electrons.
3. Liquids and gases are poor conductors because their molecules are not closely packed together in fixed positions like solids.
4. Application: Use metals to make cooking utensils.

9.3 Convection

1. Molecules/ atoms must be free to move.
2. Set-up of a convection current: The fluid closer to the heat source expands, and its density decreases and the surrounding denser fluid displaces it.
3. Application: Air conditioners are placed near the ceiling because cold air, being denser, will sink to displace the warm air in the room.

9.4 Radiation

1. Factors affecting radiation:
   (a) Colour
   (b) Roughness
   (c) Area exposed to radiation
2. Good radiator/ good absorber of radiation: black, dull surface, with a huge amount of surface area exposed.
3. Poor radiator/ poor absorber of radiation: bright, shiny and polished surface.
4. Application: Greenhouses for growing plants.

9.5 Vacuum Flask

1. Reduces heat transfer in or out through conduction, convection and radiation.
2. Can store and maintain temperature (either hot or cold) of the contents in the flask.

Type of heat transfer	How heat transfer is reduced
Convection	Vacuum between the double glass walls.
Conduction	Vacuum between the double glass walls. Insulated cover and stopper.
Radiation	Shiny silvered inner surface of the glass walls.

TOPIC 10 Temperature

Objectives

Candidates should be able to:

(a) explain how a physical property which varies with temperature, such as volume of liquid column, resistance of metal wire and electromotive force (e.m.f.) produced by junctions formed with wires of two different metals, may be used to define temperature scales

(b) describe the process of calibration of a liquid-in-glass thermometer, including the need for fixed points such as the ice point and steam point

NOTES

10.1 Temperature

1. A measure of the degree of 'hotness' or 'coldness' of a body.
2. SI Unit: Kelvin (K)
3. Commonly-used unit is degree Celsius (°C): θ (K) = θ (°C) + 273.15

10.2 Measurement of Temperature

1. Material for temperature measurement: Substance/ material which possesses temperature-dependent property and thus can change continuously with temperature variations.

2. Temperature-dependent (Thermometric) Properties:

Thermometric Property	Thermometer	Range
Volume of a fixed mass of liquid (**e.g.** mercury or alcohol)	Mercury Alcohol Clinical thermometer	–10 °C to 110 °C –60 °C to 60 °C 35 °C to 42 °C
Electromotive force (e.m.f.) (between hot and cold junctions of two different metals joined together)	Thermocouple	–200 °C to 60 °C Common ones
Resistance of metal **e.g.** Platinum	Resistance thermometer	–200 °C to 1200 ° C
Pressure of a fixed mass of gas at constant volume	Constant-volume gas thermometer	Estimated –258 °C to 1027 °C

10.3 Temperature Scale

1. Temperature is measured with reference to 2 fixed points:
   (a) Lower Fixed Point or Ice point (0 °C):
   Temperature of pure melting ice at standard atmospheric pressure.
   (b) Upper Fixed Point or Steam point (100 °C):
   Temperature of pure boiling water at standard atmospheric pressure.

2. The length between the 2 fixed points is divided into 100 equal intervals of 1 °C.

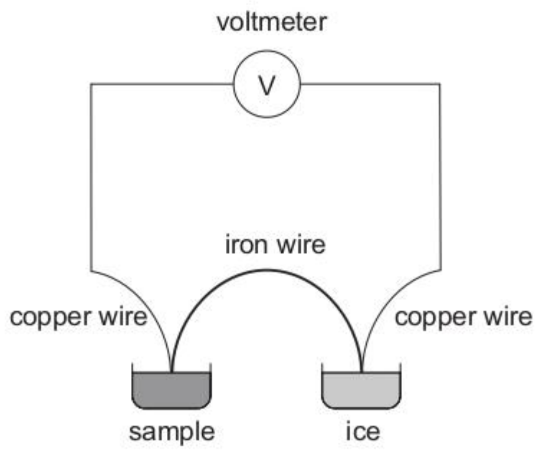
3. Apply the following general formula to calculate temperature of a material:

$$\boxed{\theta\,°\mathrm{C} = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100\ °\mathrm{C}}$$

where:
θ is temperature of material
X_θ is thermometric property at θ
X_{100} is thermometric property at steam point
X_0 is thermometric property at ice point
i.e. for clinical thermometer, X is the length of the mercury thread at temperature θ; for thermocouples, it is the voltmeter reading at temperature θ.

10.4 The Thermocouple

1. To measure the temperature of an unknown substance:
   (a) One junction is kept at a constant temperature (i.e. ice point).
   (b) The other junction is kept at the point where the temperature is to be measured.



2. Advantages:
   (a) Can withstand high temperature with suitable metals.
   (b) Large temperature range. Can measure very low or very high temperatures.
   (c) Junctions used are sharp and pointed and therefore can be used to measure temperature accurately at a point.
   (d) Rapid response to temperature change.

TOPIC 11 Thermal Properties of Matter

Objectives

Candidates should be able to:

(a) describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy)
(b) define the terms heat capacity and specific heat capacity
(c) recall and apply the relationship *thermal energy = mass × specific heat capacity × change in temperature* to new situations or to solve related problems
(d) describe melting/ solidification and boiling/ condensation as processes of energy transfer without a change in temperature
(e) explain the difference between boiling and evaporation
(f) define the terms latent heat and specific latent heat
(g) recall and apply the relationship *thermal energy = mass × specific latent heat* to new situations or to solve related problems
(h) explain latent heat in terms of molecular behaviour
(i) sketch and interpret a cooling curve

NOTES

11.1 Introduction

1. Temperature – a measure of the internal energy of the substance's atoms/ molecules.
2. Increase in temperature – caused by the supply of heat which increases internal energy.
3. Internal energy – sum of kinetic energy and potential energy of the atoms/ molecules.

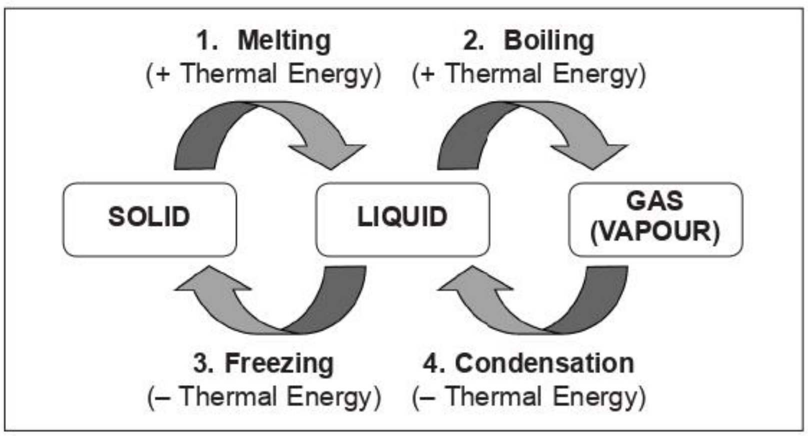
4. Types of internal energy:

State of substance	Type of internal energy
Solid	vibrational kinetic energy + potential energy
Liquid	translational kinetic energy + potential energy
Gas	mainly translational kinetic energy

11.2 Change of States

1. Two main changes occur when heat is supplied to a substance
   (a) Increase in temperature
   (b) Change of state (i.e. solid to liquid)

2. The following chart shows the changes of state (without temperature change) and their corresponding processes involved:



+ Thermal Energy: Heat is absorbed by substance
– Thermal Energy: Heat is removed from substance (Released to surroundings)

1. Melting	(i) Definition: a change of state from solid to liquid without a change in temperature. (ii) Melting point: constant temperature at which a solid melts into a liquid. (iii) Process: Heat absorbed is used to do work to break intermolecular bonds between the atoms/ molecules of the solid. (iv) The reverse process is freezing.
2. Boiling	(i) Definition: a change of state from liquid to gas without a change in temperature. (ii) Boiling point: constant temperature at which a liquid boils. (iii) Process: Heat supplied to the liquid is used to do work in separating the atoms or molecules as well as in pushing back the surrounding atmosphere. (iv) The reverse process is condensation.
3. Freezing	(i) Reverse process of melting. (ii) Definition: a change of state from liquid to solid without a change in temperature. (iii) Freezing point: constant temperature at which a liquid changes to a solid. (iv) Process: Heat is released as the intermolecular bonds are formed when the liquid atoms or molecules come together to form a solid. (v) For a pure substance, the melting point is the same as the freezing point.
4. Condensation	(i) Reverse process of boiling/ evaporation. (ii) Definition: a change of state from gas to liquid without a change in temperature. (iii) Condensation point: constant temperature at which a gas changes to a liquid. (iv) Process: Heat is released as the intermolecular bonds are formed when the gaseous atoms or molecules come together to form a liquid. (v) For a pure substance, the boiling point is the same as the condensation point.

3. Other processes:
   (a) Evaporation (liquid to gas)
   (b) Sublimation (solid to gas)

4. Differences between boiling and evaporation:

Boiling	Evaporation
occurs at a fixed temperature	occurs at any temperature
occurs throughout the liquid	occurs on the surface of substance
bubbles are visible	bubbles are not visible
fast process	slow process
heat is supplied to substance by an energy source	heat is absorbed by substance from the surroundings

5. Factors affecting melting and boiling points of water:

Factor	Melting Point	Boiling Point
Increase Pressure	Lower	Higher
Add Impurities	Lower	Higher

11.3 Heat Capacities and Latent Heat

1. The following terms are used in calculations in this chapter:

Term	SI Units	Definition	Formula
Heat capacity, C	J °C^{-1} or J K^{-1}	Thermal energy needed to increase temperature of substance by 1 °C or 1 K.	$Q = C\Delta\theta$
Specific heat capacity, c	J kg^{-1} °C^{-1} or J kg^{-1} K^{-1}	Thermal energy needed to increase temperature of 1 kg of substance by 1 °C or 1 K.	$Q = mc\Delta\theta$

Term	SI Units	Definition	Formula
Specific latent heat of fusion, l_f	J kg^{-1}	Thermal energy needed to change 1 kg of substance from solid to liquid without temperature change.	$Q = ml_f$
Specific latent heat of vaporisation, l_v	J kg^{-1}	Thermal energy needed to change 1 kg of substance from liquid to gas without temperature change.	$Q = ml_v$

Q – Amount of thermal energy needed (J), $\Delta\theta$ – Change in temperature

2. Comparison between substances of high and low heat capacities

Heat Capacity	Time to cool down/ heat up	Reason
High	Longer	Need to lose more energy (cooling) or absorb more energy (heating).
Low	Shorter	Need to lose less energy (cooling) or absorb less energy (heating).

TOPIC 12 General Wave Properties

Objectives

Candidates should be able to:

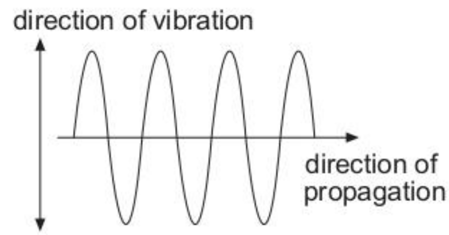
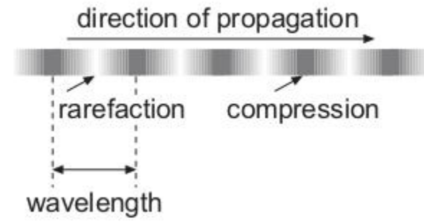
(a) describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by waves in a ripple tank
(b) show understanding that waves transfer energy without transferring matter
(c) define speed, frequency, wavelength, period and amplitude
(d) state what is meant by the term wavefront
(e) recall and apply the relationship *velocity* = *frequency* × *wavelength* to new situations or to solve related problems
(f) compare transverse and longitudinal waves and give suitable examples of each

NOTES...

12.1 Introduction

1. Wave motion is the propagation of oscillatory movement or disturbance from one region to another.
2. A wave transfers energy from one place to another without transferring matter.
3. All waves follow the laws of reflection and refraction.
4. Mechanical waves require a medium (i.e. water or air molecules) for propagation.
5. Electromagnetic waves (See Topic 14) are propagations of oscillations in electromagnetic fields. The propagation does not require a medium, thus electromagnetic waves can travel in vacuum.

6. We classify waves in this topic into two types based on their propagation method:
   (a) Transverse
   (b) Longitudinal

Transverse waves	Longitudinal waves
	
Movement of particles in the medium: Perpendicular to the direction of propagation (movement) of wave	**Movement of particles in the medium:** Parallel to the direction of propagation (movement) of wave
Examples Water waves, electromagnetic waves **Characteristics** 1. The particles oscillate perpendicularly (up and down) to the direction of travel. 2. Peak: Highest point reached by the particle from its neutral position 3. Trough: Lowest point reached by the particle from its neutral position 4. The distance between adjacent particles remains constant, in the direction of the propagation of the wave.	**Examples** Sound wave **Characteristics** 1. The particles oscillate along (to-and-fro) the direction of travel. 2. Compression: Section in which the particles are closest together 3. Rarefaction: Section in which the particles are furthest apart. 4. The distance between adjacent particles varies from a maximum value (furthest apart) to a minimum value (closest together), in the direction of the propagation of the wave.

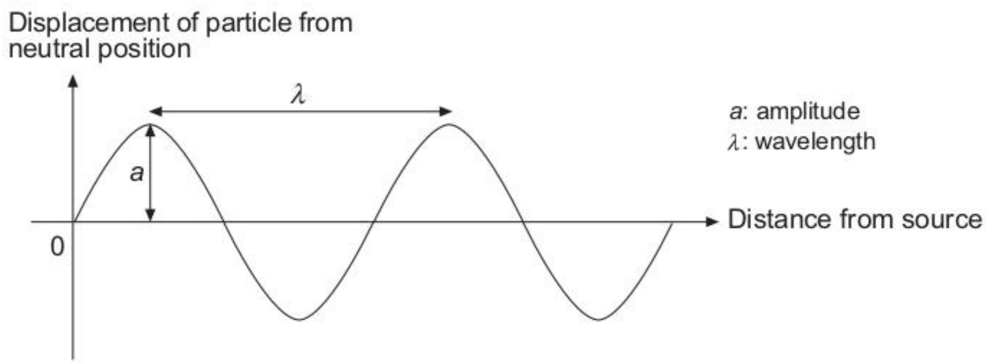
12.2 Terms used to describe a wave

1. For both transverse and longitudinal waves, the particles oscillate about their undisturbed positions (neutral positions). The neutral positions lie along an axis in the direction of wave propagation.

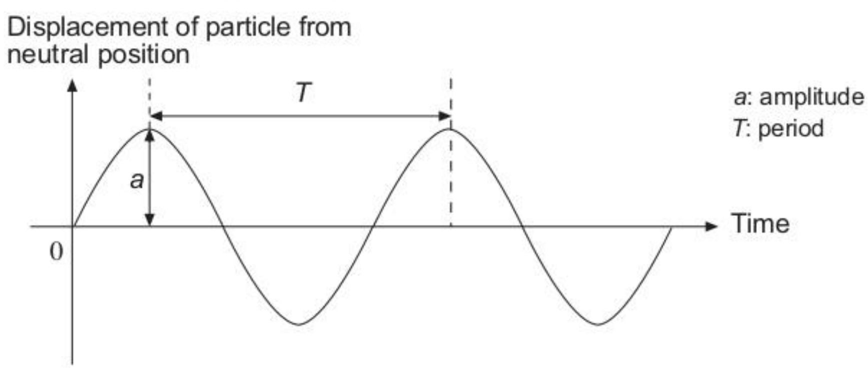
2. The following graphs show sine-curves used to describe the wave terms used for both types of waves.

Note: These are graphs and not transverse waves!

Displacement-distance Graph



Displacement-time Graph



3. Common wave terms:

Term	Transverse waves	Longitudinal waves
Amplitude, a (m)	The maximum displacement of the particle from its neutral position **perpendicular** to the direction of propagation. (i.e. height of crest from neutral position.)	The maximum displacement of the particle from its neutral position **along** the direction of propagation.
Wavelength, λ (m)	The distance between two successive crests or two successive troughs.	The distance between two successive compressions or two successive rarefractions.
Frequency, f (Hz)	The number of complete waves produced in one second.	
Period, T (s)	The time taken to produce one complete wave. **Formula:** $T = \frac{1}{f}$	
Speed, v (m)	The distance moved by any part of the wave in one second. **Formula:** $v = f\lambda$	

12.3 Wavefront

1. A wavefront is a line or surface, in the path of a wave motion, on which all particles are oscillating in phase.
2. There are two types of wavefronts:
   (a) Circular wavefront (close to point source of disturbance)
   (b) Plane wavefront (straight wavefronts far from point source of disturbance)
3. The amplitude of particles along the same wavefront is the same.

TOPIC 13 Light

Objectives

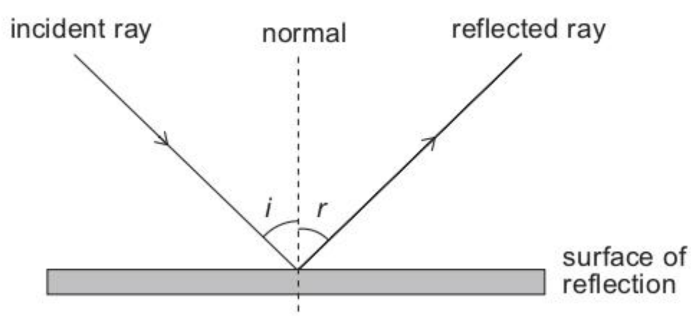
Candidates should be able to:

(a) recall and use the terms for reflection, including *normal*, *angle of incidence* and *angle of reflection*
(b) state that, for reflection, the angle of incidence is equal to the angle of reflection and use this principle in constructions, measurements and calculations
(c) recall and use the terms for refraction, including *normal*, *angle of incidence* and *angle of refraction*
(d) recall and apply the relationship $\frac{\sin i}{\sin r} = constant$ to new situations or to solve related problems
(e) define *refractive index* of a medium in terms of the ratio of speed of light in vacuum and in the medium
(f) explain the terms *critical angle* and *total internal reflection*
(g) identify the main ideas in total internal reflection and apply them to the use of optical fibres in telecommunication and state the advantages of their use
(h) describe the action of a thin lens (both converging and diverging) on a beam of light
(i) define the term *focal length* for a converging lens
(j) draw ray diagrams to illustrate the formation of real and virtual images of an object by a thin converging lens

NOTES...

13.1 Reflection

1. The diagram below shows a ray of light being reflected from a plane surface.



2. The following terms are commonly used in the reflection of light:

Term	Definition
Normal	Imaginary line perpendicular to the surface of reflection
Angle of incidence, *i*	Angle between the incident ray and the normal
Angle of reflection, *r*	Angle between the reflected ray and the normal

3. Laws of reflection:
   (a) Angle *i* = Angle *r*
   (b) The incident ray, reflected ray and the normal at the point of incidence all lie on the same plane.

4. Characteristics of an image formed in a plane mirror:
   (a) Upright
   (b) Virtual (Cannot be captured on a screen)
   (c) Laterally inverted
   (d) Same size as the object
   (e) Image distance from the other side of the surface of reflection is the same as the object's distance from the surface of reflection.

13.2 Refraction

1. The diagrams below show a ray of light refracted as it passes from air into glass and from glass into air. Note how the light ray bends in each case.

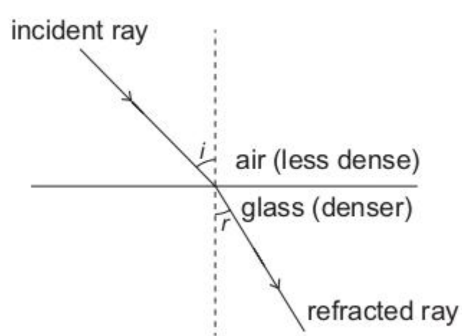


Fig. (a)

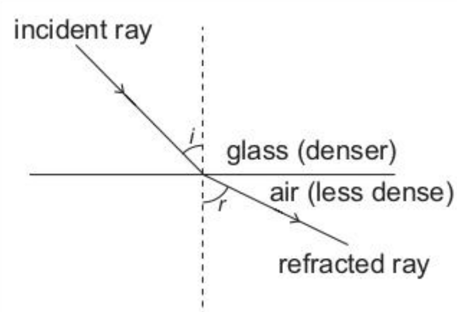


Fig. (b)

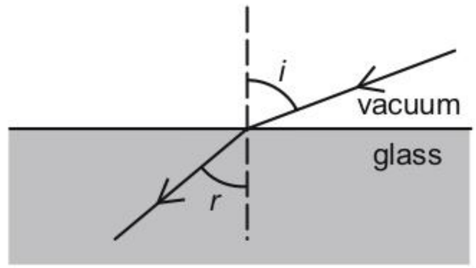
2. The following terms are commonly used in refraction:

Term	Definition
Normal	Imaginary line perpendicular to the surface of reflection
Angle of incidence, *i*	Angle between incident ray & normal
Angle of refraction, *r*	Angle between refracted ray & normal
Refractive index of a medium, *n*	Ratio of the speed of light in vacuum to the speed of light in medium
Critical angle	Angle of incidence in a denser medium for which the angle of refraction in the less dense medium is 90°
Total internal reflection	Complete reflection of an incident ray of light within a denser medium surrounded by a less dense medium when the incident angle is greater than the critical angle

3. Refractive index of vacuum is taken as 1.
   Air has a refractive index of 1.0003 which is very close to 1, but is not equal to 1.

4. Laws of refraction:
   (a) The incident ray, refracted ray and the normal at the point of incidence all lie on the same plane.
   (b) Snell's Law: $\dfrac{\sin i}{\sin r}$ = constant, for two given media.

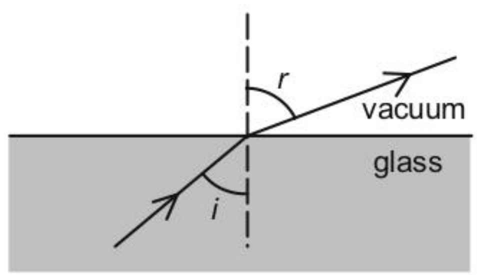
   ***E.g.* 1**: For the light ray passing from a **less dense** medium to a **denser** medium (such as vacuum to glass),



$$\frac{\sin i}{\sin r} = \frac{n_{\text{denser medium}}}{n_{\text{vacuum}}} = \frac{n}{1}$$
$$\frac{\sin i}{\sin r} = n$$

where n is the refractive index of the denser medium.

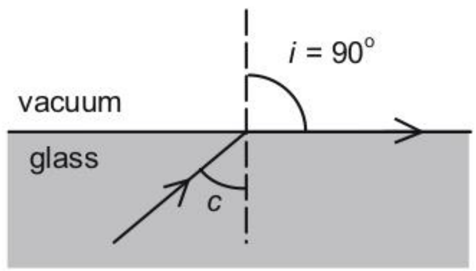
***E.g.* 2**: For the light ray passing from a **denser** medium (such as glass to vacuum) to a **less dense** medium,



$$\frac{\sin i}{\sin r} = \frac{n_{\text{vacuum}}}{n_{\text{denser medium}}} = \frac{1}{n}$$

where n is the refractive index of the denser medium.

***E.g.* 3**: For light ray passing from a denser medium into a less dense medium at a critical angle, $i = c$,



$$\frac{\sin i}{\sin r} = \frac{n_{\text{vacuum}}}{n_{\text{glass}}}$$

$$\frac{n_{\text{vacuum}}}{n_{\text{glass}}} = \frac{\sin c}{\sin 90^\circ} \text{ where } i = c \text{ and } r = 90^\circ$$

$$n_{\text{glass}} = \frac{1}{\sin c}$$

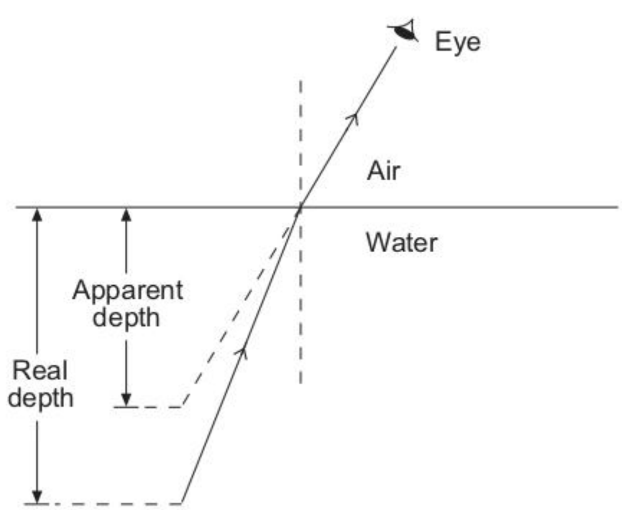
$$\Rightarrow n = \frac{1}{\sin c}$$

where n is the refractive index of the denser medium.

When other incident angles $i > c$, the incident ray will undergo total internal reflection.
Note that $n_{\text{vacuum}} = 1$ and $n_{\text{air}} = 1.0003$.

5. Refractive index, n, of a medium (i.e. water) can also be calculated as follows:

$$\frac{\text{real depth}}{\text{apparent depth}} = n$$



6. The speed of light is slower in a denser medium as compared to that in a less dense medium.

   Example 13.1
   A ray of light travels from within a piece of glass into air. The incident angle is 10° and the refractive index of glass is 1.61. Calculate the angle of refraction.

   Solution
   Refractive index of glass, $n_{\text{glass}} = 1.61$
   Refractive index of air, $n_{\text{air}} = 1.0003$

   $$\frac{\sin i}{\sin r} = \frac{n_{air}}{n_{glass}} \quad (\textit{Common mistake}: \frac{\sin i}{\sin r} = n_{glass})$$

   $$\frac{\sin 10^\circ}{\sin r} = \frac{1.0003}{1.61}$$

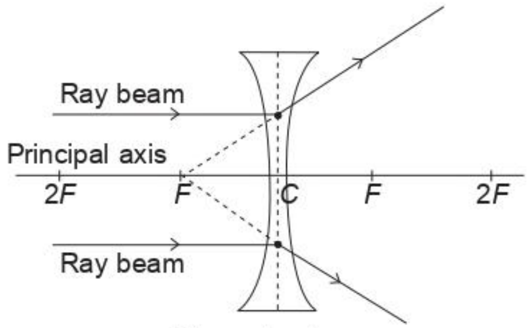
   $$\sin r = \frac{1.61 \sin 10^\circ}{1.0003}$$

   Angle $r = 16.2^\circ$ (to 1 d.p.)

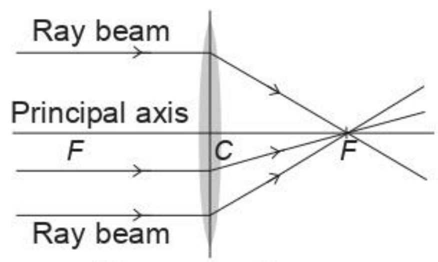
7. An application of total internal reflection: optical fibres to transmit data.
   Principle: The polished surfaces of the fibres are made of a material of suitable refractive index for total internal reflection of light.
   Advantages:
   1. Optical fibres have high electrical resistance, so it can be used near high-voltage equipment safely.
   2. Since optical fibres have lower density than copper, the mass is lower for the same volume of wires. Hence optical fibres are suitable for mobile vehicle applications such as aircrafts where mass and space are concerns.
   3. Optical fibres are resistant to chemical corrosion
   4. Optical fibres do not emit electric fields or magnetic fields since they carry light instead of electrical currents, hence they will not interfere with nearby electronic equipment or themselves be subject to electromagnetic interference.
   5. Since optical fibres are secured, it is difficult to intercept signals without disrupting them, unlike conventional current carrying copper cables.

13.3 Lenses

1. Actions of a thin lens: As shown in the following diagrams, a converging lens converges a beam of light whereas a diverging lens diverges a beam of light.



Diverging lens

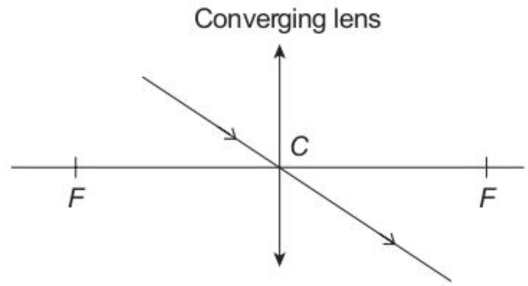
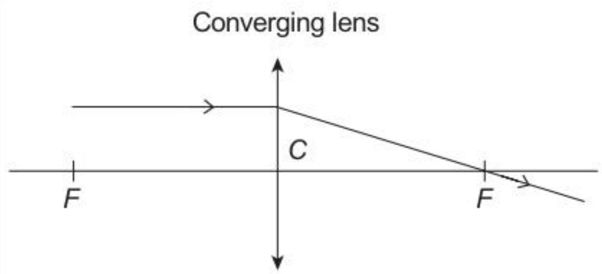
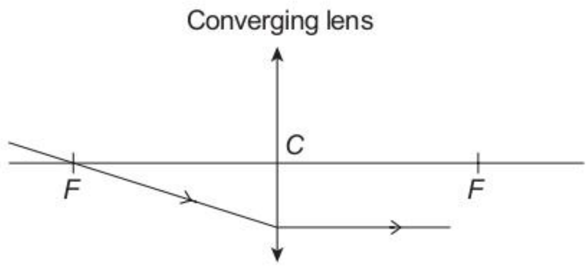


Converging lens

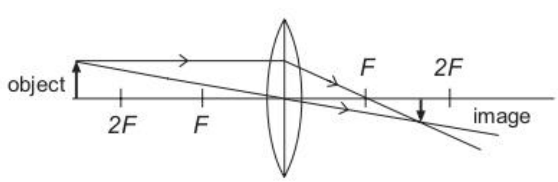
2. The following table summarises the main features of a lens:

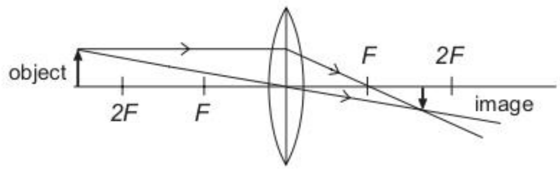
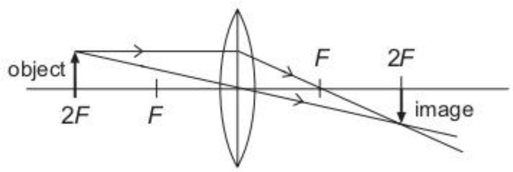
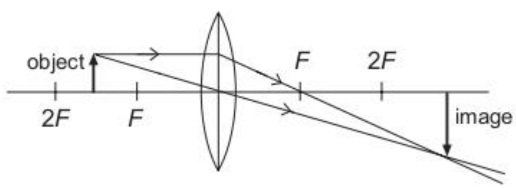
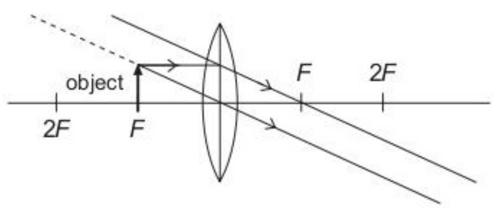
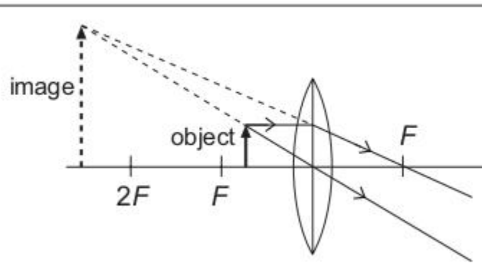
Term	Definition
Focal length, f	Distance between the optical centre, C and the principal focus F.
Optical centre, C	Midpoint between the lens' surface on the principal axis. Rays passing through optical centre are not deviated.
Principal axis	Line passing symmetrically through the optical centre of the lens.
Principal focus or Focal point, F	Point of convergence for all light rays refracted by the lens.
Focal plane	Plane which passes through F and perpendicular to the principal axis.

3. Ray diagrams are drawn to locate the position and the size of an image.

Action of incident ray	Diagram
Ray passing through *C* passes straight through without a change in direction.	
Ray parallel to principal axis passes through lens and changes direction and passes through *F*.	
Ray passing through *F* initially reaches lens and passes out parallel to principal axis.	

4. Types of images formed by a **thin** converging lens

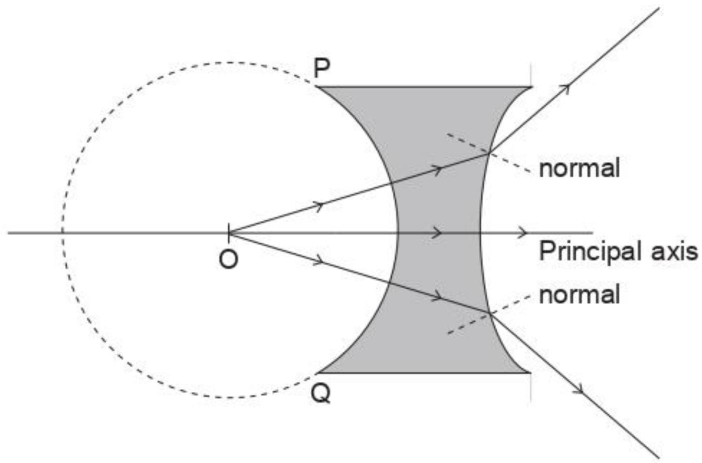
Object distance	Ray diagram	Image characteristics	Application
At infinity		• Real • At *F*	Telescope lens

Object distance	Ray diagram	Image characteristics	Application
Greater than 2*F*		• Inverted • Real • Diminished • Between *F* and 2*F*	Camera lens
At 2*F*		• Inverted • Real • Same size as object • At 2F	Photocopier
Between *F* and 2*F*		• Inverted • Real • Magnified	Projector
At *F*		• Image formed at infinity. (Light rays travel parallel to each other.)	
Less than *F*		• Upright • Enlarged • Virtual (On the same side of the lens as the object.)	Magnifying glass

Note: Ray diagrams must ALWAYS have arrows to indicate direction of the ray.

5. Special cases

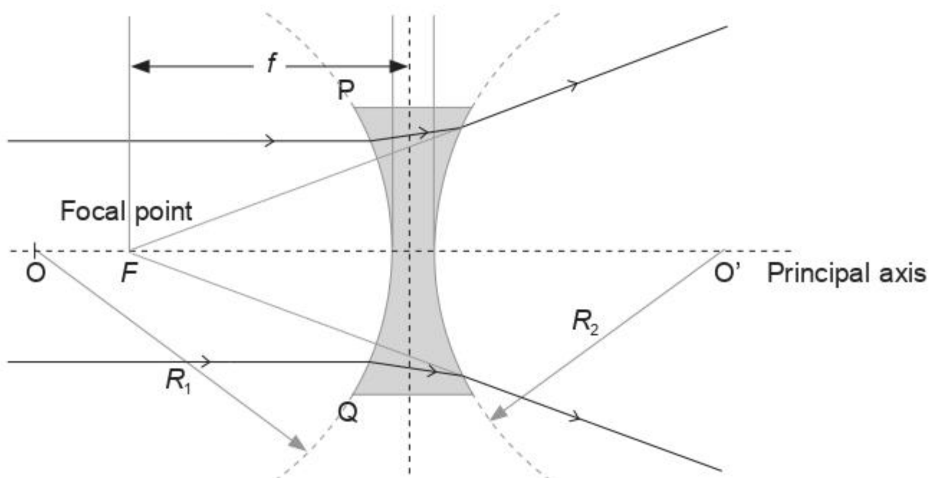
- Diverging lens: Light source from O, centre of curvature of the lens.
  The figure shows part of a diverging lens where one of the faces of the lens PQ is part of a circle with centre O.



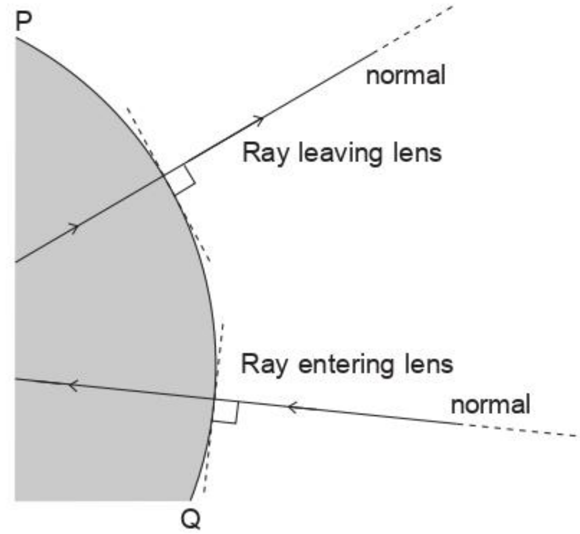
Any light rays drawn from O to PQ will be normal (90°) to the surface PQ because they are moving along the normal line.

Hence any light ray originated from O and entering into the lens PQ will be moving into the lens without changing direction.

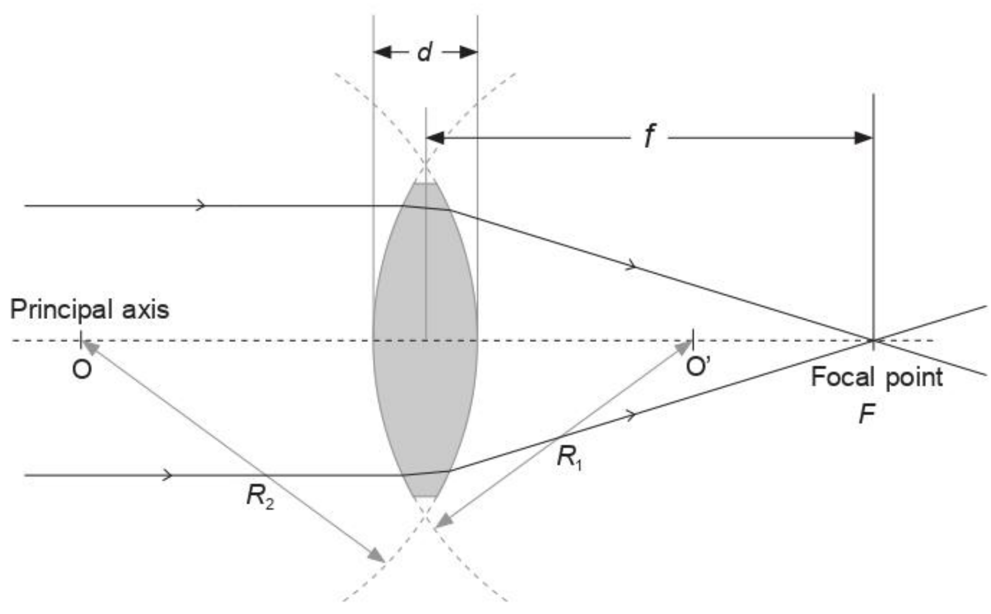
A complete diverging lens is shown in the figure below, where O and O' are the centre of the circles (dotted), F is the focal point and f is the focal length. R_1 and R_2 are the radii of the circles with centres O and O' respectively.



- Converging lens: Light rays entering or leaving the lens will travel along the path of the normal to the lens surface which is a part of a circle. The figure shows part of a converging lens where PQ is part of a circle.



The rays will not change direction because they are moving along the path of the normal line. The path forms an angle of 90° to the surface of the lens.
A complete converging lens is shown in the figure below, where O and O' are the centre of the circles (dotted), F is the focal point and f is the focal length. R_1 and R_2 are the radii of the circles with centres O and O' respectively.



TOPIC 14 Electromagnetic Spectrum

Objectives

Candidates should be able to:

(a) state that all electromagnetic waves are transverse waves that travel with the same speed in vacuum and state the magnitude of this speed
(b) describe the main components of the electromagnetic spectrum
(c) state examples of the use of the following components:
   (i) radiowaves (e.g. radio and television communication)
   (ii) microwaves (e.g. microwave oven and satellite television)
   (iii) infra-red (e.g. infra-red remote controllers and intruder alarms)
   (iv) light (e.g. optical fibres for medical uses and telecommunications)
   (v) ultra-violet (e.g. sunbeds and sterilisation)
   (vi) X-rays (e.g. radiological and engineering applications)
   (vii) gamma rays (e.g. medical treatment)
(d) describe the effects of absorbing electromagnetic waves, e.g. heating, ionisation and damage to living cells and tissue

NOTES...

14.1 Components of the Electromagnetic Spectrum

1. All electromagnetic waves (EM waves) are transverse waves that travel at the speed of light (3×10^8 m/s) in vacuum and slow down in other media.
2. EM waves do not require a medium for propagation.
3. EM waves can be absorbed or emitted by matter.
4. The main components of the electromagnetic spectrum are as follows:

EM Wave	Order of Magnitude of Wavelength, λ/m	Application
γ-ray (Gamma ray)	10^{-3}	Manufacturing: Checking of cracks/ holes in metal plates. Medical: Radiotherapy.

EM Wave	Order of Magnitude of Wavelength, λ/m	Application
X-ray	10^{-10}	Medical: Inspection of bones for signs of fractures.
Ultraviolet (UV)	10^{-8}	Medical: Production of vitamin D in the body.
Visible light spectrum: *Violet* *Indigo* *Blue* *Green* *Yellow* *Orange* *Red* In increasing order of λ	10^{-7}	
Infrared radiation (IR)	10^{-4}	Remote control for television sets.
Microwave	10^{-2}	Microwave oven for cooking.
Radio Wave	10^{-2} to 10^{3}	Telecommunication.

14.2 Harmful Effects of Absorbing EM Waves

1. EM waves transmit radiation energy from one region to another.

2. Radiation may damage living cells and tissues through heating and ionisation.
   (a) Heating: Organic molecules in tissue gain kinetic energy from incident radiation. The energy increase is detected by a temperature rise. When the temperature gets too high, the molecules break apart and the tissue gets cooked.
   (b) Ionisation: Organic molecules absorb energy to break molecular bonds to form ions which can react with neighbouring molecules. This results in destruction or changes to the tissue.

3. Mobile phones emit radiation in the form of electromagnetic waves which can heat up the brain.

4. Too much sun-tanning can lead to an overdose of ultraviolet radiation which can cause skin cancer (i.e. melanoma).

TOPIC 15 Sound

Objectives

Candidates should be able to:

(a) describe the production of sound by vibrating sources
(b) describe the longitudinal nature of sound waves in terms of the processes of compression and rarefaction
(c) explain that a medium is required in order to transmit sound waves and the speed of sound differs in air, liquids and solids
(d) describe a direct method for the determination of the speed of sound in air and make the necessary calculation
(e) relate loudness of a sound wave to its amplitude and pitch to its frequency
(f) describe how the reflection of sound may produce an echo, and how this may be used for measuring distances
(g) define ultrasound and describe one use of ultrasound, e.g. quality control and pre-natal scanning

NOTES

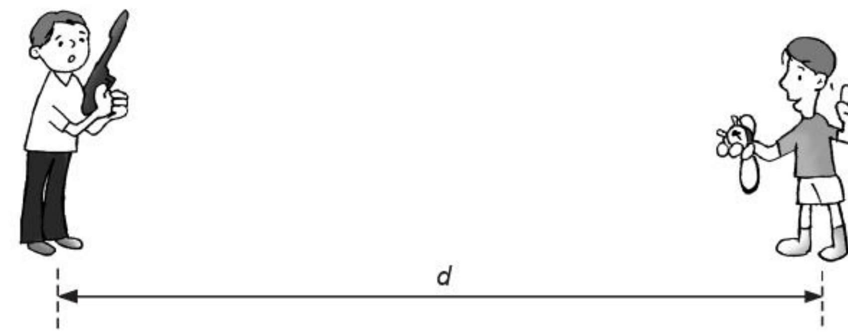
15.1 Production of Sound Waves

1. Sound waves are produced when objects vibrate in a medium.
2. Sound waves are longitudinal waves which require a medium for propagation.

15.2 Medium of Propagation for Sound

1. When sound waves travel in different media, the speed differs.
   Speed of sound in solids > speed of sound in liquids > speed of sound in air.
2. In solids, the atoms are more closely packed together, as compared to liquids and gases. Hence, sound travels the fastest in solids.

15.3 Determining the Speed of Sound



1. To determine the speed of sound, a gunman and a timer can stand apart from each other in an open field at a known distance d.

2. The gunman will fire a pistol into the air. The timer will start his stopwatch upon seeing the flash of the pistol and stop the stopwatch when he hears the sound of the pistol. The time interval is recorded as Δt.

3. The speed of sound is calculated as:

$$\boxed{v = \frac{d}{\Delta t}}$$

4. The speed of sound in air is about 330 m/s. Since the human reaction time is about $\frac{2}{3}$ of a second, d has to be sufficiently large for the experiment to be accurate.

Example 15.1

In a storm, an observer saw a lightning flash, followed by the sound of thunder 4.0 seconds later. Given that the speed of sound in air is approximately 330 m/s, find the observer's distance from where the lightning occurred.

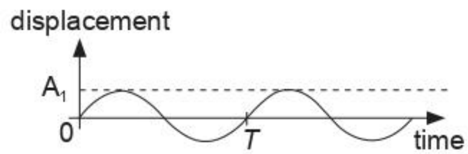
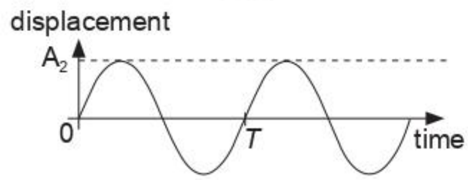
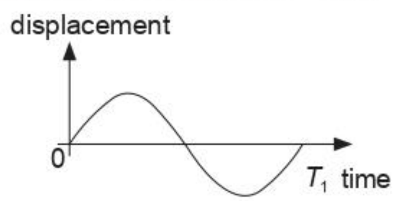
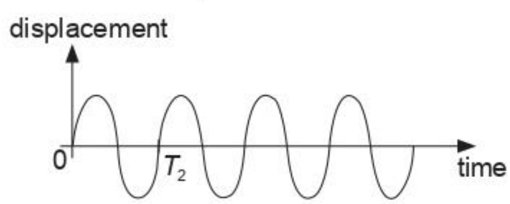
Solution

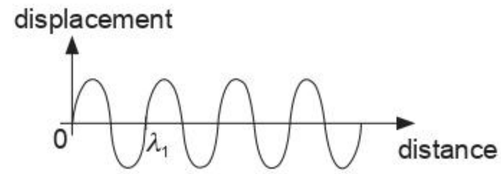
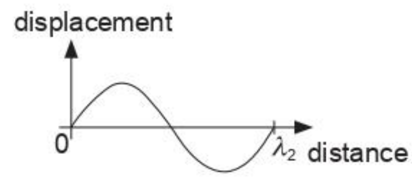
The lightning flash, which the observer sees, is assumed to reach him immediately after the lightning occurs (speed of light = 3.0×10^8 m/s).
Let the distance of the observer from the lightning be d.

$$\Delta t = 4.0 \text{ s}$$
$$330 = \frac{d}{\Delta t} = \frac{d}{4}$$
$$d = 1320 \text{ m}$$

15.4 Characteristics of Sound

1. The following table shows the main characteristics of sound and the factors affecting these characteristics:

Characteristics	Factors
Loudness	Amplitude of a sound wave (a higher amplitude leads to a louder sound)  soft  loud Note: amplitude $A_1 < A_2$
Pitch	Wavelength of a sound wave (a shorter wavelength leads to a higher pitch) Frequency of a sound wave (a higher frequency leads to a higher pitch) From the equation, $v = f\lambda$, since v is constant, we observe that when the wavelength, λ, decreases, the frequency, f, increases. As such, a shorter wavelength leads to a higher frequency which leads to a higher pitch.  low pitch  high pitch

Characteristics	Factors
	Note: $T_1 > T_2$ From the equation, $T = \frac{1}{f}$, we observe that when the period, T, increases, the frequency, f, decreases. As such, a longer period leads to a lower frequency which leads to a lower pitch.  high pitch  low pitch Note: $\lambda_1 < \lambda_2$

15.5 Echoes

1. Echoes are produced when a sound wave is reflected from a surface.
2. The reflected sound (echo) can be heard separately from the original sound if the source of the sound is much closer to the observer than to the reflecting surface.
3. To reduce the effect of echoes in buildings, walls are roughened up with padding and the floors are covered with rugs or carpets. This is to scatter the incident sound wave so that the reflected sound is reduced.
4. Using echo to measure distance.

Example 15.2

A man stood in front of a tall cliff. He fired a pistol into the air and started his stopwatch simultaneously. After 3.0 s, he heard the echo of the pistol shot. Given that the speed of sound is 330 m/s, find his distance from the cliff.

Solution

Let distance of man from cliff be d.

$2d = 330 \times 3.0$

$d = 495$ m

(We used $2d$ because 3.0 s is the time taken for the sound to hit the cliff and be reflected back to the man.)

15.6 Ultrasound

1. Ultrasound is the sound with frequencies that are greater than 20 000 Hz.
2. The audible range of sound for humans is between 20 Hz and 20 000 Hz. Hence humans cannot hear ultrasound.
3. Some applications of ultrasound:
   (a) Pre-natal scan to check the development of babies in womb.
   (b) Used by ships to find depth of seabed.
   (c) Check for cracks in metal pipes that are too small for the naked eye to see.

TOPIC 16 Static Electricity

Objectives

Candidates should be able to:

(a) state that there are positive and negative charges and that charge is measured in coulombs
(b) state that unlike charges attract and like charges repel
(c) describe an electric field as a region in which an electric charge experiences a force
(d) draw the electric field of an isolated point charge and recall that the direction of the field lines gives the direction of the force acting on a positive test charge
(e) draw the electric field pattern between two isolated point charges
(f) show understanding that electrostatic charging by rubbing involves a transfer of electrons
(g) describe experiments to show electrostatic charging by induction
(h) describe examples where electrostatic charging may be a potential hazard
(i) describe the use of electrostatic charging in a photocopier, and apply the use of electrostatic charging to new situations

NOTES

16.1 Atomic Structure

1. Matter is made up of small units called atoms.
2. An atom consists of a positively-charged nucleus surrounded by negatively charged electrons orbiting around the nucleus. The overall charge of an atom is zero.
3. The positively-charged nucleus consists of positively-charged protons held together by neutral particles called neutrons.
4. When excess electrons are added to an atom, the atom becomes negatively charged.
5. When electrons are removed from an atom, the atom becomes positively charged.

16.2 Electric Charges

1. Electric charges are either positive or negative.
2. Like charges repel each other; unlike charges attract each other.
3. Rubbing (charging by friction) causes electrons to be transferred from one object to another. Charge transfer between two objects only involves electron transfer. There is NO MOVEMENT of positive charges (which are the nuclei of the atoms). Otherwise, the solid will deform.
4. Insulators can be charged by rubbing, unlike conductors (metals), because **electrons** are not free to move about in an insulator and thus charges are localised to the surfaces where rubbing occurs.
5. Examples of insulators and the types of charges they gain from rubbing:

Type of insulator rod	Type of cloth used for rubbing	Charges gained by cloth	Charges gained by rod
Cellulose acetate	wool	$-Q$	$+Q$
Glass	silk	$-Q$	$+Q$
Ebonite	fur	$+Q$	$-Q$
Polythene	wool	$+Q$	$-Q$

6. The excess charge, Q, carried away by one body must be equal to the number of electrons removed from the other body. The charges are in multiples of an electron charge, e (-1.6×10^{-19} C) according to the equation:

$\boxed{Q = Ne}$ where N is a whole number.

7. The unit of charge is the coulomb (Symbol: C).
8. Electric charge Q is related to current I and time t by the equation:

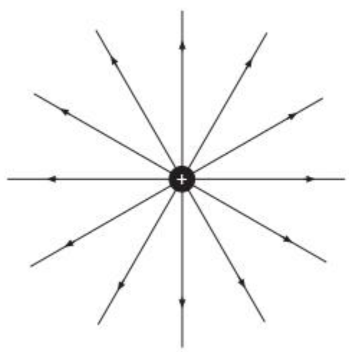
$$\boxed{Q = It}$$

16.3 Concept of Electric Field

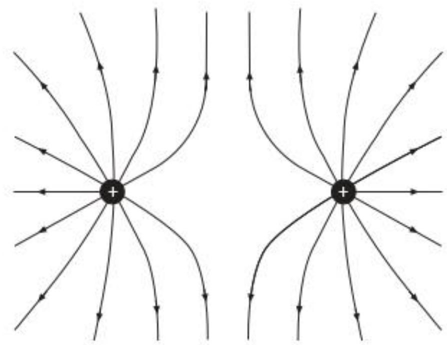
1. An electric field is a region in space in which a unit positive charge experiences a force.
2. Electric field is a vector quantity. The direction of the field is determined by the direction of the force acting on the unit positive charge.
3. An electric field is set up by a charge. When a unit positive charge is brought near a negative charge, the positive charge will experience a force of attraction towards the negative charge and vice versa.

Example 16.1: Examples of field patterns set up by point charges

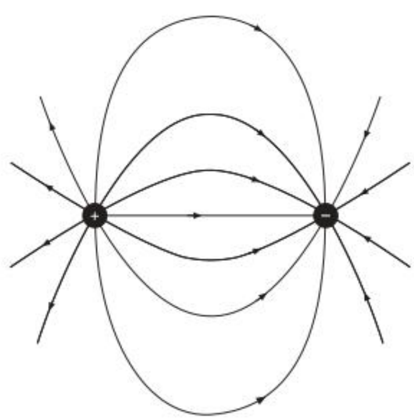
(a) Isolated positive charge



(b) Two equal magnitude, positive charges close to each other



(c) Two charges with equal magnitude but opposite signs



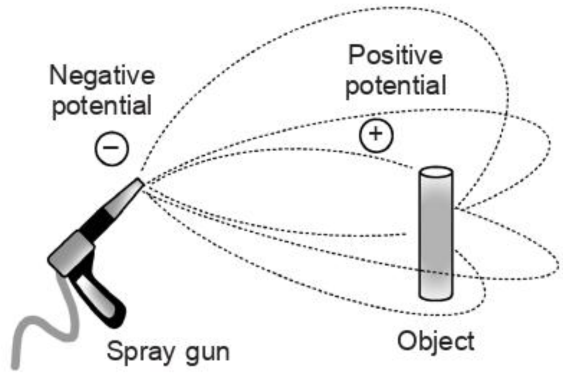
16.4 Hazards of Electrostatic Charging

1. Lightning: A large charge build-up in the clouds due to the friction between water and air molecules results in the ionisation of the air. The ionised air provides a path for conduction of electrons to the ground through tall, pointed objects.
   Remedy: Lightning conductors can be placed at the top of tall buildings to allow electrons to flow steadily from the air to the ground.

2. Fire: An excessive build up of charges due to friction with air can lead to an explosion or a fire in aircrafts.
   Remedy: Tyres are made of slightly conductive rubber to discharge the aircraft when it touches down.

16.5 Some Applications of Electrostatics

1. Spray painting:
   Steps:
   (1) A fixed electric potential difference is maintained between the paint spray nozzle and the object to be painted. (i.e. the nozzle is negatively-charged and the object is positively charged)



   (2) As the paint leaves the nozzle, the droplets are charged.
   (3) Since the droplets all have the same charge, they repel each other so that the paint spreads out evenly.
   (4) The paint droplets are all attracted to the positively-charged object and stick strongly to its surface.

2. Photocopier:
   Steps:
   (1) Positive charges are arranged in a pattern to be copied on the surface of an insulator drum.
   (2) Negatively-charged toner powder is sprinkled on the drum.
   (3) Only the portions of the drum with positive charges allow the toner powder to stick to it to form the image.
   (4) The resultant pattern is then transferred onto the paper and fixed permanently by heat.

TOPIC 17 Current of Electricity

Objectives

Candidates should be able to:

(a) state that current is a rate of flow of charge and that it is measured in amperes
(b) distinguish between conventional current and electron flow
(c) recall and apply the relationship charge = *current* × *time* to new situations or to solve related problems
(d) define electromotive force (e.m.f.) as the work done by a source in driving unit charge around a complete circuit
(e) calculate the total e.m.f. where several sources are arranged in series
(f) state that the e.m.f. of a source and the potential difference (p.d.) across a circuit component is measured in volts
(g) define the p.d. across a component in a circuit as the work done to drive unit charge through the component
(h) state the definition that resistance = *p.d. / current*
(i) apply the relationship $R = V/I$ to new situations or to solve related problems
(j) describe an experiment to determine the resistance of a metallic conductor using a voltmeter and an ammeter, and make the necessary calculations
(k) recall and apply the formulae for the effective resistance of a number of resistors in series and in parallel to new situations or to solve related problems
(l) recall and apply the relationship of the proportionality between resistance and the length and cross-sectional area of a wire to new situations or to solve related problems
(m) state Ohm's Law
(n) describe the effect of temperature increase on the resistance of a metallic conductor
(o) sketch and interpret the I/V characteristic graphs for a metallic conductor at constant temperature, for a filament lamp and for a semiconductor diode

NOTES

17.1 Conventional Current and Electron Flow

1. Definition of current: the rate of flow of electric charges.

2. Equation: $\boxed{I = \frac{Q}{t}}$

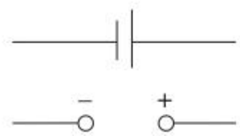
   I is the current (unit: A)
   Q is the charge (unit: C, or equivalent unit: A s)
   t is the time (unit: s)

3. Definition of ampere: 1 ampere is the current carried by 1 coulomb of charge flowing in a circuit in 1 second.

4. The flow of conventional current in a circuit arises from the flow of electrons (negative charges) in the opposite direction.

5. Direct Current (d.c.): A direct current only flows in one direction.

6. Alternating Current (a.c.): An alternating current periodically reverses its direction back and forth.

 d.c. source	 a.c. source

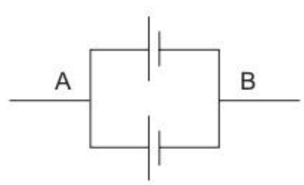
17.2 Electromotive Force (e.m.f.)

1. Definition of electromotive force: The electromotive force of a d.c. source is the work done by the source to drive a unit charge round a closed circuit.

2. Equation: $\boxed{W = QV}$

   W is the work done by source (unit: J)
   Q is the charge (unit: C)
   V is the e.m.f. (unit: V)

3. The following table shows some of the different types of arrangement of 1.5 V cells and the resultant e.m.f.:

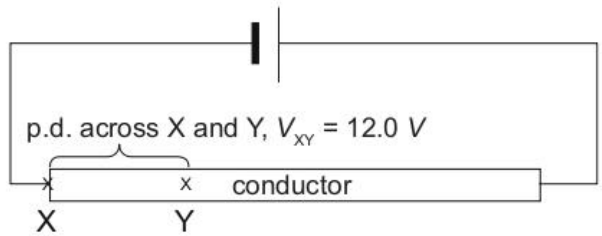
Two cells in parallel	**Two cells in series**
Overall e.m.f. across AB = 1.5 V	Overall e.m.f. across AB = 3.0 V
	

17.3 Potential Difference (p.d.)

1. Definition of potential difference: The potential difference across a circuit component is the work done to drive a unit charge through the circuit component.

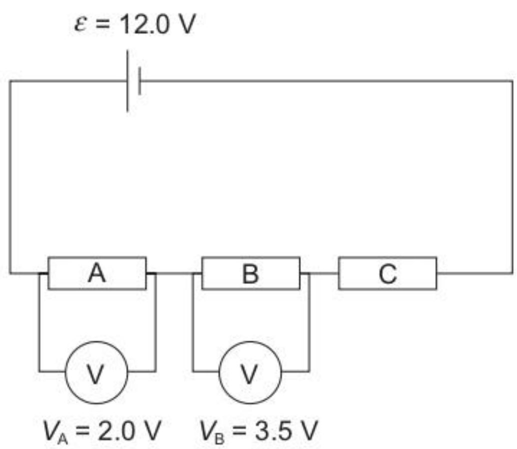
Example 17.1

For a conductor (resistor wire) connected in a closed circuit, the potential difference across two points, X and Y, in part of the conductor is the work done to drive a unit charge across the two points through that part of the conductor.



Example 17.2

The following circuit shows three resistors, A, B and C, connected in series. The potential difference across A and B are given as V_A = 2.0 V and V_B = 3.5 V. Given that the e.m.f. of the battery is 12.0 V, find the potential difference across resistor C.

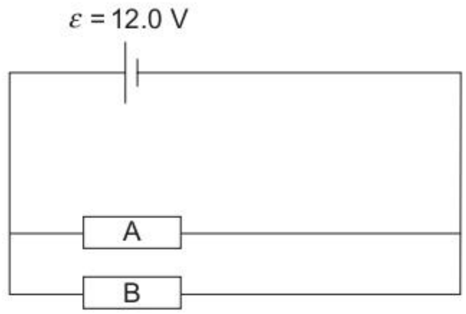


Solution

V_C = 12.0 – 2.0 – 3.5 = 6.5 V

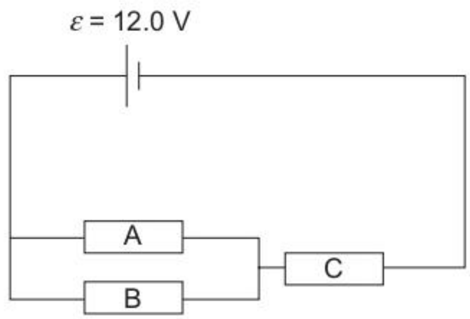
2. In a circuit with two resistors A and B, the potential difference across resistor A is the same as the potential difference across resistor B if the two resistors are arranged in parallel.

   $V_A = V_B = 12.0$ V



Example 17.3

Given that $V_C = 5.0$ V, find the potential difference across A and B.



Solution

Since resistors A and B are arranged in parallel, $V_A = V_B = 12.0 - 5.0 = 7.0$ V.

17.4 Resistance

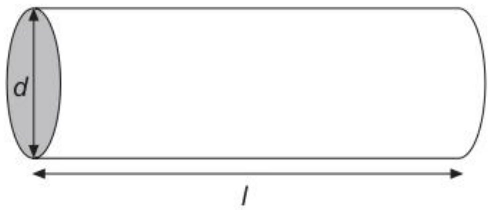
1. Definition of resistance: The ratio of potential difference (V) across the conductor to the current (I) flowing through it.

$$R = \frac{V}{I}$$

   R is resistance of conductor (unit: Ω, equivalent unit: 1 Ω = 1 V A^{-1})
   V is potential difference across the conductor (unit: V)
   I is current through the conductor (unit: A)

2. The resistance of a piece of cylindrical wire R is related to its length l, cross sectional area A and its resistivity, ρ (each type of material has its own resistivity):

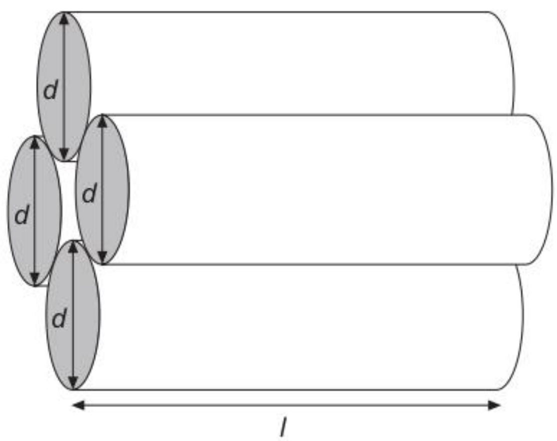
$$\boxed{R = \frac{\rho l}{A}}$$



d – diameter of wire
l – length of wire
Cross-sectional area of wire,

$$A = \pi\left(\frac{d}{2}\right)^2$$

3. Parallel resistors
4 identical resistors are connected in parallel as shown in the diagram.



Effective cross-sectional area = $4 \times A = 4A$

Effective length of bundle of 4 resistors = l

Effective resistance, R_{eff}

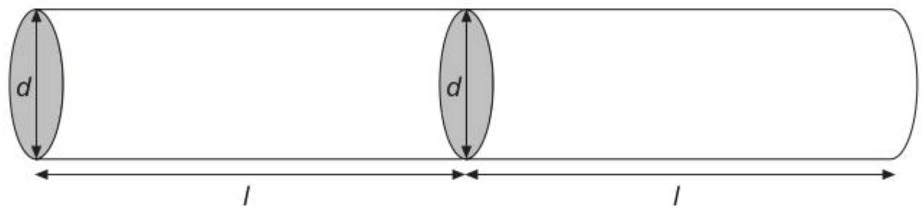
$$= \frac{\rho l}{4A} = \frac{1}{4}R$$

Formula:

$$\boxed{\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$$

4. Series resistors

2 identical resistors are connected in series as shown in the diagram.



Effective cross-sectional area = A

Effective length of 2 resistors = $2l$

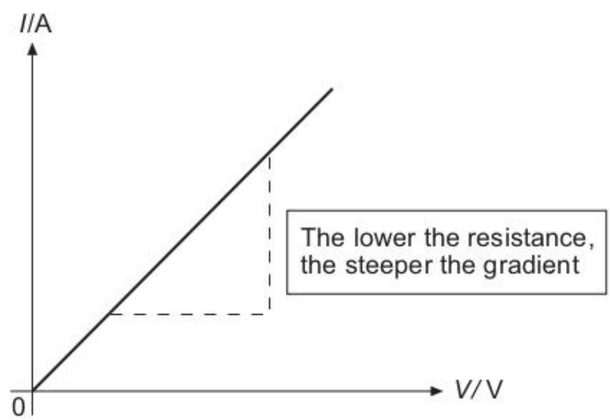
Effective resistance, $R_{eff} = \dfrac{\rho(2l)}{A} = 2\dfrac{\rho l}{A} = 2R$

Formula:

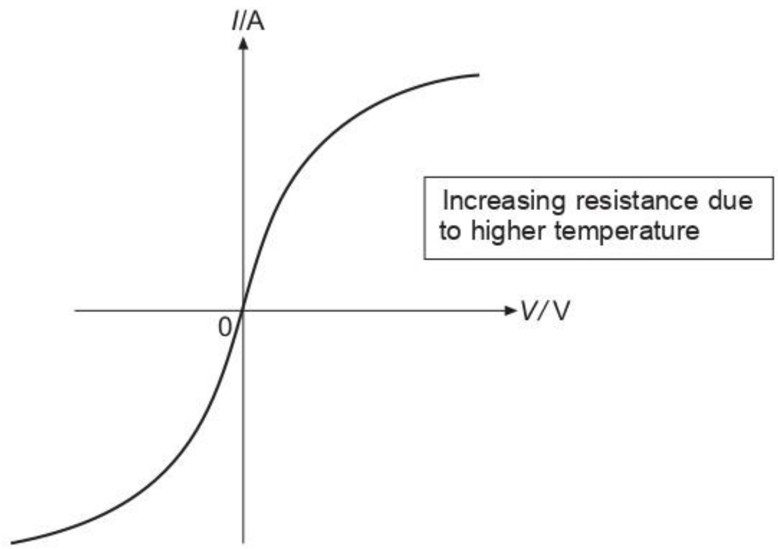
$$\boxed{R_{eff} = R_1 + R_2}$$

5. Ohm's Law: Ohm's law states that the current flowing in a conductor is directly proportional to the potential difference applied across it when all other physical conditions such as temperature are constant.

The *I*-*V* graph of an ohmic conductor is as follows:



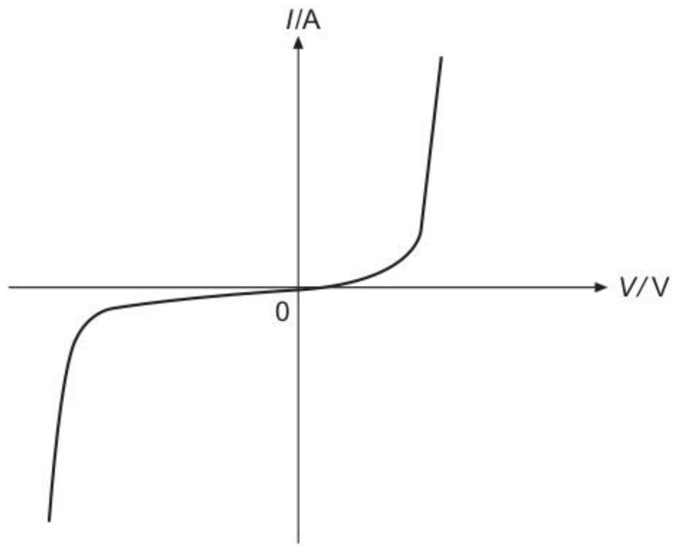
6. For a filament lamp (non-ohmic conductor), its *I*-*V* graph is not a straight line. As such, it does not obey Ohm's Law. As more current flows in a lamp, its metal filament becomes hotter and atoms in the filament vibrate faster, moving further away from their positions. This leads to an increase in the frequency of collisions with the travelling electrons that hinder their flow, causing more resistance. Hence, the gradient of its graph is fairly constant at low current *I* and potential difference *V*, but with increasing current, the resistance increases (gradient decreases).



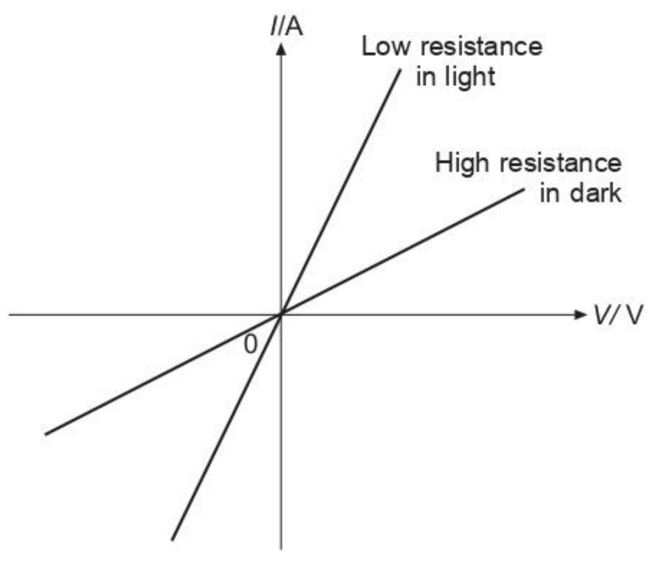
17.5 Diode and Light-dependent Resistor

1. A diode can be used to convert a.c. to d.c. in a process called rectification. A diode is a semiconductor device that allows current to only flow in one direction.

2. The *I-V* characteristic graph for the semiconductor diode is shown:



3. A light dependent resistor (LDR) is a semiconductor. When light shines onto the LDR, electrons are released. This increases the number of current-carrying electrons. As the light intensity increases, the current also increases, resulting in a fall in resistance. In the dark, there are no electrons and the current experiences a greater resistance.



TOPIC 18 D.C. Circuits

Objectives

Candidates should be able to:

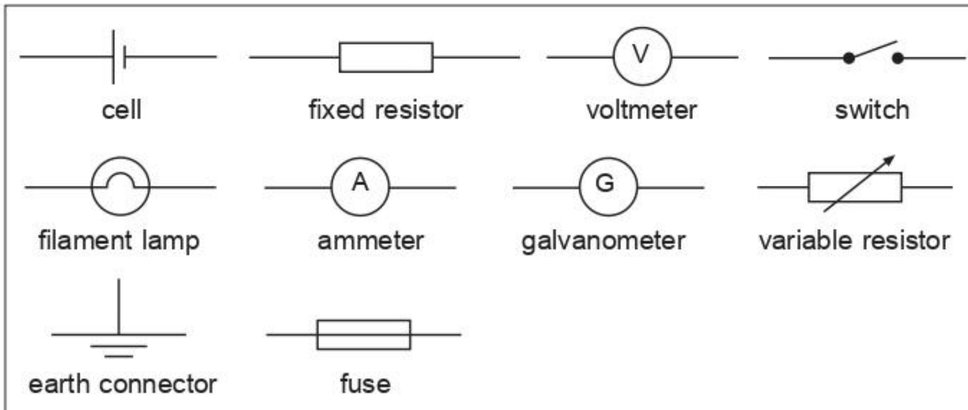
(a) draw circuit diagrams with power sources (cell, battery, d.c. supply or a.c. supply), switches, lamps, resistors (fixed and variable), variable potential divider (potentiometer), fuses, ammeters and voltmeters, bells, light-dependent resistors, thermistors and light-emitting diodes
(b) state that the current at every point in a series circuit is the same and apply the principle to new situations or to solve related problems
(c) state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit and apply the principle to new situations or to solve related problems
(d) state that the current from the source is the sum of the currents in the separate branches of a parallel circuit and apply the principle to new situations or to solve related problems
(e) state that the potential difference across the separate branches of a parallel circuit is the same and apply the principle to new situations or to solve related problems
(f) recall and apply the relevant relationships, including $R = V/I$ and those for current, potential differences and resistors in series and in parallel circuits, in calculations involving a whole circuit
(g) describe the action of a variable potential divider (potentiometer)
(h) describe the action of thermistors and light-dependent resistors and explain their use as input transducers in potential dividers
(i) solve simple circuit problems involving thermistors and light-dependent resistors

NOTES..

18.1 Current and Potential Difference in Circuits

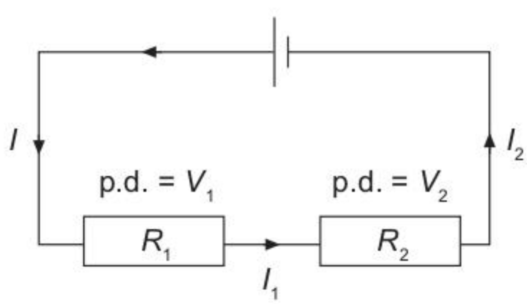
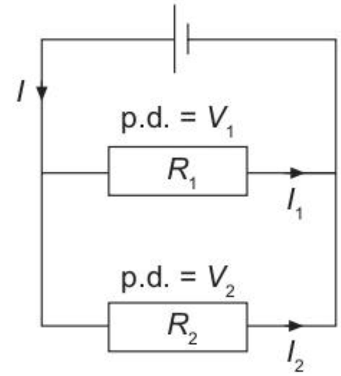
1. Current can only flow in a **closed** circuit.

2. The following table shows some of the electrical symbols used in circuit diagrams:

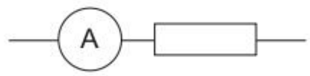
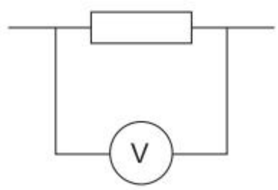


18.2 Series and Parallel Circuits

1. Comparison between a series circuit and a parallel circuit:

Series Circuit	Parallel Circuit
 • Only 1 path for current flow • The current is the same at all points in a series circuit. $I = I_1 = I_2$ • The potential difference across each resistor is different based on their resistance. • The sum of the potential differences across the resistors gives the e.m.f. of the cell. $V = V_1 + V_2$ • Effective resistance: $R_{eff} = R_1 + R_2$	 • There is more than 1 path for the current to flow. • Current: $I = I_1 + I_2$ • The potential difference across each resistor is the same and is equal to the e.m.f. of the cell. $V = V_1 = V_2$ Effective resistance: $\frac{1}{R_{elf}} = \frac{1}{R_1} + \frac{1}{R_2}$

2. Ammeter and Voltmeter

Component	Use	Characteristic
Ammeter	Measures the current flowing through resistor. To be connected in series. 	Very small resistance (so that the potential difference aross it is negligible).
Voltmeter	Measures the potential difference across resistor. To be connected in parallel. 	Very high resistance (so that negligible amount of current will flow through it).

Example 18.1

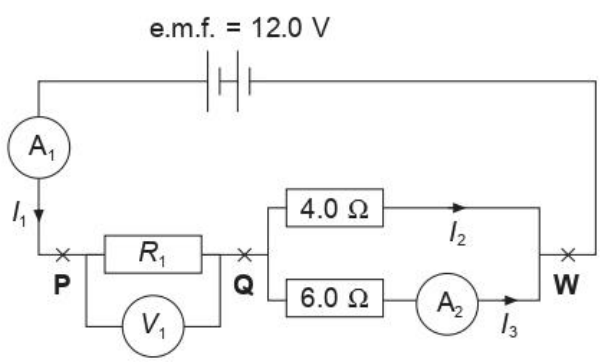
In the following circuit diagram, the effective resistance of the circuit is 5.4 Ω. Find:

(a) the resistance of R_1

(b) the reading of ammeter 1

(c) the voltmeter reading

(d) the reading of ammeter 2



Solution

(a) Effective resistance across **QW** = $\left(\frac{1}{4.0} + \frac{1}{6.0}\right)^{-1}$ = 2.4 Ω

Hence, R_1 = 5.4 – 2.4 = 3.0 Ω

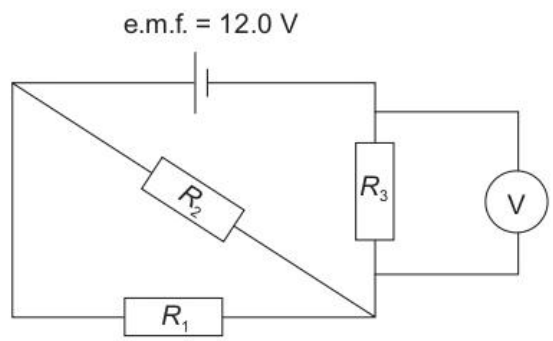
(b) Let the current reading in A_1 be I_1:
Using Ohm's Law: $V = IR$
$12.0 = I_1(5.4)$
$I_1 = 2.222$ A
$= 2.22$ A (to 3 s.f.)

(c) Current through $R_1 = I_1 = 2.222$ A
Potential difference (p.d.) across $R_1 = V$
$V = I_1R_1 = 2.222 \times 3.0$

(d) Let the current reading in A_2 be I_3:
p.d. across **QW** = 12.0 – 6.67 = 5.33 V
$5.33 = I_3(6.0)$
$I_3 = 0.888$ A (to 3 s.f.)

Example 18.2

Three resistors are connected to a 12.0 V battery as shown in the circuit below:

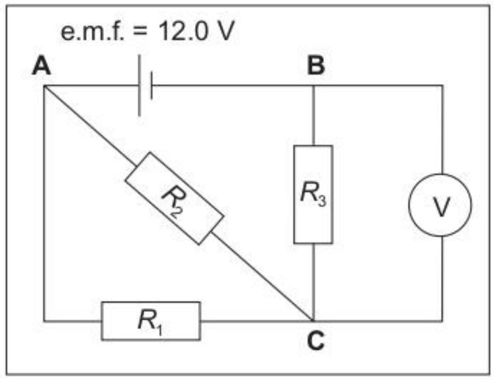


Given that $R_1 = 4.0\ \Omega$, $R_2 = 1.0\ \Omega$, $R_3 = 3.0\ \Omega$, find the voltmeter reading.

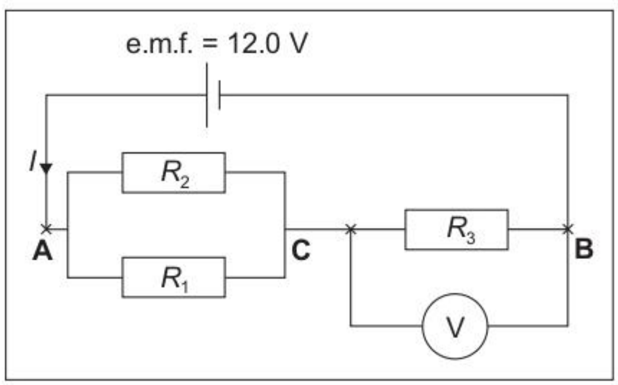
Solution

Let us add points **A**, **B**, **C** to the circuit diagram and redraw it.

Observe that R_1 and R_2 are parallel across points **A** and **C**:



Original



Redrawn

Effective resistance across **AC** = $\left(\frac{1}{4.0}+\frac{1}{1.0}\right)^{-1}$ = 0.8 Ω

Effective resistance of the whole circuit = 0.8 + R_3 = 0.8 + 3.0 = 3.8 Ω

Let the current through whole circuit be I.

Using Ohm's Law,

12.0 = I × 3.8

I = 3.158 A (to 4 s.f.)

p.d. across R_3 = IR_3 = 3.158 × 3.0 = 9.47 V

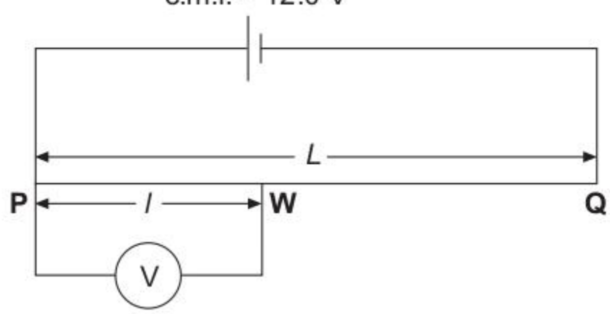
Voltmeter reading = 9.47 V (to 3 s.f.)

18.3 Potential Divider Concept

1. Recall that resistance is directly proportional to length:

   $R = \dfrac{\rho l}{A}$.

2. Let us use a uniform wire PQ of length L to replace the box resistors for the circuit below:



Let the resistance of the wire **PQ** be $R_{PQ} = \dfrac{\rho l}{A}$ --------- Equation (1)

Take a point **W** which is the distance l from **P**:

$R_{PW} = \dfrac{\rho l}{A}$ --------- Equation (2)

From Equation (1), $\dfrac{\rho}{A} = \dfrac{R_{PQ}}{L}$. Substitute into Equation (2).

$$R_{PW} = \left(\frac{R_{PQ}}{L}\right)l = \left(\frac{l}{L}\right)R_{PQ}$$

$$\left(\frac{R_{PW}}{R_{PQ}}\right) = \left(\frac{l}{L}\right)$$

Current I through a series circuit is the same.

$$V_{PW} = IR_{PW} = \left(\frac{l}{L}\right)IR_{PQ}$$

Thus,

$$V_{PW} = \left(\frac{l}{L}\right)V$$

When $l = L$, $V_{PW} = V$,

which tells us that (i) as l decreases, V_{PW} also decreases,

(ii) as l increases, V_{PW} also increases,

(iii) $\dfrac{V_{PQ}}{L}$ = constant.

Example 18.3

The wire PQ used in the circuit below has a length of 3.0 m. The resistance of PQ is 4.0 Ω. Find l for the voltmeter to register a reading of 4.0 V.

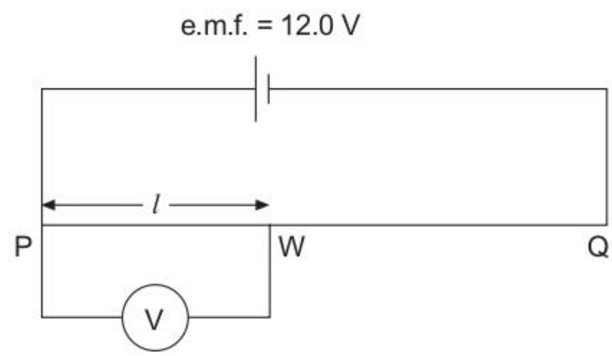
Solution

$$\frac{R_{PW}}{R_{PQ}} = \left(\frac{l}{L}\right)$$

$$\frac{R_{PW}}{R_{PQ}} = \frac{IR_{PW}}{IR_{PQ}} = \left(\frac{l}{L}\right)$$

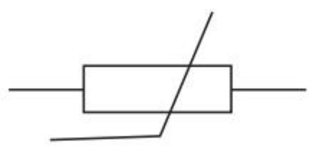
$$\frac{4.0}{12.0} = \left(\frac{l}{3.0}\right)$$

$$l = 1.0 \text{ m}$$



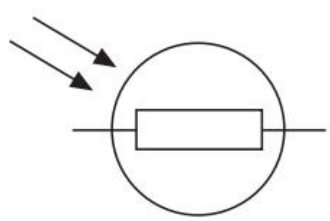
18.4 Thermistors and Light-Dependent Resistors (LDR)

1. A thermistor is a non-ohmic conductor. As it gets hotter, its resistance decreases. Thermistors are used for the control of temperature.



thermistor

2. An LDR is a semiconductor device (cadmium sulphide). Its resistance decreases as the intensity of light on it increases. LDRs are used in illumination control.



LDR

TOPIC 19 Practical Electricity

Objectives

Candidates should be able to:

(a) describe the use of the heating effect of electricity in appliances such as electric kettles, ovens and heaters
(b) recall and apply the relationships $P = VI$ and $E = VIt$ to new situations or to solve related problems
(c) calculate the cost of using electrical appliances where the energy unit is the kW h
(d) compare the use of non-renewable and renewable energy sources such as fossil fuels, nuclear energy, solar energy, wind energy and hydroelectric generation to generate electricity in terms of energy conversion efficiency, cost per kW h produced and environmental impact
(e) state the hazards of using electricity in the following situations:
  (i) damaged insulation
  (ii) overheating of cables
  (iii) damp conditions
(f) explain the use of fuses and circuit breakers in electrical circuits and of fuse ratings
(g) explain the need for earthing metal cases and for double insulation
(h) state the meaning of the terms live, neutral and earth
(i) describe the wiring in a mains plug
(j) explain why switches, fuses, and circuit breakers are wired into the live conductor

NOTES..

19.1 Application of Heating Effects of Electricity

1. Household appliances such as kettles, irons and rice-cookers make use of the heating effect of electric current.

2. Nichrome is chosen as a heating element due to the following advantages:
   (a) cheap
   (b) high resistance
   (c) high melting point
   (d) does not oxidise easily

19.2 Electrical Energy and Power

1. Recall: $W = QV$
   W is the work done by source (unit: J)
   Q is the charge (unit: C)
   V is the e.m.f. (unit: V)

2. Since $Q = It$, we have $W = (It)V = VIt$
   I is the current (unit: A)
   t is the time taken (unit: s)

3. The following table summarises the different forms of the electrical energy equation:

Equation 1	$W = VIt$	
Equation 2	$W = I^2Rt$	by substituting $V = IR$ into (1)
Equation 3	$W = \dfrac{V^2}{R}t$	by substituting $I = \dfrac{V}{R}$ into (1)

4. Power, $P = \dfrac{\text{Work time, } W}{\text{Time, } t}$
   Rearranging, we have $W = Pt$
   Compare with Equations 1, 2 and 3 in the above table:

Equation 1	$P = VI$
Equation 2	$P = I^2R$
Equation 3	$P = \dfrac{V^2}{R}$

5. SI unit for power: W or J/s

19.3 Calculating Cost of Using Electricity

1. The unit for measuring electrical consumption is the kilowatt-hour (kWh), which is the energy used by an electrical device at a rate of 1000 W in 1 hour.

   1 kWh = 1000 W × 1 h
   = 1000 × 60 × 60
   = 3 600 000 J
   = 3.6×10^6 J

   Example 19.1

   Given that electrical energy costs $0.25 per kWh, find the total cost of running eight 60 W lamps and a 3 kW electrical kettle continuously for 8 minutes.

   Solution

   Total power = (8 × 60) + (1 × 3000) = 3480 W = 3.48 kW

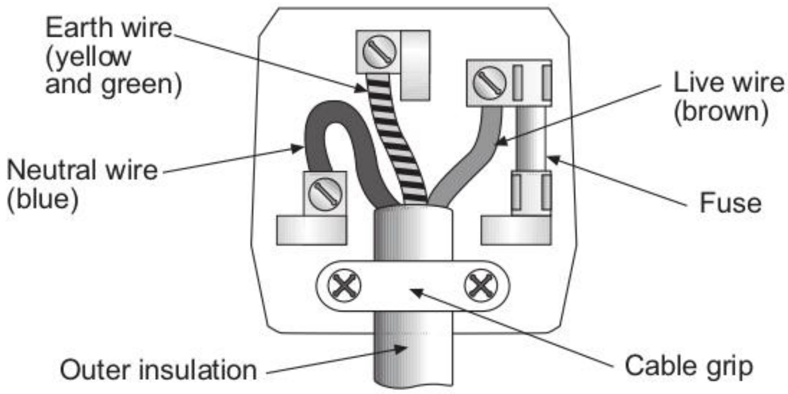
   No. of hours of operation = $\frac{8}{60} = \frac{2}{15}$ h

   Total cost = $3.48 \times \frac{8}{60} \times 0.25$ = $0.116 = $0.12 (to 2 d.p.)

19.4 Hazards of Using Electricity

1. Electricity is dangerous and can harm people if it is not used properly.
2. Some of the common dangers involved are:
   (a) Handling electrical appliances with wet hands can lead to electric shock.
   (b) Overheated cables can lead to fire.
   e.g. Plugging many appliances to one power point using multiplugs.
   (c) Electrical cables with damaged insulation, especially the live wire, can lead to an electric shock.

19.5 Safe Use of Electricity in the House



1. There are three wires in the household electric cable: live (L), neutral (N) and earth (E).
   (a) All appliances need at least 2 wires (live and neutral) to form a complete circuit.
   (b) The live (L) wire (brown) delivers the current at high voltage from the supply to the appliance. It is the most dangerous, thus switches, fuses and circuit breakers are wired to it instead of the other wires.
   (c) The neutral (N) wire (blue) completes the circuit by forming a path for the current back to the supply. It is usually at 0 V.
   (d) The earth (E) wire (yellow and green) is a low-resistance wire, usually connected to the metal casing of the appliance.
   (e) Earthing (use of earth wire) protects the user from an electric shock if the metal casing should accidentally become live (contacted with bare live wire).
   (f) The large current that flows from the loose live wire through the metal casing and the earth wire will blow the circuit fuse and cut off the supply to the appliance.

2. Fuse
   (a) A fuse is a safety device that is connected to the live wire of an electrical circuit to protect the equipment and wiring against any excessive current flow.
   (b) Characteristics:
   Made of tin-lead alloy with a low melting point.
   Common fuse ratings: 1 A, 2 A, 5 A, 10 A and 13 A.

(c) How does a fuse work?
    1. Fuse rating for a fuse in a device must be slightly higher than the current through the device.
    2. When the current is too large, the fuse becomes hot and melts (blown fuse), thus cutting off the current flow from the live wire to the device.
    3. The blown fuse will have to be replaced by a new one for the device to work again.

3. Switches are used to close and open a circuit. Switching off disconnects the high voltage from an appliance.

4. Double insulation
   (a) Double insulation is a safety feature in an electrical appliance that can substitute for an earth wire.
   (b) It means that in addition to the first insulation covering the wires, there is a second insulation (**e.g.** plastic casing of a hair dryer).

TOPIC 20 Magnetism

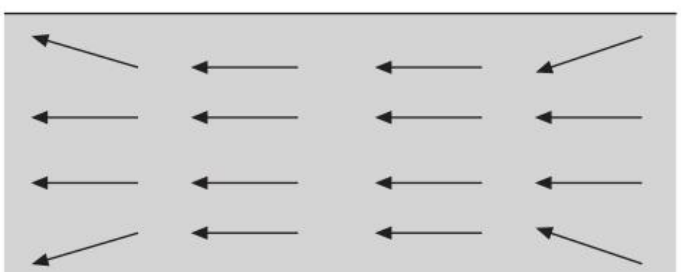
Objectives

Candidates should be able to:
(a) state the properties of magnets
(b) describe induced magnetism
(c) describe electrical methods of magnetisation and demagnetisation
(d) draw the magnetic field pattern around a bar magnet and between the poles of two bar magnets
(e) describe the plotting of magnetic field lines with a compass
(f) distinguish between the properties and uses of temporary magnets (e.g. iron) and permanent magnets (e.g. steel)

NOTES

20.1 Laws of Magnetism

1. Properties of Magnets:
   (a) A magnet has two poles where the magnetic forces are the strongest: North pole and South pole.
   (b) Magnets DO NOT exist as monopoles (unlike electric charges).
   (c) We can use arrows to indicate magnetic dipoles in a magnet. The arrowhead indicates North pole.

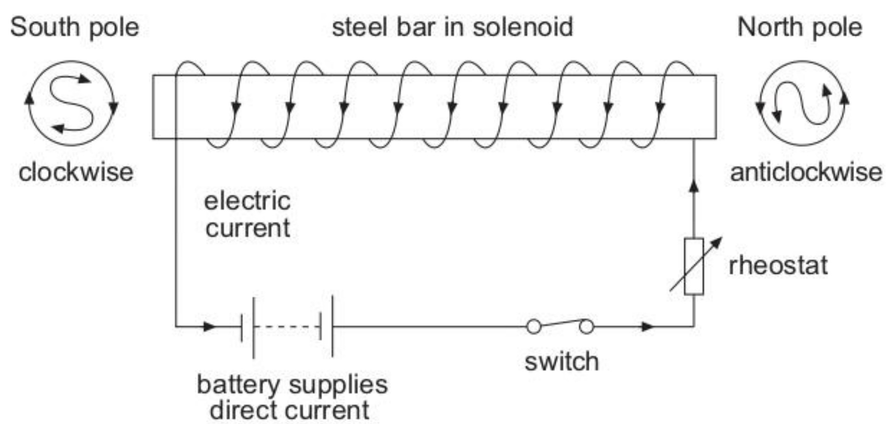


The arrows nearer to the edge are not exactly parallel due to repulsion of like poles.

   (d) The law of magnetism states that like poles repel and unlike poles attract.
   (e) Repulsion is the only way to test if an object is a magnet.

2. Induced magnetism: A magnetic material becomes an induced magnet when placed in a magnetic field, i.e. near a permanent magnet. The magnetic field from the magnet aligns the randomly arranged dipoles in the material.

3. Magnetisation using electricity:
   To magnetise a steel bar, one can place it in a solenoid connected to a d.c. source.
   (a) The magnetic field produced by the solenoid magnetises the steel bar.
   (b) The polarities of the magnetised steel bar depend on the direction of the current.
   (c) If the bar is viewed from one end and the current flows in an anticlockwise direction, then that end will be the North-pole; if clockwise, then that end will be the South-pole.



20.2 Magnetic Properties

1. Examples of magnetic materials: iron, steel, nickel and cobalt.

2. Permanent magnets are magnets that do not lose their magnetism easily. They are made from materials like steel. Steel is an alloy of carbon and iron.

3. The differences between the magnetic properties of iron and steel can be summarised in the table below:

Properties	Iron	Steel
Material	soft	hard
Magnetisation	easy	difficult
Demagnetisation	easy	difficult
Magnetic field strength in solenoid	strong	weak
Magnetism	temporary	permanent

4. Comparison between electromagnet and permanent magnet:

Electromagnet	Permanent magnet
Made of a coil of wire (often with a soft iron core).	Made of hard magnetic material like steel.
Magnetism is temporary. Requires a current through the coil to sustain the magnetic field strength.	Magnetism is permanent. Does not require any electric current to retain magnetic field strength.
Applications: telephone receivers, electric relays, electric bells, circuit breakers and loudspeakers*.	Applications: magnetic doorstops, compasses, motors, dynamos and loudspeakers*

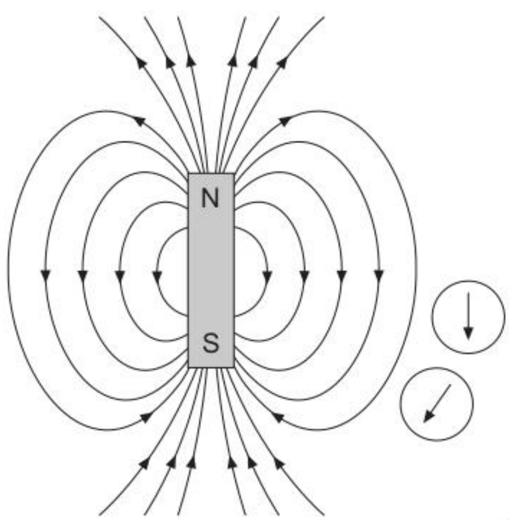
* A loudspeaker uses both an electromagnet and a permanent magnet.

20.3 Magnetic Field

1. A magnetic field is a region in space where magnetic materials experience a force.

2. Magnetic field lines: We draw magnetic field lines to help us visualise the direction of the magnetic forces.

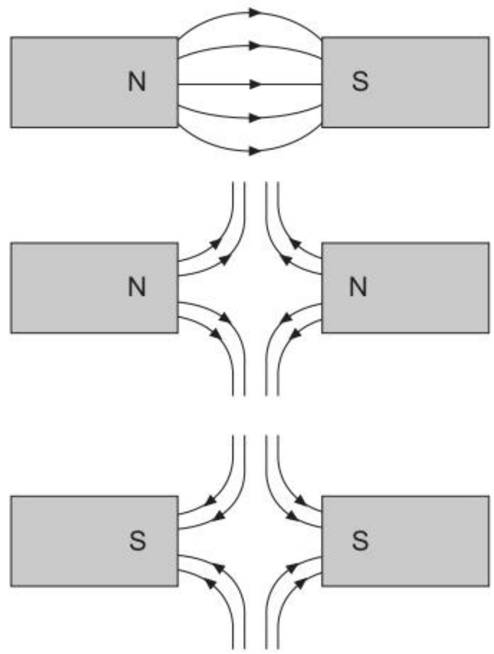
3. A compass can be used to plot the magnetic field lines around a magnet by marking each end of the compass needle with a dot as it is moved from the North pole to the South pole and linking up the dots together to form a solid line. The arrow on the line indicates the direction the compass needle points.



Important:

1. Magnetic field lines always start from North and end at South.
2. Each line is always in a complete closed loop (no matter how big the loop is) unlike electric field lines which can point to infinity.
3. Strength of a magnetic field depends on how close the lines are spaced together. (Closer ⟶ Stronger)

4. The magnetic field lines between like poles and unlike poles are as follows:



TOPIC 21 Electromagnetism

Objectives

Candidates should be able to:

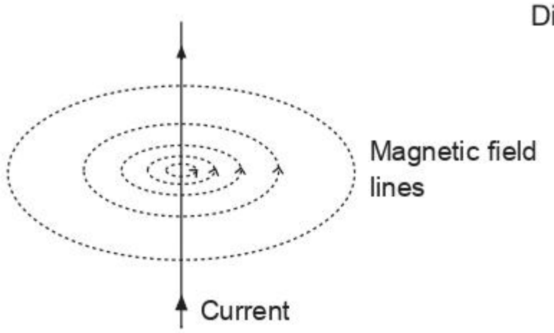
(a) draw the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and/or direction of the current
(b) describe the application of the magnetic effect of a current in a circuit breaker
(c) describe experiments to show the force on a current-carrying conductor, and on a beam of charged particles, in a magnetic field, including the effect of reversing
 (i) the current
 (ii) the direction of the field
(d) deduce the relative directions of force, field and current when any two of these quantities are at right angles to each other using Fleming's left-hand rule
(e) describe the field patterns between currents in parallel conductors and relate these to the forces which exist between the conductors (excluding the Earth's field)
(f) explain how a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by increasing
 (i) the number of turns on the coil
 (ii) the current
(g) discuss how this turning effect is used in the action of an electric motor
(h) describe the action of a split-ring commutator in a two-pole, single-coil motor and the effect of winding the coil on to a soft-iron cylinder

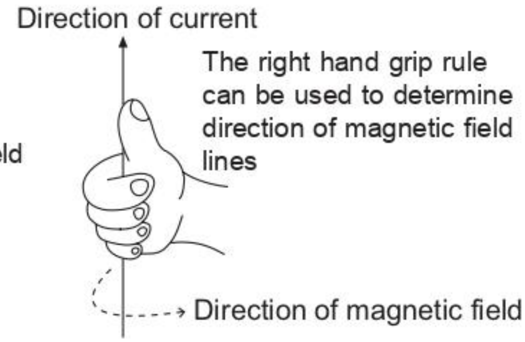
NOTES

21.1 Magnetic Effect of a Current

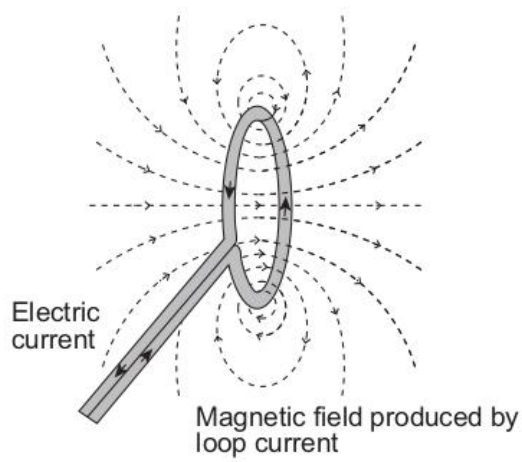
1. A current-carrying wire will produce a magnetic field around it. The pattern of the field lines depends on how the wire is shaped.

2. For a straight wire, the field lines form concentric circles around the wire as shown (note direction of arrows on field lines):

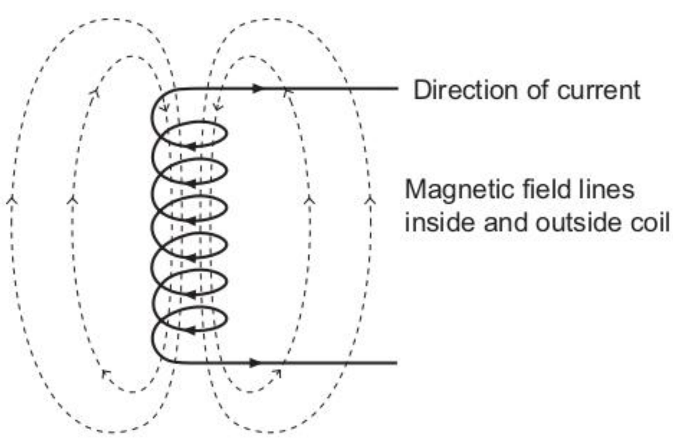




3. A higher current will result in a stronger magnetic field around the wire.
4. The field pattern of a single turn of circular wire carrying current is as shown:



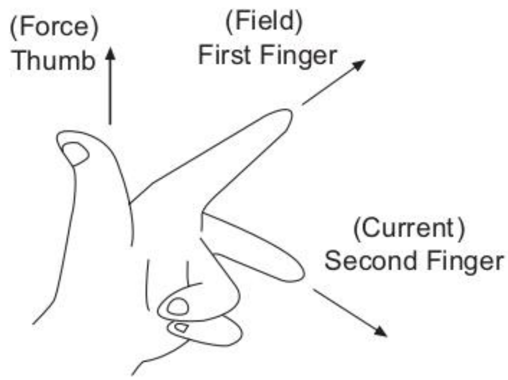
5. A solenoid's magnetic field pattern is as shown:



21.2 Force on a Current-carrying Conductor

1. When a current carrying wire is placed in a magnetic field, it will experience a magnetic force.

2. The direction of the force can be found using Fleming's Left Hand Rule:



Thumb: Direction of force

First Finger: Direction of field

Second Finger: Direction of current in wire

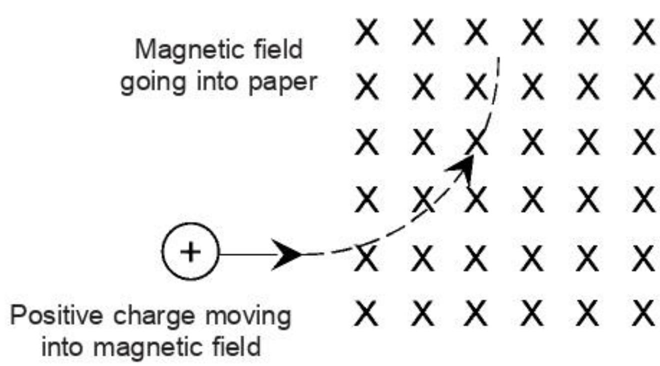
Note: The three fingers must be held at 90° to each other.

3. For a positive charge moving in space, it will behave like a current-carrying wire.

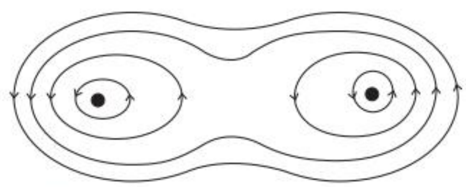
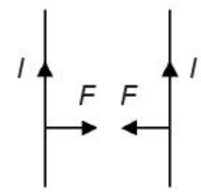
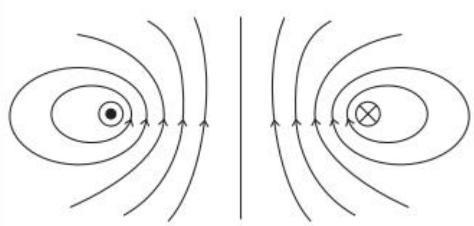
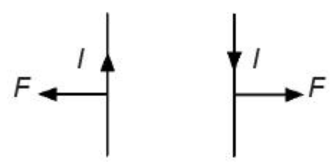
4. For a negative charge, the direction of the current will be **opposite** to its direction of travel.

Example 21.1

For a positive charge moving into a magnetic field as shown, it will experience a force to its left; hence its path is curved.



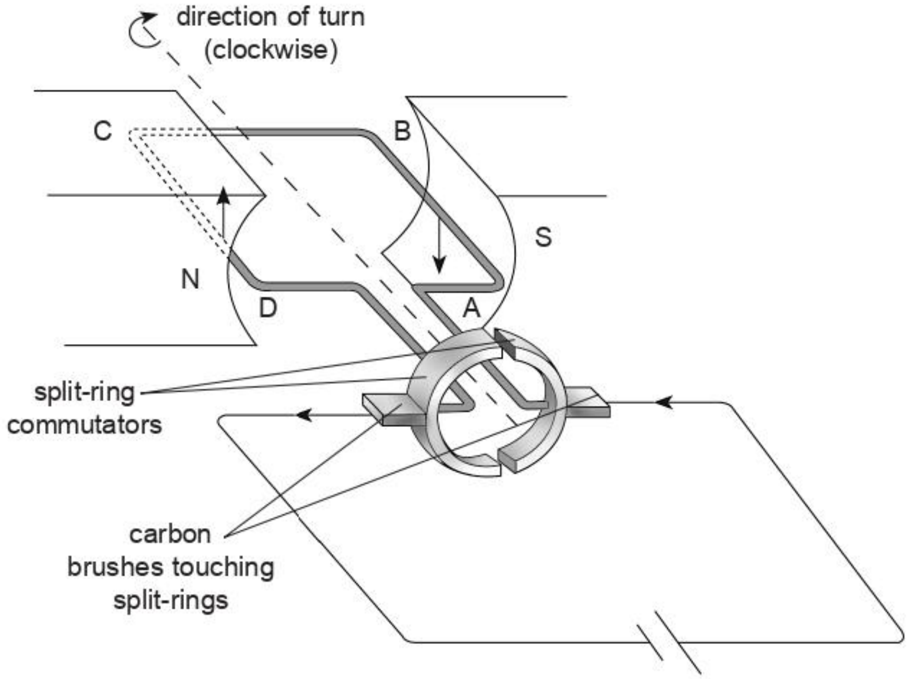
5. Force between two current-carrying wires.
   When two wires are carrying current, they will experience mutual forces of attraction or repulsion because each of them will produce a magnetic field which will affect the other. If the currents flow in the same direction, the wires will attract each other; if the currents flow in opposite directions, the wires will repel.

<table>
<tr>
<td>1. Currents in same direction

● Current coming out of paper</td>
<td>Notice that the field lines are only crowded outside and not in the middle? That is because the field lines cancel out in the middle of the wires. Hence there is an attractive force pulling the two wires together.
</td>
</tr>
<tr>
<td>2. Currents in opposite directions

● Current coming out of paper
⊗ Current going into paper</td>
<td>Notice that the field lines are crowded between the wires. Crowded field lines exert a force sideway against each other. Hence there is a repulsive force pushing the wires apart.
</td>
</tr>
</table>

21.3 D.C. Motor

1. The behaviour of a current-carrying conductor in a magnetic field can be applied in electric motors which convert electrical energy into kinetic energy (i.e. fans).

2. The electric motor makes use of the principle that a current carrying coil will experience a turning effect inside a magnetic field.



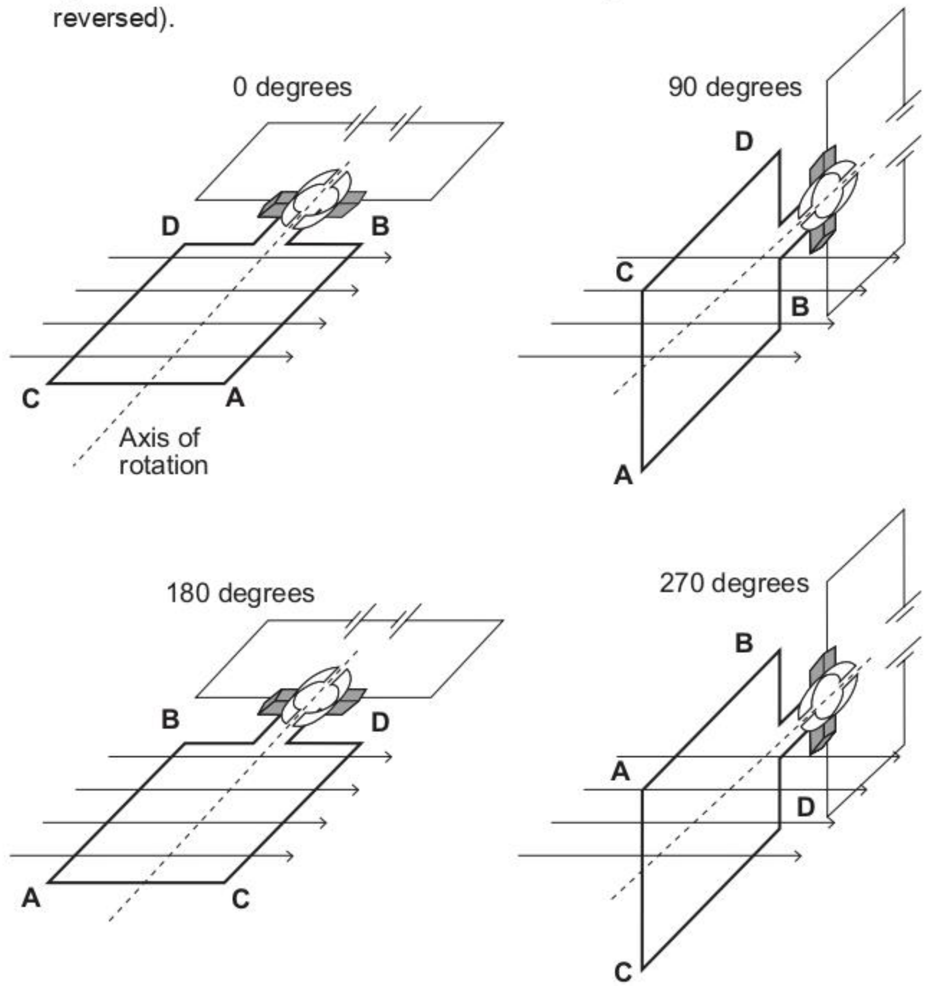
3.

Features	Role
Split-ring commutator	The split in the ring allows direction of current to be reversed in the coil to allow the coil to always rotate in one direction.
Carbon brushes	Carbon (graphite) can conduct electricity and is also a lubricant. It allows the commutator to turn smoothly with minimal friction.

4. Stages of operation
   (a) The carbon brushes make a connection with the coil every 180° turn for current to flow through the coil. In the 0° diagram, the brushes are in contact with the voltage source.
   (b) Current through wire segment C-D interacts with the magnetic field resulting in an upward force (left hand rule). Similarly, current that flows through segment A-B produces a downward force. Both forces are of equal magnitude,but opposite directions (currents in different direction). Thus a turning effect about the axis in the middle of the coil is created.

(c) In the 90° and 270° diagrams, the brushes are not in contact with the voltage source and no force is produced. In these two positions, the rotational kinetic energy of the coil keeps it spinning until the brushes regain contact.

(d) In the 180° diagram, the same thing occurs, but the force on **A-B** is upwards and force on **C-D** is downwards (direction of currents has reversed).



5. The strength of the turning effect can be increased by:
   (a) Increasing strength of magnetic field (use stronger magnets).
   (b) Increasing number of turns of wires in the coil.
   (c) Increasing the area of the coil (Area **ABDC**).
   (d) Increasing the current.
   (e) Adding a soft iron core around which the wires are coiled.

TOPIC 22 Electromagnetic Induction

Objectives

Candidates should be able to:

(a) deduce from Faraday's experiments on electromagnetic induction or other appropriate experiments:
   (i) that a changing magnetic field can induce an e.m.f. in a circuit
   (ii) that the direction of the induced e.m.f. opposes the change producing it
   (iii) the factors affecting the magnitude of the induced e.m.f.

(b) describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings (where needed)

(c) sketch a graph of voltage output against time for a simple a.c. generator

(d) describe the use of a cathode-ray oscilloscope (c.r.o.) to display waveforms and to measure potential differences and short intervals of time (detailed circuits, structure and operation of the c.r.o. are not required)

(e) interpret c.r.o. displays of waveforms, potential differences and time intervals to solve related problems

(f) describe the structure and principle of operation of a simple iron-cored transformer as used for voltage transformations

(g) recall and apply the equations $V_P / V_S = N_P / N_S$ and $V_PI_P = V_SI_S$ to new situations or to solve related problems (for an ideal transformer)

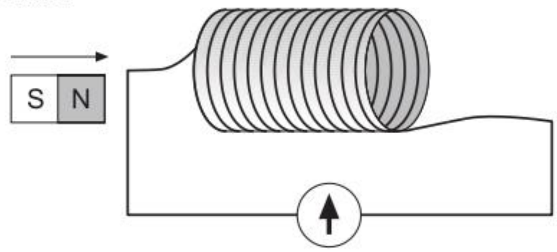
(h) describe the energy loss in cables and deduce the advantages of high voltage transmission

NOTES...

22.1 Principles of Electromagnetic Induction

1. Electromagnetic induction: When there is a change in the magnetic flux (magnetic field) linking the conductor, an e.m.f. and hence a current is induced between the ends of the conductor.

2. When the North pole of the bar magnet is moved towards the solenoid, an induced current is generated which produces a North pole at the end of the solenoid facing the magnet. The induced North pole is to oppose the motion of the magnet's North pole. Once the magnet stops moving, the induced current dies down to zero.



3. Faraday's Law of electromagnetic induction:
   The magnitude of the induced e.m.f. is directly proportional to the rate of change of magnetic flux linking the coil.

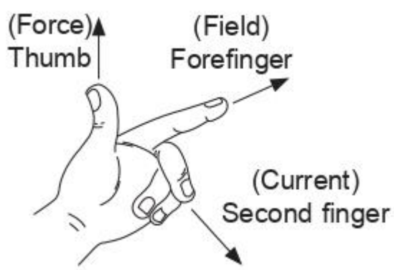
4. A larger e.m.f. is produced when:
   (a) the number of turns of wire in solenoid is increased.
   (b) a stronger magnet is used.
   (c) the speed with which magnet is moved towards or away of the solenoid is increased.
   (d) a soft iron core is placed inside the solenoid.

5. Lenz's Law: The direction of induced current sets up a magnetic field to oppose the change in the magnetic flux producing it.

6. Fleming's left hand rule and Fleming's right hand rule

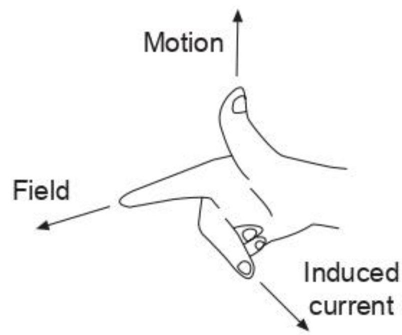
<table>
<tr><th>Left Hand</th><th>Right Hand</th></tr>
<tr><td>
Quantities involved:
• Direction of force on conductor
• Direction of current
• Direction of magnetic field.

Given directions of any two of the above three quantities, it is possible to find the direction of the third quantity.



Thumb: Direction of force
Forefinger: Direction of field
Second Finger: Direction of current in wire
Note: The three fingers must be held at 90° to each other.
</td><td>
Quantities involved:
• Direction of induced current
• Direction of magnetic field
• Direction of motion

Given directions of any two of the above three quantities, it is possible to find the direction of the third quantity.



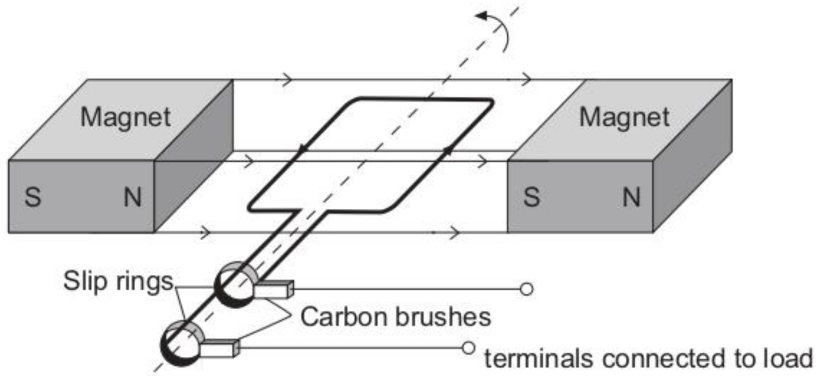
Thumb: Direction of motion
First Finger: Direction of field
Second Finger: Direction of induced current in wire
Note: The three fingers must be held at 90° to each other.
</td></tr>
</table>

7. Energy Conversion Process

Dynamo, Generator	Kinetic Energy to Electrical Energy
Motor	Electrical Energy to Kinetic Energy

22.2 A.C. Generator

1.



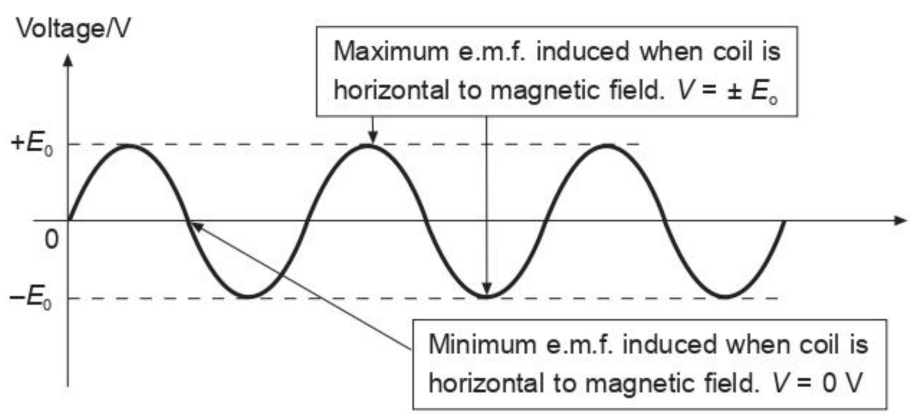
2. An a.c. generator is used to generate electricity. It consists of a coil of rectangular wires situated between two magnets as shown above.

3. When the coil is rotated, it cuts the magnetic field and causes a change in the magnetic flux linkage. As long as the coil keeps on rotating, the rate of change of magnetic flux linking the coil is non-zero and hence, an e.m.f. will be induced in the coil. By Faraday's Law of electromagnetic induction, the magnitude of the e.m.f. that is induced in the coil is directly proportional to the rate of change of magnetic flux linking the coil.

4. Kinetic energy (rotation) is converted into electrical energy.

5. The a.c. generator's coil is connected to two slip-rings which make sliding contact with the carbon brushes at all times (unlike the split-ring commutator used by d.c. motors).

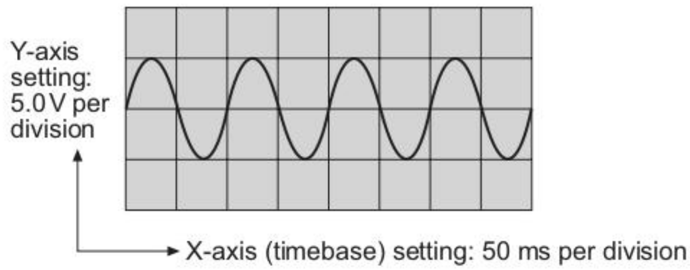
6. The voltage-time graph of the induced e.m.f. is as follows:



22.3 Uses of Cathode-Ray Oscilloscope (c.r.o.)

1. Measure p.d.
2. Display waveforms
3. Measure short time intervals

Example 22.1

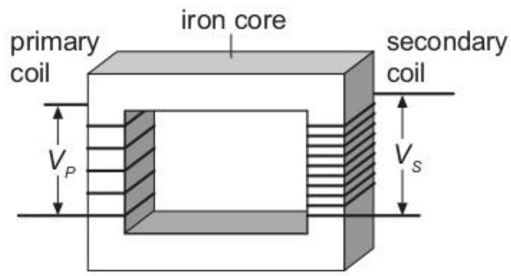


Amplitude = one division = 5.0 V
Period, T = 2 divisions = 100 ms = 0.1 s
Frequency, $f = \frac{1}{T} = \frac{1}{0.1} = 10$ Hz

22.4 Principles of Operation of a Transformer

1. The advantage of producing a.c. instead of d.c. at power plants is that a.c. can be stepped up or down to suit household and industries' needs. Household a.c. voltage is stepped down to 240 V.

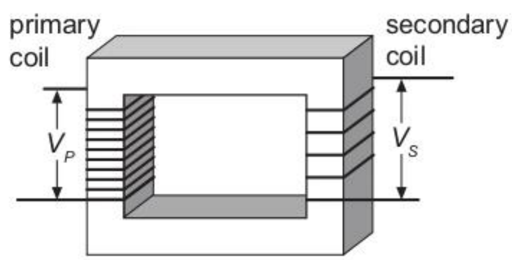
2. The following diagram shows a step-up and a step-down transformer:



Step-up transformer

$V_P < V_S$

$N_P < N_S$



Step-down transformer

$V_P > V_S$

$N_P > N_S$

3. Principle of operation of a transformer:
   a.c. will produce a changing magnetic field. By coiling a primary coil of wires and a secondary coil around an iron core, the changing magnetic field produced by the primary coil will induce an e.m.f. in the secondary coil.

4. For an ideal transformer, we have:
$P_P = P_S \Rightarrow I_P V_P = I_S V_S$

$$\boxed{\frac{I_P}{I_S} = \frac{N_S}{N_P}}$$

Also, $\boxed{\frac{V_S}{V_P} = \frac{N_S}{N_P}}$

Note:
1. For practical transformers, if the load on the secondary circuit increases in resistance (more devices connected to the secondary terminals in series), then the amount of power output required will also increase.
2. The power input ($P = I_P V_P$) from the generator is NOT FIXED. Only V_P and V_S are fixed.
For N2013/P1/Q40, the 230 V has been transmitted over a long distance <u>without transformers</u>.
3. The amount of I_p depends on consumption.

5. Power plants transmit electricity through thick cables at high voltages for the following reasons:
   (a) A higher voltage will mean a lower current travelling in the cable.
   (b) Thick cables (large cross-sectional area) mean the cables have low resistance.

   $$\left(R = \frac{\rho l}{A}\right)$$

   In this way, less power is lost as heat due to heating effect in the cables.

ElectroMagnetism

Electricity

Static Electricity → static charges.

Current Electricity → Flow of charges.

Fundamental charged particle = electron

Elementary charge = charge of an $\bar{e}$ = 1.6×10^{-19} C

C → Coulomb

Like charges repel → +ve +ve OR -ve -ve

Unlike charges attract → +ve -ve

An object can be charged by adding or removing electrons.

Na - atomic no. 11

↓

$11p + 11\bar{e} \rightarrow$ net charge = 0

if an $\bar{e}$ is removed;

$11p + 10\bar{e} \Rightarrow$ net charge = +1

↓

Na^+

Cl — atomic no. 17

↓

$17p + 17\bar{e} \Rightarrow$ net charge = 0

if an $\bar{e}$ is added;

$17p + 18\bar{e} \Rightarrow$ -1 charge

↓

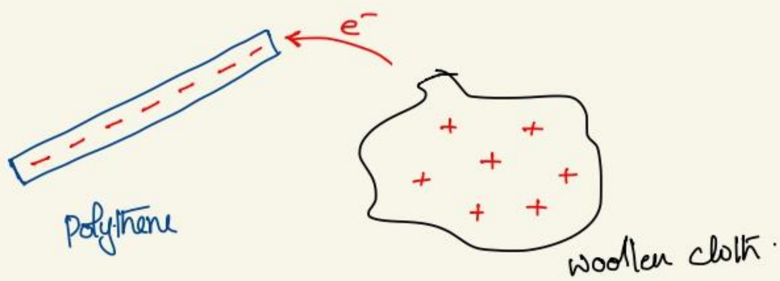
Cl^-

Excess of $\bar{e}$ / addition of $\bar{e}$ $\Rightarrow$ -vely charged

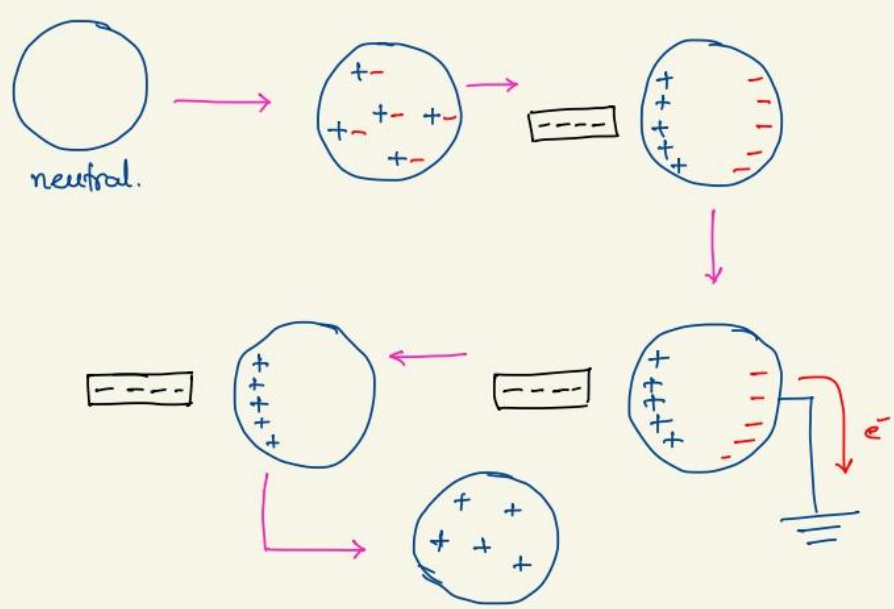
Deficiency of $\bar{e}$ / removal of $\bar{e}$ $\Rightarrow$ +ve ly charged.

charging of objects:

when friction is present; $\bar{e}$ gain thermal energy and move from one body to another.



charging by Induction:



classification of materials based electricity

Conductors - allow the flow of charges.

↓

all the metals.

Graphite

Insulators - do not allow the flow of charges.

↓

all the non-metals (except graphite)

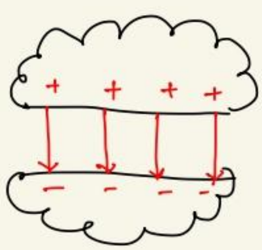
Semiconductors - allow the flow of charge depends on temperature

↓

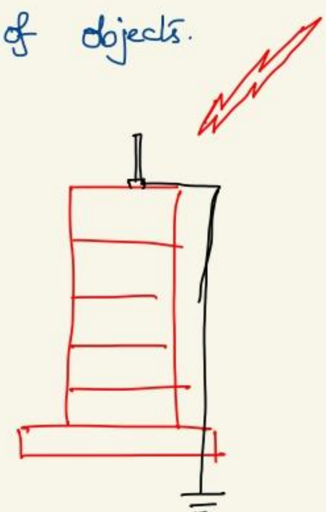
Germanium }
Silicon. } Diode Transistor Thermistor LED

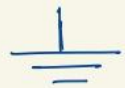
Earthing :

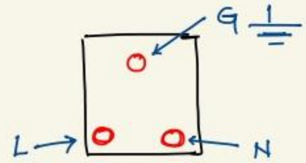
Removes the additional/excess charge from the surface of objects.



Lightning



Earthing Symbol: 



Live wire — L — current flows

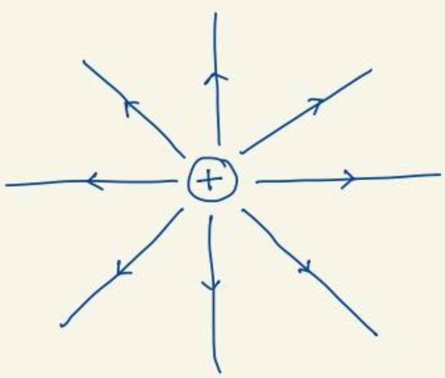
Neutral Wire — N — Completes the circuit

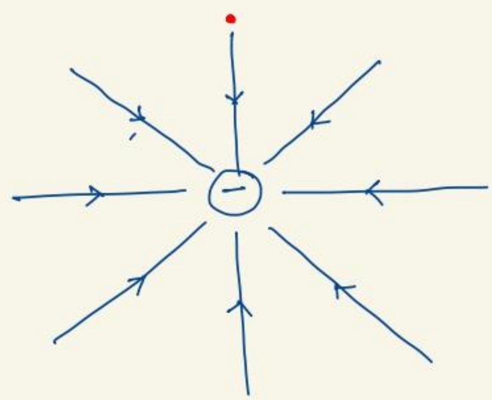
Ground — G. — Removes the additional/excess charge.

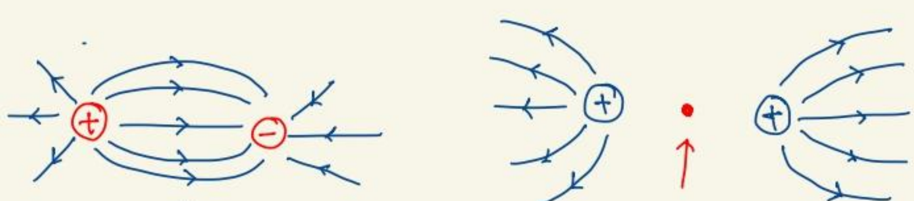
Electric Field

space around a charge in which another charge experiences the force.

Test charge – A unit positive charge





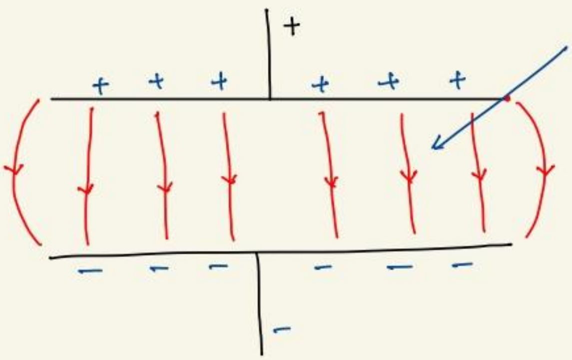


Electric field is strong.

net electric field = 0.

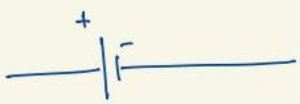
* direction of electric field is always from a positive charge to a negative charge.

Electric field between two parallel plates.



uniform electric field.

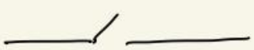
symbols of electric components:



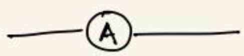
cell (DC cell)

Battery (DC)

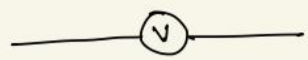
AC
alternating current



switch

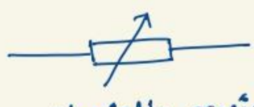


ammeter

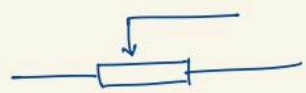


voltmeter
voltage / emf / PD

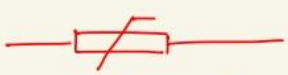
Resistor
(fixed resistance)



Variable resistor
(Rheostat)



Potential divider



Thermistor (Resistance changes with temperature).

Fuse

Lamp.

Current (I) -

Rate of flow of charge (OR) flow of charge per sec.

$$I = \frac{\text{charge}}{\text{time}} \Rightarrow I = \frac{q}{t}$$

$$\Rightarrow I = \frac{\Delta q}{\Delta t}$$

$$\frac{\text{Coulomb}}{\text{Sec}} = \text{Ampere.}$$

$$\Rightarrow 1A = \frac{1C}{1Sec}$$

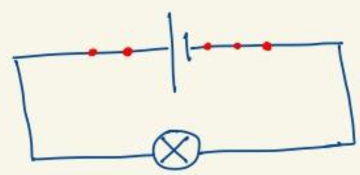
amp (OR) A

An ammeter is used to measure the current.

Ammeter should be connected in series with the component.

Voltage (V) / Electromotive Force (emf):

Energy required to move a unit charge from one terminal to another in a circuit.



$$\text{Voltage} = \frac{\text{Work done}}{\text{charge}}$$

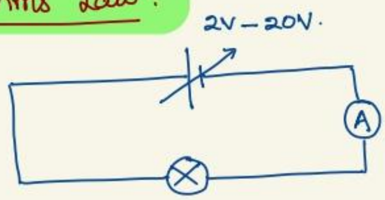
$$\Rightarrow V = \frac{W}{q}$$

units: J/C = Volt

A voltmeter is used to measure the voltage/PD/emf

Voltmeter has to be connected in parallel to the component.

Ohm's Law:



Voltage $\propto$ current @ Constant temperature

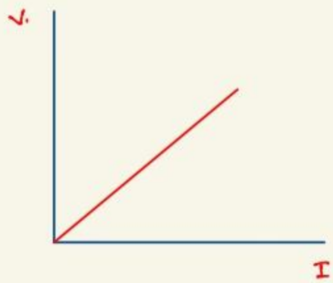
$\Rightarrow V \propto I$

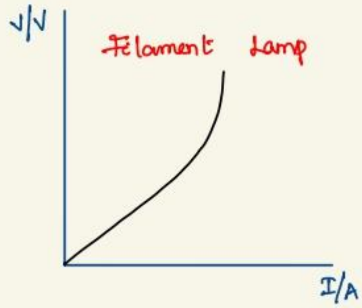
$\Rightarrow \frac{V}{I} = \text{Const}$

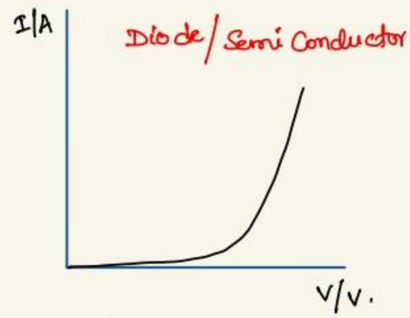
$\Rightarrow \frac{V}{I} = \text{Resistance } (R)$ <u>Unit</u>: ohm (Ω)

$\Rightarrow V = IR$

V-I characteristics:







ohmic conductors.

obey ohm's law

Non - ohmic conductor.

Do not obey ohm's law.

For a conductor; resistance increases with increasing temperature.

conductor has free electrons.

when temperature increases; free e^- gain energy & move faster

lattices / atoms vibrate

Collisions between free e^- & atoms increase

Speed of e^- decrease

Take more time to travel.

Increasing resistance. $\leftarrow$ Current decreases $\left(I = \Delta q / \Delta t\right)$

Factors affect resistance:

- material (resistivity – ρ)
- Temperature
- Length (l)
- Area of cross-section (A)

10m

4m

10m

10m

$\Rightarrow$ Resistance $\propto$ length

$$\propto \frac{1}{\text{Area of cross-section}}$$

$$\Rightarrow \left.\begin{aligned} R &\propto l \\ &\propto \frac{1}{A} \end{aligned}\right\} \quad R \propto \frac{l}{A}$$

$$\Rightarrow R = \rho \cdot \frac{l}{A}$$

ρ = resistivity = material property

$\downarrow$

$\Omega \cdot m$

if the material remains the same; ρ = constant.

Two wires are made of same material.

Wire 1	Wire 2.
l_1	l_2
A_1	A_2
R_1	R_2

$$\Rightarrow R_1 = \rho \cdot \frac{l_1}{A_1} \qquad R_2 = \rho \cdot \frac{l_2}{A_2}$$

$$\Rightarrow \rho = \frac{R_1 A_1}{l_1} \qquad \rho = \frac{R_2 A_2}{l_2}$$

$$\frac{R_1 A_1}{l_1} = \frac{R_2 A_2}{l_2}.$$

For a circular cross-section:

$$\frac{R_1 r_1^2}{l_1} = \frac{R_2 r_2^2}{l_2}$$

r_1 & r_2 = radii of wires.

Electric Power (P) :

$$\text{Power} = \frac{\text{Work done}}{\text{time}}$$

From def. of voltage; $V = \frac{W}{q}$

$\Rightarrow W = V.q$

$$\Rightarrow P = \frac{Vq}{t} = V.\left(\frac{q}{t}\right) = VI.$$

$\therefore$ Power $= VI$

From ohm's law; $V = IR \Rightarrow P = IR.I = I^2R.$

From $V = IR \Rightarrow I = \frac{V}{R}$ $\Big\}$ $P = VI = V.\frac{V}{R} = \frac{V^2}{R}.$

Electric Energy :

$\therefore$ Energy $=$ Power $\times$ time

time is in seconds.

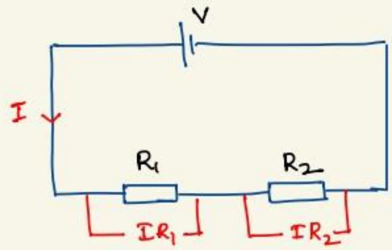
$$= VIt$$
$$= I^2R.t$$
$$= \frac{V^2}{R}.t.$$

Power $= VI$
$= I^2R$
$= \frac{V^2}{R}$

Electric Energy.

$Q = VIt$
$= I^2Rt = \frac{V^2}{R}t$

Series Circuit:



$I = \text{Constant}$

$V = V_1 + V_2$

$\downarrow \quad \downarrow \quad \downarrow$

$IR = IR_1 + IR_2$

$\Rightarrow R = R_1 + R_2$

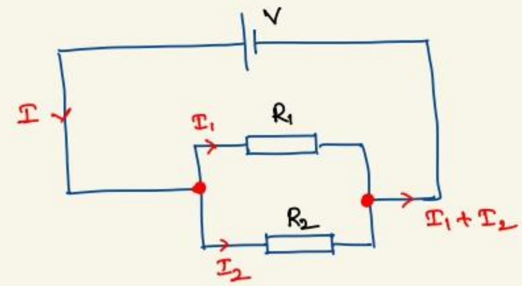
Series

$I = \text{Constant}$

$V = V_1 + V_2$

$R_s = R_1 + R_2$

Parallel Circuit:



$I = I_1 + I_2$

$V = \text{Const}$ — $V = IR$. ✓ ; $V = I_1 R_1$; $V = I_2 R_2$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2}$$

$$\Rightarrow \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\Rightarrow \frac{1}{R} = \frac{R_1 + R_2}{R_1 R_2}$$

$$\Rightarrow R_p = \frac{R_1 R_2}{R_1 + R_2}.$$

Parallel

$V = \text{Const}$

$I = I_1 + I_2$

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

(OR) $R_p = \frac{R_1 R_2}{R_1 + R_2}$

Ex: 3Ω and 6Ω are connected in an electric circuit. Calculate the combined resistance when they are in (a) Series (b) Parallel.

Soln: $R_1 = 3\Omega$ $R_2 = 6\Omega$. $R_p = \frac{R_1 R_2}{R_1 + R_2} = \frac{3(6)}{3+6} = 2\Omega$

$R_s = R_1 + R_2 = 3 + 6 = 9\Omega$

For Series; $R_s > R_{max}$

Parallel; $R_p < R_{min}$

Comparing Series and Parallel Circuits:

- In series, if one lamp goes off, all go off.
  In parallel, if one lamp goes off, remaining work the same.
- In series, voltage is divided across the components.
  ⇒ Brightness of lamps decrease.
  In parallel, voltage is constant
  ⇒ All have the same normal brightness.
- In series, lamps cannot be operated independently.
  In parallel, lamps can be operated independently.

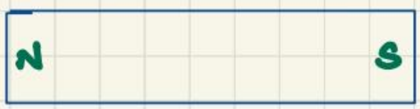
[redacted]

[redacted]

Magnets & Currents

Magnets have 2 poles - North pole & South pole.

Like poles repel and unlike poles attract



magnetic field strength is greater @ the edges.

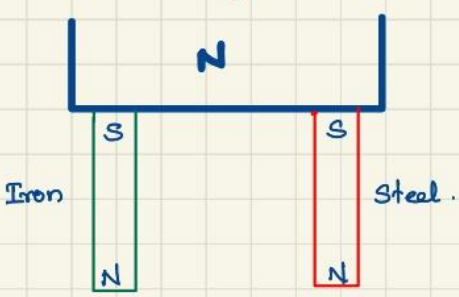
Magnetic materials are attracted by a magnet and can be magnetised permanently or temporarily.

Ex: Iron, steel, Cobalt, Nickel.

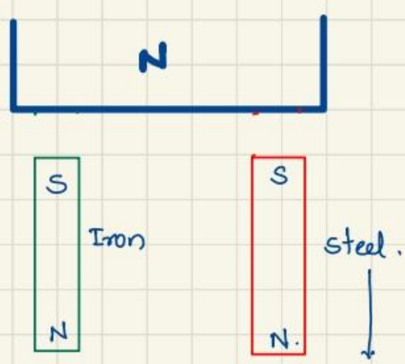
Non-magnetic materials are not attracted by a magnet and cannot be magnetised.

Ex: Wood, Paper, Aluminium, Copper.....

Induced Magnetism.



opposite poles are induced.



↓ Iron loses the magnetism quickly.

↓ retains magnetism longer.

Soft magnetic malerials.

- loose magnetism quickly.
- easy to magnetise and easy to demagnetise
- used to make temporary magnets.

Ex: Iron,

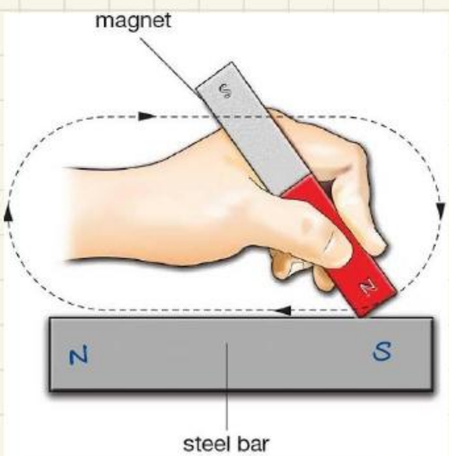
↓ Electromagnets

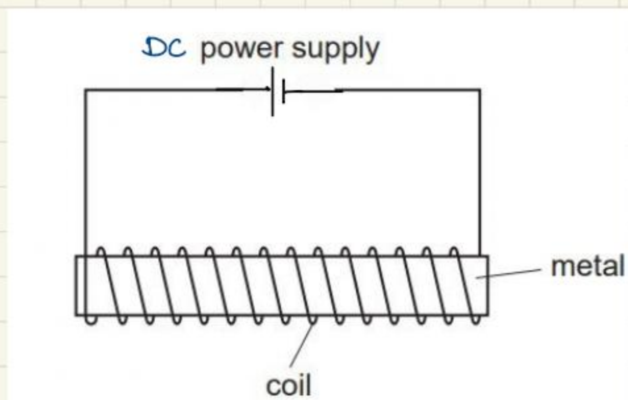
Hard magnetic materials:

- retain magnetic nature for longer.
- Hard to magnetise and demagnetise.
- used to make permanent magnets.

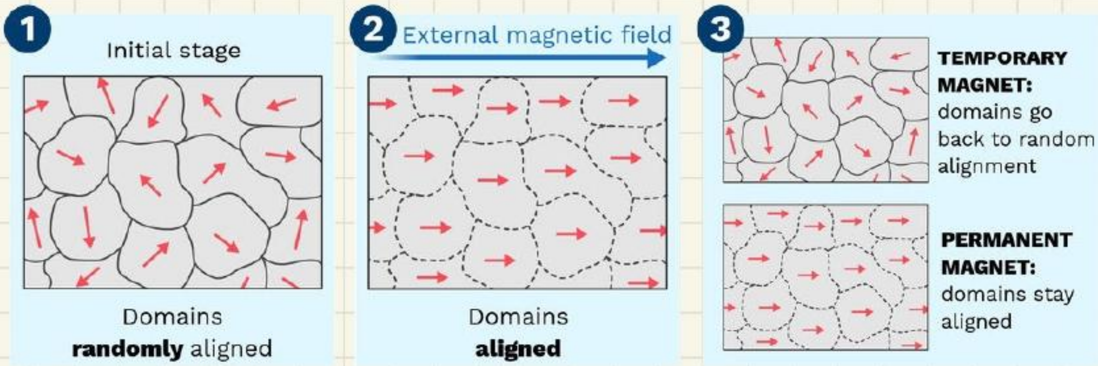
Ex: Steel

Magnetisation:





Domain Theory:

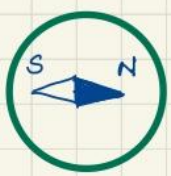


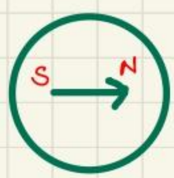
Demagnetisation Methods:

- move the magnet slowly in and out of a coil carrying AC
- Hammer the magnet
- Heat the magnets (drop them in boiling water)

Magnetic Field:

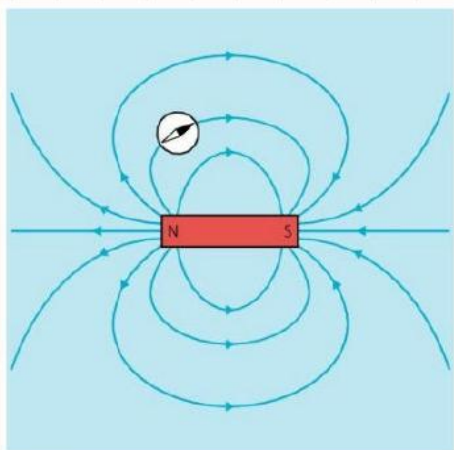
Magnetic compass is used to find the direction of magnetic field.

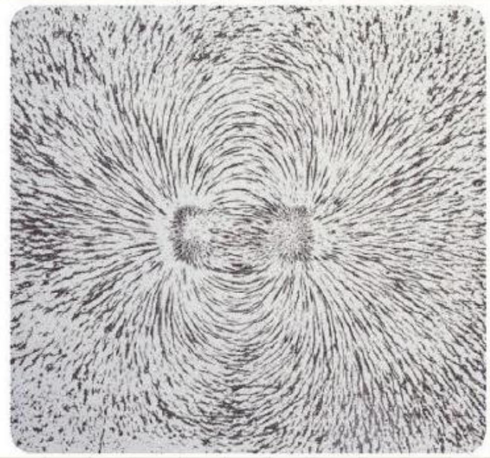




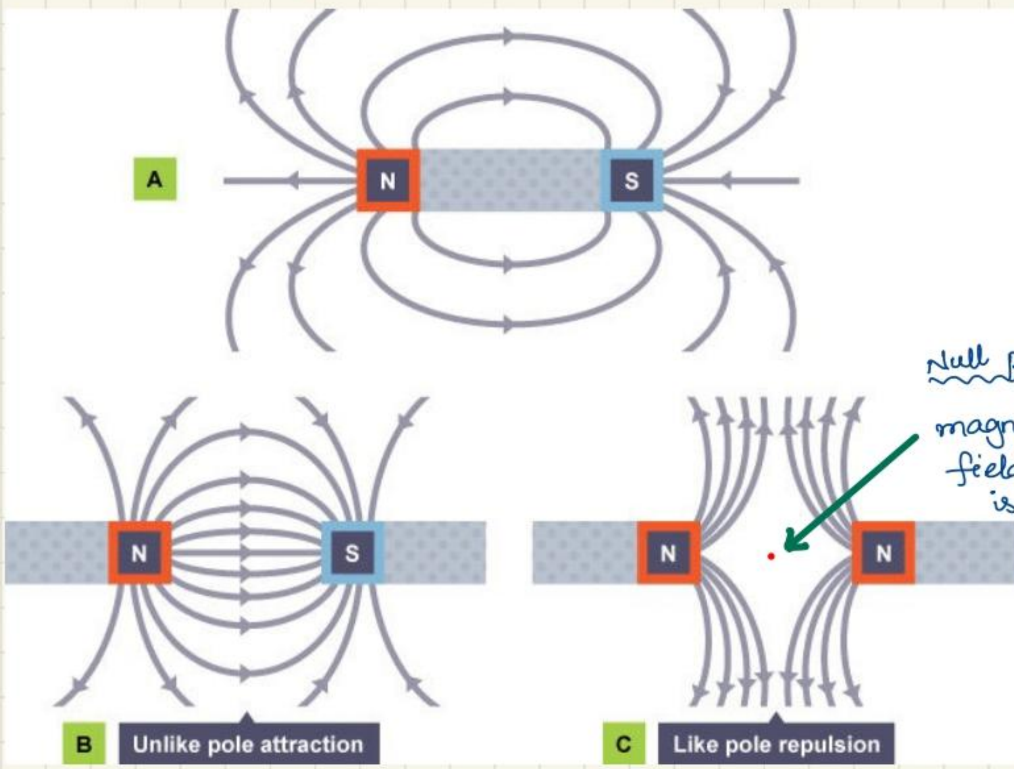
Compass needle is a tiny magnet.

Magnetic field of a bar magnet:





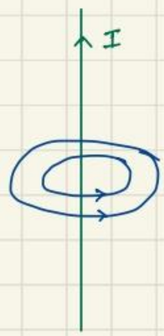
Direction of magnetic field is always from NORTH to SOUTH.



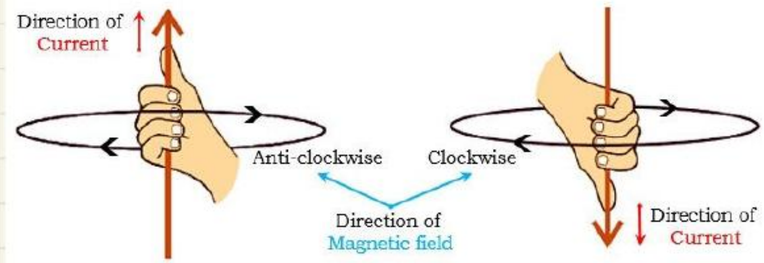
Null point:

magnetic field strength is zero.

Magnetic field around a straight current carrying wire:



Right Hand Grip Rule.



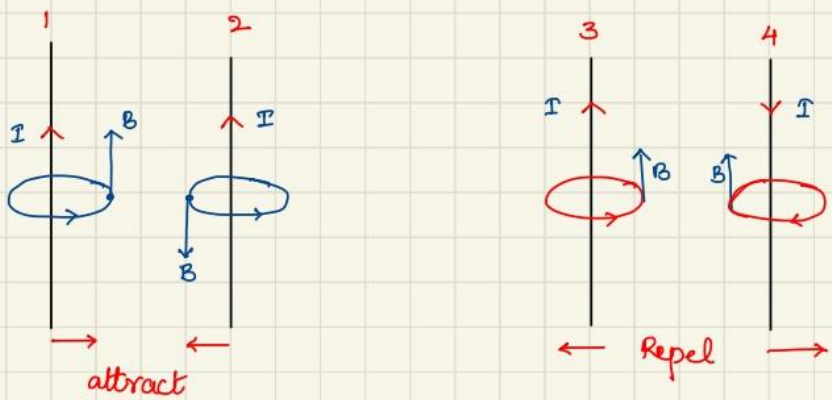
- Circular magnetic field is produced.
- magnetic field strength $\propto \frac{I}{r}$

  I = Current

  r = radius/distance

✓ Keep the thumb in the direction of current

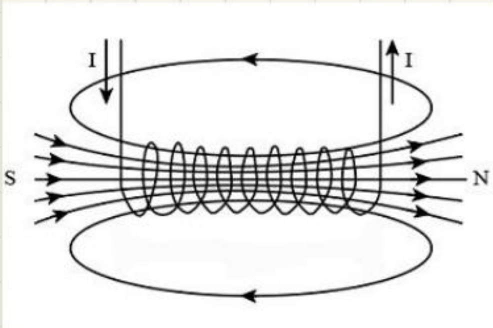
✓ Grip around wire gives the direction of magnetic field.



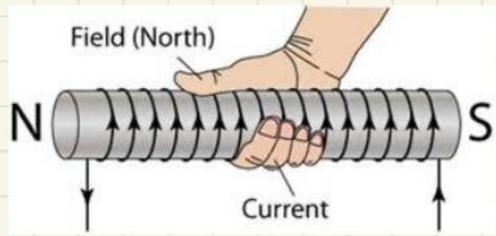
Two current carrying wires.

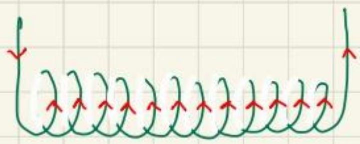
- attract if they carry the current in the same direction
- repel if they carry the current in opposite direction.

Magnetic field around a current carrying coil:



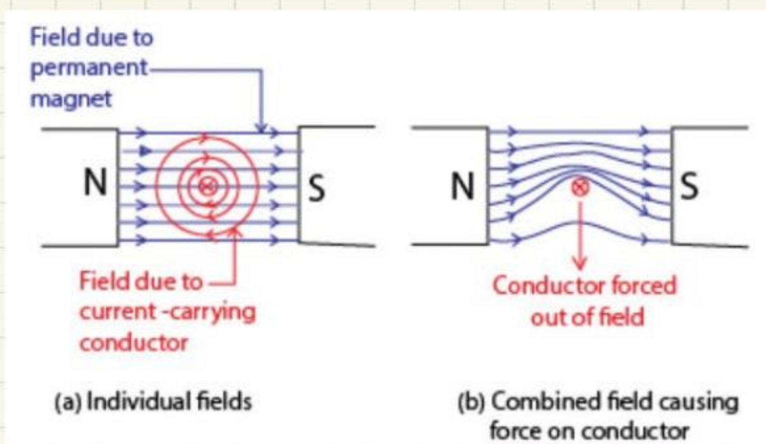
Right Thumb Rule





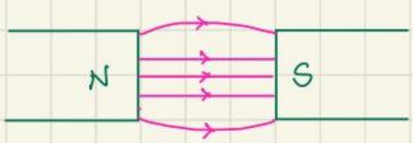
✓ Keep the grip/wrap the fingers in the direction of current
✓ Thumb gives the direction of North pole.

Force acting on a current carrying wire in a magnetic field.



(a) Individual fields

(b) Combined field causing force on conductor



When a current carrying wire is kept in an external magnetic field, the two fields interact and the wire experiences a force.

↓

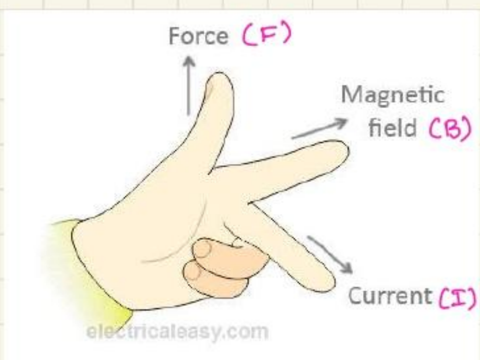
Direction of the force can be determined by using Fleming's left hand rule.

* ⊙ - outwards / out of the page.
  ⊗ - inwards / into the page.

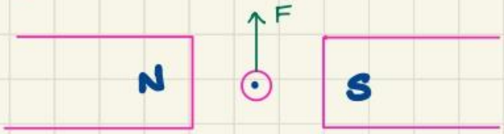
$F \perp B \perp I$

force	magnetic field	current
Thumb	1st finger	2nd finger

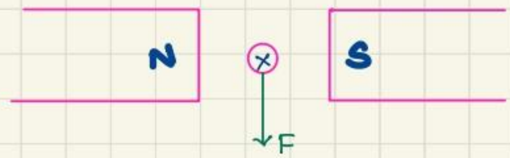
Fleming's Left Hand Rule :



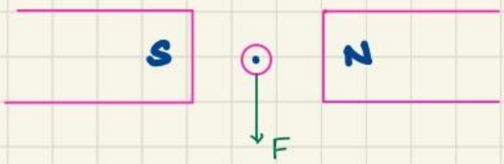
1



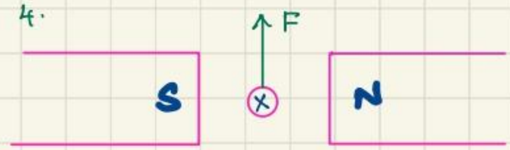
2.



3.

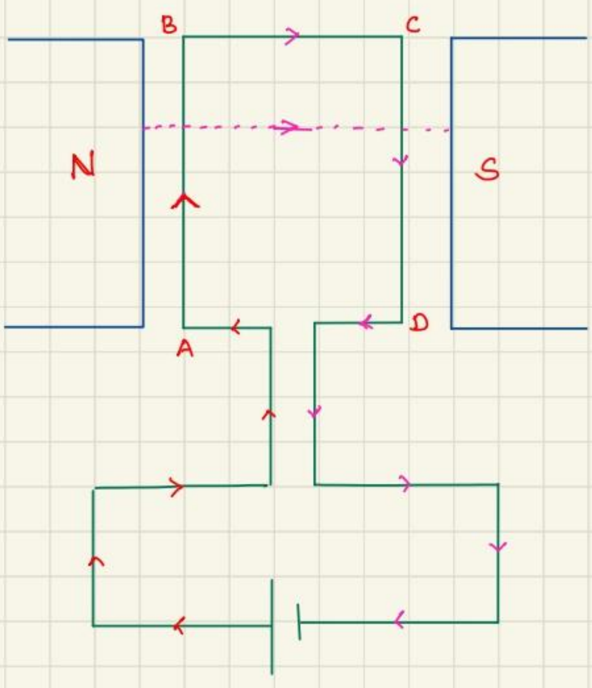


4.



To change the direction of force, change either the direction of magnetic field or the current, but not the both.

Force acting on a rectangular coil:

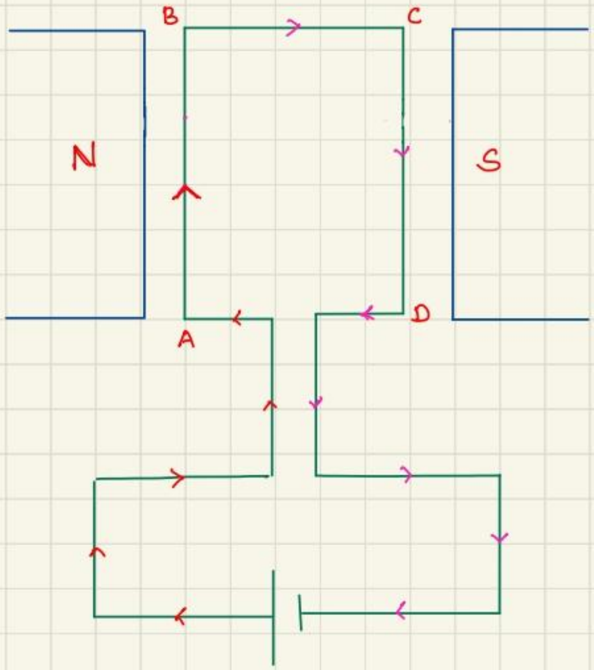


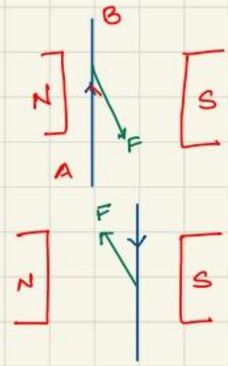
magnetic field is parallel to current in sides BC and DA (B||I)

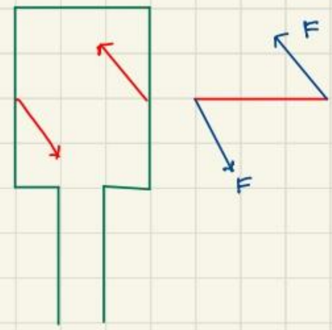
⇒ No force acts on sides BC & DA

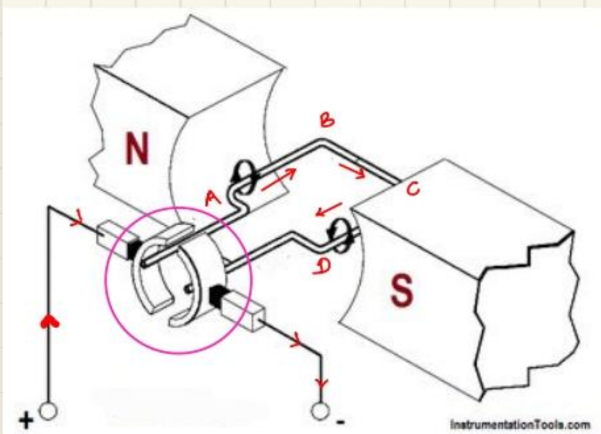
Magnetic field is perpendicular to current in sides AB & CD.

⇒ Force acts on AB & CD.









Since, equal forces acting in opposite direction separated by a distance, the coil rotates.

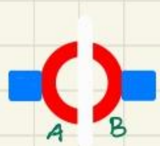
↓

Torque is produced.

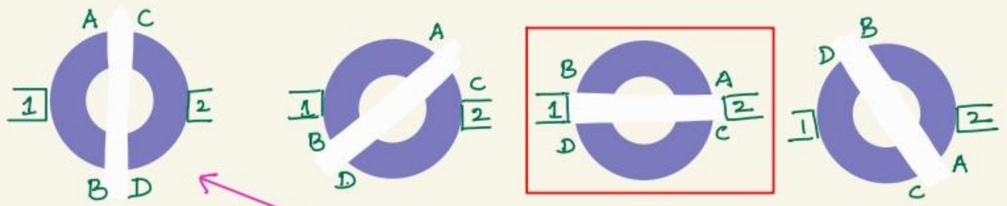
↓

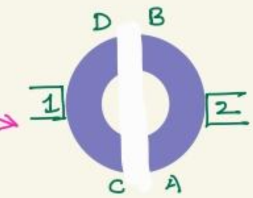
coil rotates in anti-clockwise direction.

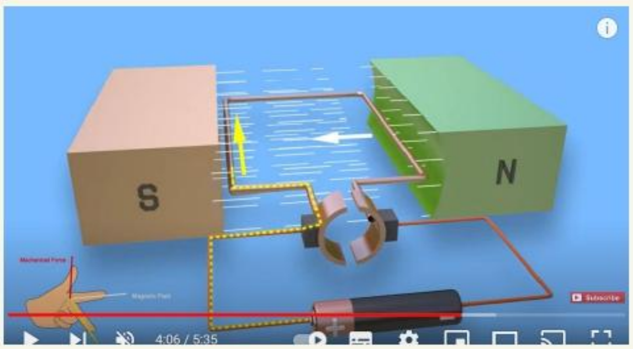
Commutator –



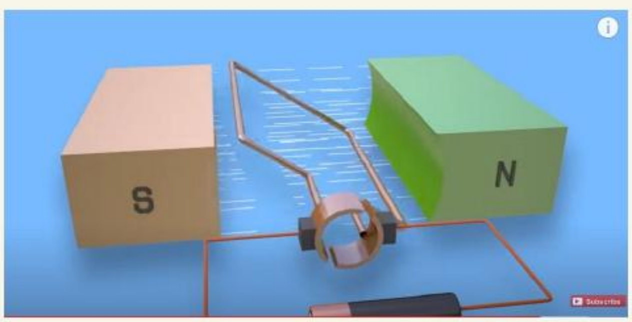
Keeps the direction of current the same so that the coil rotates in the same direction



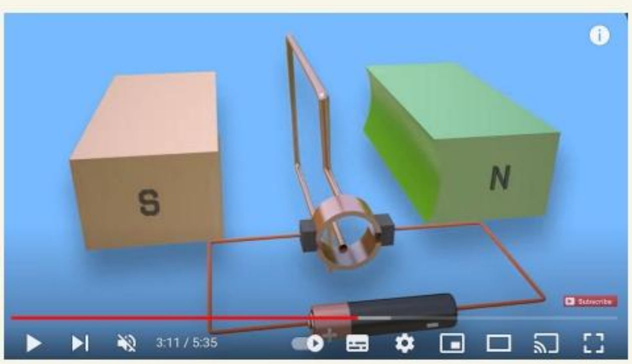




magnetic field is passing through the coil.



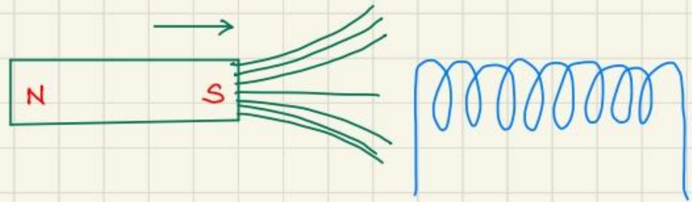
magnetic field is through the coil.



No magnetic field through coil
No current through coil.
still the coil rotates due to the momentum/ inertia

Coil overshoots its vertical position.

Induced emf:



An emf is induced in the coil due to the change in magnetic field lines passing through the coil.

Induced emf can be increased by

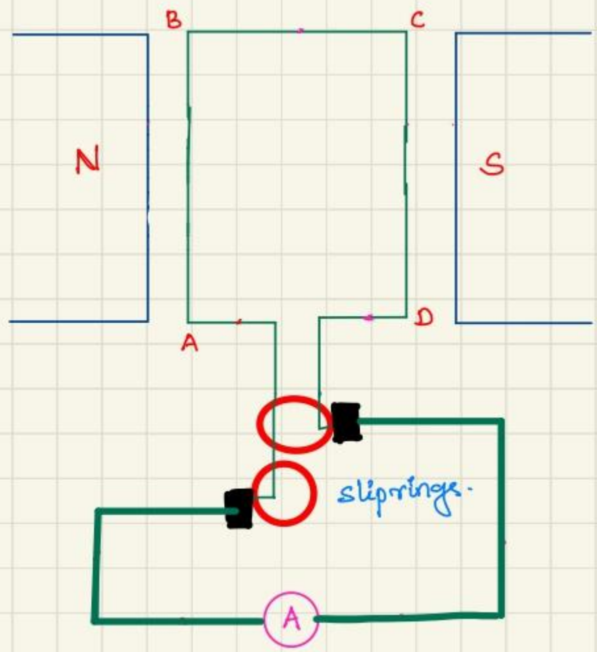
- increasing the no. of turns
- increasing the strength of the magnet (strong magnet).
- move the magnet faster.

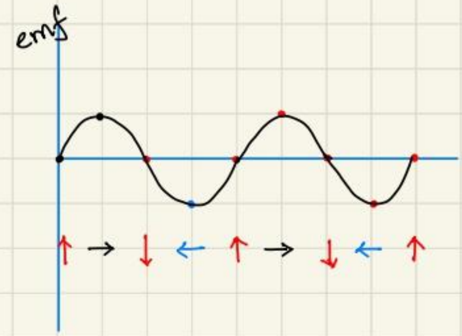
Faraday's Law:

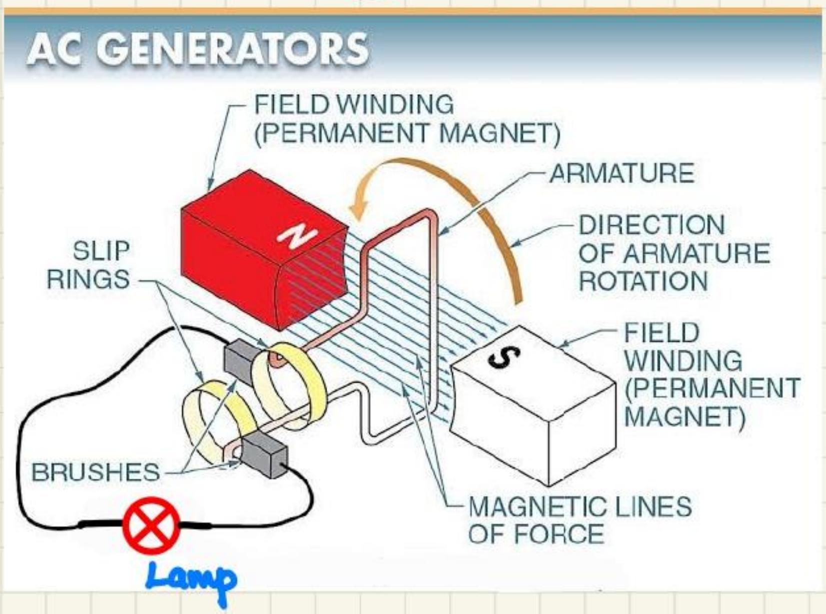
induced emf $\propto$ change in magnetic field lines through the coil per second.

$\Rightarrow$ induced emf $\propto$ Rate of change in magnetic field lines.

AC Generator : Converts mechanical energy into electric energy







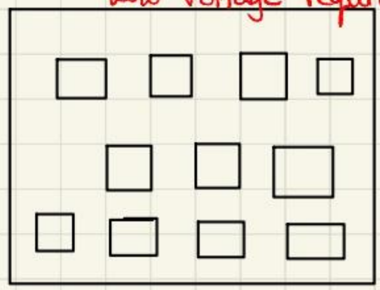
Induced emf can be increased by;

- increase the no. of turns
- move the coil faster.
- use stronger magnets

Transformer :

Power generated : 33 kV $\xrightarrow{\text{Domestic}}$

Low voltage required.

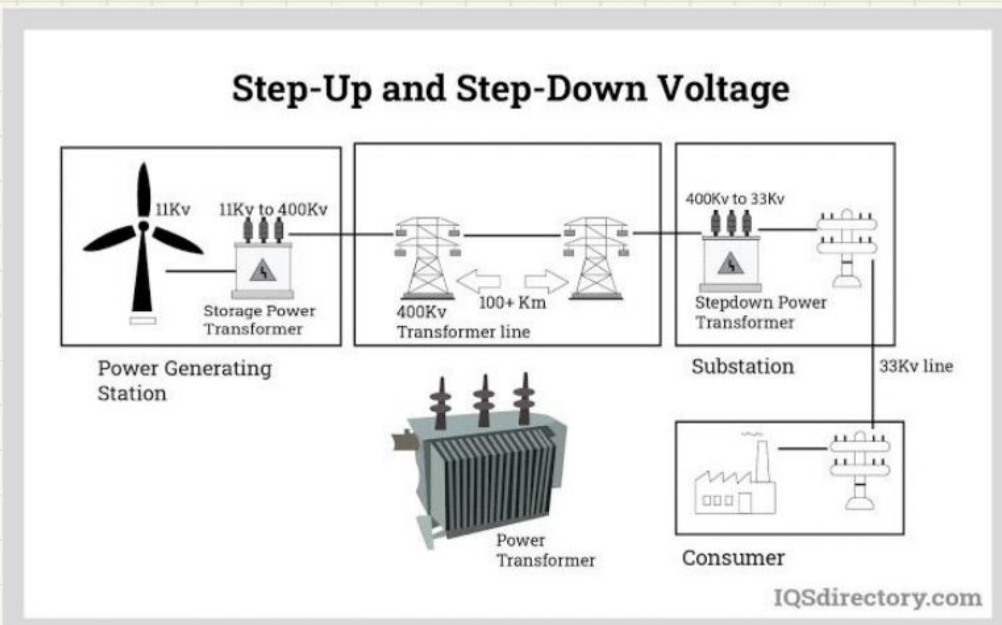


Industry.

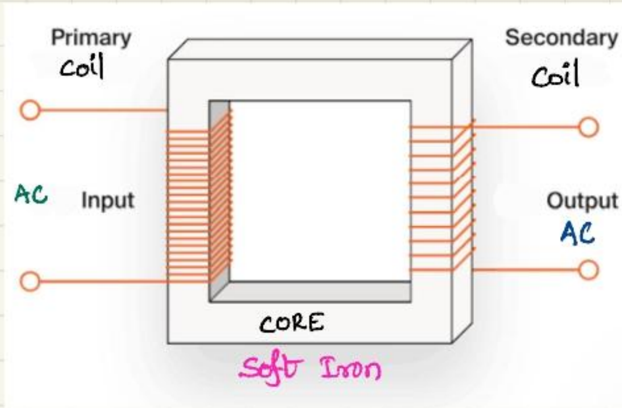
High voltage is required.

Transmission of power.

Transformers change the output voltage depends on the no. of coils in the output.



Working of a transformer:



AC connected in primary coil produces a variable magnetic field

This field passes through the core and magnetizes.

This variable magnetic field passes through the secondary coil and induces an emf

For a transformer; $\frac{V_1}{V_2} = \frac{n_1}{n_2}$

V_1 = voltage in primary coil
V_2 = voltage in sec. coil.
n_1 = no. of turns in pri coil
n_2 = no. of turns in sec. coil.

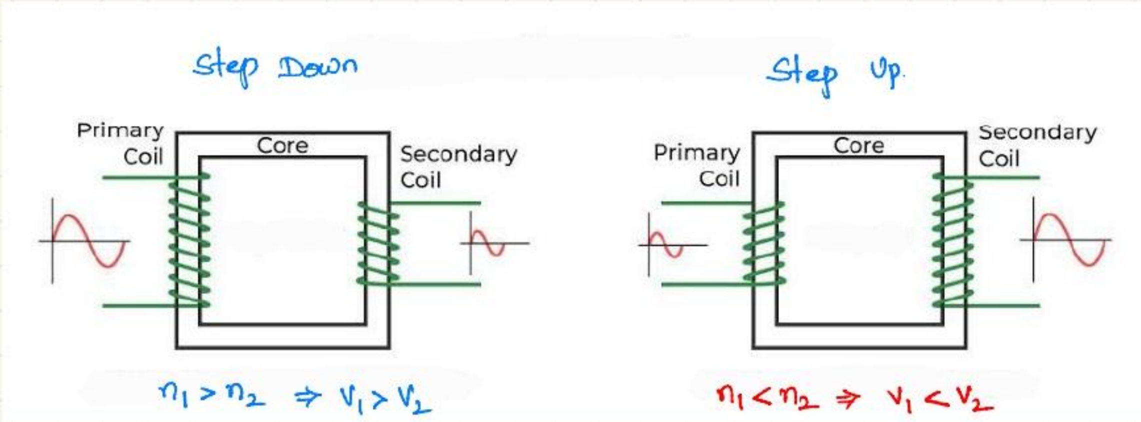
For an ideal transformer; Power loss = 0

$P_{in} = P_{out}$

$V_1 I_1 = V_2 I_2$

1 = primary coil
2 = Secondary Coil.

Types of transformers :



* During power transmission ; high voltage and low current are preferred. why ?

100 W — 50V 2A
100 W — 10V 10A

if current is greater ; wire heats up

Temperature increases

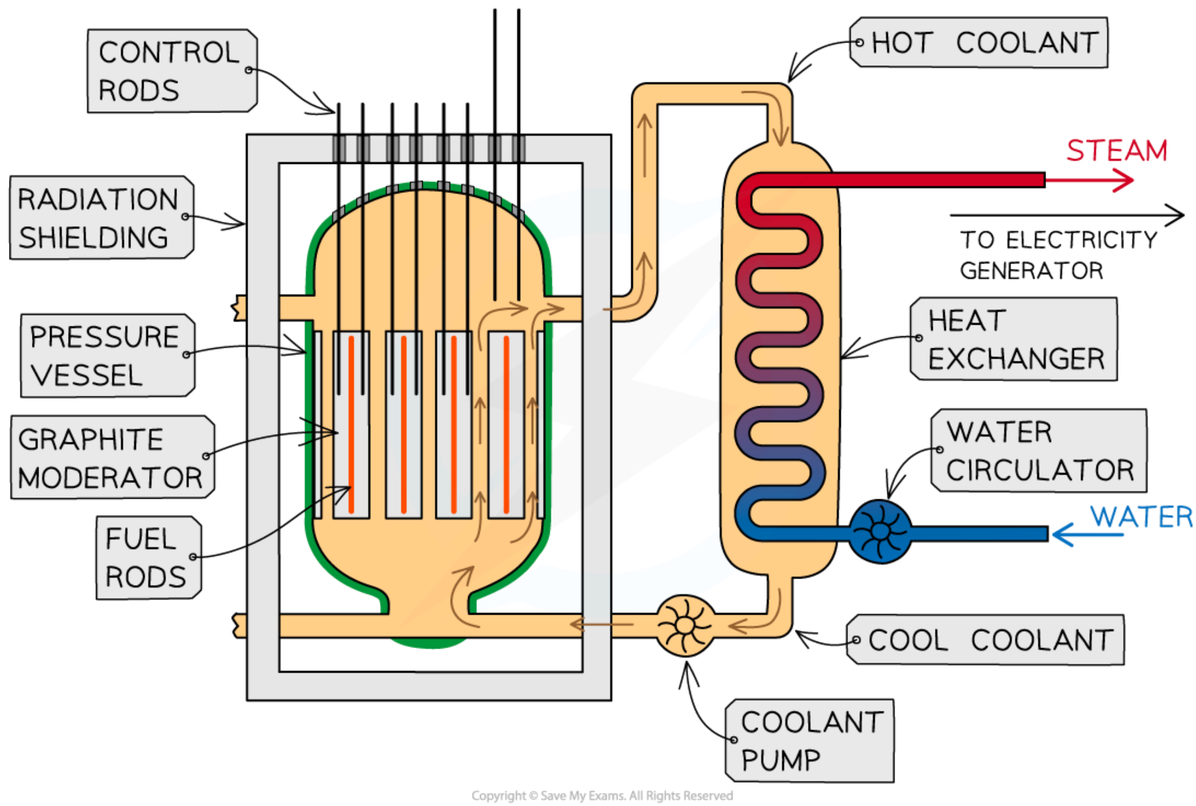
Resistance also increased

more energy is lost .

Hence more voltage & low current is preferred.

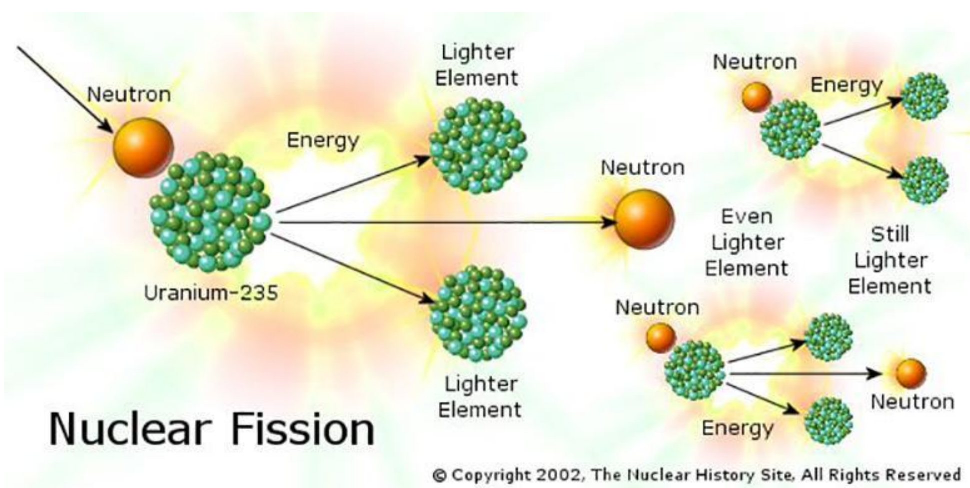
Nuclear Physics

Nuclear Reactor

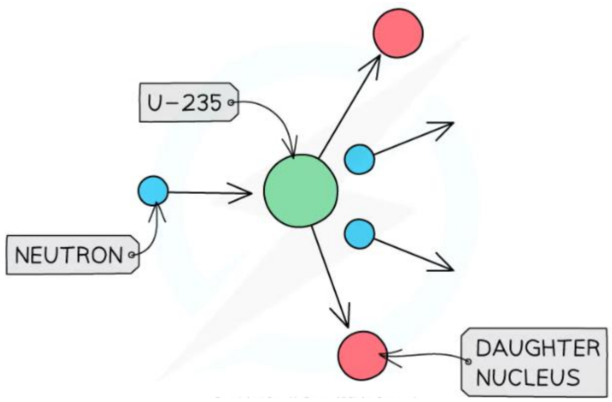


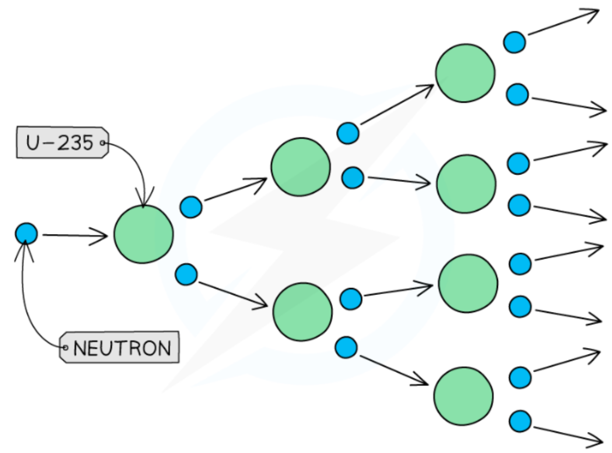
Nuclear Fission Explanation

Nuclear fission is the process by which a heavy atomic nucleus, such as uranium-235 or plutonium-239, splits into two smaller nuclei along with the release of a large amount of energy. When a neutron collides with a heavy nucleus, it can make the nucleus unstable, causing it to split. These splitting releases additional neutrons and energy in the form of radiation and kinetic energy. The emitted neutrons can then initiate further fission reactions in nearby nuclei, leading to a self-sustaining chain reaction if conditions are suitable.



$$ {}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{144}_{56}\mathrm{Ba} + {}^{89}_{36}\mathrm{Kr} + 3{}^{1}_{0}\mathrm{n} + 210MeV $$





Example of Nuclear Fission: A common example of nuclear fission involves uranium-235:

1. A neutron collides with a uranium-235 nucleus.
2. The nucleus becomes unstable and splits into two smaller nuclei (e.g., barium-141 and krypton-92).
3. This reaction releases additional neutrons (typically two or three) and a large amount of energy.

Summary of Key Components and Roles in a Nuclear Reactor

1. **Fuel Rods:**
   - ➢ Contain the fissionable material, typically uranium-235 or plutonium-239.
   - ➢ The fission process in the fuel generates the heat needed to produce energy.

➢ **Control Rods:**
   - ➢ Made of neutron-absorbing materials like boron or cadmium.
   - ➢ Inserted or withdrawn from the reactor core to control the rate of the fission chain reaction by absorbing excess neutrons.
   - ➢ Helps maintain a steady reaction rate or shut down the reactor if necessary.

2. **Moderator:**
   - ➢ Surrounds the fuel rods, often made of water or graphite.
   - ➢ Slows down the neutrons released from fission to increase the likelihood that they will cause further fission reactions in other fuel atoms.
   - ➢ Helps sustain a controlled chain reaction in the reactor.

3. **Coolant:**

- Usually water, but can also be liquid sodium or gas.
- Absorbs the heat generated in the reactor core and transfers it to a heat exchanger or directly to the turbines.
- Ensures that the reactor does not overheat and enables the production of electricity.

4. **Heat Exchanger (Steam Generator):**

   - Transfers the heat from the coolant to water in a separate loop, converting it into steam.
   - The steam produced drives turbines, which generate electricity.

5. **Containment Structure:**

   - A reinforced steel and concrete structure that houses the reactor core and other components.
   - Provides a barrier to contain radiation and prevent the escape of radioactive materials into the environment.

6. **Turbine and Generator:**

   - The steam from the heat exchanger drives the turbine.
   - The turbine is connected to a generator, which produces electricity.

Limitations:

Nuclear reactors are powerful sources of energy, but they come with several limitations and challenges:

1. **Radioactive Waste:**

   - Nuclear reactors produce high-level radioactive waste that remains hazardous for thousands of years.
   - Safe, long-term storage and disposal solutions are complex, costly, and controversial.

2. **Risk of Accidents:**

   - Accidents like those at Chernobyl and Fukushima have shown that reactor malfunctions can release dangerous levels of radiation into the environment.
   - Such incidents can cause long-lasting environmental damage, health issues, and public fear.

3. **High Initial Cost:**

- Building a nuclear power plant requires significant investment due to the need for complex safety systems, regulatory compliance, and infrastructure.
- These high costs make nuclear energy economically challenging, especially compared to some renewable sources.

4. **Limited Fuel Supply:**
   - Nuclear reactors primarily use uranium-235, which is limited and non-renewable.
   - Although breeder reactors can extend fuel supply by converting uranium-238 into plutonium-239, they are more complex and raise proliferation concerns.
5. **Thermal Pollution:**
   - Nuclear plants release large amounts of heat into nearby water bodies, potentially harming aquatic life.
   - Thermal pollution can disrupt local ecosystems by reducing oxygen levels and impacting biodiversity.
6. **Public Perception and Political Issues:**
   - Due to safety concerns and historical accidents, nuclear energy often faces public opposition.
   - Political and regulatory hurdles can delay projects, leading to increased costs and uncertainty.

Nuclear fusion

Nuclear fusion is when two or more atomic nuclei fuse to form a single heavier nucleus.

In the reaction, the matter is not conserved because some of the mass of the fusing nuclei is converted to energy.

Parameter	Nuclear fission	Nuclear fusion
Definition	Fission is defined as the splitting of a nucleus into two daughter nuclei	Fusion is defined as the combining of two lighter nuclei into a heavier one
Generation of energy	The amount of energy produced is huge	The amount of energy produced is relatively huge
Fuel	Uranium is the primary fuel that is used in the power plants	Hydrogen isotopes are the primary fuel that is used in the power plants

Differences between Nuclear Fission and Fusion

Nuclear Fission	**Nuclear Fusion**
Nuclear fission is a nuclear reaction that splits a heavy atom into multiple smaller ones.	Nuclear fusion is a nuclear reaction that combines two or more small atoms to form a large atom.
It does not occur naturally.	The universe is full of instances of nuclear fusion reactions. Every star uses it to produce energy.
It produces a large quantity of energy.	It produces greater energy than the fission reaction.
It does not require a lot of energy to split an atom into two.	It requires a lot of heat and pressure for the process to happen.

Thermal Physics

Thermal Effects

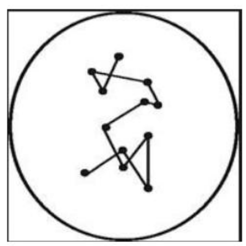
- **Classification of Matter:**

Solids	Liquids	Gases
Fixed shape, size and volume	No fixed shape but fixed volume	No fixed shape, size or volume
vibrate about a fixed position	can flow; some movement randomly around each other	can move freely and at random at very high velocity in all space available
particles are closely bound	particles loosely bound	particles are free to move
strong attractive and repulsive force between them	weaker force of attraction	exert no force on each other
little expansion upon heating	slightly more expansion upon heating	large expansion upon heating
little or no compression on application of pressure	little or no compression on application of pressure	much more compression upon heating

- **Brownian Motion:**

  The random motion of the smoke particles is called as Brownian motion.

  Smoke particles collide with the air molecules and change their direction of motion instantly.



- **Internal Energy** is the sum of kinetic and potential energies of all the atoms or molecules in a material.
- **Temperature** is the degree of hotness or coldness of an object.

  Temperature is defined as the average kinetic energy per molecule.

  It is measured in Degree Celsius (°C) or in Kelvin (K)
- **Heat** is the flow of energy that flows from a hot object to a cold object due to the temperature difference between the two objects
- **Measurement of temperature**

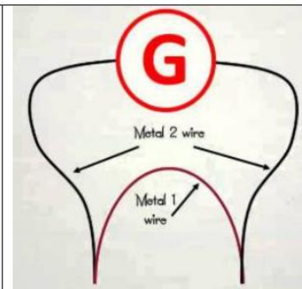
  Temperature is measured using a thermometer.

1. **Clinical Thermometer**

   Mercury or alcohol is used in clinical thermometer

2. **Thermocouple Thermometer**

Two different metals are joined to form two junctions. One junction is placed at a low temperature and the other placed at a high temperature. The temperature difference between junctions causes an induced voltage/current. The greater the current, the greater the temperature difference. A galvanometer/volt meter/ammeter is connected in the circuit.



3. **Thermistor Thermometer**

   Thermistor is a device that becomes a much better electrical conductor when its temperature rises. This means that a higher current flow from the battery causing a higher reading on the meter.

   For a thermistor, resistance decreases with increase in temperature.

- **Absolute Zero & Kelvin Scale**

  The relation between the Celsius scale and the Kelvin scale is as below:

$$T(K) = T(^{o}C) + 273$$

Kelvin temperature / K = Celsius Temperature / °C + 273

-273 °C or **0 K** is called as **Absolute Zero**.

- **Fixing a temperature** On the Celsius Scale:

  Lower Fixed Point: 0 °C, Melting point of pure ice, Ice point

  Upper Fixed Point: 100 °C, Boiling point of pure water, Steam point

- **Calibration of a thermometer:**

  Fixing lower and upper fixed points on a thermometer is known as calibration of a thermometer.

  Lower fixed point is fixed by placing a thermometer in ice that is at 0°C

  Upper fixed point is fixed by placing a thermometer above the boiling water/steam that is at 100°C

- **Liquid in glass thermometers:**

  Liquids are used in thermometers as they expand on heating.

  The liquids used in general are mercury and alcohol.

  The properties of the liquids to be used in thermometers are:

  1. Sensitivity: is the change in length or volume of the liquid per unit temperature change and the ability of measuring small temperature changes.

     Sensitivity increases by using

     - Thinner tube
     - Less dense liquid
     - Bigger bulb
  2. Range is the change in the upper and lower fixed points

     The range increases for the liquids that have low freezing points and high boiling points
  3. Linearity is the property of uniform expansion of the liquid for uniform temperature change
  4. Responsiveness is how quick a liquid expands to the temperature change.

     It is increased by using thinner bulbs.

- **Expansion of solids and liquids:**

  All matter expands when heated because of the increase in the vibration of the molecules.

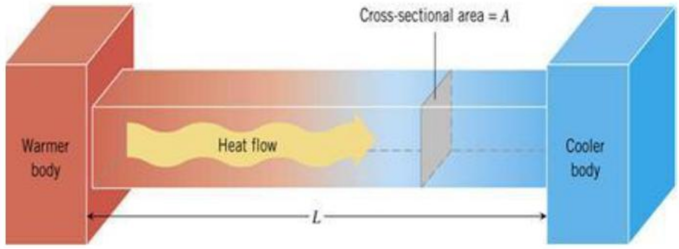
  Solids expands the least, liquids expand more than solids and gases expands the most.

  Expansion of solids:

  On heating, the molecules in a solid absorb heat energy and start vibrate from their mean positions and speed up. Their vibrations take up more space, so the solids expand.

  Example:

  1. Some gap left between the rail tracks to allow the expansion during the summer
  2. Steel rods can be used to reinforce concrete because both steel and concrete have the same expansion for the same temperature change. If the expansions are different, the steel might crack the concrete on a hot day.
  3. When overhead cables are suspended from poles, they are left slack, partly to allow the contraction on a very cold day.



More thermal energy is transferred every second/ rate of flow of heat is increased by:

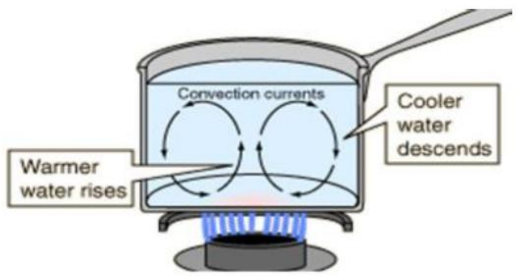
(i) Increasing the temperature difference between the ends of a bar

(ii) Increasing the cross-sectional area of the bar

(iii) Decreasing the length of the bar

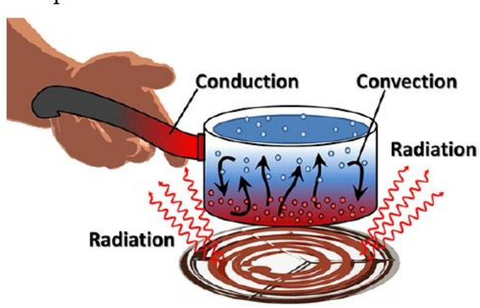
2. **Convection** occurs in liquids and gases or in fluids. When heated, the molecules gain energy and becomes less dense (lighter) and they rise.

   Due to convection, hot molecules (air) rise and cold molecules (air) fall.



3. **Radiation** is the process of transmission of heat in vacuum.

   Convection always occurs bottom to the top and **Radiation** occurs in all the direction except bottom to the top.

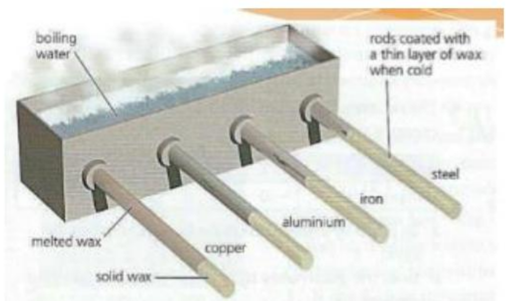


- **Thermal conductors and insulators:**

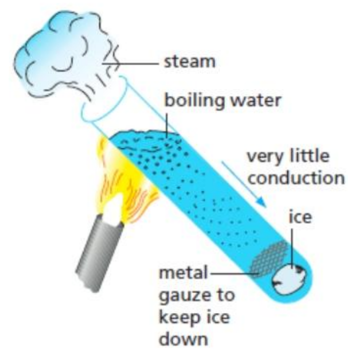
  Materials that conduct/pass thermal energy are thermal conductors and that do not pass are known as poor conductors / insulators.

  Metals are good thermal conductors.

  Air and water are poor thermal conductors.



Comparing the conductors of heat



Water is a poor conductor of heat.

- **Absorbers, emitters and reflectors:**

  An Emitter sends out thermal radiation

  A reflector reflects thermal radiation, therefore is a bad absorber

  An emitter will cool down quickly and an absorber will heat up quickly.

	MATT BLACK	WHITE	SILVER
EMITTER	Best		Worst
REFLECTOR	Worst		Best
ABSORBER	Best		Worst

  Polished surfaces, silver and shiny surfaces act as good reflectors.

- **Specific heat capacity (c):**

  The amount of energy required to change the temperature of unit mass by unit temperature

  (OR)

  The amount of heat required to change the temperature of 1 kg of mass by 1 ºC or 1 K.

$$c = \frac{E}{m\Delta T}, \qquad \text{Units: J/kg – K} \qquad \text{or} \qquad \text{J/kg - ºC}$$

$\boldsymbol{c}$ = specific heat capacity, $\boldsymbol{m}$ = mass, ΔT = temperature change

- **Thermal capacity:**

  The amount of heat required per unit temperature change

  $$Thermal\ capacity = \frac{E}{\Delta T} \qquad \text{Units: J/K} \quad \text{or} \quad \text{J/°C}$$

- **Specific Latent Heat (L):**

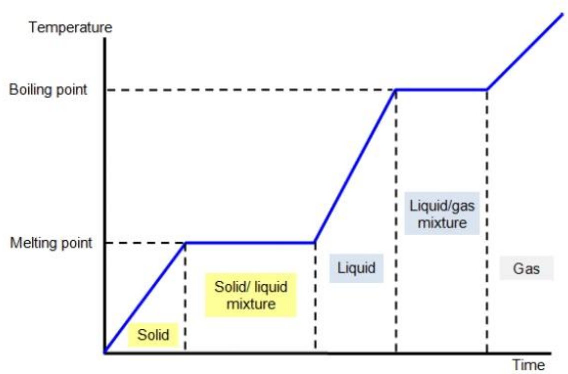
  The specific latent heat is the amount of heat energy required to change the phase of unit mass at constant temperature.

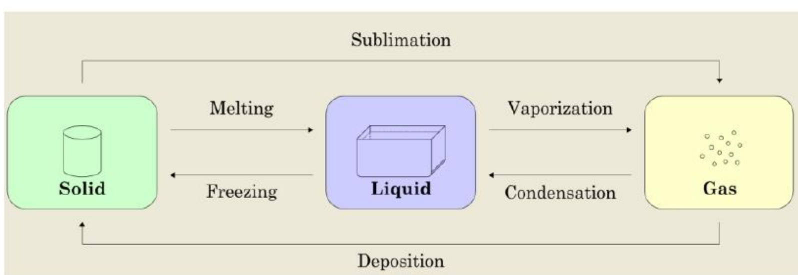
  $$L = \frac{E}{m}; \qquad \text{Units: J/kg}$$

  **During the phase change temperature remains constant

  Specific latent heat of fusion (***L_f***) is the energy required to convert a unit mass of solid into liquid or vice versa without changing the temperature.

  Specific latent heat of vaporization ***(L_v)*** is the energy required to convert a unit mass of liquid into gas or vice versa without changing the temperature.



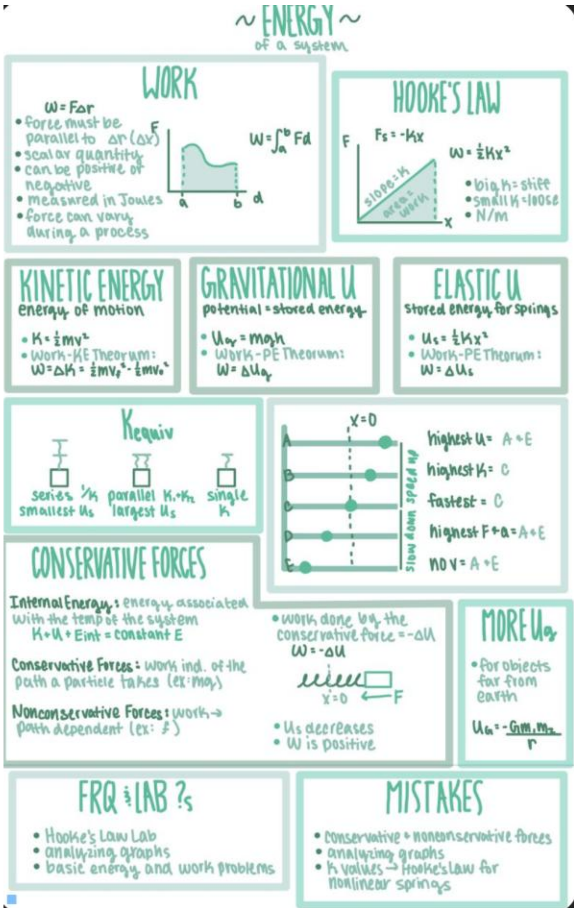


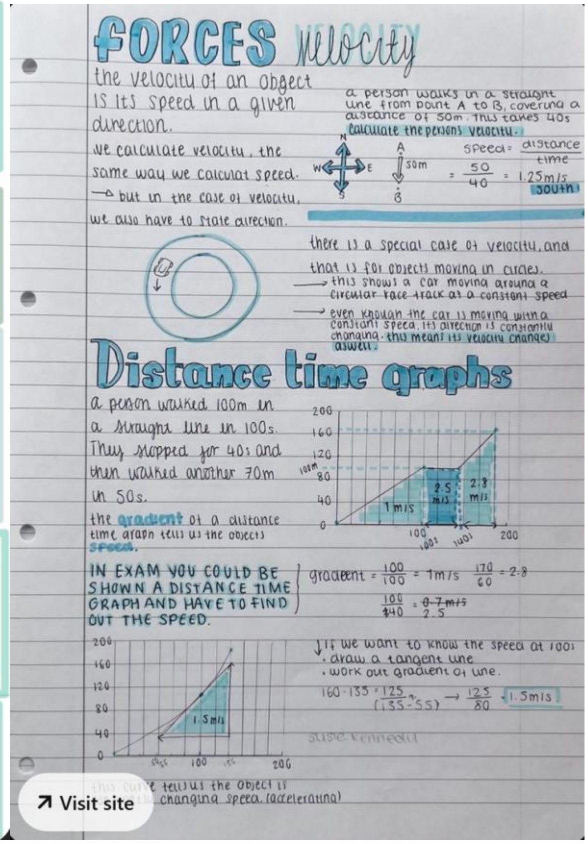
- **Evaporation and Boiling:**

Evaporation	**Boiling**
Evaporation is the process of converting liquid into vapours.	Boiling is the process of converting liquid into vapours at the boiling point.
As a result of increasing the temperature of liquid the molecules start moving faster and gain enough energy to break the intermolecular bonding and escape from the surface.	As a result of increasing the temperature of liquid the molecules start moving faster and gain enough energy to break the intermolecular bonding and escape from the liquid.
It happens at any temperature.	It happens only at the boiling point of the liquid.
It happens at the liquid surface only.	It happens anywhere within the liquid.
Average E_k decreases and therefore the temperature of liquid decreases	Average E_k stays the same and therefore the temperature of liquid does not increase

Pinterest

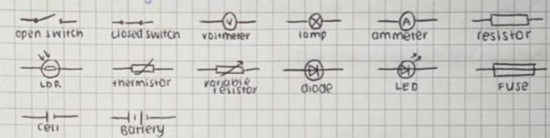
Certain images are not part of our syllabus, so please DO NOT panic.
Don’t come at me for any wrong info


~ENERGY~
of a system
WORK
W=Fdr
• force must be parallel to Δr (Δx)
• scalar quantity
• can be positive or negative
• measured in Joules
• force can vary during a process
W=∫ₐᵇ Fd
HOOKE'S LAW
Fs = -Kx
W = ½Kx²
slope=K
area = work
• big K = stiff
• small K = loose
• N/m
KINETIC ENERGY
energy of motion
• K = ½mv²
• Work-KE Theorum:
W=ΔK = ½mvf² - ½mvo²
GRAVITATIONAL U
potential = stored energy
• Ug = mgh
• Work-PE Theorum:
W= ΔUg
ELASTIC U
stored energy for springs
• Us = ½Kx²
• Work-PE Theorum:
W = ΔUs
Kequiv
series ¹/K smallest Us
parallel K₁+K₂ largest Us
single K
x=0
highest U= A+E
highest K= C
fastest = C
highest F+a= A+E
no v = A+E
speed up
slow down
CONSERVATIVE FORCES
Internal Energy: energy associated with the temp of the system
K+U+Eint = constant E
Conservative Forces: work ind. of the path a particle takes (ex: mg)
Nonconservative Forces: work → path dependent (ex: f)
• work done by the conservative force = -ΔU
W = -ΔU
x=0
F
• Us decreases
• W is positive
MORE Ug
• for objects far from earth
Ug = -Gm₁m₂/r
FRQ & LAB ?s
• Hooke's Law Lab
• analyzing graphs
• basic energy and work problems
MISTAKES
• conservative + nonconservative forces
• analyzing graphs
• K values → Hooke's Law for nonlinear springs


FORCES velocity
the velocity of an object is its speed in a given direction.
we calculate velocity, the same way we calculat speed.
→ but in the case of velocity, we also have to state direction.
a person walks in a straight line from point A to B, covering a distance of 50m. This takes 40s calculate the persons velocity.
speed = distance / time
= 50/40 = 1.25m/s south
there is a special case of velocity, and that is for objects moving in circles.
→ this shows a car moving around a circular race track at a constant speed
→ even though the car is moving with a constant speed, its direction is constantly changing. this means its velocity changes aswell.
Distance time graphs
a person walked 100m in a straight line in 100s. They stopped for 40s and then walked another 70m in 50s.
the gradient of a distance time graph tells us the objects speed.
IN EXAM YOU COULD BE SHOWN A DISTANCE TIME GRAPH AND HAVE TO FIND OUT THE SPEED.
gradient = 100/100 = 1m/s   170/60 = 2.8
1m/s
2.5 m/s
2.8 m/s
If we want to know the speed at 100s:
• draw a tangent line
• work out gradient of line.
160-135 = 125/(135-55) → 125/80 = 1.5m/s
1.5m/s
this curve tells us the object is changing speed (accelerating)
Visit site

Electricity

Electrical symbols:



Electrical charge and current

There are two types of current: direct and alternating.

Direct current - the flow of electrons is consistently in one direction around the circuit

Alternating current - the direction of electron flow is continually reversing.

Charge:

- Electrons are negatively charged particles and they transfer energy through wires as electricity
- charge is measured in coulombs (C)

Current:

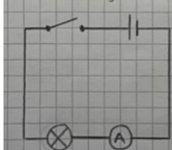
- Electrical current is the rate of flow of charge.
- When current flows, work is done and energy is transferred.

Charge = current x time

$Q = I \times t$

(coulombs) (amps, A) (seconds, s)

Measuring current



Current is measured using an **ammeter**

To measure the current through a component, the ammeter must be placed in **series** with that component.

physics cheat sheet

physics bundle

$d = v_i t + \frac{1}{2}at^2$

$v_f = v_i + a_t$

$W = F \cdot d$

$P = \frac{W}{t}$

$J = F \cdot t$

$F = m \cdot a$

$v = \frac{d}{t}$

$p = m \cdot v$

$KE = \frac{1}{2}mv^2$

$F_f = \mu F_N$

vector	scalar
displacement	distance
velocity	speed
acceleration	time
momentum	mass
force	energy

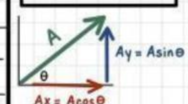
kilo	hecto	deca	Base unit	deci	centi	milli
10^3	10^2	10^1		10^{-1}	10^{-2}	10^{-3}

units	
displacement	meter (m)
distance	meter (m)
time	second (s)
velocity	meter per second (m/s)
speed	meter per second (m/s)
acceleration	meter per second squared (m/s^2)
mass	Kilogram (kg)
momentum	kg · m/s
force	Newton (N)
energy	Joule (J)

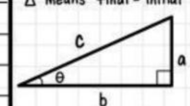
100 cm → 1 m

1000 mm → 1 m

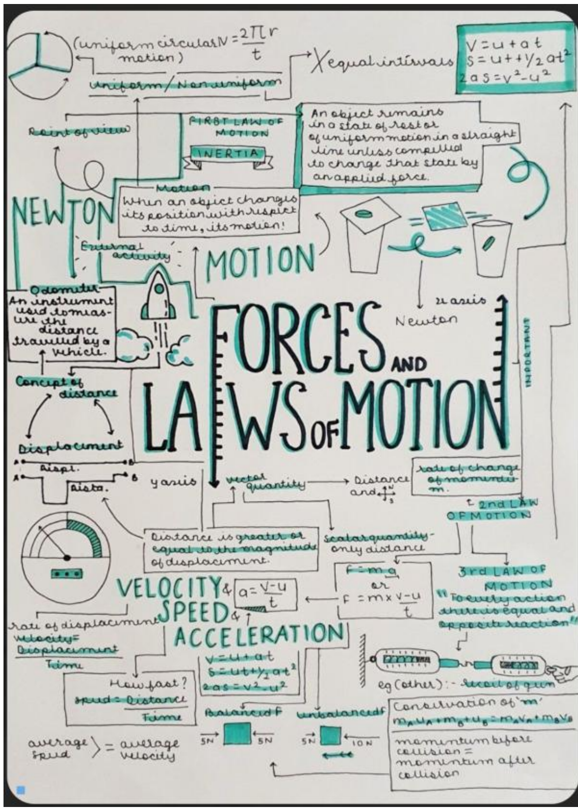
1000 m → 1 km

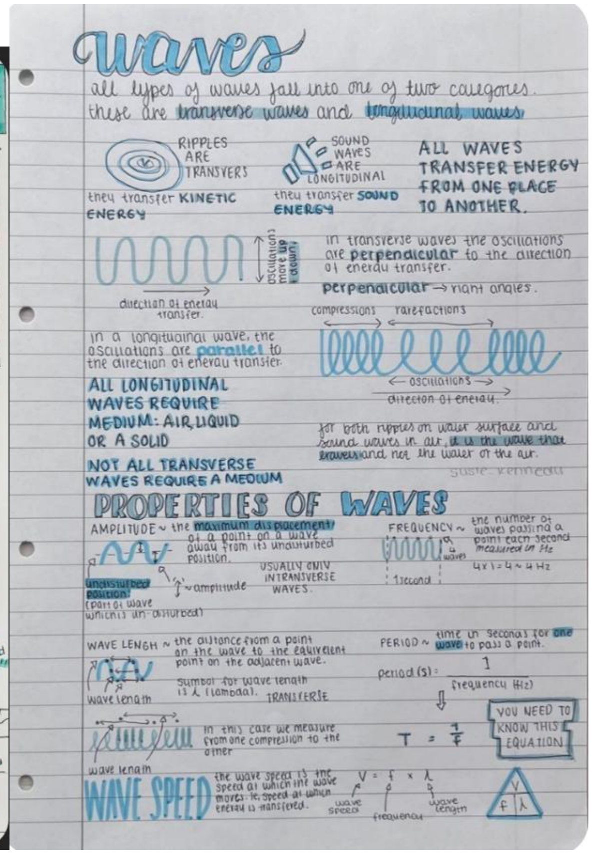


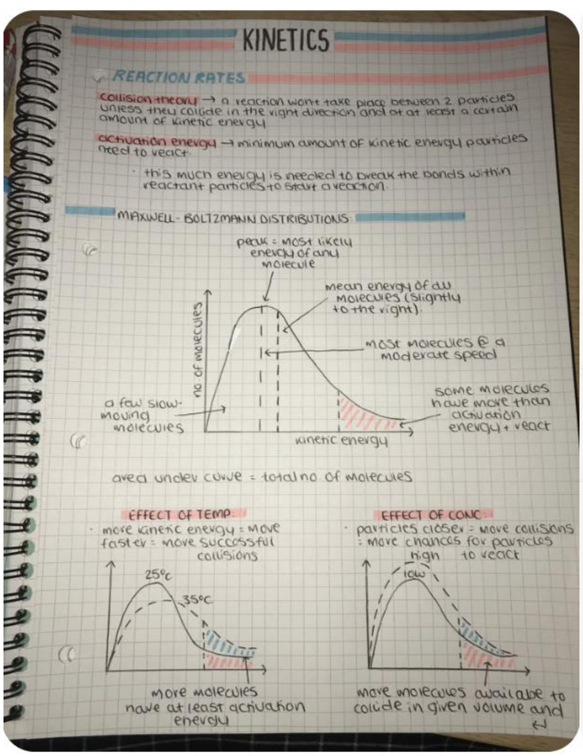
Δ means final - initial

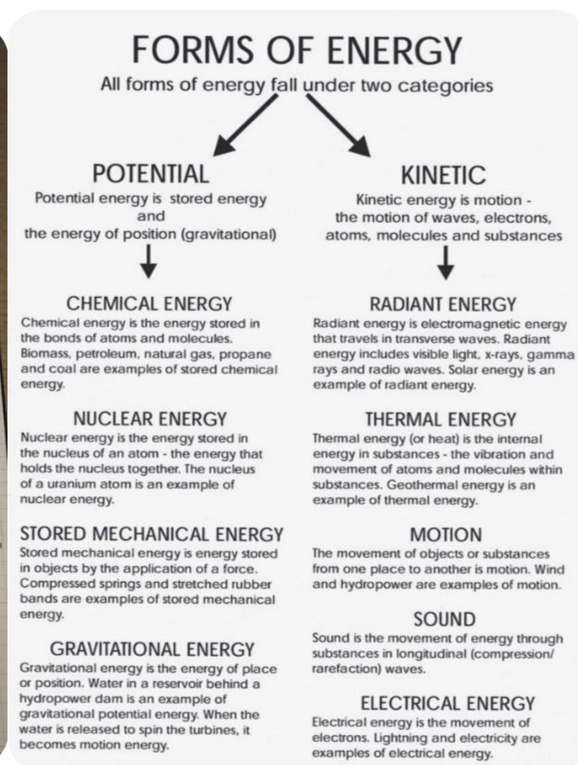


$a^2 + b^2 = c^2$









FORMS OF ENERGY

All forms of energy fall under two categories

POTENTIAL

Potential energy is stored energy and the energy of position (gravitational)

CHEMICAL ENERGY

Chemical energy is the energy stored in the bonds of atoms and molecules. Biomass, petroleum, natural gas, propane and coal are examples of stored chemical energy.

NUCLEAR ENERGY

Nuclear energy is the energy stored in the nucleus of an atom - the energy that holds the nucleus together. The nucleus of a uranium atom is an example of nuclear energy.

STORED MECHANICAL ENERGY

Stored mechanical energy is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy.

GRAVITATIONAL ENERGY

Gravitational energy is the energy of place or position. Water in a reservoir behind a hydropower dam is an example of gravitational potential energy. When the water is released to spin the turbines, it becomes motion energy.

KINETIC

Kinetic energy is motion - the motion of waves, electrons, atoms, molecules and substances

RADIANT ENERGY

Radiant energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Solar energy is an example of radiant energy.

THERMAL ENERGY

Thermal energy (or heat) is the internal energy in substances - the vibration and movement of atoms and molecules within substances. Geothermal energy is an example of thermal energy.

MOTION

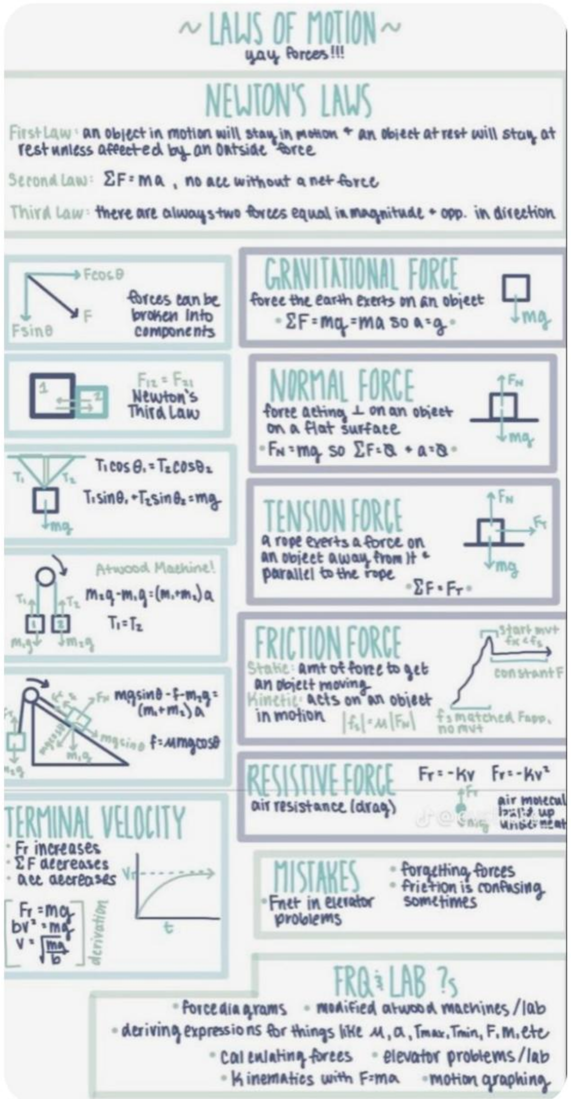
The movement of objects or substances from one place to another is motion. Wind and hydropower are examples of motion.

SOUND

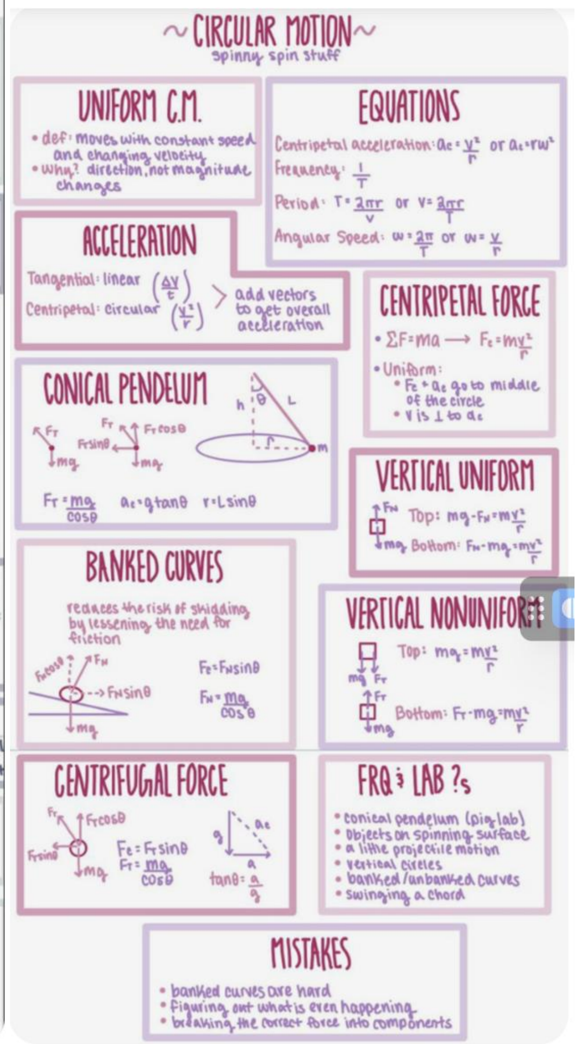
Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves.

ELECTRICAL ENERGY

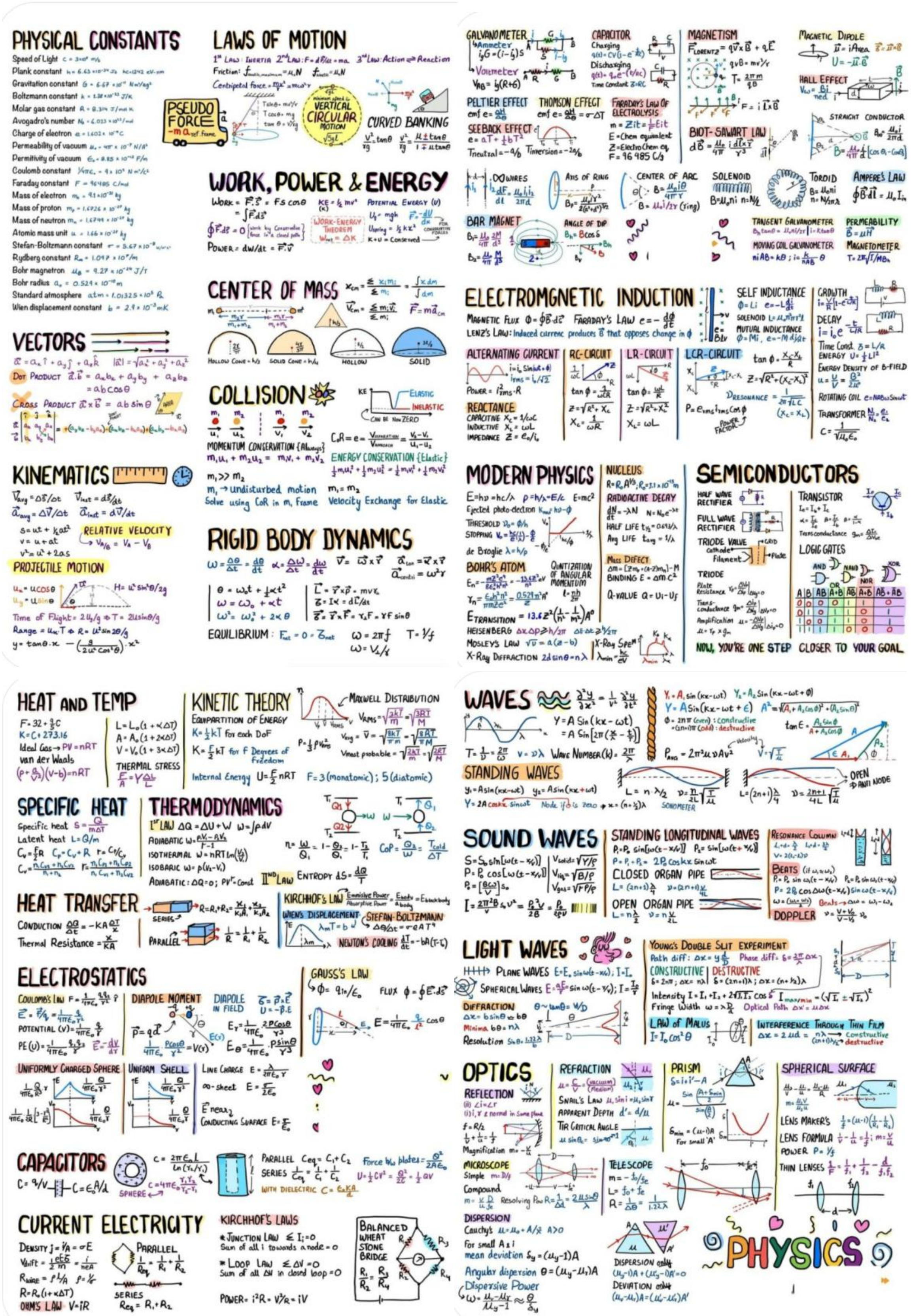
Electrical energy is the movement of electrons. Lightning and electricity are examples of electrical energy.

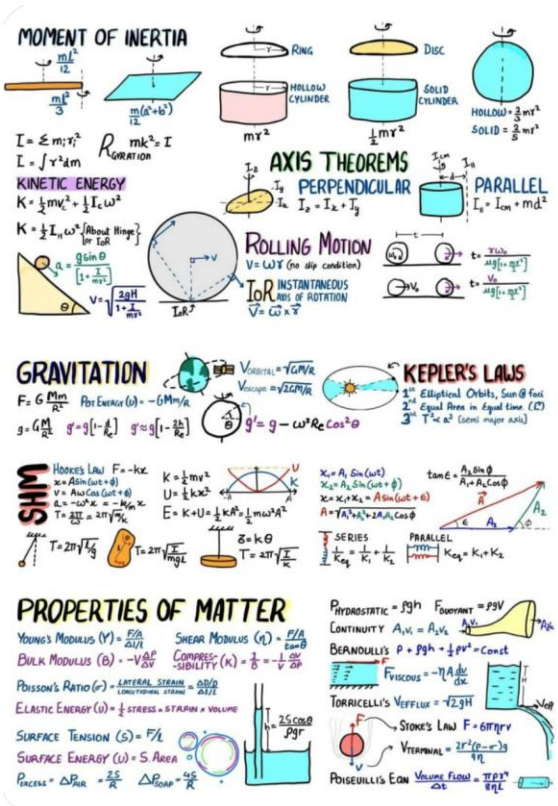


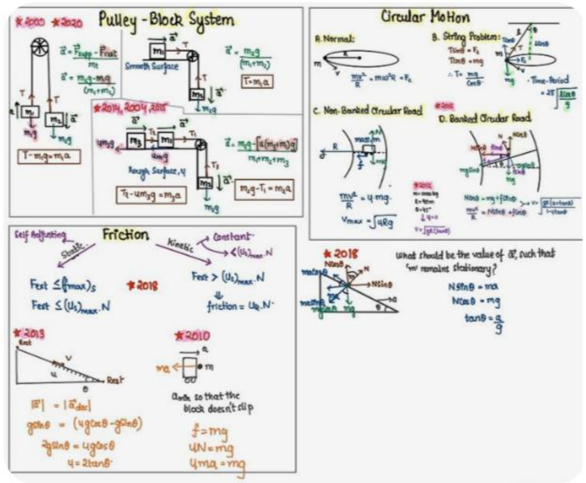
~ LAWS OF MOTION ~
yay forces!!!
NEWTON'S LAWS
First Law: an object in motion will stay in motion + an object at rest will stay at rest unless affected by an outside force
Second Law: ΣF = ma , no acc without a net force
Third Law: there are always two forces equal in magnitude + opp. in direction
Fcosθ
F
Fsinθ
forces can be broken into components
GRAVITATIONAL FORCE
force the earth exerts on an object
ΣF = mg = ma so a = g
mg
F12 = F21
Newton's Third Law
NORMAL FORCE
force acting ⊥ on an object on a flat surface
FN = mg so ΣF = 0 + a = 0
FN
mg
T1cosθ1 = T2cosθ2
T1sinθ1 + T2sinθ2 = mg
TENSION FORCE
a rope exerts a force on an object away from it + parallel to the rope
ΣF = FT
Atwood Machine!
m2g - m1g = (m1 + m2)a
T1 = T2
FRICTION FORCE
Static: amt of force to get an object moving
Kinetic: acts on an object in motion
|fk| = μ|FN|
start mvt
constant F
fs matched Fapp, no mvt
mgsinθ - f - m2g = (m1 + m2)a
f = μmgcosθ
RESISTIVE FORCE
FT = -kv
FT = -kv²
air resistance (drag)
TERMINAL VELOCITY
Fr increases
ΣF decreases
acc decreases
Fr = mg
bv² = mg
v = √(mg/b)
derivation
Vt
t
MISTAKES
Fnet in elevator problems
forgetting forces
friction is confusing sometimes
FRQ & LAB ?s
force diagrams
modified atwood machines / lab
deriving expressions for things like μ, a, Tmax, Tmin, F, m, etc
calculating forces
elevator problems / lab
kinematics with F=ma
motion graphing

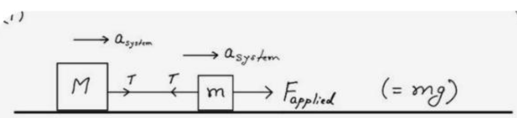


~ CIRCULAR MOTION ~
spinny spin stuff
UNIFORM C.M.
def: moves with constant speed and changing velocity
why? direction, not magnitude changes
EQUATIONS
Centripetal acceleration: ac = v²/r or ac = rω²
Frequency: 1/T
Period: T = 2πr/v or v = 2πr/T
Angular Speed: ω = 2π/T or ω = v/r
ACCELERATION
Tangential: linear (Δv/t)
Centripetal: circular (v²/r)
add vectors to get overall acceleration
CENTRIPETAL FORCE
ΣF = ma → Fc = mv²/r
Uniform:
Fc + ac go to middle of the circle
v is ⊥ to ac
CONICAL PENDELUM
FT
FTsinθ
FTcosθ
mg
h
θ
L
r
m
FT = mg/cosθ
ac = gtanθ
r = Lsinθ
VERTICAL UNIFORM
Top: mg - FN = mv²/r
Bottom: FN - mg = mv²/r
BANKED CURVES
reduces the risk of skidding by lessening the need for friction
FNcosθ
FN
FNsinθ
mg
Fc = FNsinθ
FN = mg/cosθ
VERTICAL NONUNIFORM
Top: mg = mv²/r
Bottom: FT - mg = mv²/r
CENTRIFUGAL FORCE
FTcosθ
FTsinθ
Fc = FTsinθ
FT = mg/cosθ
tanθ = a/g
FRQ & LAB ?s
conical pendelum (pig lab)
objects on spinning surface
a little projectile motion
vertical circles
banked/unbanked curves
swinging a chord
MISTAKES
banked curves are hard
figuring out what is even happening
breaking the correct force into components


PHYSICAL CONSTANTS
LAWS OF MOTION
PSEUDO FORCE
VERTICAL CIRCULAR MOTION
CURVED BANKING
WORK, POWER & ENERGY
CENTER OF MASS
VECTORS
COLLISION
KINEMATICS
RELATIVE VELOCITY
PROJECTILE MOTION
RIGID BODY DYNAMICS
GALVANOMETER
CAPACITOR
MAGNETISM
MAGNETIC DIPOLE
HALL EFFECT
PELTIER EFFECT
THOMSON EFFECT
SEEBACK EFFECT
BIOT-SAVART LAW
BAR MAGNET
ELECTROMGNETIC INDUCTION
SELF INDUCTANCE
ALTERNATING CURRENT
RC-CIRCUIT
LR-CIRCUIT
LCR-CIRCUIT
REACTANCE
MODERN PHYSICS
NUCLEUS
RADIOACTIVE DECAY
BOHR'S ATOM
SEMICONDUCTORS
LOGIC GATES
NOW, YOU'RE ONE STEP CLOSER TO YOUR GOAL
HEAT AND TEMP
KINETIC THEORY
SPECIFIC HEAT
THERMODYNAMICS
HEAT TRANSFER
ELECTROSTATICS
GAUSS'S LAW
CAPACITORS
CURRENT ELECTRICITY
KIRCHHOF'S LAWS
BALANCED WHEAT STONE BRIDGE
WAVES
STANDING WAVES
SOUND WAVES
STANDING LONGITUDINAL WAVES
DOPPLER
LIGHT WAVES
YOUNG'S DOUBLE SLIT EXPERIMENT
LAW OF MALUS
INTERFERENCE THROUGH THIN FILM
OPTICS
REFRACTION
PRISM
SPHERICAL SURFACE
MICROSCOPE
TELESCOPE
DISPERSION
PHYSICS

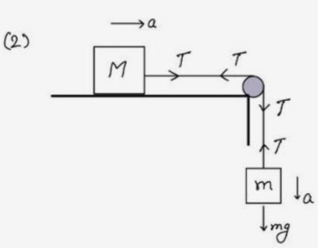






$$a_M = a_m = a_{system} = \frac{F}{M+m} = \boxed{\frac{m}{M+m}g}$$

(2)



$T = Ma$

$mg - T = ma$

$\Rightarrow mg = (M+m)$ $($

$\Rightarrow a = \boxed{\frac{m}{M+m}g}$

- If we treat the masses as a system:

$mg = (M+m)a_{system}$

$\Rightarrow a_{system} = \boxed{\frac{m}{M+m}g}$

WWW.GLOBALASSIGNMENTHELP.COM

LAWS OF MOTION

FIRST LAW:

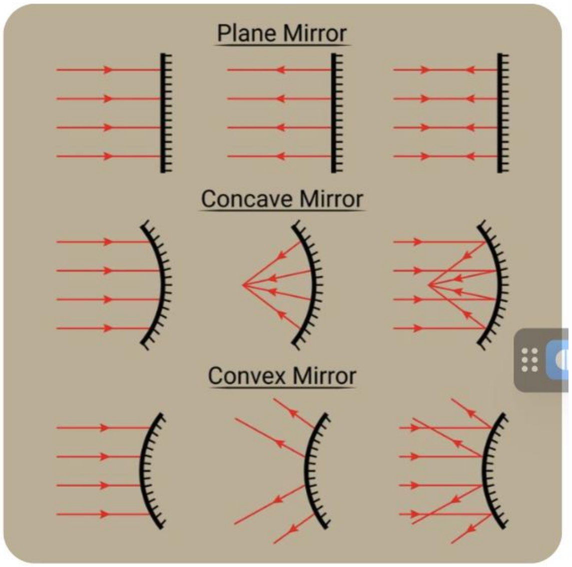
In an inertial reference frame, an object either remains at rest or continues to move in a straight line at a constant velocity, unless acted upon by a net force.

SECOND LAW:

In an inertial reference frame, the vector sum of the forces F on an object is equal to the mass m of that object multiplied by the acceleration a of the object: F = ma.
If the resultant force F acting on a body or an object is not equal to zero, the body will have an acceleration a which is in the same direction as the resultant force.

THIRD LAW:

When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body.



Nepal Science

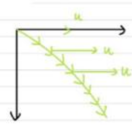
Physical Constants

@nepalsciencemagazine

1. Speed of light $c = 3\times10^{8}$ m/s
2. Plank Constant $h = 6.63\times10^{-34}$ J.s $hc = 1242$ eV-nm
3. Gravitation Constant $G = 6.67\times10^{-11}$ Nm²/kg²
4. Boltzmann Constant $k = 1.38\times10^{-23}$ J/k
5. Molar gas Constant $R = 8.314$ J/mol.k
6. Avogadro's number $N_A = 6.023\times10^{23}$ mol^{-1}
7. Charge of electron $e = 1.602\times10^{-19}$ C
8. Permeability of vacuum $\mu_0 = 4\pi\times10^{-7}$ N/A^2
9. Permittivity of vacuum $\varepsilon_0 = 8.85\times10^{-12}$ F/m
10. Coulomb Constant $1/4\pi\varepsilon_0 = 9\times10^{9}$ Nm^2/C^2
11. Faraday Constant $F = 96485$ C/mol
12. Mass of electron $m_e = 9.1\times10^{-31}$ Kg
13. Mass of proton $m_p = 1.67\times10^{-27}$ Kg
14. Mass of neutron $m_n = 1.67\times10^{-27}$ Kg
15. Atomic mass unit $u = 1.66\times10^{-27}$ Kg
16. Atomic mass unit $u = 931.49$ MeV/c^2
17. Stefan-Boltzmann Constant $\sigma = 5.67\times10^{-8}$ W/(m^{2}k^4)
18. Rydberg Constant $R\infty = 1.097\times10^{7}$ m^{-1}
19. Bohr magneton $\mu_B = 9.27 \times 10-24$ J/T
20. Bohr radius $a_0 = 5.29\times10^{-11}$ m
21. Standard atmosphere atm $= 1.01325\times10^{5}$ Pa
22. Wien displacement Constant $b = 2.9\times10^{-3}$ mK

Projectile Motion

- Projectiles move in a curved path towards the ground.
- Initially fired with a horizontal velocity u.



No horizontal component to acceleration ∴ remains constant.

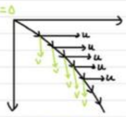
- No vertical component to its velocity.
- Projectile only feels a vertical acceleration due to gravity

Value u always remains the same

g — gravitional acceleration

- Initial velocity in the vertical direction is zero. $v=0$
- Projectile will accelerate vertically so vertical velocity increases according to free fall.

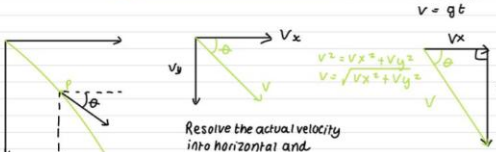
horizontal Displacement = $S_x = ut$



- change in vertical velocity that causes the projectile to curve downwards.

Actual velocity of the projectile

$v = gt$
$v = u + at$
$v = 0 + at$
$v = gt$

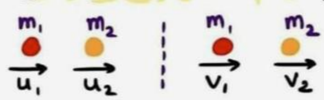


Resolve the actual velocity into horizontal and vertical components.

$v^2 = v_x^2 + v_y^2$
$v = \sqrt{v_x^2 + v_y^2}$

Actual velocity is given by Pythagoras' Theorem

COLLISION

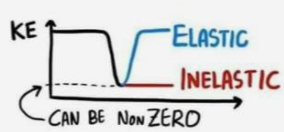


MOMENTUM CONSERVATION {Always}

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

ENERGY CONSERVATION {Elastic}

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$



$$C_oR = e = \frac{V_{SEPARATION}}{V_{APPROACH}} = \frac{V_2 - V_1}{U_1 - U_2}$$

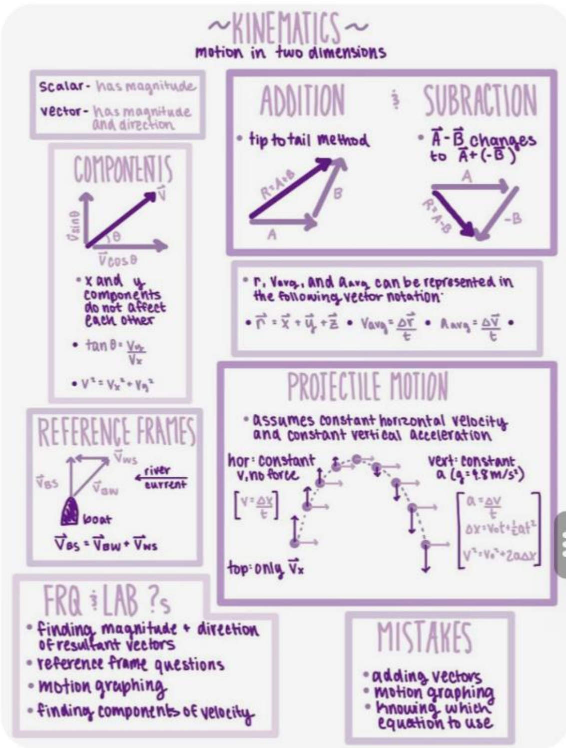
$m_1 >> m_2$

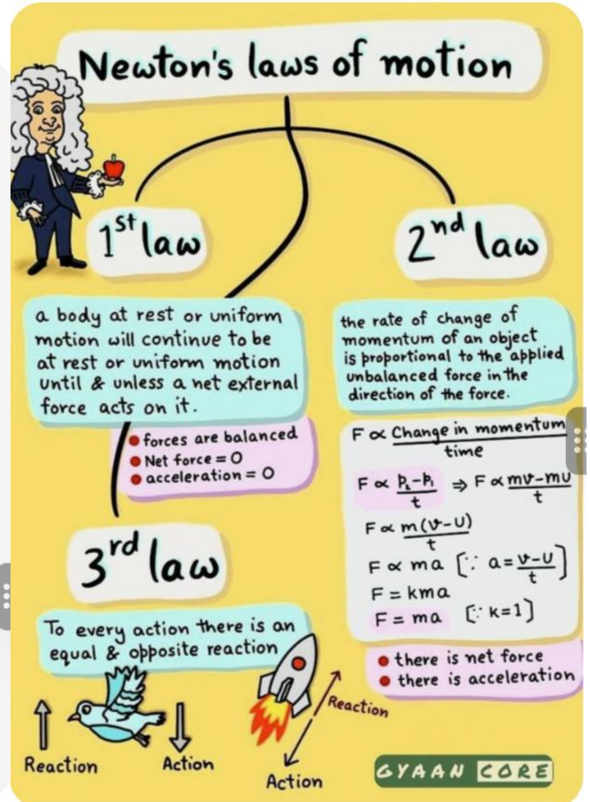
$m_1 \rightarrow$ undisturbed motion

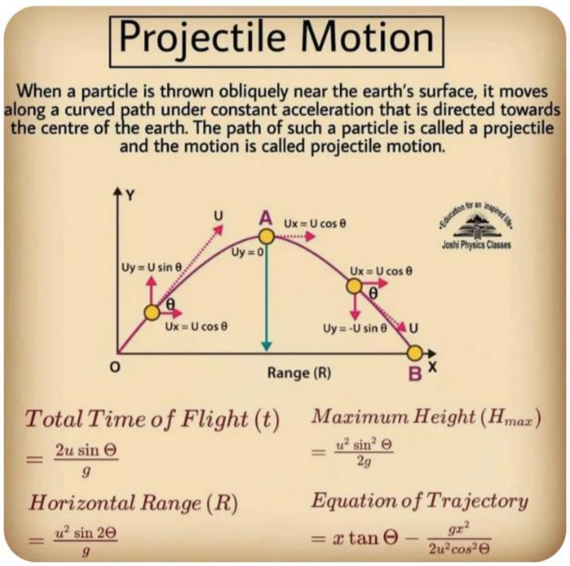
Solve using CoR in m_1 Frame

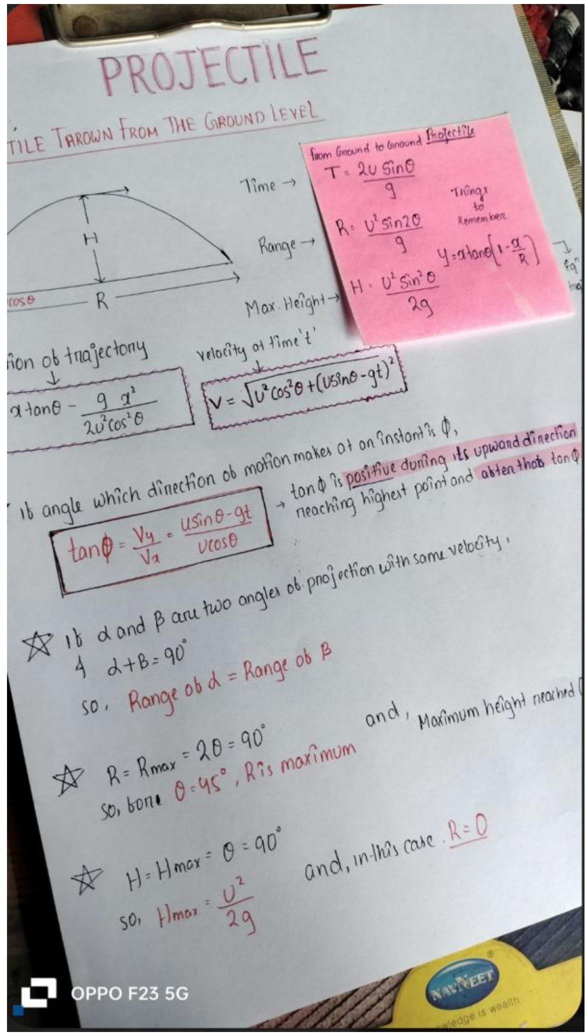
$m_1 = m_2$

Velocity Exchange for Elastic


~KINEMATICS~
motion in two dimensions
scalar- has magnitude
vector- has magnitude and direction
COMPONENTS
x and y components do not affect each other
ADDITION
tip to tail method
SUBRACTION
A-B changes to A+(-B)
r, Vavg, and Aavg can be represented in the following vector notation
REFERENCE FRAMES
river current
boat
PROJECTILE MOTION
assumes constant horizontal velocity and constant vertical acceleration
hor: constant v, no force
vert: constant a (g=9.8m/s²)
top: only Vx
FRQ & LAB ?s
finding magnitude + direction of resultant vectors
reference frame questions
motion graphing
finding components of velocity
MISTAKES
adding vectors
motion graphing
knowing which equation to use


Newton's laws of motion
1st law
2nd law
a body at rest or uniform motion will continue to be at rest or uniform motion until & unless a net external force acts on it.
forces are balanced
Net force = 0
acceleration = 0
the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of the force.
F ∝ Change in momentum / time
F = kma
F = ma
there is net force
there is acceleration
3rd law
To every action there is an equal & opposite reaction
Reaction
Action
Reaction
Action
GYAAN CORE


Projectile Motion
When a particle is thrown obliquely near the earth's surface, it moves along a curved path under constant acceleration that is directed towards the centre of the earth. The path of such a particle is called a projectile and the motion is called projectile motion.
Y
U
A
Ux = U cos θ
Uy = 0
Uy = U sin θ
θ
Ux = U cos θ
Ux = U cos θ
θ
Uy = -U sin θ
U
O
Range (R)
B
X
Joshi Physics Classes
Total Time of Flight $(t) = \frac{2u \sin \Theta}{g}$
Maximum Height $(H_{max}) = \frac{u^2 \sin^2 \Theta}{2g}$
Horizontal Range $(R) = \frac{u^2 \sin 2\Theta}{g}$
Equation of Trajectory $= x \tan \Theta - \frac{gx^2}{2u^2 \cos^2 \Theta}$


PROJECTILE
TILE THROWN FROM THE GROUND LEVEL
From Ground to Ground Projectile
$T = \frac{2u \sin\theta}{g}$
Things to Remember
$R = \frac{u^2 \sin 2\theta}{g}$
$y = x\tan\theta\left[1 - \frac{x}{R}\right]$
$H = \frac{u^2 \sin^2\theta}{2g}$
Time →
Range →
Max. Height →
H
R
ion of trajectory
$x\tan\theta - \frac{g x^2}{2u^2\cos^2\theta}$
Velocity at time 't'
$V = \sqrt{u^2\cos^2\theta + (u\sin\theta - gt)^2}$
If angle which direction of motion makes at an instant is ϕ,
$\tan\phi = \frac{V_y}{V_x} = \frac{u\sin\theta - gt}{u\cos\theta}$
→ $\tan\phi$ is positive during its upward direction reaching highest point and after that $\tan\phi$
If α and β are two angles of projection with same velocity,
& $\alpha + \beta = 90°$
so, Range of α = Range of β
and, Maximum height reached
$R = R_{max} = 2\theta = 90°$
so, for $\theta = 45°$, R is maximum
$H = H_{max} = \theta = 90°$
and, in this case $R = 0$
so, $H_{max} = \frac{U^2}{2g}$
OPPO F23 5G
NAVNEET

CIRCULAR MOTION

KINEMATICS OF CIRCULAR MOTION

- Angular disp (θ): θ is an axial vector. It is dimensionless & SI unit : radian
- Relation b/w S & θ

  $S = R\theta$
- Angular velocity (ω)

  $\frac{\text{ang disp}}{\text{time}} = \frac{\theta}{t} = \omega$

  → Avg angular velo. $= \frac{\theta_2 - \theta_1}{t_2 - t_1}$

  → Inst. angular velo $= \frac{d\theta}{dt} = \frac{\Delta\theta}{\Delta t}$

  > angular velo. is also an axial vector

  ↳ unit : radian/sec

  > $\omega = \frac{2\pi}{T} = 2\pi f$
- Relation b/w V & ω

  $V = R\omega \Rightarrow V_\perp = R\omega$

  $\vec{V} = \vec{R} \times \vec{\omega} \Rightarrow \boxed{|\vec{V}| = |R||\omega| \sin 90^\circ}$
- Angular acceleration (α)

  $= \frac{\text{change in angular velo.}}{\text{time}}$

  $\alpha = \frac{\omega_2 - \omega_1}{t_2 - t_1} = \frac{\Delta\omega}{\Delta t}$

  → Inst. $\alpha = \frac{d\omega}{dt}$

  → $\boxed{\omega = \int \alpha\, dt}$
- Some important formulae :

  > $\omega = \omega_0 + \alpha t$

  > $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

  > $2\alpha\theta = \omega^2 - \omega_0^2$

  > $\theta = \left(\frac{\omega + \omega_0}{2}\right) \times t$

  > $\omega_0 + \frac{\alpha}{2}(2t - 1) = \theta^{nth}$

  > $\boxed{\text{no. of rev} = \frac{\text{angular disp}}{2\pi}}$

- centripetal acceleration

  $a_c = \frac{v^2}{R} \Rightarrow a_c = R\omega^2$

  $a_c = v\omega \Rightarrow \vec{a_c} = \vec{\omega} \times \vec{v}$

  ↳ a_c is always present.

  ↳ a_c comes due to change in directⁿ of v.

  ↳ a_c is never const.

  ↳ a_c also known as a_r or a_n.
- Trangential acceleration

  $a_T = \frac{d|v|}{dt}$, $a_T = R\alpha$

  $a_{net} = \sqrt{a_T^2 + a_c^2}$ $\boxed{\tan\alpha = \frac{a_c}{a_T}}$

  ↳ a_T comes from change in magnitude of vel

  ↳ a_T is present only in non-uniform circular

  ↳ " jb velo. ka magnitude change hoga tbhi '$\vec{\omega}$', 'α', 'a_T' aayega.

  > $\boxed{a_c = 4\pi^2 n^2 r} \Rightarrow \boxed{\frac{4\pi^2}{T^2} r}$

  > $\boxed{F_c = \frac{mv^2}{r} = mr\omega^2 = m4\pi^2 n^2 r}$ $\boxed{= \frac{m4\pi^2 r}{T^2}}$

DYNAMICS OF CIRCULAR MOTION

$\boxed{F_c = ma_c}$

$\boxed{F_c = \frac{mv^2}{r}} \Rightarrow \boxed{F_c = mr\omega^2}$ $\boxed{F_c = mv\omega}$

↳ work done by F_c is always zero & change in KE is always zero

↳ But speed can change if $F_{Trangential}$ is present.

↳ Centripetal force is not a new force. Any force which acts towards the centre is $\vec{F_c}$.

- conical Pendulum

  > $\tan\theta = \frac{v^2}{rg}$ > $T = 2\pi\sqrt{\frac{h}{g}}$ > $h = \frac{v^2}{g}$

  > $v = \sqrt{rg\tan\theta}$ > $T = 2\pi\sqrt{\frac{l^2 - r^2}{g}}$

  > $T = 2\pi\sqrt{\frac{l\cos\theta}{g}}$ > $T = 2\pi\sqrt{\frac{r}{g\tan\theta}}$

Gravitation

ature of Gravity

The gravitational field around every object is because of its mass. Hence, there exists a gravitational field around every object (both microscopic or macroscopic) ranging from elementary particles such as electrons to huge planets and stars.

★ **Newton's Universal law of gravitation**

→ Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and is inversely proportional to the square of distance between them and this force acts along the line joining these two particles.

→ $F \propto m_1 m_2$ $\Rightarrow F \propto \frac{m_1 m_2}{r_2}$ $\therefore \boxed{F = G\frac{m_1 m_2}{r^2}}$ → Gravitational force

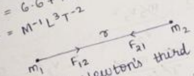
$F \propto \frac{1}{r^2}$

→ G = Universal gravitational constant.

$= 6.67 \times 10^{-8}$ dyne $\frac{cm^2}{gm^2}$ — C.G.S unit

D.F $= M^{-1}L^3T^{-2}$

$\vec{F_{12}} = -\vec{F_{21}}$



→ They obey Newton's third law - Action & Reaction

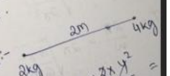
- $\vec{F_{21}} = \frac{Gm_1m_2}{r_2}\hat{r}_{21}$

  $= \frac{Gm_1m_2}{r_3}\hat{r}_{21}$
- $\vec{F_{12}} = \frac{Gm_1m_2}{r^2}\hat{r}_{12}$

  $= \frac{Gm_1m_2}{r^3}\hat{r}_{12}$

→ G = Numerically equal to gravitational forces between unit masses separately by 1m.

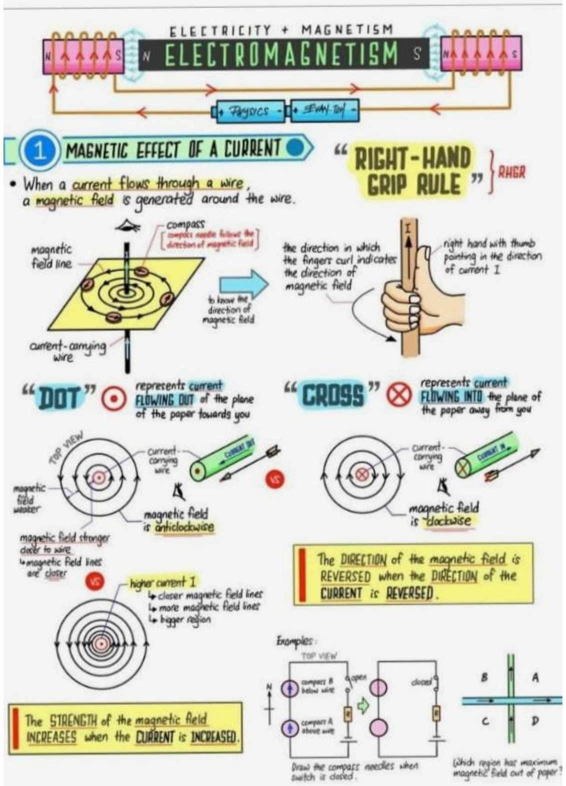
Ex:-



$F = G \times \frac{2 \times 4^2}{2^2} =$

→ **Properties**

- $F \propto m_1 m_2$
- $F \propto \frac{1}{r^2}$
- Obeys Newton's 3rd law.



work, energy AND power

work : is said to be done when a body undergoes displacement.

↳ scalor $\qquad W = FS\cos\theta = \vec{F}\cdot\vec{S}$

↳ dimension: ML^2T^{-2}

↳ SI unit : Joule → 1J = 1 N-m

↳ CGS unit : erg → 1erg = 1 dyne × 1cm

$1J = 10^7$ dyne cm

$1J = 10^7$ erg

$1erg = 10^{-7} J$ = 1 dyne × cm

- If body displace along the direction of force
  $W = F\cdot S$
- $W = \vec{F}\cdot\vec{S} = F_x S_x + F_y S_y + F_z S_z$
- $W = F_x(x_2 - x_1) + F_y(y_2 - y_1) + F_z(z_2 - z_1)$

Nature of work

I) Positive work : Force is parallel to disp
$0° \le \theta \le 90°$

II) Negative work: Force oppo. to disp
$90° \le \theta \le 180°$

III) zero work
- Force ⊥ disp ($\theta = 90°$)
- no disp ($S = 0$)
- net force zero ($F = 0$)

- **Work done by constant force**
  ↳ $W = \vec{F}\cdot\vec{S}$
  ↳ graph: straight line
- **work done by variable force**
  ↳ $W = \int_{x_1}^{x_2} F_x\cdot dx + \int_{y_1}^{y_2} F_y\cdot dy + \int_{z_1}^{z_2} F_z\cdot dz$
- **Graph of work done**
  ↳ area under F-S curve
  ↳ may be -ve or +ve

conservative force	Non-conservative force
• do not depend on path	• depend on path
• only depend on initial & final point.	• work done in round tip is not zero ↳ eg: Friction.
• Round tip is zero. ↳ eg: gravitational F.	• Forces which are velocity dependent.
• All central forces	
• KE & PE can change but ME doesn't change	• work done may be dissipated as heat energy
• work done in closed path is zero.	• work done in closed path is not zero
• Ex: Elastic, Restoring, spring force, etc.	• Ex: viscous Force, air resistance

central force
↳ All forces following inverse square law
↳ All central force → conservative forces
↳ Ex: $\vec{F} = \frac{K}{r^2}\hat{r}$ (Gravitational, Coloumb force)

Kinetic Energy → depends on frame of reference
↳ can never be negative. ↳ scalor

$KE \propto M$, $KE = \frac{1}{2}Mv^2$

$KE \propto \frac{1}{M}$, $KE = \frac{P^2}{2M}$ $\quad (P = M \times V)$

Extra : $\boxed{\frac{K_{bullet}}{K_{gun}} = \frac{M_{gun}}{M_{bullet}}}$ where, K → kinetic E. M → momentum

Examples for bodies having KE :
- A vehicle in motion.
- Water flowing along a river.
- A bullet fired from a gun.

Work-Energy Theorem
- Work done by all the forces acting on a body is equal to change in its K.E.

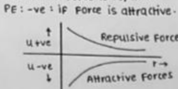
$W = \Delta K$

↳ scalor form of Newton's 2^{nd} law
↳ applicable for a single particle also for a system.
↳ $W_{net} = KE_f - KE_i = \frac{1}{2}m(v_f^2 - v_i^2)$

Potential Energy
- stored energy by virtue of position/configuraⁿ of body
- only defined for conservative forces.

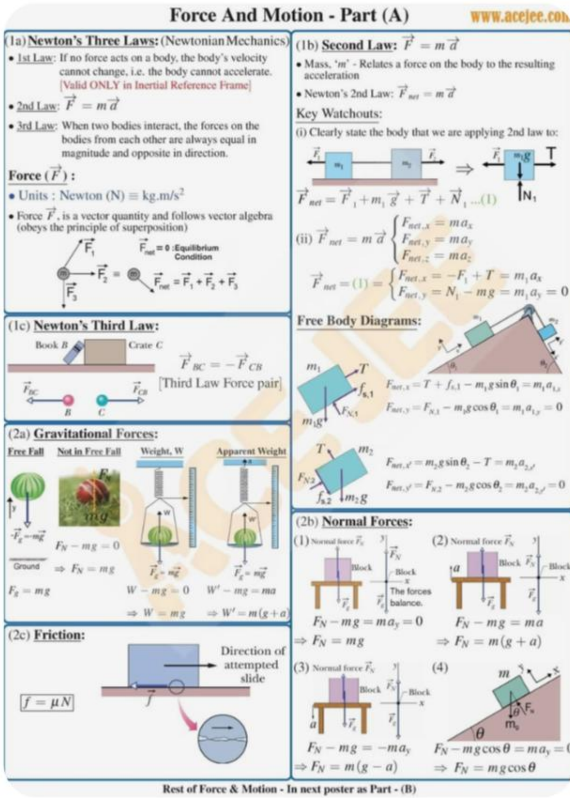
$\Delta U = -W_c$

- may be +ve or -ve or zero
- PE : +ve : if force is repulsive
  PE : -ve : if force is attractive.

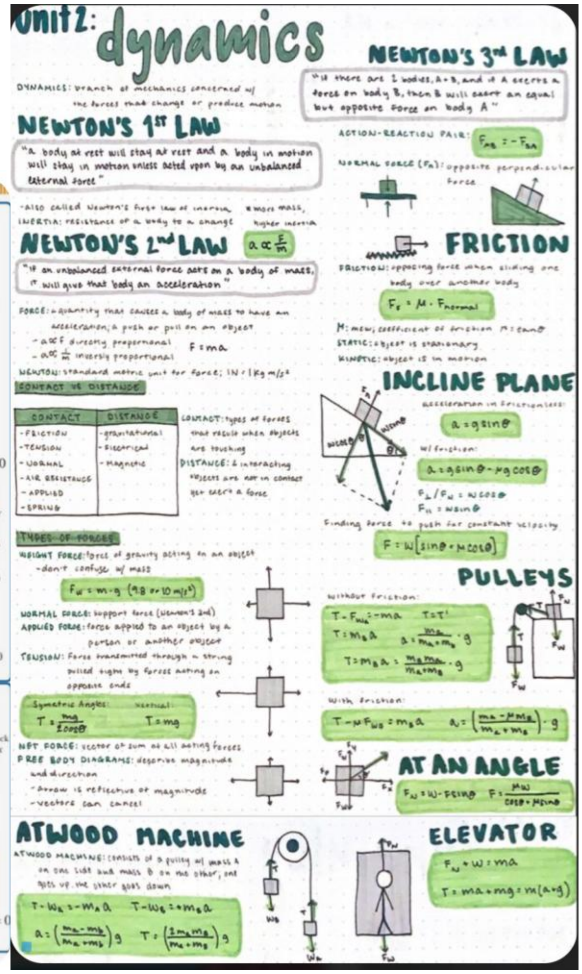


r: seperaⁿ b/w body & force centre.

↳ r↑, U↑ : Force → attractive
↳ r↑, U↓ : Force → repulsive
↳ PE↑ : work done is against conservative F.
↳ PE↓ : work is done by conservative forces.



Force And Motion - Part (A)
www.acejee.com
(1a) Newton's Three Laws: (Newtonian Mechanics)
1st Law: If no force acts on a body, the body's velocity cannot change, i.e. the body cannot accelerate.
[Valid ONLY in Inertial Reference Frame]
2nd Law: $\vec{F} = m\vec{a}$
3rd Law: When two bodies interact, the forces on the bodies from each other are always equal in magnitude and opposite in direction.
Force ($\vec{F}$):
Units : Newton (N) ≡ kg.m/s²
Force $\vec{F}$, is a vector quantity and follows vector algebra (obeys the principle of superposition)
$\vec{F}_{net} = 0$: Equilibrium Condition
$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$
(1b) Second Law: $\vec{F} = m\vec{a}$
Mass, 'm' - Relates a force on the body to the resulting acceleration
Newton's 2nd Law: $\vec{F}_{net} = m\vec{a}$
Key Watchouts:
(i) Clearly state the body that we are applying 2nd law to:
$\vec{F}_{net} = \vec{F}_1 + m_1\vec{g} + \vec{T} + \vec{N}_1$ ...(1)
(ii) $\vec{F}_{net} = m\vec{a}$ $F_{net,x} = ma_x$ $F_{net,y} = ma_y$ $F_{net,z} = ma_z$
$\vec{F}_{net} = (1)$ $F_{net,x} = -F_1 + T = m_1a_x$ $F_{net,y} = N_1 - mg = m_1a_y = 0$
Free Body Diagrams:
$F_{net,x} = T + f_{k,1} - m_1 g\sin\theta_1 = m_1 a_{1,x}$
$F_{net,y} = F_{N,1} - m_1 g\cos\theta_1 = m_1 a_{1,y} = 0$
$F_{net,x'} = m_2 g\sin\theta_2 - T = m_2 a_{2,x'}$
$F_{net,y'} = F_{N,2} - m_2 g\cos\theta_2 = m_2 a_{2,y'} = 0$
(1c) Newton's Third Law:
Book B
Crate C
$\vec{F}_{BC} = -\vec{F}_{CB}$
[Third Law Force pair]
(2a) Gravitational Forces:
Free Fall
Not in Free Fall
Weight, W
Apparent Weight
$F_N - mg = 0$
$\Rightarrow F_N = mg$
$F_g = mg$
$W - mg = 0$
$\Rightarrow W = mg$
$W' - mg = ma$
$\Rightarrow W' = m(g+a)$
(2b) Normal Forces:
(1) Normal force $\vec{F}_N$
Block
The forces balance.
$F_N - mg = ma_y = 0$
$\Rightarrow F_N = mg$
(2) Normal force $\vec{F}_N$
$F_N - mg = ma$
$\Rightarrow F_N = m(g+a)$
(3) Normal force $\vec{F}_N$
$F_N - mg = -ma_y$
$\Rightarrow F_N = m(g-a)$
(4)
$F_N - mg\cos\theta = ma_y = 0$
$\Rightarrow F_N = mg\cos\theta$
(2c) Friction:
Direction of attempted slide
$f = \mu N$
Rest of Force & Motion - In next poster as Part - (B)

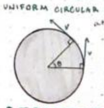


Unit 2: dynamics
DYNAMICS: branch of mechanics concerned w/ the forces that change or produce motion
NEWTON'S 1st LAW
"a body at rest will stay at rest and a body in motion will stay in motion unless acted upon by an unbalanced external force"
NEWTON'S 2nd LAW
"if an unbalanced external force acts on a body of mass, it will give that body an acceleration"
F = ma
CONTACT VS DISTANCE
TYPES OF FORCES
NEWTON'S 3rd LAW
"if there are 2 bodies, A + B, and if A exerts a force on body B, then B will exert an equal but opposite force on body A"
FRICTION
$F_f = \mu \cdot F_{normal}$
INCLINE PLANE
a = g sinθ
a = g sinθ − μg cosθ
F = W[sinθ + μcosθ]
PULLEYS
AT AN ANGLE
ATWOOD MACHINE
ELEVATOR
$F_N + W = ma$

Unit 3: circular motion

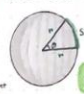
UNIFORM

UNIFORM CIRCULAR MOTION: motion in a circle at a constant speed



- velocity is always tangent to the circle; at any given moment the tangent specifies the direction of motion
- it is an accelerated motion

RADIANS



RADIAN(rad): ratio of the arc length it transverses to the radius of the circle

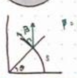
$\theta = \frac{s}{r} = \frac{\text{Arc length}}{\text{radius}}$ $s = r\theta$

- one rotation around the circle is $2\pi r$ or $360°$; $1 \text{ rad} = 57.296°$ $1 \text{ degree} = 0.01745$ rad

CENTRIPETAL ACCEL.

- vector a_c points in the same direction as acceleration vector; must point towards center

CENTRIPETAL: center seeking



$s = vt$ $r\theta = vt$ $\theta = \frac{vt}{r}$ $a_c = r\omega^2$

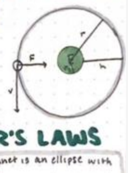
$a_c = \frac{v^2}{r}$ or $a_c = \frac{4\pi^2 r}{t^2}$

SATELLITE MOTION

$v = \sqrt{\frac{G \cdot m}{r}}$

radius E: 6.4×10^6

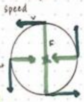
Mass E: 5.98×10^{24}



CENTRIPETAL FORCE

CENTRIPETAL FORCE: Force that causes an object to move in a circle at a constant speed

- always points toward the center of the circle
- If there were no centripetal force, the object would continue at the same constant velocity in a direction tangent to the circle



$F_c = ma_c$ $F_c = \frac{mv^2}{r}$ $F_c = \frac{m 4\pi^2 r}{t^2}$

KEPLER'S LAWS

1. the orbit of each planet is an ellipse with the sun at one focus
2. the speed of the planet varies in such a way that the line joining the planet and the sun sweeps out equal areas in equal times
3. the cube of semimajor axes of the elliptical orbit is proportional to the square of the time for the planet to make a complete revolution about the sun

LAW OF GRAVITATION

"between every 2 masses in the universe, there is a force of attraction between them that is directly proportional to the product of their masses and inversely proportional to the square of the distance separating them" - Newton

$F = \frac{G \cdot m_1 \cdot m_2}{r^2}$ $G = 6.67 \times 10^{-11} \frac{Nm^2}{Kg^2}$

EQUATIONS

Time: $T = \sqrt{\frac{4\pi^2 r^3}{G \cdot M_E}}$ $T = \frac{2\pi r}{v}$

Velocity: $v = \frac{2\pi r}{t}$ $v = \sqrt{\frac{G \cdot m}{r}}$

$PE = -G\frac{M_E m}{r}$

ACCELERATION

$g = \frac{Gm}{r^2}$

- equation can work for any planet

TORQUE + ROTATIONAL Eq

(C) LEAH4SCI.COM/MCAT ← VIDEOS + MORE

Comparison of linear + Angular Components

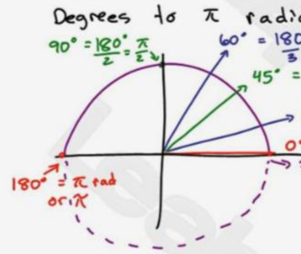
	Displacement	velocity	acceleration
Linear unit	x	v_i, v_f	a
Angular Unit	θ theta	ω omega	α alpha

Linear Equation	Angular version
$x_f = x_i + vt$	$\theta_2 = \theta_1 + \omega t$
$v_f = v_i + at$	$\omega_f = \omega_i + \alpha t$
$v_f^2 = v_i^2 + 2a\Delta x$	$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$
$\Delta x = v_i t + \frac{1}{2}at^2$	$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$

Converting linear to angular

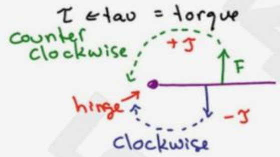
$\theta = \frac{s}{r}$ ← arc length $\omega = \frac{v}{r} = \frac{\theta}{t}$ $\alpha = \frac{a}{r} = \frac{\omega}{t}$

Degrees to π radians



$\tau = rF\sin\theta$
$= rF$ perpendicular
$= F\ell$ ← lever arm
$= I\alpha$
$= \Delta L / \Delta t$

τ ← tau = torque



Rotational Equilibrium

$\Sigma\tau = 0$

$\Sigma F = 0$ $\Sigma F_x = 0$ $\Sigma F_y = 0$

MCAT Tutorial Videos +... LEAH4SCI.COM/MCAT

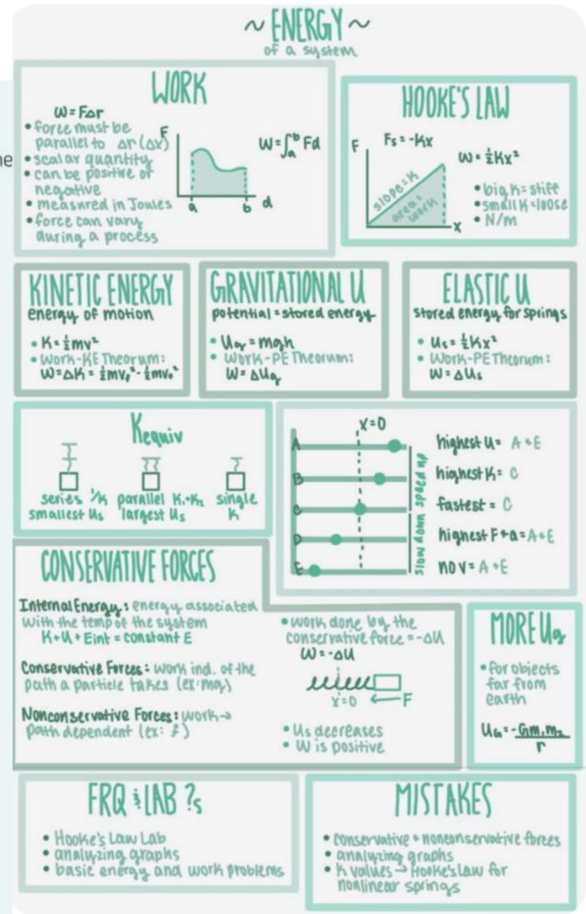
Questions/comments: LEAH4SCI.COM/contact

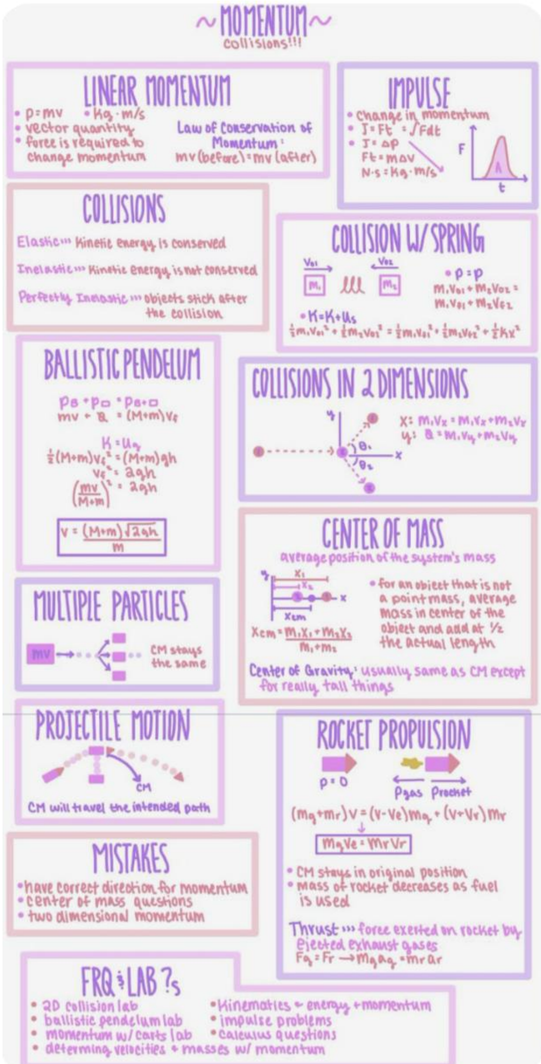
Nepal Sciece

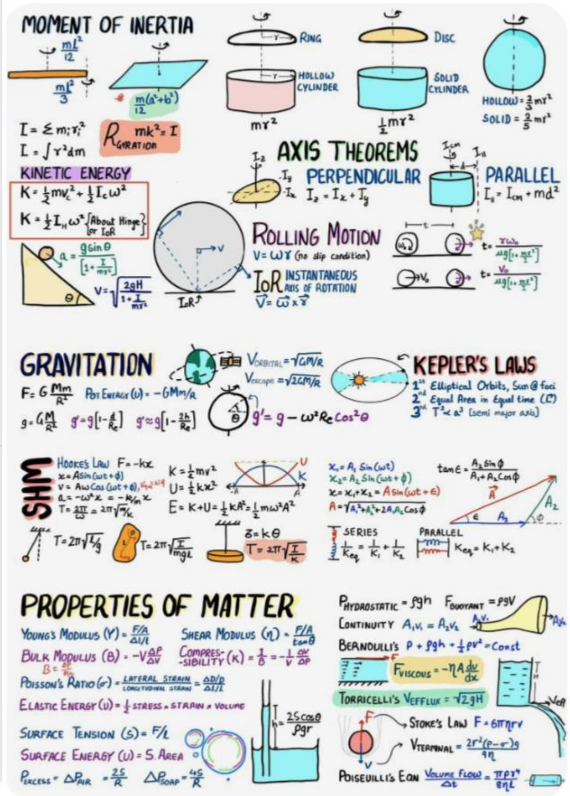
Physical Constants

@nepalsciencemagazine

1. Speed of light $c = 3\times10^{8}$ m/s
2. Plank Constant $h = 6.63\times10^{-34}$ J.s $hc = 1242$ eV-nm
3. Gravitation Constant $G = 6.67\times10^{-11}\,Nm^2/kg^2$
4. Boltzmann Constant $k = 1.38\times10^{-23}$ J/k
5. Molar gas Constant $R = 8.314$ J/mol.k
6. Avogadro's number $N_A = 6.023\times10^{23}\,mol^{-1}$
7. Charge of electron $e = 1.602\times10^{-19}$ C
8. Permeability of vacuum $\mu_0 = 4\pi\times10^{-7}\,N/A^2$
9. Permittivity of vacuum $\varepsilon_0 = 8.85\times10^{-12}$ F/m
10. Coulomb Constant $1/4\pi\varepsilon_0 = 9\times10^{9}\,Nm^2/C^2$
11. Faraday Constant $F = 96485$ C/mol
12. Mass of electron $m_e = 9.1\times10^{-31}$ Kg
13. Mass of proton $m_p = 1.67\times10^{-27}$ Kg
14. Mass of neutron $m_n = 1.67\times10^{-27}$ Kg
15. Atomic mass unit $u = 1.66\times10^{-27}$ Kg
16. Atomic mass unit $u = 931.49\,MeV/c^2$
17. Stefan-Boltzmann Constant $\sigma = 5.67\times10^{-8}\,W/(m^2k^4)$
18. Rydberg Constant $R_\infty = 1.097\times10^{7}\,m^{-1}$
19. Bohr magneton $\mu_B = 9.27 \times 10-24$ J/T
20. Bohr radius $a_o = 5.29\times10^{-11}$ m
21. Standard atmosphere atm $= 1.01325\times10^{5}$ Pa
22. Wien displacement Constant $b = 2.9\times10^{-3}$ mK




~MOMENTUM~
collisions!!!
LINEAR MOMENTUM
• p=mv • kg·m/s
• vector quantity
• force is required to change momentum
Law of Conservation of Momentum:
mv (before) = mv (after)
IMPULSE
• Change in momentum
• J = Ft = ∫Fdt
• J = Δp
Ft = mΔv
N·s = kg·m/s
F
t
COLLISIONS
Elastic → kinetic energy is conserved
Inelastic → kinetic energy is not conserved
Perfectly Inelastic → objects stick after the collision
COLLISION W/ SPRING
• p = p
m₁v₀₁ + m₂v₀₂ = m₁v₀₁ + m₂v₀₂
• K = K + Us
BALLISTIC PENDELUM
mv + 0 = (M+m)vf
K = Ug
½(M+m)vf² = (M+m)gh
vf² = 2gh
v = (M+m)√2gh / m
COLLISIONS IN 2 DIMENSIONS
x: m₁vx = m₁vx + m₂vx
y: 0 = m₁vy + m₂vy
CENTER OF MASS
average position of the system's mass
Xcm = (m₁x₁ + m₂x₂) / (m₁ + m₂)
• for an object that is not a point mass, average mass in center of the object and add at ½ the actual length
Center of Gravity: usually same as CM except for really tall things
MULTIPLE PARTICLES
mv
CM stays the same
PROJECTILE MOTION
CM
CM will travel the intended path
ROCKET PROPULSION
p = 0
Pgas Procket
(mg+mr)v = (v−ve)mg + (v+vr)mr
mgve = mrvr
• CM stays in original position
• mass of rocket decreases as fuel is used
Thrust → force exerted on rocket by ejected exhaust gases
Fg = Fr → mgag = mrar
MISTAKES
• have correct direction for momentum
• center of mass questions
• two dimensional momentum
FRQ & LAB ?s
• 2D collision lab
• ballistic pendelum lab
• momentum w/ carts lab
• determing velocities + masses w/ momentum
• kinematics + energy + momentum
• impulse problems
• calculus questions


MOMENT OF INERTIA
mL²/12
mL²/3
m(a²+b²)/12
RING
HOLLOW CYLINDER
mr²
DISC
SOLID CYLINDER
½mr²
HOLLOW = ⅔mr²
SOLID = ⅖mr²
I = Σ mᵢrᵢ²
I = ∫r²dm
R GYRATION mk² = I
KINETIC ENERGY
K = ½mvc² + ½Icω²
K = ½IHω² {About Hinge or IoR}
a = g sin θ / [1 + I/mr²]
v = √(2gH / (1 + I/mr²))
IoR
AXIS THEOREMS
PERPENDICULAR
Iz = Ix + Iy
PARALLEL
I∥ = Icm + md²
ROLLING MOTION
V = ωr (no slip condition)
IoR INSTANTANEOUS AXIS OF ROTATION
V⃗ = ω⃗ × r⃗
GRAVITATION
F = G Mm/R²
Pot Energy (U) = −GMm/R
g = GM/R²
g' = g[1 − d/Re]
g' ≈ g[1 − 2h/Re]
g' = g − ω²Re cos²θ
VORBITAL = √GM/R
Vescape = √2GM/R
KEPLER'S LAWS
1st Elliptical Orbits, Sun @ foci
2nd Equal Area in Equal time (C)
3rd T² ∝ a³ (semi major axis)
SHM
Hooke's Law F = −kx
x = A sin(ωt+ϕ)
v = Aω cos(ωt+ϕ)
a = −ω²x = −k/m x
T = 2π/ω = 2π√m/k
K = ½mv²
U = ½kx²
E = K+U = ½kA² = ½mω²A²
T = 2π√L/g
T = 2π√I/mgL
τ = kθ
T = 2π√I/k
x₁ = A₁ sin(ωt)
x₂ = A₂ sin(ωt + ϕ)
x = x₁ + x₂ = A sin(ωt + ϵ)
A = √(A₁² + A₂² + 2A₁A₂ cos ϕ)
tan ϵ = A₂ sin ϕ / (A₁ + A₂ cos ϕ)
SERIES
1/Keq = 1/K₁ + 1/K₂
PARALLEL
Keq = K₁ + K₂
PROPERTIES OF MATTER
Young's Modulus (Y) = (F/A)/(Δl/l)
Shear Modulus (η) = (F/A)/tan θ
Bulk Modulus (B) = −V ΔP/ΔV
Compressibility (K) = 1/B = −1/V ΔV/ΔP
Poisson's Ratio (σ) = Lateral Strain / Longitudinal Strain = (ΔD/D)/(Δl/l)
Elastic Energy (U) = ½ stress × strain × volume
Surface Tension (S) = F/l
Surface Energy (U) = S. Area
Pexcess = ΔPAIR = 2S/R
ΔPSOAP = 4S/R
h = 2S cos θ / ρgr
PHYDROSTATIC = ρgh
FBUOYANT = ρgV
Continuity A₁v₁ = A₂v₂
Bernoulli's P + ρgh + ½ρv² = Const
FVISCOUS = −ηA dv/dx
Torricelli's VEFFLUX = √2gH
Stoke's Law F = 6πηrv
VTERMINAL = 2r²(ρ−σ)g / 9η
Poiseuilli's Eqn Volume Flow/Δt = πρr⁴/8ηL

GRAPHS

Important Points -

1) Slope of displacement - time graph gives velocity

As $\boxed{v = \frac{ds}{dt}}$

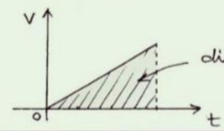
2) Slope of velocity-time graph gives acceleration.

As $\boxed{a = \frac{dv}{dt}}$

3) Area under velocity-time graph gives displacement

As $ds = v\,dt$

$\boxed{s = v \times t}$

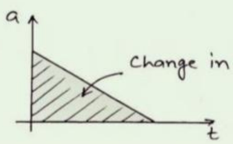


* Distance = Total Area
* Displacement = (+ve Area) − (−ve Area)

4) Area under acceleration-time graph gives change in velocity.

As $dv = a\,dt$

$\boxed{\Delta v = a \times t}$



~ROTATIONAL KINEMATICS~

spinny stuff + torque

TORQUE

- required to make an object rotate
- vector product
- force and torque arm must be ⊥

$\exists \tau = Fr \perp \epsilon$

F, r, $F\sin\theta$ $\boxed{\tau = F\sin\theta r}$

EQUILIBRIUM

- $\Sigma F = 0$
- $\Sigma \tau = 0$
- $I\alpha = 0$

$\tau = \tau$

$m_1 g r = m_2 g r$

$\Sigma \tau = 0$

ROTATIONAL INERTIA

$I = \Sigma mr^2$

- depends on mass distribution and location of axis of rotation
- when mass is spread out, there is a greater I (harder to rotate)

I > I — masses are equal but mass distribution is not

- Calculus: $I = \int r^2 dm$ (dm is found with the linear mass density)
- Parallel Axis Theorum: $I' = I_{cm} + Md^2$
- Point Mass: $I = MR^2$
- Solid Cylinder: $I = \frac{1}{2}MR^2$

ANGULAR RELATIONSHIPS

- $x = R\theta$ • $v = R\omega$ • $a = R\alpha$
- $\omega = \omega_0 + \alpha t$ • $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
- $\omega_f^2 = \omega_0^2 + 2\alpha\theta$
- $\omega = \frac{\Delta\theta}{t} = \frac{d\theta}{dt}$ • $\alpha = \frac{\Delta\omega}{t} = \frac{d\omega}{dt}$

- objects farther from the axis of rotation will move faster
- if ω changes, it has a_{tan}
- there is always a_c

$I = \frac{1}{2}mr^2$

$T_1 = m_1 a$

$T_2 = m_2 g - m_2 a$

$\Sigma\tau = T_2 R - T_1 R = I\alpha$

CONSERVATION OF ENERGY

$K_{translational} = \frac{1}{2}mv^2$ $K_{rotational} = \frac{1}{2}I\omega^2$

$U_g = K_T + K_R$

$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$mgh = \frac{1}{2}mv^2 + \frac{1}{2}mr^2(v^2/r^2)$

$gh = \frac{1}{2}v^2 + \frac{1}{2}v^2$

$v = \sqrt{gh}$

FRQ & LAB ?s

- conservation of energy problems
- pulley problems
- rolling without slipping
- rolling WITH slipping
  - find v and ω
  - find t where rotation starts
- torque lab
- equilibrium problems

MISTAKES

- remembering I
- rolling with slipping
- Knowing how to start a problem

MECHANICS

$[F = m \cdot a]$

$[work = Fd\cos\theta]$

$[power = \frac{work}{time} = F \times V]$

$[Torque = r F \sin\theta]$

F = Force (N)
m = mass (kg)
a = acceleration (m/s²)
l = length (m)
v = velocity (m/s)
t = time (sec)

$acceleration = \frac{\Delta v}{\Delta t}$ $velocity = \frac{\Delta d}{\Delta t}$

$KE = \frac{1}{2}mv^2$

$PE = \frac{1}{2}kx^2$

gravitational = mgh

parallel → $mg\sin\theta$

perpendicular → $mg\cos\theta$

UNITS MAP

Force (N) ← $(m \cdot a) = \frac{kg \cdot m}{s^2}$

Force ÷ m² → pressure (pascal) ← $\frac{F}{A} = \frac{N}{m^2}$

Force × m → Joule (J)

Torque = $rF\sin\theta$ → Joule

Joule → electrical potential (U) → × 2/V → (charge) coulomb (Q)

Joule ÷ S → power (watts) ← $\frac{work}{time} = \frac{J}{S}$

power ÷ m² → intensity (W/m²) ← power/area

coulomb (Q) → volt/m → electric field = V/d

coulomb → Amp · Sec

coulomb → CV → volts (W/A, J/C)

(F) → coulomb/volt: capacitance

volts ÷ R → resistance (Ω) ← volt/amp

current (Amps) → Coulomb/sec; → Q/Δt

OPTICS

$\left[f = \frac{1}{d_o} + \frac{1}{d_i}\right]$

$\left[\frac{h_o}{h_i} = \frac{d_o}{d_i}\right]$

$\left[\text{lens power} = \frac{1}{f}\right]$

(convex) converging — inverted real image — focal length = (+) d_o = (+) d_i = (+)

(concave) diverging → nearsight myopia — smaller virtual image — focal length = (−) d_o = (+) d_i = (−)

$\left[M = \frac{-d_i}{d_o}\right] \rightarrow [M = M_1 \times M_2]$ (lens 1) (lens 2) magnification

$[S = S_1 + S_2]$ (lens 1) (lens 2) strength

mirror: $f = \frac{R}{2}$ → radius of curvature

LIGHT

$[C = \lambda f]$ $C = 3 \times 10^8$

$[E = hf]$ $h = 6.626 \times 10^{-34}$

$[E = \frac{hc}{\lambda}]$ 380–700 → visible Spectrum

[index (n) of refraction = light in vaccum / light in medium]

$[n_1 \sin\theta_1 = n_2 \sin\theta_2]$ incident, refraction

incidence, reflection, refraction

Angle of reflection = angle of incidence

ELECTRO/MAGNETO - STATICS

POWER (WATTS)

$[P = VI]$

$[P = \frac{V^2}{R}]$

$[P = I^2 R]$

coulombs

$\left[F = \frac{kq_1q_2}{r^2}\right]$ (N)

$\left[U = \frac{kQq}{r}\right]$ (J)

U = electrical potential

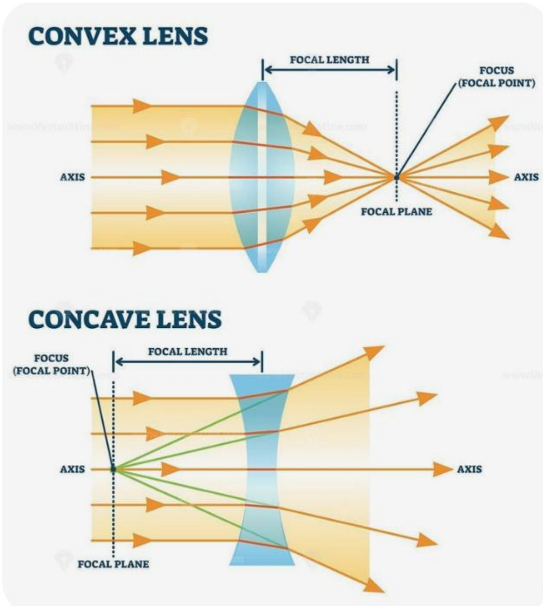
magnetic force

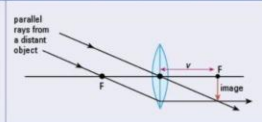
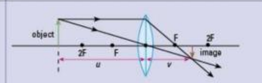
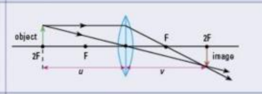
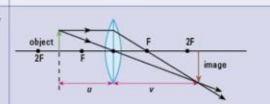
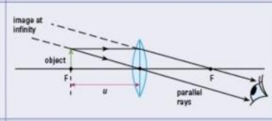
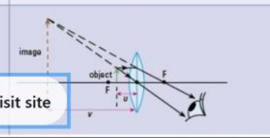
$\left[F_B = qvB\sin\theta\right]$

B = magnetic field

v = velocity

q = charge



Object distance (u)	Ray diagram	Type of image	Image distance (v)	Uses
$u = \infty$		- inverted - real - diminished	$v = f$ - opposite side of the lens	- object lens of a telescope
$u > 2f$		- inverted - real - diminished	$f < v < 2f$ - opposite side of the lens	- camera - eye
$u = 2f$		- inverted - real - same size	$v = 2f$ - opposite side of the lens	- photocopier making same-sized copy
$f < u < 2f$		- inverted - real - magnified	$v > 2f$ - opposite side of the lens	- projector - photograph enlarger
$u = f$		- upright - virtual - magnified	- image at infinity - same side of the lens	- to produce a parallel beam of light, e.g. a spotlight
$u < f$		- upright - virtual - magnified	- image is behind the object - same side of the lens	- magnifying glass

↗ Visit site

(ii) When object is beyond '$2F_1$'

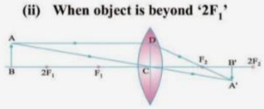


Image
Position – Between 'F_2' and '$2F_2$'
Nature – Real, inverted
Size – Diminished

(iii) When object is at '$2F_1$'

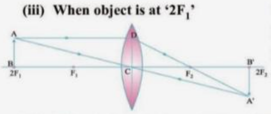


Image
Position – At '$2F_2$'
Nature – Real, inverted
Size – Same size

(iv) When object is between 'F_1' and '$2F_1$'

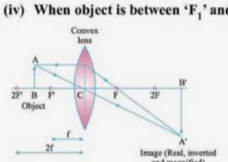


Image
Position – Beyond '$2F_2$'
Nature – Real, inverted
Size – Enlarged

(v) When object is at 'F_1'

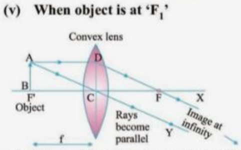


Image
Position – At Infinity
Nature – Real, inverted
Size – Highly enlarged

(vi) When object is between 'F_1' and optical centre

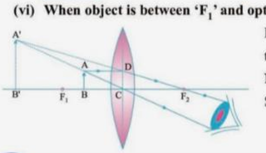


Image
Position – On the same side of the lens as object
Nature – Virtual and erect
Size – Enlarged

Kinetics

Rate Law

$K = k[A]^x[B]^y$

order	units
zero	m/s
first	1/s
second	1/ms

STP conditions

↳ 1 ATM, 101.3kPa, 760mmHg
↳ 0°C or 273K
↳ 22.4 L per 1 mol of gas

Law of Mass Action

$$K_{eq} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

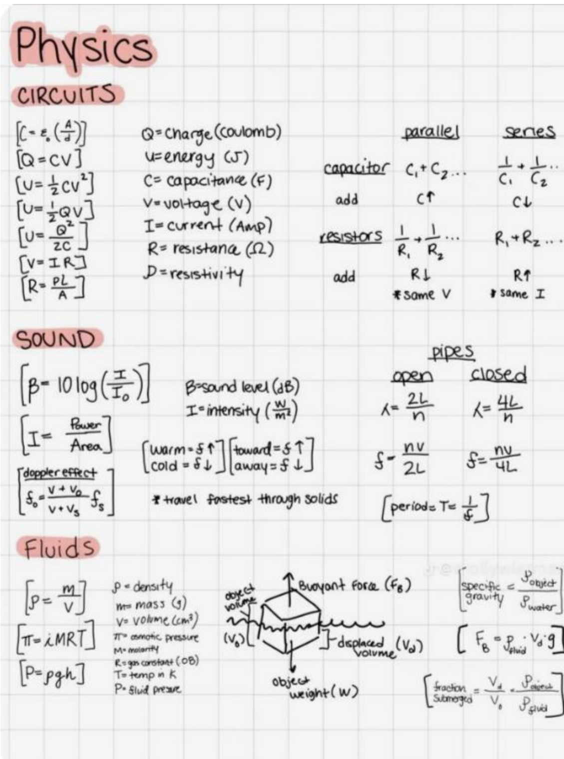
$aA + bB \rightleftharpoons cC + dD$

$K > 1 \rightarrow$ products favored
$K < 1 \rightarrow$ reactants favored
$K = 1 \rightarrow$ in equilibrium

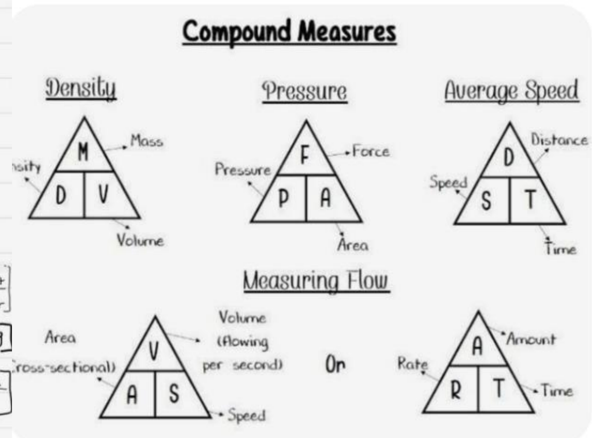
Gas laws

Boyle: $P_1V_1 = P_2V_2$ *Pressure and Volume
Charles: $V_1/T_1 = V_2/T_2$ *Volume and temperature
Gay-L: $P_1/T_1 = P_2/T_2$ *Pressure and Temperature
avogadros: $n_1/V_1 = n_2/V_2$ *moles of gas and Volume

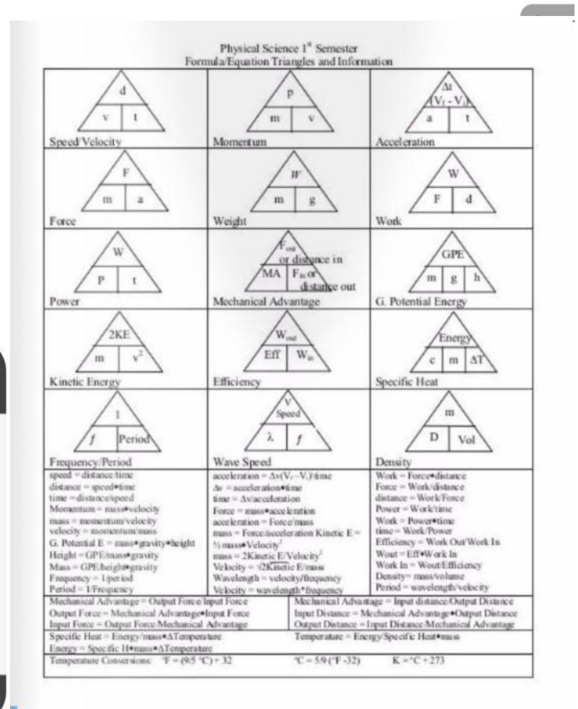
ideal gas law
↳ $PV = nRT$ → temp (K)
Pressure (atm) · molar volume · ↳ ideal gas constant → .082 · ↳ amount of substance (M)



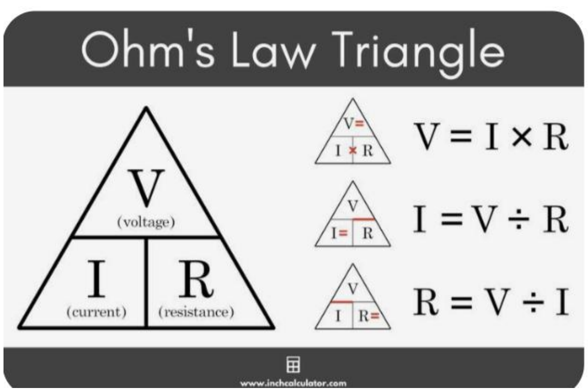
Physics
CIRCUITS
$[C = \varepsilon_0 (\frac{A}{d})]$
$[Q = CV]$
$[U = \frac{1}{2} CV^2]$
$[U = \frac{1}{2} QV]$
$[U = \frac{Q^2}{2C}]$
$[V = IR]$
$[R = \frac{\rho L}{A}]$
Q = charge (coulomb)
U = energy (J)
C = capacitance (F)
V = voltage (V)
I = current (Amp)
R = resistance (Ω)
ρ = resistivity
parallel
series
capacitor
$C_1 + C_2 \ldots$
$\frac{1}{C_1} + \frac{1}{C_2} \ldots$
add
C↑
C↓
resistors
$\frac{1}{R_1} + \frac{1}{R_2} \ldots$
$R_1 + R_2 \ldots$
add
R↓
R↑
* same V
* same I
SOUND
$[\beta = 10 \log (\frac{I}{I_0})]$
β = sound level (dB)
I = intensity ($\frac{W}{m^2}$)
$[I = \frac{\text{Power}}{\text{Area}}]$
[warm = f↑ / cold = f↓]
[toward = f↑ / away = f↓]
doppler effect
$f_o = \frac{v + v_o}{v + v_s} f_s$
* travel fastest through solids
pipes
open
closed
$\lambda = \frac{2L}{n}$
$\lambda = \frac{4L}{n}$
$f = \frac{nv}{2L}$
$f = \frac{nv}{4L}$
[period = $T = \frac{1}{f}$]
Fluids
$[\rho = \frac{m}{V}]$
$[\pi = iMRT]$
$[P = \rho g h]$
ρ = density
m = mass (g)
V = volume (cm³)
π = osmotic pressure
M = molarity
R = gas constant (08)
T = temp in K
P = fluid presure
object volume
(V_o)
Buoyant force (F_B)
displaced volume (V_d)
object weight (W)
[specific gravity = $\frac{\rho_{object}}{\rho_{water}}$]
$[F_B = \rho_{fluid} \cdot V_d \cdot g]$
[fraction submerged = $\frac{V_d}{V_o} = \frac{\rho_{object}}{\rho_{fluid}}$]



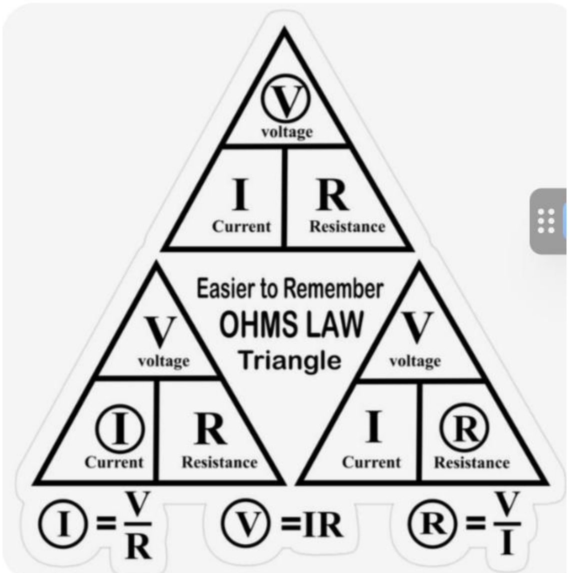
Compound Measures
Density
M
D
V
Mass
Volume
Pressure
F
P
A
Force
Pressure
Area
Average Speed
D
S
T
Distance
Speed
Time
Measuring Flow
V
A
S
Area
(cross-sectional)
Volume (flowing per second)
Speed
Or
A
R
T
Amount
Rate
Time

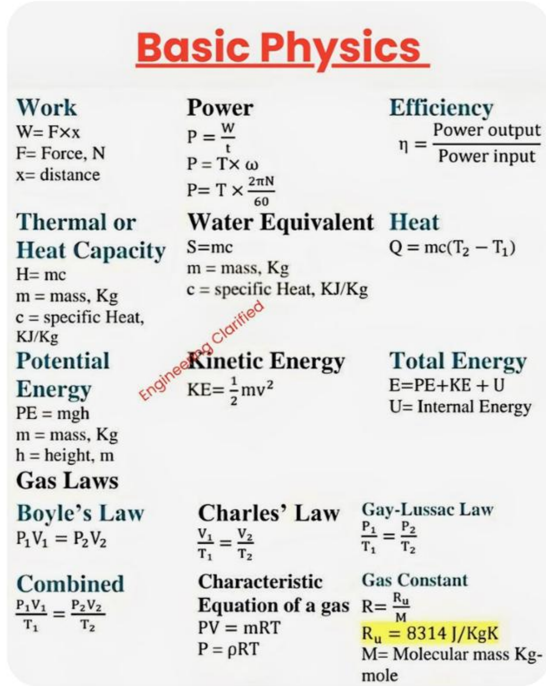


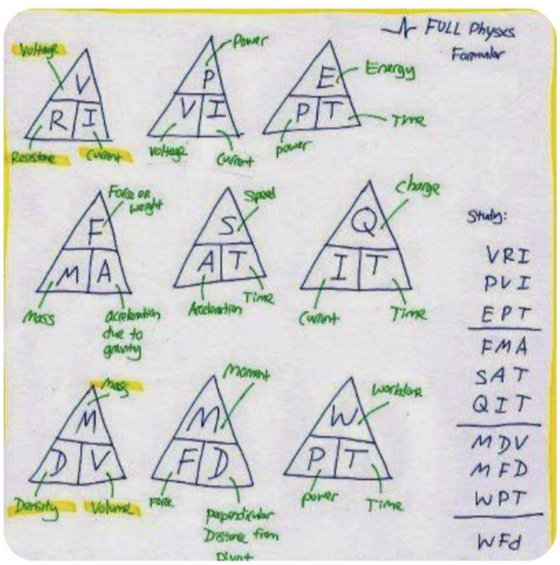
Physical Science 1st Semester
Formula/Equation Triangles and Information
Speed/Velocity
Momentum
Acceleration
Force
Weight
Work
Power
Mechanical Advantage
G. Potential Energy
Kinetic Energy
Efficiency
Specific Heat
Frequency/Period
Wave Speed
Density
speed = distance/time
distance = speed•time
time = distance/speed
Momentum = mass•velocity
mass = momentum/velocity
velocity = momentum/mass
G. Potential E = mass•gravity•height
Height = GPE/mass•gravity
Mass = GPE/height•gravity
Frequency = 1/period
Period = 1/Frequency
acceleration = Δv(Vf – Vi)/time
Δv = acceleration•time
time = Δv/acceleration
Force = mass•acceleration
acceleration = Force/mass
mass = Force/acceleration Kinetic E = ½ mass•Velocity²
mass = 2Kinetic E/Velocity²
Velocity = √2Kinetic E/mass
Wavelength = velocity/frequency
Velocity = wavelength*frequency
Work = Force•distance
Force = Work/distance
distance = Work/Force
Power = Work/time
Work = Power•time
time = Work/Power
Efficiency = Work Out/Work In
Wout = Eff•Work In
Work In = Wout/Efficiency
Density = mass/volume
Period = wavelength/velocity
Mechanical Advantage = Output Force/Input Force
Output Force = Mechanical Advantage•Input Force
Input Force = Output Force/Mechanical Advantage
Mechanical Advantage = Input distance/Output Distance
Input Distance = Mechanical Advantage•Output Distance
Output Distance = Input Distance/Mechanical Advantage
Specific Heat = Energy/mass•ΔTemperature
Energy = Specific H•mass•ΔTemperature
Temperature = Energy/Specific Heat•mass
Temperature Conversions: °F = (9/5 °C) + 32
°C = 5/9 (°F -32)
K = °C + 273



Ohm's Law Triangle
V
(voltage)
I
(current)
R
(resistance)
V = I × R
I = V ÷ R
R = V ÷ I
www.inchcalculator.com


V
voltage
I
Current
R
Resistance
Easier to Remember
OHMS LAW
Triangle
V
voltage
I
Current
R
Resistance
V
voltage
I
Current
R
Resistance
$I = \frac{V}{R}$
$V = IR$
$R = \frac{V}{I}$

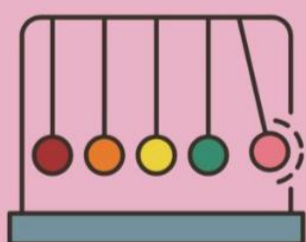

Basic Physics
Work
W= F×x
F= Force, N
x= distance
Power
$P = \frac{W}{t}$
$P = T \times \omega$
$P = T \times \frac{2\pi N}{60}$
Efficiency
$\eta = \frac{\text{Power output}}{\text{Power input}}$
Thermal or Heat Capacity
H= mc
m = mass, Kg
c = specific Heat, KJ/Kg
Water Equivalent
S=mc
m = mass, Kg
c = specific Heat, KJ/Kg
Heat
$Q = mc(T_2 - T_1)$
Engineering Clarified
Potential Energy
PE = mgh
m = mass, Kg
h = height, m
Kinetic Energy
$KE = \frac{1}{2}mv^2$
Total Energy
E=PE+KE + U
U= Internal Energy
Gas Laws
Boyle's Law
$P_1V_1 = P_2V_2$
Charles' Law
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Gay-Lussac Law
$\frac{P_1}{T_1} = \frac{P_2}{T_2}$
Combined
$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
Characteristic Equation of a gas
PV = mRT
P = ρRT
Gas Constant
$R = \frac{R_u}{M}$
$R_u = 8314$ J/KgK
M= Molecular mass Kg-mole


FULL Physics Formular
Voltage
V
R I
Resistance
Current
Power
P
V I
Voltage
Current
E
P T
Energy
Time
power
Force or weight
F
M A
Mass
acceleration due to gravity
Speed
S
A T
Acceleration
Time
charge
Q
I T
Current
Time
Study:
VRI
PVI
EPT
FMA
SAT
QIT
MDV
MFD
WPT
WFd
Mass
M
D V
Density
Volume
Moment
M
F D
Force
perpendicular Distance from Pivot
Workdone
W
P T
power
Time

Inelastic $m_1 v_{1,i} + m_2 v_{2,i} = v_f(m_1 + m_2)$

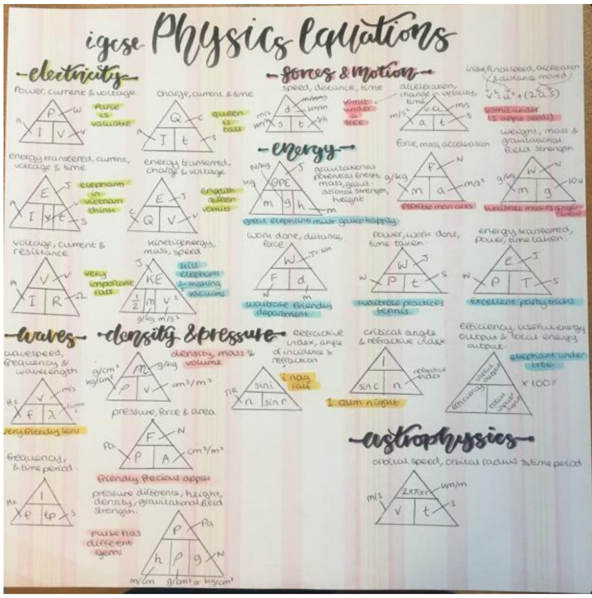
Loss of kinetic energy as heat or sound. Objects may stick and move together after the collision and are usually distorted or damaged.

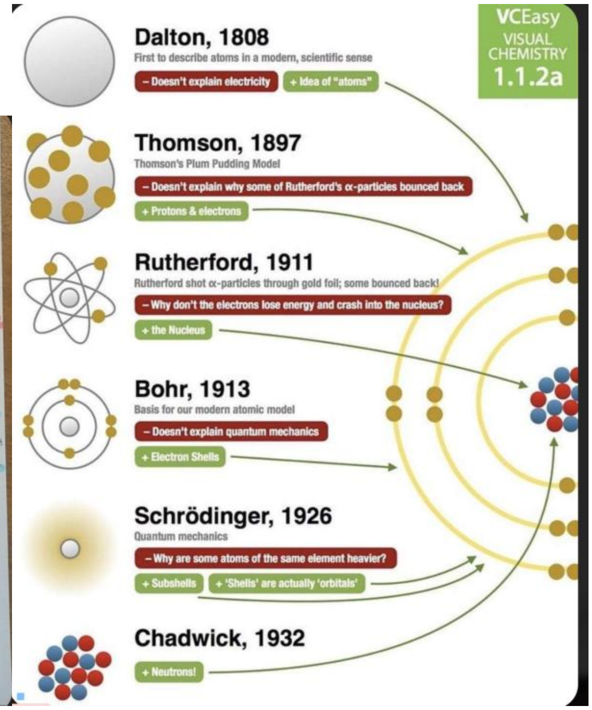
Inelastic vs. Elastic Collisions

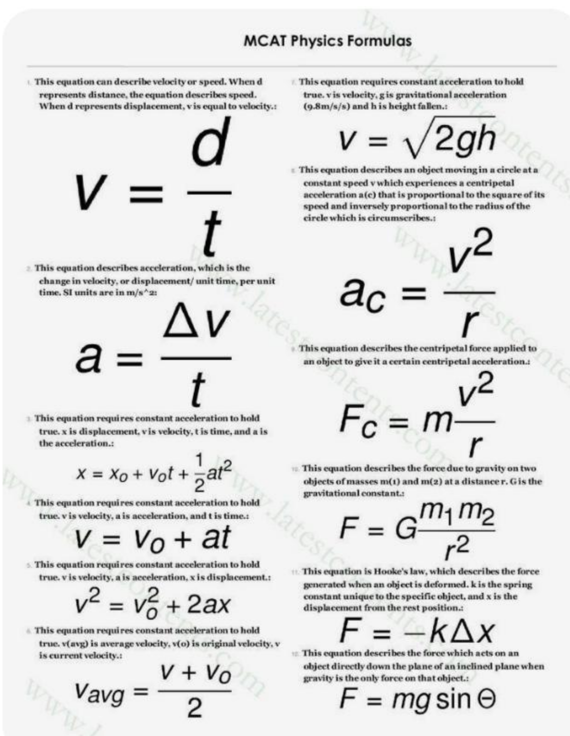


Kinetic energy remains constant. Objects bounce off each other and are not changed or distorted. Perfect elastic collision does not really exist.

Elastic $m_1 v_{1,i} + m_2 v_{2,i} = m_1 v_{1,f} + m_2 v_{2,f}$







MCAT Physics Formulas

1. This equation can describe velocity or speed. When d represents distance, the equation describes speed. When d represents displacement, v is equal to velocity.:

$$v = \frac{d}{t}$$

2. This equation describes acceleration, which is the change in velocity, or displacement/ unit time, per unit time. SI units are in m/s^2:

$$a = \frac{\Delta v}{t}$$

3. This equation requires constant acceleration to hold true. x is displacement, v is velocity, t is time, and a is the acceleration.:

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

4. This equation requires constant acceleration to hold true. v is velocity, a is acceleration, and t is time.:

$$v = v_0 + at$$

5. This equation requires constant acceleration to hold true. v is velocity, a is acceleration, x is displacement.:

$$v^2 = v_0^2 + 2ax$$

6. This equation requires constant acceleration to hold true. v(avg) is average velocity, v(o) is original velocity, v is current velocity.:

$$v_{avg} = \frac{v + v_0}{2}$$

7. This equation requires constant acceleration to hold true. v is velocity, g is gravitational acceleration (9.8m/s/s) and h is height fallen.:

$$v = \sqrt{2gh}$$

8. This equation describes an object moving in a circle at a constant speed v which experiences a centripetal acceleration a(c) that is proportional to the square of its speed and inversely proportional to the radius of the circle which is circumscribes.:

$$a_c = \frac{v^2}{r}$$

9. This equation describes the centripetal force applied to an object to give it a certain centripetal acceleration.:

$$F_c = m\frac{v^2}{r}$$

10. This equation describes the force due to gravity on two objects of masses m(1) and m(2) at a distance r. G is the gravitational constant.:

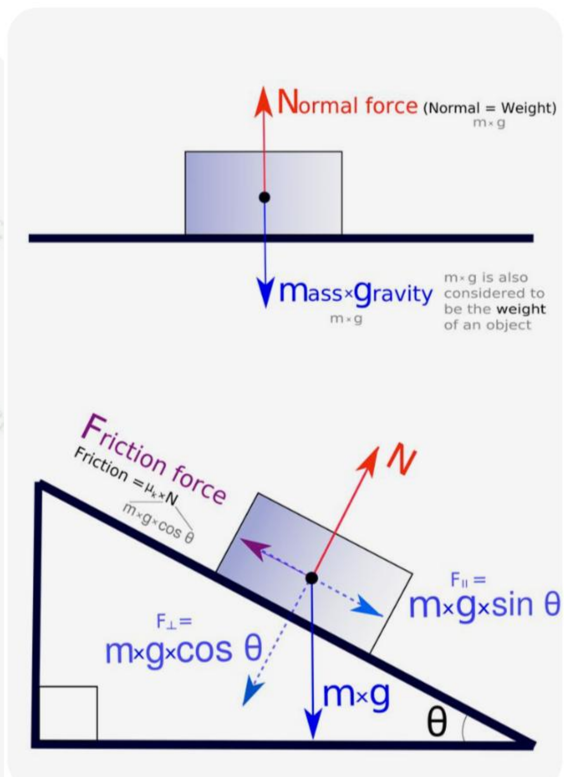
$$F = G\frac{m_1 m_2}{r^2}$$

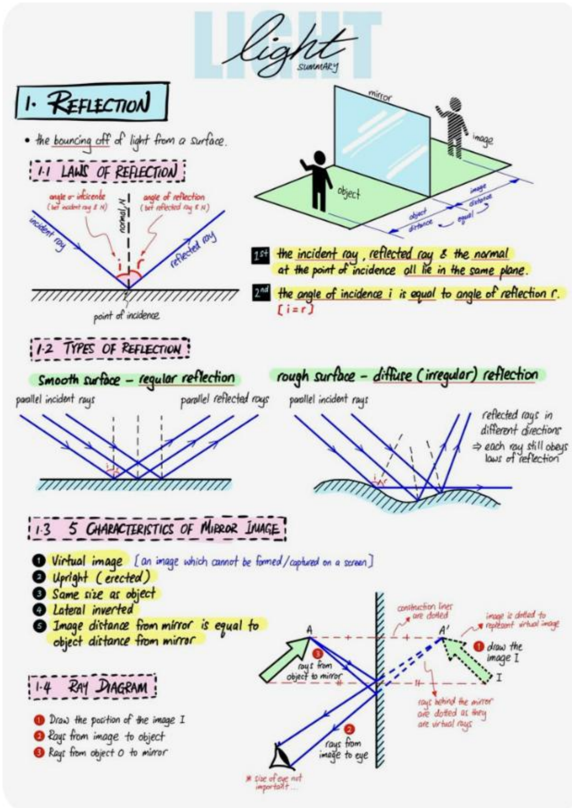
11. This equation is Hooke's law, which describes the force generated when an object is deformed. k is the spring constant unique to the specific object, and x is the displacement from the rest position.:

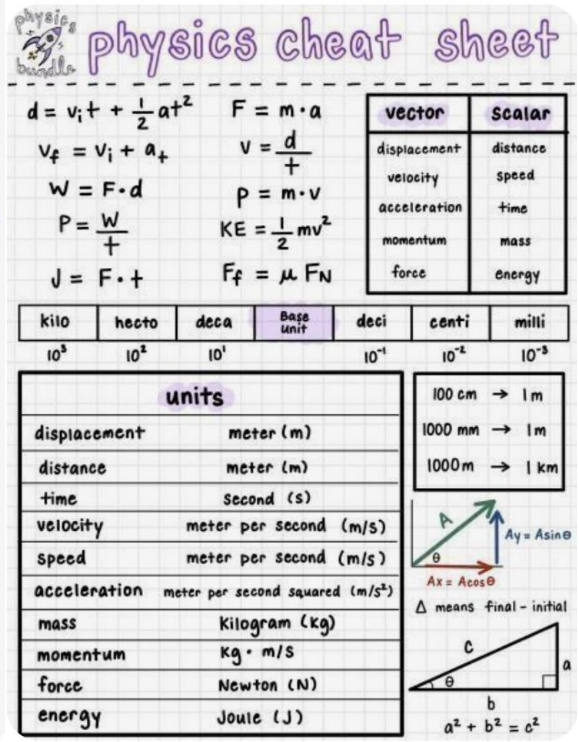
$$F = -k\Delta x$$

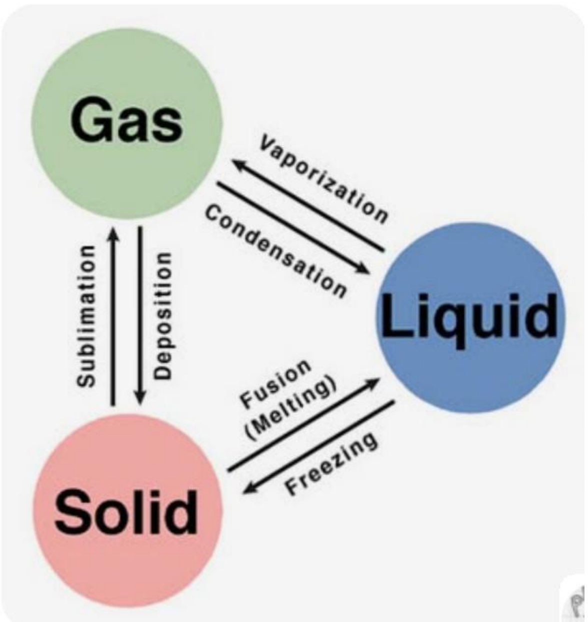
12. This equation describes the force which acts on an object directly down the plane of an inclined plane when gravity is the only force on that object.:

$$F = mg \sin \Theta$$



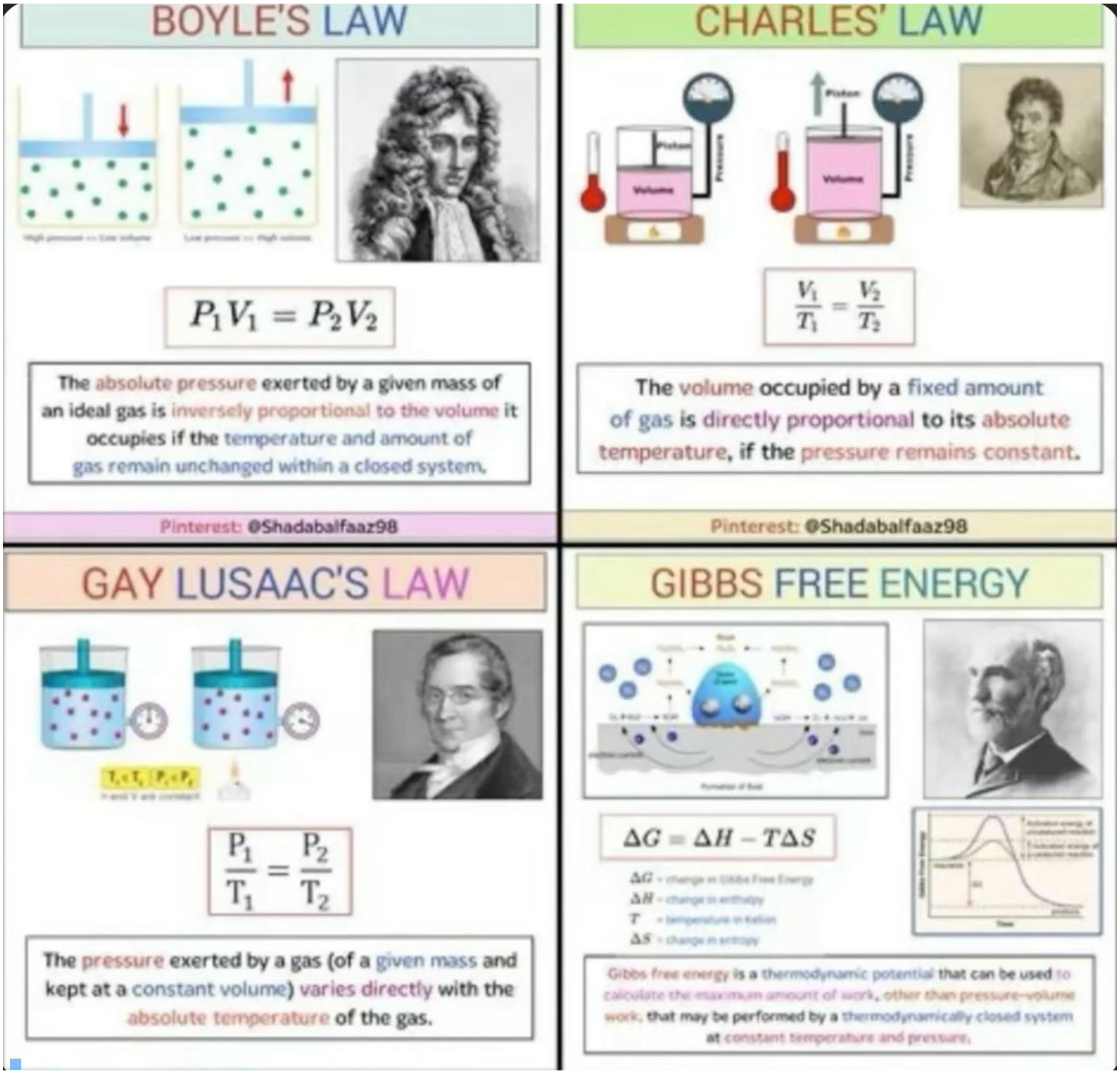

light
SUMMARY
1. REFLECTION
• the bouncing off of light from a surface.
1.1 LAWS OF REFLECTION
angle of incidence
angle of reflection
normal
incident ray
reflected ray
point of incidence
mirror
image
object
object distance
image distance
equal
1st the incident ray, reflected ray & the normal at the point of incidence all lie in the same plane.
2nd the angle of incidence i is equal to angle of reflection r. [i = r]
1.2 TYPES OF REFLECTION
Smooth surface – regular reflection
rough surface – diffuse (irregular) reflection
parallel incident rays
parallel reflected rays
parallel incident rays
reflected rays in different directions
⇒ each ray still obeys laws of reflection
1.3 5 CHARACTERISTICS OF MIRROR IMAGE
1 Virtual image [an image which cannot be formed/captured on a screen]
2 Upright (erected)
3 Same size as object
4 Lateral inverted
5 Image distance from mirror is equal to object distance from mirror
1.4 RAY DIAGRAM
1 Draw the position of the image I
2 Rays from image to object
3 Rays from object O to mirror
construction lines are dotted
image is dotted to represent virtual image
draw the image I
rays from object to mirror
rays behind the mirror are dotted as they are virtual rays
rays from image to eye
A
A'
I
* size of eye not important...


physics bundle
physics cheat sheet
$d = v_i t + \frac{1}{2}at^2$
$v_f = v_i + a_t$
$W = F \cdot d$
$P = \frac{W}{t}$
$J = F \cdot t$
$F = m \cdot a$
$v = \frac{d}{t}$
$p = m \cdot v$
$KE = \frac{1}{2}mv^2$
$F_f = \mu F_N$
vector | scalar
displacement | distance
velocity | speed
acceleration | time
momentum | mass
force | energy
kilo 10^3 | hecto 10^2 | deca 10^1 | Base unit | deci 10^{-1} | centi 10^{-2} | milli 10^{-3}
units
displacement meter (m)
distance meter (m)
time second (s)
velocity meter per second (m/s)
speed meter per second (m/s)
acceleration meter per second squared (m/s^2)
mass Kilogram (Kg)
momentum Kg · m/s
force Newton (N)
energy Joule (J)
100 cm → 1 m
1000 mm → 1 m
1000 m → 1 km
A
θ
Ay = Asinθ
Ax = Acosθ
Δ means final – initial
c
a
b
θ
$a^2 + b^2 = c^2$

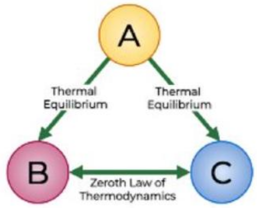


PHYSICS FORMULAS

1. $Area = legnth \times breath$
2. $Volume = legnth \times breath \times height$
3. $Density = \frac{mass}{Volume}$
4. $frequency = \frac{1}{time\ period}$
5. $velocity = \frac{displacemet}{time}$
6. $accelaration = \frac{change\ in\ velocity}{time}$
7. $force = mass \times\ accelaration$
8. $impulse = force \times time$
9. $work = force \times displacemet$
10. $power = \frac{work}{time}$
11. $momentum = mass \times velocity$
12. $pressure = \frac{force}{area}$
13. $surface\ tension = \frac{force}{length}$
14. $charge = electric\ current \times time$
15. $resistance = \frac{potential\ different}{electric\ current}$
16. $capacitance = \frac{charge}{potential\ different}$
17. $electric\ field = \frac{electric\ force}{charge}$
18. $angular\ velocity = \frac{\theta}{time}$
19. $angula\ accelaration = \frac{change\ in\ angular\ velocity}{time}$
20. $momet\ of\ inertia = mass \times (radius)^2$
21. $angular\ momentum = momet\ of\ inertia \times aangular\ velocity$
22. $torque = force \times radius$
23. $kinetic\ energy = \frac{1}{2} \times mass \times (velocity)^2$
24. $static\ energy = mass \times gravitational\ accelaration \times height$
25. $angular\ impulse = torque \times time$
26. $centrifugal\ force = \frac{mass \times (velocity)^2}{radius}$
27. $centrifugal\ accelaration = \frac{(velocity)^2}{radius}$


BOYLE'S LAW
$P_1V_1 = P_2V_2$
The absolute pressure exerted by a given mass of an ideal gas is inversely proportional to the volume it occupies if the temperature and amount of gas remain unchanged within a closed system.
Pinterest: @Shadabalfaaz98
CHARLES' LAW
Piston
Volume
Pressure
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$
The volume occupied by a fixed amount of gas is directly proportional to its absolute temperature, if the pressure remains constant.
Pinterest: @Shadabalfaaz98
GAY LUSAAC'S LAW
$\frac{P_1}{T_1} = \frac{P_2}{T_2}$
The pressure exerted by a gas (of a given mass and kept at a constant volume) varies directly with the absolute temperature of the gas.
GIBBS FREE ENERGY
$\Delta G = \Delta H - T\Delta S$
ΔG = change in Gibbs Free Energy
ΔH = change in enthalpy
T = temperature in Kelvin
ΔS = change in entropy
Gibbs free energy is a thermodynamic potential that can be used to calculate the maximum amount of work, other than pressure-volume work, that may be performed by a thermodynamically closed system at constant temperature and pressure.

ZEROTH LAW OF THERMODYNAMICS



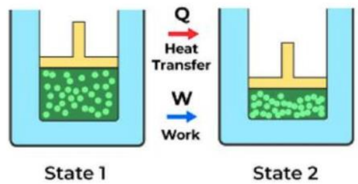
ROLPH H FOWLER

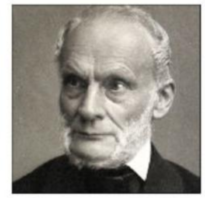
If two thermodynamic systems are both in thermal equilibrium with a third system, then the two systems are in thermal equilibrium with each other.

Two systems are said to be in thermal equilibrium if they are linked by a wall permeable only to heat, and they do not change over time.

Pinterest: @Shadabalfaaz98

FIRST LAW OF THERMODYNAMICS





RUDOLPH CLAUSIUS

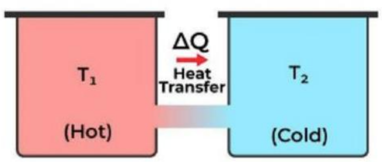
$$\Delta U = Q - W$$

ΔU = change in internal energy
Q = heat added
W = work done by the system

The change in internal energy of a system equals the net heat transfer into the system minus the net work done by the system. It is based on Conservation of Energy.

Pinterest: @Shadabalfaaz98

SECOND LAW OF THERMODYNAMICS



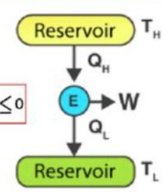
WILLIAM THOMSON

Entropy of an isolated system will never decrease over time.

ΔS = Entropy = $\frac{\Delta Q}{T}$

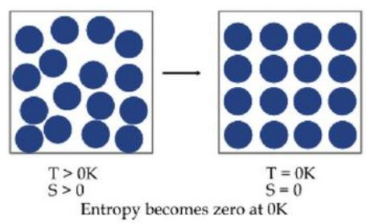
1. Kelvin-Planck Statement- It is impossible for a heat engine to produce a net amount of work in a complete cycle if it exchanges heat only with bodies at a single fixed temperature.
2. The Clausius statement: It is impossible to construct a device that operates on a cycle and produces no other effect than the transfer of heat from a cooler body to a hotter body.

$\oint \frac{dQ}{T} \leq 0$



Pinterest: @Shadabalfaaz98

THIRD LAW OF THERMODYNAMICS

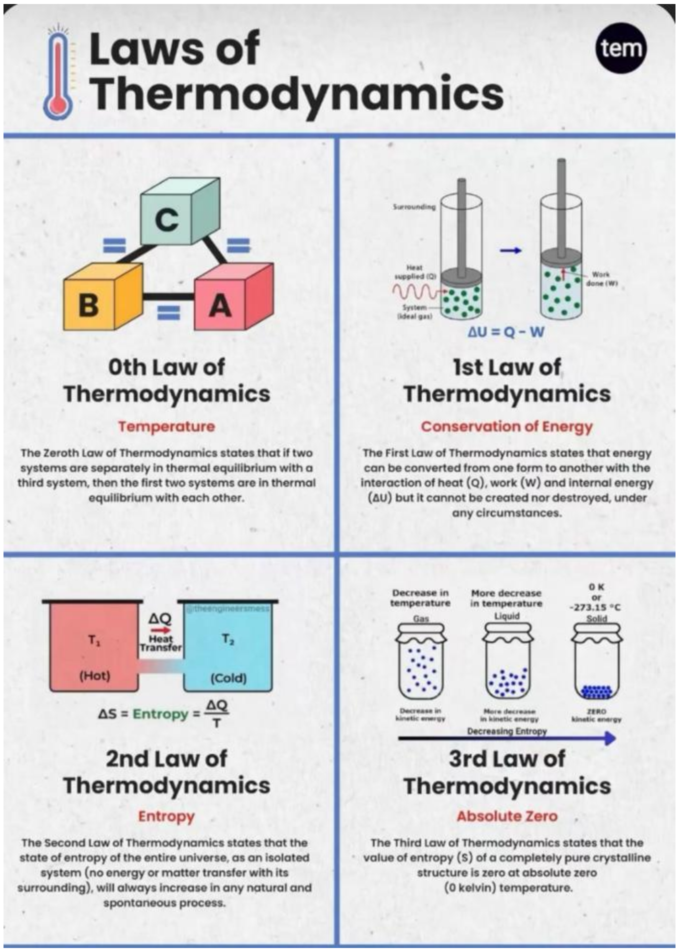


WALTHER NERST

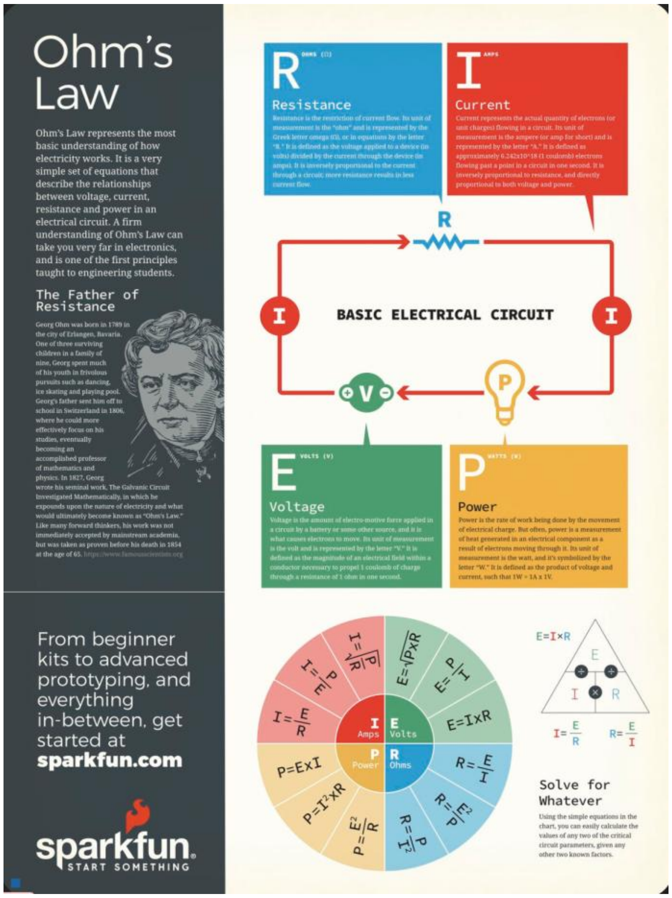
$$\Delta S = \int_{T_1}^{T_2} \frac{C(T)\,dT}{T}$$

The entropy of a closed system at thermodynamic equilibrium approaches a constant value when its temperature approaches absolute zero.

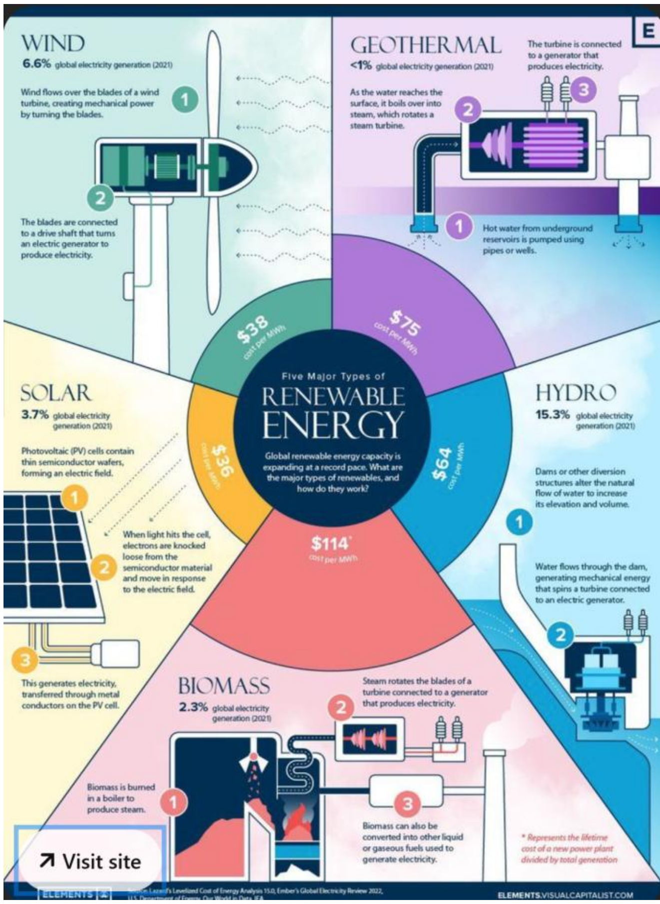
Pinterest: @Shadabalfaaz98



Laws of Thermodynamics
tem
C
B
A
0th Law of Thermodynamics
Temperature
The Zeroth Law of Thermodynamics states that if two systems are separately in thermal equilibrium with a third system, then the first two systems are in thermal equilibrium with each other.
Surrounding
Heat supplied (Q)
System (ideal gas)
Work done (W)
ΔU = Q - W
1st Law of Thermodynamics
Conservation of Energy
The First Law of Thermodynamics states that energy can be converted from one form to another with the interaction of heat (Q), work (W) and internal energy (ΔU) but it cannot be created nor destroyed, under any circumstances.
ΔQ
Heat Transfer
T1
(Hot)
T2
(Cold)
@theengineersmess
ΔS = Entropy = ΔQ/T
2nd Law of Thermodynamics
Entropy
The Second Law of Thermodynamics states that the state of entropy of the entire universe, as an isolated system (no energy or matter transfer with its surrounding), will always increase in any natural and spontaneous process.
Decrease in temperature
Gas
More decrease in temperature
Liquid
0 K or -273.15 °C
Solid
Decrease in kinetic energy
More decrease in kinetic energy
ZERO kinetic energy
Decreasing Entropy
3rd Law of Thermodynamics
Absolute Zero
The Third Law of Thermodynamics states that the value of entropy (S) of a completely pure crystalline structure is zero at absolute zero (0 kelvin) temperature.

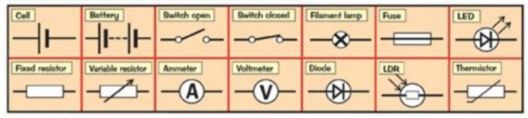


Ohm's Law
Ohm's Law represents the most basic understanding of how electricity works. It is a very simple set of equations that describe the relationships between voltage, current, resistance and power in an electrical circuit. A firm understanding of Ohm's Law can take you very far in electronics, and is one of the first principles taught to engineering students.
The Father of Resistance
Georg Ohm was born in 1789 in the city of Erlangen, Bavaria. One of three surviving children in a family of nine, Georg spent much of his youth in frivolous pursuits such as dancing, ice skating and playing pool. Georg's father sent him off to school in Switzerland in 1806, where he could more effectively focus on his studies, eventually becoming an accomplished professor of mathematics and physics. In 1827, Georg wrote his seminal work, The Galvanic Circuit Investigated Mathematically, in which he expounds upon the nature of electricity and what would ultimately become known as "Ohm's Law." Like many forward thinkers, his work was not immediately accepted by mainstream academia, but was taken as proven before his death in 1854 at the age of 65.
From beginner kits to advanced prototyping, and everything in-between, get started at sparkfun.com
sparkfun
START SOMETHING
R
Resistance
Resistance is the restriction of current flow. Its unit of measurement is the "ohm" and is represented by the Greek letter omega (Ω), or in equations by the letter "R." It is defined as the voltage applied to a device (in volts) divided by the current through the device (in amps). It is inversely proportional to the current through a circuit; more resistance results in less current flow.
I
AMPS
Current
Current represents the actual quantity of electrons (or unit charges) flowing in a circuit. Its unit of measurement is the ampere (or amp for short) and is represented by the letter "A." It is defined as approximately 6.242x10^18 (1 coulomb) electrons flowing past a point in a circuit in one second. It is inversely proportional to resistance, and directly proportional to both voltage and power.
R
I
BASIC ELECTRICAL CIRCUIT
I
V
P
E
VOLTS (V)
Voltage
Voltage is the amount of electro-motive force applied in a circuit by a battery or some other source, and it is what causes electrons to move. Its unit of measurement is the volt and is represented by the letter "V." It is defined as the magnitude of an electrical field within a conductor necessary to propel 1 coulomb of charge through a resistance of 1 ohm in one second.
P
Power
Power is the rate of work being done by the movement of electrical charge. But often, power is a measurement of heat generated in an electrical component as a result of electrons moving through it. Its unit of measurement is the watt, and it's symbolized by the letter "W." It is defined as the product of voltage and current, such that 1W = 1A x 1V.
$I=\sqrt{\frac{P}{R}}$
$E=\sqrt{P\times R}$
$I=\frac{P}{E}$
$E=\frac{P}{I}$
$I=\frac{E}{R}$
$E=I\times R$
I Amps
E Volts
P Power
R Ohms
$P=E\times I$
$R=\frac{E}{I}$
$P=I^2\times R$
$R=\frac{E^2}{P}$
$P=\frac{E^2}{R}$
$R=\frac{P}{I^2}$
$E=I\times R$
E
I
R
$I=\frac{E}{R}$
$R=\frac{E}{I}$
Solve for Whatever
Using the simple equations in the chart, you can easily calculate the values of any two of the critical circuit parameters, given any other two known factors.



Circuit Symbols and Devices

Circuit Symbols You Should Know:

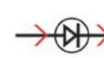


1) Variable Resistor

1) A resistor whose resistance can be changed by twiddling a knob or something.
2) The old-fashioned ones are huge coils of wire with a slider on them.
3) They're great for altering the current flowing through a circuit.
   Turn the resistance up, the current drops. Turn the resistance down, the current goes up.

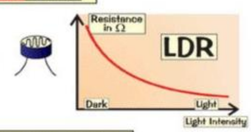
2) "Semiconductor Diode" or just "Diode"

A special device made from semiconductor material such as silicon. It lets current flow freely through it in one direction, but not in the other (i.e. there's a very high resistance in the reverse direction). This turns out to be real useful in various electronic circuits.



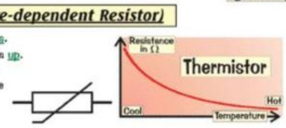
3) Light-Dependent Resistor or "LDR" to You

1) In bright light, the resistance falls.
2) In darkness, the resistance is highest.
3) This makes it a useful device for various electronic circuits, e.g. automatic night lights, burglar detectors.



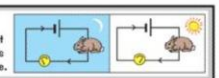
4) Thermistor (Temperature-dependent Resistor)

1) In hot conditions, the resistance drops.
2) In cool conditions, the resistance goes up.
3) Thermistors make useful temperature detectors, e.g. car engine temperature sensors and electronic thermostats.



LDRs — Light-Dependent Rabbits...

You have to learn those circuit symbols so you can read circuit diagrams in the exam. It's not too bad remembering how LDRs and thermistors behave — low light/heat means high resistance.

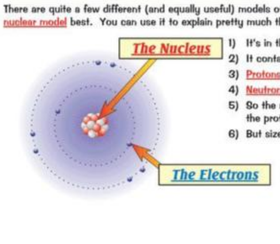


Atoms and Elements

Atoms are the building blocks of everything — and I mean everything.
They're amazingly tiny — you can only see them with an incredibly powerful microscope.

Atoms have a Small Nucleus Surrounded by Electrons

There are quite a few different (and equally useful) models of the atom — but chemists tend to like this nuclear model best. You can use it to explain pretty much the whole of Chemistry... which is nice.



The Nucleus

1) It's in the middle of the atom.
2) It contains protons and neutrons.
3) Protons are positively charged.
4) Neutrons have no charge (they're neutral).
5) So the nucleus has a positive charge overall because of the protons.
6) But size-wise it's tiny compared to the rest of the atom.

The Electrons

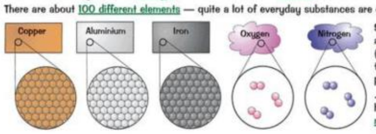
1) Move around the nucleus.
2) They're negatively charged.
3) They're tiny, but they cover a lot of space.
4) They occupy shells around the nucleus.
5) These shells explain the whole of Chemistry.

Number of Protons Equals Number of Electrons

1) Atoms have no charge overall. They are neutral.
2) The charge on the electrons is the same size as the charge on the protons — but opposite.
3) This means the number of protons always equals the number of electrons in an atom.
4) If some electrons are added or removed, the atom becomes charged and is then an ion.

Elements Consist of One Type of Atom Only

1) Atoms can have different numbers of protons, neutrons and electrons. It's the number of protons in the nucleus that decides what type of atom it is.
2) For example, an atom with one proton in its nucleus is hydrogen and an atom with two protons is helium.
3) If a substance only contains one type of atom it's called an element.
4) There are about 100 different elements — quite a lot of everyday substances are elements:



So all the atoms of a particular element (e.g. nitrogen) have the same number of protons...

...and different elements have atoms with different numbers of protons.

Number of protons = number of electrons...

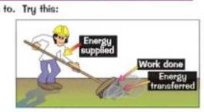
This stuff might seem a bit useless at first, but it should be permanently engraved into your mind. You need to know these basic facts — then you'll have a better chance of understanding the rest of Chemistry.

Work and Power

In Physics, 'work done' means something special — it's got its own formula and everything.

When a force moves an object, energy is transferred and work is done.

That statement sounds far more complicated than it needs to. Try this:



1) Whenever something moves, something else is providing some sort of 'effort' to move it.
2) The thing putting the effort in needs a supply of energy (like fuel or food or electricity etc.).
3) It then does 'work' by moving the object — and one way or another it transfers the energy it receives (as fuel etc.) into other forms (see p.16).
4) Whether this energy is transferred 'usefully' (e.g. by lifting a load) or is 'wasted' (e.g. lost as heat through friction), you can still say that 'work is done'. Just like Batman and Bruce Wayne, 'work done' and 'energy transferred' are indeed 'one and the same'. (And they're both given in joules.)

It's Just Another Trivial Formula:

Work Done = Force × Distance moved in the direction of the force

You might also see W used to represent work done in this equation.

Whether the force is friction or weight or tension in a rope, it's always the same. To find how much energy has been transferred (in joules), you just multiply the force in N by the distance moved in the direction of the force, measured in metres. Easy as that. I'll show you...

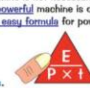
EXAMPLE: Some hooligan kids drag an old tractor tyre 5 m over rough ground. They pull with a total force of 340 N. Find the energy transferred.

ANSWER: Energy transferred is work done, so:
$E = F \times d = 340 \times 5 = 1700$ J. Phew — easy peasy isn't it?

Power is the "Rate of Doing Work" — i.e. How Much per Second

Power is not the same thing as force, nor energy. A powerful machine is not necessarily one which can exert a strong force (though it usually ends up that way). A powerful machine is one which transfers a lot of energy in a short space of time. This is the very easy formula for power:

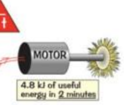
$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$



EXAMPLE: A motor transfers 4.8 kJ of useful energy in 2 minutes. Find its power output.

ANSWER: $P = E / t = 4800/120 = 40$ W (or 40 J/s) (1 kJ = 1000 J)

(Note that the kJ had to be turned into J, and the minutes into seconds.)

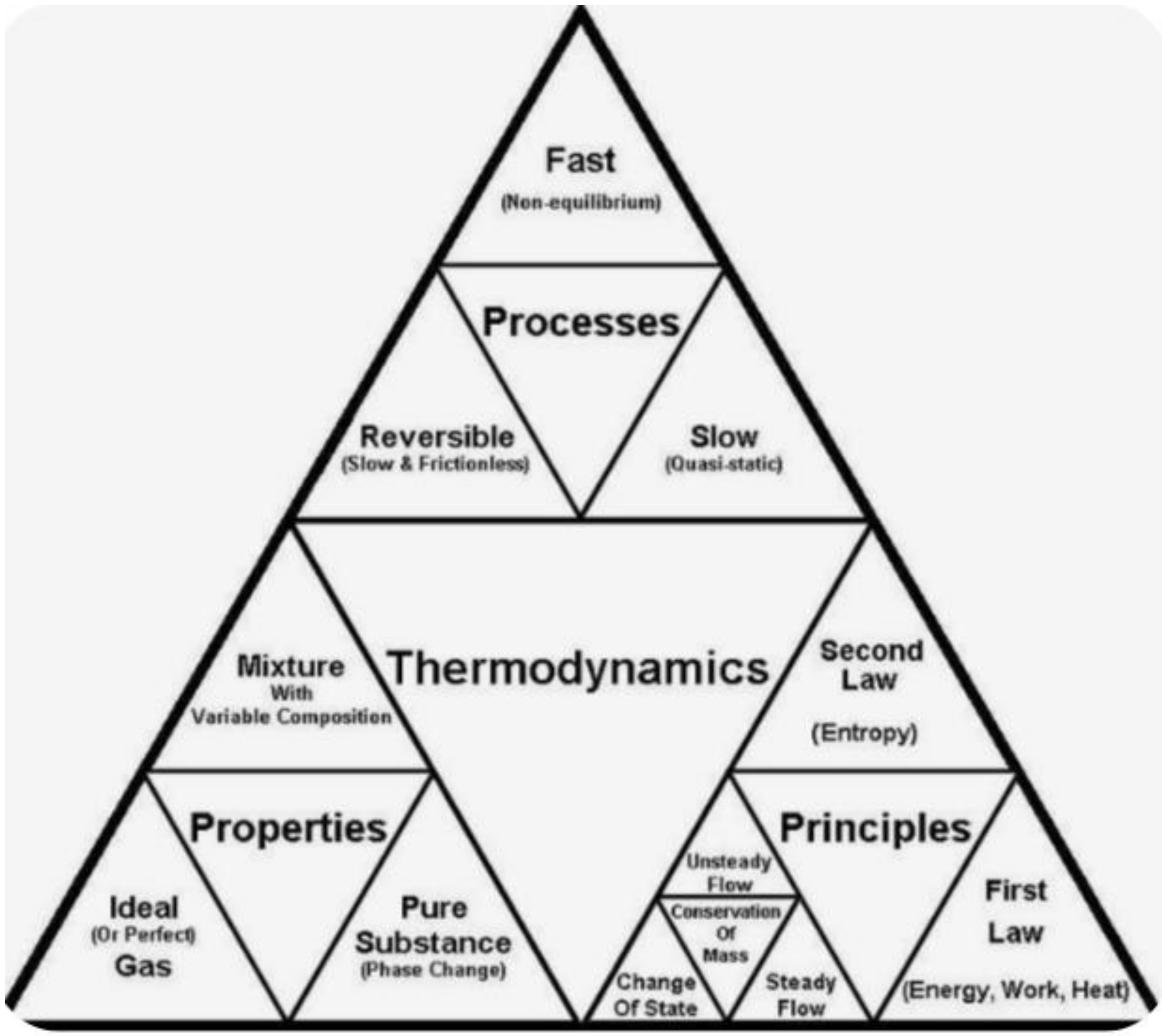


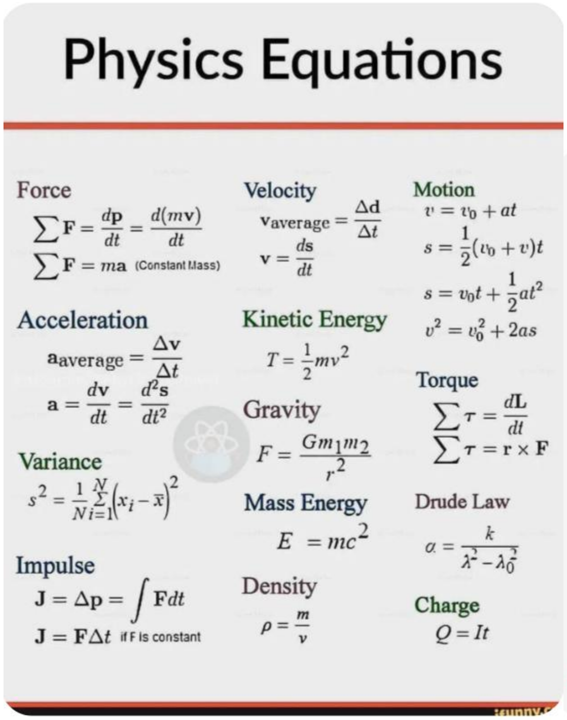
Power is Measured in Watts (or J/s)

The proper unit of power is the watt (W). One watt = 1 joule of energy transferred per second. Power means "how much energy per second", so watts are the same as "joules per second" (J/s). Don't ever say "watts per second" — it's nonsense.

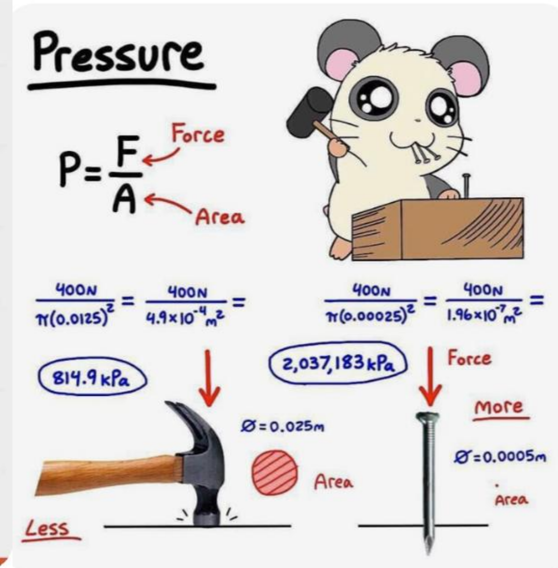
Force yourself to do some work and learn this page...

Work done can sound like quite a wishy washy term, but the thing to remember is that it's just the energy transferred to something when you force it to move some distance. Like when you push a shopping trolley — you move it down the aisles as you bask in the glory of having transferred chemical energy to kinetic.

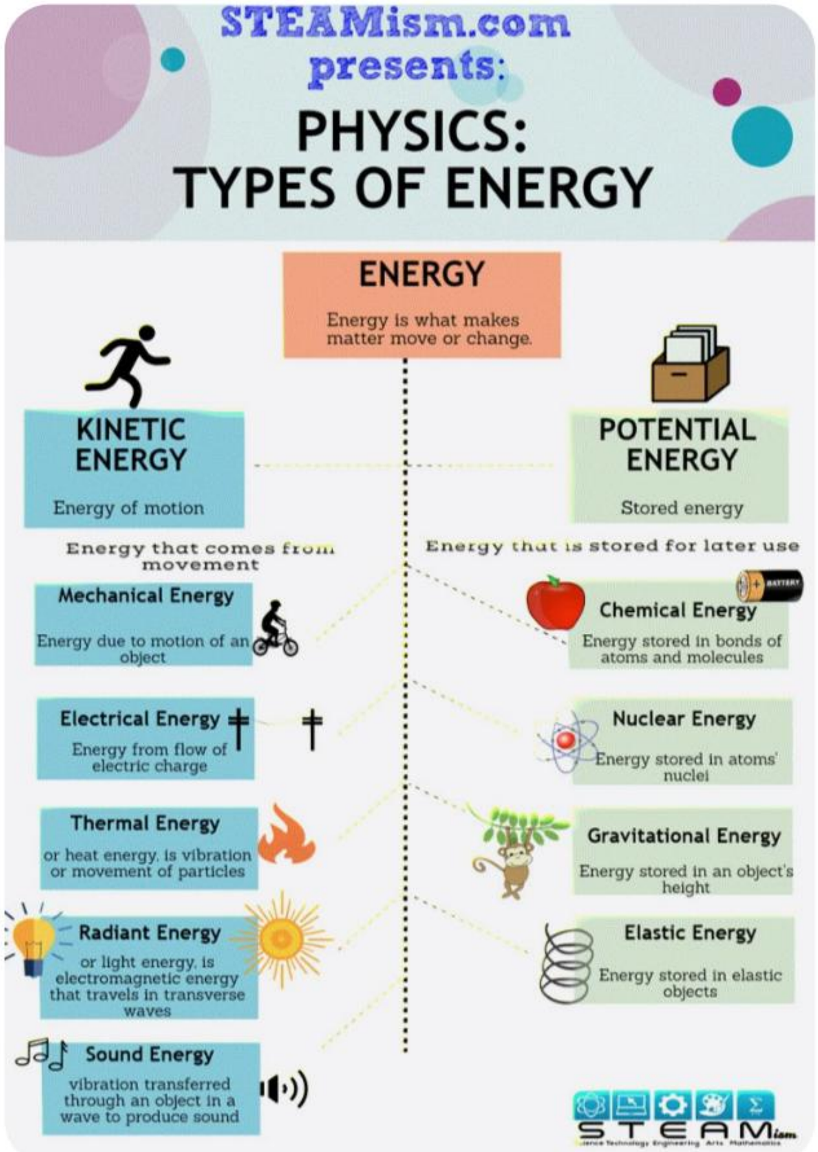

Fast
(Non-equilibrium)
Processes
Reversible
(Slow & Frictionless)
Slow
(Quasi-static)
Mixture
With
Variable Composition
Thermodynamics
Second
Law
(Entropy)
Properties
Ideal
(Or Perfect)
Gas
Pure
Substance
(Phase Change)
Unsteady
Flow
Conservation
Of
Mass
Change
Of State
Steady
Flow
Principles
First
Law
(Energy, Work, Heat)

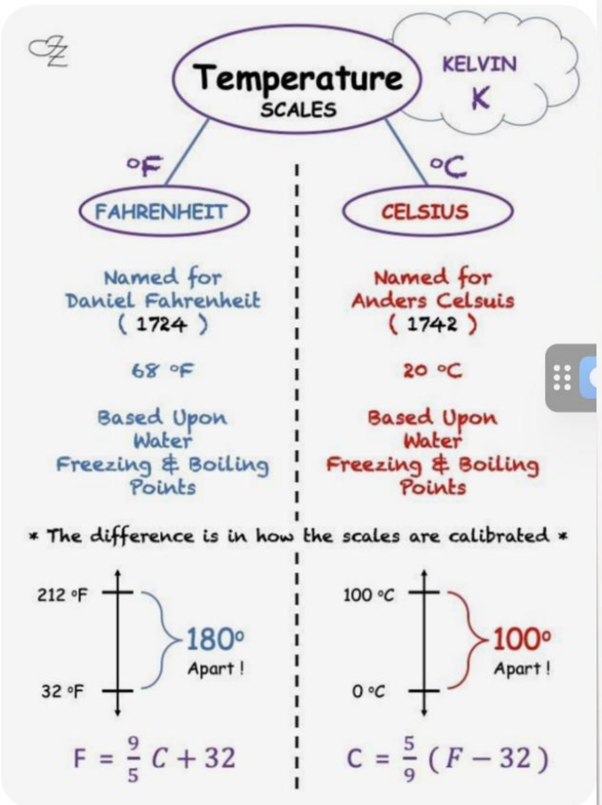


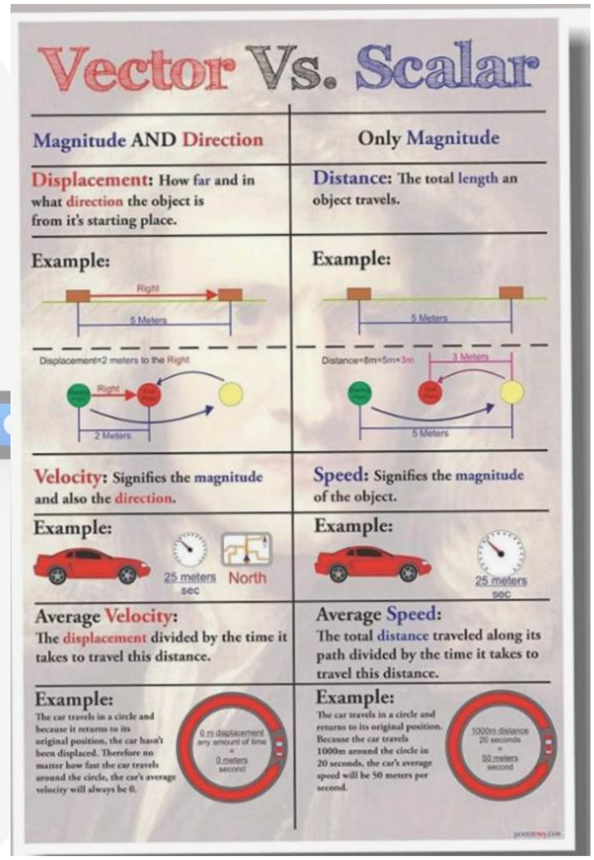
Physics Equations
Force
$\sum \mathbf{F} = \frac{d\mathbf{p}}{dt} = \frac{d(m\mathbf{v})}{dt}$
$\sum \mathbf{F} = m\mathbf{a}$ (Constant Mass)
Velocity
$\mathbf{v}_{\text{average}} = \frac{\Delta \mathbf{d}}{\Delta t}$
$\mathbf{v} = \frac{d\mathbf{s}}{dt}$
Motion
$v = v_0 + at$
$s = \frac{1}{2}(v_0 + v)t$
$s = v_0 t + \frac{1}{2}at^2$
$v^2 = v_0^2 + 2as$
Acceleration
$\mathbf{a}_{\text{average}} = \frac{\Delta \mathbf{v}}{\Delta t}$
$\mathbf{a} = \frac{d\mathbf{v}}{dt} = \frac{d^2\mathbf{s}}{dt^2}$
Kinetic Energy
$T = \frac{1}{2}mv^2$
Torque
$\sum \tau = \frac{d\mathbf{L}}{dt}$
$\sum \tau = \mathbf{r} \times \mathbf{F}$
Gravity
$F = \frac{Gm_1m_2}{r^2}$
Variance
$s^2 = \frac{1}{N}\sum_{i=1}^{N}\left(x_i - \bar{x}\right)^2$
Mass Energy
$E = mc^2$
Drude Law
$\alpha = \frac{k}{\lambda^2 - \lambda_0^2}$
Impulse
$\mathbf{J} = \Delta \mathbf{p} = \int \mathbf{F} dt$
$\mathbf{J} = \mathbf{F}\Delta t$ if F is constant
Density
$\rho = \frac{m}{v}$
Charge
$Q = It$

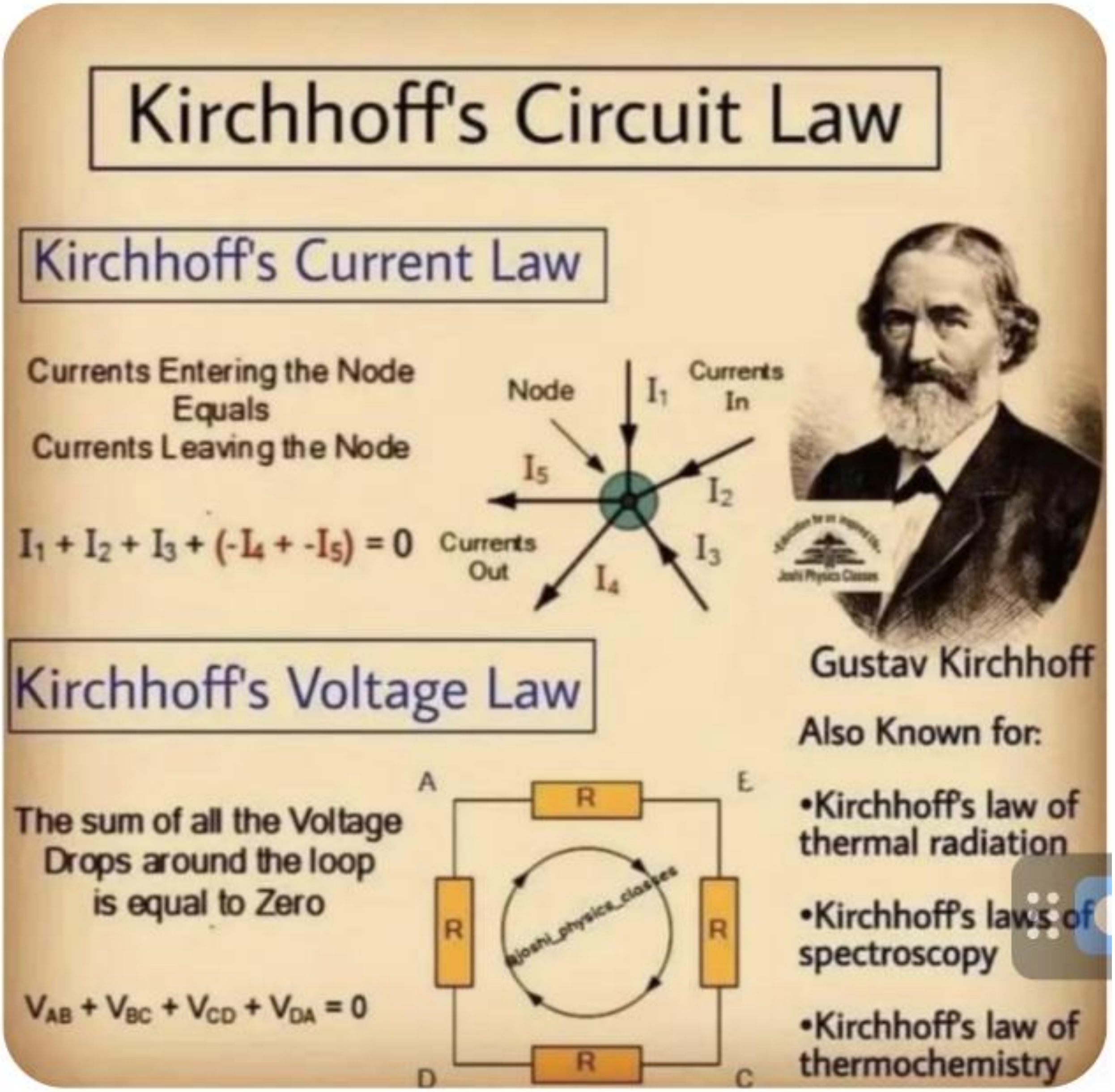


Pressure
$P = \frac{F}{A}$
Force
Area
$\frac{400N}{\pi(0.0125)^2} = \frac{400N}{4.9\times10^{-4}m^2} =$
814.9 kPa
$\frac{400N}{\pi(0.00025)^2} = \frac{400N}{1.96\times10^{-7}m^2} =$
2,037,183 kPa
Force
$\varnothing = 0.025m$
Area
Less
More
$\varnothing = 0.0005m$
Area

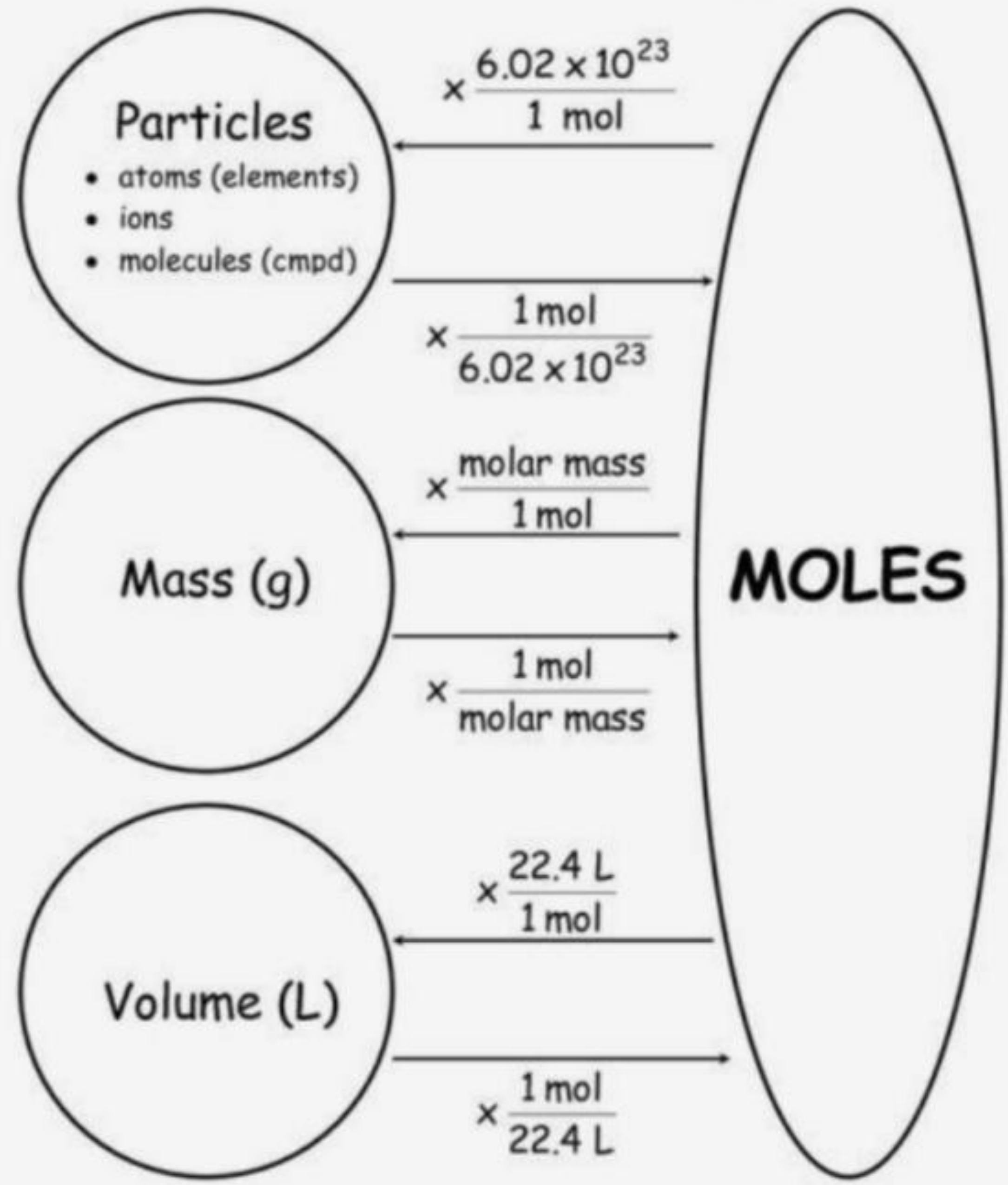

STEAMism.com
presents:
PHYSICS:
TYPES OF ENERGY
ENERGY
Energy is what makes matter move or change.
KINETIC ENERGY
Energy of motion
POTENTIAL ENERGY
Stored energy
Energy that comes from movement
Energy that is stored for later use
Mechanical Energy
Energy due to motion of an object
Chemical Energy
BATTERY
Energy stored in bonds of atoms and molecules
Electrical Energy
Energy from flow of electric charge
Nuclear Energy
Energy stored in atoms' nuclei
Thermal Energy
or heat energy, is vibration or movement of particles
Gravitational Energy
Energy stored in an object's height
Radiant Energy
or light energy, is electromagnetic energy that travels in transverse waves
Elastic Energy
Energy stored in elastic objects
Sound Energy
vibration transferred through an object in a wave to produce sound
STEAMism

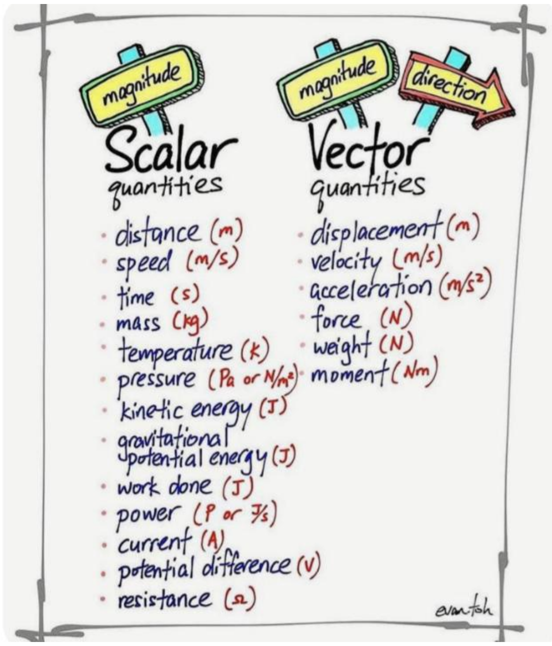

Temperature
SCALES
KELVIN
K
°F
°C
FAHRENHEIT
CELSIUS
Named for
Daniel Fahrenheit
(1724)
Named for
Anders Celsuis
(1742)
68 °F
20 °C
Based Upon
Water
Freezing & Boiling
Points
Based Upon
Water
Freezing & Boiling
Points
* The difference is in how the scales are calibrated *
212 °F
32 °F
180°
Apart !
100 °C
0 °C
100°
Apart !
$F = \frac{9}{5}C + 32$
$C = \frac{5}{9}(F - 32)$


Vector Vs. Scalar
Magnitude AND Direction
Only Magnitude
Displacement: How far and in what direction the object is from it's starting place.
Distance: The total length an object travels.
Example:
Right
5 Meters
Example:
5 Meters
Displacement=2 meters to the Right
Right
2 Meters
Distance=8m=5m+3m
3 Meters
5 Meters
Velocity: Signifies the magnitude and also the direction.
Speed: Signifies the magnitude of the object.
Example:
25 meters
sec
North
Example:
25 meters
sec
Average Velocity:
The displacement divided by the time it takes to travel this distance.
Average Speed:
The total distance traveled along its path divided by the time it takes to travel this distance.
Example:
Example:


Kirchhoff's Circuit Law
Kirchhoff's Current Law
Currents Entering the Node
Equals
Currents Leaving the Node
$I_1 + I_2 + I_3 + (-I_4 + -I_5) = 0$
Node
Currents In
Currents Out
I_1
I_2
I_3
I_4
I_5
Gustav Kirchhoff
Kirchhoff's Voltage Law
The sum of all the Voltage
Drops around the loop
is equal to Zero
$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$
A
E
D
C
R
R
R
R
Also Known for:
•Kirchhoff's law of thermal radiation
•Kirchhoff's laws of spectroscopy
•Kirchhoff's law of thermochemistry

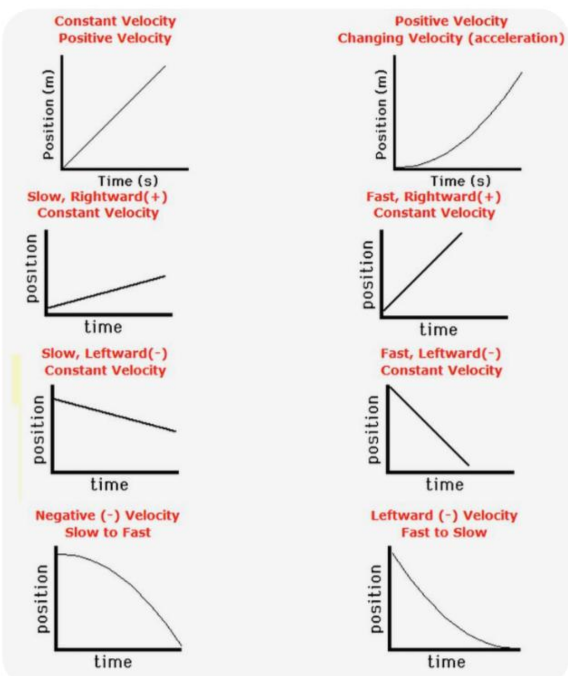
Mole Conversion Diagram

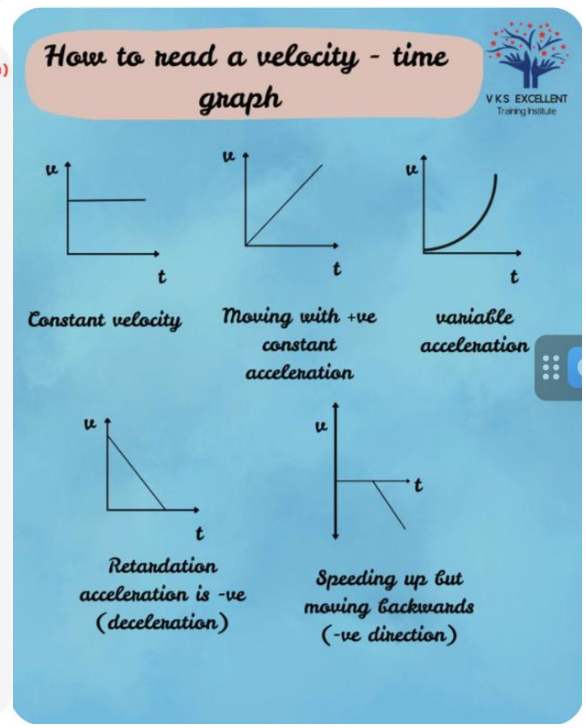




DERIVED UNITS

Quantity	Unit	Symbol
1. Area	square meter	m^2
2. Volume	cubic meter	m^3
3. Density	kilogram/ cubic meter	kg/m^3
4. Velocity	meter/second	m/s
5. Angular Velocity	radian/ second	r/s
6. Acceleration	meter/second square	m/s^2
7. Angular Accleration	radian/second square	rad/s^2
8. Frequency	hertz	Hz
9. Force	newton	N
10. Work energy	joule	J
11. Power	watt	W
12. Pressure	pascal	Pa
13. Electrical charge	coulomb	C
14. Potential difference	volt	V
15. Electrical resistance	ohm	Ω
16. Capacitance	farad	F
17. Inductance	henry	H
18. Magnetic field	telsa	T
19. Luminious flux	lumen	lm
20. Dynamic Viscocity	newton sec./ square meter	$N\text{-}s/m^2$





Resources w/Flashcards

Ninsamum’s resources(@bluestarsyt_15241): HAS FLASHCARDS
Ninsamum's resources

PLEASE REFER TO MEMORISE TOPICS

More notes

Idk what to name this tab, these notes are randoming found

PHYSICS NOTES

"Physics Topics in a nutshell"

Credit: msg0909

[Physics Topics in a nutshell]

Dr. Nassim 🤘

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

FORCES & ENERGY

- A force is simply an agent that produces or tends to produce motion and/or rest.
- Speed is the distance moved in a given period of time. Speed can be found using.

average speed = distance moved / time taken

- Speed is a scalar quantity (has only magnitude). Velocity is speed in a certain direction, making it a vector quantity. velocity can be found using:

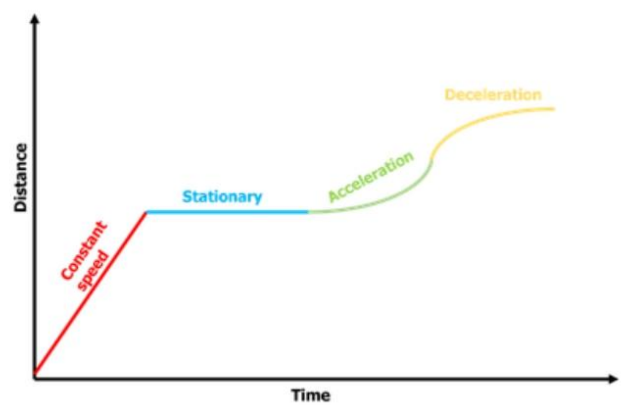
velocity = displacement / time

- Attentively, a vector quantity has both magnitude and direction. – Acceleration is the measure of the rate of increase in velocity. It is also a vector quantity. Acceleration can be found using:

acceleration = increase in velocity /time taken

- Deceleration, or Retardation, is the rate of decrease in velocity.
- If an object decelerates at 3 m/s2, its acceleration is −3 m/s2.
- Although m/s2 is acceptable, the unit ms−2 is more commonly accepted.

A distance-time graph is plotted to show the increase in distance over time.



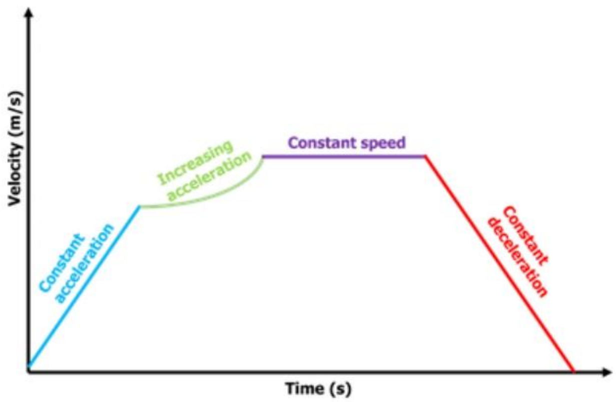
- The gradient of the distance – time graph shows the velocity of the car. this can be found using:

Gradient =y2−y1x2−x1 – Distance Time graph for E an accelerating car.

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

- **A velocity-time** graph shows the changing velocity over time.



- The gradient of a velocity-time graph is the acceleration of that specific object (same formula)
- The area under a velocity-time graph is the distance that object has moved.

There are 3 main equations of motion. These are:

(1) v=u+at

(2) S=ut+1/2 at2

(3) v2=v2+2as

where

v= final velocity

U= initial velocity

s= distance

t= time

a= acceleration FO: FUT

- While they may be used interchangoly, Mass and Weight are completely different things. The differences are:

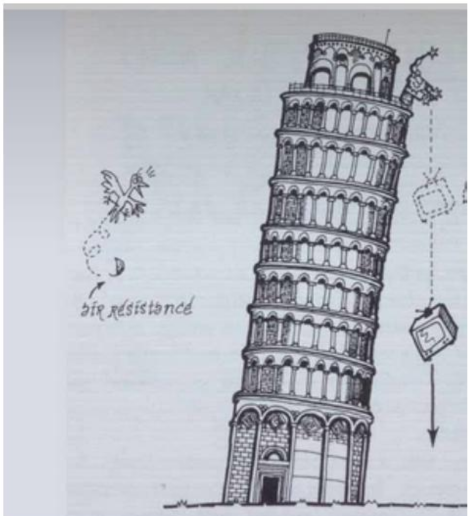
Mass	Weight
The amount of matter present in a body.	- The force exerted on the ground.
Unit ⇒ Kg (kilograms)	- Unit ⇒ N(Newtons)
- Independent of weight. - Remains constant access different gravitational strengths.	- Dependent on mass - Changes across different gravitationd strengths.
- Formula: None	Formula: w=mg (g =gravitational sting
- Scalar quantity	- Vector quantity
- Independent) of gravity	- Dependent on gravity
- Has no given direction	- Has given direction (downwards)

- The gravitational strength of Earth is almost constant →9.8 m/s2 or ms21. However, it should be noted that in the cases of free fall, a (acceleration)=g.

Common Example

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim



A person on a building drops a ball (not throwing with force) FUCHS

- However, it should be noted that an object only accelerates until it reaches its terminal velocity. Teminal velocity is the highest attainable velocity of an object while falling through mid-air.

It can be fond using.
v=2mgpAC, where

v=2mgpAC, where

v= terminal velocity

m= mass of falling abject

g= gravitational acceleration

p= density of fluid through which the object is falling

A= the projected area of the object

C= the drag coefficient

- The value of g varies slightly from place to place on Earth, but is roughly ≈9.8 ms−1. Date
- Gravity pulls all objects towards the earth at the same time naturally. However, some light objects fall slowerdoe to air resistance. This is why all objects would fall together in a vacuum.

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

- Force, mass and acceleration are all relatable. Isaac Newton's 3 laws of motion best describes them.

Newton's Laws of motion:

1) Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it.

2) Force is equal to the change, in momentum per change in time. For. a constant mass, force equals mass times acceleration.

3) For every action, there is an equal and opposite reaction.

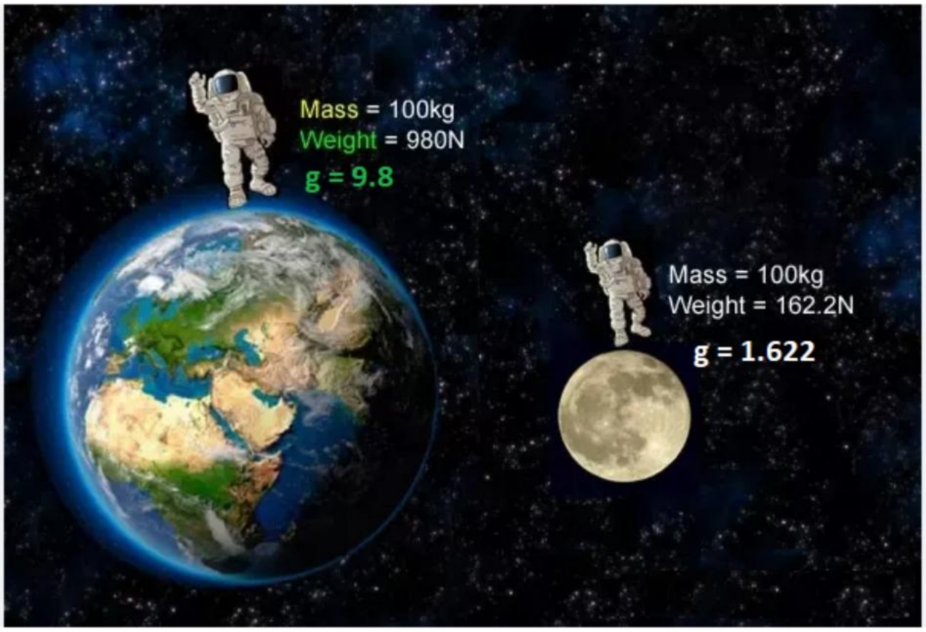
- The first law of motion explains how everything has inertia to change in state of motion or rest. It with remain stationary or moving unless external forces act upon it.
- The second law can be summarized:

Force = mass × acceleration (F=ma), or can be replaced by

- Weight = mass x gravitational strength (w=mg)
- The third law of motion explains how the net result of every force is 0 , due to an equal but opposite reaction.
- How force/weight changes from Earth to moon (f=w,g=a)

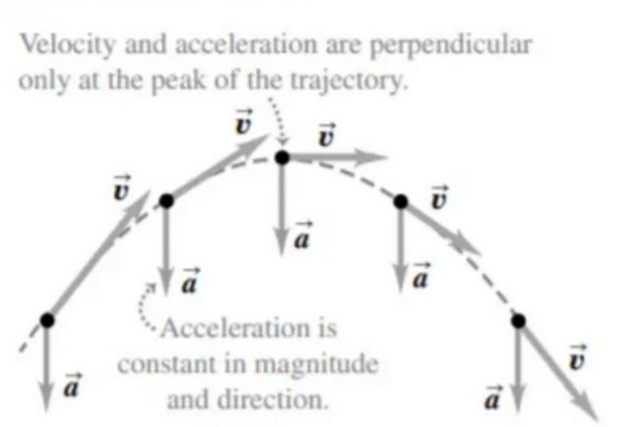
MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim



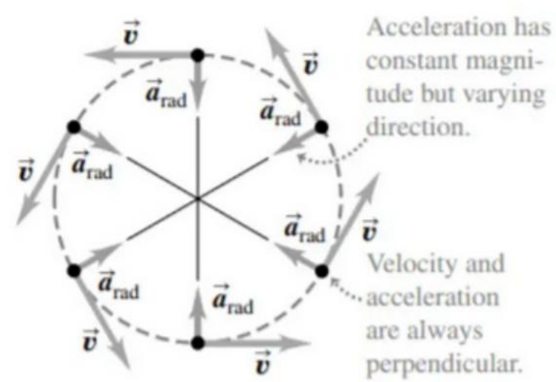
Mass is constant, while weight changes

- When materials try to slide across each other, a force called **friction** stops them. The types of friction are:
- Static: The friction between objects that start to slide.
- Dynamic: The friction during the sliding
- Fluid: The friction caused when an object tries to slide inside a gas or a liquid.
- There are several types of motion:
- Straight-line motion
- Projectile motion



Projectile motion

- Centripetal motion

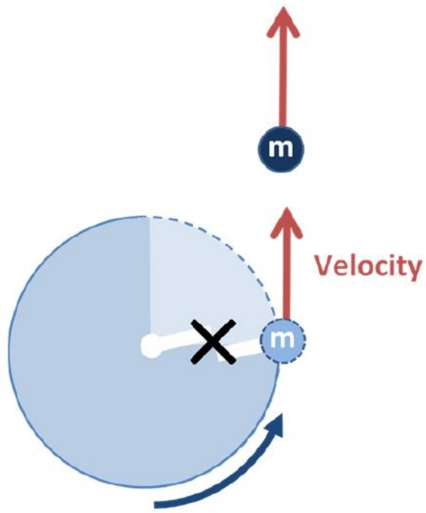


Uniform Circular Motion

- Centripetal motion is circular motion produced by forces applied at right-angles. This can be found by:

Centripetal force =mv2rradius of

- Immediately after centripetal force, if the wire or what is causing right-angular motion stops doing so, the object will travel straight on due to centrifugal force:



- The earth's gravity also causes objects such as satellites to travel in centripetal motion. To escape this, the object must reach escape velocity, which is 11,000 m/s.
- The momentum of an object is its mass x velocity. It is the "quantity" of motion in a moving body:

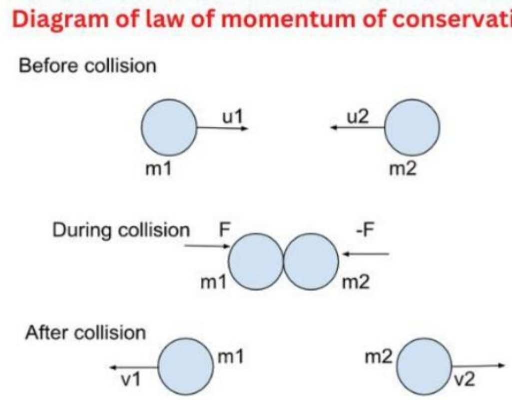
(1) Momentum = mass x velocity
(2) Force =mv−mvt, where
mv is the final momentum

mu is the initial momentum
so
Force = rate of change of momentum

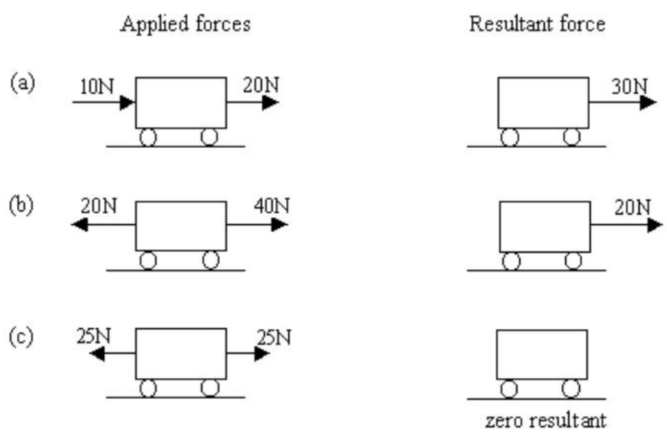
- This formula can be rearranged to say:

Ft=mv−mv Impulse Gain in momentum

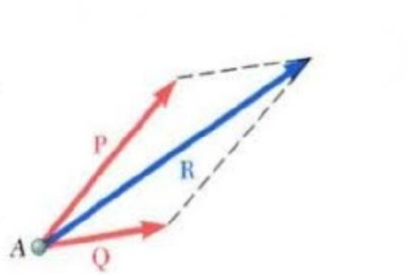
- Impulse is really just the change in momentum.
- Momentum is conserved when two objects collide. Their sum remains the same:

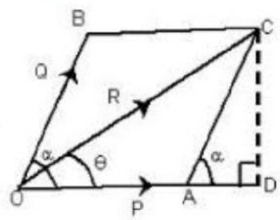


- This can be given from the formula
  (m1×v1)+(m2×v2)=m1v+m2v
- V is constant as the final velocity will remain the same:
- All this confirms Newton's 2nd Law.
- Finding resultant forces between objects directly horizontal or vertical) is simple addition/subtraction



- The resultant forces of angular forces is found by the Parallelogram we:





When two forces act at a point.
When two forces act at a point, their resultant is found by the law of parallelogram of forces.
The magnitude of Resultant force R
$R=P2+Q2+2PQcos\alpha$
The direction of Resultant force R with the force P
$\theta=tan-1(Qsin\alpha P+Qcos\alpha)$

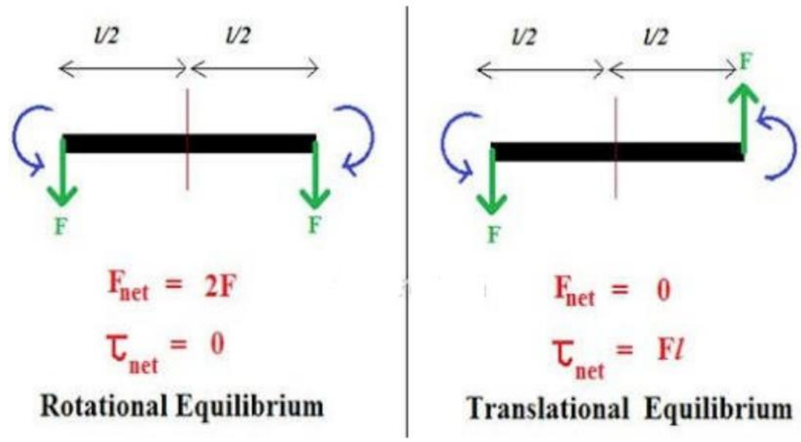
- Two forces can also be acting on the same object. If the object is straight, it is in a state of equilibrium, where the clockwise and anfi-clockwise moments are equal. A moment of a force is a measure of the turning effect of the force about a particular point. It is found by:

Moment = force × distance (Nm) (N)(m)

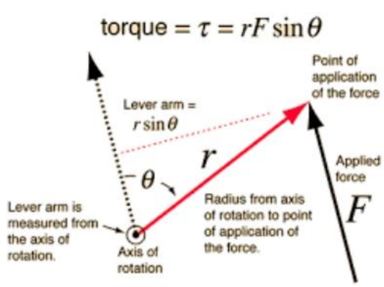
Example of Equilibrium:

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim



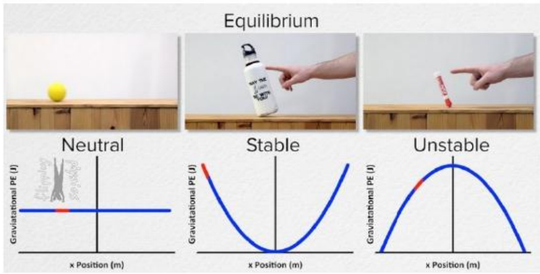
- For equilibrium, the sum of forces in one direction must equal those of the other direction. Plus, the principe of moments must apply.
- Using, the principle/concept of moments, couples are created? These are long, parallel yet opposite forces.



- The moment amount of a couple is called its torque.
- Considering the rules for equilibrium, there ore different forras of stability. These are dependent upon:
- Center of gravity: Where the weight of an object pulls.
- Center of mass: The mean position of the mass of an -object.
- There are 3 types of equilibrium:

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

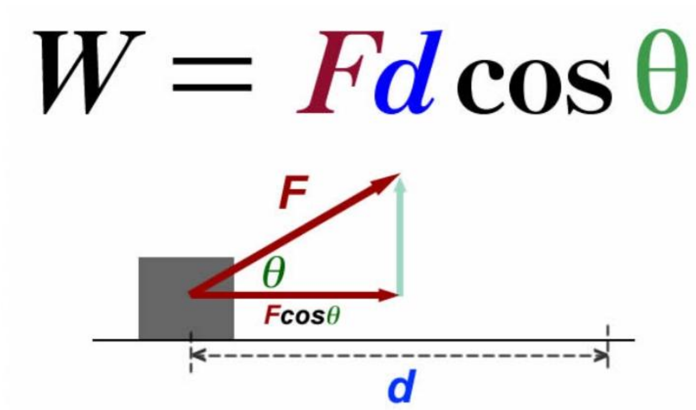


S.no	Stable equilibrium	Unstable equilibrium	Neutral equilibrium
1	Net force is zero	Net force is zero	Net force is zero
2	$dU/dr = 0$ or slope of U-r graph is zero	$dU/dr = o$ or slope of U-r graph is zero.	$dU/dr=0$ or slope of U-r graph is zero.
3	When displaced slightly, from its equilibrium position a net restoring force starts acting on the body which has a tendency to bring the body back to its equilibrium position.	When displaced slightly from its equilibrium position, a net force starts acting on the body which moves the body in the direction of displacement or away from the equilibrium position.	When displaced slightly from its equilibrium position the body has neither the tendency to come back to original position nor to move away from the original position.
4	Potential energy in equilibrium position is minimum as compared to its neighboring points or $d^2U/dr^2 =$ positive	Potential energy in equilibrium position is maximum as compared to its neighboring points or $d^2U/dr^2 =$ negative	Potential energy remains constant even if the body is displaced from its equilibrium position. points or $d^2U/dr^2 = 0$
5	When displaced from equilirbium position the centre of gravity of the body goes up.	When displaced from equilibrium position the centre of gravity of the body comes down.	When displaced from equilibrium position the centre of gravity of the body remains at the same level.

- Work (in Physics) is done when a fore produces movement. The SI unit for work is Joule. It can be found by:

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim



Work = The product of the component of the Force in the direction of the displacement

Work (Joules) = Force (N) x Distance (m)

- To work, everything needs energy. The re are different types of these:
- Thermal : Heat
- Kinetic: Moving
- Potential : stored
- Electrical: Relating to current
- Chemical: Relating to chemicals
- Kinetic energy is created when particles collide with one another, causing effective collision. This process can be sped up by providing more heat to the particles reducing their masses,kinetic energy can be determined using the formula:

Kinetic Energy =1/2mv2

- Potential energy is the stored energy and is found by:

Potential Energy =mgh

- Energy cannot be created or destogel, it only converts into other forms. After the work is done, the energy is subsequently transferred
- The energy crisis has taken a step forward in the whole world, for which, new methods have to be come up with. But they are releasing carbon dioxide and causing Climate Change (see IDU topic).

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

The power of any energy source is the rate at which it gets work done. It can be measured by:

Power = work done/ time = energy transfered time

- It is measured by watts (w)
- In motion examples, it is true that:

Power = force × velocity

- The efficiency of an energy source is hence also measured by:

  Power output/ Power input in percentage.

Unit 4: Waves

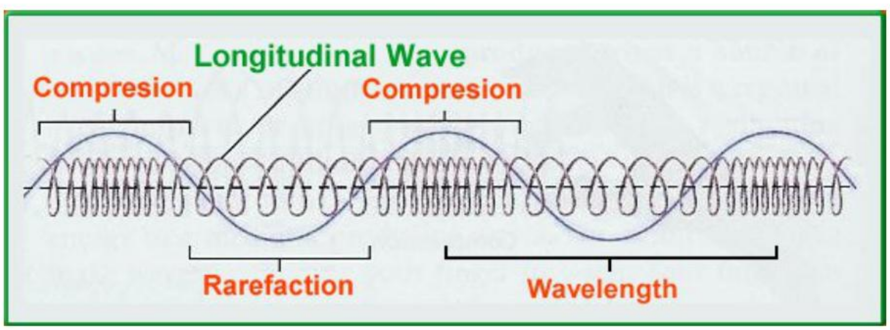
WAVES

- Waves are mediums of transferring energy without particles. In layman's terms, they are disturbances propagating through space.

Two types of waves:

- Longitudinal (coils move horizontally)
- Transverse (coils move vertically)

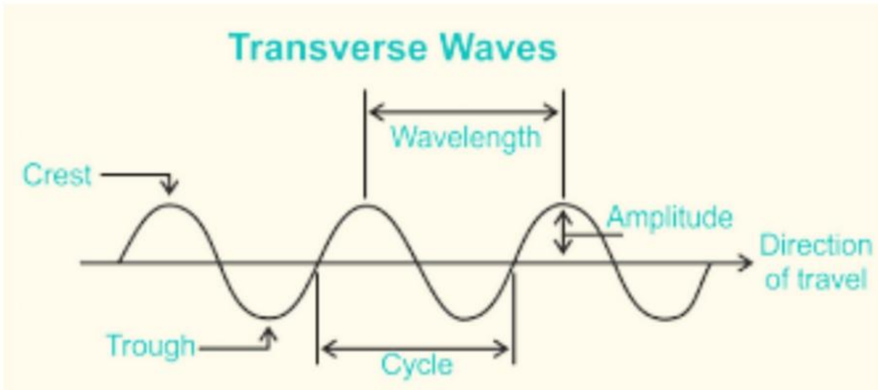
Longitudinal Wave:



Transverse wave:

MYP5 – Physics/ Grade 10 revision material

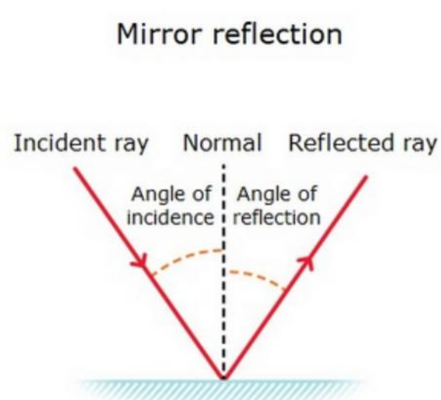
Prepared by Dr. Nassim



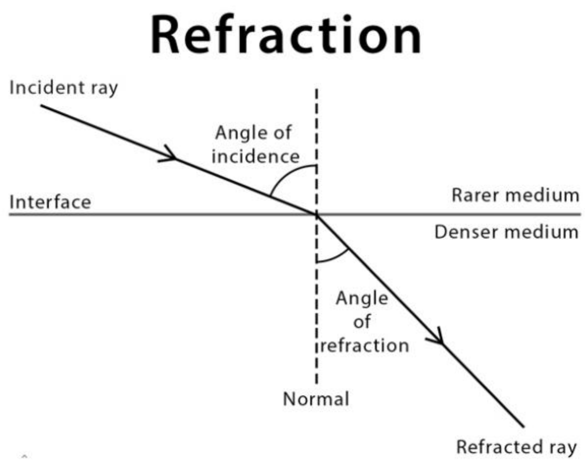
- The wavelength is the distance from one point to the same in the next oscillation. (length of an oscillation) –λ
- The amplitude is the distance from the maximum minimum point to the mean line.
- The time period of a wave is the time taken for an oscillation. The frequency (H2) is the number of oscillations in one second. They are inversely proportional.

T=1f,f=1T

- There are 4 main phenomena of waves. These are as follows:
- Reflection is the bouncing of of a wave off a mirror-like substance. Specular reflection takes place when the mirror surface is smooth. Here, the angle of incidence = angle of refraction.



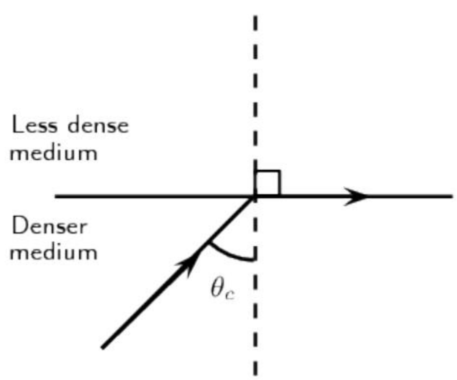
- Refraction is the bending of light due to varying speeds of Hight across different mediums.
- If the speed is faster, the ray will move away from the normal line.



- To find the refractive index, use:

$n=cV$ or $n=\sin\theta1\sin\theta2$
c= speed of light in medium

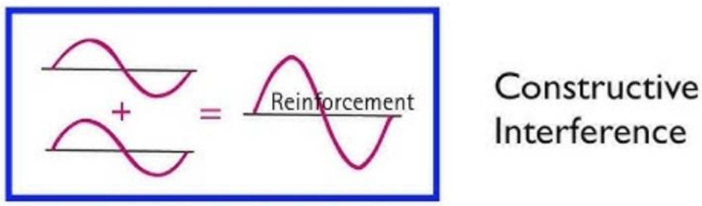
- The critical angle is the angle at which, if light refracts, it becomes straight.



- The third phenomenon is interference. There are two types of interference (waves interacting with other wavers):

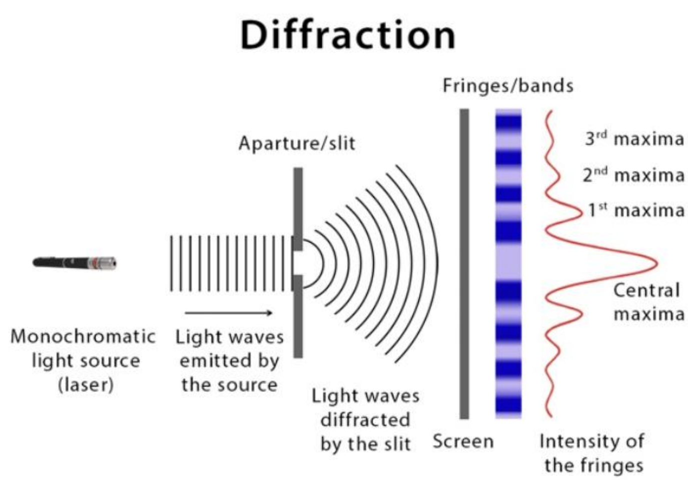
- Constructive interference is crest on crest and trough an trough. This causes a bigger wave to be produced as a result. Destructive interference is crest on trough and vice versa. This causes a smaller wave or no wave at all as the net result.

(1)- constructive interference



(2) – Destructive interference

The last phenomenon is Diffraction, which is the bending of waves as they move through a shit.



MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

- The optimum level of diffraction takes place when the slit's length is equal to the wavelength of the wave.
- A wave with longer wavelength has lesser energy.
- About the speed/velocty of a wave:

$V=f\lambda$ wavelength
frequency
or
$V=\lambda T\rightarrow$ Time period

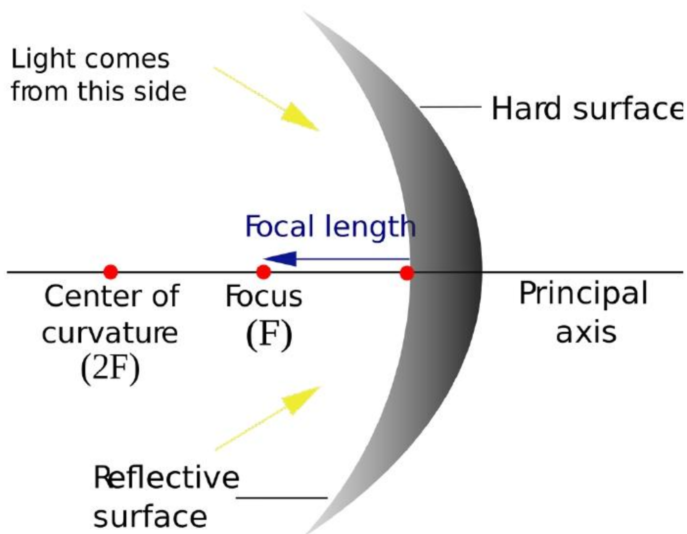
- There are several characteristics of sound. These are as follows.
- Pitch is the quality of sounds that distinguishes between grave and shrill sound. pitch is directly proportional to the frequency.
- Quality in a sound is when two sounds have the same amplitude and frequency, but different wave patterns (such as flutes and pianos).
- Intensity is the sound energy transmitted per unit area, which is held perpendicular.
- Amplitude is directly proportional to energy, whereas wavelength is inversely proportional to energy
- How loud a sound depends on 5 factors:
- Intensity
- Amplitude
- Surface Area of vibrating body.
- Sensation of your ear
- Distance from vibrating body.
- For the intensity of a wave:

Intensity = Power Area

- Waves can help in imaging as well. There are 2 types of mirrors:
- Concave converges
- Convex Diverges

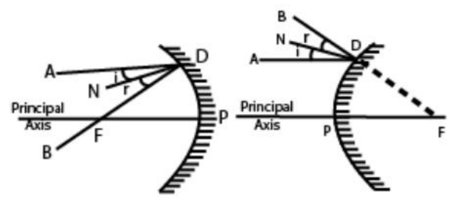
REMEMBER : CAPTAIN COLD VALUED DIAMONDS

Example of Concave Mirror

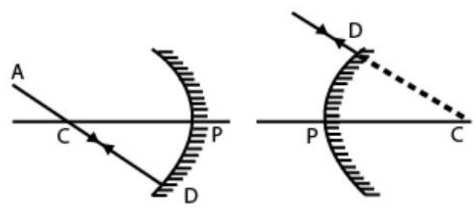


Types of rays + Appearances

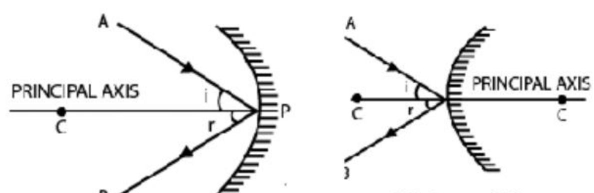
Prepared by Dr. Nassim



(a) Concave Mirror (b) Convex Mirror

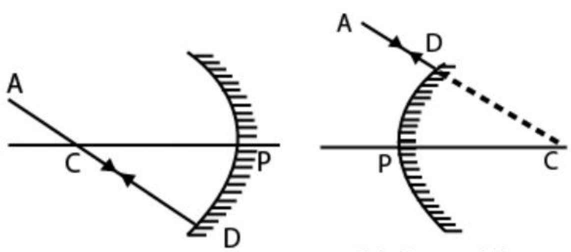


(a) Concave Mirror (b) Convex Mirror



(b) Convex Mirror

(a) Concave Mirror



(a) Concave Mirror (b) Convex Mirror

- For ray diagrams:
- p is the object distance

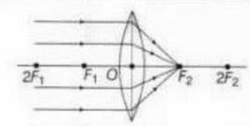
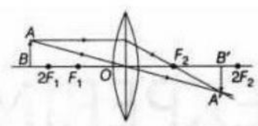
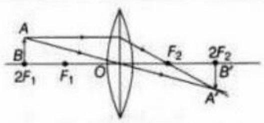
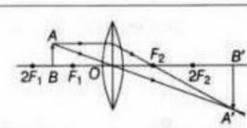
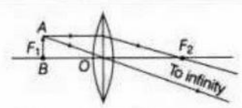
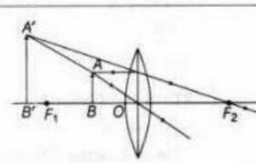
- q is the image distance.
- f is the focal length
- 1p+1q=1f= Power of lens
- ·qp=HiH0= Magnification

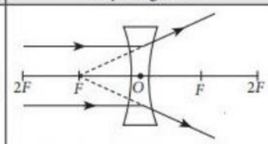
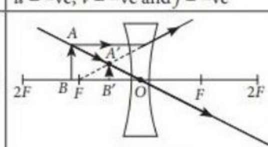
Image formed by a convex mirror

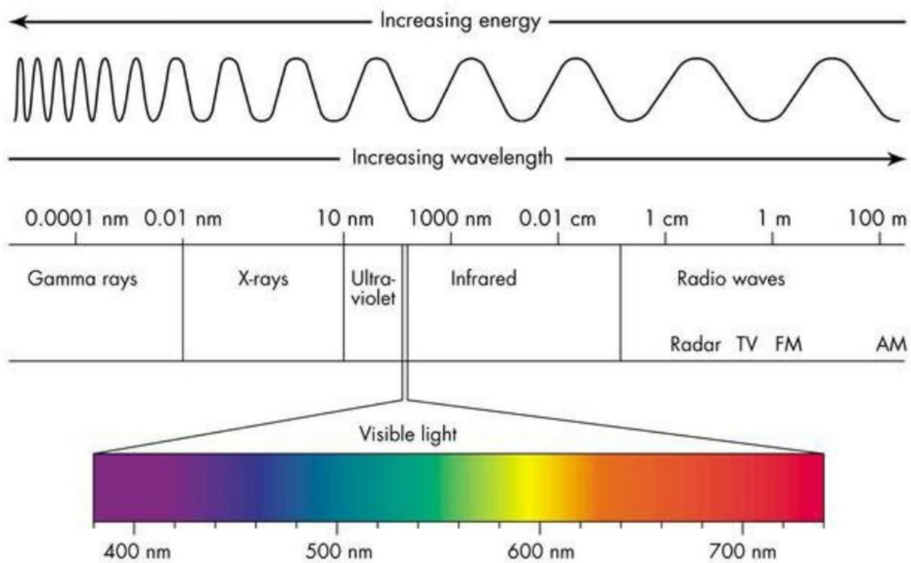
Position of the Object	Position of the Image	Image Size	Nature of the Image
At infinity	At F	Highly diminished, point sized	Virtual and erect
Between infinity and the pole (P)	Between P and F	Diminished	Virtual and erect

Image formed by a concave mirror

Position of the Object	Position of the Image	Image Size	Nature of the Image
At infinity	At F	Highly diminished	Real and inverted
Beyond C	Between C and F	Diminished	Real and inverted
At C	At C	Same size as the object	Real and inverted
Between C and F	Beyond C	Magnified	Real and inverted
At F	At infinity	Highly magnified	Real and inverted
Between F and P	Behind the mirror	Magnified	Virtual and erect

Position of object	Position of image	Size of image	Nature	Ray diagram
At infinity	At F_2	Extremely diminished	Real and inverted	
Beyond $2F_1$ (at finite distance)	Between F_2 and $2F_2$	Diminished	Real and inverted	
At $2F_1$	At $2F_2$	Same size	Real and inverted	
Between F_1 and $2F_1$	Beyond $2F_2$	Magnified	Real and inverted	
At F_1	At infinity	Highly magnified	Real and inverted	
Between lens and F_1	On same side of object	Magnified	Virtual and erect	

Concave lens				
	Ray diagram	Position of object	Position of image	Nature of image
(a)	 $u = -\text{ve}$, $v = -\text{ve}$ and $f = -\text{ve}$	At infinity	At F	Virtual, erect and highly diminished
(b)	 $u = -\text{ve}$, $v = -\text{ve}$ and $f = -\text{ve}$	Between infinity and O	Between F and O	Virtual, erect and diminished


Increasing energy
Increasing wavelength
0.0001 nm
0.01 nm
10 nm
1000 nm
0.01 cm
1 cm
1 m
100 m
Gamma rays
X-rays
Ultra-violet
Infrared
Radio waves
Radar
TV
FM
AM
Visible light
400 nm
500 nm
600 nm
700 nm

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

ELECTRICITY AND MAGNETISM

- Charge is the tendency of atoms to attract other objects. A charge belongs to an. ion, or a charged particle. An atom gets charged by loosing or gaining electrons:
- Coulombs's law deals with the intermobular forces of attraction, and the repulsion. between objects.

F∝q1q2
F=Force
q1q2=charge

The more the force of attraction, the more the product of the charges.

F∝1r2

r2→ Distance

e force is inversely proportional the distance squared.

F=Kq1q2r2

k= Coulomb's constant

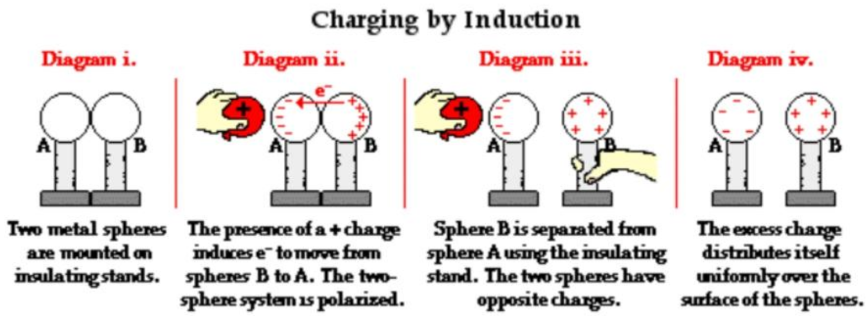
coulomb's constant is approximately 9×109 for air. Its the electric ce constant.
the force is increased, the rage will increase too.
; should be noted that Coulomb' stant varies across different diums. For instance, it is lower paper.

- Static electricity is the charge in stationary (resting) objects. When an objet rubs against something, due to heat, the electrons have enough energy to escape the object (abject A, as it can be called). The free electrons stick to another object (we can refer to it as object B). Hence, object A is positive, while B is negative- when they both come into contact, a spark follows, and both objects become neutral.
- Electrostatic induction is the. phenomenon in which, in a presence of a charged body, the charges on the insulator lother body are distributed in asuch a way that like charges come on one side, while unlike charges come on the other end.

Electrostatic induction:

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

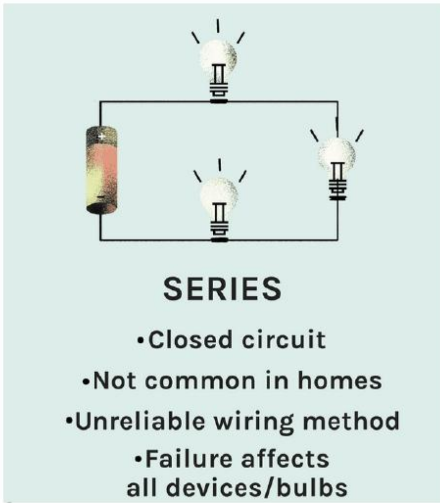


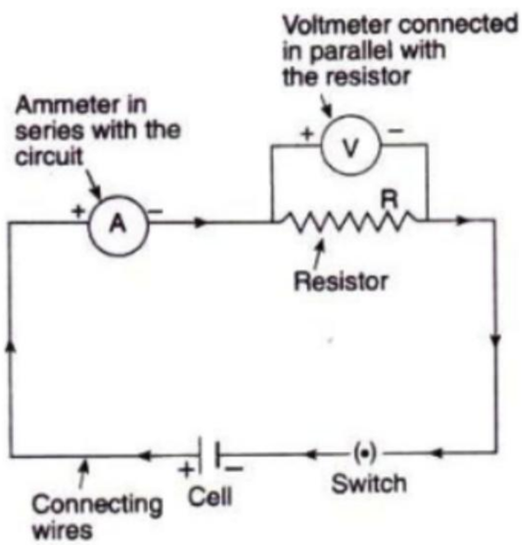
word “electrostatic” means having – with electric charges/ fields of brionary objects.

circuit is an enclosed path through electricity flows. On the other, current is the rate of flow negative/positive charges. Current easured by an ammeter in eres(A).

- Electrons flow in a circuit that carry energy. The nucleus of an atom, inside a circuit serves no purpose. However, if it becomes unbalanced, the substance can become radioactive.
- There are 2 types of circuits:
- Series: Only one path in which
- current electricity can flow through.
- Parallel: Multiple paths.

Example of series circuit:





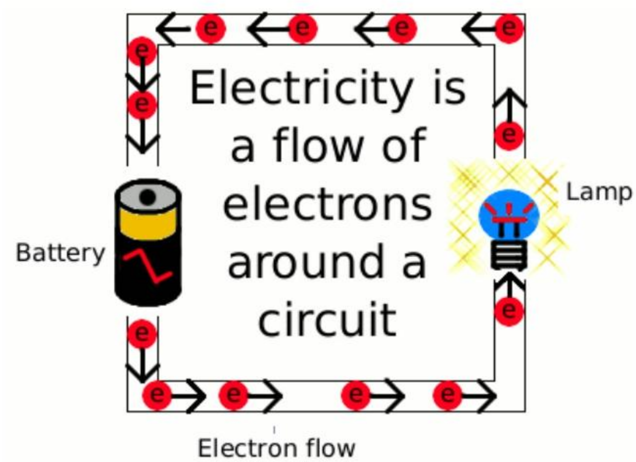
- Series circuit, the voltage gets across different resistors, the current stays constant. voltage is defined as the energy that is consumed. It can also be the difference between two points, or the work done or energy given to a charge in moving from a point to another against the field. Electric potential is the same. Findable using. (v)

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

VB−VA= Energy (Work Done) q→ charge

- Resistance is the opposition to the flow of charges.
- should be noted that electrons are actually consumed in a series is it. The following is what actually happens:



- So, over usage of a battery causes it to drain.
- Current, voltage and Resistance are inter-relatable using Ohm's law:

I=VR

V→ vollage

C→ current

R→ Resistance

and the equivalent resistance in a is circuit, use:

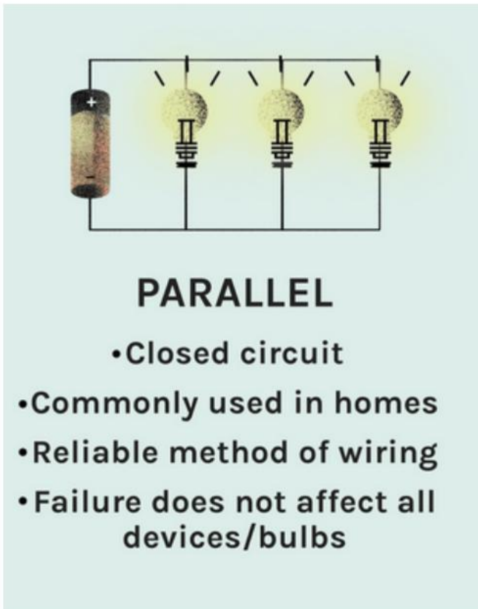
VT=R1+R2+R3+⋯

addition, Power of a circuit can calculated using: (measured in Watts)

VI or P=V2R or P=I2R

- transistor is the tool that provides ristance to a circuit. It basically converts electrical energy into heat energy. It divides the electric potental. circuit divider is called the initial divider.

Example of parallel circuit:



- To find the equivalent resistance in a parallel circuit:

1RT=1R1+1R2+1R3+⋯

- Electromotive Force (EMF) is the energy that is supplied by a battery to a unit coulomb charge. It is only the energy, not actually a force.- Super conductivity is the ability of "superconductors" to conduct electricity without any resistance whatsoever. They can only, however do this in low temperatures. This is because if this is the case, then there shall be lesse kinetic energy (due to the particles having lesser energy). The other condition, apart from low temperatures, is the current being AC current (Altemating Current). Only metals can be sup erconductors, since they have a whole sea of mobile electrons. Hence they have more electronmobility. This means that the electrons are able to move about more freely.
- Electromagnetic refers to an thing. that has to do with the phenomenon of the interaction of electric currents or fields and magnetic fields.
- Electromagnetic Induction is the ability of a magnetic field to create current inside a conductor. A change in magnetic field causes current to be created. It causes the production of an EMF across an electric conductor in a changing magnetic field.

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

- Magnetic flux is a measurement of the total magnetic field which passes through a given area. Faraday's Law States that a change in magnetic flux can induce an EMF.

Faraday's Law:

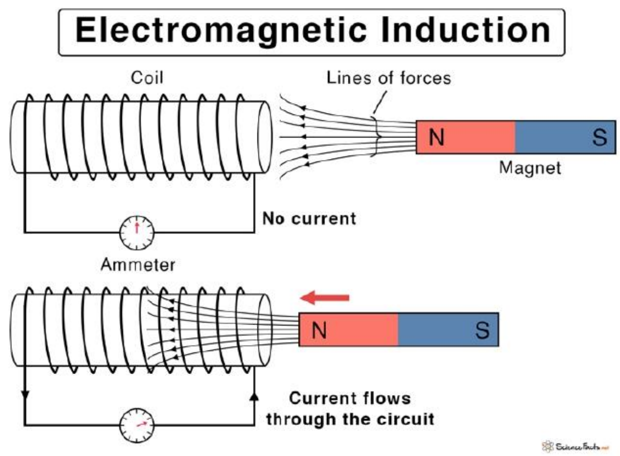
N=ΔΦΔt

ΔΦ→ change im magnetic flux

Δt→ change in time

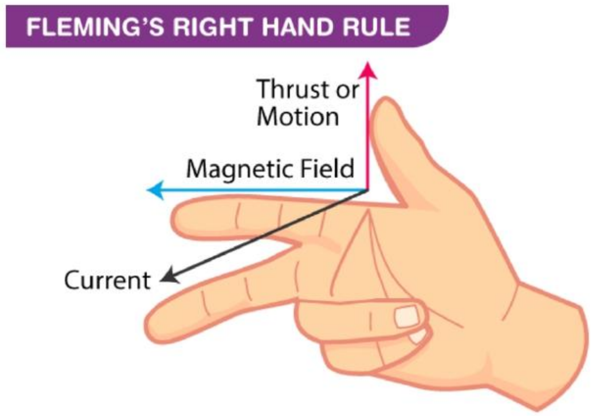
N→ induced EMF

- Diagram of this process:

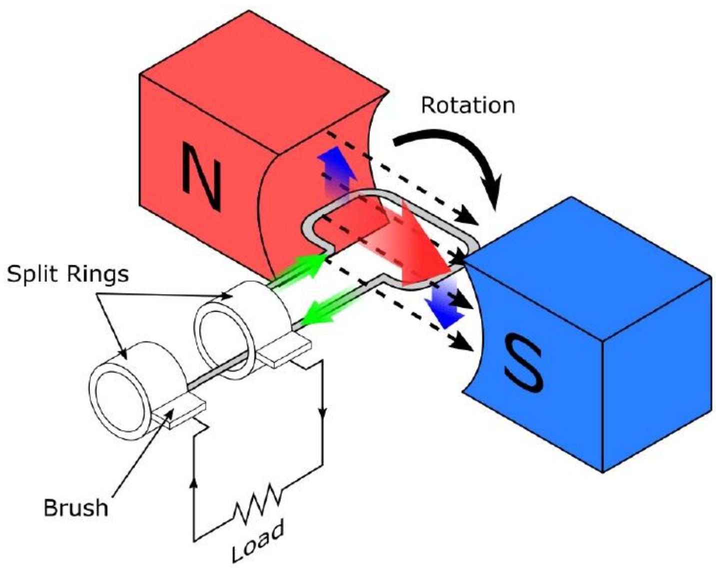


- The electrons move back and forth. Adding the magnet sends the reading in t, but then retums to zero. Once pulled out, it goes into – . This is due. to the changes in magnetic flux. If the magnet is pulled back and forth the electrons will travel that way too, producing an emf. The graph of the emf will look similar to that of y=sinx.
-
- Factors affecting this process:
- Strength of magnet: Higher will cause higher emf.
- Number of coils. Higher will cause high her emt.
- Lenz's Law states that the direction of an induced current is always such as to oppose the changes in the circuit or the magnetic field that produces it (perpendicular to it)

Fleming's right-hand rule confirms this:

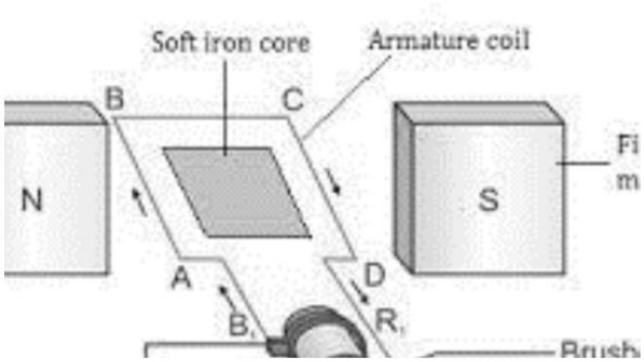


- On the principles of electromagnetic induction, electricity can be produced on very large scale. All that is needed is a huge rotor and magnet.
- An AC generator is a rotor that spins and turns mechanical energy into electrical energy.

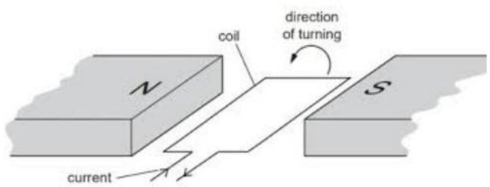


Parts of AC Generator

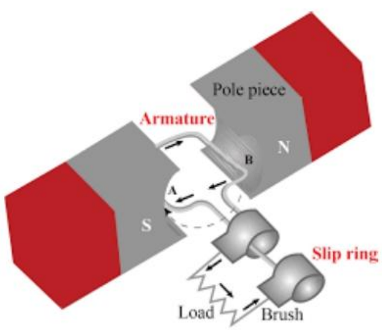
(1) Armature



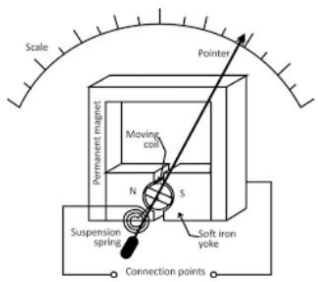
(2) Rectangular coil with many turns



(3) Slip rings (rotate with armature)



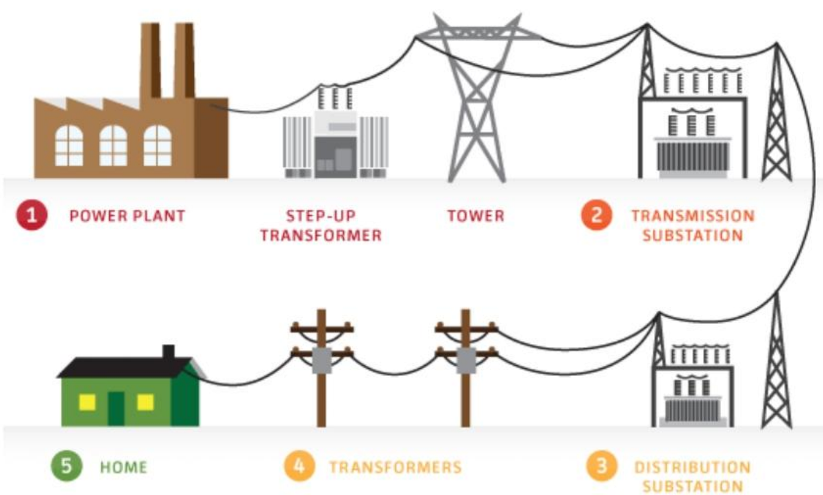
(4) Galvanometer/Load



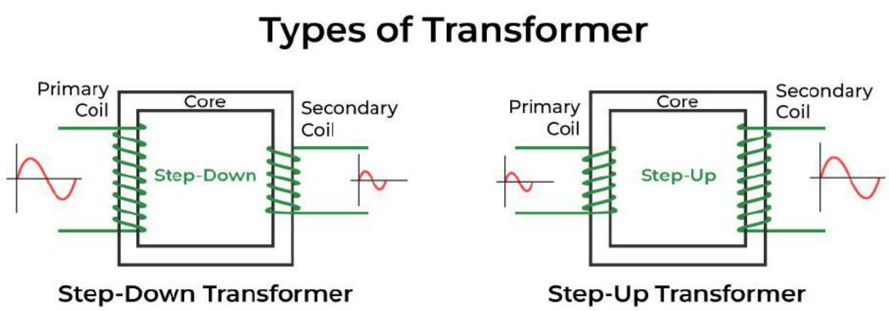
- AC (Alternating current) is different from DC (Direct Current).

Alternating Current	Direct current
Source : Electromagnetic Induction	Source: Batteries. Solar Power etc.
Fluctuates	Constant
Electrons move back and forth	Electrons only Move in one direction
Both positive and negative	Only po vive
Dangerous	Harmless
Good for long -range transportation through power grid	Not good tor song range transportation
Efficiently used in transformers	Inefficiently used in transtormets.

How electricity is distributed:



- Transformers are devices that increase decrease voltage. There are 2 types:
- Step-up: Increase voltage tor long-distance traveling.
- Step-down: Decrease voltage so it is usable in homes etc.



MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

ASTROPHYSICS

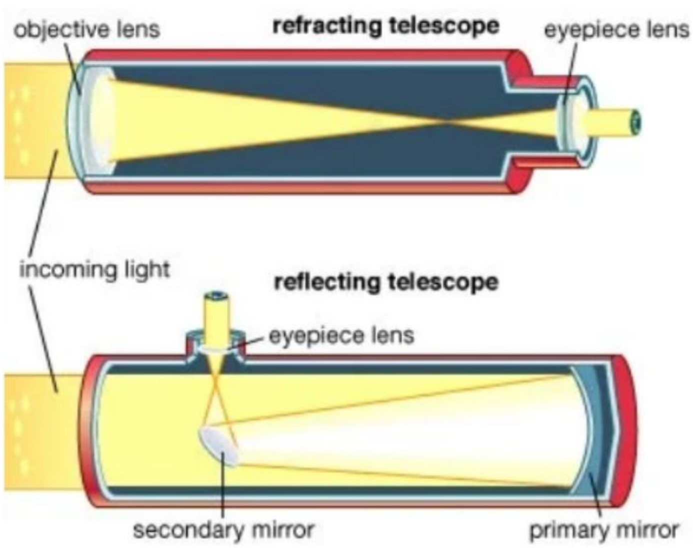
- Astrophysics is the study of stars, planets, moons and other celestial bodies, including their satellites.
- Celestial bodies include stars, planets, moons, satellites etc.
- Stars are huge masses of fire that are constantly burning. They fuse gasses and pro vide light and heat.
- Planets are, according to the International Astronomical Union, celestial bodies that:
- Orbit a star around a circular/ovalthike path.
- Are (nearly) round
- Are not any other planet's moon
- Do not have debris around their orbit.
- There are an estimated 1024 planets in the observable universe. There are 2 types of planets:
- Terrestiali small and Rocky
- Jovian: Giant, made of gasses
- There are 36 sub-categories of planets.
- Terrestrial planets have a smaller size and mass. They have a heavy molten core and topological features like volcanoes and craters. Examples inclu de Earth. Mars etc. They make up the inner part of our Solar System. They are rocky.
- Jovian Planets have larger sizes. They only have small amounts of rooks in cores, and are mostly made of gasses (Hydrogen and telium in atmosphere. They include Jupiter, Saturn etc. (outer planets).
- All planets revolve around a star and rotate on different axes. scientists stay that planets continue to rotate in the same manner in which they were when they collided, due to inertia.
- Dwarf Planets are the same as normal Planets, except they have debris in their outer surroundings.
- Scientists say planets were formed by the collision and vibration of rocky substances. Due to their great masses, they turned circular.

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

- A satellite is a moon, planet or star that orbits a planet or star. Moons are generally regarded as “Natural satellites”.
- There are many types of satellites:
- Natural Solellifes → Naturally orbit stars or planets
- Low Earth Orbits →160 km away from Earth. Complete an or bit in 90 minutes. Used by military to locate tanks.
- Geosynchronous →24 hours for an orbit. Used for communication at high altitudes.
- Geo stationary → majority of communication satellites Orbit once in 24 hours, 14788 km above the Earth.
- Sun-synchronous →15–16 orbits daily. They in polar orbits make weather predictions, being fixed relative to the sun.
- Satellites work by reflecting signals back to barth. An uplink is sent from earth to the satellite, after which data is processed. Transponder’s are used to avoid incoming and outgoing signals. Finally, a downlik is used to send the data from the Satellites back to Earth.
- Everything, according to the Big Bang Theory, came into existence about 13.7 billion years ago. It says that at the time there was infinitely dense and small “dot” that “burst “into existence. It also states that all galaxies are spreading apart from one another. After the do “burst”, it was spreading. There was no actual explosion, just the stretching of the universe. That dot stretched into gluons, then quarks, and matter was able to “triumph over antimatter. Then, the yessential forces were formed (Electromagnetic, Strong \& weak Nuclear and gravity).
- Within 10–9 seconds of the event, the universe was already a billion km in diameter. Quarks Started producing neutrons and protons. Within a second, the universe had already spreat over a 100 billion km, and synthesized the first atom -Hydrogen. It was around 10 billion’ C at the time. within a few minutes, atoms formed stars, ga laxies, planets etc.
- Some people question as to what existed before the Big Bang. It is important that we understand that the Big Bang did not just create Space, but Space – Time. Meaning that time did n ot exist before the Big Bang.
  “Scientists “travel back inline” to the Big Bang using the Redshift Theory. This suggests that as.

- galaxies spread out, their wavelengths become larger. Scientists reversed this to "see in the past"
- A telescope is an optical instrument that makes distant objects (celestial) bodies) appear to be nearer. It contains an arrangement of lenses and mirrors, and focuses rays onto one point. Types of telescopes.
- Astrograph: for photographing distant astronomical objects
- Comet Seeker: Searching co mes
- Go To: Automatically points to distant objects /celestial bodies.
- Infrared Uses infrared rays.
- Etc.
- There are two main categories of telescopes: Refractive and Reflective.



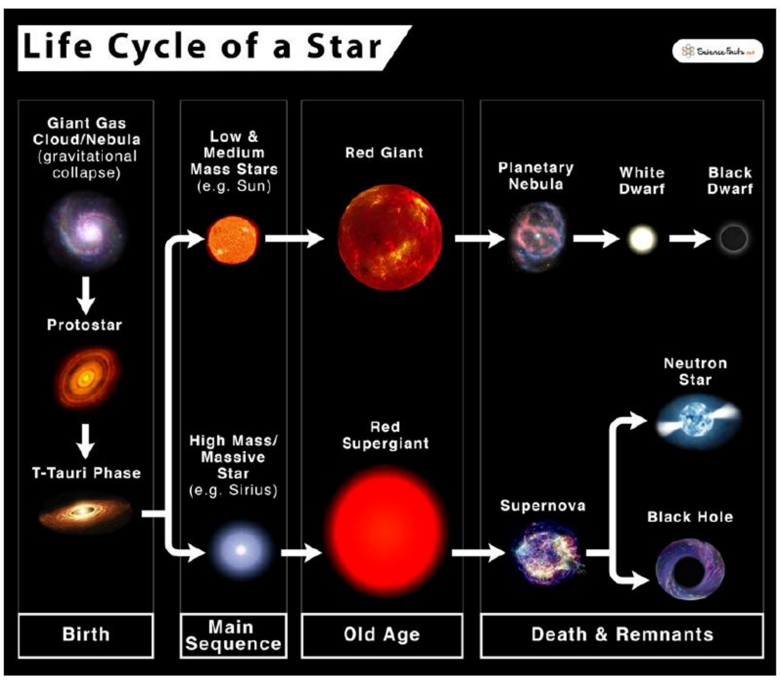
- A telescope basically works by gathering light. The "ob jective" is the lens that collects light. The bigger it is, the more light is collect ad. If there is more light, one can see far then.
- **Solar system (4.5 billion years old):**

MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

- Mercury, Venus, Garth, Mars, Asteroid Belt, Jupiter, Saturn, Uranus and Neptune.

Life Cycle of a star:



MYP5 – Physics/ Grade 10 revision material

Prepared by Dr. Nassim

Practice questions on covered topics: criteria A

1- **Define the term "refraction" and explain the conditions under which it occurs. Provide an example from everyday life where refraction is observed.** (3 marks)

Answer: Refraction is the bending of waves as they pass from one medium to another, caused by a change in their speed. It occurs when a wave crosses the boundary between two media at an angle other than 90 degrees. One common example of refraction in everyday life is the apparent bending of a pencil partially submerged in a glass of water.

2- **Describe how the speed of light changes when it enters a medium with a higher refractive index. Use an equation, if necessary, to support your answer.** (3 marks)

Answer: When light enters a medium with a higher refractive index, its speed decreases. The relationship between the speed of light in a vacuum (c), the speed of light in the medium (v), and the refractive index (n) of the medium is given by the equation $v = c/n$. As the refractive index increases, the speed of light in the medium decreases proportionally.

3- **Calculate the wavelength of a sound wave with a frequency of 500 Hz, traveling in air at room temperature (approximately 20°C). Assume the speed of sound in air to be approximately 343 meters per second.**

4- **This question is about thermal physics**

a. Match the words with the correct definitions (1 mark)

Convection It is a method of heat transfer that does not require a medium or direct contact. It involves the emission and absorption of electromagnetic waves, primarily in the form of infrared radiation. Conduction It is a method of heat transfer that occurs through direct contact between particles or objects. Radiation: It is a method of heat transfer that involves the movement of fluids (liquids or gases).

b. What are the units used to measure temperature and heat? (2 marks)

c. Consider a solid metal rod of length L and cross-sectional area A. The rod is initially at a temperature T1 and is heated until it reaches a final temperature T2. Explain the concept of thermal expansion and how it relates to the change in length of the rod. (4 marks)

2. a) Define the term "refraction" and explain the conditions under which it occurs. Provide an example from everyday life where refraction is observed. (3 marks)

Answer: Refraction is the bending of waves as they pass from one medium to another, caused by a change in their speed. It occurs when a wave crosses the boundary between two media at an angle other than 90 degrees. One common example of refraction in everyday life is the apparent bending of a pencil partially submerged in a glass of water.

b) Describe how the speed of light changes when it enters a medium with a higher refractive index. Use an equation, if necessary, to support your answer. (3 marks)

Answer: When light enters a medium with a higher refractive index, its speed decreases. The relationship between the speed of light in a vacuum (c), the speed of light in the medium (v), and the refractive index (n) of the medium is given by the equation $v = c/n$. As the refractive index increases, the speed of light in the medium decreases proportionally.

c) Calculate the wavelength of a sound wave with a frequency of 500 Hz, traveling in air at room temperature (approximately 20°C). Assume the speed of sound in air to be approximately 343 meters per second. (4 marks)

Answer: 0.686 m Explanation: To calculate the wavelength of a sound wave, we can use the formula: Wavelength (λ) = Speed of sound (v) / Frequency (f) Given: Frequency (f) = 500 Hz Speed of sound (v) = 343 m/s

Criteria B and C : Sample of student's work

1. Title: *Investigating how changing the length of the string (20, 25, 30, 35, 40) of the pendulum (cm) affects the time taken for the pendulum to complete 1 oscillation (s)*
2. Variables:
   Independent Variable: *Length of the Pendulum String (20cm, 25cm, 30cm, 35cm, 40cm)*
   Dependent Variable: *The time (seconds) it takes for the pendulum ball to oscillate, measured using a stopwatch*

   Control Variables Table:

Table 1, Control Variables Table

Controlled Variable.	Units	Why Should It Be Controlled?	How Will It Be Controlled?	Have you included it i the method?
Angle of Origin	Degrees	If the angle at which the pendulum is dropped is not controlled, the results will be affected, leading to errors. This is due to the fact that a pendulum swinging through a big angle feels the pull of gravity for a longer amount of its swing than a pendulum swinging through a small angle, which causes the large pendulum to swing rapidly.	The angle at which the pendulum is dropped each time will remain the same for each trial in order to maintain control over the angle of origin throughout this experiment (90 degrees).	Yes
Person with the stopwatch	n/a	If the person holding the stopwatch is changed throughout the experiment, then the results would turn out to be imprecise, due to reaction time. Each person has a different reflex time which could result in e.g., a person's reflex time being (0.2 – 0.4) or another person's reflex time would be (0.3 – 0.5).	To ensure the person holding the stopwatch stay's controlled throughout the experiment, before the experiment is conducted, only 1 person will be assigned to hold and measure the time using the stopwatch throughout the entire experiment.	Yes
Force of Origin	Newtons (N)	The amount of time it takes for the pendulum to oscillate would vary for each trial if the force of	In order to maintain control over the force of origin throughout the experiment, the force will remain at 0N and simply be	Yes

		origin were altered throughout the experiment.	dropped at 90 degrees without providing any force to the pendulum ball.	
Person dropping the Pendulum	n/a	If the person dropping the pendulum is changed throughout this experiment, then the force of origin would be changed which would affect the time it takes to complete a full oscillation.	To ensure the person dropping the pendulum stay's controlled throughout the experiment, before the experiment is conducted, only 1 person will be assigned to drop the pendulum throughout the entire experiment.	Yes
State of external environment	n/a	It is likely that the momentum and speed would be affected by the experiment's changing external environment, causing results to be less exact.	To ensure that the state of external environment is kept controlled throughout this experiment, the experiment will take place in the same area for each trial, closing all windows to ensure that any wind doesn't affect the data.	Yes

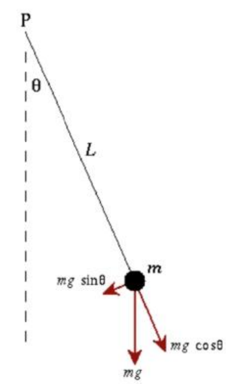
3. Research Question
How does changing the length of the pendulum string (20, 25, 30, 35, 40) in centimeters (cm), affect the time it takes to complete a full oscillation (s), measured using a stopwatch, while keeping the height of the retort stand holding the pendulum ball, mass of the bob, the angle of origin and the same person dropping the pendulum the same throughout the entire experiment?

4. Background Information

What is Oscillation?
Oscillatory motion is defined as a motion that repeats itself. A restoring force causes an object in such motion to oscillate around an equilibrium position. No matter which direction the system is displaced, such force tends to restore the system to its equilibrium position. Many phenomena, such as electromagnetic waves, alternating current circuits, and molecules, rely on this motion.

What is Oscillation in a Pendulum?
A simple pendulum is a relatively heavy object hung by a string from a fixed support. In its equilibrium position, it usually hangs vertically. The massive object is known as the pendulum bob. When the bob is shifted out of equilibrium and then released, it begins to

swing back and forth around its fixed equilibrium position. The motion is regular and repetitive, demonstrating periodic motion.

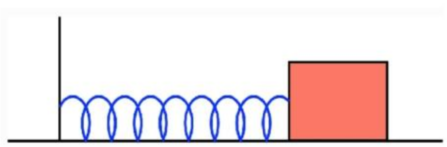


(Figure 1, oscillation of a simple pendulum)

A simple pendulum is made up of a ball (point-mass) m hanging from a (massless) string of length L and fixed at a pivot point P. When displaced to an initial angle and released, the pendulum swings back and forth with periodic motion. The equation of motion for the pendulum can be obtained by applying Newton's second law for rotational systems. The formula for this is:

$$\tau = I\alpha \quad \Rightarrow \quad -mg\sin\theta\, L = mL^2\,\frac{d^2\theta}{dt^2}$$

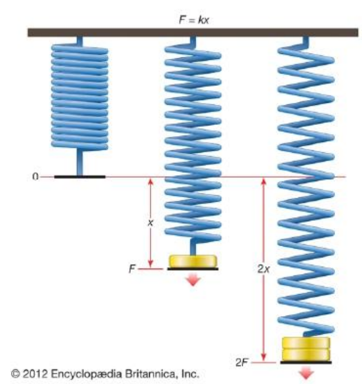
Which can also be written as: -d2θdt2+gLsinθ=0



(Figure 2, example)

Consider a mass m block attached to a light spring with a spring constant k that is fixed at one end. Assume the system is lying on a frictionless horizontal surface. Hook's law gives the restoring force exerted by the spring on the block for small displacements.

What is Hooks law?



(Figure 3, explaining Hooks law)

Hooke's law is a law of elasticity discovered by the English scientist Robert Hooke in 1660 that states that the displacement or size of a deformation is directly proportional to the deforming force or load for relatively small deformations of an object. It is the fundamental principle underlying the manometer, spring scale, and clock balance wheel. Hooke's law is the underlying principle of seismology, acoustics, and molecular mechanics.

What is Newtons Law?

Newton's laws of motion relate the movement of an object to the forces acting on it. According to the first law, an object's motion will not change unless a force acts on it. According to the second law, the force acting on an object is equal to its mass multiplied by its acceleration. The basic equation of motion in classical mechanics is Newton's second law, which states that the force F acting on a body is equal to the mass m of the body multiplied by the acceleration an of its center of mass, F = ma.

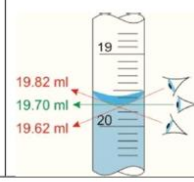
5. Hypothesis

   If the length of the string holding a pendulum (20cm, 25cm, 30cm, 35cm, 40cm) in centimeters is increased (measured using a ruler), then the time it takes for a pendulum to complete one full oscillation, measured using a stopwatch, will increase because the mass is not lifted as much when the string is longer, resulting in less energy being expended for the same displacement and as a result the pendulum swings slower.

6. Materials Table

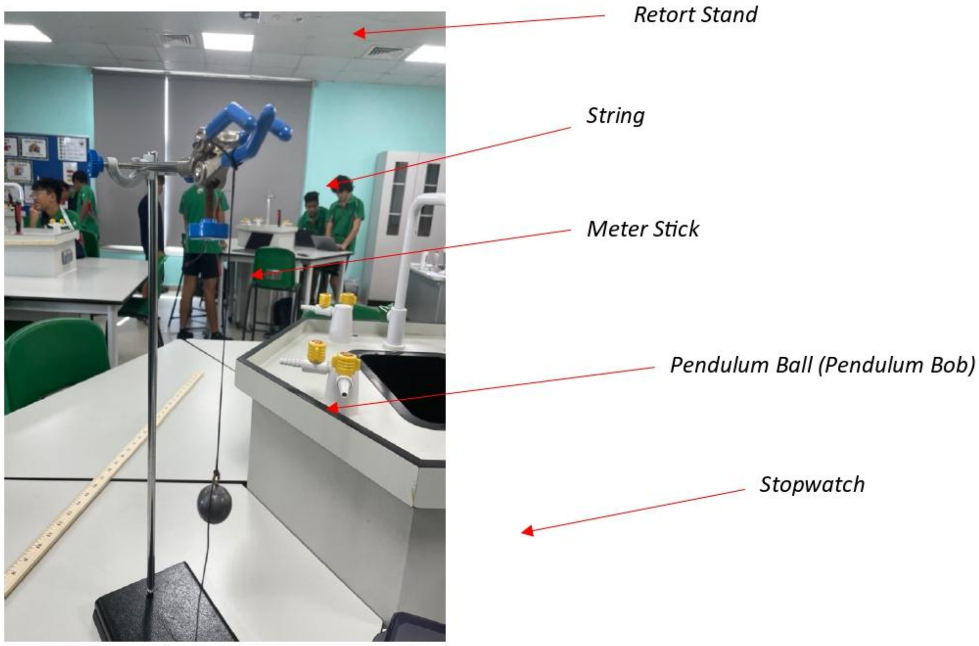
Table 2, Materials Table

Materials	Units	Quantity	Uncertainty
Retort Stand	n/a	1	n/a
Pendulum Ball (Pendulum Bob)	Grams (g)	1	n/a
String	n/a	50 centimeters	n/a
Stopwatch	Seconds (s)	1	**The uncertainty of a stopwatch is ± 0.01s seconds.** Because of the experimenter's reflex time, there is some uncertainty when measuring both the start and stopping times (as much as 0.2 s each, i.e., resulting in 0.4 s). As the total time measured increases, the percentage uncertainty represented by this 0.4 s decreases. Another uncertainty example is for example, in this picture, its 3 minutes, and 53.17 seconds, but it could be 3 minutes and 53.179 seconds, which might differ the results. The same thing could happen in the experiment. *(Figure 4: stopwatch)*

			
Meter Stick (Rulers)	Centimeter (cm)	2	**The uncertainty for a meter stick is ± 0.1cm.** In addition, when using different types of rulers, there may be false measurement as the string could be slightly above or under the mark. False measurements as such can be prevented by taking our times to adjust the string and placing the ruler and string and viewing it at eye level to avoid eye parallax. An example in this picture shows that if results and measurements aren't viewed at an eye level, but are viewed at different angles, the results which will be received will be false. *(Figure 5: explaining parallax error)* 

7. Image of Set up

(Figure 6: image set up)



8. Safety, Ethical & Environmental Concerns

Table 3, Safety, Ethical and Environmental Concerns		
Risk Posed Place each new risk in its own row. Think about the equipment and the method you are using.		Precaution Taken How can you lessen the risk caused?
Safety	There are concerns that need to be considered when it comes to safety. If one is not careful with the materials and surroundings, injuries	To prevent any injuries, a practice drop should be performed first, when the pendulum is held throughout the entire drop to determine how far it will swing. Other measures that might be done to

	could occur. By dropping a pendulum ball at a 90-degree angle, oscillation is being measured. These are particularly dangerous since they can lead to bruises and scarring if someone is hit by the pendulum while it is swinging.	reduce the risk of accidents occurring, which include setting an age restriction for the experiment, having an adult monitor it at all times, tying up long hair, avoiding running around, and keeping an emergency kit in the room.
Ethical	To fit their hypothesis and data, one may modify the process or even write the fake results as data.	If in doubt, one can record the entire experiment and use it as evidence. Additionally, adult supervision must be available to monitor the student's behavior.
Environmental	n/a	n/a

9. Method

Step 1: All required materials (Retort Stand, Stopwatch, Meter stick, Pendulum Bon, String) will be collected and placed on the table in which the experiment will be conducted on. The windows of the room will be closed, to ensure State of external environment will be kept constant

Step 2: For the first range, 20cm of string will be measured from the point where it's tied on the retort stand, and tie the pendulum ball at the end of the string to that exact measurement

Step 3: To the retort stand, the string will be tied.

Step 4: Before the experiment is conducted, assign 2 people in the group, one to use the stopwatch and one to drop the pendulum. These will be kept constant throughout the entire experiment.

Step 5: Bring the pendulum up to 90 Degrees and get the stopwatch prepared for the first trial conduction

Step 6: At the same time, begin the time on the stopwatch and drop the pendulum at the same time, applying no force, simply just a drop. A group member should place their hand either at the stop of the retort stand, or at the bottom, to ensure the retort stand stays stable during the experiment.

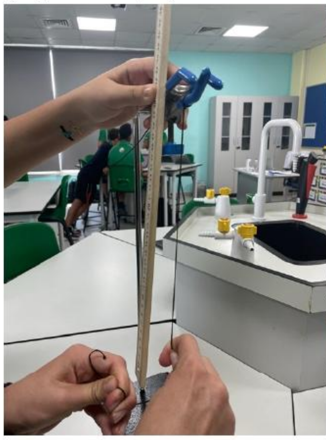
Step 7: End the timer on the stopwatch one the pendulum completes 3 full oscillations

Step 8: Divide the given time it took for 3 complete oscillations and divide it by 3, to get the answer for how long it takes to complete a full oscillation

Step 9: Steps 5-9 will be conducted for 3 trials, adding all outcomes at the end to get an average time between all trials

Step 10: For the rest of the ranges (25cm, 30cm, 35cm, 40cm, 45cm, 50cm), injuries could occur if one is not sensible with the materials and surroundings, steps 2-9 will be repeated

(Figure 7: Step 2) *(Figure 8: Step 6)*



10. Raw Data

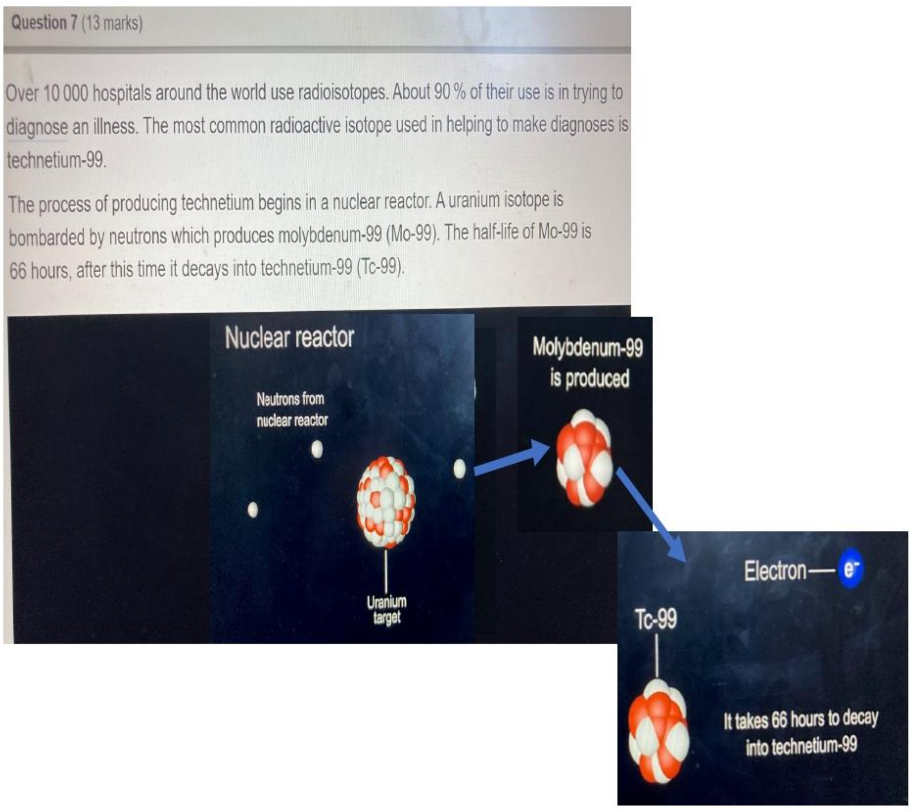
10.1 Quantitative Data

Table 4, Raw Data Table				
Length of the string holding the pendulum bob	The time it takes for the pendulum string to oscillate			
	Trial 1	Trial 2	Trial 3	Averages
20cm	1.05	1.07	0.99	1.04 seconds
25cm	1.12	1.22	1.14	1.16 seconds
30cm	1.27	1.23	1.26	1.25 seconds
35cm	1.39	1.39	1.40	1.39 seconds
40cm	1.56	1.65	1.58	1.60 seconds

10.2 Qualitative Data:

I noticed after writing down the data that the shorter the string, the quicker it takes to complete a full oscillation. Longer strings require more time to complete one full oscillation because the results were declining as the ranges were changed. This is because the pendulum with the shortest duration will also have the highest vibrational frequency. A longer pendulum will have a higher period than a shorter one, and vice versa. The pendulum with the shorter string will therefore vibrate at a higher frequency. Table 4 depicts the raw data that we gathered while conducting the experiment and illustrates this.

Question Criteria D:


Question 7 (13 marks)

Over 10 000 hospitals around the world use radioisotopes. About 90 % of their use is in trying to diagnose an illness. The most common radioactive isotope used in helping to make diagnoses is technetium-99.

The process of producing technetium begins in a nuclear reactor. A uranium isotope is bombarded by neutrons which produces molybdenum-99 (Mo-99). The half-life of Mo-99 is 66 hours, after this time it decays into technetium-99 (Tc-99).

MYP5 – Physics/ Grade 10 revision material

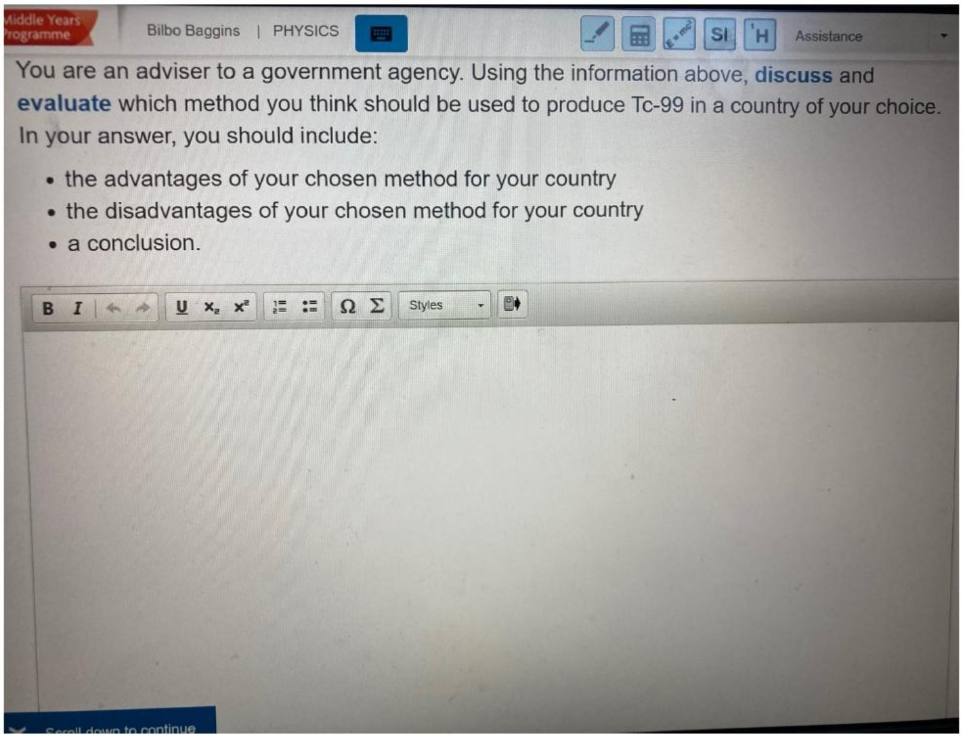
Prepared by Dr. Nassim

Tc-99 emits gamma rays which have enough energy to be detected by a gamma camera. Tc-99 has a half-life of about 6 hours. When injected into the human body, the Tc-99 allows for medically useful images to be produced.

Question 7a (2 marks)

Outline why a half-life of 6 hours is useful for producing medical images.

Hazard	Uses radioactive uranium (U-238) Radioactive waste produced	No radioactive waste	Uses uranium compounds Virtually no radioactive waste with long half-life is produced
Other information	Large size, approximately the size of a factory Takes a week to produce Tc-99 Lifetime of nuclear reactors is coming to an end Can also be used to generate electricity	Small size, approximately the size of a small car Takes 6 hours to produce Tc-99 Modern equipment that can be easily maintained Can be used to generate radioisotopes for other areas of research	Medium size, approximately the size of a school bus Takes 24 hours to produce Tc-99 Modern equipment that can be easily maintained Can be used for other areas of research



Middle Years Programme | Bilbo Baggins | PHYSICS | Assistance

You are an adviser to a government agency. Using the information above, **discuss** and **evaluate** which method you think should be used to produce Tc-99 in a country of your choice. In your answer, you should include:

- the advantages of your chosen method for your country
- the disadvantages of your chosen method for your country
- a conclusion.

Styles

Scroll down to continue

Question 8 (11 marks)

In 1987, a forgotten radiotherapy source was stolen from an abandoned hospital in Brazil. By the time the authorities had been alerted, 249 people who had been in contact with the stolen source were found to have very high levels of radioactive material either in or on their bodies. Four people died from being exposed to the radioactive isotope. Houses that had been contaminated had to be demolished and the topsoil had to be removed due to contamination. The International Atomic Energy Agency called it *"one of the world's worst radiological incidents"*.

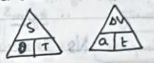
Using radioactive materials for diagnoses and treatment helps many patients but there are also risks attached to its use. **Discuss** and **evaluate** the implications of using radioactive materials in medicine. In your answer, you should include:

- an advantage and a disadvantage of using radioactive materials in medicine for a hospital
- the political implications for governments of using radioactive materials
- the environmental implications
- a concluding appraisal.

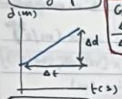
MY NOTES

Physics formulas *(which aren’t included in the formula booklet)*

PHYSICS FORMULAS
(Not included in formula sheet)

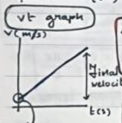


dt graph



Gradient = $\frac{\Delta d \text{ (m)}}{\Delta t \text{ (s)}}$ = speed (m/s)

vt graph



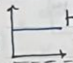
Initial velocity.

Average velocity: $\frac{(v+u)}{2}$

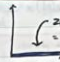
Note: −ve velocity = travelling backwards

Gradient = $\frac{\Delta v \text{ (m/s)}}{\Delta t \text{ (s)}}$ = acceleration (m/s²)

used in KINEMATICS problems
- Freefall Motion
- Projectile Motion
- Linear Motion & constant acceleration



Horizontal line = constant velocity. (zero acceleration)



zero velocity = stationary object.

SUVAT Equations

S = displacement/distance travelled (m)
U = initial velocity (m/s)
V = final velocity (m/s)
A = acceleration (m/s²)
T = time (s)

INCLUDED IN FORMULA BOOKLET.

$v = u + at$
$v^2 = u^2 + 2as$
$s = ut + \frac{1}{2}at^2$
$s = vt - \frac{1}{2}at^2$
$s = \frac{1}{2}(u+v)t$ (or) $s = \frac{(u+v)}{2}t$

(N) Force = mass (kg) × acceleration
F = m × a $F = ma$

Weight (N) = mass × acceleration due to gravity (m/s²) $W = mg$
Weight (N) = mass × gravitational field strength (N/kg) or $N\,kg^{-1}$ $W = mg$

difference:
9.81 m/s² ① describes motion
9.81 N/kg ② force per unit mass

P. T. O

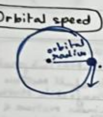
Pressure = Measured in Pa (Pascals) or N/m²
Momentum = " kg m/s
Density = " kg/m³

Impulse: Ns = Force (N) × time force acts for (s) = Δ in momentum (kg m/s)
$F\Delta t = mv - mu$

Centripetal acceleration: (m/s²) = $\frac{[\text{velocity (m/s)}]^2}{\text{radius (m)}}$ $a = \frac{v^2}{r}$

Centripetal force: = ma (m/s²) = $\frac{\text{mass (kg)} \times [\text{velocity (m/s}^2)]^2}{\text{radius (m)}}$
$F = \frac{mv^2}{r}$

Orbital speed (m/s) = $\frac{\text{orbital circumference (m)}}{\text{orbital period (s)}}$ = $v = \frac{2\pi r}{t}$



Moment (Nm)
Force (N) × ⊥ distance from line of action of the force to the axis of rotation

Energy transferred = work done.

+ Gravitational Field strength = $\frac{\text{force}}{\text{mass}}$ $g = \frac{F}{m}$

+ Gravitational potential energy: $\Delta E_p = mg\Delta h$
Δ in gravitational potential energy = mass × g × Δ in height

Nuclear energy

Energy released (J) = Δ in mass (kg) × (speed of light (m/s))² $\Delta E = \Delta mc^2$ $E = mc^2$

Intensity (W/m²) = $\frac{\text{power (W)}}{\text{area (m}^2)}$ $I = \frac{P}{A}$

Refractive index $n = \frac{\text{speed of light in vaccum (m/s)}}{\text{speed of light in medium (m/s)}}$ $n = \frac{c}{v}$

sin (critical ∠) = $\frac{\text{refractive index of 2nd material}}{\text{refractive index of 1st material}}$ $\sin C = \frac{n_r}{n_i}$

Magnification = $\frac{\text{image height}}{\text{object height}}$

Power of lens (dioptre) = $-\frac{1}{\text{focal length (m)}}$

Angular magnification = $\frac{\text{focal length of objective lens}}{\text{focal length of eyepiece lens}}$

+ Current (A) = $\frac{\text{charge passing (C)}}{\text{time taken (s)}}$ $I = \frac{Q}{t}$

Potential diff. (V) = $\frac{\text{energy transferred (J)}}{\text{charge passing (C)}}$ $V = \frac{E}{Q}$

Resistance (Ω) = $\frac{\text{potential diff. (V)}}{\text{current (A)}}$ $R = \frac{V}{I}$ ★

Power = [current (A)]² × resistance (Ω) $P = I^2R$
Power = $\frac{[\text{voltage (V)}]^2}{\text{resistance (}\Omega)}$ $P = \frac{V^2}{R}$
+ Power (W) = current (A) × voltage (V) $P = IV$

Electrical energy (kWh) = power (kW) × time (h)

Kinetic energy of an electron (J) = $KE = eV$
= charge on electron (C) × potential diff. (V)

Kelvin $\xrightarrow{\text{to}}$ °C = $\left(\frac{\text{temp.}}{K}\right) - 273$
°C $\xrightarrow{\text{to}}$ Kelvin = $\left(\frac{\text{temp.}}{°C}\right) + 273$

Energy supplied (J) = mass (kg) × specific heat capacity (J/kg K) × Δ in temp. (K)
$\Delta E = m \times shc \times \Delta T$ + $Q = mc\Delta t$.

$\frac{\text{Pressure (Pa)}}{\text{Temperature (K°)}}$ = constant $\frac{P}{T}$ = constant

Pressure (Pa) × volume (m³) = constant PV = constant.

Waves Notes

PHYSICS

Waves

all types of waves fall into one of two categories these are transverse waves and longitudinal waves

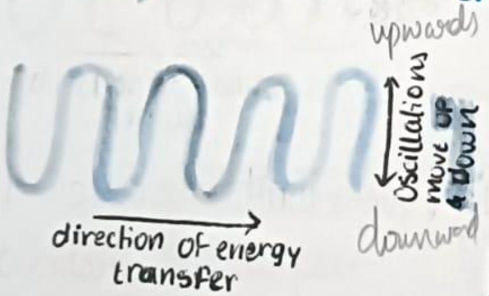
RIPPLES ARE TRANSVERS

they transfer KINETIC ENERGY

SOUND WAVES ARE LONGITUDINAL

they transfer SOUND ENERGY

ALL WAVES TRANSFER ENERGY FROM ONE PLACE TO ANOTHER.



in transverse waves the oscillations are perpendicular to the direction of energy transfers

PERPENDICULAR ⟶ right angles.

in a longitudinal wave, the oscillations are **parallel** to the direction of energy transfer.

ALL LONGITUDINAL WAVES REQUIRE MEDIUM: AIR, LIQUID OR A SOLID

NOT ALL TRANSVERSE WAVES REQUIRE A MEDIUM

for both ripples on water surface and sound waves in air, it is the wave that travels and not the water or the air

categories
dinal waves

WAVES
NSFER ENERGY
ONE PLACE
NOTHER.

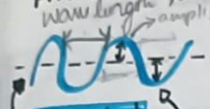
s the oscillations
the direction

right angles.

ater surface and
It is the wave that
e water or the air

PROPERTIES OF WAVES

AMPLITUDE ~ the maximum displacement of a point on a wave away from its undisturbed position.



undisturbed position: (part of wave which is undisturbed)

~~amplitude~~ trough

USUALL ONLY IN TRANSVERSE WAVES.

FREQUENCY ~ the number of waves passing a point each second

Frequency is measured in Hz

∴ 5×1 = 5 ~ 5Hz

1 Hz means 1 wave/sec

$f = \frac{1}{T}$

PERIOD ~ time in seconds for one wave to pass a point.

WAVE LENGTH ~ the distance from a point on the wave to the equivalent point on the adjacent wave.

wave length - λ

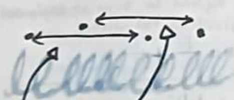
symbol for wave length is λ (lambda).

TRANSVERSE.

$$\text{Period (s)} = \frac{1}{\text{frequency (Hz)}}$$

$$\boxed{T = \frac{1}{F}}$$

YOU NEED TO KNOW THIS EQUATION



wave length

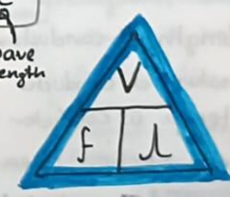
In this case we measure from one compression to the other.

$$\boxed{V = f \times \lambda}$$

wave speed

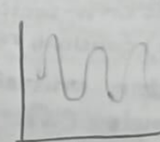
frequency

wave length



WAVE SPEED the wave speed is the speed at which the wave moves. i.e, speed at which energy is transfered.

no wave present = equilibrium position.



Ohm's Law Notes

Ohm's Law

> A german physicist **George Simon ohm** (1857) established the **relationship between the potential difference, resistance and electric current** in a circuit.

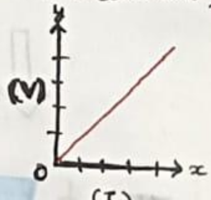
> According to ohm's law, **the potential diff. (V) is directly proportional to the current flowing through it,** provided its temperature and physical condition, remains the same.

↳ $V \propto I$

→ $V = RI$ — ① (where R is constant)

→ $R = V/I$ — ②

→ $I = V/R$ — ③



Resistance

oppose the flow of current in circuit

FACTOR AFFECTING

- $R \propto$ length of conductor
- $R \propto$ nature of conductor
- $R \propto$ temp. of conductor
- $\frac{1}{R} \propto$ cross section area of conductor

RESISTIVITY The electrical resistance offered by a substance of unit length and unit cross-sectional area

ρ (rho) constant, resistivity of the conductor, unit of resistivity is ohm-metre (Ω-metre)

THERMAL EFFECTS OF CURRENT

> According, to the law of conservation, the electric energy transformed into heat energy.

→ $H \propto I^2$

→ $H \propto R$

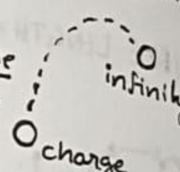
→ $H \propto t$

Electric potential and potential difference

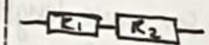
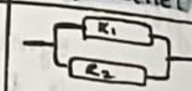
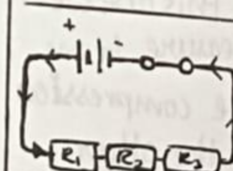
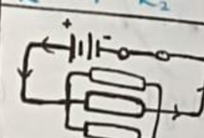
> **ELECTRIC POTENTIAL** – amount of work to move a unit of charge from a reference point to a specific point inside the field.

→ Potential = $\frac{\text{workdone}}{\text{charge}}$

→ $V = \frac{W}{Q}$



COMBINATION OF RESISTANCE

series	parallel
 total resistance is equal to the sum of individual resistance $R = R_1 + R_2$	 reciprocal of total resistance is equal to sum of reciprocal individual resistance $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$
 only one path in which charge can flow, current is same every where $I = I_2 = I_2 = I_3$	 more than one path for current flow. current is equal to sum of sub current $I = I_1 + I_2 + I_3$
Sum of p.d across individual in series circuit is equal to the p.d across the whole circuit. $V_1 = V_2 + V_2 + V_4$	The p.d across all the components in the parallel circuit is same. $V_1 = V_2 = V_3 = V_4$

Onymous

https://aminahaider.wixsite.com/website-3/myp-physics

STATES & PROPERTIES OF MATTER

STATES & PROPERTIES OF MATTER

Matter - any object with mass; substance that has inertia, consists of particles, and occupies physical space
This includes gases (air, oxygen, helium, etc.), liquids, and solids. Any matter is comprised of basic particles - atoms - bonded together.

Molecules - groups of two or more atoms; the smallest unit in which a pure substance can be identified and still retain all of its chemical composition and properties

STATES OF MATTER

Solids:

- Molecules are **packed closely together**
- Molecules are **not free to move** within their substance, and instead vibrate
- This lack of movement means that solids have a **fixed shape**, and will not change their shape to match the shape of the container/space in which they are placed
    - If a strawberry is placed in a bowl, it does not change its shape the way water might when being moved from a glass to a bowl

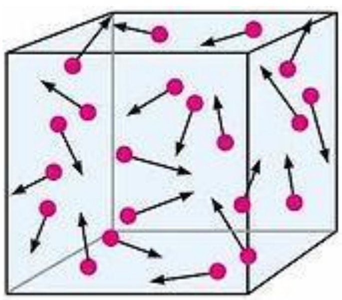
Liquids:

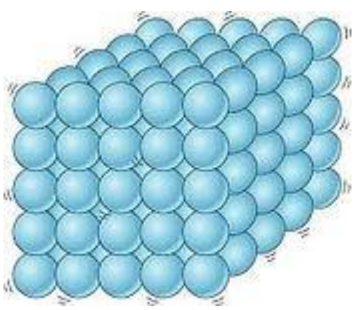
- Molecules are **not packed *as* closely together** as they are in solids
- Molecules are **free to move around** within the confines of their container and gravity

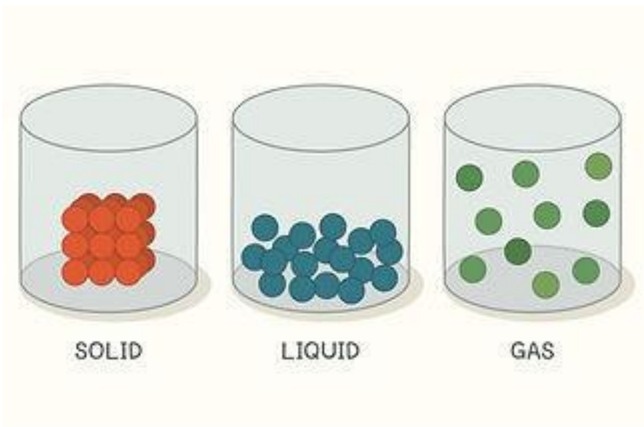
- Liquids **do not have fixed shapes**, and will thus take the shape of their containers
    - When in a bottle, coke takes the shape of the bottle. When transferred to a glass, the coke takes the shape of the glass

<u>Gases:</u>

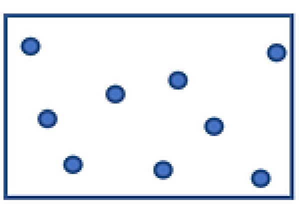
- Molecules are **not packed closely together**
- Molecules are **free to move around** within the confines of their containers, and are not typically confined by gravity
    - This means that molecules in a gas can escape a bowl, for example, and move around in the room where the bowl was placed
- Gases **do not have fixed shapes**, and will thus take the shape of their surroundings







	Gas	Liquid	Solid
Arrangement of particles	- Highly disorderly - Particles tend to be distant from one another - Particles do not conform to shape of container (free flowing)	- Frequent movement - Disorderly, but within the confines of their container and, in most cases, gravity	- Little movement (vibrations) - Particles are close together - Particles do not conform to shape of container (stoic to pre-assigned shape)
Attractive forces between particles	Low	Strong	Extremely strong
Kinetic energy of particles	High	Slight	Little to none



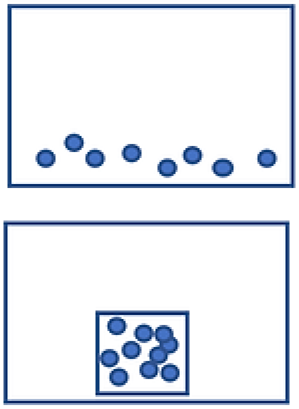


Fig. 1 - Diagrams showing the molecular arrangements of gases, liquids, and solids (left to right).

FLUIDS

Fluid - a substance that flows and takes the shape of its container; liquids and gases are both fluids

A liquid like water is easily identifiable as a fluid - once poured into a cup or bowl, it adapts to the shape of the cup of bowl and moves freely within its confines. Similarly, if air is trapped within a sealed flask, it will move freely within the flask's confines, and only move out when the seal is broken.

Hydraulics - the mechanics, science and technology of liquids and their pressure; an example of a hydraulic system is a syringe

Fluid statics - the study of fluids at rest

Pneumatics - the mechanics, science and technology of gases and their pressure; an example of a pneumatic system is a chair with an adjustable height

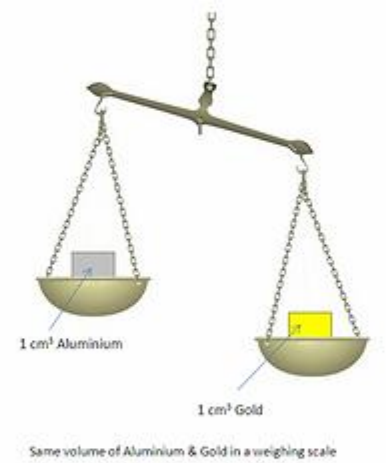
DENSITY

Density - the ratio of mass to volume in a substance; the mass of a unit volume of a material substance; how compact a substance is

- scalar quantity
- SI unit is kilogram per cubic meter (kg/m^3)
- can be quantified with *ρ = m/v*
    - *ρ - density (kg/m^3)*
    - *m - mass (kg)*
    - *v - volume (m^3)*

If an object is not dense, it is lighter than other objects with the same volume, and the spaces between its particles allow for that substance to be compressed; 25mL of gas is less dense (and thus lighter) than 25mL of water because it has fewer particles per unit volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$
$$\rho = \frac{m}{V}$$



PRESSURE

When assessing fluids (gasses and liquids) and their behaviors, it becomes more convenient to refer to pressure rather than force. When dealing with gas pressure, we assess the pressure of gas molecules on the walls of their container - this is the same concept applied in blood pressure.

Pressure - force applied per unit area

- scalar quantity
- SI Unit is a pascal (Pa)
- can be quantified with $P = F/A$
    - *P - pressure (Pa)*
    - *F - force (N)*
    - *A - area (m^2)*

Barometric/atmospheric pressure - the force exerted on a surface by the air above it; the total weight of the air above a unit area.

At higher altitudes, the atmospheric pressure is lower, because less air is weighing down on a space.

$$Pressure\ (p) = \frac{Force\ (F)}{Area\ (A)}$$

MOLECULAR ARRANGEMENTS

Diamonds are the hardest known naturally occurring material known to man. They are extremely dense, rated the highest on the Mohs scale of mineral hardness, unreactive, insoluble, and transparent in X-rays. The hardness and density of diamonds is because of their molecular structure, a giant lattice formation.

Giant lattice formation -a molecular structure in which pure carbon atoms are linked together in covalent tetrahedral units and one carbon atom shares its electrons with four other carbon atoms.

<u>Uses of diamonds</u>

- fashion industry
- glass cutting
- polishing of precious stones → diamond dust enhances lustre
- drilling
- heat sinks in electrical systems
- engravings
- tungsten wires

Graphite is the only non-metal that can conduct electricity. It is not dense, but rather soft, has a metallic lustre, and is opaque. The properties of graphite arise from its molecular structure, the honeycomb lattice. Carbon atoms in graphite form metallic bonds (rather than covalent bonds), which means there are free electrons between the carbon layers. The vertical bonds that connect separate layers are very weak, which is why it is softer and less dense.

Graphenes - single-atom layers of carbon arranged in a honeycomb lattice structure

Honeycomb lattice structure - each carbon atom is joined to three other carbon atoms.

<u>Uses of graphite</u>

- pencil lead for writing or art → more graphite means darker pigment
- lubricant in manufacturing processes → graphite reacts with atmospheric water vapor to form a thin film on nearby surfaces
- lithium-ion batteries → graphite anodes with lithium cathode last long as batteries
- lightweight sports equipment → graphene technology
- moderator rods in nuclear fission reactors → carbon nuclides absorb kinetic energy

MEASUREMENTS IN SCIENCE

MEASUREMENTS IN SCIENCE

Quantity	SI unit	Symbol
Mass	Kilogram	kg
Distance	Meter	m
Time	Second	s
Electric current	Ampere	A
Amount of substance	Mole	mol
Temperature	Kelvin	K

Fig. 1 - The seven base SI units and their symbols.

SI BASE UNITS

There are seven standard 'base' or 'fundamental' SI units (see Fig. 1); all other SI units are derived from these base units.

Standard international units are typically globally used and recognized units assigned to certain types of quantities. These SI units also have recognized symbols used to denote the unit. This is different from mathematical symbols used to denote the type of quantity; for example, an equation may denote the variable of time with 't', but when you solve the equation for 't', the answer will be in seconds, 's'.

Examples of SI units include:

- Length - meters (m)
  - Centimeters (cm) = 1/100 * meters
  - Millimeters (mm) = 1/1000 * meters
  - Kilometers (km) = 1000 * meters

- Mass - kilograms (kg)
  - Grams (g) = 1/1000 * kilograms
  - Milligrams (mg) = 1/1000000 * kilograms

- Time - seconds (s)
  - Minutes (m) = 60 * seconds
  - Hours (hr) = 3600 * seconds

- Volume (solids) - centimeters-cubed (cm^3)

- Volume (liquids)- liters (l)
  - Liters (l) = 1000 * cm^3
  - Milliliters (ml) = 1/1000 * liters

SIGNIFICANT FIGURES

All non-zero digits are significant; trailing zeroes on the right of decimals are significant; zeroes between significant figures are also significant. Moreover, the 'n' number in the standard form/scientific notation of numbers will be significant according to the general rules of significance, but the '10' and its index will not count as a significant figure.

Non-significant figures include:

- Zeroes trailing a whole number
  - e.g. 123000
  - an exception to this rule is that zeroes trailing on the left side of a decimal point will be significant - 120.0 has three significant figures

- Zeroes leading any number
  - e.g. 042, 0.00123

Find the product of 72 and 86 to three significant figures

72 x 86= 6,192

=6,190

Find the product of 0.0123 and 0.789 to three significant figures

0.0123 x 0.789 =0.0097047

=0.00970

	unit name	*unit symbol*	*derived from*	*quantity*	*named after*
all lower case unit symbols	meter	m		length	
	kilogram	kg		mass	
	second	s		time	
	candela	cd		luminous intensity	
	mole	mol		amount of substance	
	liter	ℓ, L	$10^{-3} \cdot m^3$	volume	
	ohm	Ω	$W \cdot A^{-2}$	resistance	Georg Simon Ohm
leading capital letter in unit symbol	ampere	A		electric current	André-Marie Ampère
	kelvin	K		thermodynamic temperature	William Thomson (Lord Kelvin)
	hertz	Hz	s^{-1}	frequency	Heinrich Hertz
	newton	N	$kg \cdot m \cdot s^{-2}$	force	Sir Isaac Newton
	joule	J	$N \cdot m$	energy	James Joule
	watt	W	$J \cdot s^{-1}$	power	James Watt
	volt	V	$W \cdot A^{-1}$	voltage	Alessandro Volta

COMPOUND UNITS

Compound units are derived from base/fundamental units and are used to increase the efficiency of varying values.

The most common example of this is a Newton (N).

1 Newton is equivalent to:

1 Kilogram x 1 Meter ÷ 1 Second x 1 Second
or
*kg*m/s^2*

Name	Symbol	Value
Universal gravitational constant	G	6.67×10^{-11} N•m²/kg²
Acceleration due to gravity	g	9.81 m/s²
Speed of light in a vacuum	c	3.00×10^{8} m/s
Speed of sound in air at STP		3.31×10^{2} m/s
Mass of Earth		5.98×10^{24} kg
Mass of the Moon		7.35×10^{22} kg
Mean radius of Earth		6.37×10^{6} m
Mean radius of the Moon		1.74×10^{6} m
Mean distance – Earth to the Moon		3.84×10^{8} m
Mean distance – Earth to the Sun		1.50×10^{11} m
Electrostatic constant	k	8.99×10^{9} N•m²/C²
1 elementary charge (charge of the electron)	e	1.60×10^{-19} C
1 coulomb (C)		6.25×10^{18} elementary charges
1 electronvolt (eV)		1.60×10^{-19} J
Planck's constant	h	6.63×10^{-34} J•s
1 universal mass unit (u or amu)		9.31×10^{2} MeV
Rest mass of the electron	m_e	9.11×10^{-31} kg
Rest mass of the proton	m_p	1.67×10^{-27} kg
Rest mass of the neutron	m_n	1.67×10^{-27} kg

STANDARD FORM

Standard form, also referred to as scientific notation, is a method used to shorten numbers. The numbers are expressed as powers of ten; the general form of scientific notation is as follows:

*N * 10^x*

In this case, 'N' is a number with only one digit (unit) on the left of a decimal and two/three (or as appropriate) digits on the right of its decimal. 'x' is the power of 10 which indicates how many numbers are on the right side of the decimal of 'N'.

Examples of standard form are:

- $134 = 1.34 \times 10^2$
- $10{,}800{,}000 = 1.08 \times 10^7$
- $0.01 = 1 \times 10^{-2}$
- $0.00123 = 1.23 \times 10^{-3}$

FORCES & THEIR EFFECTS

FORCES & THEIR EFFECTS

Force - any influence which can distort, produce stress in, or alter the motion of a body of matter; force produces an effect on the shape, motion, direction, and speed of mass.

- vector quantity
- SI Unit is Newton (N)
- Compression of an object - <u>force influencing shape</u>
    - lightly squeezing an elastic ball will cause a distortion in its form
    - squeezing a balloon will likely change its shape from a tear-drop-like figure to a figure resembling two awkward balls (see Fig. 1)

- Blocking a moving object's path - <u>force influencing motion</u>
    - if a goalkeeper were to block a soccer ball from entering the net, they are changing the motion of the ball by reducing its speed to equal or almost equal to 0 (see Fig. 2)

- Hitting an object - <u>force influencing direction</u>
    - if a baseball player were to hit the baseball with the bat, they would be changing the direction of the ball (see Fig. 3)

- Pushing an object - <u>force influencing speed</u>
    - if a bottle is rolling on a flat surface, and it suddenly pushed forward, it will move at a faster pace than before

There are two key categories of forces:

- **Contact forces** - forces that occur while two (or more) objects are in direct physical contact, e.g., friction.
- **Non-contact forces** - forces that occur at a distance, without physical contact (these are also known as distant forces), e.g., gravitational force

DIFFERENT TYPES OF FORCES/FORCE TERMINOLOGY

- **Normal force** - a contact force exerted by all objects which is perpendicular to the surface of the objects (see Fig. 4)

- **Friction** - the force between objects in contact which acts opposite to the direction of movement, slowing down motion; frictional force depends on the texture of the surfaces in question (every surface has its own friction coefficient for both static and dynamic friction; in general, rough texture means more friction)
    - **Static friction** - the force that prevents stationary objects from moving
    - **Kinetic friction** - the force that acts against an object's motion
    - **Drag force** - the resistive force experienced by a body moving through a fluid (gas or liquid), e.g., air resistance, which slows down motion & works at a greater magnitude with larger masses

- **Tension** - the general pulling force exerted by strings, ropes, fibers and cables

- **Applied force** - a general term for any contact force

- **Weight** - a force which acts on all matter within gravitational fields, can be defined as the product of gravitational field strength (N/kg) and an object's mass (kg)

- **Resultant force** - the single force that results from two or more combined forces; can be found mathematically (using algebra) or geometrically (using the parallelogram rule)

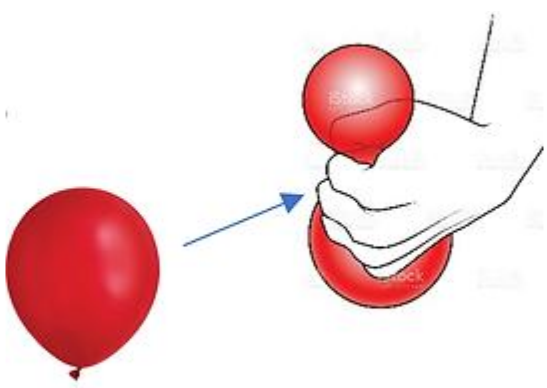


Fig. 1: Compressed balloon.

Fig. 2: Goalkeeper catching a ball.

Fig. 3 - Baseball player striking ball.

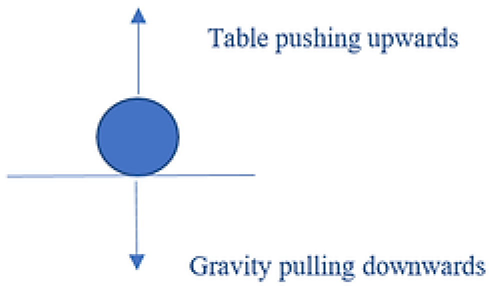


Fig. 4 - Normal force demonstration.

CALCULATING RESULTANT FORCES

<u>Parallelogram rule</u>

1. Draw two lines (vectors) from a point ‘O’ to represent two forces
2. Ensure that the direction and length of these vectors are proportional to those of the exact forces being represented
    1. Use a protractor to ensure that the angles the vectors make are the same as the angles the forces make with a relative surface or direction
    2. Choose a scale ratio that can be used to represent the magnitude of the force as the length of the vector
3. Draw two more lines starting at the ends of the two vectors to complete the parallelogram
4. Draw a diagonal from point 'O' to the convergence of the second pair of lines
5. Calculate the direction and magnitude of this vector - this is the resultant force

FORCES IN CIRCULAR MOTION

When objects are moving in circular paths, there are several forces at play which wouldn't necessarily be present in linear motion.

- **Centripetal force** - the net force acting on the object in motion, which will always be pulling the object inwards towards the center of its circular trajectory
  - if the moving object is attached to a string or rod (or other object), the tension force experienced by the string/rod will be the centripetal force
  - the moving object will be constantly accelerating since its velocity is also constantly changing (velocity is a vector quantity affected by direction - non-linear direction means change in velocity even if the speed does not change)
  - can be quantified with *F = mv^2/r*
    - *F - centripetal force (N)*
    - *m - mass (kg)*
    - *v - velocity (m/s)*
    - *r - radius of circular trajectory (m)*

- **Centrifugal force** - the fictitious force that is equal in magnitude but opposite in direction to the centripetal force; the force that pushes an object in a circular trajectory outwards from the center
  - this force does not actually exist, and if the circular motion stops, the object will continue to move in a straight path tangent to its last position in the circular path - this occurs due to inertia.

FORCES IN ROTATIONAL MECHANICS

In a linear system, force provides acceleration; in a rotational system, torque (which requires a causal force) provides angular acceleration.

Torque - the measure of a force that can cause an object to rotate about an axis; the rotational equivalent of a linear force. Torque can be understood when opening a door; a smaller force is required to open it when it is applied further from the hinges. In this case, the hinge is the rotational axis, and the door is the moment arm.

- vector quantity
- SI unit is Newton-meter (Nm)
- can be quantified with *T = F*r*sin(θ)*
    - *T - torque (Nm)*
    - *F - force vector (N)*
    - *r - length of moment arm, or from axis of rotation to the point of application of force (m)*
    - *θ - angle between force vector and moment arm (degrees)*

Torque is different from centripetal force because torque causes rotation about an axis, whereas centripetal force changes the direction of a moving object.

MOMENTUM & IMPULSE

Momentum - the product of any moving object's mass and velocity; a quality that results from motion

- vector quantity
- SI unit is kilogram-meters per second (kg*m/s)
- can be quantified with *p = mv*
    - *p - momentum (kg*m/s)*
    - *m - mass (kg)*
    - *v - velocity (m/s)*

Impulse - change in momentum; the product of force and time

- vector quantity
- SI unit is Newton-second (Ns)
- can be quantified with *Δp = m*Δv* OR *Δp = m*a*Δt* OR *Δp = F*Δt*
    - *Δ - delta, signifying 'a change in'*
    - *p - momentum (kg*m/s)*
    - *m - mass (kg)*
    - *v - velocity (m/s)*
    - *a - acceleration (m/s^2)*

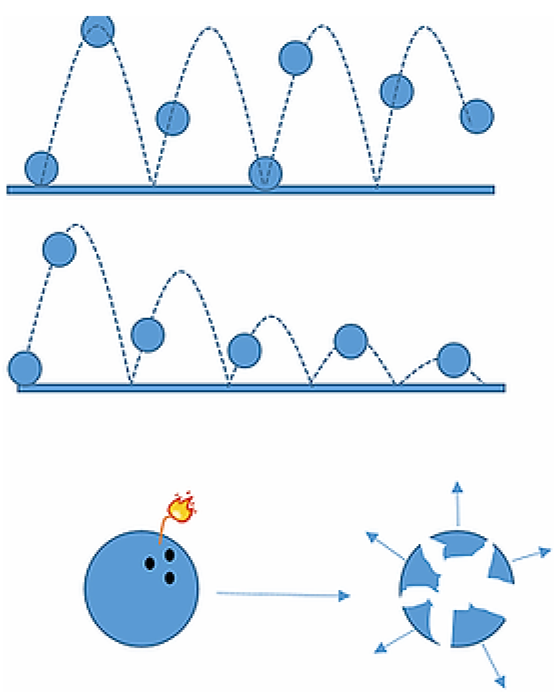
  - *t - time (s)*
  - *F - force (N)*

Law of conservation of momentum - when two or more objects in a system act on each other (exchange direct contact, e.g. collide), the total momentum of the system remains constant, provided no external forces are acting on it

- this does not necessarily mean that the momentum of the individual objects will not change; just that the total momentum before the collision will be equal to the total momentum after the collision

There are multiple types of collisions in which the law of conservation of momentum may apply. These are listed in the table below.

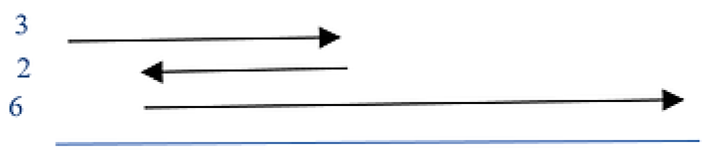
Before the explosion, the total momentum of the bomb is zero. Upon the explosion, the bomb will crack into fragments and accelerate into varying, random directions. The vector sum of the moments of the fragments is zero, thus the momentum is conserved



Type	Total Momentum	Total Kinetic Energy
Elastic	Conserved	Conserved
Inelastic	Conserved	Not Conserved
Explosion	Conserved	Not Conserved

MOTION

MOTION



DISTANCE & DISPLACEMENT

Distance (d) - numerical measurement of the length between two objects or points

- scalar quantity
- SI unit is meter (m)

Displacement (s) - the shortest distance from the origin point to the final destination

- vector quantity
- SI unit is meter (m)

If an object moves forward from the origin point 3 centimeters, back 2 centimeters, and forward 6 centimeters, *the distance travelled by the object is 11 centimeters;* if an object moves forward from the origin point 3 centimeters, back 2 centimeters, and forward 6 centimeters, *it has been displaced by 7 centimeters to the right.*

SPEED & VELOCITY

Speed - the rate at which an object covers distance; a quantity that can be used to describe how fast or slow an object is moving

- scalar quantity
- SI unit is meters per second (m/s)

Velocity (v) - used to describe how fast or slow an object is moving in a given direction; the rate at which an object is moving in a given direction

- vector quantity
- SI unit is meters per second (m/s)

If an object is moving an average of 10 kilometers every 20 minutes, the object's speed is 30km/h; if an object is moving an average of 10 kilometers north every 20 minutes, the object's velocity is 30km/h north-bound.

The velocity of an object is likely constantly changing. This is why we refer to velocity as either:

- **Instantaneous velocity** - the velocity of an object at any given moment
- **Average velocity** - the average velocity of an object over any given period of time

ACCELERATION

Acceleration (a) - the rate at which the velocity of an object changes over a period of time

- vector quantity
- SI unit is meters per seconds-squared (m/s^2)

When finding instantaneous acceleration, time is equal to zero; this is not the case for the process of finding average acceleration.

$$speed = \frac{distance}{time}$$

$$a = \frac{v_f - v_i}{t_f - t_i}$$

$$a = \frac{\Delta v}{\Delta t}$$

EQUATIONS OF MOTION

<u>Conditions for using the equations of motion:</u>

- All quantities must be in SI units
- motion must be linear
- acceleration must be constant

FREEFALL MOTION

Freefall motion - any motion of a body in which gravitational force is the only force acting on it, unless stated otherwise

In freefall motion, objects accelerate towards the ground; that acceleration has varying values at different places in the universe.

On Earth, the gravitational field strength is 9.8 m/s^2 - this means that, assuming there is no effect of resistive force, the speed of the freely falling object would increase by 9.8 m/s every second.

MOTION GRAPHS

Motion graphs can be used to

- Depict motion visually
- Calculate kinematic variables

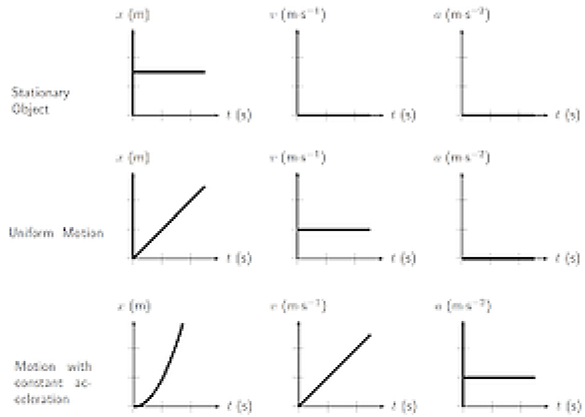
In most (if not all) motion graphs, time will always be shown on the x-axis. The x-axis usually represents the independent variable, whereas the y-axis shows the dependent variable.

The important features of any motion graph that you may be asked to find are the gradient and the area under the graph.

There are many types of motion graphs:

1. Position-time graph
2. Distance-time graph
3. Velocity-time graph
4. Acceleration-time graph

Graph	Slope	Area under the graph
position vs. time	velocity	-----
velocity vs. time	acceleration	displacement
acceleration vs. time	-----	change in velocity



POSITION-TIME GRAPHS

In a position-time graph, the gradient is the velocity. In some cases, the position-time graph can be considered the same as a displacement-time graph. For the following notes, 'positive' and 'negative' refers to direction of velocity rather than magnitude - remember that velocity and acceleration are both vector quantities.

<u>Position-time graphs with a straight line</u> (see Fig. 1):

- the object is moving at a constant speed
- an upward-pointing line depicts motion being of a positive velocity - in the forwards or upwards direction
- a downward-pointing line depicts motion being of a negative velocity - in the downwards or backwards direction

Position-time graphs with a curved line (see Fig. 2):

- the object is either accelerating in either a positive or negative direction

- if the gradient/velocity is decreasing, the object would be accelerating negatively
  - when the velocity is positive and decreasing, the object is slowing down in the positive direction
  - when the velocity is negative and decreasing, the object is speeding up in the negative direction

- if the gradient/velocity is increasing, the object would be accelerating positively
  - when the velocity is positive and increasing, the object is speeding up in the positive direction
  - when the velocity is negative and increasing, the object is slowing down in the negative direction

$$\frac{y_2 - y_1}{x_2 - x_1}$$

$$\frac{8 - 0}{4 - 0}$$

$$\frac{8}{4}$$

$$gradient = 2$$

$$velocity\ of\ object = 2$$

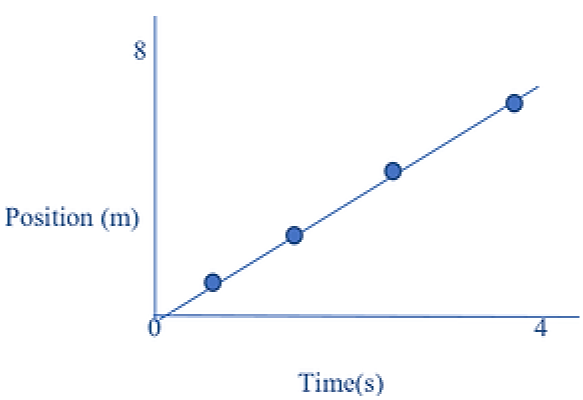


Fig. 1 - Position-time graph with a straight line.

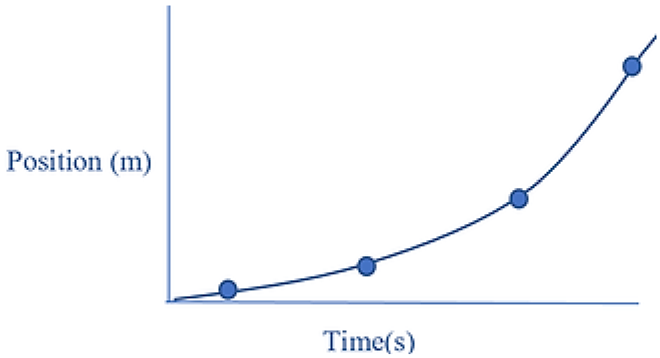


Fig. 2 - Position-time graph with a curved line; this graph depicts increasing velocity, therefore positive acceleration.

DISTANCE-TIME GRAPHS

In a distance-time graph, the gradient is the speed. A distance-time graph can never have a negative slope, because distance and speed are both scalar quantities meaning that they do not possess a directional element. The magnitude of speed or distance cannot be below zero. A downwards-sloping line would indicate a decrease in distance, which is not possible - motion in a different direction would still contribute to an increasing amount of length being covered.

Distance-time graphs with a straight line:

- the object is moving at a constant speed
- if the gradient is greater than zero, distance is being covered at the given speed (gradient)

- if the gradient is zero, distance is not being covered and the object is stationary

Distance-time graphs with a curved line:

- the object is either accelerating or decelerating
- if the gradient is decreasing, the object would be decelerating
- if the gradient is increasing, the object would be accelerating

VELOCITY-TIME GRAPHS

In a distance-time graph, the gradient is the acceleration; the area under the graph is displacement. The velocity is indicated by the y-axis value, whereas time lies on the x-axis as usual. For the following notes, 'positive' and 'negative' refers to direction of velocity rather than magnitude - remember that velocity and acceleration are both vector quantities.

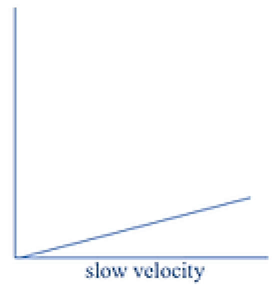
Velocity-time graphs with a straight line:

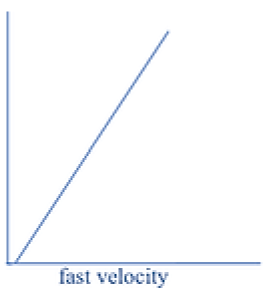
- the object is moving at a constant acceleration
- if the gradient is zero, the velocity is constant and the object is not accelerating
- if the gradient is greater than zero, the object is accelerating positively
    - if the gradient is greater than zero and the velocity is negative (y-axis value), the object is slowing down in the negative direction
    - if the gradient is greater than zero and the velocity is positive (y-axis value), the object is speeding up in the positive direction
- if the gradient is less than zero, the object is accelerating negatively
    - if the gradient is less than zero and the velocity is negative, the object is speeding up in the negative direction

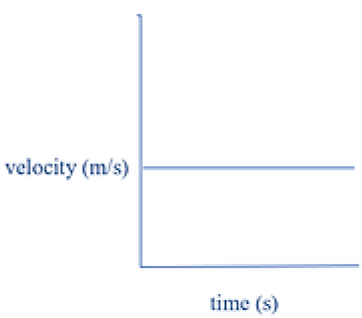
    - if the gradient is less than zero and the velocity is positive, the object is slowing down in the positive direction

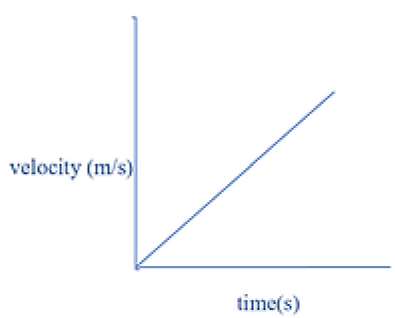
<u>Velocity-time graphs with a curved line</u>:

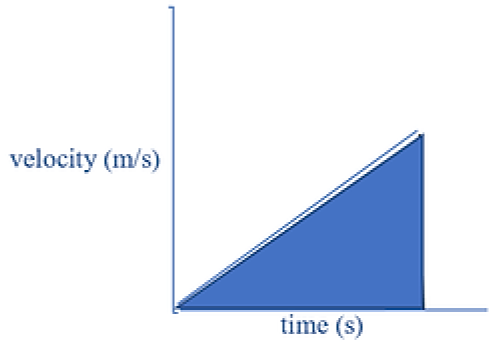
- the object is moving with a non-constant acceleration
- the same rules as above will apply, keeping in mind that the acceleration (whether positive or negative) is not constant











area of triangle= (bh)/2

area of triangle= displacement of object

ACCELERATION-TIME GRAPHS

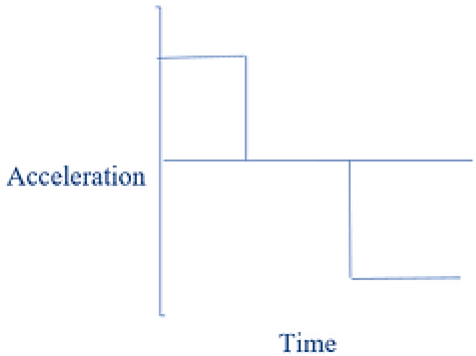
In an acceleration-time graph, the gradient is the jerk; the area under the graph represents the change in velocity. The jerk is a quantity that describes change in acceleration. The change in velocity is not the same as the initial or final velocity.

Acceleration-time graphs with a straight line:

- if the gradient is zero, the object is moving at a constant acceleration
- if the gradient is greater or less than zero, the object is moving at a non-constant acceleration

Acceleration-time graphs with a curved line:

- the object is not moving at a constant acceleration


Acceleration
Time

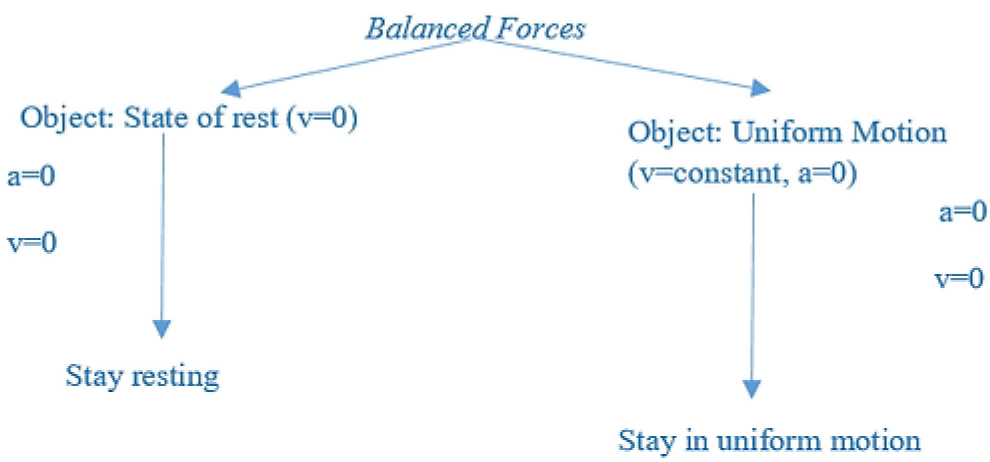
NEWTON'S LAWS

NEWTON'S LAWS

Newton's laws of motion - laid out by English physicist and theorist, Isaac Newton - were developed as the basis of Newtonian physics and mechanics. Newton's primary three laws can be applied in a wide range of everyday physics scenarios - they only become inconsistent in at a quantum scale, at extremely high speeds, or in very strong gravitational fields (these exceptions are not part of the MYP physics syllabus, therefore do not need to be worried about.)

NEWTON'S FIRST LAW

An object at rest will remain at rest, and an object in motion will remain in motion unless acted upon by an external force.



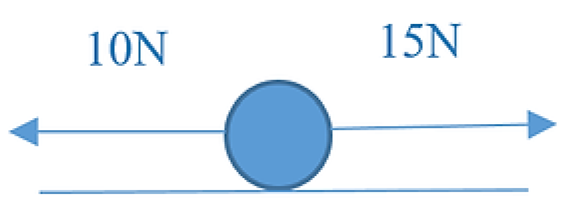
To clarify, if an object is still, it will remain still unless an outside force (a push or pull) acts upon the object. If an object is in motion, it will continue moving uniformly (no change in direction or speed), unless acted upon by an outside force. Newton's first law is supported by the concept of inertia.

Inertia - the resistance of any physics object to any change in its velocity; this property results in the tendency of objects to continue moving at a constant speed in a straight line, given that no forces are acting on them

Net force - the vector sum of forces acting on a particle or body with mass

<u>Newton's first law tells us that:</u>

- a force is not required to maintain an object's velocity
- mass is directly proportional to inertia
  - objects with greater mass tend to resist change more than objects with less mass; objects with greater mass possess greater inertia
- external and internal forces are relative
  - gravitational force acting on objects in the Earth's gravitational field is an external force; however, the gravitational force is an internal force for the Earth, since the Earth is the object possessing/producing that force



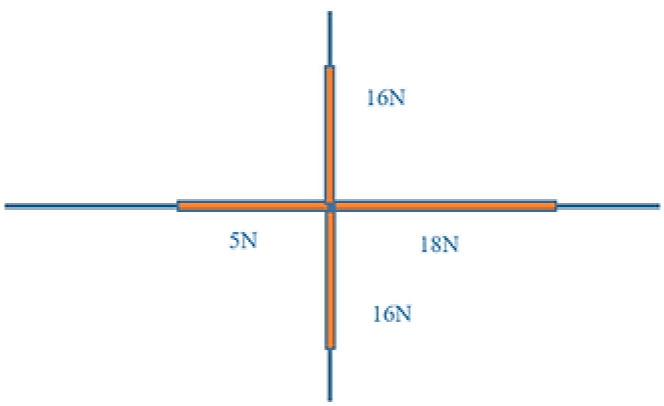
15 - 10 =

$$\Sigma F = 5N$$

NEWTON'S SECOND LAW

The acceleration of any object is dependent on its net force & mass. This can be quantified with:

F = ma



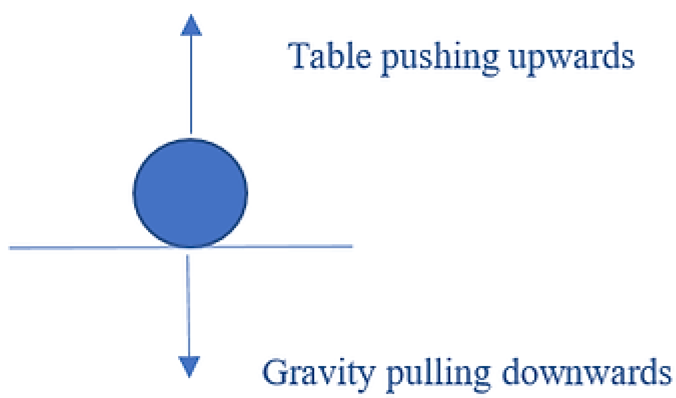
In the above grid, we see a 16N force being exerted downwards (gravitational force, for example), a 16N force being exerted upwards (normal force, for example), an 18N push force and a 5N pull force (friction force, for example). Therefore, the net horizontal force is (18-5) 13N; the net vertical force is (16-16) 0. Therefore, the net force is 13N towards the left. This net force divided by the mass of the object experiencing it would give us the acceleration.

Newton's second law tells us:

- a quantitative representation of force (including the SI unit of force)
- the acceleration of an object is produced by the net force (ΣF) acting on it

NEWTON'S THIRD LAW

Every action has an equal and opposite reaction.



This law states that all forces come in pairs; this is to say that in nature, no single force can act on an object without either an external or internal force reaction. These pairs of forces are referred to as **action-reaction pairs**, and tend to be equal in magnitude and opposite in direction; they must also act on the same object. From this law, we also derive the concept of a normal force. For example, if a book is resting on a table, the force of gravity would be pulling the book downwards and in response, the table exerts an upward force to keep the book still.

Normal force - the perpendicular contact force exerted by one object in order to prevent the other object from passing through it

Action-reaction pairs do not cancel out, because the forces are acting on different systems. If the action-reaction pair was being exerted on or within the same object, they would be canceled out. But in the case of different objects, the forces do not cancel out.

Even when objects collide and break, there is still an action-reaction pair present. The weaker object (which ends up breaking) will still exert an equal and opposite force on the other object; the fact that it breaks is instead dependent on the material, design, pressure resistance, and other such properties of the object. The force applied will be reciprocated regardless of the physical structure of the other (breaking) object.

ASTROPHYSICS

ASTROPHYSICS

CLASSIFICATIONS OF STELLAR BODIES

Category	*Examples*	*Approximate Diameters (m)*	*Characteristics*
Planetoids	Ceres, 4 Vesta, 90377 Sedna, 2 Pallas	$1 - 10^3$	Small; larger ones are spherical and smaller ones are irregular in size; mostly located in asteroid belt
Satellites	ISS, moons, GPS satellites, Hubble telescope, Jupiter's moons	10^4 - 10^6	Orbit planets instead of the sun; can be natural or artificial
Rocky Planets	Mercury, Venus, Earth, Mars	10^6 - 10^7	Made of rock and metal; close to the sun, smaller in size than gas giants; formed mainly by silicate and has a metallic core; similar surface structure includes craters and volcanoes
Gas giant planets	Jupiter, Saturn, Uranus, Neptune	10^8	Composed mainly of gases e.g helium, hydrogen; small rocky core
Stars	Sun, Sirius, Betelgeuse	10^9	Emits its own light (bright);

Rogue planets - worlds without suns, molten at the core, frozen at the surface and thus there may be life somewhere inside

Comets - leftovers from the formation of the solar system - grouped in an Oort cloud, which encases the solar system

Stellar nurseries - places where there is so much energy and temperature that stars are all born there

ASTRONOMERS & ASTROPHYSICISTS

1. Ptolemy - Egyptian; first person to give a model of the solar system, famous for preserving Hipparchus's star catalogue; his model was geocentric

2. Copernicus - Polish; first heliocentric model of the solar system - his model showed the sun at the centre, with all the planets orbiting around it in perfect circles, and the stars were fixed. This was incorrect because it assumed uniform circular motion

3. Brahe - Danish; sun orbits the earth, all the other planets orbit around the sun

4. Kepler - German; introduced law of ellipses (elliptical orbits) and 3 laws of planetary motion. The three laws of planetary motion are still valid/applicable today. He also said that there were 2 foci (focus pl.) in every ellipse, and the sun was at one of the two foci for each planet's orbit.

5. Galileo - Italian; designed refracting telescope, defended Copernician model of heliocentric solar system. Proved that the surface of the moon and the sun was not perfect/unchanging, discovered Jupiter's moons (hence Galilean moons), discovered phases of Venus which disproved the Ptolemaic model.

6. Newton - English; proved Kepler's laws, developed law of gravitation.

THE EARTH'S MOON

Lunar eclipse - when the earth is directly between the sun and the moon so no light shines on the moon; happens almost every 29-day lunar cycle

Solar eclipse - when the sun, earth and moon directly align so that the moon covers the sun completely; UV light still shines so in order to look at the eclipse you must wear protective shades

The moon is 384,400 km away from the earth. The gravitational field strength of the moon is 1.6N/kg.

Luminous objects - objects which emit their own light; **reflective objects** - objects which allow light to bounce off of their surface. Both of these kinds of surfaces/objects allow us to see things because, either way, light hits our eyes.

UNITS OF MEASUREMENT

- AU (astronomical unit)
  - 1 AU = 150 million km (on average)
  - 1 AU is measured as the average distance from the center of the earth to the center of the sun (average because the earth's orbit is elliptical so it doesn't always stay the same)

- lightyear
  - 1 lightyear = 9.46×10^{12} km
  - 1 lightyear is a measure of astronomical distance; it is the distance travelled by light in one year.

OUR COSMIC ADDRESS

- Planet Earth
- Solar System
- Milky Way Galaxy
- Local Group
- Virgo Cluster
- Virgo Super-cluster
- Observable Universe

Observable universe - the spherical region of the universe comprising of all matter that can be observed from Earth, space-based telescopes, or exploratory probes; electromagnetic radiation from this matter has had time to reach the Earth and our solar system since the beginning of the universe, therefore it can be observed in some way.

The local group is our group of galaxies - Milky Way and Andromeda and smaller ones. The observable universe is defined as different from the unobservable universe because the light of the unobservable universe hasn't reached us yet.

LIFE CYCLE OF A STAR

In the (relative) beginning of the universe's existence, planets and stars were formed due to gravitational force pulling hydrogen and helium together. Electrons can get so charged due to extremely high temperatures that they release excess energy in the form of photons - this is how light was first created, 200 million years after the formation of the universe. Further planets formed because of the repeated collisions of asteroids and comets. Suns and similar stars formed from the gas and dust remnants of supernovae.

In the center/core of every star, nuclear fusion is taking place. This results in a large amount of fuel being produced within the star. The mass of a star determines the speed of the fuel-burning as well as the end of their life cycle; smaller stars (like our sun) burn fuel slower, will last for several billion years, and end in a white dwarf & larger stars burn fuel faster, therefore are short-lived and will end in neutron stars.

Hydrostatic equilibrium - when external forces like gravity are balanced by a pressure-gradient force (e.g. inward gravitational force vs outward thermal pressure due to nuclear fusion)

Protostar - a star that has not started producing helium via hydrogen nuclear fusion; basically a pre-star

1. <u>Stellar nebula</u> - gravitational force of clouds of helium, hydrogen, space dust and plasma causes them to aggregate and collapse in on themselves onto a number of ‘cores’

2. <u>Stellar ignition</u> - nuclear fusion occurs in the core of the protostar due to extremely high temperatures

3. <u>Main-sequence</u> - 90% of a star’s lifetime in which the core is fusing hydrogen into helium via nuclear fusion and it remains in hydrostatic equilibrium

4. Red giant/supergiant - when hydrostatic equilibrium is broken due to less energy being produced in the core, the nuclear fusion reactions will begin to move outwards to the surface of the star, which causes outer shells to expand and change color; meanwhile, gravitational force of the star itself will cause the core to collapse inward and shrink - this causes increase in core temperature so that nuclear fusion starts again, this time turning helium into carbon.

5. Planetary nebulae - due to hydrogen-helium nuclear fusion on the surface in the red giant phase, when new helium shells gravitate towards the core and are ignited, the surge of energy blows off outer shells as planetary nebulae.

6. White dwarves (for low-mass stars) - the core of a star remaining at the end of planetary nebula events is extremely hot and white, consisting mainly of oxygen and carbon; it produces massive amounts of UV and thermal radiation and will eventually burn out/cool down since it no longer has any nuclear reactions occurring within it.

7. Supernova (for high-mass stars) - when hydrostatic equilibrium is broken for a high-mass star and the star runs out of nuclear fuel, the outer layers collapse into the core and are then expelled at extremely high force due to a nuclear explosion; remaining shockwaves cause an expanding shell of gas and dust, while the core becomes a neutron star, pulsar (if it is spinning), or a black hole.

COMPOSITION OF STELLAR BODIES

Most stars, for the majority of their existences, consist of 71% hydrogen and 27% helium, with the remaining percentage being heavier elements. The same applies for gas giant planets. On the other hand, terrestrial planets (which are comparatively rare) such as the Earth are composed of rocks (silicates) and metals (iron). The chemical composition of moons can be similar to that of terrestrial planets, or similar to the cores of the planets they orbit.

Spectrometer - a device capable of concentrating sunlight through a prism via a narrow slit; prism creates a spectrum of colorful light based on wavelength intensity. Dark lines interrupting the resulting spectrum can be used to identify atmospheric chemical composition of stars.

Spectroscopy - the process of using spectrometers

Fraunhofer lines - dark lines appearing in diffraction spectra by absorption of energy by the photons (light-carrying particles) in the ionic clouds of gases and other elements (e.g. hydrogen) around stars; each element absorbs light at specific wavelengths - scientists can use this to determine what elements are present.

Wein's law - the peak wavelength radiated by a star is inversely proportional to the temperature on the surface of the star, which also determines the color of the star

Planck's law - describes the spectral density of the electromagnetic radiation (visible light etc.) emitted by a blackbody with minimal external factors like interstellar dust etc.

Blackbody - an idealized physical body that absorbs all electromagnetic radiation and emits thermal radiation instead - some stars like our sun are only a close approximation of a blackbody.

Dispersing electromagnetic radiation from stellar objects through a red and blue filter and using Wein's law is a method used to determine the temperature or brightness of a star. However, since Wein's law only applies to bodies with a Planck spectrum computer modelling needs to be used to compare the ratio to ratios of other bodies to accurately determine the temperature.

WORK, ENERGY & POWER

WORK, ENERGY & POWER

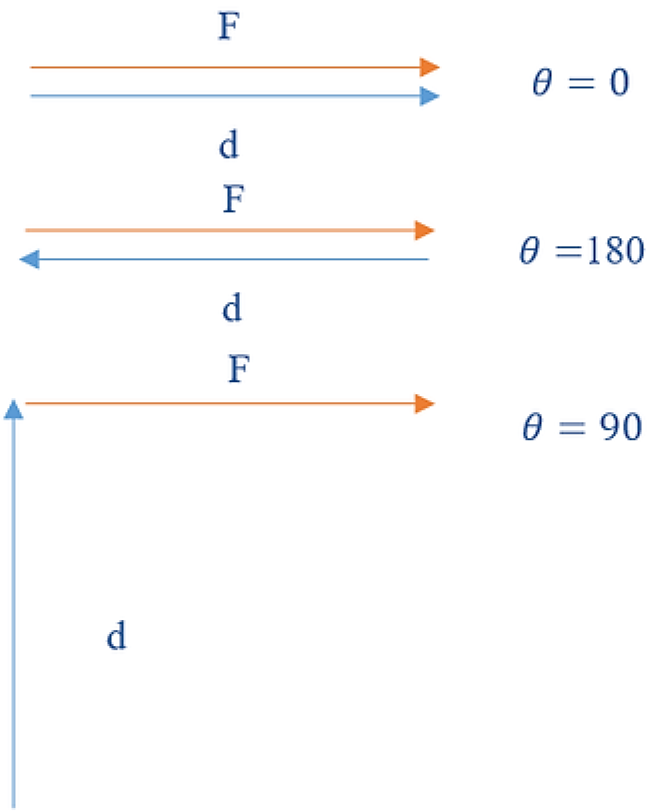
WORK

- **Work** - the energy transfer that occurs when an object is moved over a distance in the direction of an external force acting on it
  - vector quantity
  - SI unit is Joule (J); 1J is equal to 1Nm (Newton-meter)

- There are three key factors required for work to occur:
  - Force
  - Displacement
  - Cause
- In order for a force to qualify as having done work on an object, the object must be displaced.

- Work can be quantified with *F*d*cos(θ)*
  - *F - force (Newtons)*
  - *d - displacement in the direction of force (meters)*
  - *θ - angle between the force and displacement vector (degrees)*

- **Work-energy theorem** - work done against resistance is equal to change in energy
  - This theorem allows work and energy to be interchangeable in mathematical contexts.



ENERGY

- **Energy** - the capacity of a physical system to do work
    - scalar quantity
    - SI unit is Joules (J)

- **Law of conservation of energy** - energy cannot be created or destroyed, but it can transfer forms in an isolated systems

- There are two main types of energy, which can take many forms.
    - **Potential energy** - the energy stored in an object while it is not in motion; this energy is due to the object's position.
        - **Gravitational potential energy** - the potential energy an object carries due to its height and/or its capacity to fall in the direction of a gravitational force (e.g., a rock sitting at the edge of a cliff carries gravitational potential energy).
            - Gravitational potential energy can be quantified with *PE = mgh*
                - *m - mass (grams)*

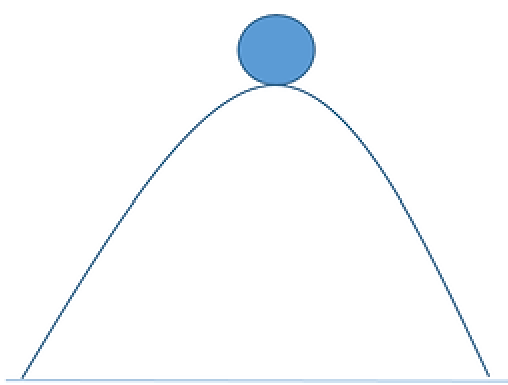
        - *g - gravitational acceleration (ms^-2)*
        - *h - height from ground (meters)*
    - **Elastic potential energy** - the potential energy stored in elastic material due to tension (e.g., the pulled string of a bow carries elastic potential energy before the arrow is released).
    - Electric potential energy
    - Magnetic potential energy
    - Nuclear potential energy
    - Chemical potential energy

  - **Kinetic energy** - the energy an object has because of its motion; the work needed to accelerate an object from rest to a certain velocity

- **Mechanical energy** - the sum of an object's kinetic energy and gravitational potential energy

- **Internal energy** - the energy of the particles inside matter

$$W = F \times d \times \cos(\theta)$$



$$PE_{gravity} = mass \times gravity \times height$$

$$KE = \frac{1}{2}mv^2$$

POWER

- **Power** - a measurement of work done/energy per unit time
  - quantified with *P = W/t = E/t*
    - *P - power (watts)*
    - *W - work done (joules)*
    - *t - time (seconds)*
    - *E - energy (joules)*
  - SI Unit is the *watt,* which is equivalent to *Joule/time*

- Power can also be redefined as the product of the force applied to an object and its (resulting) velocity
  - this definition is quantified with *P = Fv*
    - *F - force (Newtons)*
    - *v - velocity (meters per second)*

- **Power rating** - how much energy is used per a unit of time

$$P = \frac{Work\ Done\ (W)}{Time\ (t)}$$

CONSERVATION OF ENERGY & EFFICIENCY

- **Law of conservation of energy** - energy cannot be created or destroyed, but it can transfer forms in an isolated systems

- Many systems require energy to be transformed (e.g., A kettle transforms electrical energy into thermal energy; a ball falling off a cliff transforms gravitational potential energy to kinetic energy).
    - Typically, when energy is transformed in systems, a significant fraction is lost via transformation into non-useful energy.
    - This useless energy is most often lost in the form of thermal or sound energy; e.g., a lamp's purpose is to emit light, but thermal energy is often also emitted, meaning useful potential energy is lost.

- The efficiency of a system is measured by the following:

$$Power = \frac{Work\ Done\ (W)}{Time\ (t)}$$

$$Power = \frac{Force\ \times Displacement}{Time}$$

$$Power = Force\ \times \frac{Displacement}{Time}$$

$$Power = Force \times Velocity$$

$$Efficiency = \frac{useful\ energy\ out}{total\ energy\ in}$$

$$Efficiency = \frac{useful\ power\ out}{total\ power\ in}$$

GRAVITY

GRAVITY

GRAVITY

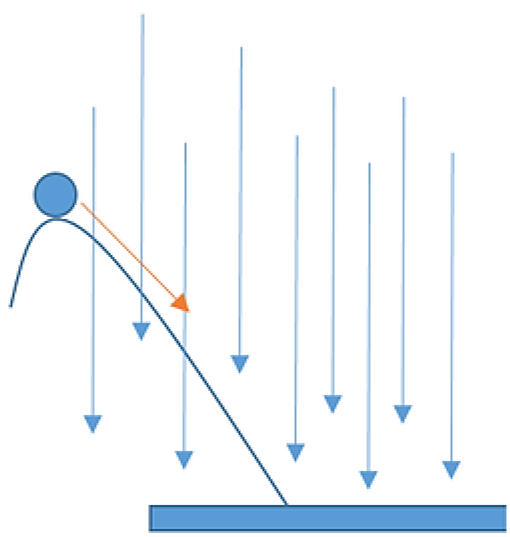
Gravitational force - the attractive force possessed by all objects with mass, which exerts a pull on all other objects with mass

- SI unit is Newtons (N)

Gravitational acceleration - the acceleration of an object in freefall in a vacuum, caused by gravitational force (can be used interchangeably with gravitational field strength)

Gravitational force is one of the four fundamental forces; it acts on a distance, without requiring direct contact. It causes objects to have weight and pulls all masses towards the center of mass of the source of the gravitational force. All objects with mass exert gravitational force on all other masses within their gravitational field.

Newton's law of universal gravitation states that the force of gravity is directly proportional to the products of the masses in question, and inversely proportional to the square of the distance between the masses.



$$F_g = G\frac{m_1 m_2}{r^2}$$

$$G = 6.67 \times 10^{-11}\frac{N \cdot m^2}{kg^2}$$

Weight - the product of an object's mass and the gravitational force being exerted on it

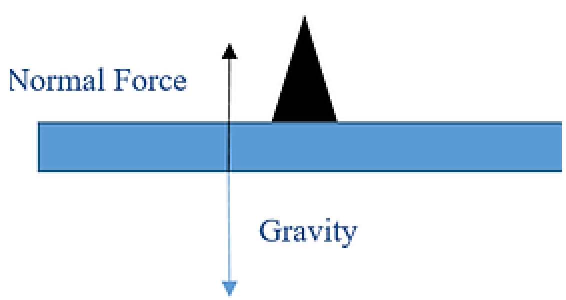
- can be quantified with *W = mg*
  - *W - weight (N)*
  - *m - mass (kg)*
  - *g - gravitational acceleration (m/s^2)*

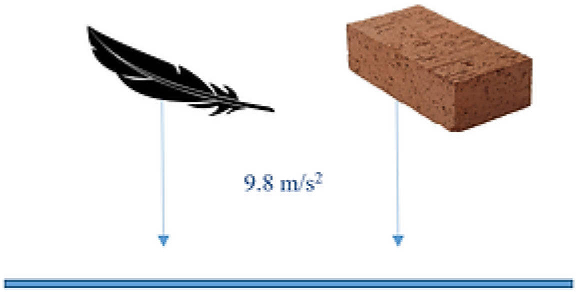
The equation for weight allows for the assumption that the greater the mass of an object, the greater its weight would be.

If an object is resting on a table (or any other surface), two forces act on the object - the force of gravity pulling the object down, and the resulting normal force which is directly opposite to gravity.

$$w = mg$$

$$weight = mass \times gravity$$





GRAVITATIONAL FIELDS

Gravitational field - a field in which an object with mass experiences gravitational force; all objects with mass have a gravitational field

Gravitational fields spread in all directions, but the force of the field decreases as the distance from the object at its center increases.

Gravitational field strength - the gravitational force exerted on an object per unit mass (used interchangeably with gravitational acceleration); gravitational field strength increases as you get closer to the center of mass of the object producing the field

- Earth's gravitational field strength is 9.8 m/s^2 (can be rounded up to 10)
- the product of gravitational field strength and the total mass of an object is another way of calculating gravitational force

The gravitational acceleration acting on all objects in a field will be the same regardless of their masses - the mass determines the magnitude of the overall force being experienced by the object rather than its velocity. However, gravitational acceleration around a body varies depending on distance from the center of its mass. Such distances would only be significant if they were on an astronomical scale, but on and around the surface of most large/massive objects, the differences in the varying distance from their center of mass are negligible. Therefore, gravitational field strength on the surface of most massive bodies is assumed to remain constant.

Due to Newton's law of universal gravitation, mass is also a key factor in gravitational fields; the force between two pens would be much less significant than the force between the pen and the Earth. Because the Earth is much more massive, it has an enormous gravitational field compared to the gravitational field of the pen. This is essentially how all bodies in our solar system stay in orbit around the sun - because of its huge gravitational field.

ENERGY SOURCES & RESOURCES

ENERGY SOURCES & RESOURCES

Energy - power derived from physical or chemical sources

This definition of energy is not to be confused with the definition that applies in mechanical physics.

Energy sources can be divided into <u>two primary categories</u>:

- **Renewable sources** - resources that can be restored, or from which energy can be reaped immediately or almost immediately after energy has already been obtained; unlimited energy sources, e.g. solar power, wind power
- **Non-renewable sources** - sources of energy which are limited in quantity and will effectively run out over time, e.g. fossil fuels, natural gas.
  - although these resources will eventually be produced again by natural processes, they will take millions of years to do so

NON-RENEWABLE ENERGY

COAL

Coal - a sedimentary black or brown rock composed predominantly of organic carbon

There are <u>two main types of coal:</u>

- **thermal coal** - coal with a significant moisture count, thus burned for steam and used in energy production

- **metallurgical coal** - coal that can be mined to produce the carbon necessary for steel-making

Biomass - the biological raw material that an energy resource/fuel is made of

Coal is formed from the energy stored in plants hundreds of millions of years ago. As time passes, layers of rock form over dead organic matter, allowing for pressure and heat to be exerted on the biomass. This initiates chemical and physical change within the biomass to form coal as we see it now. Coal is typically found in layers of vein-resembling 'seams' underground.

<u>The process of generating electricity with coal is:</u>

1. Coal rocks are pulverized in powder then exposed to hot air, allowing for combustion to take place
2. Water pumped through the system is exposed to the heat and turns to steam
3. This steam, due to the high pressure, has the strength to turn a turbine
4. The turbine is attached to a generator, which converts kinetic energy to electric energy
5. The team returns to a liquid state once more (water) and the process continues

Type of Resource	Resource	Advantages of Resource	Disadvantage of Resource
Non-Renewable	Coal (As a fossil fuel, coal is a natural fuel formed in the geological past from the remains of living organisms)	• Coal is **found in abundance** (although coal sources are quickly depleting) relative to many other non-renewable energy resources • Due to it's solid state, it is easily **transportable** • Coal is extremely **affordable**, which is why it has been used for many decades • Relative ease for the conversion to energy allows coal to be a **viable option** for energy production **in developing countries**	• When burned, coal releases high levels of **carbon dioxide**, a greenhouse gas which is a key contributor to global warming and climate change • Carbon dioxide is **poisonous** if inhaled in large quantities • The extraction process of coal can be extremely **dangerous**, and lead to negative secondary effects (such as, most prominently, acidified streams and lakes)

NATURAL GAS

Natural gas - flammable gas, composed predominantly of hydrocarbons

A large percent of natural gas is methane. Natural gas occurs underground; similar to coal, over the process of millions of years, organic matter was pressurized to incident physical and chemical changes, causing the biomass to become partly coal, partly petroleum (crude oil), and partly natural gas.

By drilling holes underground where geologists believe there to be a significant reserve of natural gas, this gas can be captured and used to produce energy. The gas obtained is usually mixed in with other hydrocarbons and substances, those of which are not useful. Because of this, the gas must be filtered and separated at a plant.

Natural gas is versatile and can be utilized in various power production plants including:

- Steam engines
- Industrial natural gas-fired turbines
- Microturbines

Type of Resource	Resource	Advantages of Resource	Disadvantage of Resource
Non-Renewable	Natural Gas (Natural gas is composed primarily of methane)	• Relative to coal, natural gasses emit **smaller quantities of carbon dioxide**, making it a *relatively* cleaner energy source • Natural gasses are relatively **cheap** due to its high production and storage levels • The industry **employs** 2.8 million in the U.S. alone- provides employment	• Natural Gas (methane) is a **powerful greenhouse gas**, although less so than CO_2 • Natural gas leaks are highly **detrimental for the environment** + human health • **Extraction methods** (fracking, for example) for natural gas are extremely **damaging** to the environment as well as human and wild-life that live near extraction sites •

PETROLEUM

Petroleum - a naturally occurring liquid found under the Earth's surface that can be refined into fuel

As mentioned above, petroleum is formed the way coal and natural gas is formed; biomass is pressurized over millions of years to form coal, petroleum and natural gas

There are three technologies that convert petroleum to fuel:

- Petroleum oil is combusted to produce steam. This steam turns a turbine, allowing a generator to convert kinetic energy to electrical energy
- Petroleum oil is burned, the heat allowed the water pumped through the column to heat as well as turn to steam. This steam turns a turbine, allowing a generator to convert kinetic energy to electrical energy
- Oil is first combusted to turn a turbine. Once the exhaust gasses are recovered, they are used to heat water in a boiler, which once more emits steam and turns a turbine.

Type of Resource	Resource	Advantages of Resource	Disadvantage of Resource

Non-Renewable	Petroleum (Petroleum (also called *crude oil)* is a toxic liquid that occurs in geological formations beneath the Earth's surface)	• Petroleum can be **extracted** easily and **quite cheaply** due to our well-developed technology • Small amount of petroleum can reap **large amounts of energy** for use • Because petroleum is liquid, it can be **transported easily** and over long distances • Petroleum is largely useful in the transportation industry as it has the capability to **provide energy for most vehicles**	• Petroleum **resources are limited**, and will eventually run out, as all non-renewable resources eventually will • The extraction and burning of petroleum (releasing carbon dioxide and other greenhouse gasses) contribute greatly to **environmental pollution** and global warming. • **Oil spills** are quite common, are enormously detrimental to the environment, be it bodies of land *or* water

RENEWABLE ENERGY

URANIUM

Uranium - a heavy metal commonly used in nuclear reactors to produce nuclear energy via fission

Enriched uranium - a type of uranium in which the percentage composition of uranium-235 has been increased via the process of isotope separation

Uranium is thought to be formed in cosmic events like supernovae or the merger of two neutron stars. Naturally occurring uranium in the Earth is found in ores; these ores are composed of three major isotopes of uranium: uranium-238, uranium-235, uranium-234. Uranium-235 is most commonly used for nuclear power generation, as it can sustain a fission chain reaction, and weaponry. Low-enriched uranium is preferred for nuclear power.

Nuclear fission - the the process in which the nucleus of an unstable atom is split into two or more smaller nuclei, which are referred to as fission products

Fission chain reactions are commonly used in nuclear power plants as a source of clean and renewable energy. Nuclear fission energy requires the presence of a moderating substance to sustain the reaction for as long as possible so that the maximum amount of energy is produced. Moreover, the rate of the reaction must also be controlled in order to ensure efficiency and safety of the reaction – this is done using control rods made of elements that can absorb neutrons (most often boron).

Nuclear fusion has not been used as an energy source on Earth because we do not currently possess the technology to cause fusion reactions (extremely high amounts of energy are required).

Type of Resource	Resource	Advantages of Resource	Disadvantage of Resource

Non-Renewable	Uranium (Also called nuclear energy)	• Uranium is considered an **environmentally friendly** energy source, due to the fact that it doesn't discharge any greenhouse gasses • While nuclear power plants are often expensive to install, nuclear power is **cost-effective** • Unlike solar or wind power, nuclear power is **reliable**, in that plants are able to operate no matter weather or outside conditions • Small amounts of **uranium can yield enormous amounts of energy** as compared to *any* other energy resource • Uranium, although non-renewable, is so **abundant** in the Earth that some consider it renewable • Scientists may be able to replicate the sun's **fusion** methods of uranium to produce energy, thus make uranium and nuclear power a renewable energy source	• The mining and processing of uranium presents **environmental damages** • Waste uranium is **radioactive,** and thus lethal for humans, animals and flora. • Used uranium must also be stored due to its radioactivity, and this **storage takes up significant amounts of space** and can be highly unstable • Nuclear power plants, due to their instability, are **prime targets for terrorist activity** • Expensivity is definite when functioning a nuclear power plant, due to the **high cost of production and storage**

WIND

Wind energy is produced mainly using wind turbines. Typically, wind turbines are located in rural areas as they take up a large amount of space. Wind turbines require high-speed winds to spin the blades of the turbine, and then a generator is used to convert that kinetic energy into electrical energy

<u>The wind turbine blades are designed in two different ways</u>:

- **Drag type blades** - this blade design uses the force of wind to rotate the blades; they have a higher torque than lift designs but rotate at a slower speed, making them less efficient for large-scale energy production

- **Lift type blades** - this design allows wind to remain within the blade's grasp for a longer period of time, resulting in a pressure being built on the tail edge; the pressure difference forces the blade to move at a higher speed

Type of Resource	Resource	Advantages of Resource	Disadvantage of Resource
Renewable	Wind	• Wind energy is considered **clean energy**, wherein there is no strenuous, pollution-causing extraction or processing required • **Costs for production are relatively low** and as science and technology advance, these prices continuously become lower • For a **domestic** supply of energy, wind power is ideal • Once infrastructure has been implemented, **power essentially becomes free** • Wind energy does **not emit any pollution**	• Wind power, due to its **lack of reliability**, is consistent and unpredictable • Wind power is **dependant on weather** conditions; on days where wind is lacking, power is scarce • Many consider wind farms to **ruin the visual aesthetic** of their location, especially due to the fact that they are predominantly located in rural locations • Turbines are often **loud**, and can cause inconvenience to those within its vicinity • Wind energy has a significant **impact on wildlife**, fatally harming birds and other flying animals

SOLAR POWER

Solar power - electric or thermal energy generated by harnessing the energy of the sun via photovoltaic cells in solar panels (other technologies are also used)

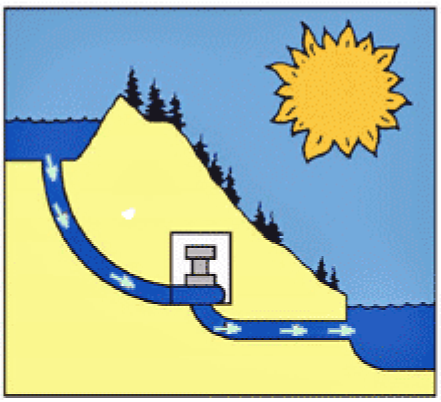
Solar power is generated by solar panels, which are comprised of PV cells. These cells are made of silicon combined with other materials that ensure that there are extra electrons on one side of the cell and less electrons on the opposing side. When the sunlight hits the cell, photons remove electrons from the silicon; the electrons then travel to the side with missing electrons. This causes an electrical current, which eventually reaches a converter that turns it into electrical energy.

Type of Resource	**Resource**	**Advantages of Resource**	**Disadvantage of Resource**
Renewable	Solar	• Solar power is a **sustainable energy alternative**- the sun is a reliable source of energy, and shines down significant amounts of power • Solar power does not require the burning of fossil fuels, or any other harmful substance, and thus **contributes minimally to polluting** the air/earth and playing a role in climate change • Because the sun shines on every part of the globe, it provides **political independence** in terms of energy production and transportation; if technology advances far enough, no individual country would be reliable on another for power	• Solar power requires materials similar to those of the **hazardous** electronics that we use; waste and disposal of these materials is **highly toxic** • Energy is only yielded if the sun is shining; on cloudy days and during the nighttime, solar power is **unreliable** • Solar power plants **requires a generous amount of land,** thus harming the natural environment in which they are placed

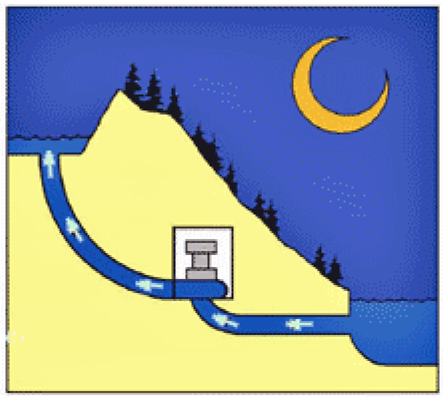
HYDRO-ELECTRIC POWER

Hydro-electric power - electric energy produced through the force and power of moving water; this energy is harnessed via HEP plants

The most common type of hydroelectric power plant stores water in a reservoir and allows it to move through a turbine. This rotates the turbine and a generator converts this kinetic energy to electrical energy. Such power plants can even be downsized, so as to provide energy domestically.



Daytime: Water flows downhill through turbines, producing electricity



Nightime: Water pumped uphill to reservoir for tomorrow's use

Type of Resource	Resource	Advantages of Resource	Disadvantage of Resource
Renewable	Hydro	• Hydroelectricity is quite **reliable** in that hydro-plants are able to provide constant supplies of energy no matter climate or other minute circumstances • Hydro-electricity is **flexible**, and plants can be adjusted to supply certain amounts of power as determined by the owner	• Because hydro-plants are built in natural water bodies, they often **disrupt the flow and migrations of aquatic wildlife** • As well as this, the construction of dams are known to **flood** parts of near-by cities and towns, and cause **droughts** in others, although this is often manageable

BIOMASS

Biomass - any matter that is living, be it flora or fauna, is considered biomass; the term is typically used to describe plant matter and animal and human waste

Biomass can be converted to electrical power through many methods, the most common being the burning/combustion of biomass to heat water, the steam of which will rotate turbines attached to a generator. Typically wood-based material (wood chips, trunks, logs, etc.) are used for the production of electrical energy. Corn and wheat are typically combusted to produce steam.

Type of Resource	Resource	Advantages of Resource	Disadvantage of Resource
Renewable	Biomass	• Biomass from agricultural waste may add **value to the agriculture** itself, as well as the crop yield • The growth of biomass **increases natural oxygen production and minimizes the amount of CO_2** in the present atmosphere. The net carbon footprint of biomass is zero- carbon dioxide released from the incineration of biomass is almost equal to the amount of carbon dioxide that is used up during the photosynthesis process of biomass. This is called **carbon neutrality**. • Biomass energy is **versatile** in that it can be converted into a variety of fuel types	• The land utilized for the growth of biomass **reduces the amount of land available for the growth of crops**- this being a dire issue due to the already apparent lack of food within civilizations • The **cost of production and incineration is higher than the fuel's monetary value**. Especially in the face of more environmentally and financially friendly and options like solar and wind power, biomass often is not a viable option • The growth of biomass **requires water**, an unstable and highly required substance. Not only does this lead to the increased costs for irrigation, but with water itself becoming an alternative for energy production, the use of biomass becomes questionable.

A link to the wordfile containing the advantages and disadvantages table can be found here.

FUELS & THE ENVIRONMENT

FUELS & THE ENVIRONMENT

The generation of energy is one of the most vital components of modern civilization. However, it has created a plethora of environmental issues that have become too wide-spread and dire to ignore. Some methods of energy production are more environmentally friendly than others, but each has its own disadvantages. After the industrial revolution, the combustion of fossil fuels became widespread to an extent that the release of carbon in the atmosphere escalated from being a minor, domestic issue to a global issue. Scientists began to realize that the Earth's climate was beginning to shift, and this was changing the entire structure of Earth itself.

FOSSIL FUELS & THEIR EFFECTS

Despite the high energy outcome paired with the relatively low cost, there are environmental issues that arise when using fossil fuels. Fossil fuels are a scarce, non-renewable resource and their reserves are rapidly depleting. Extraction methods like mining to extract fossil fuels from resource-abundant areas has greatly impacted local ecosystems and societies. Forest environments are often rich in fossil fuels and other valuable materials and as such, are cleared for mining and excavation processes. This clearing involves deforestation and destroying natural habitats.

As well as this, the actual burning of fossil fuels has also played a great role in harming the environment - the combustion reaction, as mentioned above, releases carbon dioxide, nitrogen, and water vapor into the atmosphere, all of which are major greenhouse gases.

Greenhouse gases - gases in the Earth's atmosphere which absorb and emit thermal infrared energy, essentially trapping heat within the atmosphere; greenhouse gases contribute to global warming and climate change

Ozone layer - a region of the Earth's stratosphere which absorbs the sun's ultraviolet radiation

The result of climate change is immense; it harms almost every ecosystem on Earth, either by **climate variations** or by altering the dynamics of a certain area. Thus, it has become necessary, especially in recent times, to consider the effect of the fuels we use on the environment, so as to ensure environmental sustainability.

Climate change - a long-term change in the earth’s climate, especially due to an increase in the average atmospheric temperature

THE INDUSTRIAL REVOLUTION

The sudden acceleration of climate change is primarily due to decades of industrial activity. The globe has warmed significantly in the last two centuries, posing an undeniable threat to the entire planet. Although carbon emissions and other greenhouse gases (e.g. water vapor) were released into the atmosphere even before the industrial revolution, the rate at which they are being produced has skyrocketed in recent decades - the Earth's natural reparation of imbalanced ecosystems and the atmosphere can no longer keep up (Reynolds, 2010).

A great portion of this issue began with the Industrial Revolution (18th-19th centuries), which marked a turning point for civilization and the way humans interact with their environment. The Industrial Revolution, which began in Britain around 200 years ago, has improved our standard of living immensely, but while doing so, has also destroyed the environment. Now, different regions are experiencing great variations is over minimal time periods. This affects the health of all organisms, as well as having significant psychological, physical and emotional effects (UK Essays, 2013). In a study conducted by the University of California – Berkeley, and Princeton University, scientists found that the increase in temperature and change in overall climate has actually heightened violet urges in not only humans, but other species as well (Kaita, 2017).

CLIMATE CHANGE

CAUSES

Climate variation can be credited to two causes - natural and human.

<u>Natural causes of climate variation include</u>:

- volcanic eruptions
  - the particles (water vapor, sulfur dioxide, dust, ash etc.) released when volcanoes erupt cause a haze-like field in the atmosphere, reducing the amount of solar radiation entering the Earth, leading to a lower global

temperature (Pidwirny, 2006)

- oceanic currents
    - oceanic currents play a part in controlling the concentration of carbon dioxide as they
    - oceanic currents distribute solar energy absorbed from the equator to the poles, regulating global temperature
    - oceans also absorb carbon dioxide and it reacts with saltwater to form carbonic acid

- the Earth’s orbital changes
    - at different points in the elliptical orbit of the Earth around the sun, the Earth will be exposed to more heat for a sustained period of time
    - the axial tilt of the Earth also determines which regions are exposed to the sun

- livestock
    - cattle produce large amounts of methane, which is a major greenhouse gas - methane has 21 times the global warming potential of carbon dioxide

<u>Human causes of climate variation:</u>

- deforestation
    - the reduction of forest area and trees in general means that there is less regulation of the carbon cycle and contributes to an increased amount of carbon dioxide in the atmosphere

- industrialization
    - the burning of fossil fuels causes harmful emissions
    - the widespread usage of motor vehicles causes harmful emissions

- CFC usage
    - chlorofluorocarbons are chemical compounds produced by industrial processes and domestic appliances (refrigerators, air conditioners, etc.) which destroy ozone molecules - 1 chlorine molecule can destroy up to 100,000 molecules of ozone before being removed from the stratosphere

CONSEQUENCES

Research suggests that there are three main effects of climate change.

Impact on human health & survival:

- the melting of the permafrost will release frozen viruses and bacteria, against which there will be no effective medicines or immunity
- major climate events (e.g. droughts, floods, etc.) will cause illness, disease, resource shortages, and more
- world hunger will increase as a result of the effects on agriculture, fishing, cattle-farming, etc.
- the lack of clean water will increase and threaten survival and sanitation
- the forced consumption of unsafe materials may increase due to resource shortage, which will cause further diseases
- warmer and wetter climate areas may foster the increased spread of infectious diseases like malaria and dengue

Impact on biodiversity:

- forced migration of animal species causing imbalance in ecosystems
- drying up of freshwater bodies harming freshwater fish
- ocean acidification harming coral reefs and other marine organisms
- destruction of habitat of animals that live in colder regions
- driving animals to endangerment or extinction due to lack of resources
- desertification affecting plant species

For example, zebra mussels, found in Canadian waters, first documented in the 1980s, have caused great distress, as they produce extremely quickly (a female mussel can produce up to a million eggs per year) which has caused a reduction in the population of algae and plankton, the food source for many native inhabitants.

Impact on human psychology & social behavior:

- climate change indirectly increases poverty via resource depletion and its consequential impact on economic and political system
- general guilt, anxiety & stress experienced by people about the climate
- temperature variations affecting anger and happiness rates
- population growth being affected by climate change

WHAT CAN WE DO?

- Using clean power plants - for most nations, implementing renewable energy resources is difficult due to already-existing infrastructure and a lack of sufficient monetary and financial power
    - more than 20% of Americans plants built in 2013 use renewable energy sources (Biello, 2007)
    - clean energy can not only keep cities clean, but also create a more reliable source of energy
    - most renewable energy sources, although expensive, do not produce any gaseous emissions or chemical pollution

- Taking action in small numbers
    - individuals can protest against unsustainable power production & pollution
    - in 2008, six states in the US launched a political effort to minimize carbon dioxide pollution in their areas - by 2014, this movement grew to nine states and 4 of those states cut greenhouse emission by nearly half (Biello, 2007)

- Minimizing unnecessary transportation - in the US, transportation is the second leading source of greenhouse emissions - burning a single gallon of gas produces twenty pounds of carbon dioxide; millions of citizens commute long distances daily, creating an enormous number
    - instead, taking a bike, walking, or taking public transportation would reduce the unnecessary usage of fuel (Biello, 2007)

    - moving close to work or working in an area close to home would assist greatly in the prevention of the issue.

- Cutting down on long-distance travel - aircraft emissions are relatively closer to the atmosphere and utilize a great amount of fuel; coal-powered trains are also contributors of carbon emissions
    - using public aircraft services is significantly better than using personal aircrafts
    - using electric trains or trams is a better alternative to steam-powered trains which have emissions

- Discouraging consumer culture - consumer culture encourages bulk production and consumption of unnecessary products, increasing industrialization and pollution
    - ensuring one only supports eco-friendly manufacturers
    - supporting local farms and home-owned stores, as this reduces transportation/shipping emissions
    - buying bulk material can reduce wasteful packaging

- Going vegetarian - cattle farming is considered to contribute 14% of greenhouse emissions from human sources
    - less product and material is used to grow crops than rear animals
    - crop farming does not produce gaseous emissions; it increases oxygen circulation

- Unplug devices - the average American will use more energy with devices on standby than when in usage, due to unnecessary electricity (energy) consumption
    - the simple action of unplugging devices will reduce energy consumption
    - purchasing energy-efficient electronics will also reduce energy consumption

- One child rule - overpopulation is a threat to the Earth's already depleting fuels and resources; it is estimated that in the following 50 years, the population will increase to 9B.
    - having one child per couple/pair/individual woman would reduce overpopulation and its stress on the Earth
    - family planning education and awareness programs may help to dispel social beliefs that pressure families into having more than 2-3 children
    - awareness about contraceptives would also decrease population growth

- smaller populations will help nations reduce their carbon footprint (among other benefits)

THERMODYNAMICS

THERMODYNAMICS

THERMAL ENERGY

Heat is what allows molecules to constantly be in motion. An increase in heat will result in an increase in motion, and vice versa. Through each state (solid, liquid, gas), the transfer of heat varies in method.
All methods of energy transfer are forms of work being done - including thermal energy transfer.
Thermal/heat energy - the energy produced when a rise in temperature causes the molecules of matter to collide at faster speeds

<u>Heat energy can be transferred from bodies of masses in three ways</u>:

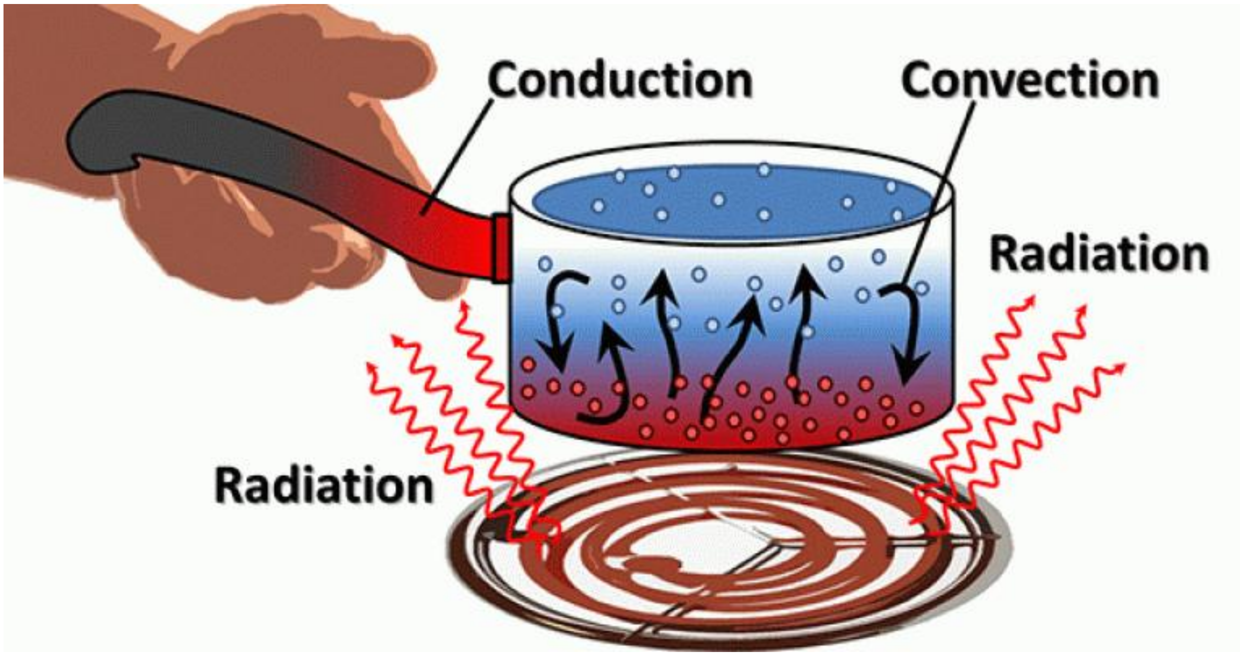
- **Conduction** - the transfer of internal energy within a body via the collisions of particles and movement of electrons; heat will from a hotter region to a colder region via conduction

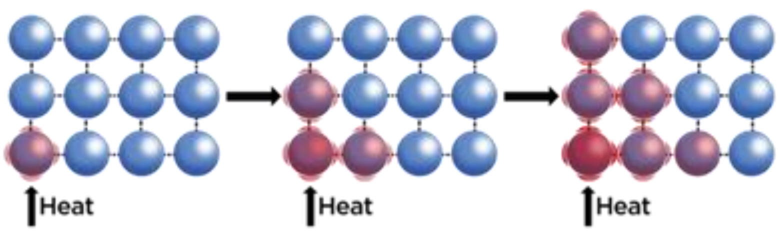
- **Convection** - the movement of thermal energy (heat) through fluids, such as gases or liquids

- **Radiation** - the emission of electromagnetic waves from all matter with a temperature above absolute zero, regardless of medium; occurs when thermal energy converts to electromagnetic energy

Absolute zero - the temperature at which a thermodynamic system has the lowest possible energy; −273.15 °C

Nothing in the universe (as far as we know) has reached absolute zero.





CONDUCTION

Through solids, the transfer of heat is called *conduction.* Solids are heat conductors because of the close proximity between particles. Metals are some of the best thermal conductors.

Thermal expansion - when a rise in temperature causes molecules to begin to move faster and further apart

Thermal equilibrium - the condition under which two substances in physics contact exchange no heat energy

Conduction occurs when two objects with varying temperatures come into contact with one another. As the heat energy in molecules increases, the mass will undergo thermal expansion. Thermal energy is constantly in motion, so in the case of two objects in contact (one with greater heat energy), heat will move out of the warmer object into the cooler object, until the system reaches thermal equilibrium. Heat always moves out of warmer objects/regions and into cooler objects/regions.

Conduction occurs due to the fact that warmer objects have a greater kinetic energy, therefore, they vibrate at a greater speed. When the masses make contact, the object with faster moving particles (in other words, the object with more thermal energy) will cause the other object's particles to move faster as well, via transfer of heat energy.

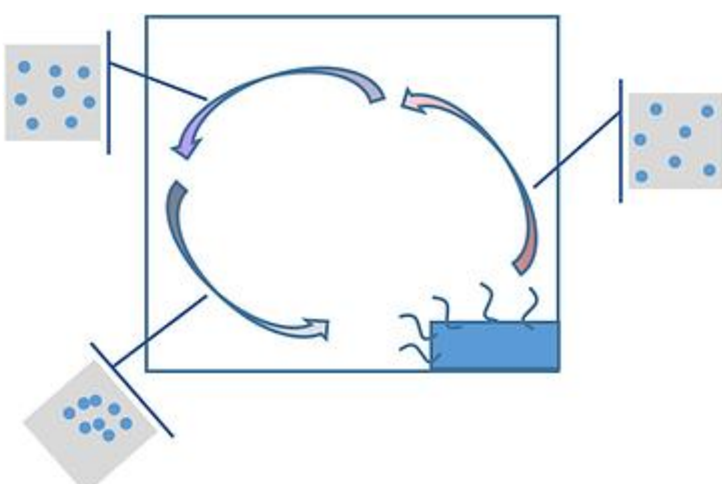
CONVECTION

Convection describes the movement of heat through fluids (gases and liquids).

Convection current/convection heat transfer - the circulating path of fluid particles that results from the process of continuous heating up of liquids or gases via convection

As heat is applied to a space, the air molecules near the source of heat begin to gain energy, colliding with one another and spacing apart. As they spread out, the heated gas becomes less dense, and rises. When warm air rises, the cooler air has the opportunity to move towards the heat source and obtain thermal energy. Meanwhile, the warm air cools down due to distance from the heat source, becomes dense, and descends back to the level as the previously cool air. The previously cool air, now heated, rises, and the cycle thus continues.

This cycle can also occur in water bodies (or other liquids), as convection currents occur in all sorts of fluids.



RADIATION

Radiation is the process by which thermal energy is transferred through electromagnetic waves.

While both convection and conduction require particles to transfer energy, it is also possible that energy be transferred through a vacuum and not require any matter via which the transfer occurs. We know this because the sun transmits thermal energy to the Earth. All objects with mass transmit thermal radiation via infrared waves.

Infrared radiation - the electromagnetic radiation that can transfer heat energy; the wavelengths are longer than those of visible light but shorter than radio waves

If an object's rate of absorption and emission of infrared radiation is equal, the temperature of the object remains the same. If an object absorbs more radiation than it emits, the temperature of the object will rise. If an object emits more radiation than it absorbs, the temperature of the object will fall.

Emission of infrared radiation occurs when the molecules of an object change their rotational-vibrational movements; as an object heats up, the kinetic energy of its particles increases and thus the emission of IR also increases. Absorption of infrared radiation is dependent on the frequency at which the atoms of the object in question are vibrating - if they vibrate at the same frequency as IR radiation, the radiation will be absorbed. Substances like water vapor, carbon dioxide, and ozone can efficiently absorb IR radiation.

Vibrational motion - the movement of a body moving back and forth in its general position

MEASURING TEMPERATURE

Apparatus used to measure temperature:

- Clinical thermometer (mercury)
- Thermistor
- Thermopole
- Laboratory thermometer (alcohol)

Heat causes molecules in mercury to expand, thus the mercury goes ‘up’ the thermometer (the mercury is contained inside the hollowness of the thermometer, known as the bore), and when the temperature goes down, it contracts and the height decreases. The meniscus of mercury is convex (for comparison, water is concave).

Kelvin, Celsius and Fahrenheit - units of measurement of temperature

Calibrating a thermometer:

1. *Ice point is determined* (the temperature at which ice forms)
   this is done by putting the thermometer in crushed ice and wait for the thermometer level to stabilize. Where the meniscus rests is the ice point.

2. *Steam point is determined* (the temperature at which water becomes vapor)
   This is done by putting the thermometer in a sealed jar of steam and wait for the temperature to stabilize. Where the meniscus rests is the steam point

3. Find the length of one division of celsius degree and then divide the length of the thermometer by this

WAVES

WAVES

Waves - oscillations that carry energy; alternatively, disturbances produced in a medium to create energy

Medium - substances that make possible the transfer of energy from one location to the other, predominantly through waves

There are several types of waves, e.g. electromagnetic waves and sound waves. EM waves include visible light waves, which allow us to see objects around us. Different waves also travel using different mediums - sound waves require matter to travel through, whereas EM waves can also travel in a vacuum and require no medium at all.

Mechanical waves - waves that require a medium, be it a fluid, solid, or otherwise, to transmit energy

WAVE PHENOMENA

Waves undergo a variety of reactions when travelling in various mediums, or when faced with an obstacle. This is because waves won't simply stop once they encounter a different medium, or meet an obstacle.

The most common behavior of waves are as follows:

- Reflection
- Refraction
- Diffraction
- Interference

REFLECTION

Reflections - the change in direction of a wave when met with a mirror-like obstacle

Reflections can be observed with light waves, sound waves, and water waves.

- With light waves, reflection causes the direction of light to change, and thus hit another object
- With sound waves, reflection causes echoes
    - sound reflection is used in sonar technology
- If water waves hit a plane, they reflect in the opposite direction

The law of reflection - the angle of incidence of a wave on a reflective surface is equivalent to the angle of reflection of that wave (see Fig. 1)

The law of reflection applies to all sorts of waves, however, the nature of the wave may change the way it interacts with or is affected by reflective surfaces (note that 'reflective surface' here does not mean reflective in the optical sense). For example, light waves bounce entirely off of highly reflective surfaces, but in situations involving sound waves, part of the incident ray will be transmitted to the medium it is in contact with.

Incident ray - the first ray/wave to hit the reflective surface or plane

Reflected ray - the ray that is reflected off the surface or plane

Normal ray - the ray that is perpendicular to the surface and bisects the incident and reflective rays

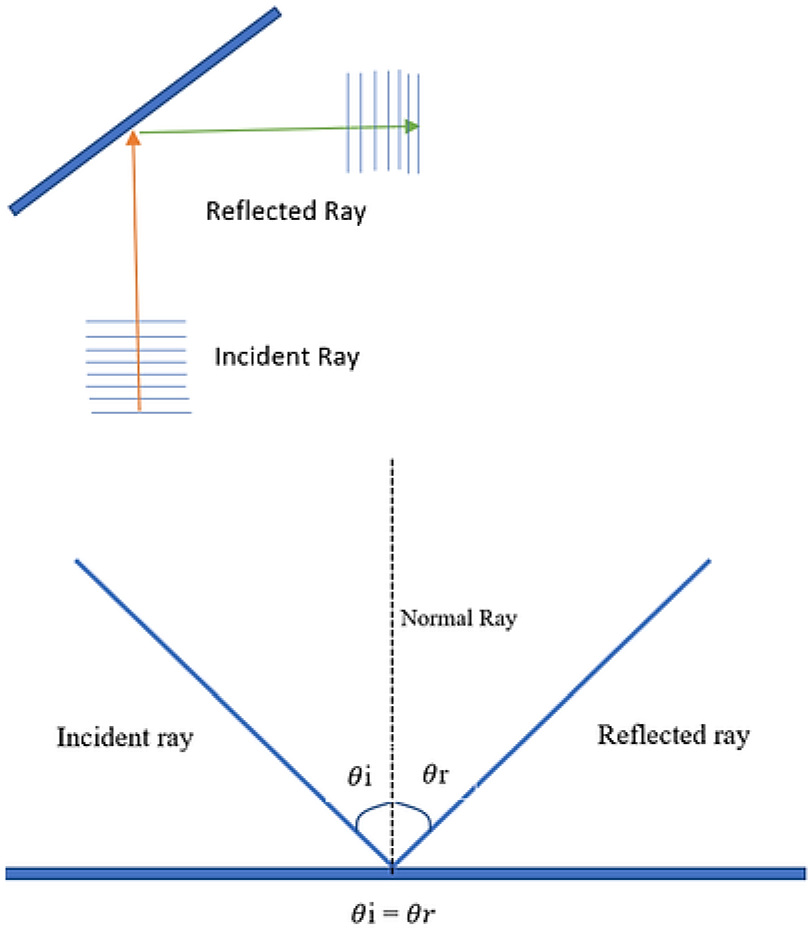
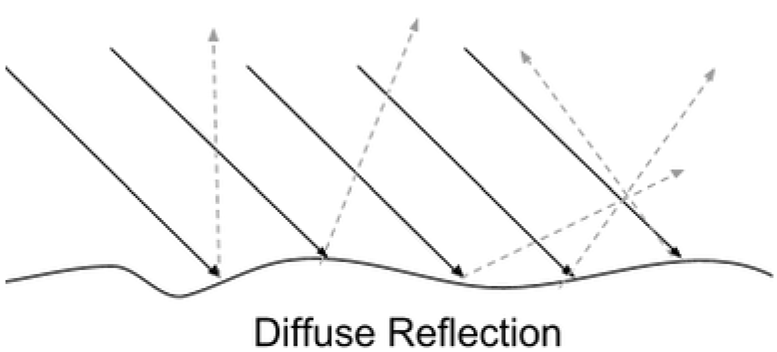


Fig. 1 - Demonstration of the law of reflection.

Waves striking a highly smooth and reflective surface causes **specular/regular reflection**; waves striking a rough or uneven surface causes a **diffuse reflection** (see Fig. 2). A diffuse reflection is also produced when waves are incident on convex surfaces.



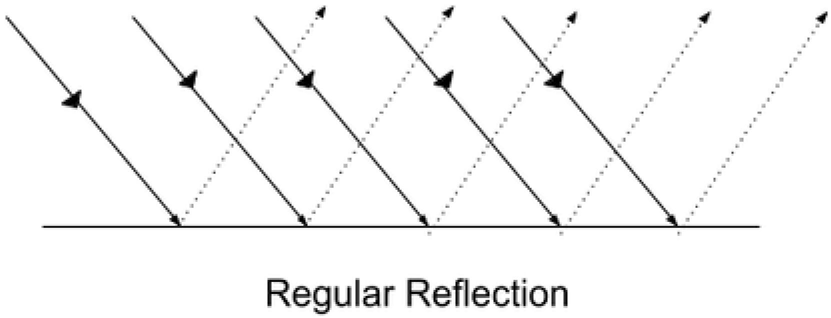


Fig. 2 - Diffuse reflection and specular/regular reflection of light waves.

If the reflective surface, rather than being a plane, is parabolic (curved), the incidents waves converge to a single point called the **focal point** (see Fig. 3).

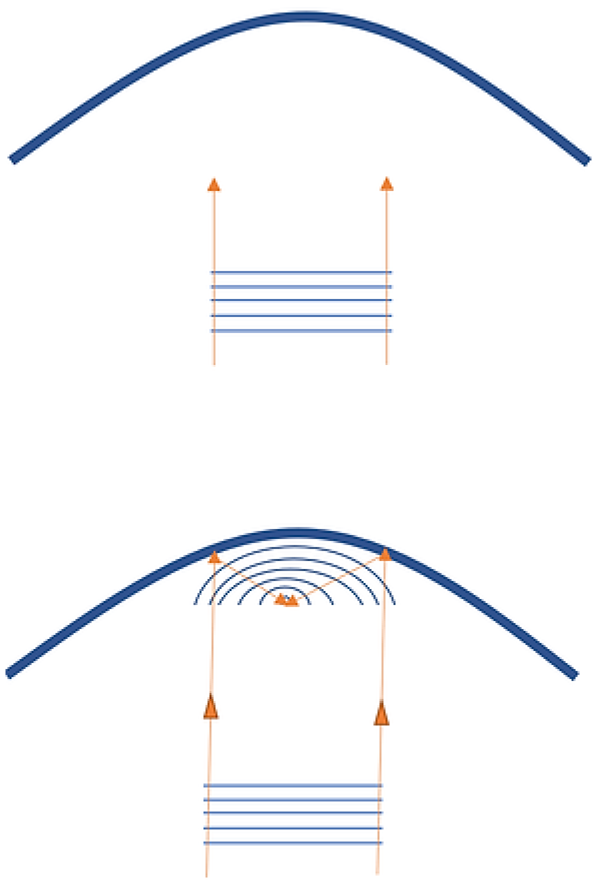


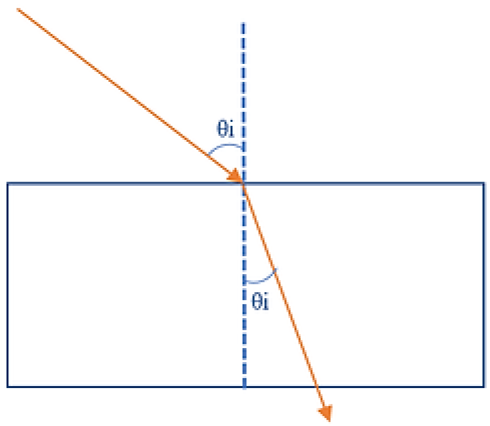
Fig. 3 - Convergence of waves to a focal point on a concave surface.

REFRACTION

Refraction - a change in direction of a wave after passing from one medium to another; the bending of waves as they travel through varying mediums, often accompanied by a change in speed and wavelength

The speed of a wave is dependent on the properties of the medium it travels in.

Refractive index - a dimensionless number that quantifies how light refracts through a medium; a number that indicates the number of times slower that a light wave would be in a given material than it is in a vacuum



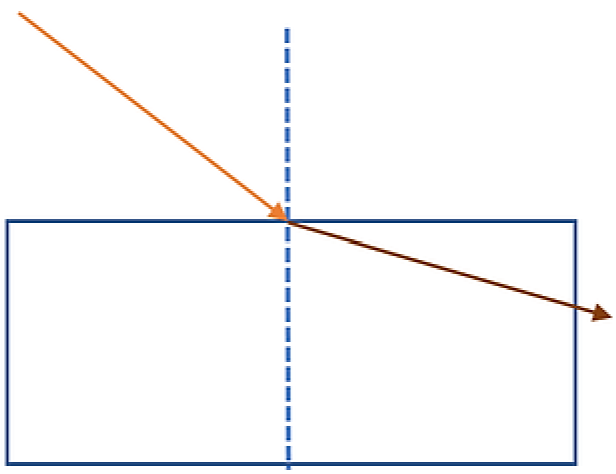
$$Refractive\ Index: \frac{\sin \theta i}{\sin \theta r}$$

$$Refractive\ Index\ (n): \frac{speed\ of\ light\ in\ air\ (c)}{speed\ of\ light\ in\ medium\ (v)}$$

Fig. 4 - Equations that can be used to find the refractive index of light; 'c' is a constant which represents the speed of light in air (3 * 10^8)

Refracted ray - a ray that undergoes a change of velocity (speed, direction, or both) as a result of interaction with a medium

The close to the normal ray that the refracted ray is, the denser the medium is - in denser mediums, the speed of the refracted ray also decreases. Therefore, a denser medium will generally result in decreased velocity of the refracted ray; the refracted ray will also bend closer towards the normal ray (see Fig. 5).



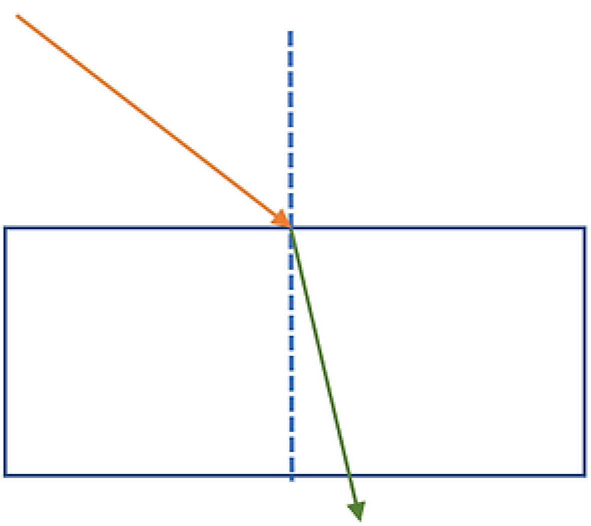
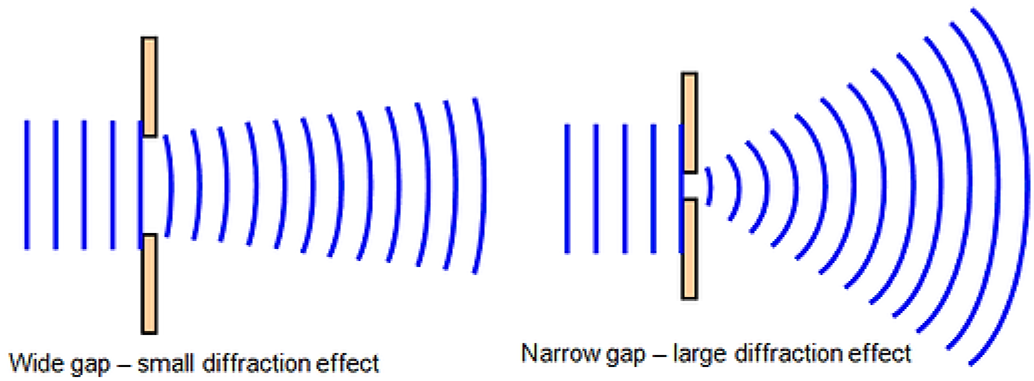


Fig. 5 - Diagrams demonstrating refraction in different mediums; the orange ray is the incident ray, the dotted line is the normal ray, and the green ray is the refracted ray in a denser medium than the brown refracted ray

DIFFRACTION

Diffraction - the bending of waves as they pass through openings or around barriers in their paths



WAVE PROPERTIES

All waves have certain properties that allow us to quantify and classify them.

Oscillation - one oscillation is equal to one wave, starting from the rest point and hitting the rest point twice more in order to complete one entire wave

<u>Wave properties</u>:

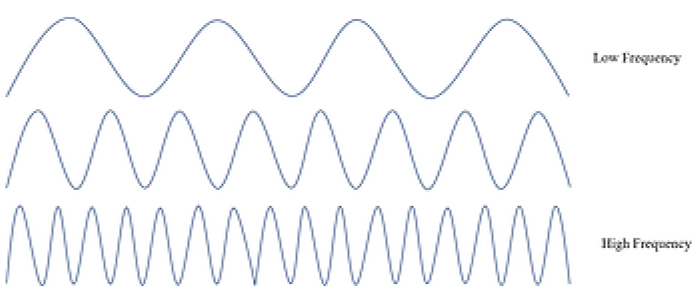
- **Frequency (f)** - the number of oscillations that pass through a point in a second
  - SI unit is Hertz (Hz)
- **Wavelength (λ)** - the length of one wave; the consecutive distance from one crest to a trough
  - SI unit is meters (m)
- **Velocity (v)** - the wave's speed (in a specific direction); the product of frequency and wavelength
  - SI unit is meters per second (m/s)
- **Time-period (t)** - the time it takes for one oscillation to occur
  - SI unit is seconds (s)

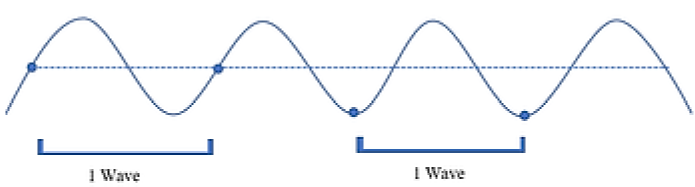
$$Frequency\ (f) = \frac{1}{Time\ Period\ (t)}$$

$$Time\ Period\ (t) = \frac{1}{Frequency\ (f)}$$

$$Velocity\ (v) = \frac{Wavelength\ (\lambda)}{Time\ period\ (t)}$$

$$Velocity\ (v) = Frequency\ (f) \times Wavelength\ (\lambda)$$





LONGITUDINAL & TRANSVERSE WAVES

Waves can be categorized by the direction in which particles of the medium move relative to the direction of the wave (see Fig. 6).

Transverse waves - waves in which oscillations occur perpendicular to the direction of energy transfer or the propagation of the wave, e.g. water waves, EM waves, seismic waves

Longitudinal waves - waves in which oscillations occur parallel to the direction of energy transfer or the propagation of the wave, e.g. springs

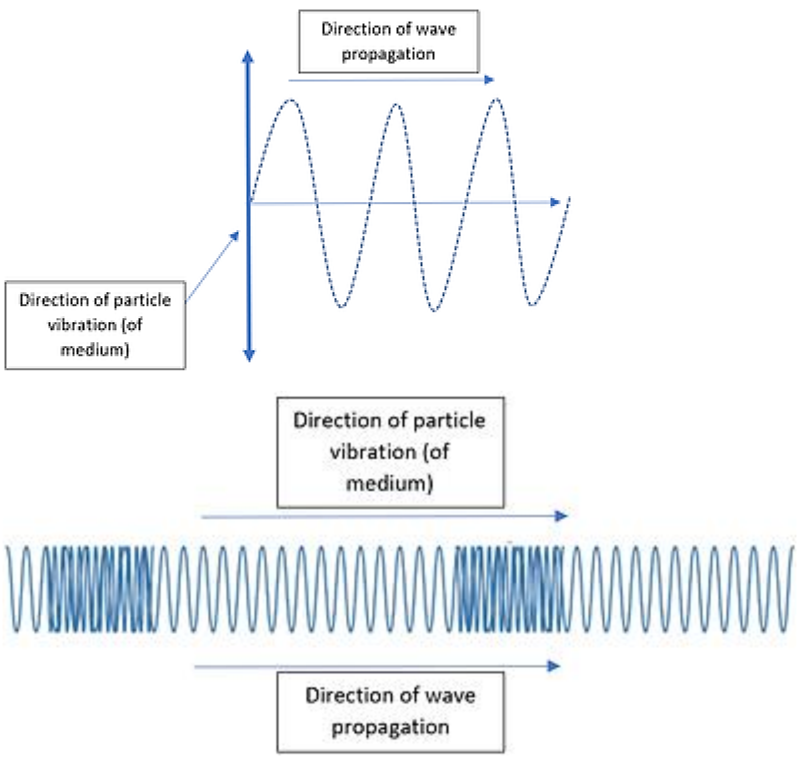
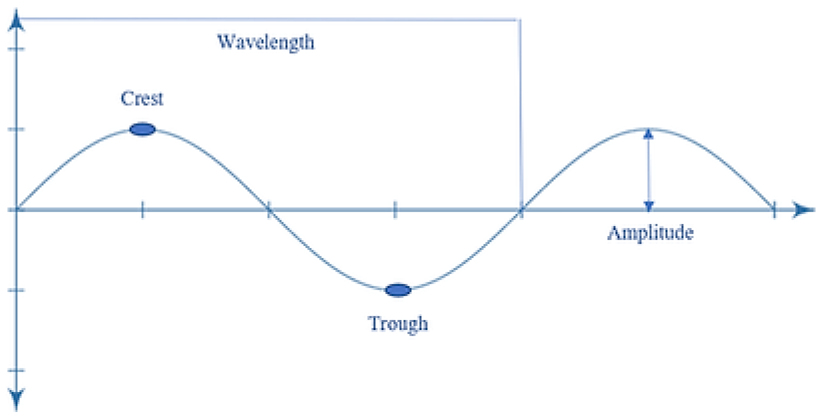


Fig. 6 - Transverse & longitudinal wave diagrams.

TRANSVERSE WAVE



<u>Properties of a transverse wave:</u>

- **Center line** - depicts the wave at an equilibrium wherein no energy is being carried

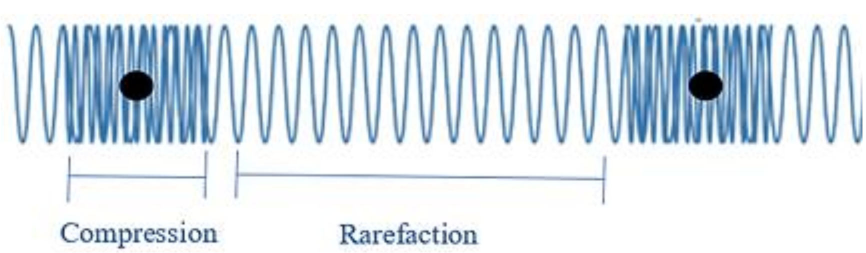
- **Crest** - depicts the spot on the wave with the greatest upwards displacement from the equilibrium line

- **Trough** - depicts the spot on the wave with the greatest downwards displacement from the equilibrium line

- **Amplitude** - depicts the distance from the equilibrium point to the spot of greatest displacement of the wave from the rest position (the crest and trough). The amplitude can be represented by a vertical extension from the rest point to the crest/trough

- **Wavelength** - the length that one oscillation covers; the length remains constant throughout a wave, but can be measured from any part of the wave. Most typically, the wavelength is depicted by drawing a line from the wave hitting the rest position twice, after a crest and trough

LONGITUDINAL WAVE

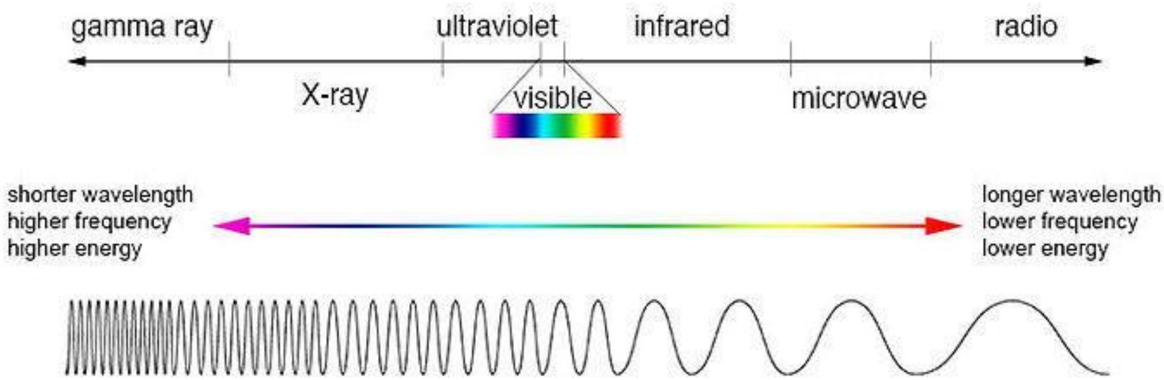


<u>Properties of a longitudinal wave:</u>

- **Compression** - the area where particles in a medium are closest together
- **Rarefaction** - the area where particles in a medium are farthest apart
- **Wavelength** - the length between one rarefaction and another, or the length between one compression and another (as portrayed by the two black circles on the diagram)

ELECTROMAGNETIC SPECTRUM

ELECTROMAGNETIC SPECTRUM



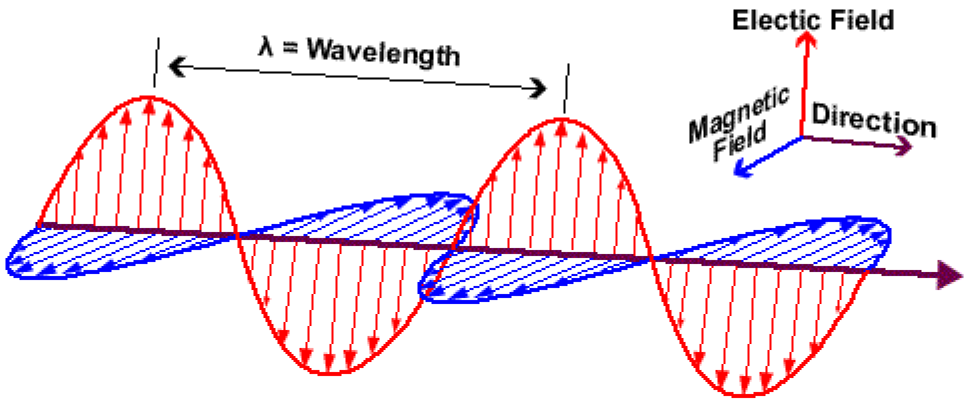
Electromagnetic waves - transverse waves which have the capacity to carry energy and travel without a medium (or in a vacuum)

Electromagnetic spectrum - the term used by scientist to describe the entire range of light

Electromagnetic waves are produced by the movement of charged particles which create an electric field and accelerate in an oscillating motion. Although their frequencies and wavelengths may differ, all electromagnetic waves travel at the speed of light. EM waves have electric and magnetic fields that oscillate perpendicular to one another.

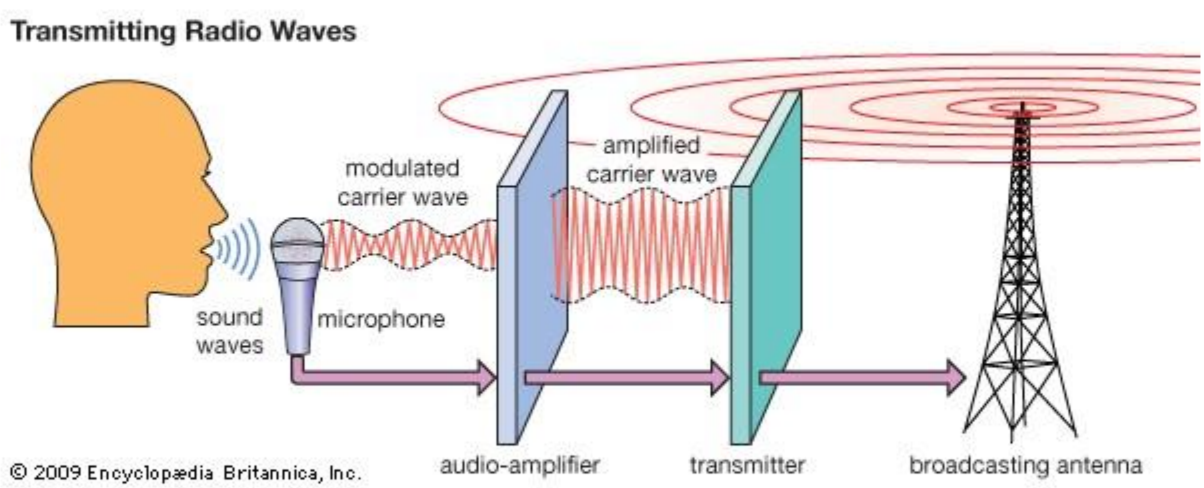
The electromagnetic spectrum exists in a large range of frequencies, spanning wavelengths from 10 picometres (10-12) to 100 kilometers.

RADIO WAVES



Radio waves have the longest wavelengths on the EM spectrum, and thus the lowest frequencies/energy.

- Wavelength: 1mm - 100km
- Frequency: 30 Hz - 300 GHz
- Natural sources: lightning, other astronomical objects
- Usage: mobiles, radio communication, broadcasting, radar

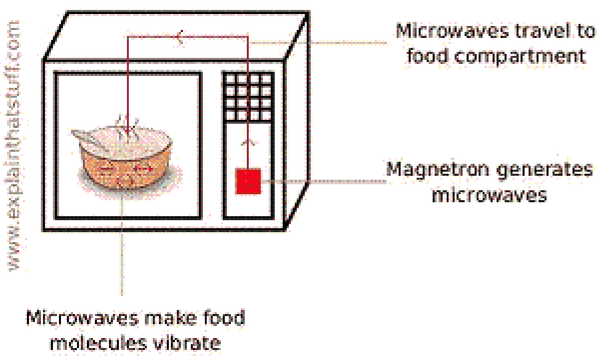


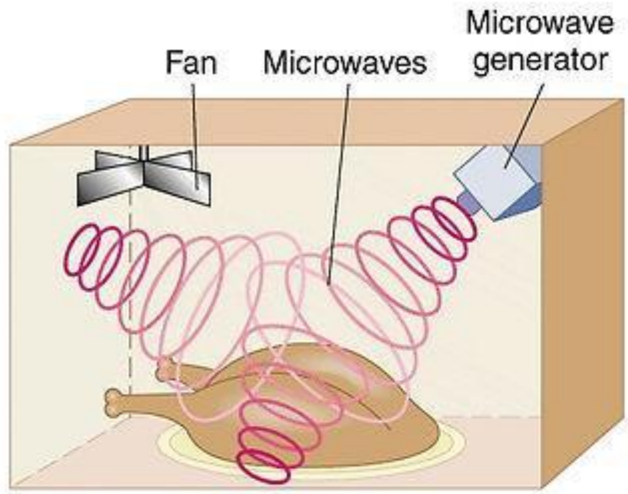
MICROWAVES

Microwaves are generally considered to overlap with the larger frequencies on the EM spectrum.

- Wavelength: 1m - 1mm
- Frequency: 300 MHz - 300 GHz
- Natural sources: the sun, big bang
- Usages: cordless phones, television broadcasts, radio astronomy, remote sensing, microwave ovens, satellite communication, LANs (usage depends on frequency)

Cosmic Microwave Background Radiation permeates all of space, and was one of the key discoveries in understanding and theorizing the big bang.

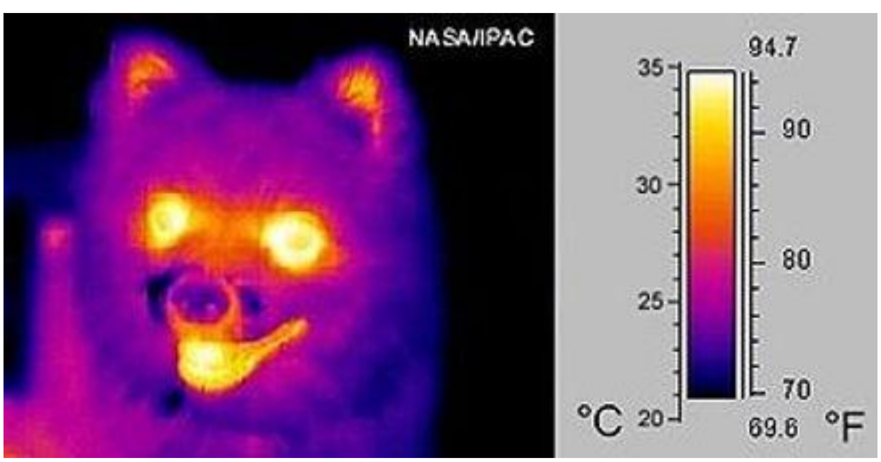




INFRARED WAVES

Infrared radiation is radiation with longer wavelengths than visible light, extending from the red edge of visible light (thus given its name infrared). Infrared is known as “heat radiation”, and accounts for 49% of the sun’s heat on Earth, although all waves can heat surfaces that will absorb them.

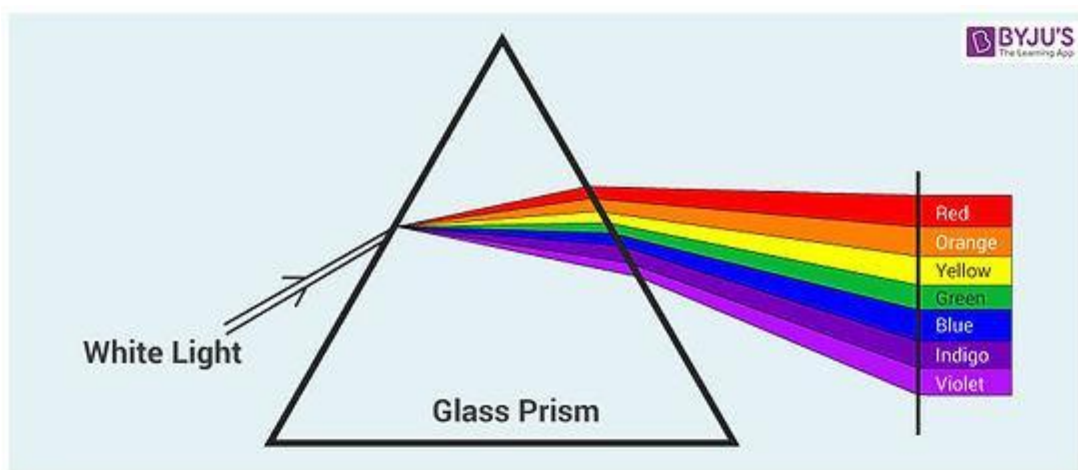
- Wavelength: 780nm - 1mm
- Frequency: 300 GHz - 400 THz
- Natural sources: the sun, any object with temperature
- Usages: heating, communication, art analysis



VISIBLE LIGHT WAVES

Visible light is the range of wavelengths in the EM spectrum that can be detected by the human eye. Red light has the lowest frequency and greatest wavelengths, and violet light has the highest frequency and smallest wavelength.

- Wavelength: 400nm - 700nm
- Frequency: 430 THz - 730 THz
- Natural sources: the sun, luminous celestial bodies
- Usages: photography, illumination, fiber optics communication

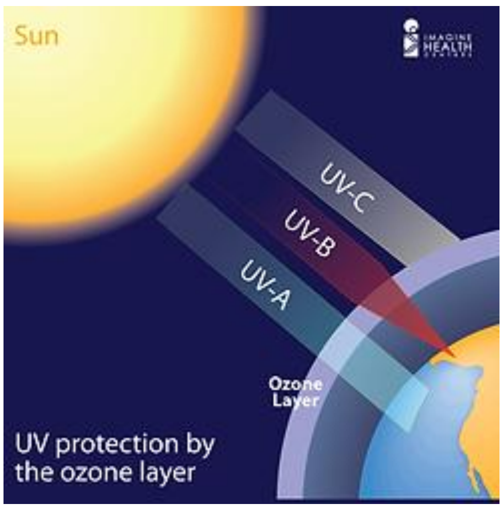


ULTRAVIOLET LIGHT WAVES

UV light can cause chemical reactions, such as providing substances the ability to glow or fluoresce. Most UV radiation is non-ionizing, although higher energy UV radiation can occasionally be ionizing. Ionizing UV radiation is blocked by oxygen molecules in the atmosphere, meaning astronomical UV radiation does not touch the Earth's surface.

Overexposure to UV radiation from sunlight can cause tanning, skin cancer, and other chronic health effects on the skin, eyes, and immune system. This being said, UV radiation also produces the production of vitamin D in the skin, and a large amount of positive health effects can result from this.

- Wavelength: 10nm - 400nm
- Frequency: 30 PHz - 750 THz
- Natural sources: the sun
- Usages: fluorescence, disinfection, tanning, industrial processes



X-RAY WAVES

X-ray photons carry enough energy to ionize atoms and disrupt molecular bonds. This means that exposure to x-rays for a significant period of time can cause illness and cancer-like disease within living organisms, primarily animals (including humans).

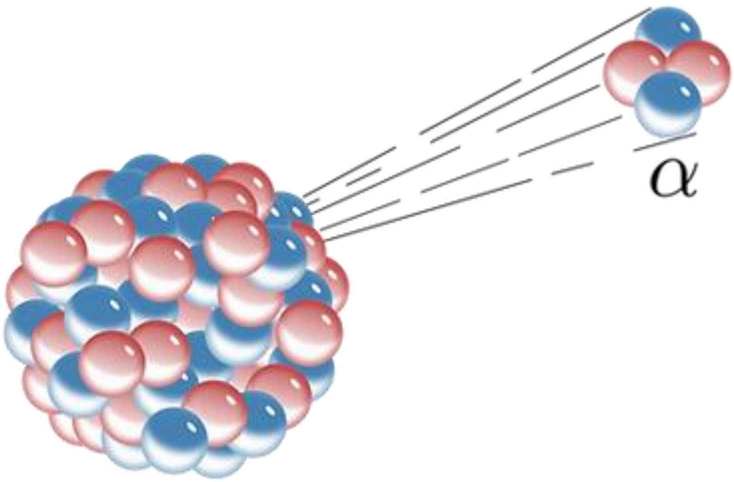
- Wavelength: 0.01nm - 10nm
- Frequency: 30 EHz - 30 PHz
- Natural sources: radionuclides, cosmic rays
- Usages: medical diagnostics, airport luggage scanners, art analysis, cancer treatment

In medical practices, the use of x-rays for imaging greatly out-values the potential radiation-based consequences that exposure can have. In diagnostic applications, low energy x-rays are absorbed by the bones in the body, allowing for an image to be formed.

GAMMA WAVES

Gamma rays are the highest energy waves on the EM spectrum. Gamma rays have high ionizing energy, and are thus biologically hazardous.

- Wavelength: 100 pm or less
- Frequency: 3 EHz or more
- Natural sources: neutron stars, pulsars, supernovae, nuclear reactions
- Usages: food irradiation, cancer therapy


α

IMAGING & APPLICATIONS

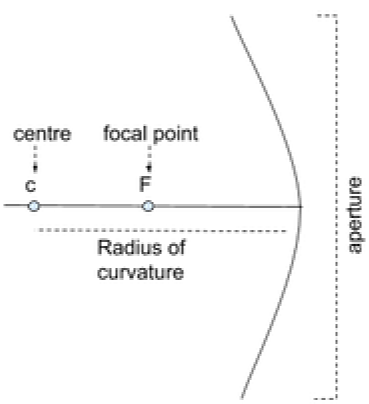
IMAGING & APPLICATIONS

Mirror - a reflective surface with a silver-polished back

Concave mirrors - sections of a glass, hollowed sphere which are polished from the outside, and whose inner side reflects.

Concave mirrors convert all parallel beams of light to a single point known as the **principal focus** or **converging point**, in which rays of light will reflect and converge on a point 'F'.

- **Center of curvature (C)** - the point where, if the curved mirror was spherical, the center would be
- **Radius of curvature** - the distance between the center of curvature and the mirror
- **Focal length (f)** - the distance between the mirror and the focal point
    - *focal length = 1/2 radius of curvature*



IMAGES FORMED BY CONCAVE MIRRORS

If an object is distant (left of/beyond C on Fig. 2), the concave mirror forms an image that is

- smaller
- inverted

- appears to *float* when looked at

If the object is even more distant, the reflected rays are nearly parallel and the image is formed near the principal focus. As the object is brought closer to the mirror, its reflected image moves further away from the mirror and gets larger.

Reflected rays actually meet to form this image, which can be picked up by a screen. This is known as a **real image**, distinct from a **virtual image**, which can not be picked up by a screen. In a virtual image, the rays don't come to focus after the reflection, but instead diverge, appearing to come from a point behind the mirror

<u>The rules of reflection for a concave mirror are as follows:</u>

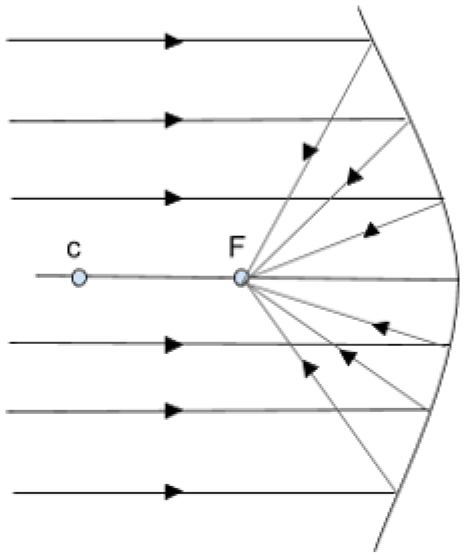
1. If the ray of light goes through C, it is reflected back through C

2. If the ray of light is parallel to the principal axis, it is reflected back through F

3. If the ray of light goes through F, it is reflected back parallel to the principal axis (inverse of rule two)

4. If an object is between C and F, a concave mirror forms an image that is
    - placed at the center of curvature
    - real
    - inverted
    - the same distance from the mirror as the object

5. If an object is between C and P, a concave mirror forms an image that is
    - magnified
    - upright
    - Virtual


c
F

Past Papers

Bro, I need to make a checklist- help

Past Papers Page Numbers:

- M16 [1 to 32]
- M22
- M23
- M24
- N23
- N24

Marking Schemes Page Numbers:

- M23
- M24
-

Subject Reports Page Numbers:

- M16 [1 to 3]
- M17 [3 to 5]
- M18 [5 to 7]
- M19 [8 to 10]
- M20 **[N/A]** *Covid19*
- M21 [11 to 14]
- M22 [15 to 19]
- M23 [19 to 22]
- M24 [22 to 25]
- N

Papers

GC Related Years *(Scientific & Technical Innovation)*:
May 2017 [ ]
November 2019 [ ]
November 2022 [ ]

MAY SESSIONS

May 2016

https://colourlex.com/project/x-ray-fluorescence/

Question 1 (5 marks)

The following table contains information that can be used to describe mass or weight.

Question 1a (2 marks)

Select the correct option to complete the table.

Draggable:

newton | size only | independent of gravitational field strength

kilogram | size and direction | dependent on gravitational field strength

	Mass	Weight
Units		
Type of quantity		
Effect of gravitational field strength		

Question 1b (2 marks)

The table below contains information about four planets in the solar system. Using this information, **select** the **three** unnamed planets and complete the table.

Draggable:

Jupiter

Venus

Neptune

	Relative mass compared to Earth	Orbital period/ Year	Number of moons	Main gases in atmosphere	Are there any rings present?
Earth	1	1	1	N_2, O_2, Ar	No
	0.82	0.62	0	CO_2, N_2	No
	17.2	164.8	14	H_2, He	Yes
	317.8	11.86	67	H_2, He	Yes

Question 1c (1 mark)

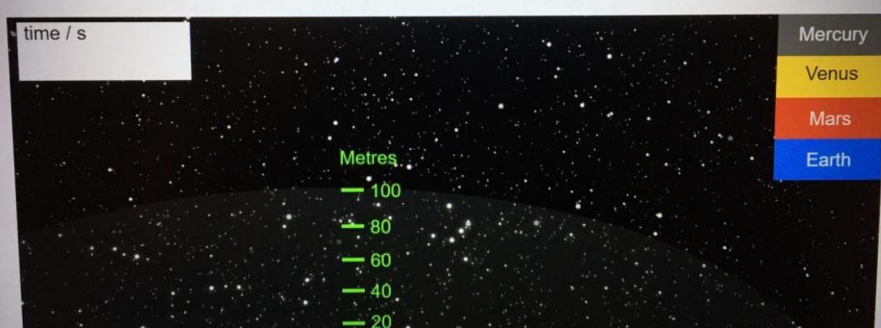
State why the outer planets tend to be colder than the inner planets.

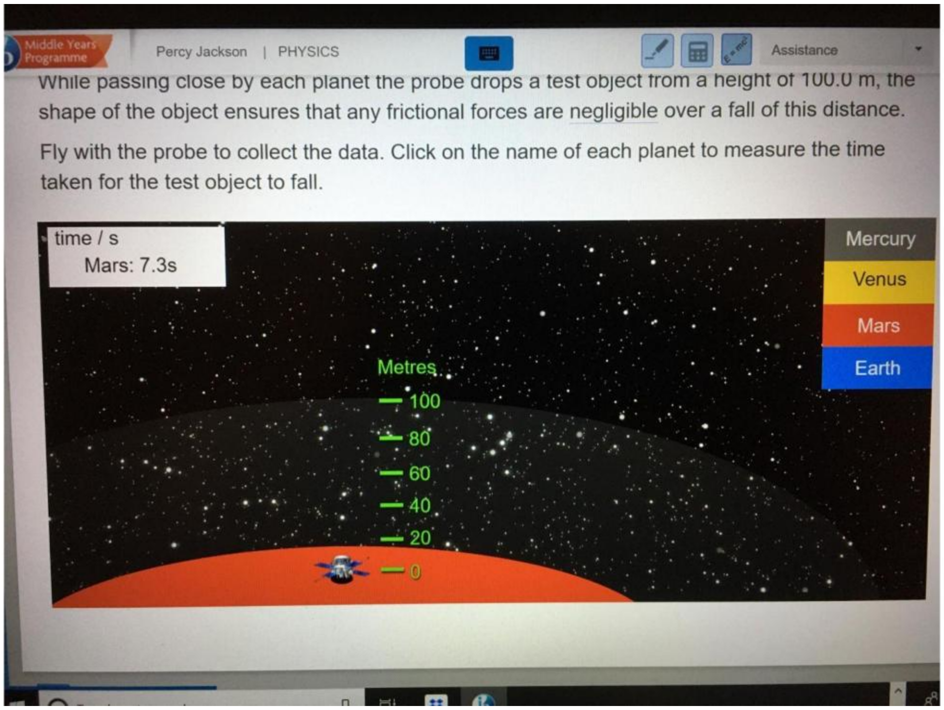
Question 2 (11 marks)

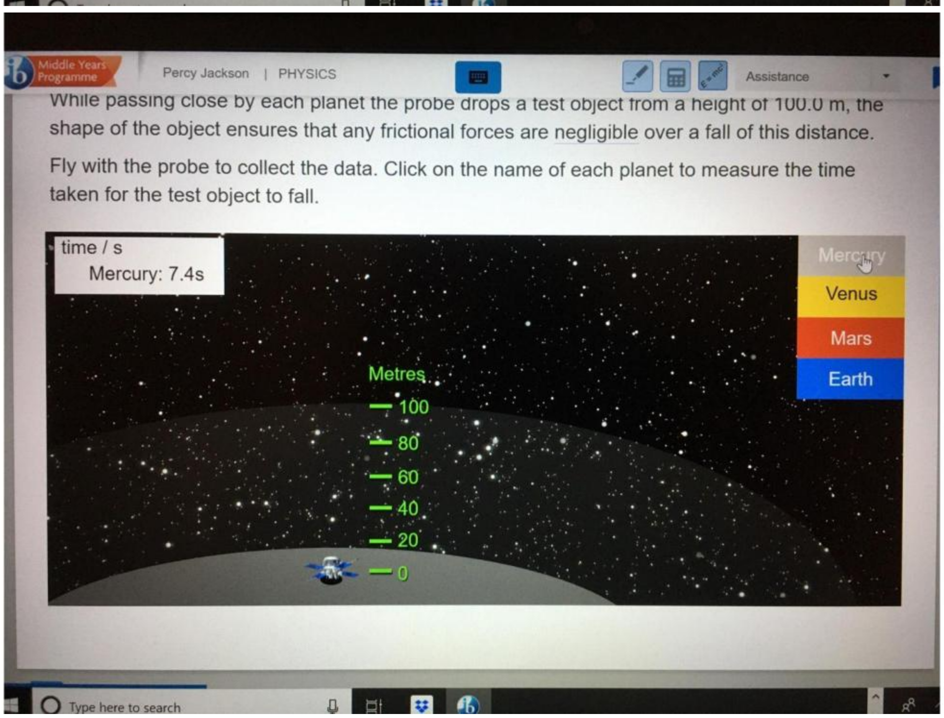
A robotic probe is sent into space to collect data from three of the four inner planets: Mercury, Mars and Venus.

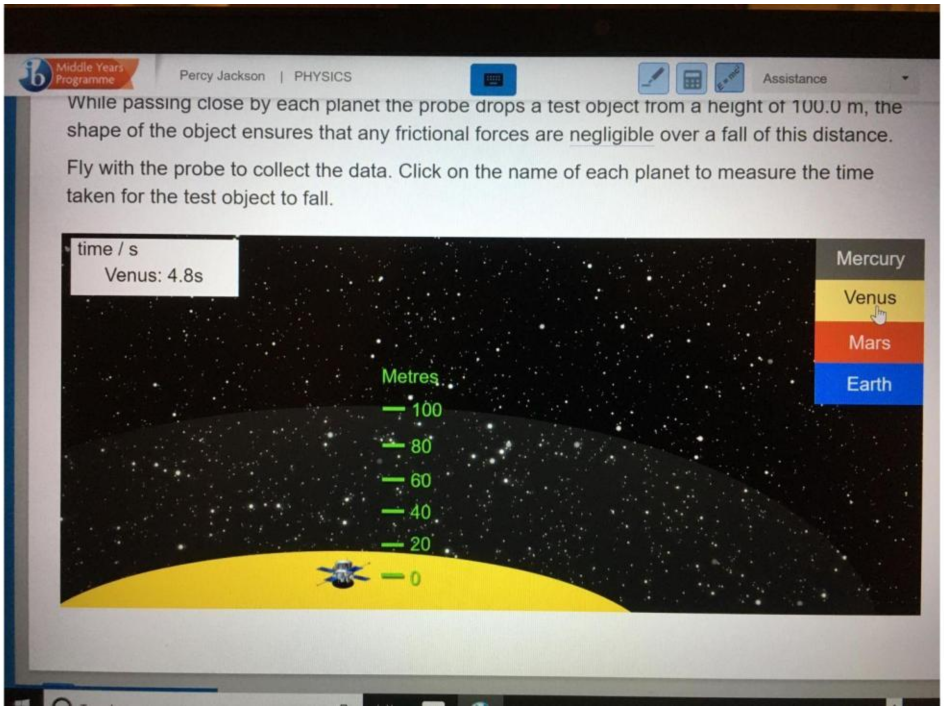
While passing close by each planet the probe drops a test object from a height of 100.0 m, the shape of the object ensures that any frictional forces are negligible over a fall of this distance.

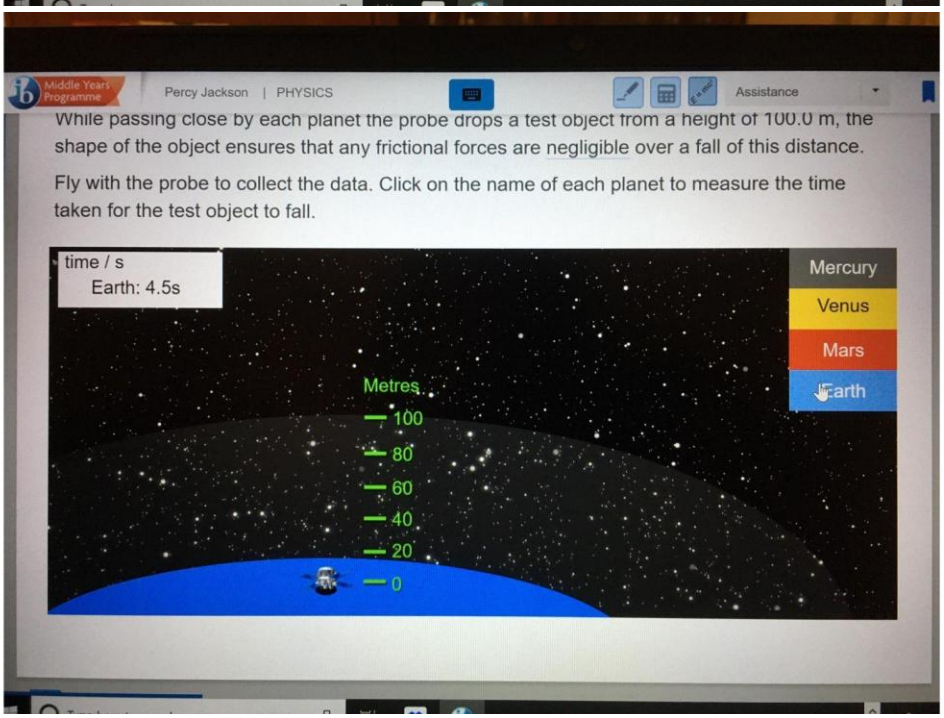
Fly with the probe to collect the data. Click on the name of each planet to measure the time taken for the test object to fall.




Middle Years Programme
Percy Jackson | PHYSICS
Assistance
While passing close by each planet the probe drops a test object from a height of 100.0 m, the shape of the object ensures that any frictional forces are negligible over a fall of this distance.
Fly with the probe to collect the data. Click on the name of each planet to measure the time taken for the test object to fall.
time / s
Mars: 7.3s
Mercury
Venus
Mars
Earth
Metres
100
80
60
40
20
0


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
While passing close by each planet the probe drops a test object from a height of 100.0 m, the shape of the object ensures that any frictional forces are negligible over a fall of this distance.
Fly with the probe to collect the data. Click on the name of each planet to measure the time taken for the test object to fall.
time / s
Mercury: 7.4s
Mercury
Venus
Mars
Earth
Metres
100
80
60
40
20
0
Type here to search


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
While passing close by each planet the probe drops a test object from a height of 100.0 m, the shape of the object ensures that any frictional forces are negligible over a fall of this distance.
Fly with the probe to collect the data. Click on the name of each planet to measure the time taken for the test object to fall.
time / s
Venus: 4.8s
Mercury
Venus
Mars
Earth
Metres
100
80
60
40
20
0


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
While passing close by each planet the probe drops a test object from a height of 100.0 m, the shape of the object ensures that any frictional forces are negligible over a fall of this distance.
Fly with the probe to collect the data. Click on the name of each planet to measure the time taken for the test object to fall.
time / s
Earth: 4.5s
Mercury
Venus
Mars
Earth
Metres
100
80
60
40
20
0

Question 2a (3 marks)

Using the data you collected above, **calculate** the acceleration due to gravity on Mercury and Mars. You may wish to use the formula sheet.

Mercury:

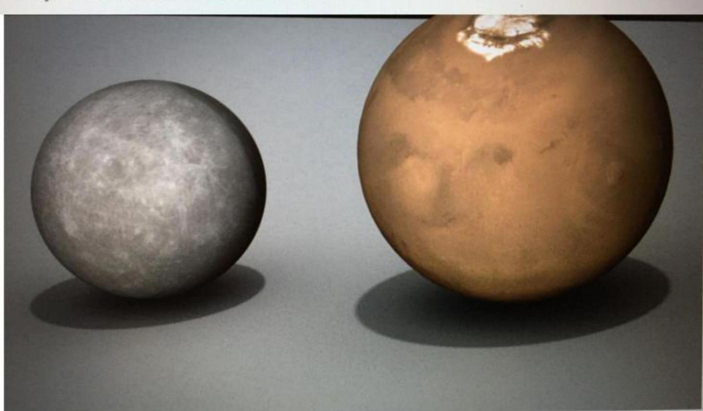
Mars:

The scientists receiving the data on Earth know that gravitational field strength (*g*) is proportional to a planet's density (ρ) and its radius (*r*).

$$\textit{gravitational field strength} \sim \textit{density} \times \textit{radius}$$

$$g \sim \rho \times r$$

The radius of Mercury is about two thirds of the radius of Mars.



Mercury Mars

Middle Years Programme Percy Jackson | PHYSICS Assistance

Explain why Mars and Mercury can have almost the same value of *g*, if Mars has a much larger radius.

Middle Years Programme Percy Jackson | PHYSICS Assistance

Next, the space probe visits two of Jupiter's moons: Io and Ganymede.

The experiment is repeated and again a test object is dropped from a height of 100.0 m.

The gravitational field strength of Io = 1.8 N kg^{-1}.

The gravitational field strength of Ganymede = 1.4 N kg^{-1}.

The test object has a mass of 20 kg.

Question 2c (3 marks)

Use information from the formula sheet to **calculate** the gravitational potential energy (E_p) of the test object before it is dropped over Io.

Type here to search

All of the test object's gravitational potential energy (E_p) transforms to kinetic energy before hitting the surface of the moons.

Question 2d (3 marks)

The test object travels faster before hitting the surface of Io than it does before hitting the surface of Ganymede. **Explain** this observation.

Styles

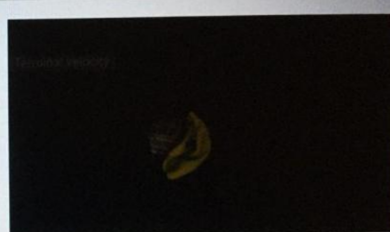
Type here to search

Question 3 (11 marks)

When the space probe in Question 2 is investigating acceleration, air resistance is negligible.

On Earth, a parachute can be used to increase air resistance.

The maximum speed a falling object reaches is known as the terminal velocity.



Question 3a (2 marks)

Some students perform an investigation into the terminal velocity of a simple parachute. One of the students wants to investigate how the area of the parachute affects its terminal velocity.

Some students perform an investigation into the terminal velocity of a simple parachute. One of the students wants to investigate how the area of the parachute affects its terminal velocity.

Suggest one piece of equipment that the student will need to perform this experiment.

Equipment:

Reason:

Question 3b (3 marks)

Suggest and **explain** a hypothesis for this experiment.

Question 3c (3 marks)

State one variable that the student will need to control. **Describe** how this variable should be controlled and why it should be controlled.

Variable

How the variable should be controlled

Why the variable should be controlled

Middle Years Programme

Percy Jackson | PHYSICS

Assistance

Question 3d (3 marks)

Explain what results the student will need to collect to ensure that they have sufficient relevant data.

B I U Styles

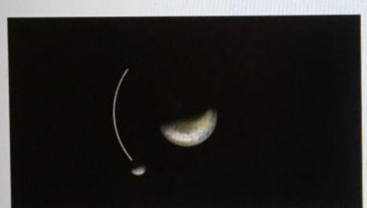
Middle Years Programme

Percy Jackson | PHYSICS

Assistance

Question 4 (3 marks)

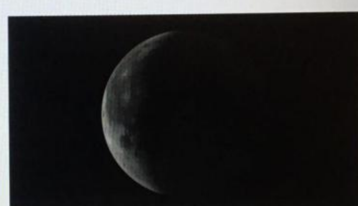
The first animation shows the Moon orbiting the Earth.



©

This video contains no audio

The second animation shows how the Moon looks each day, when viewed from the Earth over a complete month.



©

This video contains no audio

Question 4a (2 marks)

Using the information from both animations, **describe** why the appearance of the Moon changes over a month.

Question 4b (1 mark)

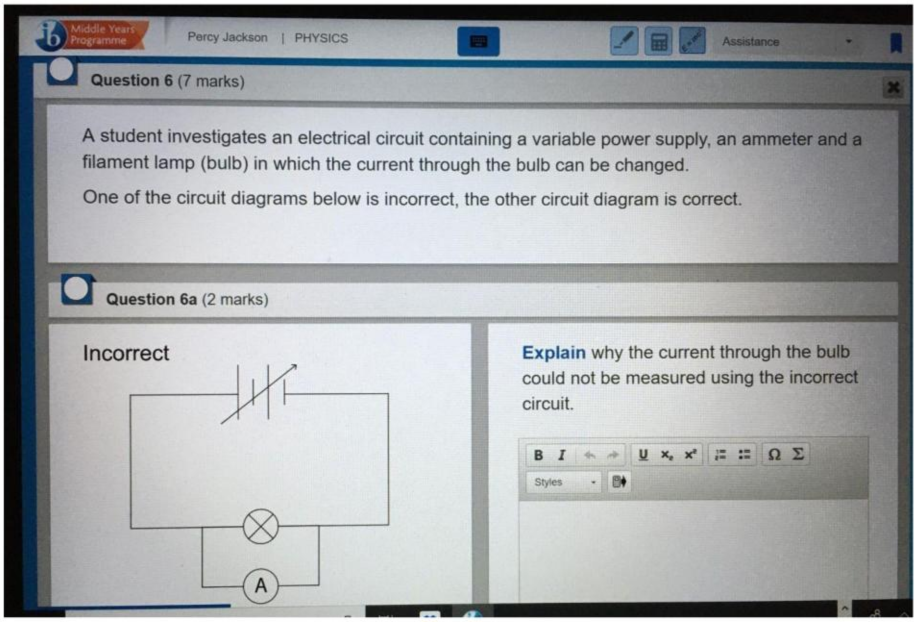
The Moon affects the tides on Earth. **Identify** the force that produces this effect.

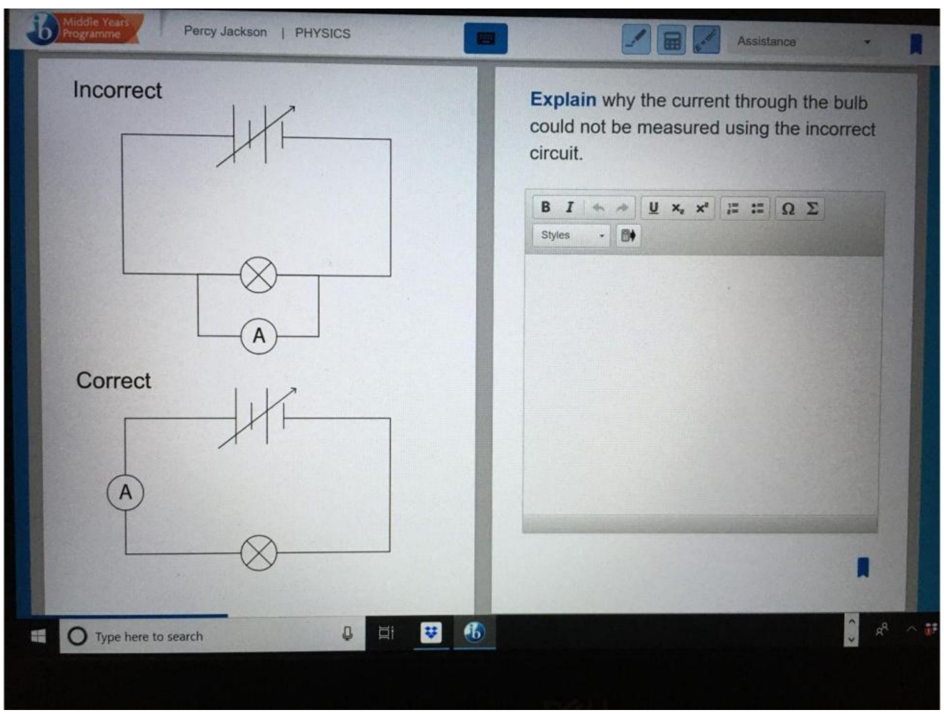
Question 5 (2 marks)

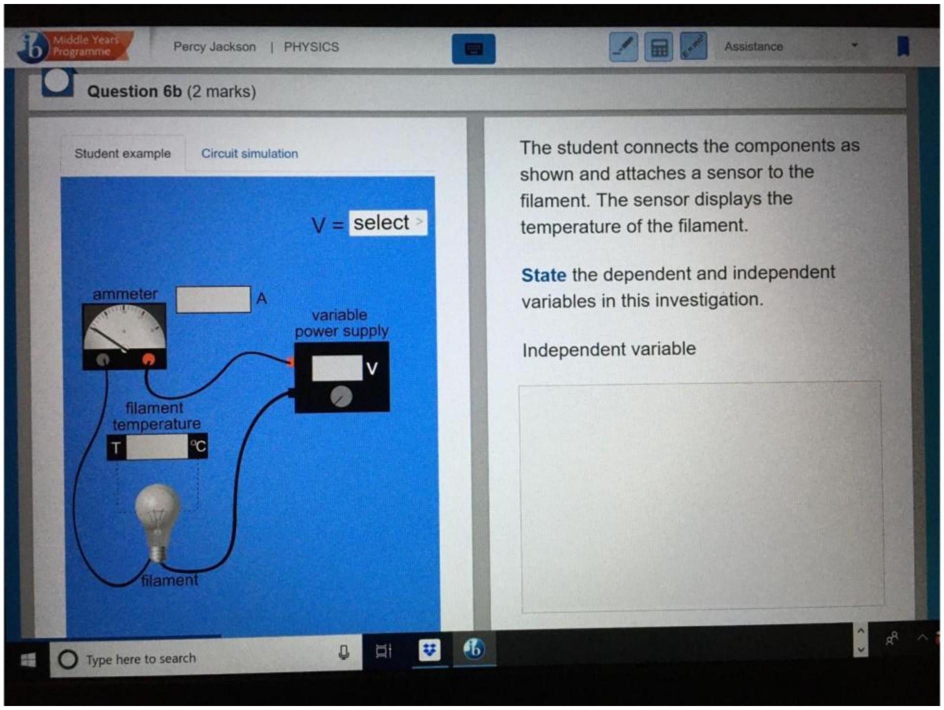
In the 1950s, cosmologists proposed the "steady-state" theory to explain certain aspects of the universe after it was observed to be expanding. This theory states that:

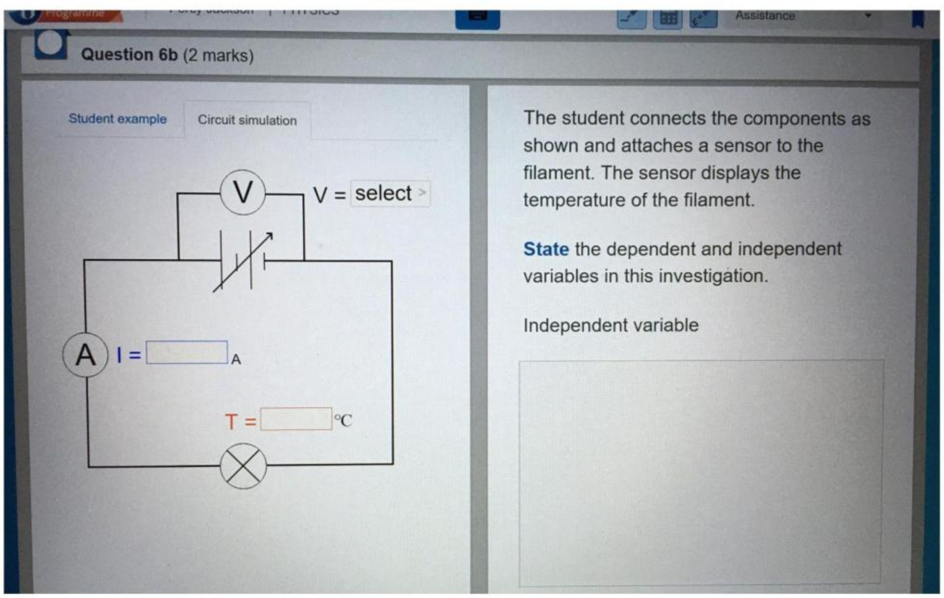
- the universe has no beginning or end
- the temperature of the universe has always been constant and will not change in the future
- as the universe expands, new matter is created and the density of the universe remains constant.

Outline two ways in which this theory is different to the "big-bang" theory.


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
Question 6 (7 marks)
A student investigates an electrical circuit containing a variable power supply, an ammeter and a filament lamp (bulb) in which the current through the bulb can be changed.
One of the circuit diagrams below is incorrect, the other circuit diagram is correct.
Question 6a (2 marks)
Incorrect
A
Explain why the current through the bulb could not be measured using the incorrect circuit.
Styles


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
Incorrect
A
Correct
A
Explain why the current through the bulb could not be measured using the incorrect circuit.
Styles
Type here to search


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
Question 6b (2 marks)
Student example
Circuit simulation
V = select
ammeter
A
variable
power supply
V
filament
temperature
T
°C
filament
The student connects the components as shown and attaches a sensor to the filament. The sensor displays the temperature of the filament.
State the dependent and independent variables in this investigation.
Independent variable
Type here to search


Assistance
Question 6b (2 marks)
Student example
Circuit simulation
V
V = select
A
I =
A
T =
°C
The student connects the components as shown and attaches a sensor to the filament. The sensor displays the temperature of the filament.
State the dependent and independent variables in this investigation.
Independent variable

Percy Jackson | PHYSICS

Assistance

Question 6c (3 marks)

The student decides to measure the current at each of the following voltages.

Voltage / V
0.0
0.4
0.8
1.2
3.6
4.0
9.2
11.6
12.0

When asked about the reason for choosing these values the student says:

"I consider this to be a valid variation of voltage as it provides an appropriate number of measurements within the proposed range of voltage I am covering from 0 V to 12 V."

Evaluate the values of voltage the student has chosen.

Styles

Type here to search

Percy Jackson | PHYSICS

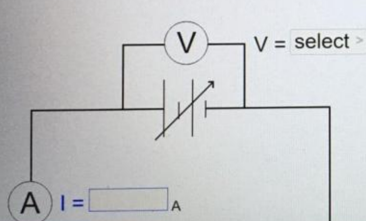
Assistance

Question 7 (13 marks)

Choose your own appropriate values of voltage and use the simulation to **measure** the current. Also collect data about filament temperature and state any changes you observe in the lamp. When you finish completing the table, double click on "**Plot data**" below to produce the graph for your data and proceed to the next question.

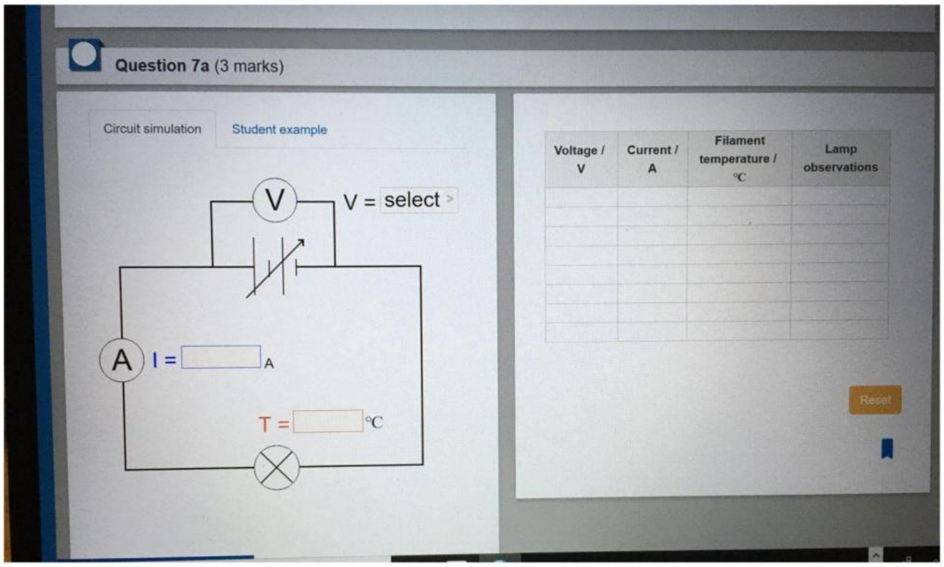
Question 7a (3 marks)

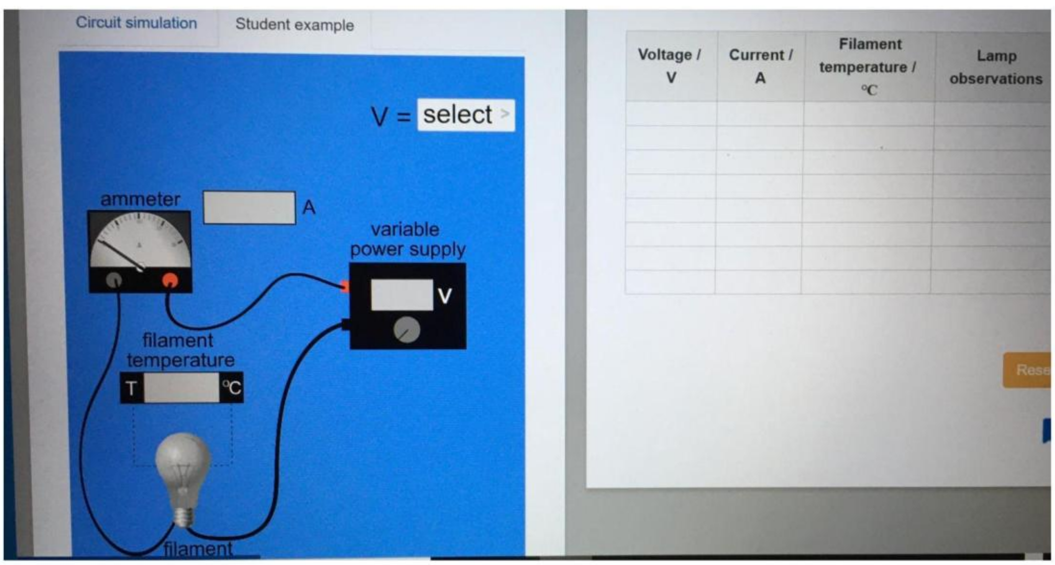
Circuit simulation | Student example



Voltage / V	Current / A	Filament temperature / °C	Lamp observations

Type here to search


Question 7a (3 marks)
Circuit simulation
Student example
V = select
I =
A
T =
°C
Voltage / V
Current / A
Filament temperature / °C
Lamp observations
Reset


Circuit simulation
Student example
V = select
ammeter
A
variable power supply
V
filament temperature
T
°C
filament
Voltage / V
Current / A
Filament temperature / °C
Lamp observations

Middle Years Programme | Percy Jackson | PHYSICS | Assistance

Question 7b (3 marks)

Plot data

Using the graph, **describe** the relationship between voltage and current in the circuit.

Styles

Resistance (*R*) is defined as the ratio of

Type here to search

Middle Years Programme | Percy Jackson | PHYSICS | Assistance

Plot data

Resistance (*R*) is defined as the ratio of voltage (*V*) across a material to the current (*I*) flowing through the material. The unit of resistance is the ohm and its symbol is Ω.

$$R = \frac{V}{I}$$

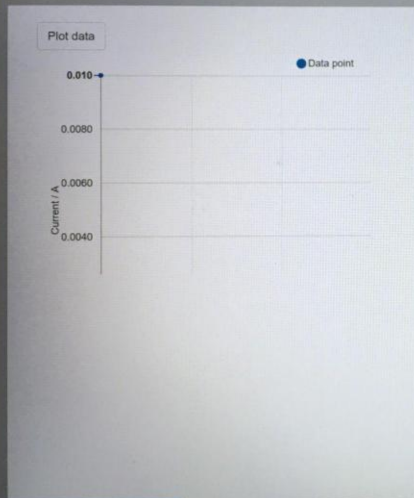
Question 7c (4 marks)

Describe how resistance changes in the filament across the range of the experiment. You should choose two points on the graph to calculate values of resistance to support your answer.

Type here to search

Middle Years Programme | Percy Jackson | PHYSICS | Assistance

Question 7d (3 marks)



Before starting the experiment, the following hypothesis was proposed:

"In all materials, the current is directly proportional to the voltage."

Discuss whether or not the results from this experiment support this hypothesis.

Styles

Type here to search

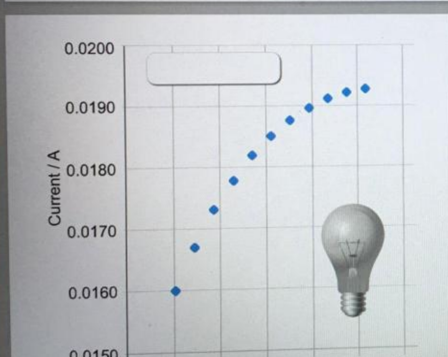
Middle Years Programme | Percy Jackson | PHYSICS | Assistance

Question 8 (10 marks)

A second student carries out a similar experiment using a different light bulb.

He realizes that the lamp begins to glow above a certain temperature.

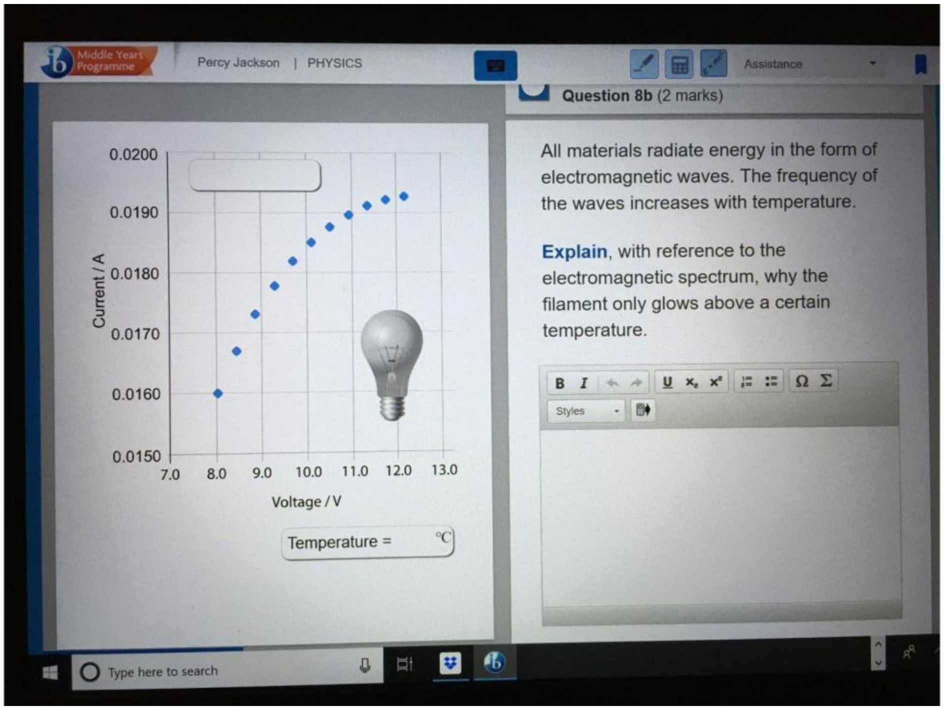
Hover over the points on the graph to show the data values.

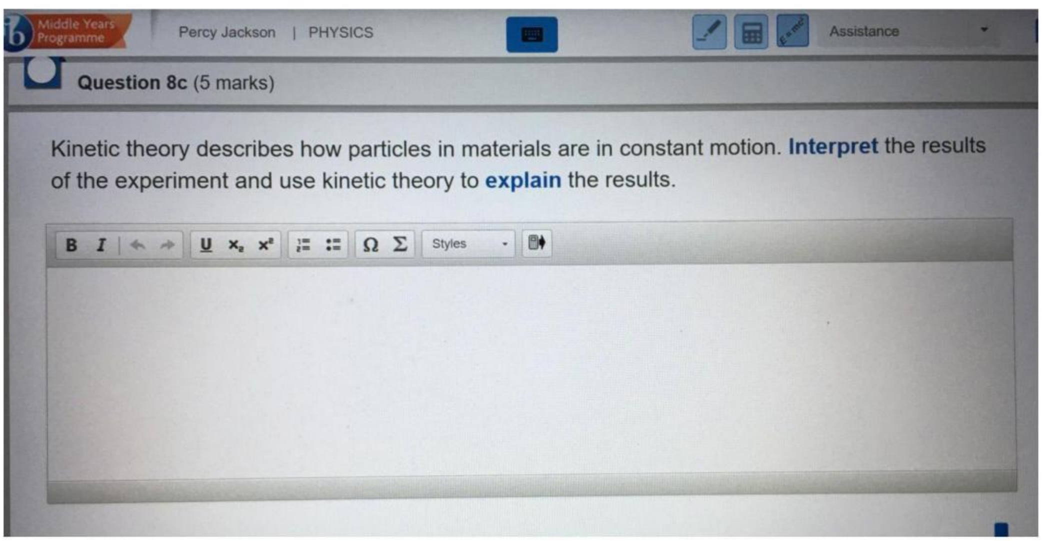


Question 8a (1 mark)

For these results, **state** the voltage at which the light bulb begins to glow.

Type here to search


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
Question 8b (2 marks)
0.0200
0.0190
0.0180
0.0170
0.0160
0.0150
Current / A
7.0
8.0
9.0
10.0
11.0
12.0
13.0
Voltage / V
Temperature = ℃
All materials radiate energy in the form of electromagnetic waves. The frequency of the waves increases with temperature.
Explain, with reference to the electromagnetic spectrum, why the filament only glows above a certain temperature.
Styles
Type here to search


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
Question 8c (5 marks)
Kinetic theory describes how particles in materials are in constant motion. Interpret the results of the experiment and use kinetic theory to explain the results.
Styles

Middle Years Programme | Percy Jackson | PHYSICS | Assistance

Question 8d (2 marks)

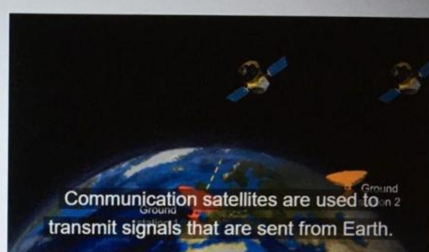
Outline another experiment that the student could perform to extend this investigation.

B I U x_2 x^2 Ω Σ Styles

Middle Years Programme | Percy Jackson | PHYSICS | Assistance

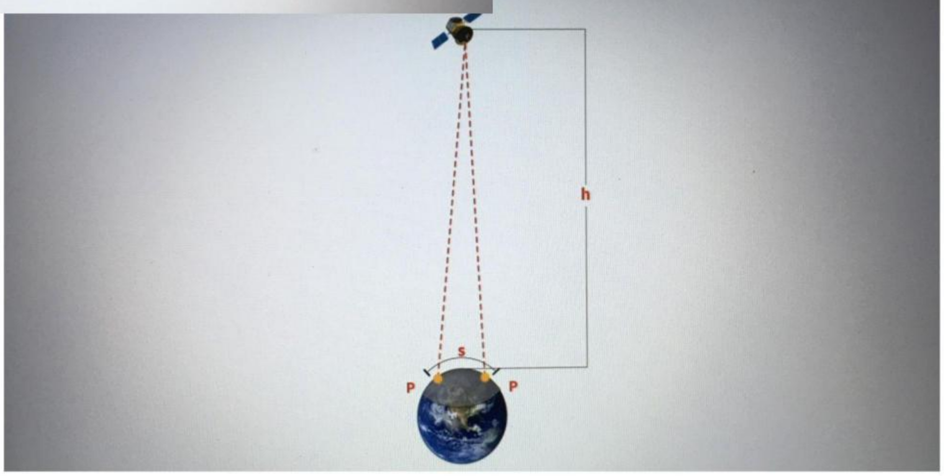
Question 9 (16 marks)

Communication in the modern world relies on transmission using satellites. Pictures, documents, videos and songs are examples of information that can be converted into electromagnetic waves. The electromagnetic waves are sent from a ground station to a satellite and then retransmitted to a second station on Earth. Satellite transmission means that the electromagnetic waves can be sent over much larger distances than are possible with ground transmission.



The animation shows a simple model of a satellite transmission where *s* is the ground distance between the two stations, *h* is the height of the satellite above the surface of the Earth and the P marks show the limits of the satellite footprint. Signals travel at the speed of light from the ground station to the satellite and back.

A study is performed to determine if there is a relationship between ground distance (*s*) and transmission time (*t*).



Middle Years Programme

Percy Jackson | PHYSICS

Assistance

Question 9a (2 marks)

Identify the independent, dependent and control variables for this experiment.

transmission time *t*:

height *h*:

ground distance *s*:

Middle Years Programme

Percy Jackson | PHYSICS

Assistance

Question 9b (3 marks)

Formulate and **justify** a hypothesis about the relationship between the variables for this study.

Styles

Middle Years Programme

Percy Jackson | PHYSICS

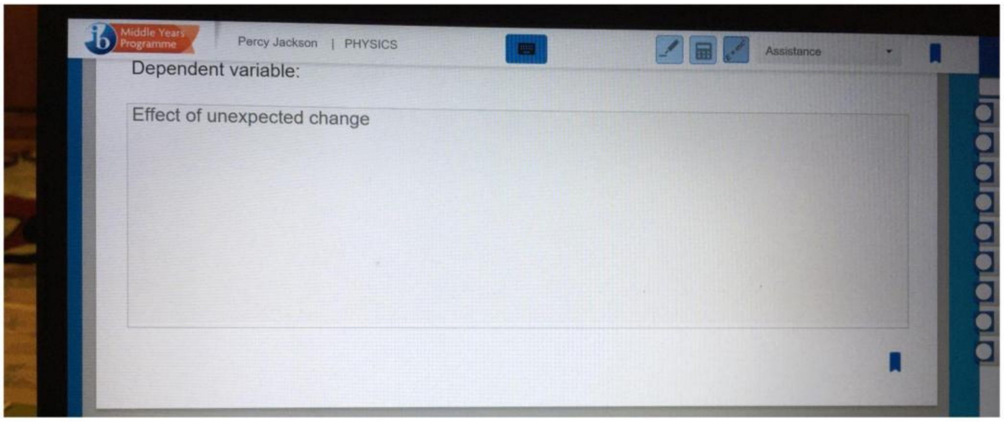
Assistance

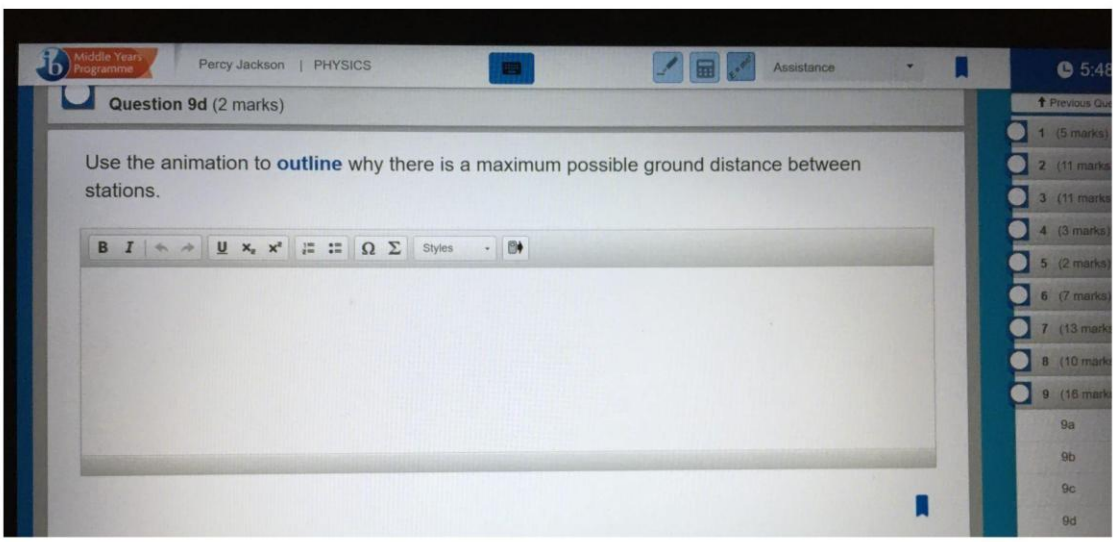
Question 9c (3 marks)

Describe the effect an unexpected change of the control variable would have on the **independent** and **dependent** variables.

Independent variable:

Effect of unexpected change


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
Dependent variable:
Effect of unexpected change


Middle Years Programme
Percy Jackson | PHYSICS
Assistance
Question 9d (2 marks)
Use the animation to outline why there is a maximum possible ground distance between stations.
Styles
1 (5 marks)
4 (3 marks)
5 (2 marks)
6 (7 marks)
9a
9b
9c
9d

Percy Jackson | PHYSICS

Assistance

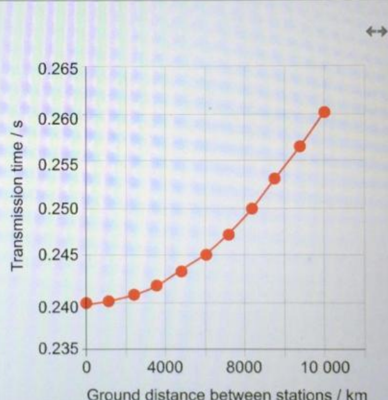
Question 9e (2 marks)

In the animation above, the value of *s* can be set to small values (even zero).

Explain why in a real situation, satellite transmission would not even be considered for small distances.

Question 9f (2 marks)

The graph shows data collected from the satellite animation. **Comment** on the shape of the graph.



2 (11 marks)
3 (11 marks)
4 (3 marks)
5 (2 marks)
6 (7 marks)
7 (13 marks)
8 (10 marks)
9 (16 marks)
9a
9b
9c
9d
9e
9f
9g
10 (12 marks)

Question 9g (2 marks)

Use your answer to part (f) to **select** the correct option. **Justify** your answer.

- The results support the hypothesis.
- The results do not support the hypothesis.

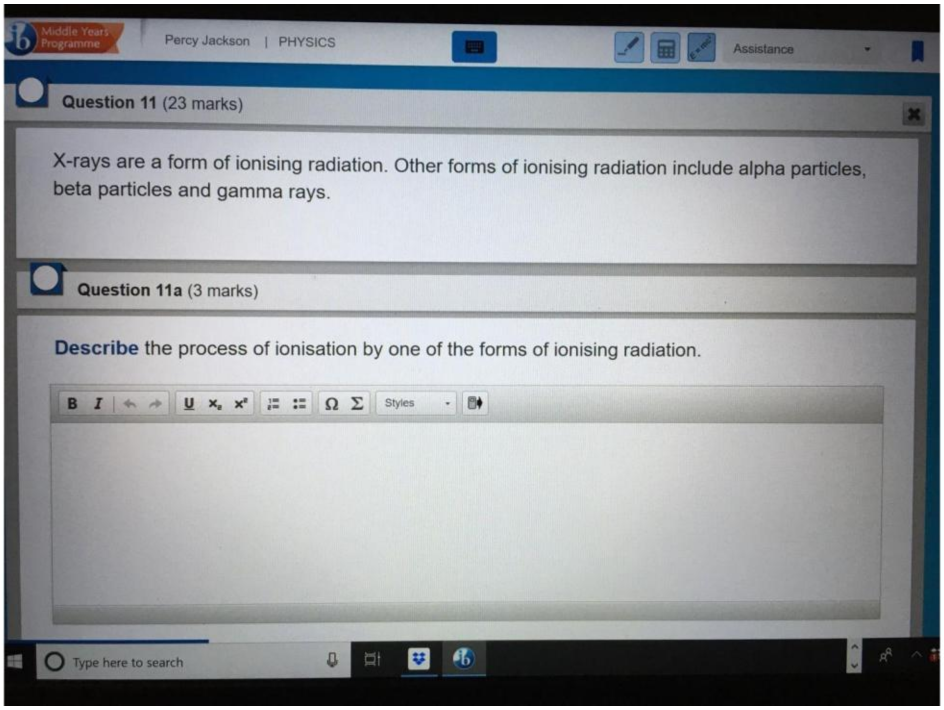
Justification

Question 10 (12 marks)

Satellites can be used to access the internet.

Discuss and **evaluate** the advantages and disadvantages of internet access using satellites compared to traditional cable-based internet access. In your answer you should include:

- an advantage of satellite internet access
- a disadvantage of satellite internet access
- technological considerations
- economic factors
- a concluding appraisal.


Middle Years Programme
Percy Jackson | PHYSICS
Assistance

Question 11 (23 marks)

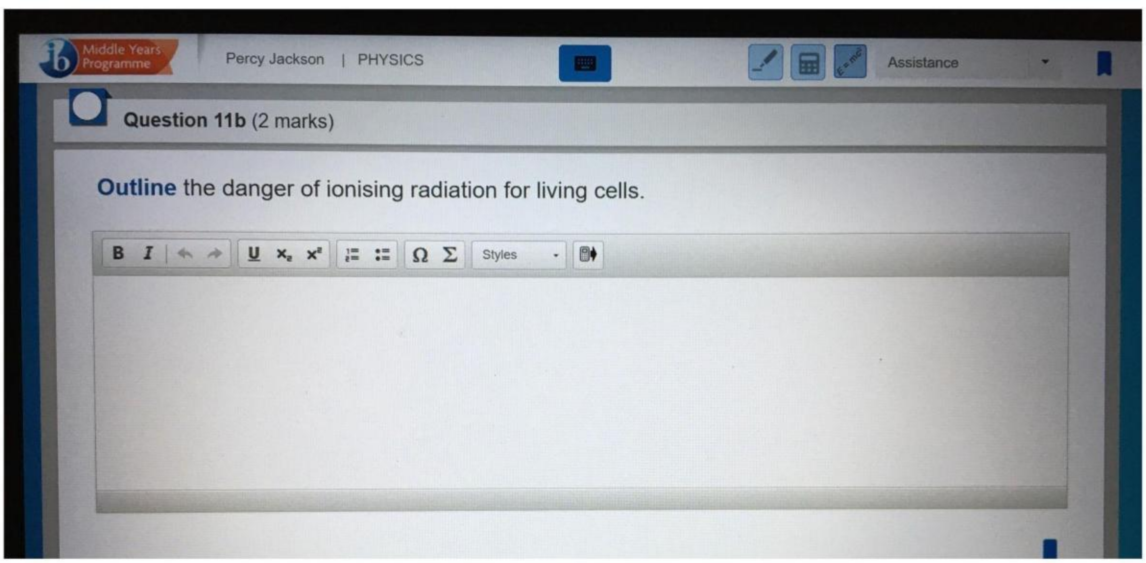
X-rays are a form of ionising radiation. Other forms of ionising radiation include alpha particles, beta particles and gamma rays.

Question 11a (3 marks)

Describe the process of ionisation by one of the forms of ionising radiation.

Styles

Type here to search


Middle Years Programme
Percy Jackson | PHYSICS
Assistance

Question 11b (2 marks)

Outline the danger of ionising radiation for living cells.

Styles

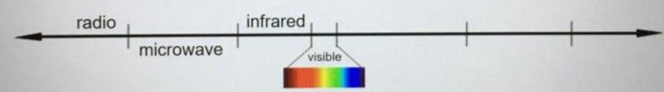
Question 11c (1 mark)

X-rays, gamma rays and ultraviolet light are all forms of electromagnetic radiation.

Label the diagram of the electromagnetic spectrum.

Draggable:

ultraviolet | X-ray | gamma ray



Question 11d (3 marks)

X-rays and gamma rays can both be used by doctors to produce images of the internal structure of the human body. The different properties of X-rays and gamma rays produce different types of image.

An X-ray image is formed by projecting X-rays, and then capturing the "shadow" on a surface that reacts to X-ray radiation.

Using information from the table, **discuss** why X-rays are used, rather than ultraviolet or gamma rays, when doctors wish to make images of a person's bones.

	ultraviolet	X-rays	gamma rays
absorption by skin	high	low	low
absorption by bones	high	high	low
absorption by soft tissue	high	medium	low

Middle Years Programme | Percy Jackson | PHYSICS | Assistance

X-ray | CT scan | MRI | Ultrasound

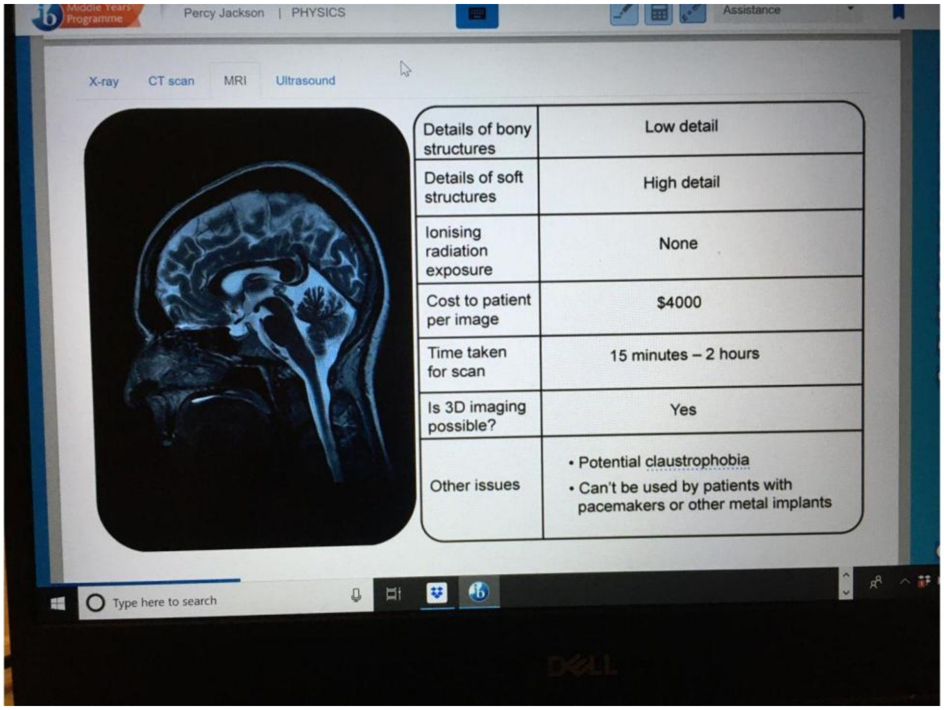
Details of bony structures	High detail
Details of soft structures	No image possible
Ionising radiation exposure	Equivalent to 1/10 annual radiation dose from natural sources
Cost to patient per image	$70
Time taken for scan	5 seconds
Is 3D imaging possible?	No
Other issues	None

Type here to search

X-ray | CT scan | MRI | Ultrasound

Details of bony structures	High detail
Details of soft structures	Good detail
Ionising radiation exposure	10 times annual radiation dose from natural sources
Cost to patient per image	$2000
Time taken for scan	30 seconds – 5 minutes
Is 3D imaging possible?	Yes
Other issues	• Very obese patients may not fit in the scanning machine or may be too heavy for the table • Can't scan image bone, soft tissue and blood vessels at the same time

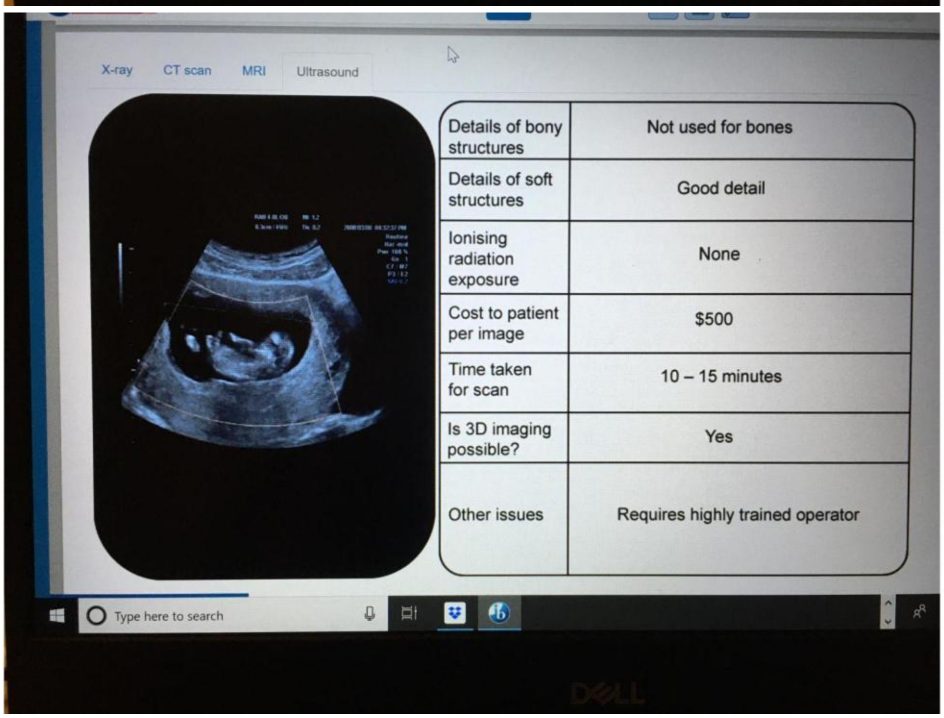
Type here to search



Percy Jackson | PHYSICS

X-ray | CT scan | MRI | Ultrasound

Details of bony structures	Low detail
Details of soft structures	High detail
Ionising radiation exposure	None
Cost to patient per image	$4000
Time taken for scan	15 minutes – 2 hours
Is 3D imaging possible?	Yes
Other issues	• Potential claustrophobia • Can't be used by patients with pacemakers or other metal implants



X-ray | CT scan | MRI | Ultrasound

Details of bony structures	Not used for bones
Details of soft structures	Good detail
Ionising radiation exposure	None
Cost to patient per image	$500
Time taken for scan	10 – 15 minutes
Is 3D imaging possible?	Yes
Other issues	Requires highly trained operator

Percy Jackson | PHYSICS

Assistance

Question 11e (14 marks)

All hospitals have a limited amount of money to spend on medical equipment. Hospital managers have to balance the advantages and disadvantages of different types of equipment when they decide how to spend their money.

Using the information in the tables, **discuss** and **evaluate** the medical imaging equipment **you** would recommend to the hospital manager, clearly justifying your recommendation. In this extended piece of writing, you should consider the social and economic factors and include:

- the advantages of your chosen equipment
- the disadvantages of your chosen equipment
- the perspective of the hospital
- the perspective of the patients.

Styles

Type here to search

Percy Jackson | PHYSICS

Question 12 (3 marks)

Look at the two very different images of feet.

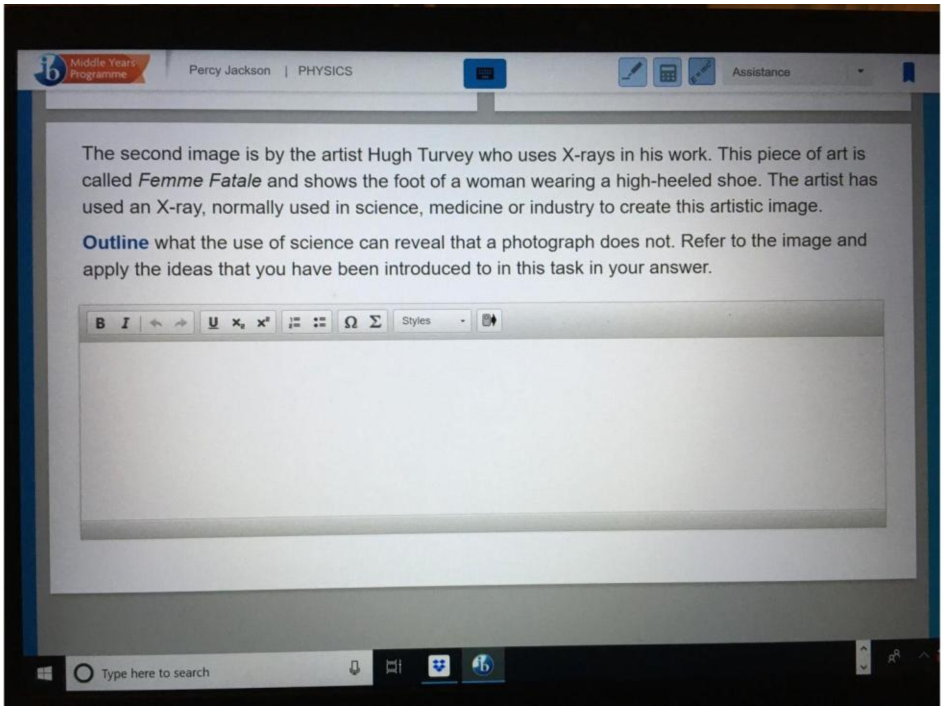
Image 1

©

Image 2

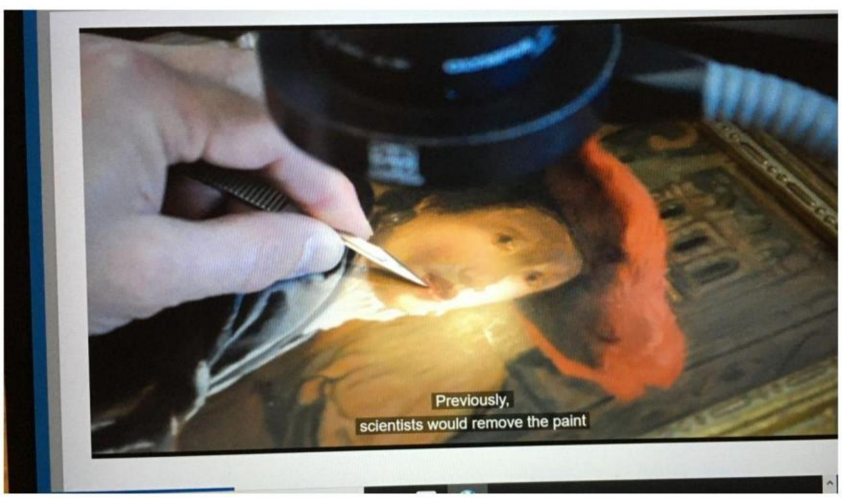
©

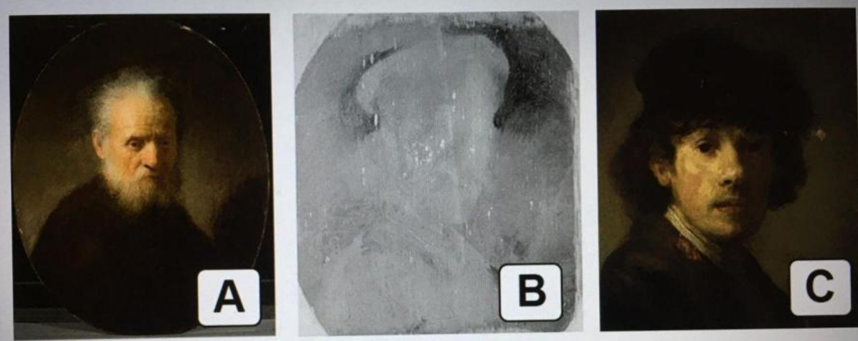
Type here to search



The link below gives similar information about
the use of XRFS & Rembrandt's work

https://colourlex.com/project/x-ray-fluorescence/





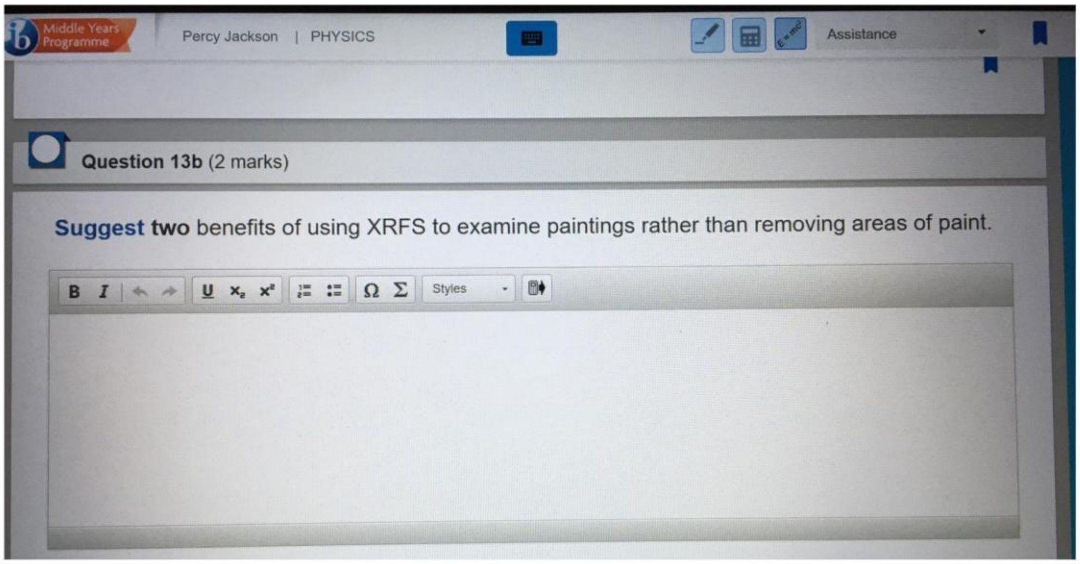
Compare **image C** to **images A** and **B**.

Some art historians suggest that Rembrandt reused the canvas shown in **image B**.

Question 13a (2 marks)

Outline the evidence in these three images that supports the suggestion that the canvas was reused.

Styles



May 2017

May 2018

May 2019

May 2020

May 2021

May 2022

Question 1 (11 marks)

The Shinkansen, commonly known as a bullet train, is a network of high-speed magnetic levitation trains in Japan. The video below explores how the trains were redesigned to minimize the loud booms produced when the trains entered a tunnel.

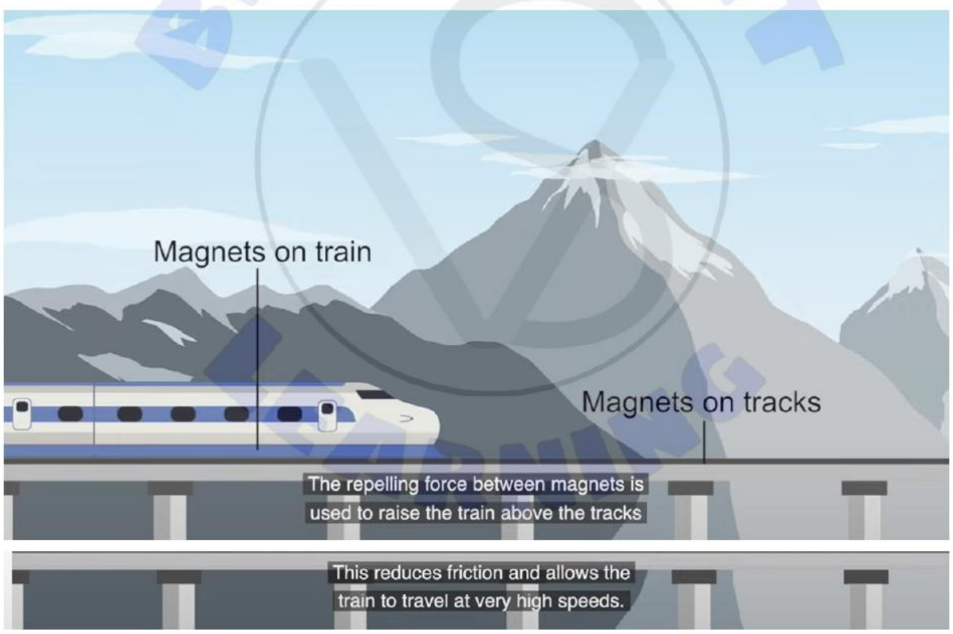
Video | Script

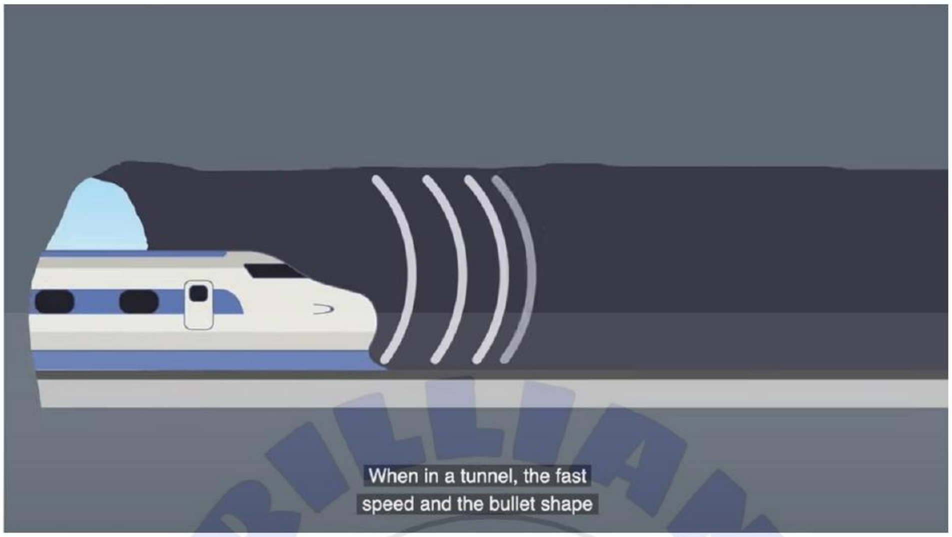
Japanese bullet trains were first designed in 1964. These trains use magnetic levitation. The repelling force between magnets is used to raise the train above the tracks. This reduces friction and allows the train to travel at very high speeds.

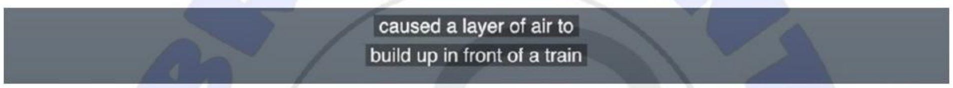
When in a tunnel, the fast speed and the bullet shape caused a layer of air to build up in front of a train. This caused a loud booming sound when the train exited the tunnel.

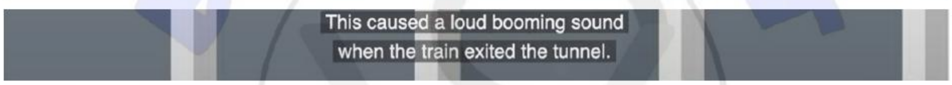
Scientists noticed that kingfisher birds did not disturb water when they dived into it due to the shape of their beaks. They redesigned the nose of the train by modelling it on a kingfisher's beak.

The redesigned train cut through the air and reduced the build-up of layers of air in tunnels. This reduced the loud booming sound and increased the train's efficiency.




When in a tunnel, the fast
speed and the bullet shape


caused a layer of air to
build up in front of a train

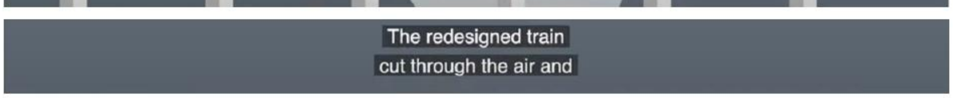

This caused a loud booming sound
when the train exited the tunnel.

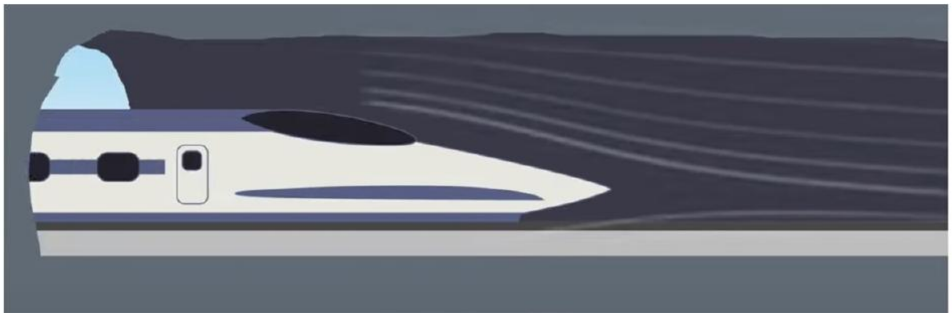

Scientists noticed that kingfisher
birds did not disturb water


when they dived into it
due to the shape of their beaks.


They redesigned the nose of the train
by modelling it on a kingfisher's beak.


They redesigned the nose of the train
by modelling it on a kingfisher's beak.


The redesigned train
cut through the air and



reduced the build-up
of layers of air in tunnels.

This reduced the loud booming sound

and increased the
train's efficiency.

Question 1a (1 mark)

Select the unit for measuring force.

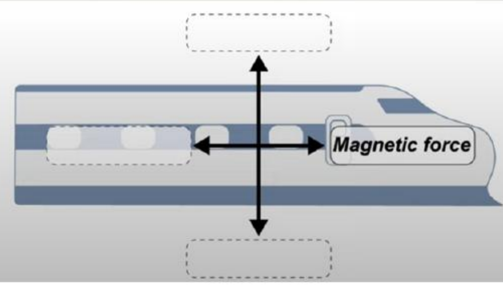
✓ Select
joule
kilogram
newton
watt

Question 1b (2 marks)

The diagram below shows the forces acting on the 1964 train traveling at a constant maximum speed of 220 km h^{-1}.

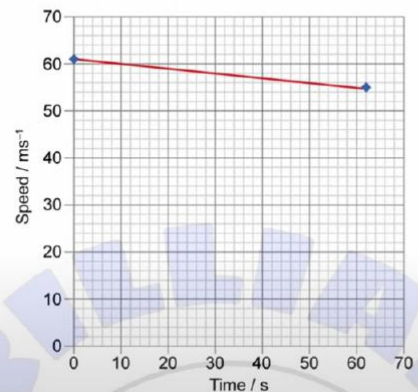
Label the forces in the diagram.

Draggable items: Weight | Normal force | Magnetic force | Drag force



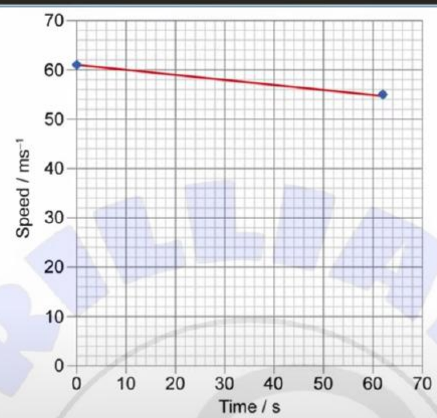
Question 1d (3 marks)

The speed–time graph shows the motion of the 1964 train on its journey through a tunnel.
Use the graph to **calculate** the length of the tunnel.



Question 1e (2 marks)

Draw a line on the graph to represent the journey of the redesigned train through the tunnel at the same initial speed.



Question 2 (7 marks)

Question 2a (1 mark)

Transformers are electrical devices that are used for reducing or increasing the voltage of an alternating current.

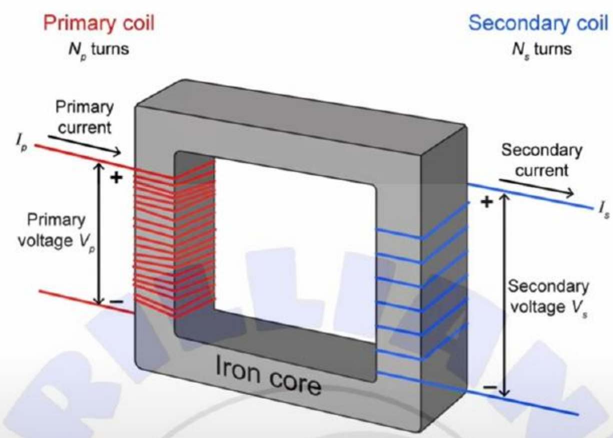
Select the correct terms to complete the sentence.

In a transformer that is 100% efficient, the input [Select] must be [Select] the output power.

	✓ Select power current voltage	✓ Select less than equal to greater than

Question 2b (2 marks)

Transformers are composed of primary and secondary coils wrapped around an iron core.



©

Transformers are commonly used to reduce the voltage from supply lines to the voltage required for homes.

	Voltage / V	Current / A
Primary coil		1.2
Secondary coil	240	60

Reset

Use information from the formula sheet to **calculate** the primary supply voltage. You should assume this transformer is 100% efficient.

B I U ×₂ x² Ω Σ Styles

Question 2c (2 marks)

In reality, transformers are only 98% efficient. **Calculate** the actual power supplied by the secondary coil.

B I U ×₂ x² Ω Σ Styles

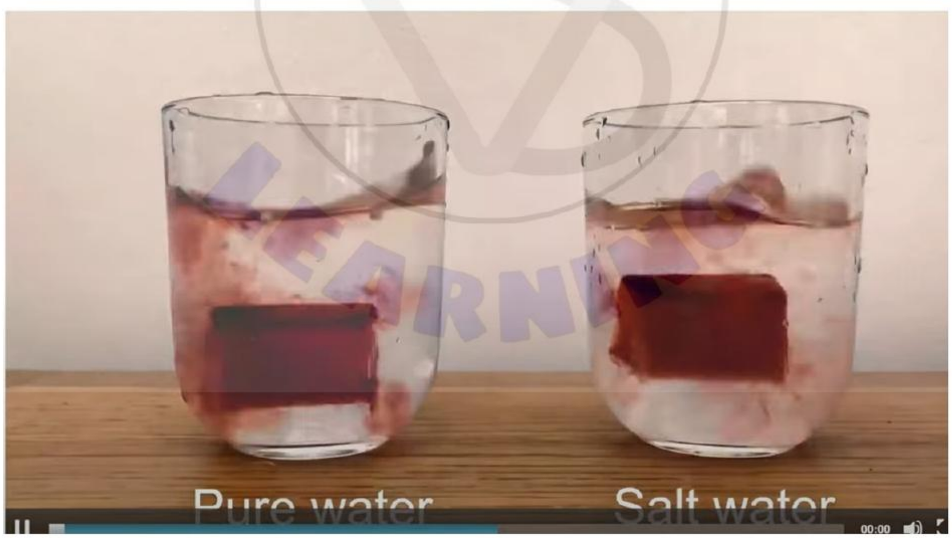
Question 2d (2 marks)

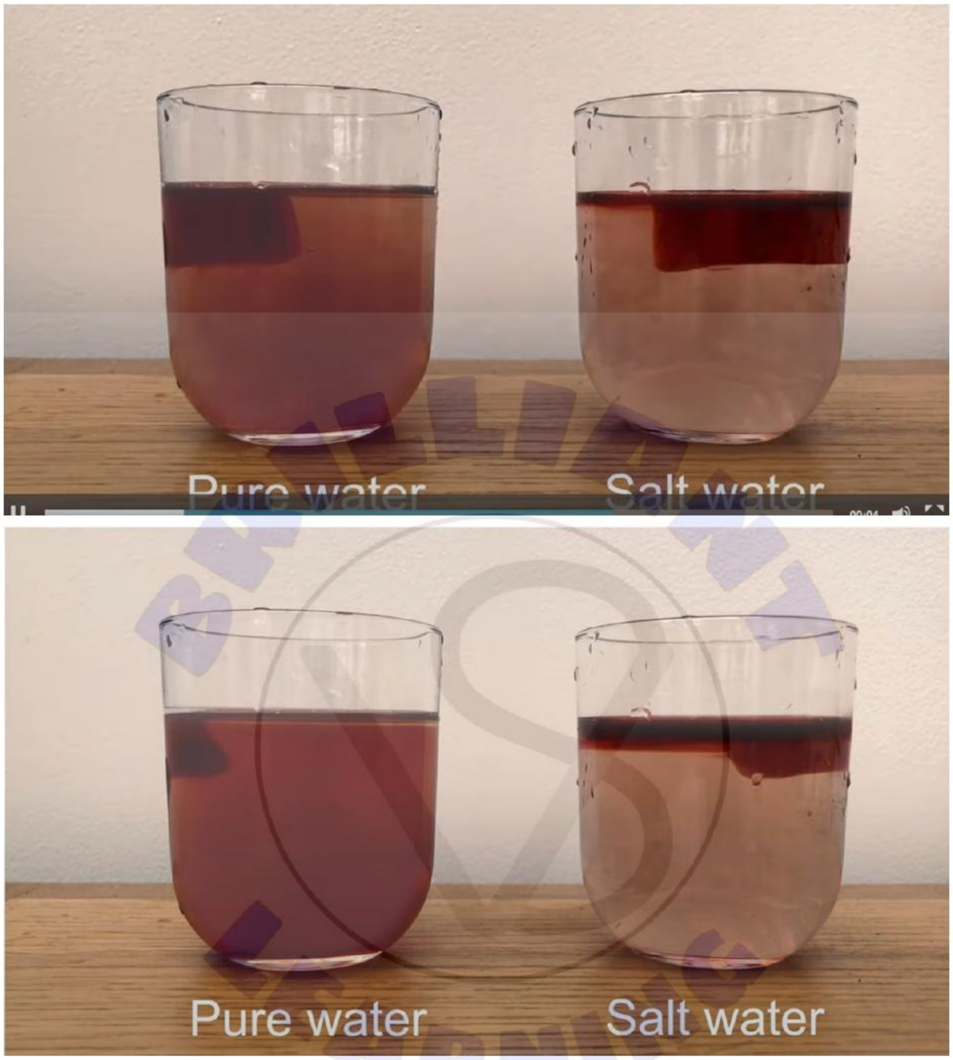
The relationship between power and current can be expressed as $P = I^2 R$ where P = power, I = current and R = resistance. Use this relationship to **describe** why electricity is transmitted over long distances at high voltage.

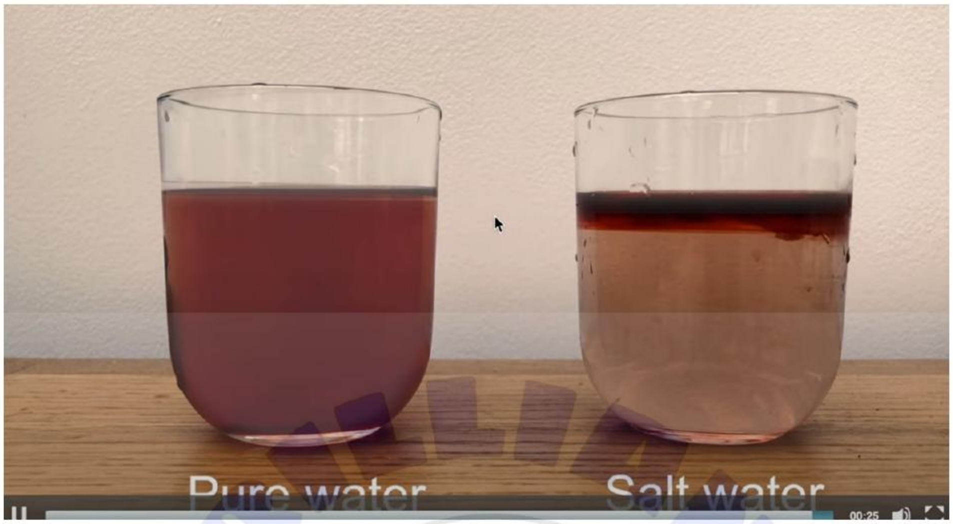
Question 3 (9 marks)

The video below shows ice cubes made from pure water melting in glasses of pure and salt water. The ice cubes have been coloured so they are more visible while melting. The ice cube in pure water melts faster than the ice cube in salt water.

This media contains no audio




Pure water
Salt water
Pure water
Salt water


Pure water
Salt water

Question 3a (1 mark)

There are three methods of heat transfer. **Select** the most appropriate description for each method.

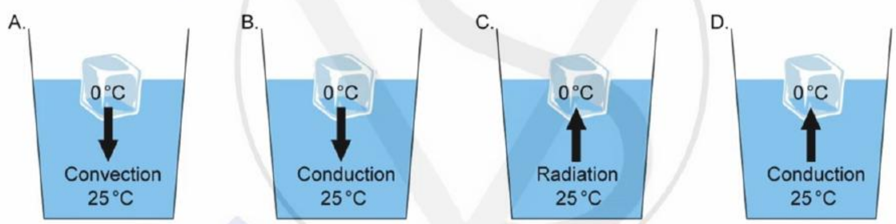
Draggable items:

- Transfer of heat by direct contact
- Transfer of heat by moving fluids
- Transfer of heat by electromagnetic radiation

Radiation	
Conduction	
Convection	

Question 3b (1 mark)

Select the diagram that best represents the process of heat energy transfer between the ice cube and the water.



✓ Select
A
B
C
D

n 3c (1 mark)

Question 3d (1 mark)

Question 3c (1 mark)

In the video, tiny water droplets begin to form on the outside of each glass. **State** the physical change that is shown by the formation of these water droplets.

Question 3d (1 mark)

Tiny water droplets form around most of the outside of the glass containing pure water but only form at the top of the glass containing salt water. **Suggest** why the pattern of water droplets is different.

Question 3e (3 marks)

Using your knowledge of heat transfer processes, **explain** why the ice cube melts more slowly in the salt water.

Question 3f (2 marks)

Predict how the results of the experiment would change if the water in both glasses was stirred continuously.

Question 4 (16 marks)

A pan flute is a musical instrument made from hollow tubes that are closed at one end. The tubes are commonly made from natural materials, such as bamboo. The tubes are cut to different lengths. When air is blown across a tube, the air vibrates and produces a sound.

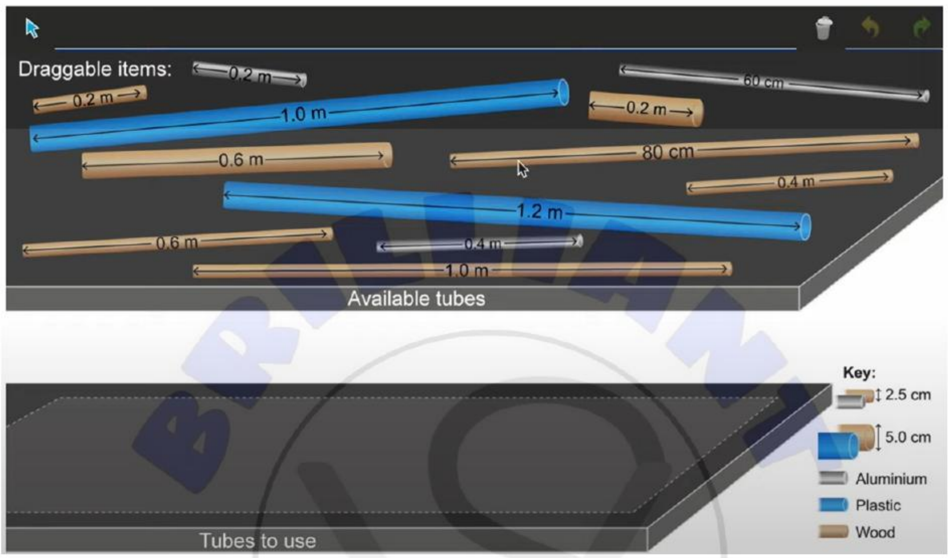
Question 4a (1 mark)

An MYP student is interested in the relationship between the length of a tube and the frequency of the sound being produced.

State a research question that would be tested by this investigation.

Question 4b (3 marks)

You are provided with a box of tubes. **Select** the tubes you would use in the investigation in part (a) to collect appropriate data. Drag your selected tubes from the top box of available tubes into the bottom box.



Question 4c (2 marks)

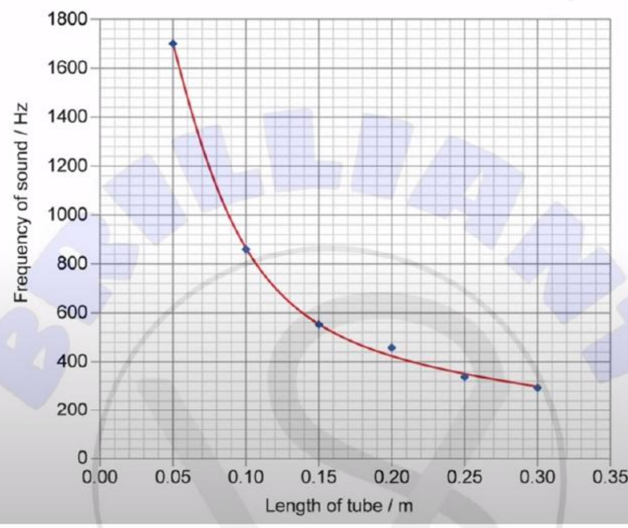
Justify the selection you made in part (b).

Question 4d (3 marks)

A student doing a similar investigation made the following prediction:

As the length of the tube increases, the frequency of the sound produced will decrease. I predict that there will be an inversely proportional relationship between the variables.

The graph of her results is shown below:



Use data from the graph and a calculation to **explain** whether the student's prediction is supported.

Question 4e (1 mark)

This data can be used to find the speed of sound in air using the relationship:

$$f = \frac{v}{4L}$$

Where:
f – frequency
L – length of the tube
v – speed of sound in air

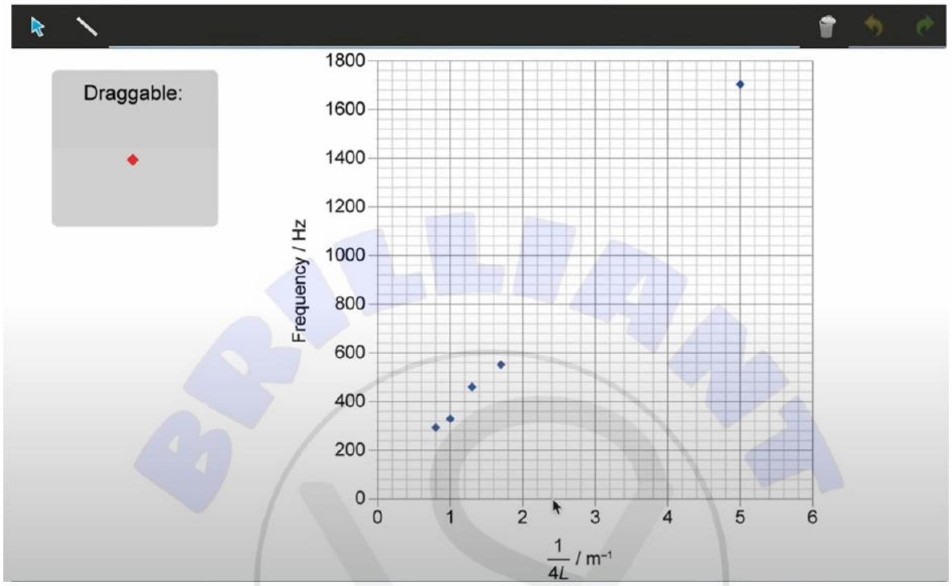
Determine the missing values and add them to the table of processed data below.

Length L / m	Frequency f / Hz	$4L$ / m	$\frac{1}{4L}$ / m^{-1}
0.05	1715	0.2	5.0
0.10	860		
0.15	572	0.6	1.7
0.20	450	0.8	1.3
0.25	343	1.0	1.0
0.30	290	1.2	0.8

Question 4f (2 marks)

The graph below shows the processed data from part (e).

Plot the data point you determined in part (e) and **draw** a line of best fit on the graph.



Question 4g (1 mark)

The student is investigating the relationship $f = \frac{v}{4L}$. **Identify** what quantity is shown by the gradient of the graph in part (f).

○ $\frac{1}{v}$

○ v

○ $\frac{1}{4L}$

○ $\frac{v}{4L}$

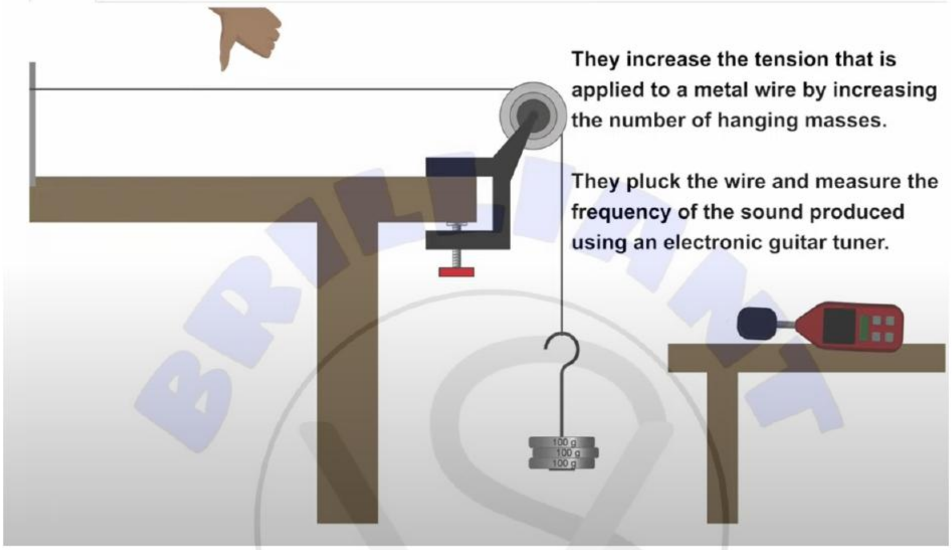
Question 4h (3 marks)

Calculate the gradient of your line of best fit. You should include your working and **state** the unit.

Question 5a (2 marks)

Some musical instruments, such as the guitar, make sounds by vibrating strings.

Video Script



Calculate the force of tension in the wire if the hanging mass is 300 g. You should assume that gravitational field strength is 10 N kg^{-1}.

Styles

Question 5b (2 marks)

The student's research question is:

How does increasing the force of tension affect the frequency of vibration of a wire?

Suggest two variables the student should have controlled during this investigation.

Control variable 1:

Control variable 2:

Question 5c (4 marks)

The student's notebook containing the results from this investigation is shown below:

Organize and **present** the data in a table.

Create New Table

Reset

May 2023

Question 1 (11 marks)

Horses can perform work for farming activities. In the past, they were used to loosen the soil before planting. Physics can be used to explore the ways in which horses complete these tasks.

Question 1a (2 marks)

A horse covers a distance of 3 km in 45 minutes. **Calculate** its speed in km per hour (km h^{-1}).

Question 1b (1 mark)

Power is the rate of transforming energy or the rate of doing work. **Select** the formula for energy transformed.

- A. energy transformed = power × distance
- B. energy transformed = power ÷ distance
- C. energy transformed = power × time
- D. energy transformed = power ÷ time

Question 1c (2 marks)

The table below gives some data about two horses A and B. **Calculate** the missing values and complete the table. You should assume the value of $g = 10\,N\,kg^{-1}$.

Horse	Mass of horse / kg	Weight / N
A	350	
B		5100

Reset

Question 1d (1 mark)

Select the correct terms to complete the energy transformation diagram for a horse that starts from rest at the bottom of a hill, runs up the hill and then stops at the top of the hill.

Draggable items:

- Chemical potential energy
- Gravitational potential energy
- Elastic potential energy
- Electrical energy

.... → **Kinetic energy** → ....

Question 1e (3 marks)

The hill in part (d) is 12 m high. Horse B reaches the top of the hill in 5.50 s. Use information from part (c) and the formula sheet to **calculate** the minimum power required for horse B to reach this height. You should give your answer in kW.

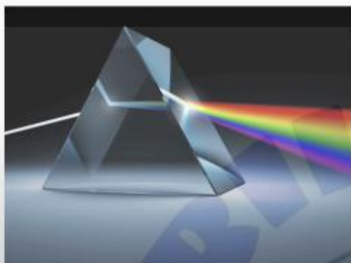
Question 1f (2 marks)

The power of some modern devices is given in horsepower (hp), where 1.0 hp is equivalent to 746 W. An example of such a device is an electric water pump. **Calculate** the current that would be needed by a water pump with a power of 2.0 hp operating at a voltage of 230 V.

Question 2 (7 marks)

Newton carried out experiments on light. Working in his darkened room, he directed white light through a glass prism, which separated the light into the seven colours we now know as the colour spectrum (red, orange, yellow, green, blue, indigo and violet). Before Newton's experiments, scientists believed that the prism itself transformed white light into these colours.

Question 2a (1 mark)



The image shows white light being separated into different colours. **Select** the term for this process.

- A. Absorption
- B. Deflection
- C. Reflection
- D. Dispersion

Question 2b (3 marks)

Explain why red light is at the top of the image in part (a). You should use scientific terminology in your answer.

Beac

Words: 1

Question 2c (1 mark)

Another scientist called Herschel detected infrared waves beyond the visible spectrum. Unlike red light, infrared waves are not visible to the human eye. **State** one other difference between infrared waves and red light.

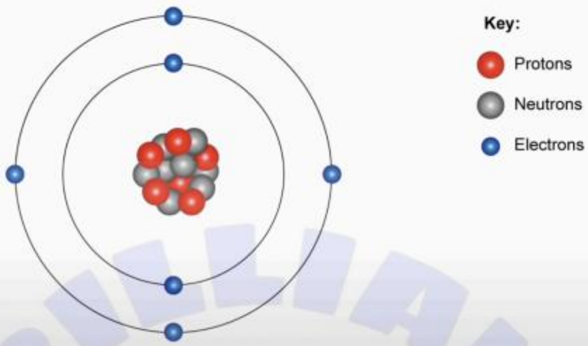
Question 2d (2 marks)

In air, all the colours of light in the spectrum travel at a speed of $3.00 \times 10^{8}\,ms^{-1}$. Use the formula sheet to **calculate** the frequency of red light with a wavelength of 750 nm. You should use scientific notation in your answer.

Question 3 (9 marks)

Question 3a (2 marks)

The diagram below shows an atom of carbon-14 which has 6 protons and 8 neutrons.



State the atomic number and mass number for this atom.

Atomic number	Mass number

Question 3b (2 marks)

State one similarity and one difference between a nucleus of carbon-12 and a nucleus of carbon-14.

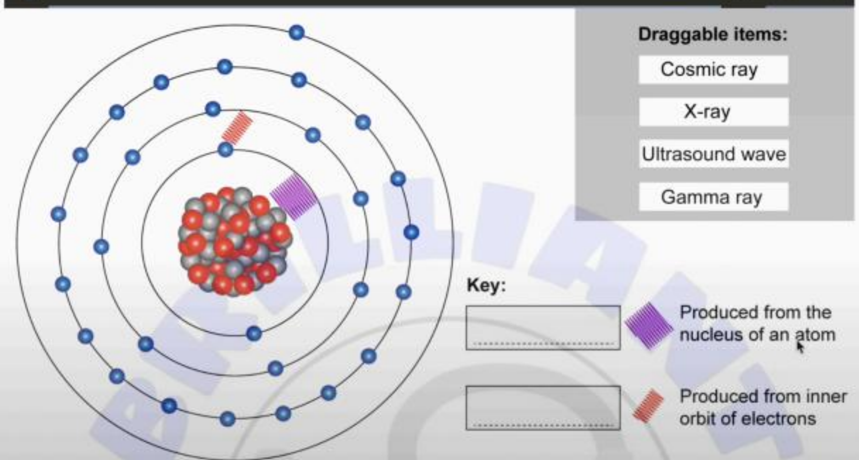
Similarity:

Difference:

Question 3c (2 marks)

The diagram below shows two electromagnetic rays being emitted from a radioactive isotope.

Select the terms to complete the key.



Scroll down to continue

Question 3d (2 marks)

The composition of a nucleus can change during nuclear reactions. **Select** items and drag them into place to balance the equations for the nuclear reactions below.

Draggable items: ${}^{0}_{-1}\beta$ ${}^{4}_{2}\alpha$ ${}^{0}_{1}\beta$ ${}^{1}_{1}p$

$${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + \boxed{}$$

$${}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + \boxed{}$$

Question 3e (1 mark)

Suggest what is happening in the reaction shown below that results in the formation of a Uranium-239 nucleus.

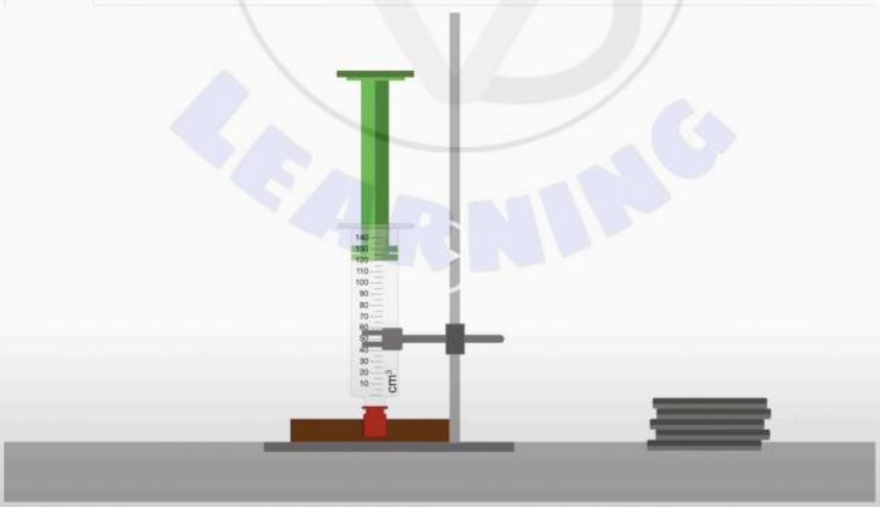
$$^{238}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{239}_{92}\text{U}$$

Question 4 (13 marks)

The pressure, volume and temperature of a gas are related. The ideal gas law describes the relationship between them. Gas is all around us in the form of air.

A student decides to investigate the effect of adding masses on the volume of air in a syringe. The student adds the masses slowly so that the temperature of the air in the syringe remains constant, as shown in the animation below.

Animation Script



Animation Script

The tip of the syringe is sealed so that the amount of air is constant.

Masses are added and the plunger is pushed downwards, compressing the air in the syringe.

Question 4a (1 mark)

State the research question that could be answered in this scientific investigation.

Question 4b (2 marks)

Identify the variables for this investigation.

Variable	Independent	Dependent	Control
Amount of air in the syringe	☐	☐	☐
Mass added to plunger	☐	☐	☐
Size of syringe	☐	☐	☐
Temperature	☐	☐	☐
Volume of air	☐	☐	☐

Reset

Question 4c (1 mark)

Select the correct response to complete the sentence.

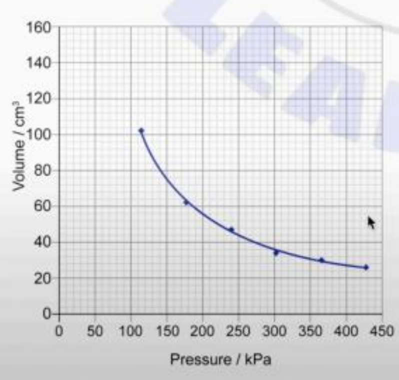
When masses are added to the plunger, the pressure will [Select].

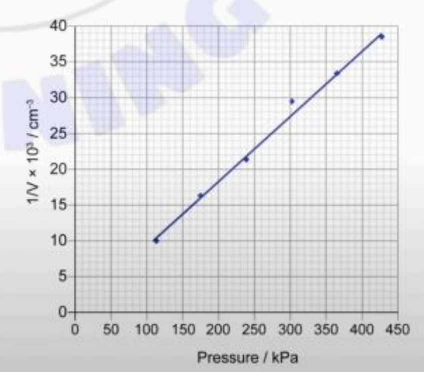
Question 4d (3 marks)

The plunger has an area of 7.9×10^{-5} m^2. Atmospheric pressure is 100 000 Pa. Use the formula sheet to **calculate** the total pressure on the air in the syringe if the mass applied is 1.2 kg. You should assume that the value of $g = 10\,\text{N kg}^{-1}$.

Question 4e (2 marks)

The student calculated the total pressure for each of the masses used. She presented the processed data in the graphs below.

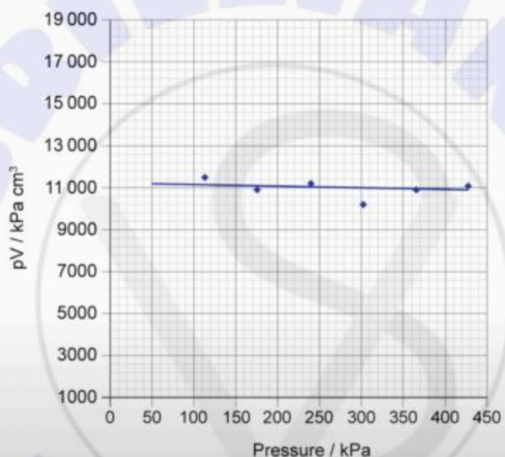




Use both graphs above to **describe** the relationship between pressure and volume of a gas.

Question 4f (2 marks)

Another student decided to multiply pressure by volume (pV) and presented this on the graph below.



Boyle's law states that pV is constant for a fixed amount of gas at constant temperature. **Suggest** whether the graph supports Boyle's law. **Justify** your answer.

Question 4g (2 marks)

Use the graph in part (f) to **calculate** the volume of gas when the pressure is 75 kPa. You should include a unit in your answer.

Question 5 (17 marks)

Another group of students decides to use balloons to investigate the relationship between the volume of a gas and its temperature.

They make the following prediction:

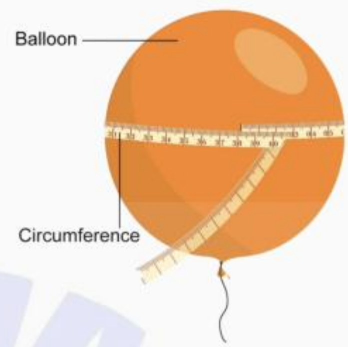
> If the temperature of a fixed amount of gas inside a balloon increases, the volume of the balloon will increase.

Question 5a (3 marks)

Use kinetic theory to **explain** the prediction.

Question 5b (14 marks)

Measuring the volume of a balloon directly is difficult. The students plan to measure the circumference of the balloon instead of measuring its volume.



The students are interested in how the temperature of the balloon affects its circumference. **Design** an experiment that the students could use to carry out this investigation. They are provided with standard laboratory equipment, including an oven to change the temperature. In your plan, you must include:

- a research question
- the independent, dependent and one control variable
- a list of the equipment they will need
- a detailed method for collecting data
- an explanation of how the students will collect sufficient data
- details of how they will make sure that the method is safe.

Question 6 (17 marks)

When the air inside an inflated balloon is released, the balloon accelerates forward.

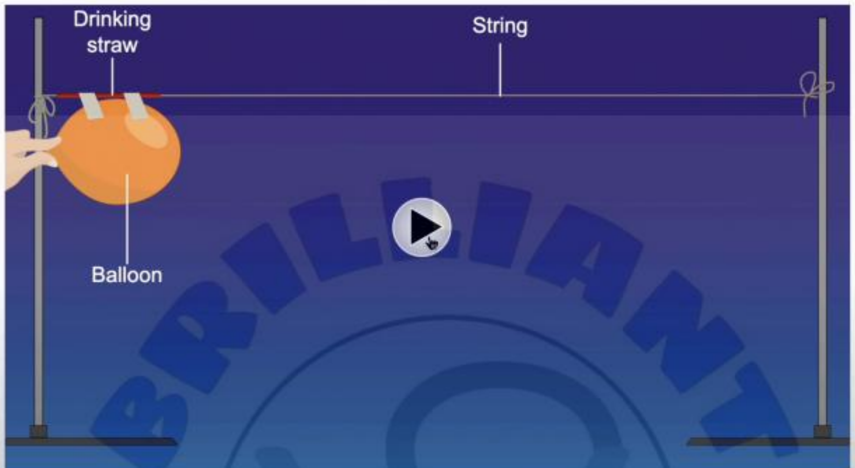
Question 6a (3 marks)

Use Newton's laws to **explain** the motion of the balloon.

Question 6b (1 mark)

A group of students decide to investigate the distance travelled by a balloon filled with different volumes of air. They use the following equipment.

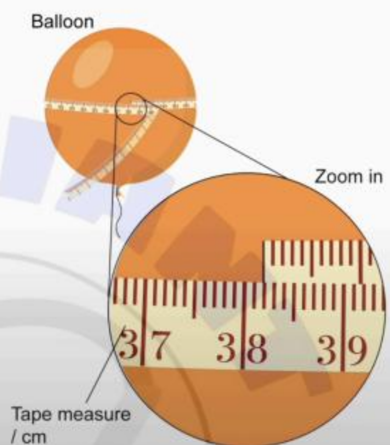
Diagram not to scale



State the research question that the students are investigating.

Question 6c (1 mark)

The students' data is shown below. The circumference of one of the balloons has not been recorded. **Measure** the circumference as shown in the picture.



Question 6d (4 marks)

Organise and **present** the data from the experiment into a table, including the result from part (c).

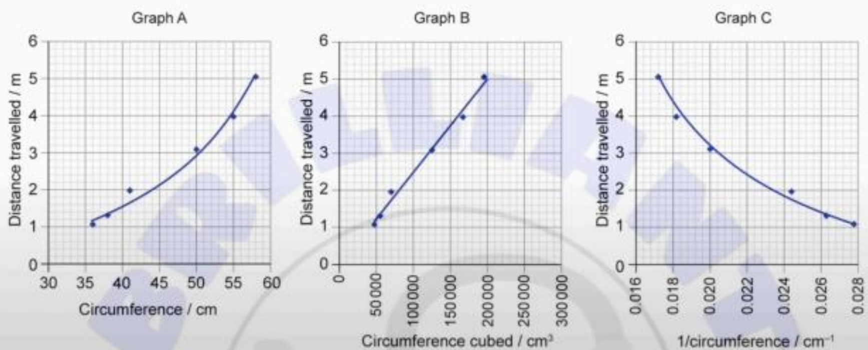
Reset

Question 6e (3 marks)

Before their investigation, the students suggested the following hypothesis:

If the circumference of the balloon increases, then the distance travelled will increase because the resultant or net force will be greater with an increased volume of air. The distance travelled will be directly proportional to the circumference.

The students plotted three different graphs of their data. Use the graphs of the students' data below to **evaluate** the validity of their hypothesis.



Question 6f (3 marks)

The students wanted to extend their investigation. **Suggest** variables that the students could use to extend this investigation. The dependent variable has been completed for you.

Independent variable:

Control variable 1:

Dependent variable:

distance travelled

Control variable 2:

Scroll down to continue

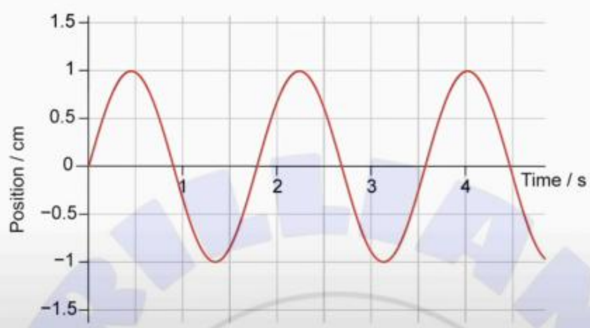
Question 6g (2 marks)

Formulate a hypothesis that your extension in part (f) would test.

Question 7 (18 marks)

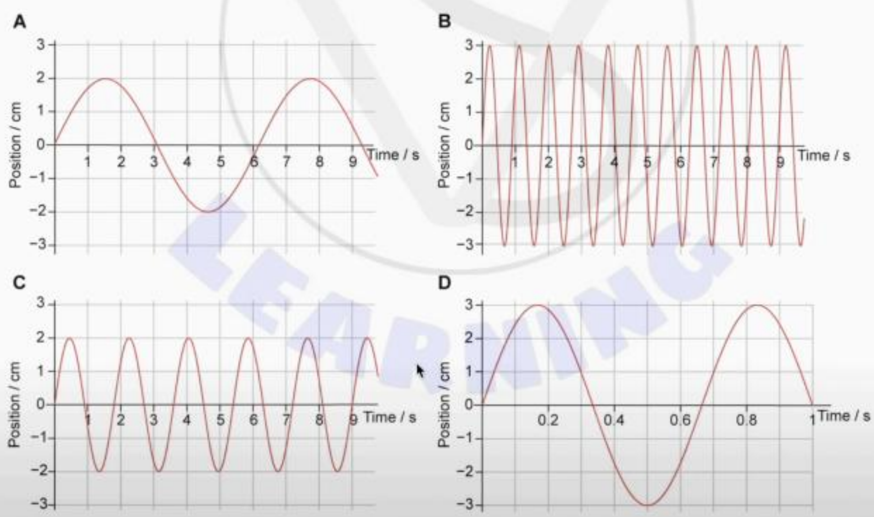
Question 7a (3 marks)

The frequency of any wave can be found from a graph of the wave position against time. Use the formula sheet to **calculate** the frequency of the waveform shown below. Give your answer to two significant figures and include a unit.



Question 7b (1 mark)

Select the waveform with the same frequency as the waveform in part (a).



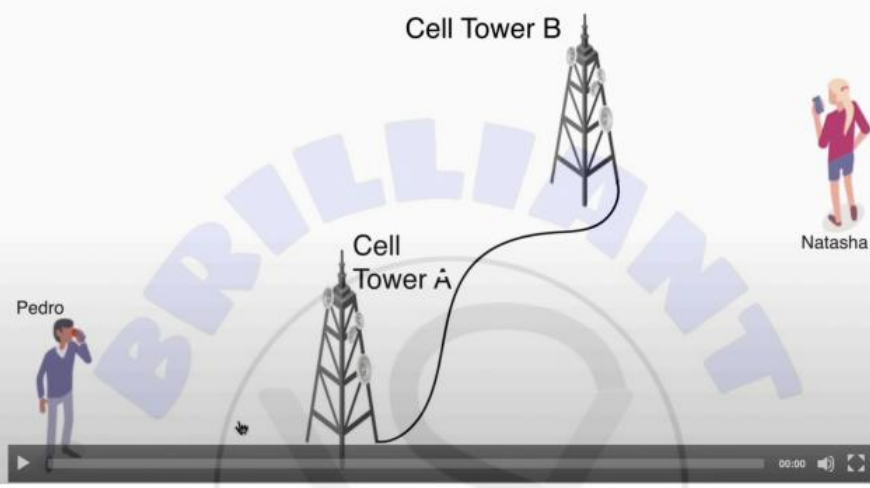
Select

Question 7c (1 mark)

Pedro and Natasha are communicating using mobile phones. The phones send and receive information in the form of radio waves. Different frequencies are used to transmit this information.

The animation below shows a simplified view of the mobile phone network that is used.

This media contains no audio



Put the following statements in order to **outline** the process taking place in the animation above.

Draggable items:

- Tower A receives the signal, then sends the signal out through a connection using wires or fibre-optic cables to Tower B, where the signal is converted again.
- Natasha's phone receives the radio wave signal and converts it back into a sound wave that she can hear.
- The radio wave signal is transmitted from the mobile phone to tower A.

Pedro's voice is converted into an electrical signal by the microphone in his mobile phone. The phone then converts that electrical signal into a radio wave.
↓
↓
↓

The use of radio waves enables high-speed communication, but the technology requires the location of the phone to be detectable. This has consequences for security and data protection.

Video Script

Video Script

There are networks of cell towers all over the world. Mobile phones work by sending signals to and receiving signals from the nearest cell tower. When the user moves from one area to another, the phone disconnects from one cell tower and connects to a new cell tower to maintain a strong signal.

A consequence of this technology is that the location of a phone, and therefore the user of that phone, can be detected at any time. Even a phone that is switched off but has its battery inserted can be located.

User location information can be used in navigation apps and fitness trackers. Even applications not directly used in navigation can track the location of the phone and map the movements of the user. It is not widely known that this personal movement data can be bought by companies who have an interest in it.

People in large gatherings can be tracked and this information can be used to identify where they live and other personal details.

Question 7d (13 marks)

Discuss and **evaluate** the implications of mobile phone technology being used to track the locations and movements of individuals. In your answer, you should discuss:

- the advantages and disadvantages of location-tracking technology for an individual
- the economic benefits of location-tracking technology for a company
- the positive and negative security implications of location-tracking technology for a country
- an overall appraisal in which you evaluate the points discussed.

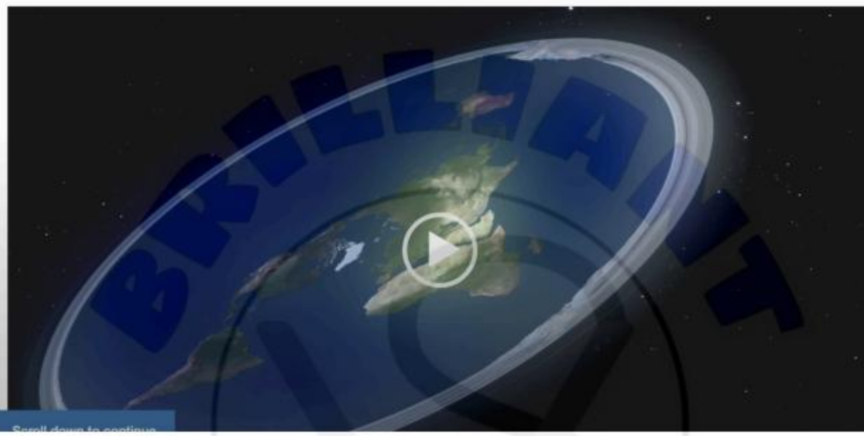
B I U Styles

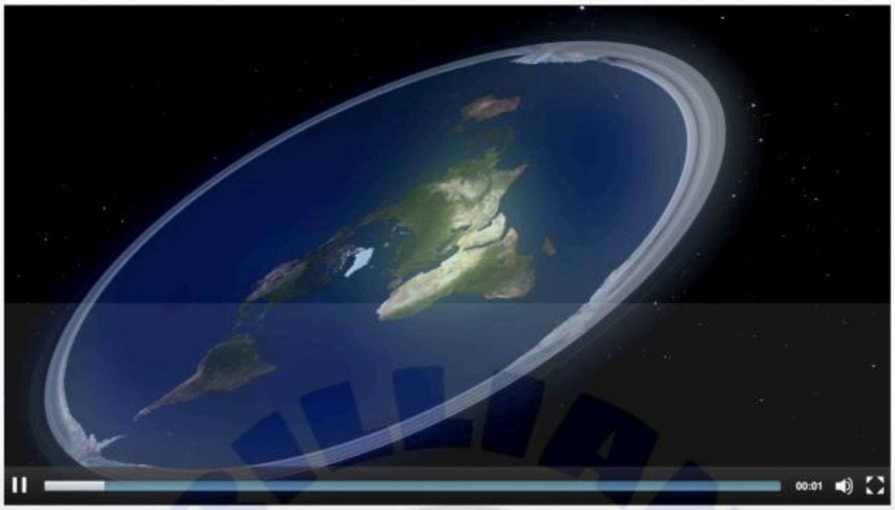
Question 8 (8 marks)

The ability of modern mobile phones to access the internet has influenced the way that people communicate. On the internet, people tend to communicate with other people that have the same ideas as they do, which can reinforce opinions that may not be logical or scientifically accurate.

Some people think that this kind of communication has led to an increase in the number of people believing in conspiracy theories. One such idea is the flat-Earth theory.

This media contains no audio

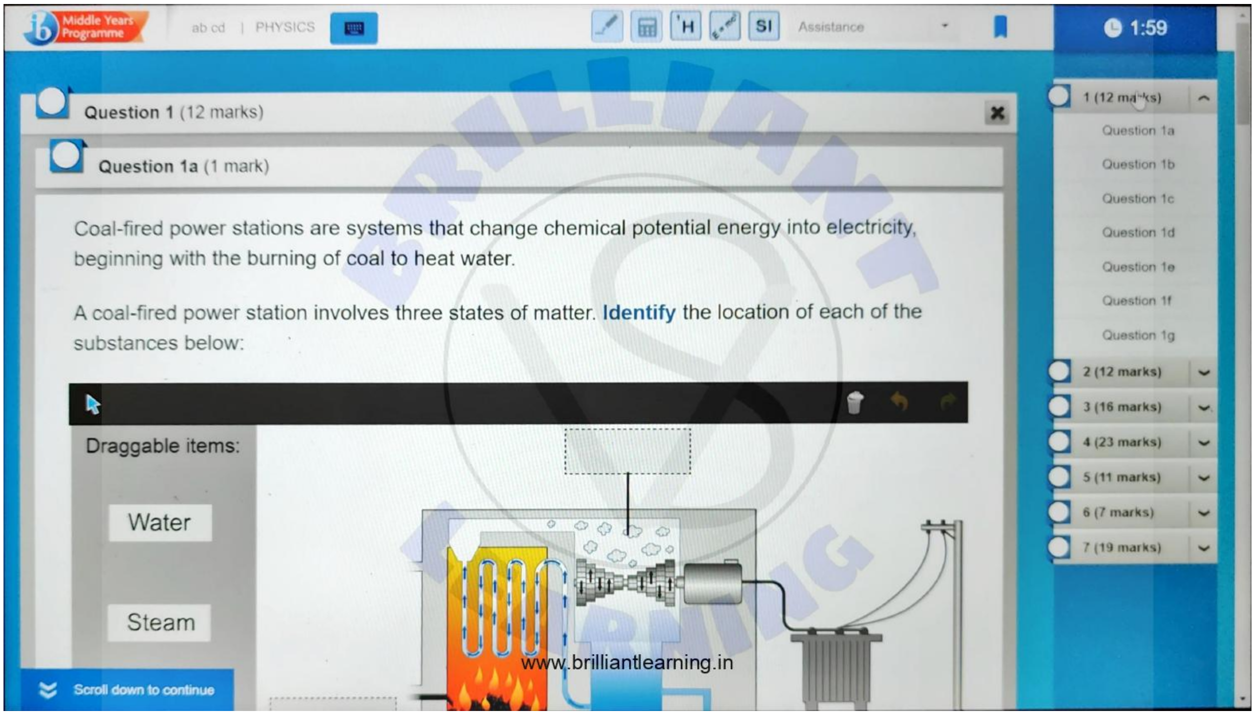




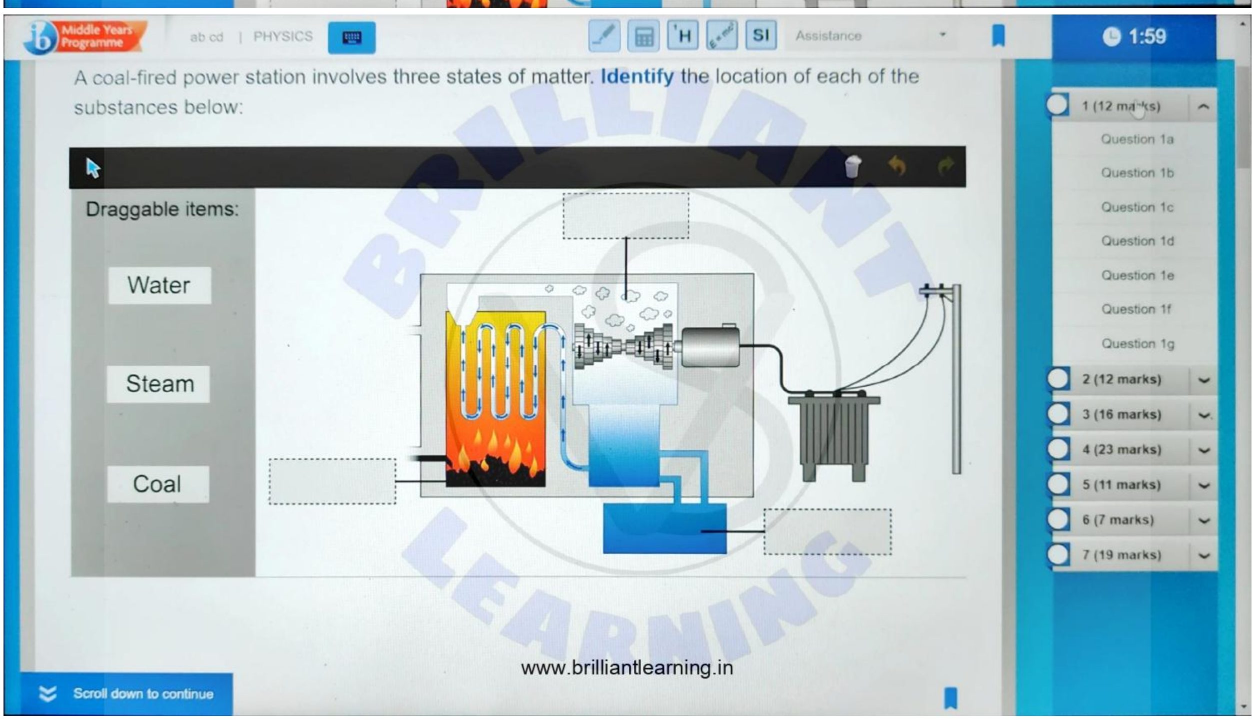
Some people have suggested that any scientific information that is shared through the internet should be checked for accuracy. Information that is incorrect or misleading should be removed.

Discuss and **evaluate** the benefits and limitations of controlling scientific information that is shared through the internet.

May 2024



Middle Years Programme
ab cd | PHYSICS
Assistance
1:59
Question 1 (12 marks)
Question 1a (1 mark)
Coal-fired power stations are systems that change chemical potential energy into electricity, beginning with the burning of coal to heat water.
A coal-fired power station involves three states of matter. **Identify** the location of each of the substances below:
Draggable items:
Water
Steam
Scroll down to continue
www.brilliantlearning.in
1 (12 marks)
Question 1a
Question 1b
Question 1c
Question 1d
Question 1e
Question 1f
Question 1g
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)



Middle Years Programme
ab cd | PHYSICS
Assistance
1:59
A coal-fired power station involves three states of matter. **Identify** the location of each of the substances below:
Draggable items:
Water
Steam
Coal
www.brilliantlearning.in
Scroll down to continue
1 (12 marks)
Question 1a
Question 1b
Question 1c
Question 1d
Question 1e
Question 1f
Question 1g
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

Middle Years Programme ab cd | PHYSICS Assistance 1:59

Question 1b (1 mark)

Absorbing heat can affect the kinetic energy of water molecules. **State** how water molecules are affected by this increase in kinetic energy.

Question 1c (2 marks)

Scroll down to continue

Middle Years Programme ab cd | PHYSICS Assistance 1:59

1 (12 marks)
Question 1a
Question 1b
Question 1c
Question 1d
Question 1e
Question 1f
Question 1g
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

Question 1c (2 marks)

As water boils into steam, the heat energy absorbed does not affect the kinetic energy of the molecules. **Outline** what happens to this heat energy referring to the movement and arrangement of particles.

arks)

Scroll down to continue

ab cd | PHYSICS

Assistance

1:59

Question 1d (2 marks)

One kilogram of coal contains approximately 2.5×10^7 J of chemical potential energy. For a coal-fired power station that burns 4.5×10^5 kg of coal per hour, **calculate** the energy released in one hour. You should give your answer to two significant figures.

1 (12 marks)
Question 1a
Question 1b
Question 1c
Question 1d
Question 1e
Question 1f
Question 1g
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

Question 1e (2 marks)

Scroll down to continue

ab cd | PHYSICS

Assistance

1:58

Question 1e (2 marks)

Another coal-fired power station burns enough coal per hour to generate a power of 26 700 MW. If the efficiency of this power station is 28 %, **determine** the useful power output.

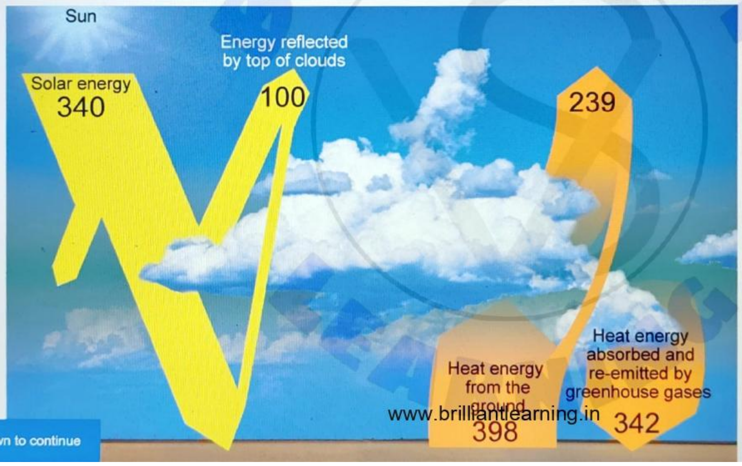
1 (12 marks)
Question 1a
Question 1b
Question 1c
Question 1d
Question 1e
Question 1f
Question 1g
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

www.brilliantlearning.in

Scroll down to continue

Question 1f (1 mark)

Burning coal contributes to climate change by altering the composition of Earth's atmosphere, increasing the quantity of greenhouse gases. The diagram below shows the flow of energy through the Earth's atmosphere.



Scroll down to continue

Select the arrow on the diagram which would be most affected by burning coal.

Select
- Select
- Solar energy
- Energy reflected by top of clouds
- Heat energy from the ground
- Heat energy absorbed and re-emitted by greenhouse gases

Question 1g

Greenhouse gases trap heat energy in Earth's atmosphere. This trapped heat is associated with more extreme weather events like storms, droughts, floods and changes to Earth's climate. Using scientific knowledge, **explain** why trapping heat energy in Earth's atmosphere would cause more extreme weather events and changes to Earth's climate.

Scroll down to continue

Question 1g (3 marks)

Greenhouse gases trap heat energy in Earth's atmosphere. This trapped heat is associated with more extreme weather events like storms, droughts, floods and changes to Earth's climate. Using scientific knowledge, **explain** why trapping heat energy in Earth's atmosphere would cause more extreme weather events and changes to Earth's climate.

1 (12 marks)
Question 1a
Question 1b
Question 1c
Question 1d
Question 1e
Question 1f
Question 1g
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)
Scroll down to continue

Question 2a (2 marks)

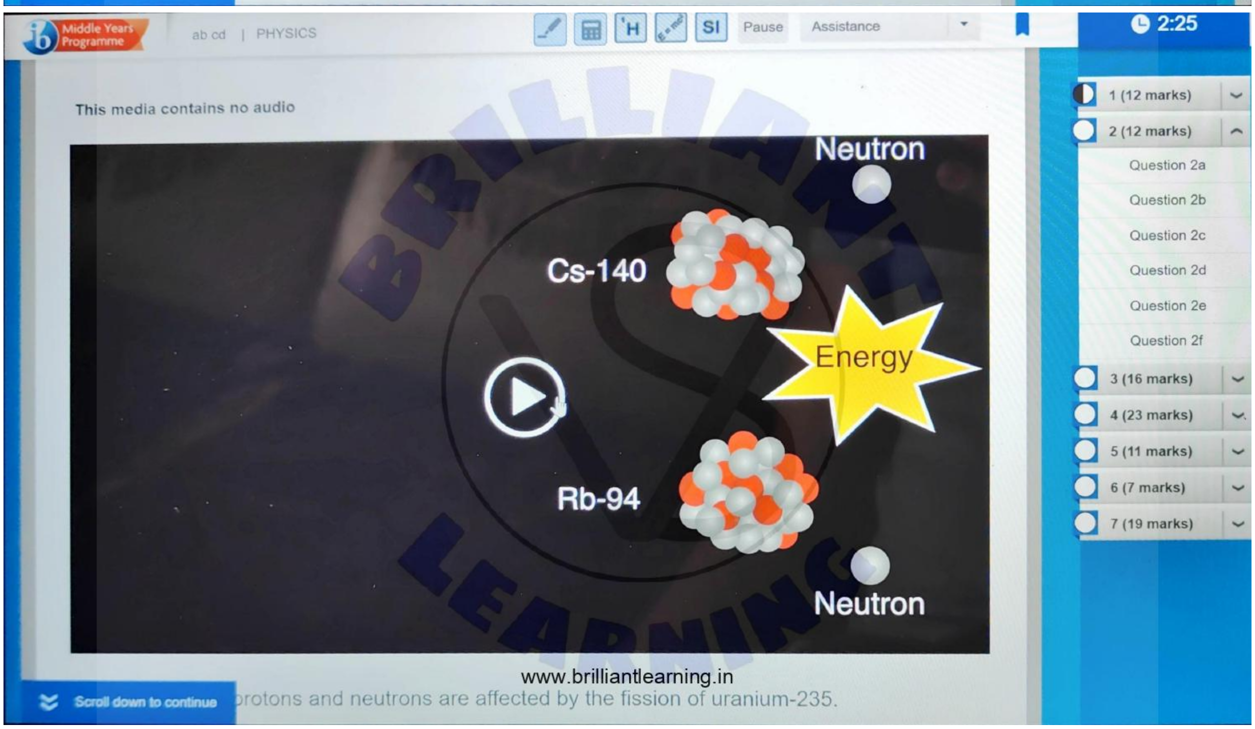
Using the periodic table, **state** the number of protons and the number of neutrons present in the nucleus of one atom of uranium-235.

Number of protons:

Number of neutrons:

1 (12 marks)
2 (12 marks)
Question 2a
Question 2b
Question 2c
Question 2d
Question 2e
Question 2f
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)
Scroll down to continue

Middle Years Programme
ab cd | PHYSICS
Pause
Assistance
2:26
This media contains no audio
Fission
00:03
1 (12 marks)
2 (12 marks)
Question 2a
Question 2b
Question 2c
Question 2d
Question 2e
Question 2f
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)
Scroll down to continue
protons and neutrons are affected by the fission of uranium-235.



Middle Years Programme
ab cd | PHYSICS
Pause
Assistance
2:25
This media contains no audio
Neutron
Cs-140
Energy
Rb-94
Neutron
1 (12 marks)
2 (12 marks)
Question 2a
Question 2b
Question 2c
Question 2d
Question 2e
Question 2f
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)
Scroll down to continue
protons and neutrons are affected by the fission of uranium-235.

ab cd | PHYSICS

Pause Assistance

2:25

Neutron

Outline how the protons and neutrons are affected by the fission of uranium-235.

1 (12 marks)
2 (12 marks)
Question 2a
Question 2b
Question 2c
Question 2d
Question 2e
Question 2f
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

Question 2c (2 marks)

A neutron is needed to start this fission reaction. Neutrons are also produced during the reaction. This means that a chain reaction can occur with the fission of uranium-235.
Suggest the meaning of the term *chain reaction*.

Scroll down to continue

ab cd | PHYSICS

Pause Assistance

2:25

1 (12 marks)
2 (12 marks)
Question 2a
Question 2b
Question 2c
Question 2d
Question 2e
Question 2f
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

Question 2c (2 marks)

A neutron is needed to start this fission reaction. Neutrons are also produced during the reaction. This means that a chain reaction can occur with the fission of uranium-235.
Suggest the meaning of the term *chain reaction*.

Question 2d (3 marks)

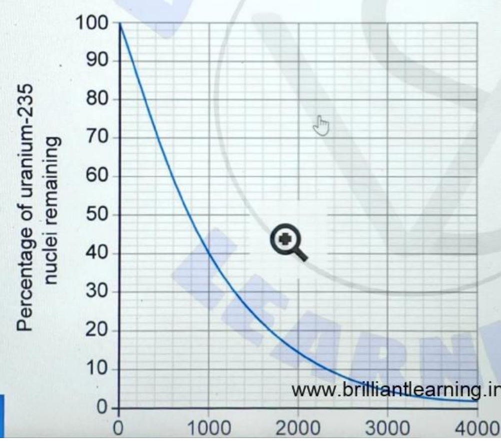
Scroll down to continue

Question 2d (3 marks)

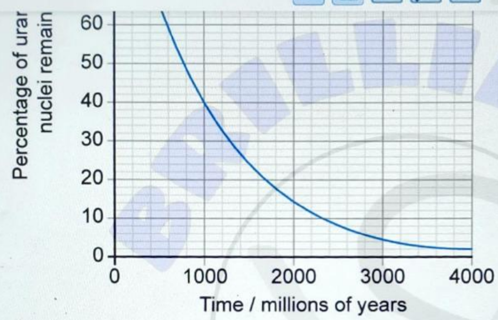
In nuclear power plants, fission reactions are used to supply energy but these chain reactions have to be carefully controlled. **Describe** a possible danger of an uncontrolled chain reaction in a nuclear power plant.

Question 2e (1 mark)

Nuclear power plants use uranium in the form of fuel rods. These rods are no longer useable when the level of uranium-235 remaining is low. However, used fuel rods still contain a small amount of remaining uranium-235 which decays over time, emitting radiation as shown in the graph below.



ab cd | PHYSICS



Use the graph to **predict** how many years it would take for 75% of the remaining uranium to decay.

ab cd | PHYSICS

Question 2f (2 marks)

Suggest why the long decay time of uranium-235 poses a significant challenge for the safe disposal of fuel rods.

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:22

Question 3a (1 mark)

State a research question that would be tested in this investigation.

Question 3b (3 marks)

Formulate a hypothesis for this investigation using scientific reasoning.

Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:22

1 (12 marks)
2 (12 marks)
3 (16 marks)
Question 3a
Question 3b
Question 3c
Question 3d
Question 3e
Question 3f
Question 3g
Question 3h
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

Question 3b (3 marks)

Formulate a hypothesis for this investigation using scientific reasoning.

If:

Then:

Scroll down to continue

ab cd | PHYSICS

Pause Assistance

2:22

Then:

Because:

Scroll down to continue

1 (12 marks)
2 (12 marks)
3 (16 marks)
Question 3a
Question 3b
Question 3c
Question 3d
Question 3e
Question 3f
Question 3g
Question 3h
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

ab cd | PHYSICS

Pause Assistance

2:22

Question 3c (3 marks)

Select the wires the student should use to collect sufficient data to determine the relationship between the resistance and the length of the wire.

	Length / cm	Material	Cross-sectional area / mm^2
☐	40	Silver	2.5
☐	60	Silver	2.5
☐	80	Silver	2.5
☐	100	Copper	1.0
☐	100	Silver	1.5
☐	100	Copper	2.0
☐	100	Aluminium	2.5
☐	100	Copper	2.5
☐	100	Gold	2.5
☐	100	Nichrome	2.5
☐	100	Silver	2.5
☐	100	Copper	3.0
☐	120	Silver	2.5

Question 3d (2 marks)

Justify the selection you made in part (c).

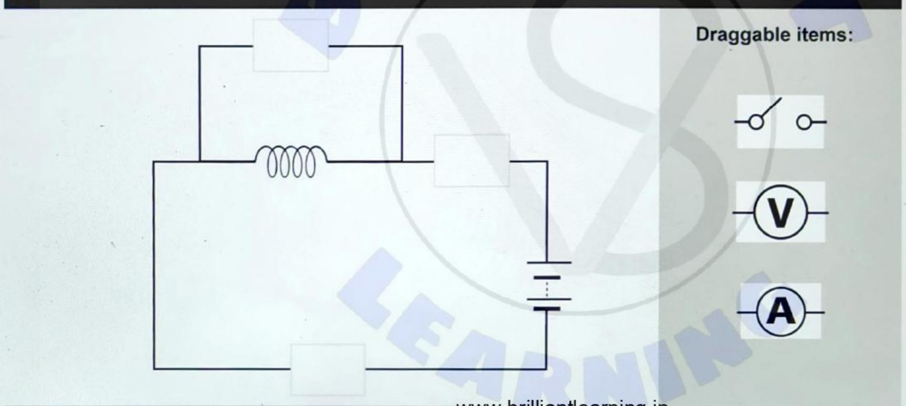
1 (12 marks)
2 (12 marks)
3 (16 marks)
Question 3a
Question 3b
Question 3c
Question 3d
Question 3e
Question 3f
Question 3g
Question 3h
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:21

Question 3e (1 mark)

Select the location in the circuit below for each piece of equipment required to take measurements to calculate the resistance of a wire.



Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:21

Question 3f (2 marks)

For one of the trials when the wire was 100 cm long, the voltage across the wire was 1.5 V and the current through the wire was measured as 0.24 A. **Determine** the resistance of the wire.

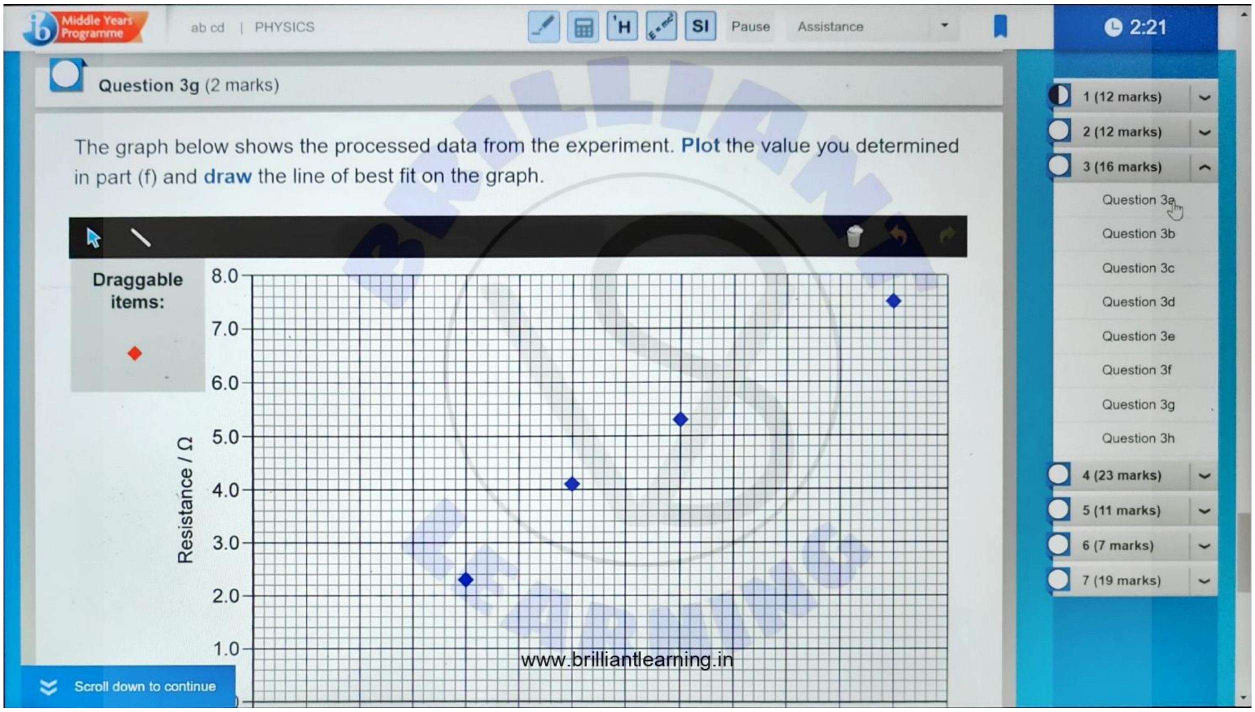
B I U x_2 x^2 Ω Σ Styles

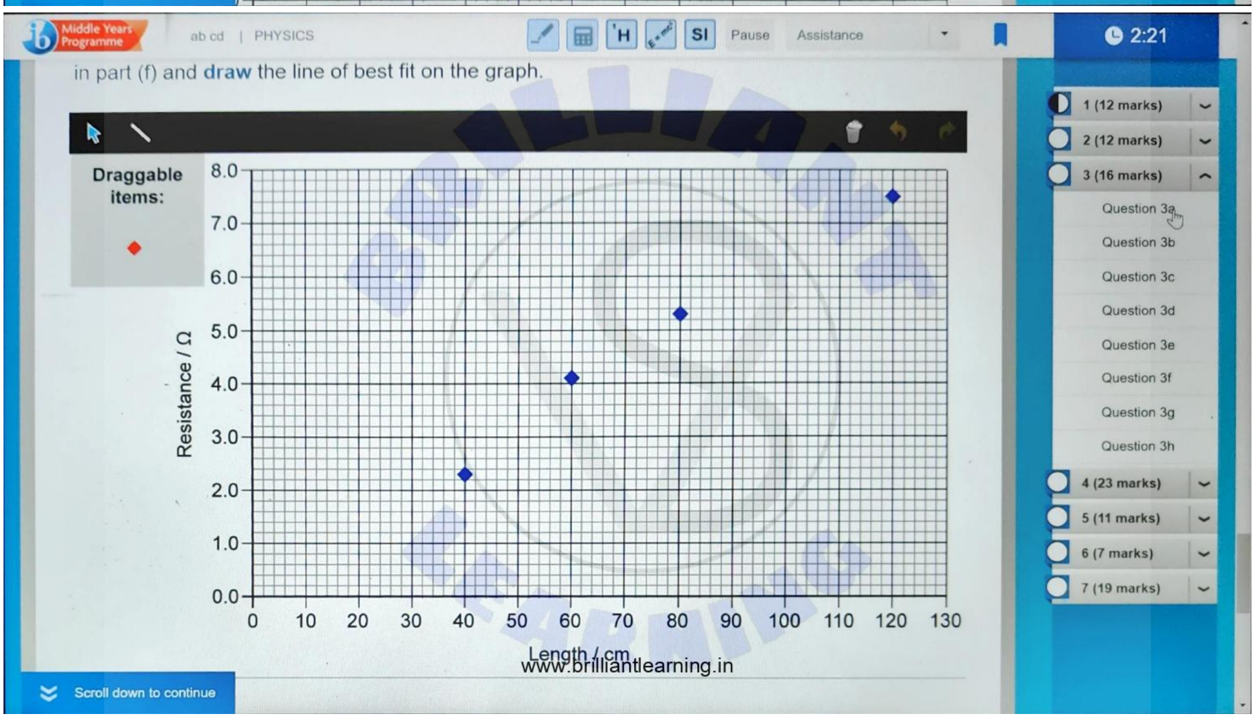
Question 3g (2 marks)

Scroll down to continue

shows the processed data from the experiment. **Plot** the value you determined

1 (12 marks)
2 (12 marks)
3 (16 marks)
Question 3a
Question 3b
Question 3c
Question 3d
Question 3e
Question 3f
Question 3g
Question 3h
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)


Middle Years Programme
ab cd | PHYSICS
Pause
Assistance
2:21
Question 3g (2 marks)
The graph below shows the processed data from the experiment. Plot the value you determined in part (f) and draw the line of best fit on the graph.
Draggable items:
Resistance / Ω
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
www.brilliantlearning.in
Scroll down to continue
1 (12 marks)
2 (12 marks)
3 (16 marks)
Question 3a
Question 3b
Question 3c
Question 3d
Question 3e
Question 3f
Question 3g
Question 3h
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)


Middle Years Programme
ab cd | PHYSICS
Pause
Assistance
2:21
in part (f) and draw the line of best fit on the graph.
Draggable items:
Resistance / Ω
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
Length / cm
www.brilliantlearning.in
Scroll down to continue
1 (12 marks)
2 (12 marks)
3 (16 marks)
Question 3a
Question 3b
Question 3c
Question 3d
Question 3e
Question 3f
Question 3g
Question 3h
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

1 (12 marks)
2 (12 marks)
3 (16 marks)
Question 3a
Question 3b
Question 3c
Question 3d
Question 3e
Question 3f
Question 3g
Question 3h
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)

Question 3h (2 marks)

According to theory, the relationship between resistance and length should be proportional, however, the student's results do not fit perfectly on the line of best fit. **Suggest** one source of error in this investigation and how this would affect the calculated value of resistance.

Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:21

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
5 (11 marks)
6 (7 marks)
7 (19 marks)

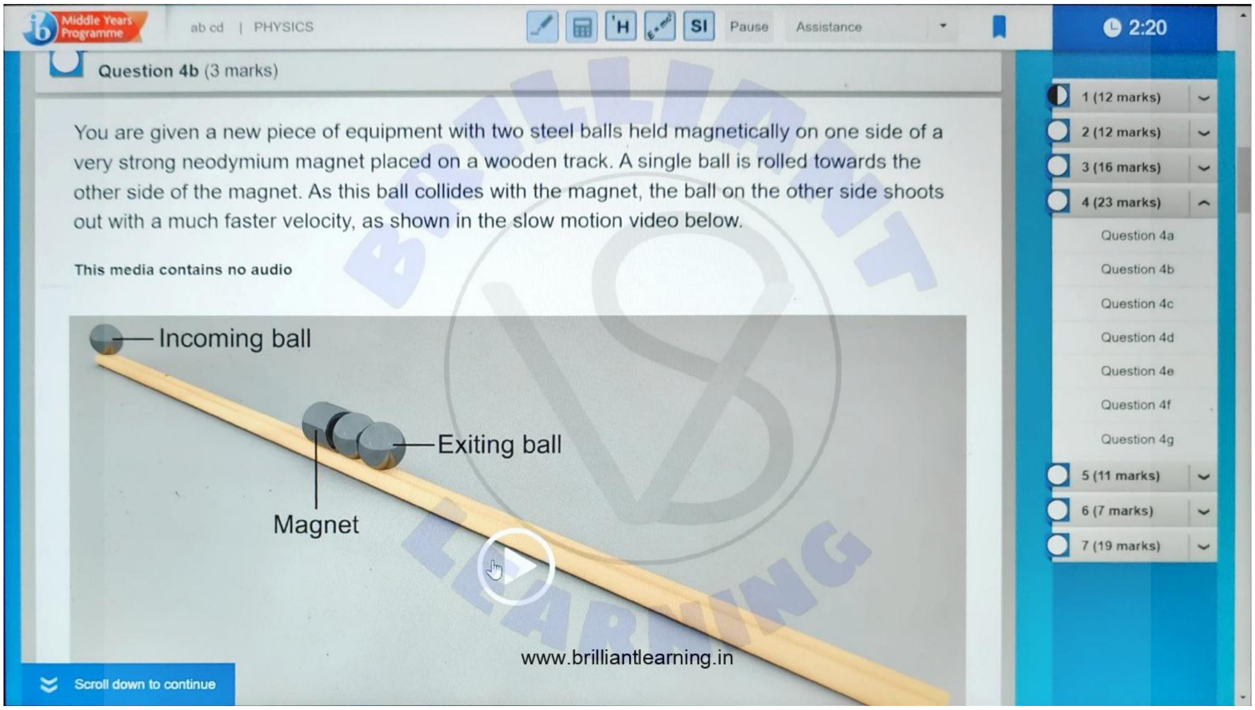
Question 4a (1 mark)

State the conservation law that explains why the ball reaches the same height for both angles.

Question 4b (3 marks)

You are given a new piece of equipment with two steel balls held magnetically on one side of a very strong neodymium magnet placed on a wooden track. A single ball is rolled towards the magnet. As this ball collides with the magnet, the ball on the other side shoots aster velocity as shown in the slow motion video below

Scroll down to continue


Middle Years Programme
ab cd | PHYSICS
H
SI
Pause
Assistance
2:20
Question 4b (3 marks)
You are given a new piece of equipment with two steel balls held magnetically on one side of a very strong neodymium magnet placed on a wooden track. A single ball is rolled towards the other side of the magnet. As this ball collides with the magnet, the ball on the other side shoots out with a much faster velocity, as shown in the slow motion video below.
This media contains no audio
Incoming ball
Exiting ball
Magnet
Scroll down to continue
1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
5 (11 marks)
6 (7 marks)
7 (19 marks)


Middle Years Programme
ab cd | PHYSICS
H
SI
Pause
Assistance
2:20
00:05
The slow-motion video shows the motion of the ball just before it collides with the magnet. Drag and drop to draw and label the forces acting on the ball while it is rolling just before it collides
Scroll down to continue
1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
5 (11 marks)
6 (7 marks)
7 (19 marks)

This media contains no audio

The slow-motion video shows the motion of the ball just before it collides with the magnet. Drag and drop to **draw** and **label** the forces acting on the ball while it is rolling **just before** it collides

Middle Years Programme
ab cd | PHYSICS
Pause
Assistance
2:20
1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
5 (11 marks)
6 (7 marks)
7 (19 marks)

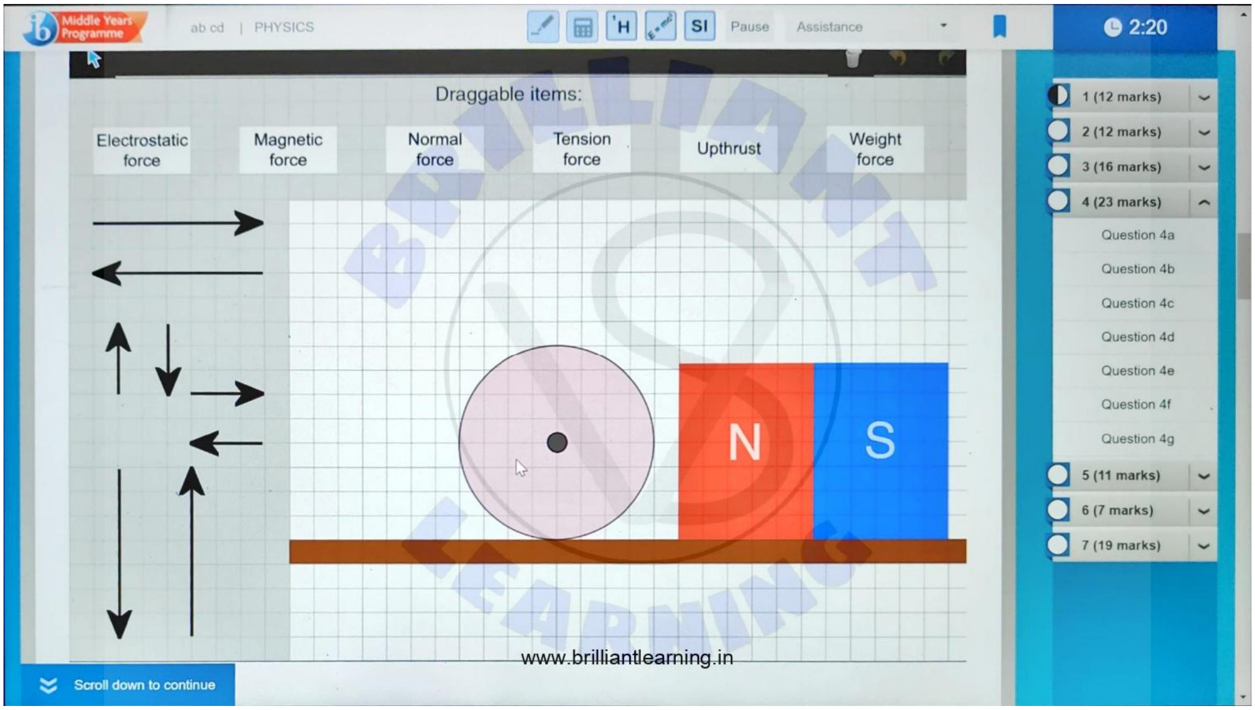
00:00

The slow-motion video shows the motion of the ball just before it collides with the magnet. Drag and drop to **draw** and **label** the forces acting on the ball while it is rolling **just before** it collides with the magnet.

Draggable items:

Electrostatic force	Magnetic force	Normal force	Tension force	Upthrust	Weight force

Scroll down to continue



Question 4c (2 marks)

Suggest why the acceleration of the ball is not constant as it approaches the magnet. **Justify** your answer using scientific reasoning.

Question 4d (1 mark)

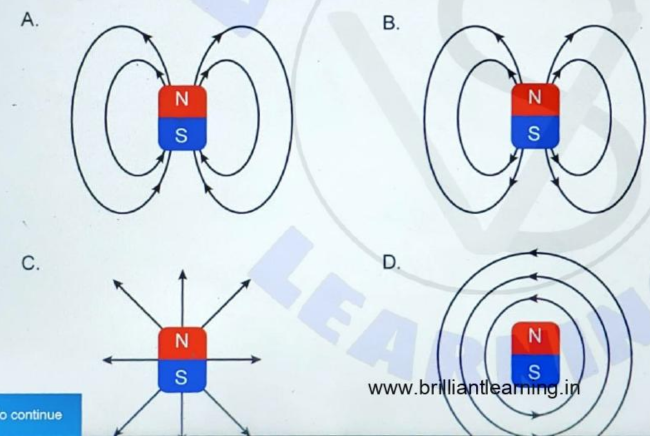
…be assumed to have a magnetic field similar to that of the Earth. **Select** the

Scroll down to continue

Question 4d (1 mark)

The magnet can be assumed to have a magnetic field similar to that of the Earth. **Select** the diagram that best represents the magnetic field lines around the magnet.

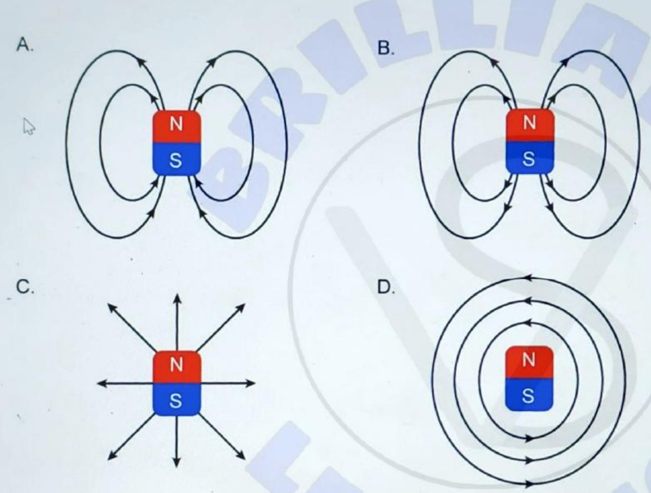
Select



Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:19

Select



1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
5 (11 marks)
6 (7 marks)
7 (19 marks)

www.brilliantlearning.in

Scroll down to continue

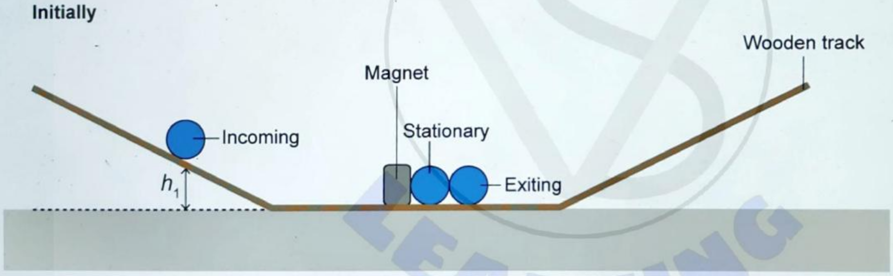
Question 4e (1 mark)

Once the incoming ball collides with the magnet, the exiting ball on the other side has a much greater kinetic energy than the incoming ball before the collision. Use your scientific knowledge to **suggest** a reason for this observation.

Question 4f (11 marks)

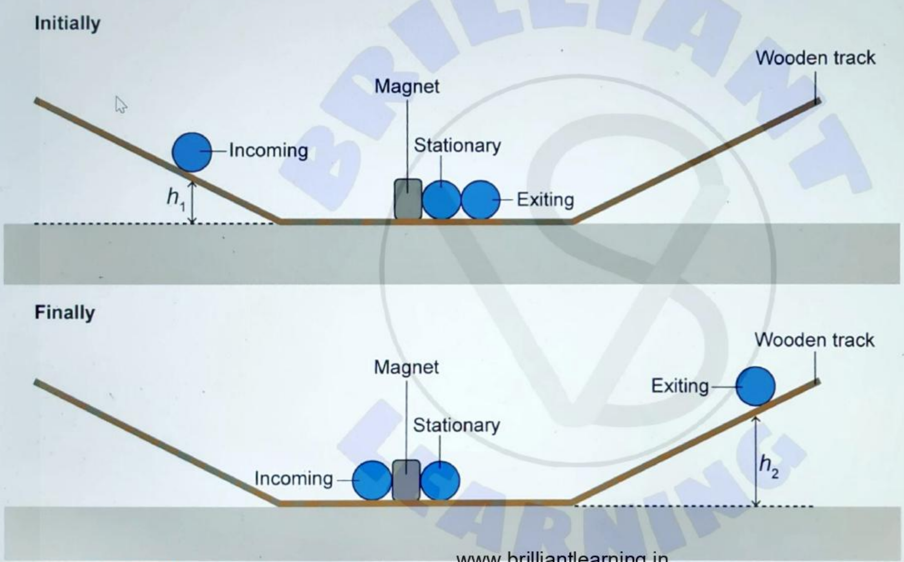
You plan to design an experiment using this equipment with a ball rolling down an inclined plane at a fixed angle and colliding with a magnet on a level surface. The exiting ball on the right moves along an upward inclined plane at the same angle, as shown below.

Initially



Finally

moves along an upward inclined plane at the same angle, as shown below.



Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:19

Design an investigation to find out the relationship between the maximum height (h_2) reached by the exiting ball and the initial height (h_1) of the incoming ball. In your plan, you should include:

- the independent variable, dependent variable and one control variable
- a hypothesis which is explained using scientific reasoning
- a detailed method for how you will collect data, including the equipment you will use
- details of how you will make sure your method is safe.

Scroll down to continue

Middle Years Programme ab cd | PHYSICS

Question 4g (4 marks)

Construct a data table that could be used to record data from the investigation in part (f).

The table must include:

- an appropriate number of rows and columns
- the values of the independent variable that will be used
- a column for processed data with an appropriate title.

Create New Table

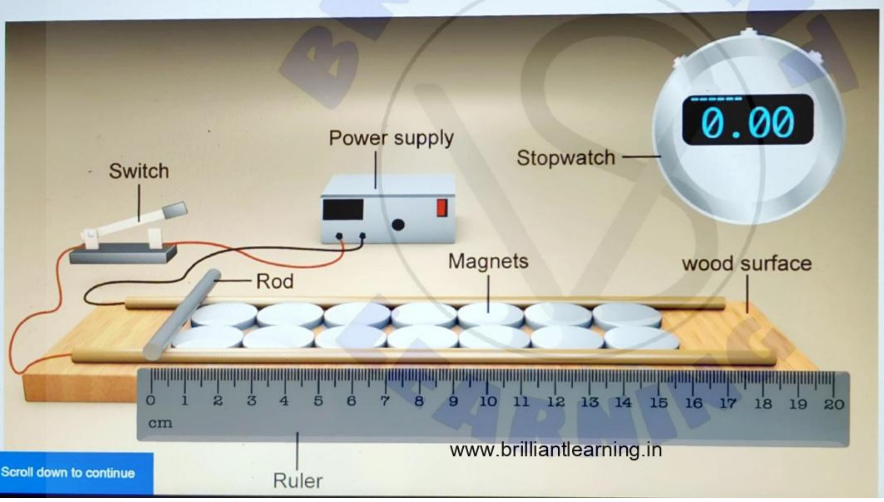
Reset

Scroll down to continue

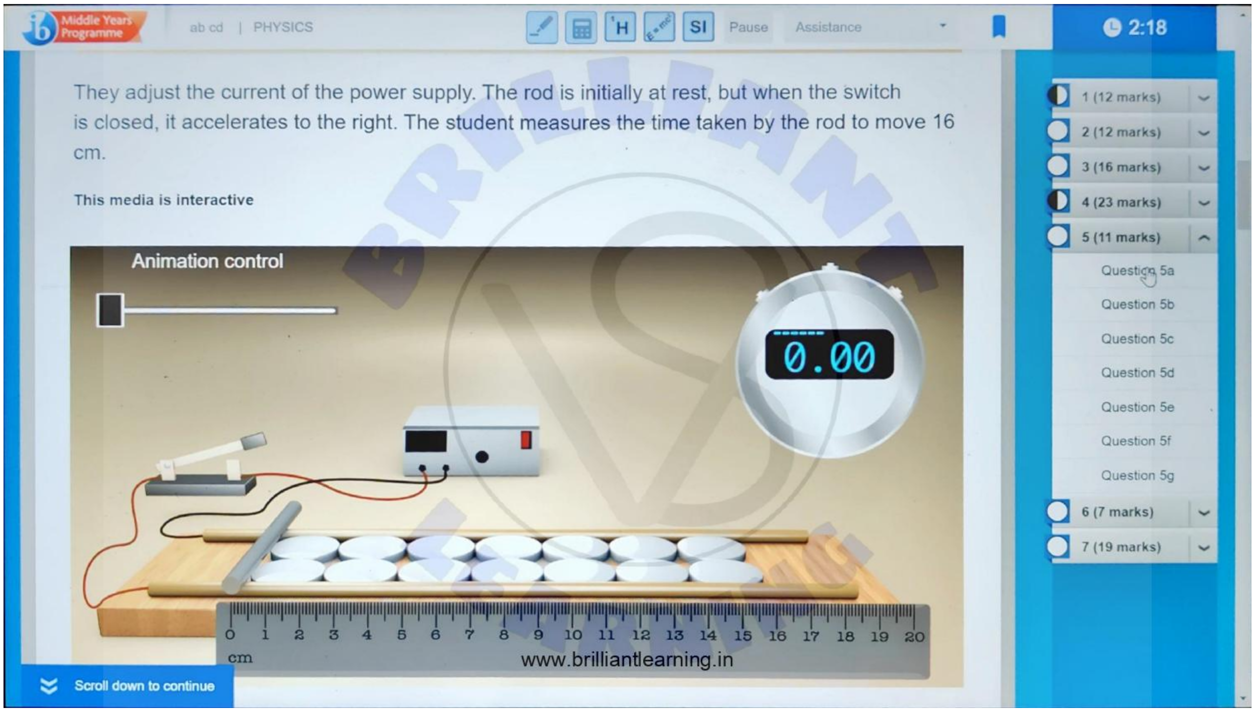
Middle Years Programme ab cd | PHYSICS H SI Pause Assistance

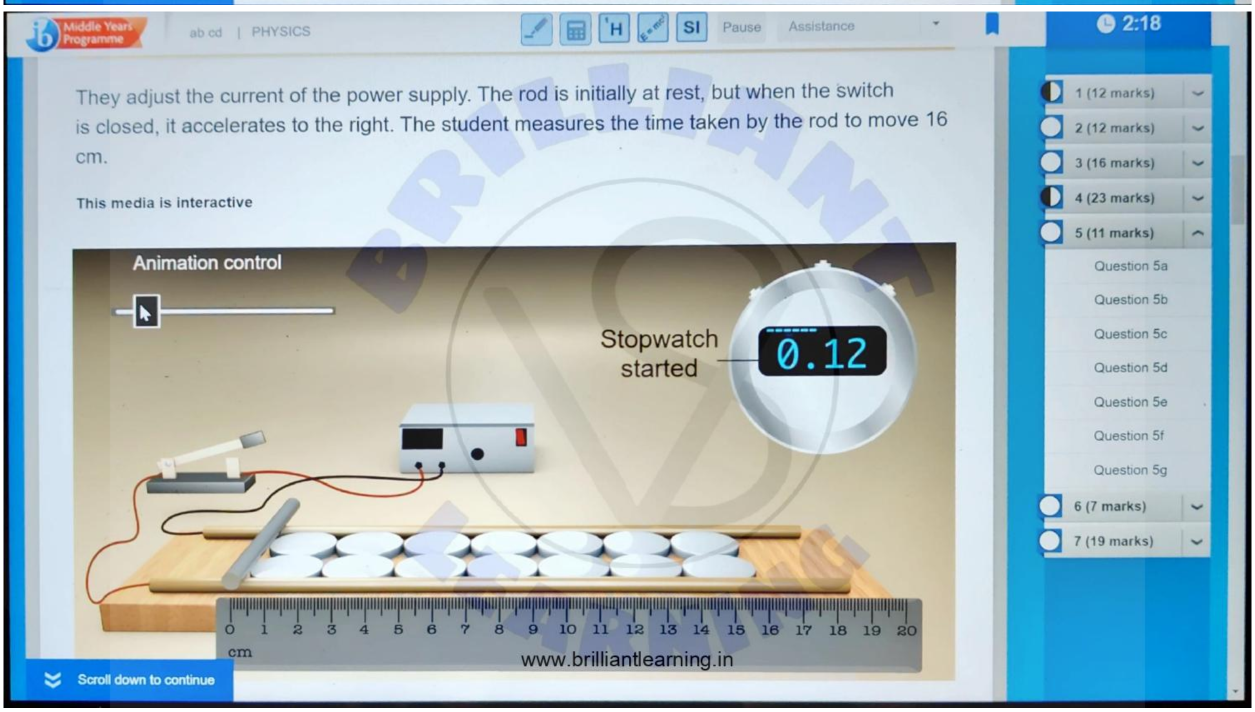
Question 5a (1 mark)

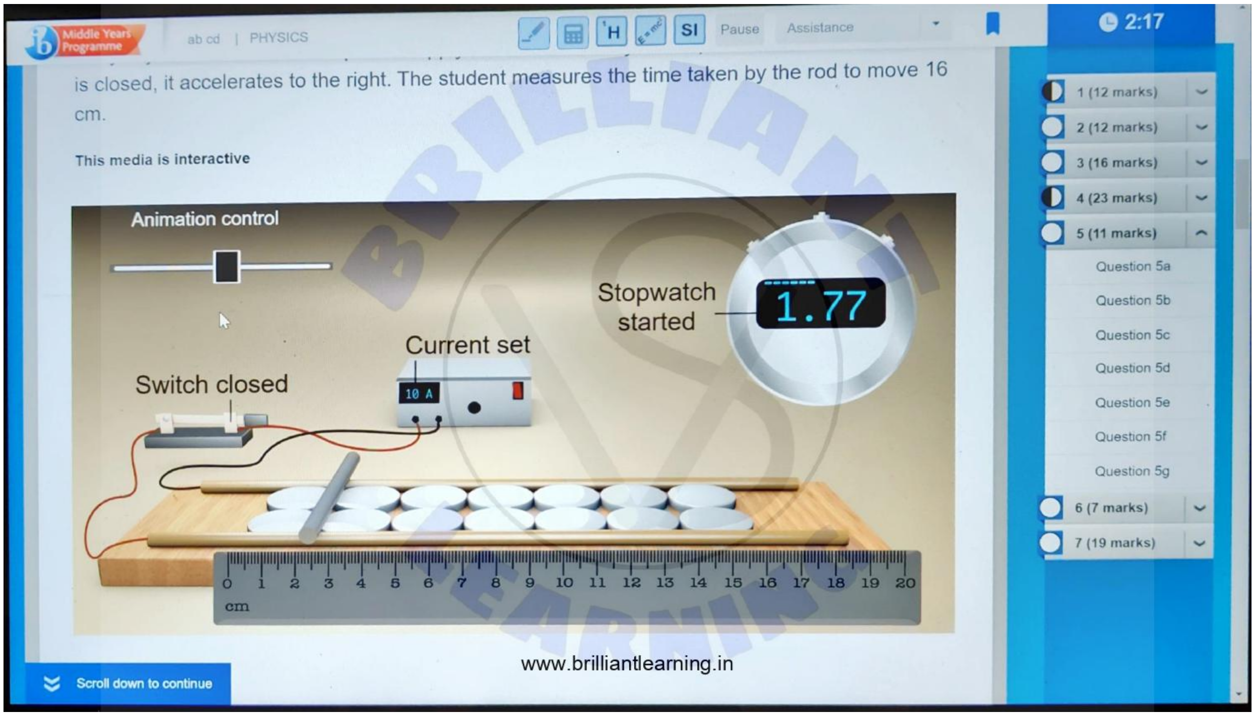
A student carried out an experiment using the equipment below.



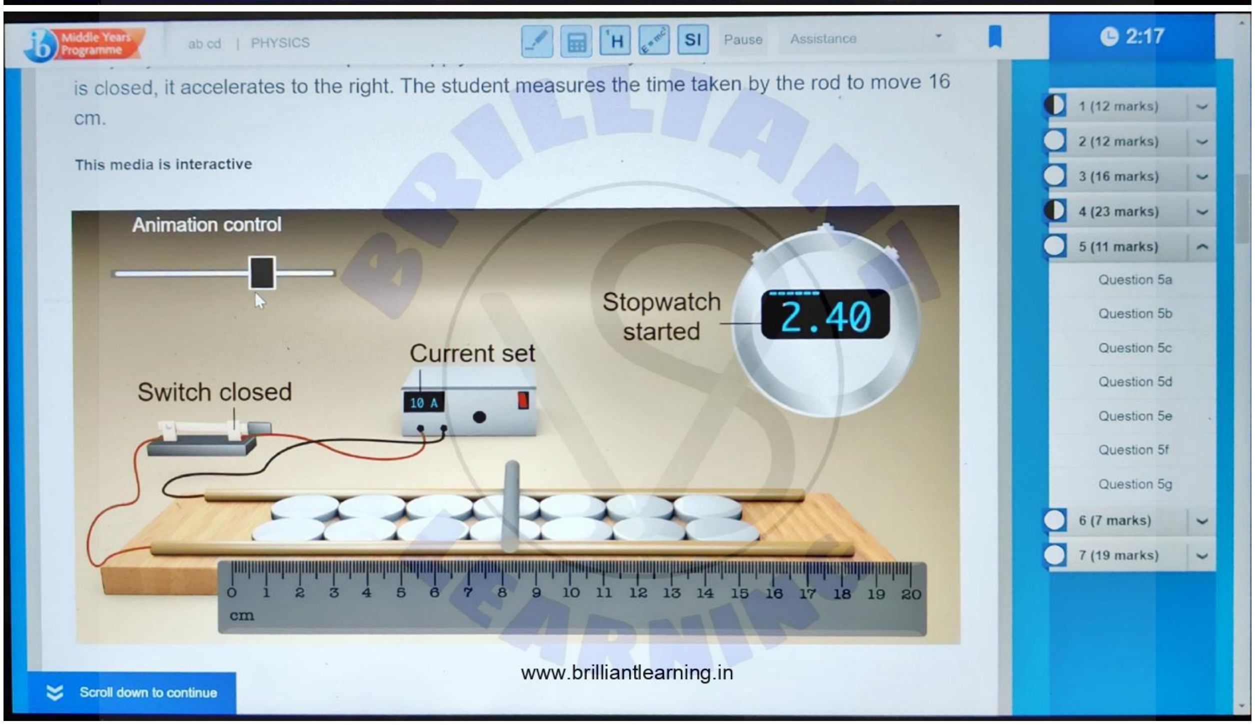
Scroll down to continue


Middle Years Programme
ab cd | PHYSICS
Pause
Assistance
2:18
They adjust the current of the power supply. The rod is initially at rest, but when the switch is closed, it accelerates to the right. The student measures the time taken by the rod to move 16 cm.
This media is interactive
Animation control
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
cm
www.brilliantlearning.in
Scroll down to continue
1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
Question 5f
Question 5g
6 (7 marks)
7 (19 marks)


Middle Years Programme
ab cd | PHYSICS
Pause
Assistance
2:18
They adjust the current of the power supply. The rod is initially at rest, but when the switch is closed, it accelerates to the right. The student measures the time taken by the rod to move 16 cm.
This media is interactive
Animation control
Stopwatch started
0.12
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
cm
www.brilliantlearning.in
Scroll down to continue
1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
Question 5f
Question 5g
6 (7 marks)
7 (19 marks)



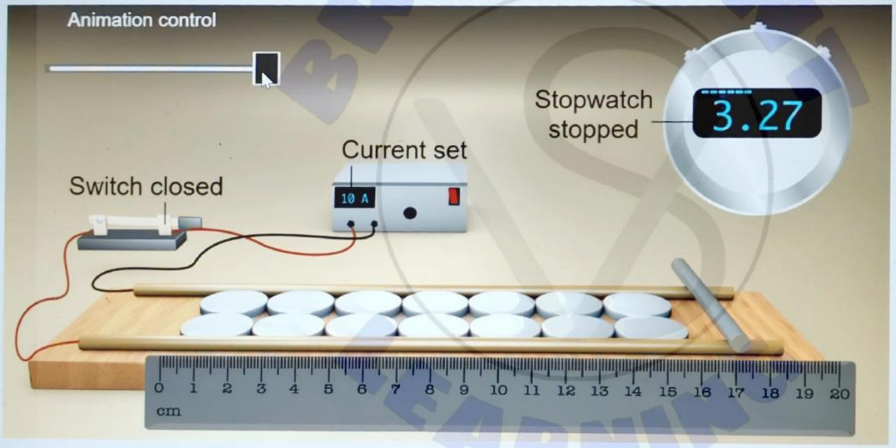
ab cd | PHYSICS
Pause
Assistance
2:17
is closed, it accelerates to the right. The student measures the time taken by the rod to move 16 cm.
This media is interactive
Animation control
Stopwatch started
1.77
Current set
10 A
Switch closed
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
cm
1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
Question 5f
Question 5g
6 (7 marks)
7 (19 marks)
Scroll down to continue
www.brilliantlearning.in



ab cd | PHYSICS
Pause
Assistance
2:17
is closed, it accelerates to the right. The student measures the time taken by the rod to move 16 cm.
This media is interactive
Animation control
Stopwatch started
2.40
Current set
10 A
Switch closed
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
cm
1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
Question 5f
Question 5g
6 (7 marks)
7 (19 marks)
Scroll down to continue
www.brilliantlearning.in

is closed, it accelerates to the right. The student measures the time taken by the rod to move 16 cm.

This media is interactive



Scroll down to continue

The time for a current of 10 A was not recorded by the student. Using the animation, **measure** the time it takes the rod to travel 16 cm from rest.

Current / A	Time / s
7	2.73
8	2.40
9	2.10
10	
11	1.83
12	1.70

Reset

B I U Styles

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
Question 5f
Question 5g
6 (7 marks)
7 (19 marks)

Scroll down to continue

BRILLIANT LEARNING
www.brilliantlearning.in

Question 5b (3 marks)

The student assumes that the rod accelerates uniformly. For the last trial, at a current of 12 A, the student records a time of 1.70 s. Using the formula sheet, **calculate** the acceleration of the rod.

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
Question 5f
Question 5g
6 (7 marks)
7 (19 marks)

Question 5c (1 mark)

Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:17

Question 5c (1 mark)

After calculating its acceleration, the student wanted to calculate the net force acting on the rod. **State** what additional quantity would be needed for this calculation.

Insert/Remove Bulleted List

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
Question 5f
Question 5g
6 (7 marks)
7 (19 marks)

Question 5d (1 mark)

Before starting the experiment, the student makes the following prediction:

Scroll down to continue

If the electric current passing through the rod doubles,

Question 5d (1 mark)

Before starting the experiment, the student makes the following prediction:

> If the electric current passing through the rod doubles,
> the force on the rod will double. The relationship will be proportional.

If the results of the experiment support this hypothesis, **select** the graph that would represent the data.

Select
Select
A
B
C
D

A.

B.

C.

D.

Scroll down to continue

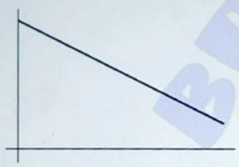
Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:17

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
Question 5f
Question 5g
6 (7 marks)
7 (19 marks)

the data.

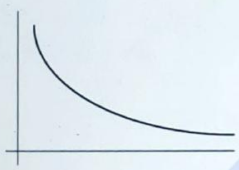
Select

A.



B.

C.



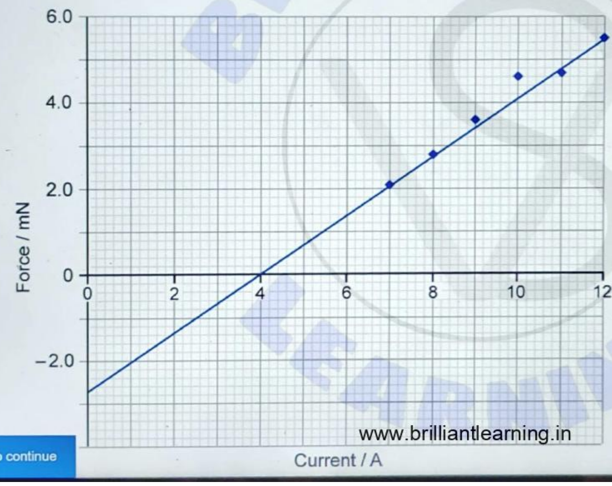
D.

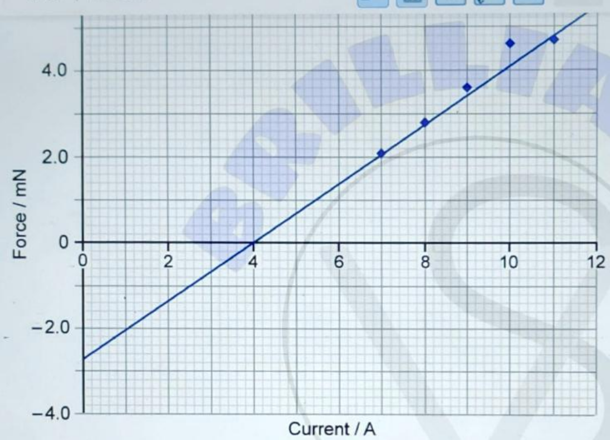
Question 5e (2 marks)

Scroll down to continue

Question 5e (2 marks)

Another student processed the data and calculated the force on the rod for each current. The student plotted their data on the graph below.





Referring to the graph, **outline** why the student's hypothesis in part (d) is not supported by the data.

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:16

Question 5f (2 marks)

The student adjusts the current to 4 A. Use the graph in part (e) to **suggest** what you think would happen to the rod. **Justify** your answer.

Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:16

Question 5g (1 mark)

For the rod to move, it needs to overcome frictional forces. Use the graph to **suggest** the size of the frictional forces.

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
Question 5f
Question 5g
6 (7 marks)
7 (19 marks)

Scroll down to continue

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
Question 6a
Question 6b
Question 6c
Question 6d
Question 6e
7 (19 marks)

Question 6a (2 marks)

Outline why a refracting telescope causes the different colours of light to separate.

Question 6b (1 mark)

Clearer images can be obtained by using mirrors to create a reflecting telescope. The first reflecting telescope was made by Isaac Newton in 1668. Parallel rays from a distant object are ...ved primary mirror onto a plane secondary mirror. The rays are reflected again ... mirror and come into focus at the eyepiece.

Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:16

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
Question 6a
Question 6b
Question 6c
Question 6d
Question 6e
7 (19 marks)

Question 6b (1 mark)

Clearer images can be obtained by using mirrors to create a reflecting telescope. The first reflecting telescope was made by Isaac Newton in 1668. Parallel rays from a distant object are reflected by a curved primary mirror onto a plane secondary mirror. The rays are reflected again by the secondary mirror and come into focus at the eyepiece.

Label the primary mirror, secondary mirror and the position of the eyepiece in the diagram shown.

Draggable items:

- Primary mirror
- Secondary mirror

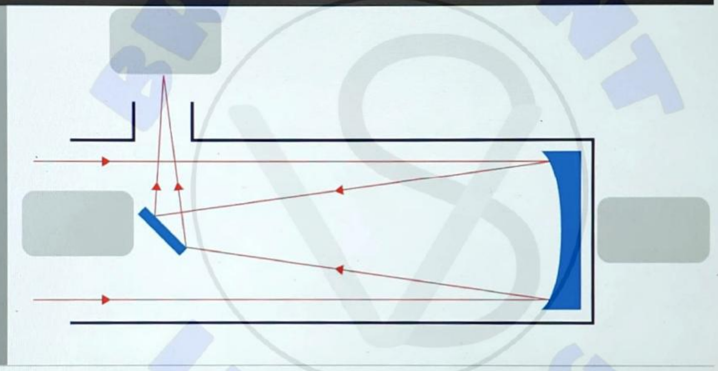
Scroll down to continue

PHYSICS

Label the primary mirror, secondary mirror and the position of the eyepiece in the diagram shown.

Draggable items:

- Primary mirror
- Secondary mirror
- Eyepiece

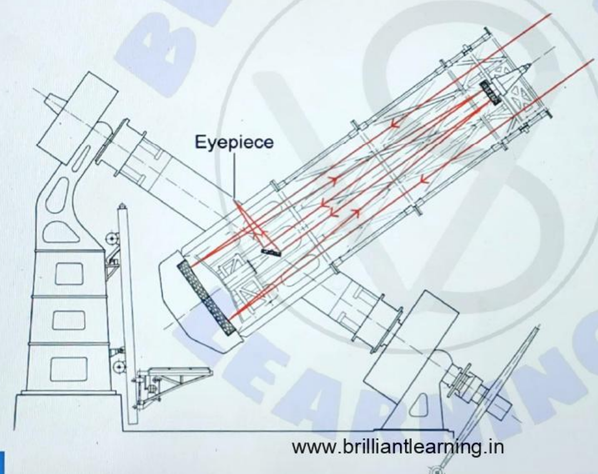


Scroll down to continue

PHYSICS

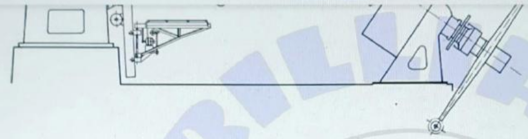
Question 6c (1 mark)

One of the most famous telescopes of the 20th century was called the Hooker telescope. It was the world's largest telescope from 1917 to 1949 and included a 2.5 m reflecting mirror.



Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:15



State the number of times a single ray of light is reflected after it enters the Hooker telescope.

B I U x_2 x^2 Ω Σ Styles

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
Question 6a
Question 6b
Question 6c
Question 6d
Question 6e
7 (19 marks)

Question 6d (1 mark)

The Hooker telescope was used by Edwin Hubble to make observations that would

Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:15

Question 6d (1 mark)

The Hooker telescope was used by Edwin Hubble to make observations that would change our view of the universe forever. He was able to prove that the universe extends far beyond the edge of the Milky Way galaxy. Hubble also proposed that the universe is expanding.

Suggest what phenomenon Hubble observed to show him that the universe is expanding.

B I U x_2 x^2 Ω Σ Styles

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
Question 6a
Question 6b
Question 6c
Question 6d
Question 6e
7 (19 marks)

Scroll down to continue

ab cd | PHYSICS

Pause Assistance

2:15

Question 6e (2 marks)

The idea of having a telescope in space, instead of on the surface of the Earth, was proposed early in the 20th century. This was an idea to improve the quality of the observations that could be made.

Suggest why a telescope in space can make clearer observations than a telescope on the Earth's surface.

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
Question 6a
Question 6b
Question 6c
Question 6d
Question 6e
7 (19 marks)

Scroll down to continue

ab cd | PHYSICS

Pause Assistance

2:15

Question 7 (19 marks)

Video Script

The Hubble Space Telescope, named after Edwin Hubble, was built in the 1970s, but wasn't launched until 1990 due to technical delays and budget problems.

Soon after the telescope had been successfully launched into space, a problem with the main mirror of the telescope was discovered.

A mission in 1993 corrected the problem with the mirror and brought instrument upgrades to the telescope. The mission to correct the telescope took almost 11 days and the crew members made five spacewalks during the mission.

The Hubble Space Telescope changed our understanding of the universe forever. A famous image was taken in 1995 of the Eagle Nebula at a distance of around 7000 light years from Earth. The image showed dust and gas in the process of creating new stars.

This image has been replicated on everything from T-shirts to coffee mugs.

Plans for a new space telescope started in 1996. The new telescope would include a larger mirror and would have to travel further from Earth so that it could see deeper into space than ever before. This telescope, named the James Webb Space Telescope, was designed to look for waves in the infrared region of the electromagnetic spectrum.

would be sent to a location that was so far from Earth that it couldn't be repaired

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)
Question 7a
Question 7b

Scroll down to continue

www.brilliantlearning.in

the telescope. The mission to correct the telescope took almost 11 days and the crew members made five spacewalks during the mission.

The Hubble Space Telescope changed our understanding of the universe forever. A famous image was taken in 1995 of the Eagle Nebula at a distance of around 7000 light years from Earth. The image showed dust and gas in the process of creating new stars.

This image has been replicated on everything from T-shirts to coffee mugs.

Plans for a new space telescope started in 1996. The new telescope would include a larger mirror and would have to travel further from Earth so that it could see deeper into space than ever before. This telescope, named the James Webb Space Telescope, was designed to look for waves in the infrared region of the electromagnetic spectrum.

The telescope would be sent to a location that was so far from Earth that it couldn't be repaired if there were problems.

The telescope is the most expensive piece of scientific equipment ever made. However, the 10-billion-dollar cost is much less than the over 750 billion dollars that the US has as its annual military budget.

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)
Question 7a
Question 7b

Scroll down to continue

ab cd | PHYSICS
Pause Assistance
2:15

Question 7a (13 marks)

Using the information in the video and your wider MYP studies, **discuss** and **evaluate** the development of the JWST and its role in extending our knowledge and understanding of the universe. In your answer, you should include:

- the scientific challenges of launching a telescope into space
- the social or cultural implications of the observations made with telescopes
- the economic implications of spending government funds on a space telescope
- a concluding appraisal giving your opinion on the impact of the JWST.

Styles

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)
Question 7a
Question 7b

www.brilliantlearning.in

Scroll down to continue

Question 7b (6 marks)

The JWST carries a mid-infrared instrument that some people believe could provide evidence of life on other planets.

Some facts about the JWST are given below.

- The instrument can detect substances such as water, oxygen, ozone, methane and carbon dioxide on planets outside our solar system. These planets are known as exoplanets.
- The exoplanet has to be orbiting a specific kind of star, known as a white dwarf, for the substances to be detected by the instrument.
- The nearest white dwarf star to Earth is over eight light-years away and there are only about 34 known white dwarf stars within 40 light-years of Earth.

Scroll down to continue

Middle Years Programme | ab cd | PHYSICS | Pause | Assistance | 2:14

34 known white dwarf stars within 40 light-years of Earth.

Use the information above to **evaluate** the benefits and limitations of using the mid-infrared instrument on the JWST to search for evidence of life on other planets.

1 (12 marks)
2 (12 marks)
3 (16 marks)
4 (23 marks)
5 (11 marks)
6 (7 marks)
7 (19 marks)
Question 7a
Question 7b

Scroll down to continue

NOVEMBER SESSIONS

November 2016

November 2017

November 2018

November 2019

November 2020

November 2021

November 2022

November 2023

Question 1 (10 marks)

This question is about astronomy, astrophysics and units.

Question 1a (2 marks)

Drag and drop to **select** the correct location for the planet names on the diagram.

Diagram not to scale

Scroll down to continue

Middle Years Programme abc abc | PHYSICS Assistance 1:59

Drag and drop to **select** the correct location for the planet names on the diagram.

Diagram not to scale

Scroll down to continue

1 (10 marks)
Question 1a
Question 1b
Question 1c
Question 1d
Question 1e
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Question 1b (1 mark)

In addition to the Sun and planets, **state** one type of object **not** made by humans that forms part of the solar system.

Question 1c (2 marks)

The Sun is a star. **Outline** two differences between a star and a planet.

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:59

Question 1d (3 marks)

Stars and planets are found in huge collections called galaxies. Observations of distant galaxies show that they are moving away from our galaxy. The more distant the galaxy, the greater its speed. From these observations, scientists developed the Big Bang theory. **Describe** the Big Bang theory and how it is supported by these observations.

Question 1e (2 marks)

Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:59

Question 1e (2 marks)

The closest star to the Earth is *Proxima Centauri* which is 4×10^{16} m away. Astronomers may state this distance as 1.3 parsecs. The parsec is a unit of distance which is not an SI unit.

Suggest an advantage and a disadvantage of using non-SI units in astrophysics.

Advantage:

Disadvantage:

1 (10 marks)
Question 1a
Question 1b
Question 1c
Question 1d
Question 1e
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:59

Question 2 (8 marks)

This question is about using carbon dating to identify the age of organic matter.

An atom of carbon-14 is represented as:

$$^{14}_{6}C$$

Question 2a (2 marks)

Determine the number of protons and the number of neutrons in a nucleus of carbon-14.

Number of protons:

1 (10 marks)
2 (8 marks)
Question 2a
Question 2b
Question 2c
Question 2d
Question 2e
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Scroll down to continue

An atom of carbon-14 is represented as:

$$^{14}_{6}C$$

Question 2a (2 marks)

Determine the number of protons and the number of neutrons in a nucleus of carbon-14.

Number of protons:

Number of neutrons:

An atom of carbon-14 is represented as:

$$^{14}_{6}C$$

Number of neutrons:

Question 2b (2 marks)

Carbon-14 is an unstable isotope.
It decays to nitrogen-14. **Select** the type of decay process and **state** one product of this decay, apart from the nitrogen-14 nucleus that is formed.

An atom of carbon-14 is represented as:

$$^{14}_{6}C$$

Question 2b (2 marks)

Carbon-14 is an unstable isotope.
It decays to nitrogen-14. **Select** the type of decay process and **state** one product of this decay, apart from the nitrogen-14 nucleus that is formed.

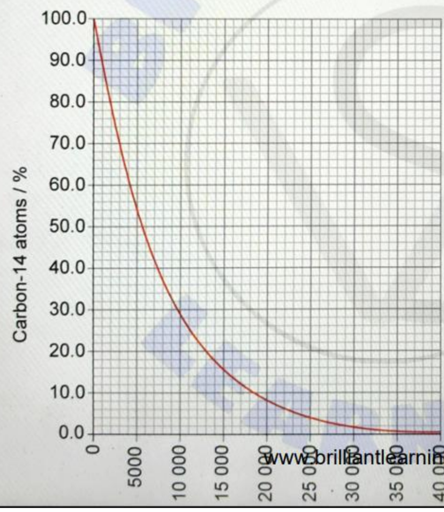
Select

Scroll down to continue

Middle Years Programme abc abc | PHYSICS Assistance 1:58

Question 2c (1 mark)

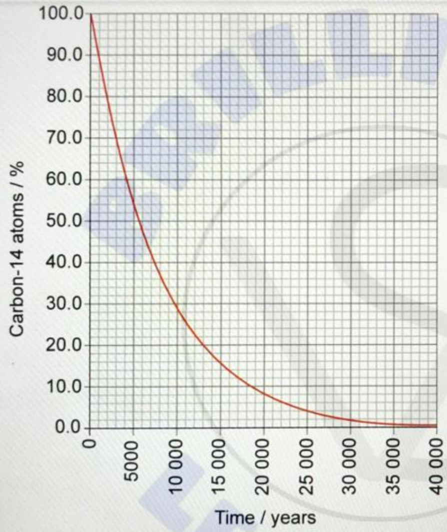
The graph below shows the percentage of carbon-14 atoms remaining as a sample decays over time.



1 (10 marks)
2 (8 marks)
Question 2a
Question 2b
Question 2c
Question 2d
Question 2e
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:58



Using the graph, **determine** the half-life of carbon-14.

Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:58

1 (10 marks)
2 (8 marks)
Question 2a
Question 2b
Question 2c
Question 2d
Question 2e
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Question 2d (1 mark)

Living things contain a large number of carbon atoms. The proportion of carbon-14 atoms compared to the total number of carbon atoms stays constant until they die. If an ancient sample of wood contains 20% of the carbon-14 possessed by living things, use the graph to **determine** the approximate age of the sample.

Scroll down to continue

Question 2e (2 marks)

A student makes the following claim:

Carbon-14 dating has shown that dinosaur bones are over 65 million years old.

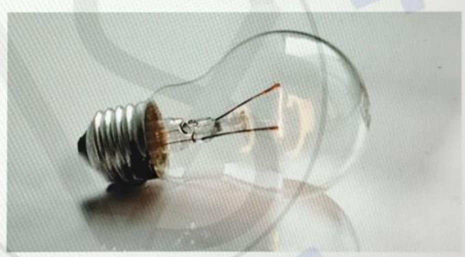
Use the graph in part (c) to **evaluate** this statement.

Question 3 (9 marks)

A student decides to compare the efficiency of modern lightbulbs using Light Emitting Diodes (LEDs) to older filament lightbulbs.

LED bulb

Filament bulb

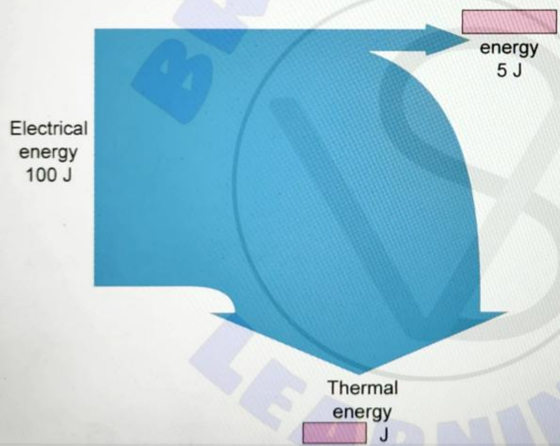


Question 3a (2 marks)

… diagram for a filament light bulb by writing in the text boxes.

Question 3a (2 marks)

Label the Sankey diagram for a filament light bulb by writing in the text boxes.



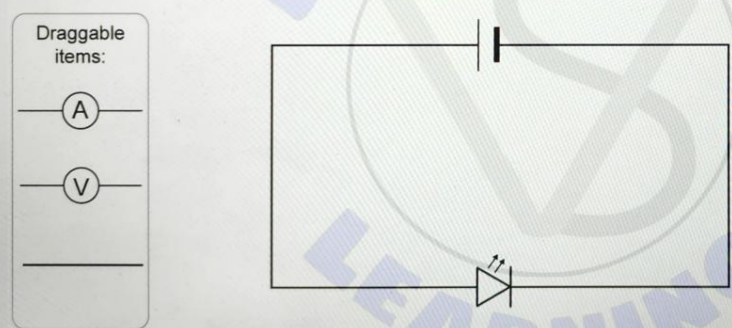
Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:58

Question 3b (2 marks)

The student uses the circuit below to investigate an LED.

Design a circuit to measure current through the LED and the voltage across the LED.



Scroll down to continue

1 (10 marks)
2 (8 marks)
3 (9 marks)
Question 3a
Question 3b
Question 3c
Question 3d
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Question 3c (2 marks)

The student takes measurements using her circuit and finds that the current through the LED is 0.05 A when the voltage is 1 V. Use information on the formula sheet to **calculate** the power of the LED.

Question 3d (3 marks)

Scroll down to continue

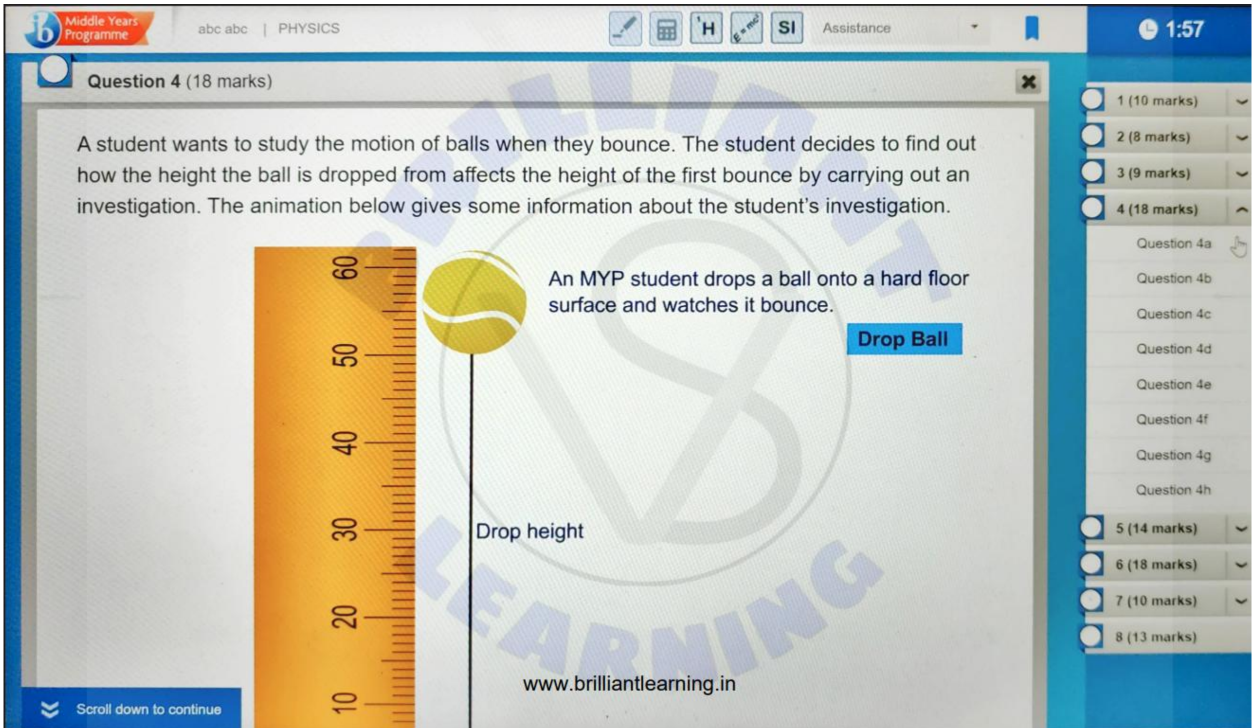
Middle Years Programme | abc abc | PHYSICS | Assistance | 1:58

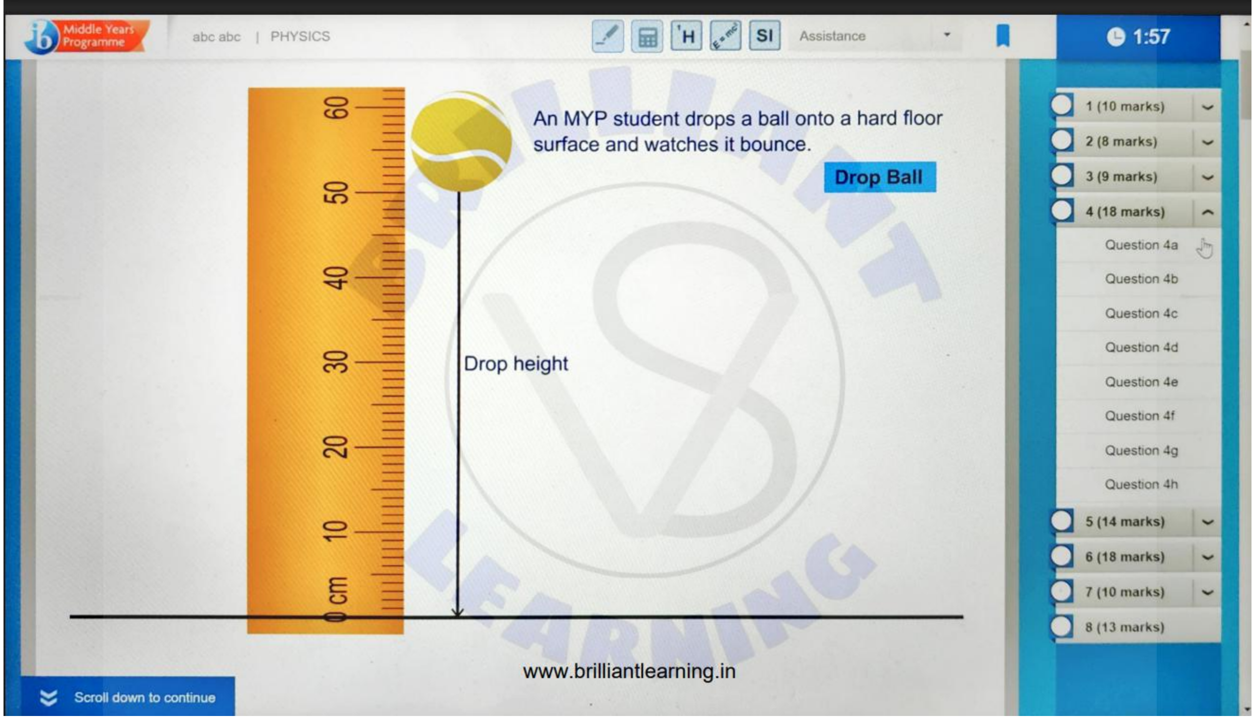
Question 3d (3 marks)

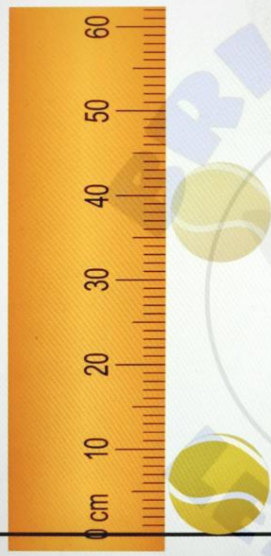
The LED emits 0.02 W of light. Using information from part (a) and your answer to part (c), **compare** the efficiency of an LED with that of a filament bulb.

www.brilliantlearning.in

Scroll down to continue


Middle Years Programme
abc abc | PHYSICS
SI
Assistance
1:57
Question 4 (18 marks)
A student wants to study the motion of balls when they bounce. The student decides to find out how the height the ball is dropped from affects the height of the first bounce by carrying out an investigation. The animation below gives some information about the student's investigation.
An MYP student drops a ball onto a hard floor surface and watches it bounce.
Drop Ball
Drop height
60
50
40
30
20
10
1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)
Scroll down to continue
www.brilliantlearning.in


Middle Years Programme
abc abc | PHYSICS
SI
Assistance
1:57
An MYP student drops a ball onto a hard floor surface and watches it bounce.
Drop Ball
Drop height
60
50
40
30
20
10
0 cm
1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)
Scroll down to continue
www.brilliantlearning.in



She notices that the height of the first bounce is not the same as the drop height.

She considers the different factors that could affect the height the ball bounces to.

Reset

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:57

Reset

Question 4a (1 mark)

State a research question that would be addressed by this investigation.

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Question 4b (3 marks)

Scroll down to continue

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Question 4b (3 marks)

Classify the variables for this investigation by completing the table below.

	Independent variable	Dependent variable	Control variable
Height of the first bounce	☐	☐	☐
The kind of ball used	☐	☐	☐
Surface that the ball bounces from	☐	☐	☐
Drop height	☐	☐	☐
Temperature of the ball	☐	☐	☐

Question 4c (2 marks)

The simulation below shows how data was collected by the student's experiment.

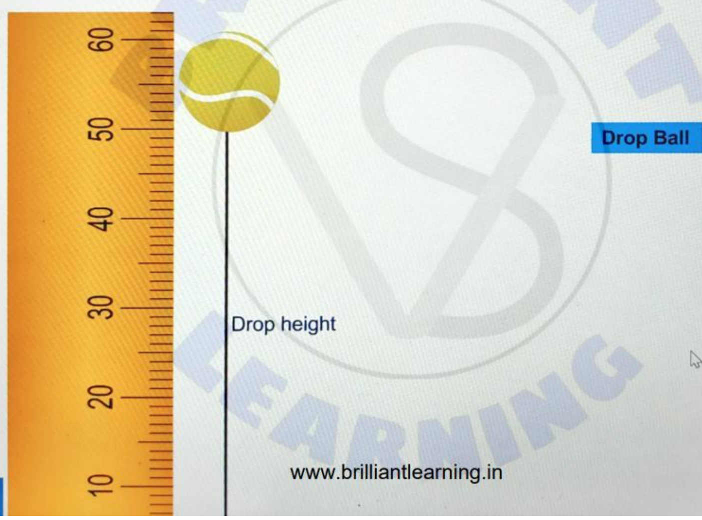
Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:57

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

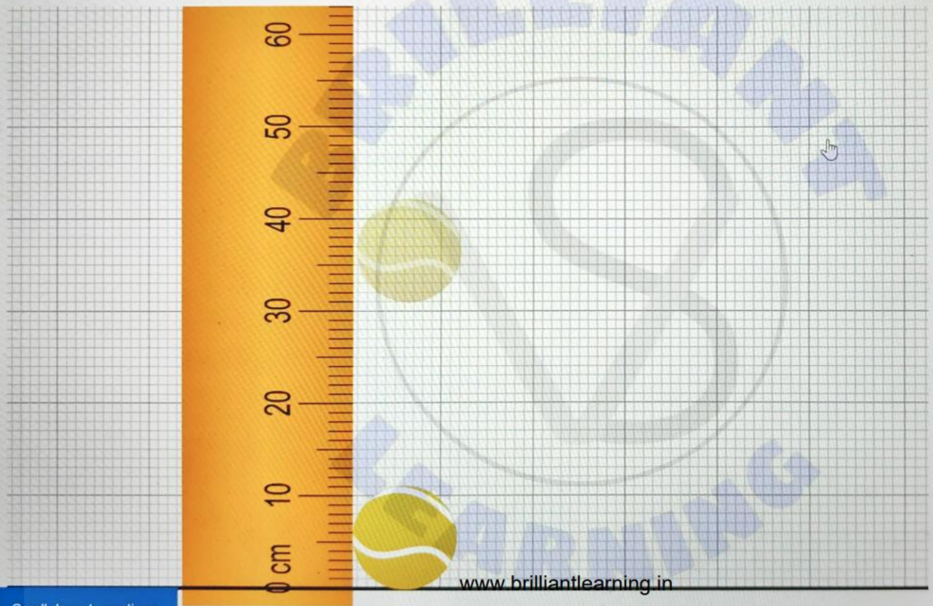
Question 4c (2 marks)

The simulation below shows how data was collected by the student's experiment.



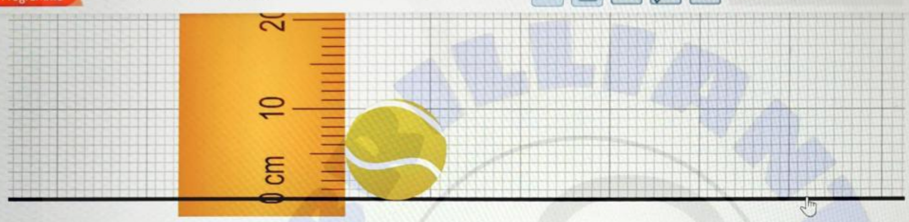
Scroll down to continue

The simulation below shows how data was collected by the student's experiment.



Scroll down to continue

Middle Years Programme abc abc | PHYSICS Assistance 1:57



Reset

State the height of the bounce.

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Scroll down to continue

Question 4d (3 marks)

The student starts to write an explanation for what they think happens to a ball when it bounces but the work is unfinished:

> The reason that the height of the first bounce of a ball is different to the drop height is because of the energy transformations that occur…

Use the concept of energy transformations to **explain** why the height of the first bounce is not the same as the drop height.

Scroll down to continue

Question 4e (2 marks)

The student collects data that is presented in the table below:

Calculate the missing average height and add it to the table.

Drop height / m	Height of first bounce / m			
	Trial 1	Trial 2	Trial 3	Average
0.40	0.25	0.27	0.25	
0.80	0.43	0.42	0.45	0.43
1.20	0.66	0.64	0.65	0.65
1.60	0.80	0.80	0.81	0.80
2.00	0.93	0.92	0.95	0.93

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

www.brilliantlearning.in

Scroll down to continue

abc abc | PHYSICS

Assistance

1:56

Question 4f (2 marks)

Outline why multiple trials were performed in this investigation and why this would lead to more reliable results.

Question 4g (2 marks)

Two graphs of the student's results are shown below. The data plotted on each graph are the same but the scaling and trendline chosen for each graph is different.

Scroll down to continue

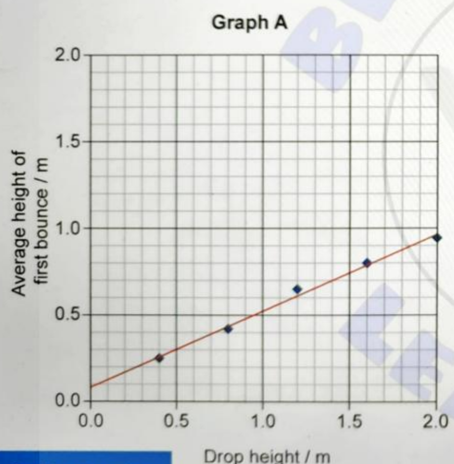
abc abc | PHYSICS

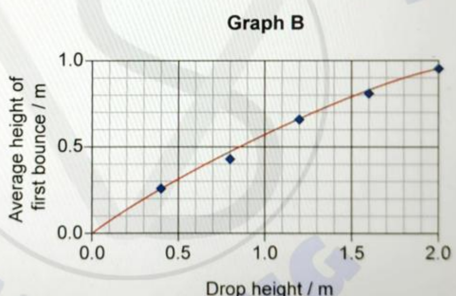
Assistance

1:56

Question 4g (2 marks)

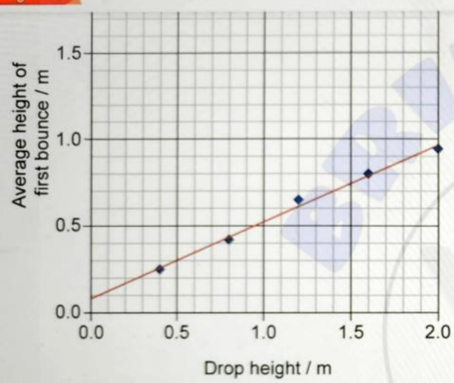
Two graphs of the student's results are shown below. The data plotted on each graph are the same but the scaling and trendline chosen for each graph is different.

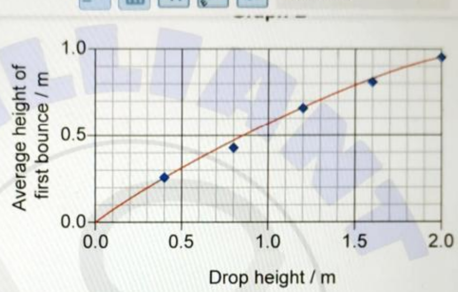




Scroll down to continue

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)





Identify which graph shows more clearly the relationship between the variables. **Justify** your answer.

Select
- Select
- Graph A
- Graph B

Scroll down to continue

Middle Years Programme abc abc | PHYSICS Assistance 1:56

Drop height / m

Identify which graph shows more clearly the relationship between the variables. **Justify** your answer.

Select

Justification:

B I U Ω Σ Styles

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Question 4h (3 marks)

Scroll down to continue

data, the student made the following prediction:

abc abc | PHYSICS

Assistance

1:56

Question 4h (3 marks)

Before collecting data, the student made the following prediction:

> As the drop height increases, the height of the first bounce will also increase.
> There will be a proportional relationship between the variables.

Use the graphs in part (g) to **evaluate** the student's prediction.

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
Question 4a
Question 4b
Question 4c
Question 4d
Question 4e
Question 4f
Question 4g
Question 4h
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Scroll down to continue

abc abc | PHYSICS

Assistance

1:56

Question 5 (14 marks)

Another student in the same class is doing a similar investigation. They do some research and read about a quantity called the coefficient of restitution.

The video has information about the coefficient of restitution.

Video | Script

When two objects collide their velocities change. Energy transformations also take place.

The velocities of each object involved in a collision can be used to calculate a value known as the coefficient of restitution, *e*.

When a ball bounces there is a collision between the ball and the ground.

For bouncing a ball, *e* can be calculated using speed instead of velocity. *e* is calculated by dividing the speed of the ball after the collision by the speed of the ball before the collision.

The quantity, *e*, has no units.

When $e = 1$, this means that the ball has the same speed after the collision as it had before the

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
6 (18 marks)
7 (10 marks)
8 (13 marks)

Scroll down to continue

abc abc | PHYSICS

Assistance

1:56

Video Script

When two objects collide their velocities change. Energy transformations also take place.

The velocities of each object involved in a collision can be used to calculate a value known as the coefficient of restitution, *e*.

When a ball bounces there is a collision between the ball and the ground.

For bouncing a ball, *e* can be calculated using speed instead of velocity. *e* is calculated by dividing the speed of the ball after the collision by the speed of the ball before the collision.

The quantity, *e*, has no units.

When *e* = 1, this means that the ball has the same speed after the collision as it had before the collision.

This relationship can be written using heights instead of speeds.

Scroll down to continue

abc abc | PHYSICS

Assistance

1:56

Question 5a (1 mark)

The student decides to calculate the coefficient of restitution (*e*) as part of their data processing.

For a bouncing ball investigation, *e* can be calculated using the relationship:

$$e = \sqrt{\frac{\text{height of first bounce}}{\text{drop height}}} = \sqrt{\frac{h_2}{h_1}}$$

Suggest why this student would find it easier to measure height than measure the speed of the ball in order to calculate *e*.

B I U Ω Σ Styles

www.brilliantlearning.in

Scroll down to continue

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
6 (18 marks)
7 (10 marks)
8 (13 marks)

Question 5b (1 mark)

State what would be observed if $e = 0$ for the ball.

Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:55

Question 5c (6 marks)

The student's table of processed data is shown below.

Drop height (h_1)	Average height of first bounce (h_2) / m	Coefficient of restitution (e)
50.0 cm	0.34	0.82
2.50m	1.44	0.76
1.50m	0.94	0.79
2.00m	1.21	
1.00m	0.65	0.806

There are many errors in the way this student has presented their data.

Present the data in the correct format.
Calculate the e value for a drop height of 2.00 m and add your value to the table.

Create New Table

Scroll down to continue

Create New Table

There are many errors in the way this student has presented their data.

Reset

Question 5d (3 marks)

Before collecting this data, the student wrote the following hypothesis:

> The coefficient of restitution, *e*, will not be affected by the drop height. The value of *e* will be constant as it depends on the material the ball is made from and not on the drop height.

Use the table of processed data in part (c) to **evaluate** the student's hypothesis.

Scroll down to continue

Middle Years Programme abc abc | PHYSICS Assistance 1:55

Question 5e (3 marks)

A collision with an *e* value of 1 is known as a perfectly elastic collision. This means that all of the kinetic energy of the system is conserved and none is converted to other forms.

A student in the class made the following statement:

> A collision with an *e* value of 0.5 means that 50 % of the kinetic energy of the ball is converted to other forms of energy.

Use the equation for kinetic energy from the formula sheet and the equation below to **evaluate** the statement made by the student.

$$e = \frac{\textit{speed after collision}}{\textit{speed before collision}} = \frac{v_2}{v_1}$$

www.brilliantlearning.in

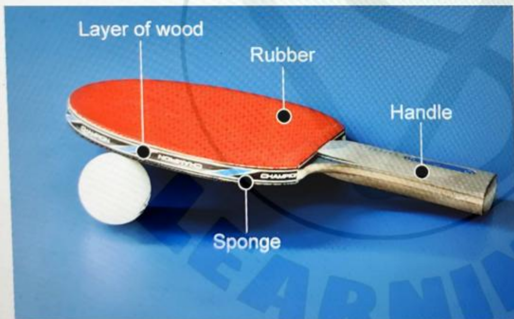
Scroll down to continue

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
Question 5a
Question 5b
Question 5c
Question 5d
Question 5e
6 (18 marks)
7 (10 marks)
8 (13 marks)

abc abc | PHYSICS   Assistance   1:55

Question 6 (18 marks)

The game of table tennis or ping pong involves hitting a plastic ball with a wooden racket. The racket is usually made from wood covered with a layer of sponge and rubber on top. The thickness of the sponge layer depends on the choice of the player. Some players prefer a thick layer of sponge and other players prefer a thin layer. The thickness can vary from no sponge to a thickness of around 2.5 mm.



Scroll down to continue

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
Question 6a
Question 6b
7 (10 marks)
8 (13 marks)

Question 6a (14 marks)

A student is interested in how the bounce of a table tennis ball is affected by the thickness of the sponge layer on the racket. They decide to put a table tennis racket on the floor, drop table tennis balls onto the racket and measure the height of the first bounce.

Use the student's idea to **design** an investigation to find out how the thickness of the sponge layer on a table tennis racket affects the height of the first bounce.

In your plan you should include:

- the independent and dependent variables together with the justification of **one** control variable
- a hypothesis for your investigation including a scientific explanation
- a list of equipment you will use
- how you will collect sufficient data
- a method detailing the procedure you will follow.

Scroll down to continue

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
Question 6a
Question 6b
7 (10 marks)
8 (13 marks)

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
Question 6a
Question 6b
7 (10 marks)
8 (13 marks)

Question 6b (4 marks)

In question 4 you considered the effect of drop height on bouncing balls and in part (a) of this question you considered the effect of the sponge layer on a table tennis racket.

Suggest an investigation into another factor that could affect the height of bounce of a ball. In your answer you should include a research question and independent and control variables. The dependent variable is the height of first bounce, this has been completed for you.

Research question:

Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:55

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
Question 6a
Question 6b
7 (10 marks)
8 (13 marks)

Independent variable:

Dependent variable:

Height of the first bounce

BRILLIANT LEARNING
www.brilliantlearning.in

Scroll down to continue

Middle Years Programme   abc abc | PHYSICS   Assistance   1:54

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
Question 6a
Question 6b
7 (10 marks)
8 (13 marks)

Control variable 1:

Control variable 2:

Middle Years Programme   abc abc | PHYSICS   Assistance   1:54

Question 7 (10 marks)

Houses in cold climates are usually heated to provide a comfortable living environment. Passively heated houses are designed to lower the energy required for heating. In passively heated houses, the amount of heat lost to the surroundings is greatly reduced compared to houses which are actively heated. Passively heated houses are built to standards that guarantee their quality and performance. The video below gives some more information about passively heated houses.

Video   Script

In many parts of the world with cold climates, people need to heat their houses to maintain a comfortable living environment. This can result in them spending large amounts of money or using significant resources. An alternative is to spend money on adapting the design of their house to be more energy efficient.

Passively heated houses are designed to lower the energy required for heating. In passively heated houses, the amount of heat lost to the surroundings is greatly reduced compared to houses which are actively heated.

Scroll down to continue   assively heated house are positioned to allow sunlight to enter for as much of

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
Question 7a
Question 7b
Question 7c
Question 7d
Question 7e
8 (13 marks)

Video | Script

In many parts of the world with cold climates, people need to heat their houses to maintain a comfortable living environment. This can result in them spending large amounts of money or using significant resources. An alternative is to spend money on adapting the design of their house to be more energy efficient.

Passively heated houses are designed to lower the energy required for heating. In passively heated houses, the amount of heat lost to the surroundings is greatly reduced compared to houses which are actively heated.

Windows in a passively heated house are positioned to allow sunlight to enter for as much of the day as possible. The direction of the windows will depend on the country in which the house is located.

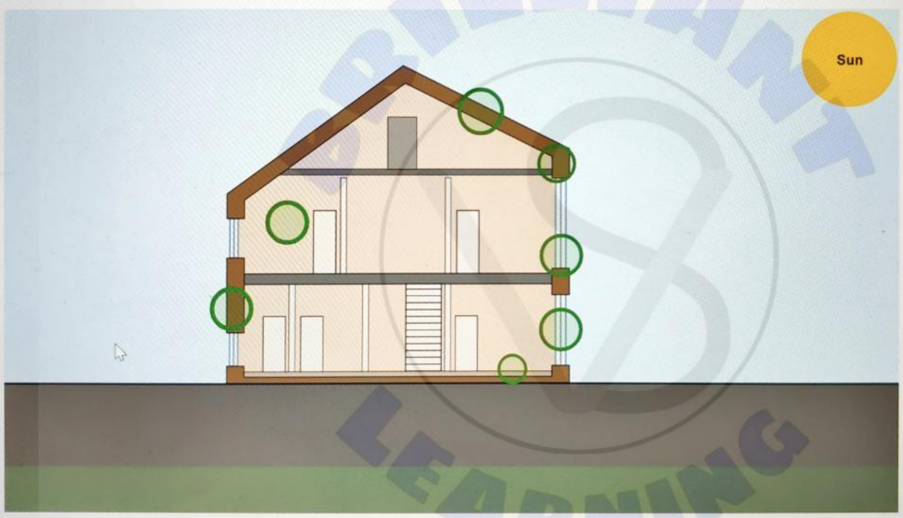
The walls, floor, windows, roof and doors are all designed to minimize the flow of heat out of the house. Thermal bridges are created when solid components directly connect the inside and outside of a house. In a passively heated house, the walls will be insulated as much as possible and include some gaps to avoid creating thermal bridges.

A mechanical air ventilation system circulates air from rooms where heat is produced, for example the kitchen, and distributes it so that the entire house is maintained at a consistent, comfortable temperature.

Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:54

This media is interactive

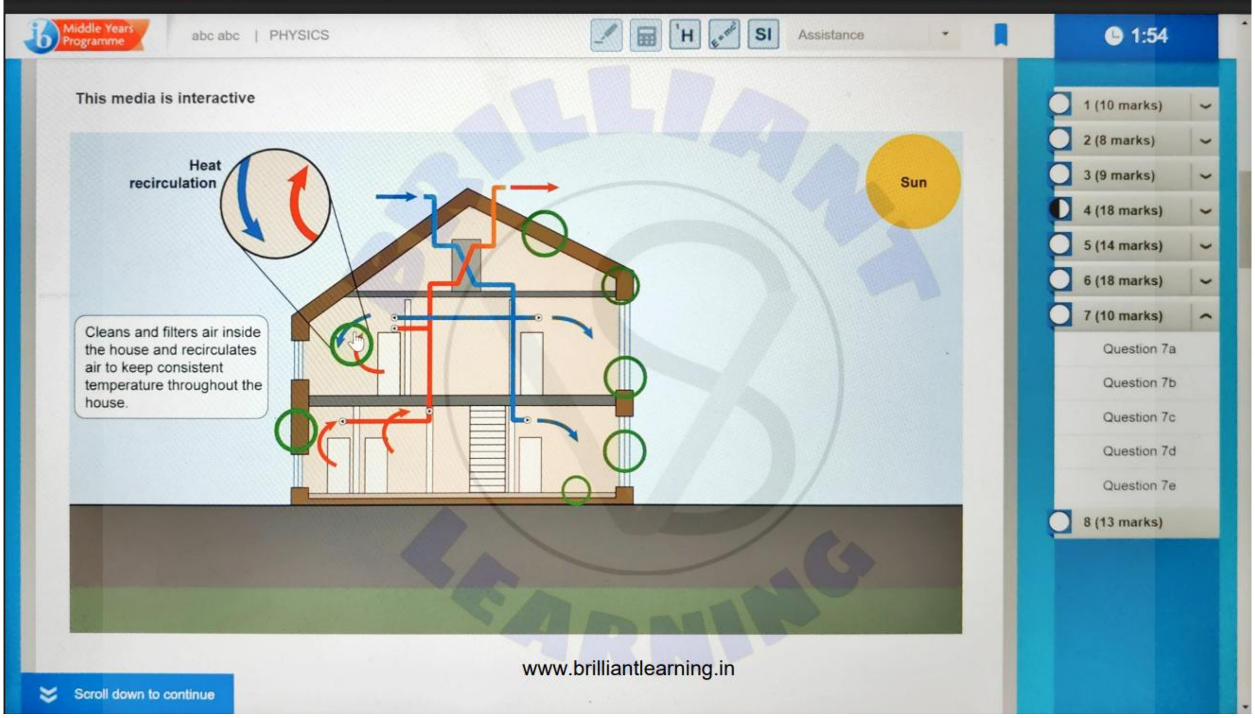


1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
Question 7a
Question 7b
Question 7c
Question 7d
Question 7e
8 (13 marks)

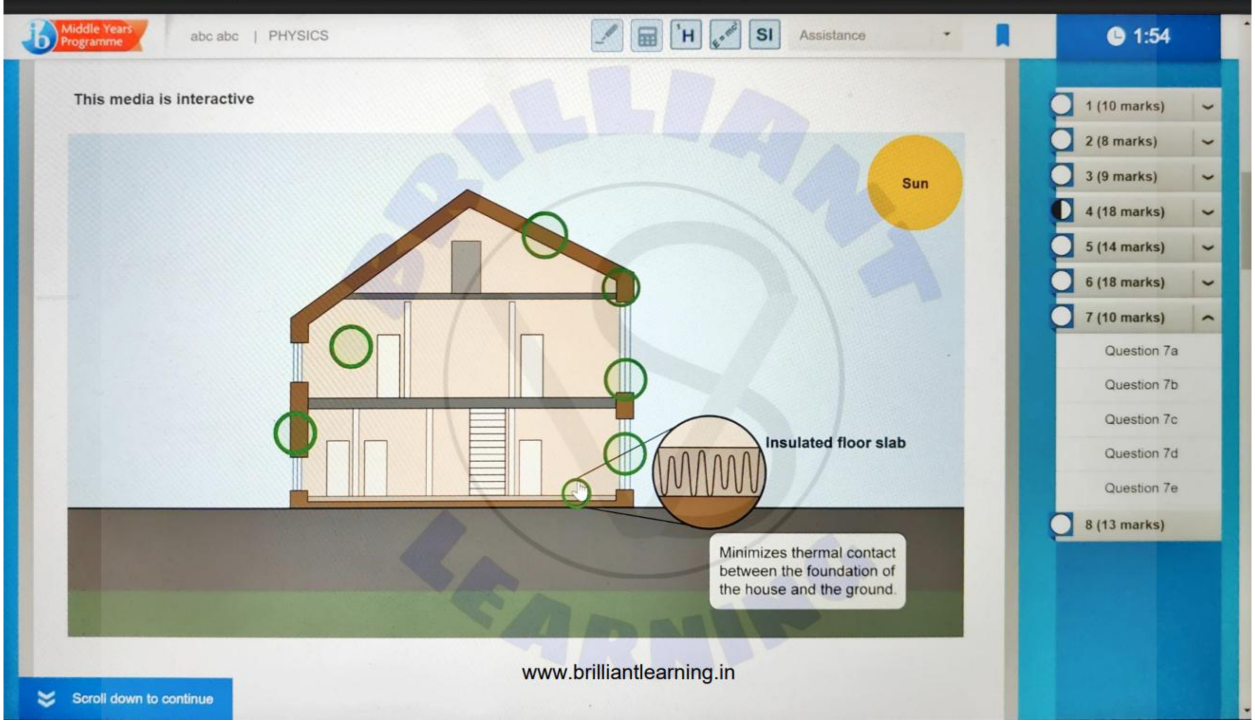
www.brilliantlearning.in

Scroll down to continue

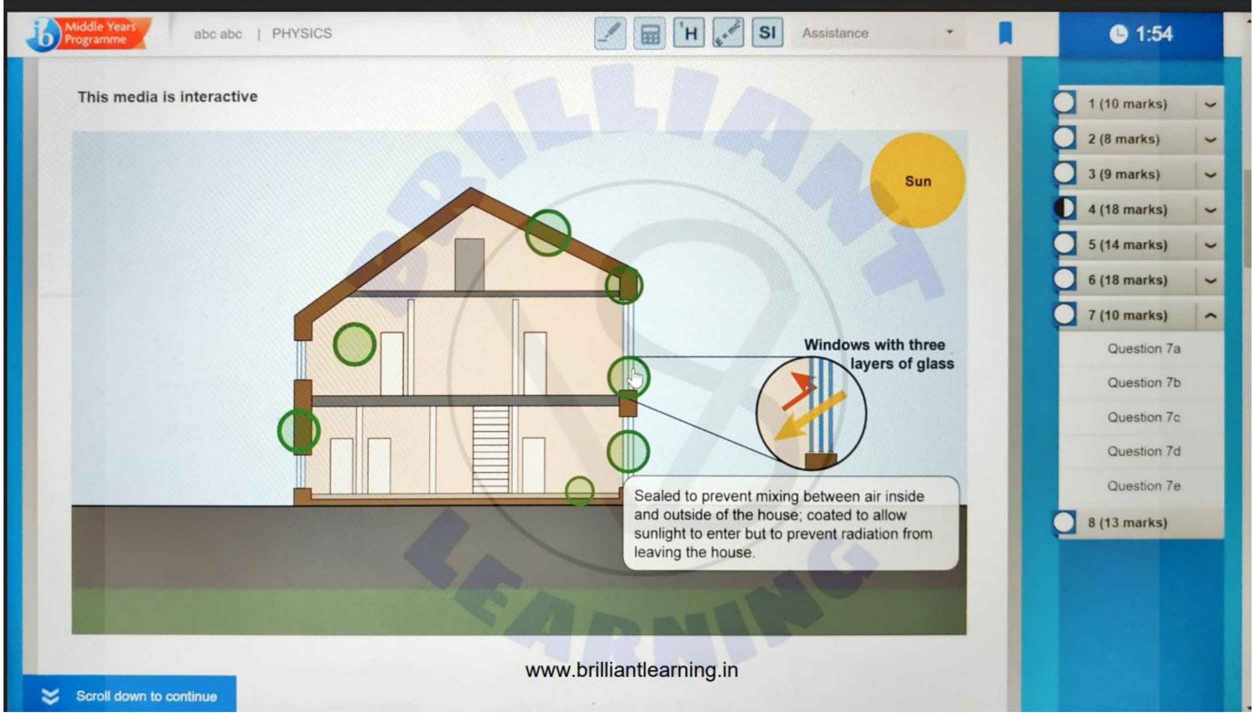

Middle Years Programme
abc abc | PHYSICS
SI
Assistance
1:54
This media is interactive
Airtightness
Sun
To prevent air moving between the inside and the outside of the house.
1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
Question 7a
Question 7b
Question 7c
Question 7d
Question 7e
8 (13 marks)
www.brilliantlearning.in
Scroll down to continue


Middle Years Programme
abc abc | PHYSICS
SI
Assistance
1:54
This media is interactive
Heat recirculation
Sun
Cleans and filters air inside the house and recirculates air to keep consistent temperature throughout the house.
1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
Question 7a
Question 7b
Question 7c
Question 7d
Question 7e
8 (13 marks)
www.brilliantlearning.in
Scroll down to continue


Middle Years Programme
abc abc | PHYSICS
Assistance
1:54
This media is interactive
Sun
Thermal insulation of walls and roof
Does not easily transfer heat and prevents the flow of air into or out of the house.
1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
Question 7a
Question 7b
Question 7c
Question 7d
Question 7e
8 (13 marks)
www.brilliantlearning.in
Scroll down to continue


Middle Years Programme
abc abc | PHYSICS
Assistance
1:54
This media is interactive
Sun
Insulated floor slab
Minimizes thermal contact between the foundation of the house and the ground.
1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
Question 7a
Question 7b
Question 7c
Question 7d
Question 7e
8 (13 marks)
www.brilliantlearning.in
Scroll down to continue


Middle Years Programme
abc abc | PHYSICS
Assistance
1:54
This media is interactive
Sun
Direction of windows
Positioned on the side of the house that receives the most sunlight to maximize the amount of solar heat entering.
1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
Question 7a
Question 7b
Question 7c
Question 7d
Question 7e
8 (13 marks)
www.brilliantlearning.in
Scroll down to continue


Middle Years Programme
abc abc | PHYSICS
Assistance
1:54
This media is interactive
Sun
Windows with three layers of glass
Sealed to prevent mixing between air inside and outside of the house; coated to allow sunlight to enter but to prevent radiation from leaving the house.
1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
Question 7a
Question 7b
Question 7c
Question 7d
Question 7e
8 (13 marks)
www.brilliantlearning.in
Scroll down to continue

Question 7a (2 marks)

Passively heated houses are designed to reduce the amount of money people spend on energy while allowing them to keep their houses warm. Use your knowledge of physics to **outline** how passive houses are able to stay warm inside, while requiring less heat energy compared to actively heated houses.

Question 7b (2 marks)

Question 7b (2 marks)

Outline how using three layers of glass in windows reduces heat loss by conduction.

Question 7c (3 marks)

Question 7c (3 marks)

Passively heated houses are tested for airtightness by creating a pressure difference between the inside and the outside of the house. Use kinetic theory to **describe** how a higher pressure inside the house can help to locate the places where air can escape through the walls of the house.

Scroll down to continue

Middle Years Programme | abc abc | PHYSICS | Assistance | 1:53

Question 7d (1 mark)

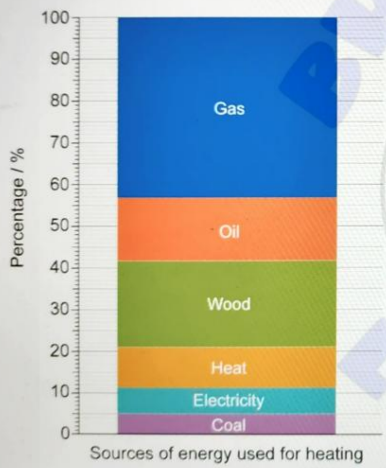
The passively heated house concept was developed in Germany with an aim of reducing the environmental impact of housing. The diagram below shows the percentage of households using different sources of energy for heating in the last decade in Germany.

Household energy consumption for heating by energy

State the percentage of households using oil as a source of energy for heating.

Scroll down to continue

Household energy consumption for heating by energy



State the percentage of households using oil as a source of energy for heating.

Question 7e (2 marks)

Suggest why the move to passive housing has a positive effect on the environment.

Middle Years Programme abc abc | PHYSICS Assistance 1:53

1 (10 marks) 2 (8 marks) 3 (9 marks) 4 (18 marks) 5 (14 marks) 6 (18 marks) 7 (10 marks) 8 (13 marks)

Question 8 (13 marks)

The infographic below gives some information about passively heated houses.

Cost comparison of actively heated and passively heated buildings

- Typical costs to build: for an actively heated house €180 000, passively heated house €195 000.
- Passive houses save 90 % on heating costs, typically saving €822 per year on heating.
- Typical cost to upgrade a typical house to a passive house would be €15 000.
- Costs to upgrade are decreasing with increasing demand.

Scroll down to continue

Middle Years Programme abc abc | PHYSICS Assistance 1:53

1 (10 marks) 2 (8 marks) 3 (9 marks) 4 (18 marks) 5 (14 marks) 6 (18 marks) 7 (10 marks) 8 (13 marks)

Cost comparison of actively heated and passively heated buildings

- Typical costs to build: for an actively heated house €180 000, passively heated house €195 000.
- Passive houses save 90 % on heating costs, typically saving €822 per year on heating.
- Typical cost to upgrade a typical house to a passive house would be €15 000.
- Costs to upgrade are decreasing with increasing demand.

The government of a country in a cold climate is considering giving money to people to upgrade their houses to meet the standards for passively heated houses.

Scroll down to continue

...luate the implications of upgrading houses to passively heated standards.

Middle Years Programme abc abc | PHYSICS Assistance 1:53

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Regulating the passive house standard

- Governments are responsible for determining building regulations, urban planning strategy and infrastructure.
- Developing passive house standards is a slow and costly process.
- Legal standards guarantee the safety, quality and performance of passive houses.

The government of a country in a cold climate is considering giving money to people to upgrade their houses to meet the standards for passively heated houses.

Scroll down to continue

...luate the implications of upgrading houses to passively heated standards.

Middle Years Programme abc abc | PHYSICS Assistance 1:53

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Paying for heat

- Heating costs can be a large part of family expenditure and are likely to rise in the future.
- Households in "fuel poverty" may have to choose between paying their energy costs and purchasing other essential items, like food and clothing.
- Fuel poverty is also associated with adverse effects on physical and mental health from coping with cold temperatures.
- Fuel poverty is most common in low-income areas, where housing quality tends to be poor and residents have access to limited disposable income.

The government of a country in a cold climate is considering giving money to people to upgrade their houses to meet the standards for passively heated houses.

Scroll down to continue

...luate the implications of upgrading houses to passively heated standards.

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

Air quality in passively heated houses

- Outdoor pollutants cannot enter a passively heated house because it is airtight.
- Passive houses need a well-maintained filter system to prevent build-up of indoor pollutants.
- If properly maintained, passively heated houses have higher air quality than actively heated houses.
- Indoor air pollutants can cause nausea, dizziness, shortness of breath, disorientation and long-term effects to health.
- Harmful indoor air pollutants can be produced from printers, copiers and fossil-fuel burning heaters.

The government of a country in a cold climate is considering giving money to people to upgrade their houses to meet the standards for passively heated houses.

Scroll down to continue

...luate the implications of upgrading houses to passively heated standards.

1 (10 marks)
2 (8 marks)
3 (9 marks)
4 (18 marks)
5 (14 marks)
6 (18 marks)
7 (10 marks)
8 (13 marks)

The government of a country in a cold climate is considering giving money to people to upgrade their houses to meet the standards for passively heated houses.

Discuss and **evaluate** the implications of upgrading houses to passively heated standards.
In your answer you should include:

- positive and negative social and economic implications for individuals in the community
- positive and negative economic implications for governments and businesses
- a concluding appraisal giving your opinion.

Scroll down to continue

November 2024

Links:

Q.1b.mp4
Q.2f Video.mp4
Q,6c Video.mp4
Q.7a.mp4
Q.7c.mp4

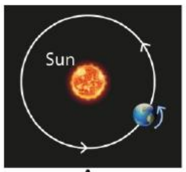
Question 1 (12 marks)

Question 1a (1 mark)

Regular, repeating movement can be described as periodic motion.

Select the image that does **not** show periodic movement.

Select



A.

B.

C.

D.

1b Video link: Q.1b.mp4

Select the option that describes the energy and speed of the pendulum at positions A, B and C.

	Kinetic energy	Potential energy	Speed
Position A	Select	Select	Select
Position B	Select	Select	Select
Position C	Select	Select	Select

Question 1c (3 marks)

A pendulum can be used to determine the acceleration due to gravity, g.

The period T of a pendulum is the time taken to complete one swing. T depends on the length of the pendulum, L and g. It is given by the relationship:

$$T^2 = 4\pi^2 \frac{L}{g}$$

The value of g varies with location on the Earth's surface. A pendulum used in a laboratory in Canada has a length of 72.5 cm. The time taken for 10 periods is measured to be 17.1 s.

Calculate the acceleration due to gravity in m s^{-2} in this laboratory, giving your answer to three significant figures.

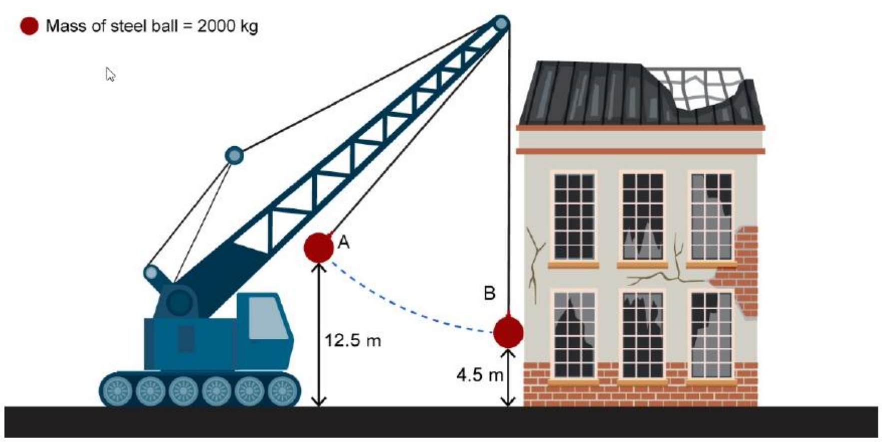
Question 1d (1 mark)

The expected value of acceleration due to gravity at this location is 9.82 m s^{-2}. **Suggest** why the experimental value in part (c) is different.

Question 1e (4 marks)

A wrecking ball is an example of a pendulum that can be used to demolish buildings. It is a very heavy steel ball hanging from a crane, which is released and swung to hit the structure.

Diagram not to scale



Initially, the ball is stationary. The crane operator releases the ball from a height of 12.5 m.

Calculate the kinetic energy of the ball when it hits the building at 4.5 m above the ground. You should assume that the acceleration due to gravity, g = 9.81 m s^{-2}. Give your result in kJ rounded to two significant figures.

Question 1f (1 mark)

Suggest why the real-world kinetic energy of the wrecking ball would be lower than the calculated value.

Question 2 (12 marks)

Smoke detectors are devices that sound an alarm when smoke enters them. The sound of the alarm warns people to take action in the event of a fire. Some smoke detectors use the properties of radiation to detect smoke.

Question 2a (2 marks)

Outline why smoke detectors are installed on the ceiling in a house instead of on the walls or floor.

Question 2b (2 marks)

Some smoke detectors use a small amount of a radioactive isotope, americium-241. Americium-241 emits alpha particles. **State** two properties of alpha particles.

Question 2c (1 mark)

Select the equation that represents the radioactive decay of americium-241 in a smoke detector:

${}^{241}_{95}Am \rightarrow {}^{237}_{93}Np + {}^{4}_{2}\alpha$	${}^{241}_{95}Am + {}^{4}_{2}\alpha \rightarrow {}^{237}_{93}Np$	${}^{241}_{95}Am \rightarrow {}^{234}_{91}Pa + {}^{4}_{2}\alpha$	${}^{241}_{95}Am \rightarrow {}^{237}_{93}Np + {}^{0}_{-1}\beta$
A. ○	B. ○	C. ○	D. ○

Question 2d (2 marks)

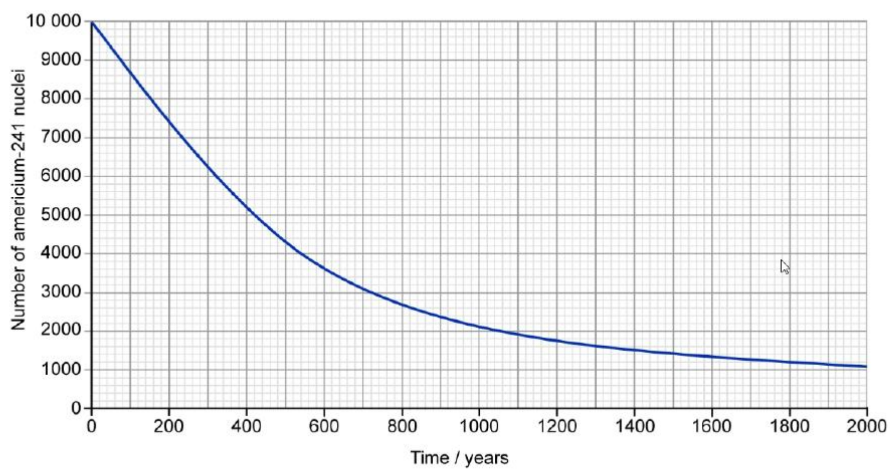
Americium-241 is an isotope of americium. **Select** which of the following is **not** an isotope of americium-241. Use scientific terminology to **justify** your answer.

A.	B.	C.	D.
$^{243}_{95}Am$	$^{240}_{93}Am$	$^{242}_{95}Am$	$^{223}_{95}Am$

Justification:

Question 2e (1 mark)

The graph below shows the radioactive decay of americium-241. Using the graph, **determine** the half-life of americium-241 in years.



2f Video link: Q.2f Video.mp4

Question 2f (1 mark)

Use your answer to part (e) to **calculate** the time taken for 625 nuclei to remain in this sample.

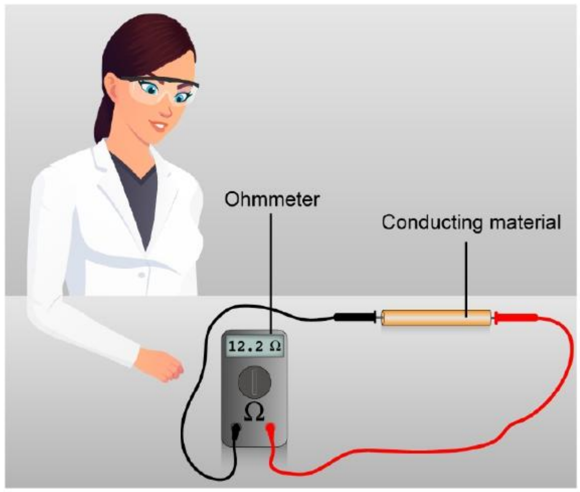
Question 2g (3 marks)

Explain why this kind of smoke detector would not function correctly with a radioactive isotope that emits beta or gamma radiation.

Question 3 (17 marks)

Question 3a (2 marks)

A resistor is an electrical component that limits the flow of current in a circuit and converts electrical energy to heat. Resistance can be measured using an ohmmeter.



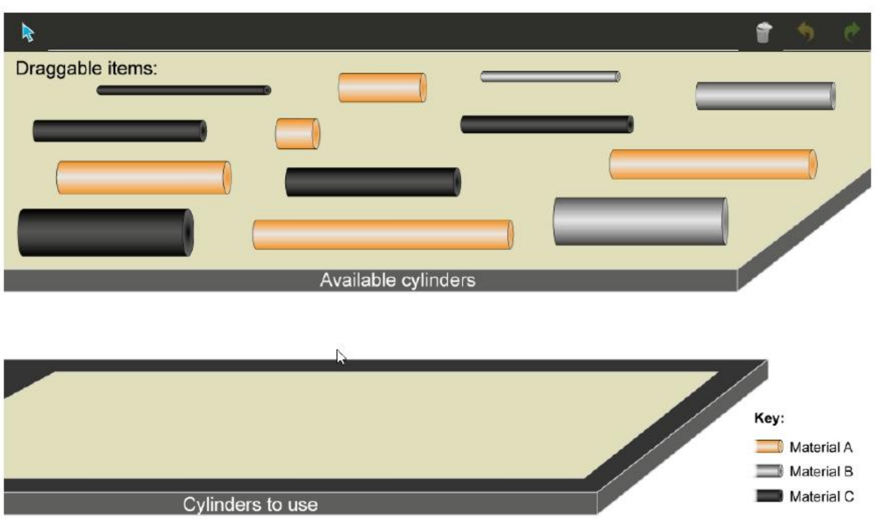
A student is interested in studying resistance. They decide to model resistors using cylinders of conducting material. Their research question is:

What is the relationship between the diameter of a cylinder and its resistance?

Formulate a hypothesis to test this research question.

Question 3b (3 marks)

Select the cylinders the student should use to collect appropriate data by dragging the cylinders from the box onto the table.

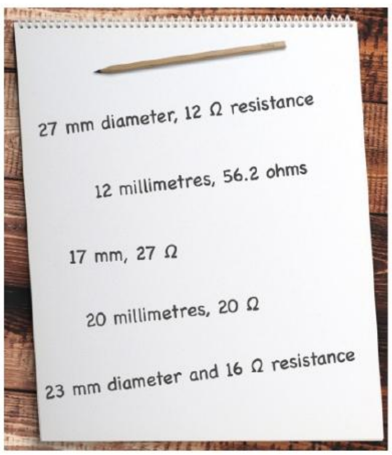


Question 3c (2 marks)

Justify your selection of cylinders in part (b).

Question 3d (4 marks)

Having carried out one trial for each cylinder, the student records their data as shown below.



Organize and **present** the data in a table.

Create New Table

Reset

Question 3e (2 marks)

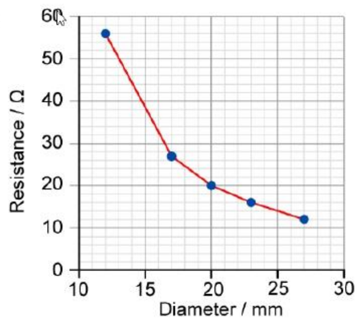
The student's lab partner wants to carry out more trials. **Suggest** how this would improve the investigation.

Question 3f (1 mark)

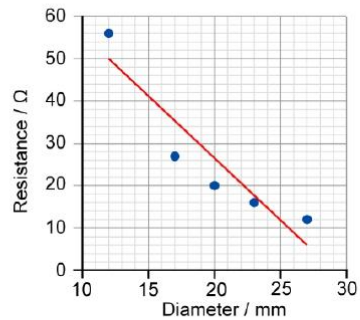
The student draws four graphs using the data from part (d). **Select** the most appropriate trend line to show the relationship between diameter and resistance.

Select

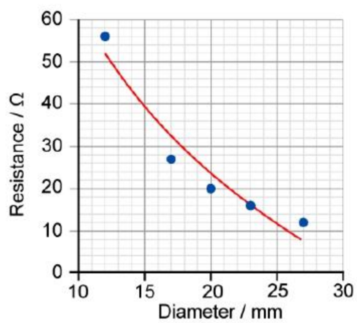
A.



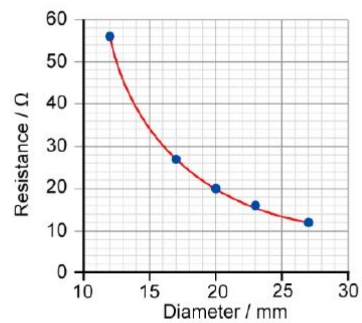
B.



C.



D.



Question 3g (3 marks)

The student wishes to extend the investigation using the same materials and equipment available in parts (a) and (b). The dependent variable will be resistance.

State an appropriate research question, independent variable and one control variable for this extension.

Question 4 (14 marks)

The resistance of a light-dependent resistor (LDR) depends on the intensity of light shining on its upper, light-sensitive surface. A student predicts:

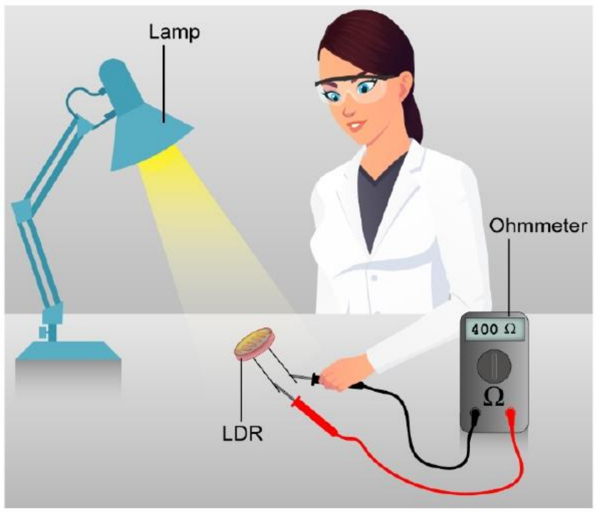
> If the distance between a light source and an LDR increases,
> then the resistance of the LDR will also increase.

Question 4a (1 mark)

State a research question for the student's investigation.

Question 4b (13 marks)

The student uses a lamp as a light source and an ohmmeter to measure the resistance.

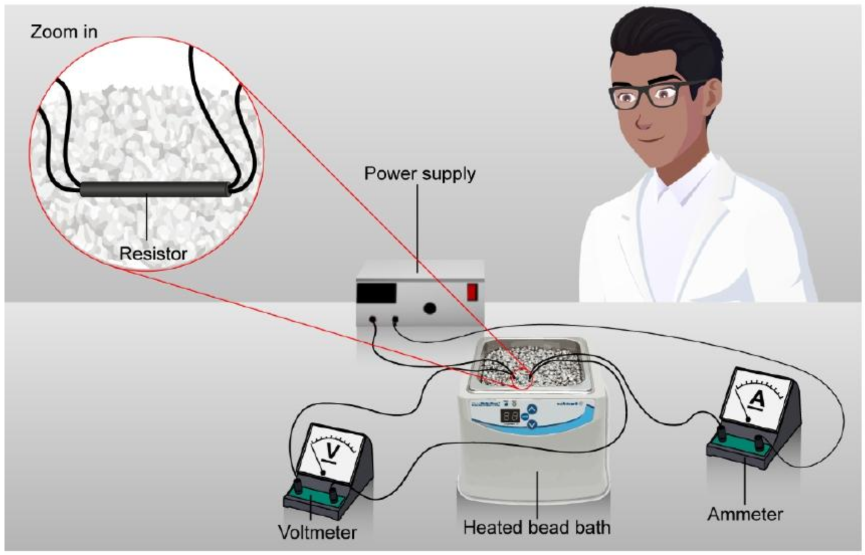


Design an investigation the student could use to test their prediction. In your answer, you should include:

- the independent variable and dependent variable
- two control variables and a justification of why they should be controlled
- a list of equipment
- a detailed method for how you will collect data
- an explanation of how you will collect sufficient data.

Question 5 (19 marks)

Another student decides to investigate the effect of varying the temperature of a resistor on its resistance. Instead of using an ohmmeter, this student measures current in order to calculate resistance. The supply voltage is kept constant throughout the investigation. The temperature of each resistor is modified by immersing it in a temperature-controlled bead bath.

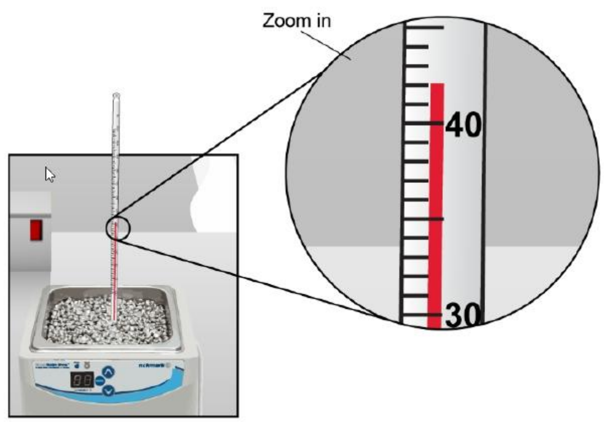


The student's research question is:

How does the temperature of a resistor affect the current in a circuit?

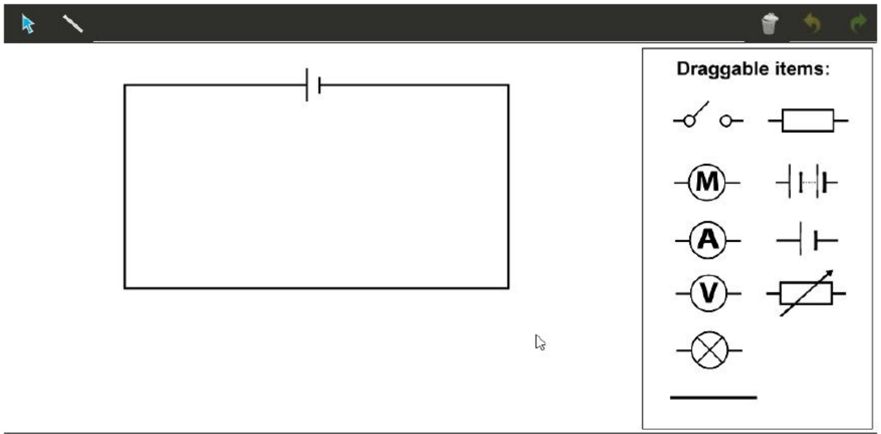
Question 5a (1 mark)

Measure the temperature of the bead bath.



Question 5b (3 marks)

Draw a diagram of the circuit used by the student. You do not need to include a bead bath in your diagram.



Question 5c (3 marks)

Identify the variables in this investigation.

Variable	Independent	Dependent	Control
Temperature of the resistor	☐	☐	☐
Length of the resistor	☐	☐	☐
Current in the circuit	☐	☐	☐
Diameter of the resistor	☐	☐	☐
Voltage across the resistor	☐	☐	☐

Reset

Question 5d (1 mark)

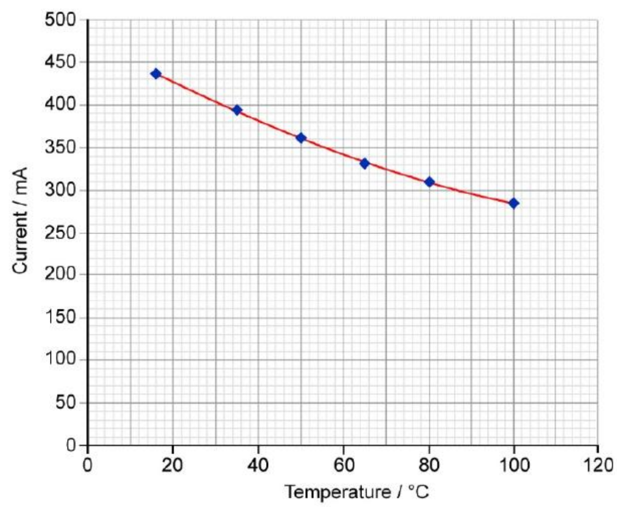
Identify a safety issue that the student should have considered when planning this investigation.

Question 5e (3 marks)

The student predicts:

> As the temperature of the resistor increases, the current through the resistor will decrease.
> I predict that there will be an inversely proportional relationship between the variables.

The graph of their results is shown below:



Use data from the graph and a calculation to **explain** whether the student's prediction is supported.

Question 5f (2 marks)

Having measured the current and voltage, additional processing is required to find the relationship between temperature and resistance. The voltage was kept constant at 30 V.

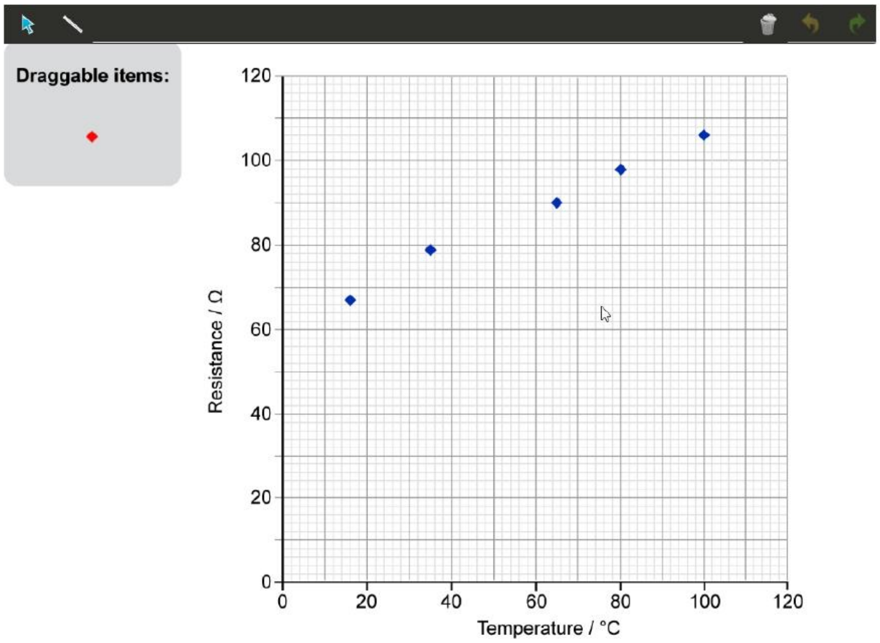
Using the graph in part (e) and information from the formula sheet, **calculate** the missing value and add it to the table of processed data below.

Temperature / ° C	Current / mA	Resistance / Ω
18	461	65
35	378	79
50	359	
65	341	88
80	297	101
100	284	106

Question 5g (2 marks)

The graph below shows the processed data from part (f).

Plot the data point you determined in part (f) and **draw** a line of best fit on the graph.



Question 5h (1 mark)

Using the graph in part (g), **predict** the value of resistance at 0°C.

Question 5i (2 marks)

Calculate the gradient of the line of best fit drawn in part (g). You should include your working and the unit in your answer.

Question 5j (1 mark)

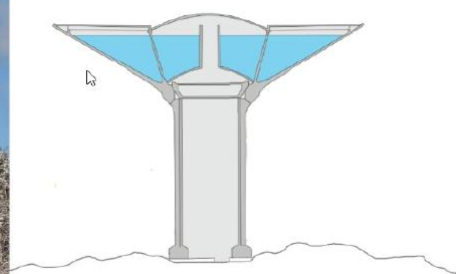
The student calculated that the resistance would be 500 Ω when the temperature was 1000°C.
Comment on the validity of the result from this calculation.

Question 6 (13 marks)

Different communities around the world do not have equal access to clean water and this is a challenge for fair development.

A water tower is an elevated structure found in many economically developed countries. It holds a water tank high above the ground. This allows the water to be distributed to the local area through a network of pipes.

The images below show a water tower in Finland with a capacity of 12 600 m³ and a height of 52 m.



Question 6a (3 marks)

Calculate the work done in filling this water tower with water from ground level. You should assume that the value of g = 9.81 N kg^{-1} and the density of water = 1000 kg m^{-3}. Give your answer in standard form to two significant figures.

Question 6b (1 mark)

In many countries, water must be collected from sources that are sometimes located far away from the home. It is estimated that around a quarter of the global population have to collect water.

In a lot of these countries, women and girls bear the responsibility for water collection, spending a worldwide total of around 200 million hours every day collecting water.

Suggest why the need to collect water is a barrier to development for the people that live in these regions.

Question 6c (9 marks)

The United Nation's (UN) Sustainable Development Goal for clean water and sanitation calls for fair and universal access to safe and affordable drinking water by 2030. However, this is a significant global challenge, as shown in the video below.

Video | Script

It is estimated that one in four, or around two billion people worldwide, do not have access to water that is safe to drink. 1.4 million people die annually and 74 million people will have their lives shortened due to diseases caused by drinking unclean water, and the related problems of poor sanitation and hygiene.

The UN Sustainable Development Goal for clean water and sanitation aims to provide everyone in the world with a source of clean water within a 30-minute round trip. Currently, the UN estimates that around a third of sub-Saharan Africa's population rely on water sources that do not meet this standard.

Most of the water sources used are accessed by hand pumps. These raise clean water up from under the ground. However, up to 50 % of these hand pumps are broken at any given time. A recent study found that charging a small amount of money to use the pump can help train people to maintain the pumps so that they can remain in use for decades.

6c Video Link: Q,6c Video.mp4

You are tasked with giving advice to a charity collecting money to improve access to clean water. The charity wants to provide a hand pump to a local village community in rural sub-Saharan Africa. The charity wants to make sure that the hand pump will remain usable for a long time.

Discuss and **evaluate** providing a hand pump to a local village community. In your answer, you should include:

- the benefits to health that are associated with access to clean, drinkable water
- the ethical advantages or disadvantages of asking the villagers to pay a small fee to access the clean water
- a concluding appraisal giving your opinion about how the charity should ensure a long-term solution to water access for the village.

Question 7 (13 marks)

Water must be treated before it is safe to be consumed by humans.

Video Script

In more economically developed countries, water treatment facilities are used to make sure that water is safe for human consumption. However, less economically developed countries do not have access to such facilities and different ways of making the water safe to drink are required.

One method that is used in less economically developed countries, where no centralized water treatment facilities are available, is solar disinfection, or SODIS. SODIS involves placing untreated water into a transparent container and exposing it to sunlight for several hours before drinking. The container is often a reused plastic water bottle. It is the combined effect of the UV waves and high temperatures that kills the harmful microbes that are present in the untreated water.

To be effective, the SODIS technique requires 6 hours of exposure to sunlight on a clear day in countries close to the equator. This increases to 48 hours on cloudy days. It also requires the availability of plastic bottles in which to hold the water.

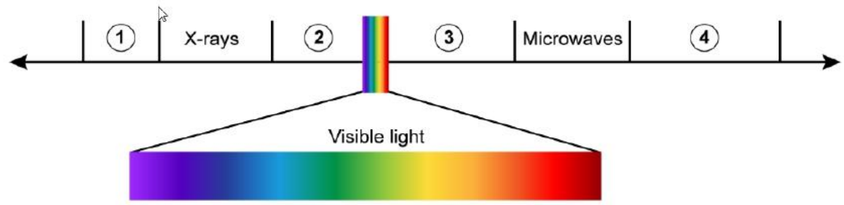
SODIS is recommended by the World Health Organization as a method for household water treatment, especially in locations where fuel is expensive.

7a Video Link: Q.7a.mp4

Question 7a (1 mark)

Select the region where ultraviolet (UV) waves are found in the electromagnetic spectrum shown below.

Select



Question 7b (1 mark)

State the property of ultraviolet waves that is useful for killing harmful microbes in water.

7c Video Link: Q.7c.mp4

Markschemes

GC Related Years *(Scientific & Technical Innovation)*:
May 2017 [ ]
November 2019 [ ]
November 2022 [ ]

May 2016

May 2017

May 2018

May 2019

Markscheme

May 2019

Physics

On-screen examination

13 pages

The following are the annotations available to use when marking responses.

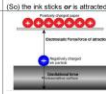
Annotation	Explanation
✔	Correct point, place at the point in the response where it is clear that the candidate deserves the mark. For use in analytically marked questions only.
λ	Omission, incomplete
CON	Contradiction
	Valid part (to be used when more than one element is required to gain the mark)
ECF	Error carried forward
	Dynamic annotation, it can be expanded to surround work
	Horizontal wavy line that can be expanded
	Highlight tool that can be expanded to mark an area of a response

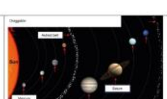
Annotation	Explanation
NGE	Not good enough
0	The candidate has given a response but it is not worthy of any marks
T	Test box used for additional marking comments
SEEN	Seen; must be stamped on all blank response areas and on duplicate pages of concatenated responses
	Vertical wavy line that can be expanded
WTTE	Words to that effect
1 2 3 4	Award 1, 2, 3, 4 marks. For use in holistically marked questions only

Markscheme instructions

1 Mark positively. Give candidates credit for what they have achieved and what is correct. Do not deduct marks for incorrect responses.
2 Follow the markscheme provided and award only whole marks.
3 Each marking point appears on a separate line.
4 The maximum mark for each subpart is indicated in the "Total" column.
5 Where a mark is awarded a tick should be placed in the text at the precise point where it is clear the candidate deserves the mark.
6 Each marking point in a question part should be awarded separately unless there is an instruction to the contrary in the Notes column.
7 A question subpart may have more marking points than the total allows. This will be indicated by the word "***max***" in the Answer column. Further guidance may be given in the Notes column.
8 Additional instructions on how to interpret the markscheme are in bold italic text in the Answer column.
9 Alternative wording may be indicated in the Answer column by a slash (/). Either alternative is equally acceptable but the candidate cannot be rewarded for both as they are associated with the same marking point.
10 Alternative answers are indicated in the Answer column by "***or***". Either alternative is equally acceptable but the candidate cannot be rewarded for both as they are associated with the same marking point.
11 If two related points are required to award a mark, this is indicated by "***and***" in the answer column.
12 Words in brackets ( ) in the Answer column are not necessary to gain the mark.
13 Words that are underlined are essential for the mark.
14 In some questions a reverse argument is also acceptable. This is indicated by the abbreviation *ORA (or reverse argument)* in the Notes column. Candidates should not be rewarded for reverse arguments unless *ORA* is given in the Notes column.
15 If the candidate's response has the same meaning or is clearly equivalent to the expected answer the mark should be awarded. In some questions this is emphasized by the abbreviation *WTTE (or words to that effect)* in the Notes column.
16 When incorrect answers are used correctly in subsequent question parts the follow through rule applies. Award the mark and add ECF (error carried forward) to the candidate response.
17 The order of marking points does not have to be the same as in the Answer column unless stated otherwise.
18 Marks should not be awarded where there is a contradiction in an answer. Add CON to the candidate response at the point where the contradiction is made.
19 Do not penalize candidates for errors in units or significant figures unless there is specific guidance in the Notes column.
20 Questions with higher mark allocations will generally be assessed using a level response method using task specific clarifications developed with reference to the criteria level descriptors. A candidate's work should be reviewed to determine holistically the mark for each row of the holistic grid and a mark awarded for each row.

Question		Answers	Notes	Total	Criterion
1	a	 All correct		1	A
	b	Celsius/(°)C ***or*** Kelvin/K Joules/J ***or*** kilojoules/kJ		2	A
	c	***Feature of Dewar flask and named type of heat transfer [2 max]*** ***correctly linked scientific explanation [2 max]*** • silvered surface reflects (infra red) radiation • so the sun's rays are reflected away from the ice • vacuum prevents conduction • because conduction needs a medium and there is no medium for heat / (thermal) energy to transfer (from the surroundings) to the ice • insulated support prevents conduction • heat / (thermal) energy cannot transfer through insulating materials and (so) cannot transfer (from the surroundings) to the ice	*Do **not** accept reference to the stopper* *Accept references to moving particles*	4	A

2	a	 All correct	*Accept overlapping protons and neutrons*	1	A
	b	Electrostatic force		1	A
	c	Positives and negative charges attract ***or*** there is an attractive force (So) the ink sticks ***or*** is attracted to the paper to create the copy	*Ignore references to magnetism*	2	A
	d	 single arrow pointing up at 90° to the photosensitive surface single arrow pointing down at 90° to the photosensitive surface labels: electrostatic (force) ***or*** gravitational force	*Ignore relative size of arrows* *Arrows must touch or be very close to touching the surface of the particle (judge by eye)* *Additional arrows are CON* *Award separately* *Accept weight or gravity*	3	A
	e	Force ***or*** attraction increases as the distance between charges ***or*** the oppositely charged surfaces decreases Distance needs to be small so the electric force can be greater than any opposing ***or*** downward force or weight Ink will then stick to the paper	*Accept reference to attractive force from positive drum surface*	3	A

3	a	 Two correct – one mark All three correct – two marks		2	A
	b	Distance ***or*** mass		1	A
	c	 One arrow pointing towards the Sun Both arrows point in the direction of the Sun Arrow at A shorter than arrow at B	*Judge by eye*	3	A
	d	evidence of use of the correct equation 562 000 000 (kg) ***or*** 5.62×10^{8} (kg)	*Seen or implied* *Award two marks for the correct answer.*	2	A
	e	Selection of correct equation 56 200 000 (N) ***or*** 5.62×10^{7} (N)	*Seen or implied* *ECF from part d*	2	A

4	a	100 $km h^{-1}$	*Accept km/h. Do **not** accept kmh^-1 for unit written out as words*	2	C
	b	Only weight identified as the IV Only air speed identified as the DV Only CSA ***and*** shape identified as the CV		3	B
	c	As the weight increases, the air speed needed increases Reference to air speed^2 ***Correct scientific information, for example [1 max]:*** • reference to Newton's first law • description of forces in equilibrium (weight and drag)	*Accept reference to gravitational force, do **not** accept gravity*	3	B
	d	All balls have the same CSA Balls with weight 1.20 N and 0.40 N are chosen Only 5 balls chosen	*No ECF from part b* *Award the third mark only if the first two marks are awarded*	3	B
	e	***Any two points from the following list [2 max]:*** • greatest possible range • this will generate sufficient data • control variables held constant		2	B
	f	Number of trials between 3 and 5 ***Any reasonable justification, for example [1 max]:*** • it is difficult to spot outliers for fewer than three trials • you can be sure you have reliable data • you can calculate the mean/average	*Do **not** accept references to accuracy*	2	B

– 9 – physmmoeengtz0xxm

5	a	How does the CSA affect the air speed needed for it to float?	*WTTE*	1	B
	b	38 cm^2		1	D
	c	***Column title:*** CSA ***and*** unit ***Column title:*** speed ***and*** unit Units in column header only All data recorded ***and*** arranged in order	*Accept area for CSA* *Accept table arranged in columns or rows* *Accept ecf from part b* *Accept either ascending or descending*	4	C
	d	Graph C Allows for a straight line to be drawn Arranges IV and DV so that relationship can be determined		3	C
	e	(If hypothesis supported) a graph of $1/v^2$ ~ CSA would be a straight line (going through the origin) Graph C shows this trend (Therefore) the hypothesis is supported **or** (If hypothesis supported) two sets of data would show same constant Data used to demonstrate this (Therefore) the hypothesis is supported	*Award one mark only if candidate has stated there is an (inverse) relationship* *Do **not** award the third mark unless either of the first two marks are awarded* *Seen or implied* *Do **not** award the third mark unless either of the first two marks are awarded*	3	C
	f	Repeats measurements ***or*** increases the number of trials Reduces the effect of (random) errors ***or*** increases reliability		2	C

– 10 – physmmoeengtz0xxm

6	a	Scatter / line graph Graph of weight against volume (of boat) below the water *x*-axis: weight of boat ***and*** *y*-axis: volume of boat below the water	*Accept displaced.*	3	C
	b	Straight line through the points Line goes through the origin		2	C
	c	***Any reasonable improvement, for example: [2 max]*** • greater range • more trials • regular increment ***Correctly linked effect, for example: [2 max]*** • gives more evidence for a proportional relationship over a greater range • reduces experimental uncertainty • better evidence for an observed trend		4	C

– 11 – physmmoeengtz0xxm

	d	(see table below)		11	B

	1 mark	2 marks	3 marks
1. RQ **(Research question)**	Research question links IV and DV	Research question links IV and DV and refers to a control variable	
2.E **(Equipment)**	Specific equipment for measuring mass of boat/cup eg top pan balance	Specific equipment for measuring mass of boat/cup eg top pan balance, ***and*** equipment to monitor at least one control variable	
3. V **(IV and DV)**	IV identified as mass of salt (weight or density accepted) ***or*** DV identified as mass (weight) of boat/cup	IV identified as mass of salt (weight or density accepted) ***and*** DV identified as mass (weight) of boat/cup	
4. M **(Method)**	Attempt at a method but detail is insufficient to follow	Method described and could easily be followed by another student including reference to control of the control of displacement (eg measured line on the boat/cup)	
5. D **(Data)**	Method implies a range of values of the IV (eg. mass of salt added)	Method implies a range of values of the IV (eg. mass of salt added) with at least 3 trials/repeats	Method implies a range of values of the IV (eg. mass of salt added) with 3 trials/repeats ***and*** plans to calculate average (mean)

– 12 – physmmoeengtz0xxm

7	a	Long enough half-life to record images Short enough to prevent long term exposure		2	D
	b	***Any two reasonable advantages, for example [2 max]:*** • gamma rays are not blocked by bone or skin • they do not damage cells (by ionisation) • they can be detected by a gamma camera	*Do **not** accept references to half-life.*	2	D
	c	(see table below)		9	D

	1 mark	2 marks	3 marks	4 marks
1. A **(Advantages)**	A statement of an advantage	A statement of two or more advantages ***or*** A statement of one advantages with an explanation	A statement of two or more advantages with at least one explained	A statement of two or more advantages with at least one explained ***and*** linked to the specific country
2. D **(Disadvantages)**	A statement of a disadvantage	A statement of two or more disadvantages ***or*** A statement of one disadvantage with an explanation	A statement of two or more disadvantages with at least one explained	A statement of two or more disadvantages with at least one explained ***and*** linked to the specific country
3. C **(Conclusion)**	A simple conclusion			

– 13 – physmmoeengtz0xxm

8		(see table below)		11	D

	1 mark	2 marks	3 marks	4 marks
1. Ad/Dis **(Advantages and disadvantages)**	States either an advantage ***or*** disadvantage	An advantage ***and*** disadvantage	An advantage ***and*** disadvantage ***one*** of which is supported with scientific understanding	An advantage ***and*** disadvantage ***both*** of which are supported with scientific understanding
2. P **(Political implications)**	General reference to a factor relating to government or public affairs	Specific reference to a factor relating to government or public affairs with an example (eg public safety)	More than one specific reference to a governmental responsibility each with an example	
3. E **(Environmental implications)**	General reference to an environmental implication	A specific environmental implication with an example		
4. A **(Appraisal)**	A simple conclusion	A concluding appraisal with reference to issues raised		

May 2020

May 2021

May 2022

May 2023

Middle Years Programme

Markscheme

May 2023

Physics

On-screen examination

15 pages

The following are the annotations available to use when marking responses.

Annotation	Explanation
✓	Correct point, place at the point in the response where it is clear that the candidate deserves the mark. For use in analytically marked questions only.
λ	Omission, incomplete
CON	Contradiction
	Valid part (to be used when more than one element is required to gain the mark)
ECF	Error carried forward
	Dynamic annotation, it can be expanded to surround work
	Underline tool that can be expanded
	Highlight tool that can be expanded to mark an area of a response

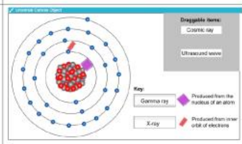
Annotation	Explanation
NGE	Not good enough
	The candidate has given a response but it is not worthy of any marks
T	Text box used for additional marking comments
SEEN	Seen; must be stamped on all blank response areas and on duplicate pages of concatenated responses
	Vertical wavy line that can be expanded
WTTE	Words to that effect
✓1 ✓2 ✓3 ✓4	Award 1, 2, 3, 4 marks. For use in holistically marked questions only

Markscheme instructions

1 Mark positively. Give candidates credit for what they have achieved and what is correct. Do not deduct marks for incorrect responses. Do not deduct marks for spelling errors.
2 Follow the markscheme provided and award only whole marks.
3 Each marking point appears on a separate line.
4 The maximum mark for each subpart is indicated in the "Total" column.
5 Where a mark is awarded a tick should be placed in the text at the precise point where it is clear the candidate deserves the mark.
6 Each marking point in a question part should be awarded separately unless there is an instruction to the contrary in the Notes column.
7 A question subpart may have more marking points than the total allows. This will be indicated by the word "**max**" in the Answer column. Further guidance may be given in the Notes column.
8 Additional instructions on how to interpret the markscheme are in bold italic text in the Answer column.
9 Alternative wording may be indicated in the Answer column by a slash (/). Either alternative is equally acceptable but the candidate cannot be rewarded for both as they are associated with the same marking point.
10 Alternative answers are indicated in the Answer column by "***or***". Either alternative is equally acceptable but the candidate cannot be rewarded for both as they are associated with the same marking point.
11 If two related points are required to award a mark, this is indicated by "***and***" in the answer column.
12 Words in brackets ( ) in the Answer column are not necessary to gain the mark.
13 Words that are underlined are essential for the mark.
14 In some questions a reverse argument is also acceptable. This is indicated by the abbreviation *ORA (or reverse argument)* in the Notes column. Candidates should not be rewarded for reverse arguments unless *ORA* is given in the Notes column.
15 If the candidate's response has the same meaning or is clearly equivalent to the expected answer the mark should be awarded. In some questions this is emphasized by the abbreviation *WTTE (or words to that effect)* in the Notes column.
16 When incorrect answers are used correctly in subsequent question parts the follow through rule applies. Award the mark and add ECF (error carried forward) to the candidate response.
17 The order of marking points does not have to be the same as in the Answer column unless stated otherwise.
18 Marks should not be awarded where there is a contradiction in an answer. Add CON to the candidate response at the point where the contradiction is made.
19 Do not penalize candidates for errors in units or significant figures unless there is specific guidance in the Notes column.
20 Questions with higher mark allocations will generally be assessed using a level response method using task specific clarifications developed with reference to the criteria level descriptors. A candidate's work should be reviewed to determine holistically the mark for each row of the holistic grid and a mark awarded for each row.

Question		Answers	Notes	Total	Crit
1	a	Use of speed = distance/time 4(kmh^{-1})	*Seen or implied*	2	A
	b	C. energy transformed = power × time		1	A
	c	Horse / Mass of horse/kg / Weight/N A / 350 / **3500** B / **510** / 5100		2	A
	d	Chemical potential energy → **Kinetic energy** → Gravitational potential energy		1	A
	e	Calculate work done 61200 (J) Calculate power 11127 11.127 (kW)	*Award 3 marks for 11.127 expressed to 2 or more sig figs ECF*	3	A
	f	I=P/V I= 6.48695.. or 6.5 (A)	*Seen or implied* *Accept answer stated to 2 or more sig figs*	2	A

2	a	D. Dispersion		1	A
	b	Red light has the longest wavelength ***or*** the lowest frequency Red is refracted the least (of the colours) Red light is the fastest (in the prism) ***or*** Red light has the lowest refractive index ***or*** Red light is slowed down the least (by the glass)		3	A
	c	IR has longer wavelength ***or*** IR has lower frequency ***or*** IR is detectable as heat	*WTTE*	1	A
	d	$f = \frac{v}{\lambda}$ seen or implied 4(.00) x 10^{14} (Hz)		2	A

3	a	Atomic number= 6 Mass number=14		2	A
	b	***Accept any similarity from the list [max 1]*** • same number of protons • same charge on the nucleus ***Accept any difference from the list [max 1]*** • different number of neutrons • different number of nucleons • C-14 nucleus is unstable but C-12 nucleus is stable	*Do not accept same atomic number or both are carbon nuclei* *Do not accept different mass number*	2	A
	c	 Gamma ray in correct location X-ray in correct location		2	A
	d	$^{238}_{92}U \rightarrow ^{232}_{90}Th + ^{4}_{2}\alpha$ $^{232}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}\beta$		2	A
	e	A neutron is absorbed by the nucleus of uranium-238	*WTTE*	1	A

4	a	A RQ linking mass ***or*** force ***or*** weight ***or*** pressure ***and*** volume		1	B
	b	Mass as only IV Volume of air as only DV		2	B
	c	Increase		1	B
	d	Correct use of (m x g) Increase in pressure = 1.51898 x 10^5 or 151899 (Pa or Nm^{-2}) Total pressure = 2.5 x 10^5 (Pa or Nm^{-2}) or 251899 (Pa or Nm^{-2})	*Seen or implied* *Correct to at least 2 sig figs, no ECF* *Award 3 marks for correct total pressure value stated to at least 2 sig figs*	3	C
	e	As the pressure increases, the volume decreases ***Second mark, accept any further description [max 1]*** • in an inverse relationship • pressure is proportional to 1/volume • pressure is inversely proportional to volume • when pressure doubles, volume halves		2	C
	f	***Reference to the graph, for example [max 1]*** • the line is horizontal ***or*** flat ***or*** the same value (of 11000) is found for every pressure • There is a slight slope to the line • The value at 300kPa is not constant ***Justification [max 1]*** • (so) the graph supports Boyle's Law (within experimental error) • (so) the graph does not support Boyle's Law	*Reference to the graph must be made for the first marking point* *Do **not** award the second marking point without the first marking point being awarded*	2	C
	g	Answer in range 145-155 cm^3	*Award unit mark independently*	2	C

5	a	As temperature increases, the kinetic energy ***or*** speed increases The number of collisions between the gas particles and the wall of the balloon increases ***or*** The force of the collisions between the gas particles and the wall of the balloon increases ***or*** The kinetic energy of the particles is transferred to elastic potential energy So the balloon expands because the balloon is elastic ***or*** The balloon expands because its wall is pushed out by the pressure of the gas	*WTTE*	3	B

b

	1	2	3	4
RQ	an RQ correctly linking temperature and volume or circumference			
V (Variables)	temperature as independent variable ***or*** circumference implied as dependent variable	independent variable of temperature ***and*** dependent variable of circumference stated	independent variable of temperature ***and*** dependent variable of circumference stated ***and*** one control variable stated	
E (Equip)	equipment to measure temperature ***or*** circumference	equipment to measure temperature ***and*** circumference		
M (Method)	attempt at a method linked to circumference ***or*** temperature	method is described with measurements of circumference ***and*** temperature but not detailed enough to be followed by another student	complete method is realistic and described with measurements of circumference ***and*** temperature ***and*** could easily be followed by another student	
D (Data)	a reference to different temperatures	at least five increments of temperature	at least five increments of temperature ***and*** repeated measurements of circumference	at least five increments of temperature ***and*** repeated measurements of circumference ***and*** plans to calculate average
S (Safety)	mentions a relevant safety precaution for example: working at elevated temperature or making sure the balloon is not inflated too much at the start			

14 B

6	a	Acceleration is due to an unbalanced force ***or*** Newton's second law says the greater the force, the greater the acceleration ***or*** F=ma Expulsion of gas and thrust are paired forces ***or*** Forces are an action-reaction pair of forces (this is an example of) Newton's third law		3	C
	b	An RQ correctly linking circumference ***or*** volume with distance travelled		1	B
	c	38.2 ***and*** cm	*Unit **and** value required for the point. Accept 0.382 m.*	1	C

d

Table Object

Circumference / cm	Distance travelled / m
35.8	1.07
38.2	1.30
41.0	1.97
50.3	3.10
54.9	3.99
58.2	5.06

	d	Table with circumference and distance travelled ***and*** units in headers only Data in ascending or descending order Data to consistent dp Numbers correctly converted to consistent units	*Accept data arranged in either vertical columns or horizontal rows* *Accept either metres or centimetres for each column*	4	C
	e	The graphs show that as the circumference increases, the distance travelled will increase		3	C

		(but) the graph shows that there is a proportional relationship between distance travelled and circumference cubed ***or*** (but) the graph shows that there is not a proportional relationship between distance travelled and circumference (so) the hypothesis is not valid ***or*** The hypothesis is only partially valid	*Only award the 3rd marking point if the first 2 points have been awarded*		
	f	***Accept any reasonable IV, for example [max 1]*** • gas inside • temperature • shape of balloon ***Accept any two reasonable CV relevant to the DV above, for example [max 2]*** • length of straw attached to balloon • angle of line • circumference or volume of gas • elasticity of balloon		3	C
	g	***Accept any reasonable hypothesis correctly linked to the IV given above and distance travelled*** If (the IV) increases then distance travelled will increase or decrease Attempt at explanation using scientific reasoning		2	C

7	a	Accept period in the range 1.6-1.8 Accept frequency in the range 0.56-0.63 Hz *or* s^{-1}	*Seen or implied* *Must be expressed as 2 sig figs* *Award the unit mark independently*	3	C D
	b	C		1	A
	c	Pedro's voice is converted into an electrical signal by the microphone in his mobile phone. The phone then converts that electrical signal into a radio wave. ↓ The radio wave signal is transmitted from the mobile phone to tower A. ↓ Tower A receives the signal, then sends the signal out through a connection using wires or fibre-optic cables to Tower B, where the signal is converted again. ↓ Natasha's phone receives the radio wave signal and converts it back into a sound wave that she can hear. All correct		1	D

d (13, D)

	1	2	3	4
Advantages and disadvantages (location-tracking tech)	a statement of one advantage ***or*** disadvantage for an individual	a statement of one advantage ***and*** one disadvantage for an individual ***or*** a statement of one advantage for an individual ***or*** disadvantage for an individual with support	a statement of more than one advantage for an individual ***and*** more than one disadvantage for an individual	a statement of at least two advantages for an individual with support for one ***and*** at least two disadvantages for an individual with support for one
Economic (Economic benefits)	an economic benefit for a company	more than one economic benefit for a company ***or*** one benefit with support	more than one economic benefit for a company with support for at least two	
Security (Security implications)	a positive ***or*** a negative security implication for a country	a positive ***and*** a negative security implication for a country	a positive ***and*** a negative security implication for a country with support for ***one***	a positive ***and*** a negative security implication for a country with support for ***both***
Con (Concluding appraisal)	a concluding opinion is given	a concluding appraisal linking to previous arguments		

8 (8, D)

	1	2	3
Benefits of controlling	a statement of a benefit	a statement of two or more benefits ***or*** a statement of one benefit with an explanation	a statement of two or more benefits with at least one explained
Limitations of controlling	a statement of a limitation	a statement of two or more limitations ***or*** a statement of one limitation with an explanation	a statement of two or more limitations with at least one explained
Con (Conclusion)	a simple conclusion	a conclusion with a detailed appraisal of the issues raised	

May 2024

Markscheme

May 2024

Physics

On-screen examination

21 pages

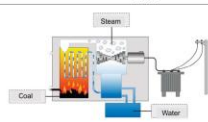
The following are the annotations available to use when marking responses.

Annotation	Explanation
✔	Correct point, place at the point in the response where it is clear that the candidate deserves the mark. For use in analytically marked questions only.
λ	Omission, incomplete
CON	Contradiction
●	Valid part (to be used when more than one element is required to gain the mark)
ECF	Error carried forward
⬭	Dynamic annotation, it can be expanded to surround work
	Underline tool that can be expanded
	Highlight tool that can be expanded to mark an area of a response

Annotation	Explanation
NGE	Not good enough
	The candidate has given a response but it is not worthy of any marks
T	Text box used for additional marking comments
SEEN	Seen; must be stamped on all blank response areas and on duplicate pages of concatenated responses
	Vertical wavy line that can be expanded
WTTE	Words to that effect
1 2 3 4	Award 1, 2, 3, 4 marks. For use in holistically marked questions only

Markscheme instructions

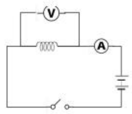
1 Mark positively. Give candidates credit for what they have achieved and what is correct. Do not deduct marks for incorrect responses. Do not deduct marks for spelling errors.
2 Follow the markscheme provided and award only whole marks.
3 Each marking point appears on a separate line.
4 The maximum mark for each subpart is indicated in the "Total" column.
5 Where a mark is awarded a tick should be placed in the text at the precise point where it is clear the candidate deserves the mark.
6 Each marking point in a question part should be awarded separately unless there is an instruction to the contrary in the Notes column.
7 A question subpart may have more marking points than the total allows. This will be indicated by the word "***max***" in the Answer column. Further guidance may be given in the Notes column.
8 Additional instructions on how to interpret the markscheme are in bold italic text in the Answer column.
9 Alternative wording may be indicated in the Answer column by a slash (/). Either alternative is equally acceptable but the candidate cannot be rewarded for both as they are associated with the same marking point.
10 Alternative answers are indicated in the Answer column by "***or***". Either alternative is equally acceptable but the candidate cannot be rewarded for both as they are associated with the same marking point.
11 If two related points are required to award a mark, this is indicated by "***and***" in the answer column.
12 Words in brackets ( ) in the Answer column are not necessary to gain the mark.
13 Words that are underlined are essential for the mark.
14 In some questions a reverse argument is also acceptable. This is indicated by the abbreviation *ORA (or reverse argument)* in the Notes column. Candidates should not be rewarded for reverse arguments unless *ORA* is given in the Notes column.
15 If the candidate's response has the same meaning or is clearly equivalent to the expected answer the mark should be awarded. In some questions this is emphasized by the abbreviation *WTTE (or words to that effect)* in the Notes column.
16 When incorrect answers are used correctly in subsequent question parts the follow through rule applies. Award the mark and add ECF (error carried forward) to the candidate response.
17 The order of marking points does not have to be the same as in the Answer column unless stated otherwise.
18 Marks should not be awarded where there is a contradiction in an answer. Add CON to the candidate response at the point where the contradiction is made.
19 Do not penalize candidates for errors in units or significant figures unless there is specific guidance in the Notes column.
20 Questions with higher mark allocations will generally be assessed using a level response method using task specific clarifications developed with reference to the criteria level descriptors. A candidate's work should be reviewed to determine holistically the mark for each row of the holistic grid and a mark awarded for each row.

Question		Answers	Notes	Total	
1	a	 All correct		1	A
	b	Molecules move faster	*Accept move more, or vibrate more*	1	A
	c	***Accept any two points from the list [max 2]*** • speed of movement of particles does not increase • energy is being used to break bonds • energy is used to separate molecules/particles • potential energy of particles is increased		2	A
	d	1.125 x10^{13} (J) Rounded correctly to 1.1x10^{13} (J)	*Accept 11 x 10^{12} or 11TJ* *Award 2 marks for a correct answer rounded to 2 sf*	2	A
	e	Recognition/application of efficiency formula 7476 MW or 7.476 x 10^{9} W	*Seen/implied* *Award 2 marks to correct answers given with units of kW, W or MW to 2 or more significant figures.*	2	A

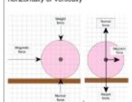
	f	Heat energy absorbed and re-emitted by greenhouse gases		1	A
	g	***Relevant concept from thermal physics identified [max 1]*** • melting of ice • convection currents • evaporation • kinetic energy of molecules in atmosphere ***Link between increased temperature/heat and its influence on the process in marking point 1, for example [max 1]*** • increased heat in the atmosphere increases the rate of evaporation of water ***Connection to weather, for example [max 1]*** • movement of air masses across globe • more energy in storms • more water/precipitation to fall from atmosphere • flooding • drought • rising sea levels	*Only award MP3 if MP1 and MP2 have been awarded*	3	A

2	a	Protons = 92 Neutrons = 143		2	A
	b	**Any correct statements from the list [maximum two]** • Protons ***or*** neutrons ***or*** protons and neutrons are divided (between the daughter nuclei) • The total number of protons in the daughter nuclei is the same as in U-235 • Two free neutrons are released • Total number of neutrons and protons is the same after the reaction as before		2	A
	c	One reaction causes another reaction to occur The released neutrons cause other reactions	*WTTE*	2	A
	d	More reactions mean more energy is released ***or*** each reaction in a chain reaction releases energy ***or*** too much energy is released Results in an atomic explosion **or** a nuclear melt down Emission of radioactive material into the surrounding environment ***or*** Nuclear fallout ***or*** harmful effects of radiation on living things ***or*** effects of fire/explosion on the surrounding environment	*Accept reference to heat in place of energy*	3	A
	e	1400-1600 million years or 1.4 - 1.6 billion years		1	C
	f	***Comment about the risk of radioactive material [max 1]*** • radiation is harmful to human health/living things/cells • radiation causes environmental damage/problems to agriculture ***Comment about storage concerns [max 1]*** • needs to be stored safely for a long time • needs to be stored securely for a long time • stays radioactive for a long time		2	D

3	a	How does the length of the wire affect the resistance of the wire?		1	B
	b	***If, Then:*** hypothesis links length and resistance ***or*** hypothesis links length and brightness of the bulb ***Correctly linked explanatory points, for example [max 2]*** • current is a flow of electrons • electrons have to travel a further distance with more obstacles in the way • electrons collide with more ions as they pass through a longer wire • as R=ρL/A, resistance is directly proportional to length	*Does not have to be correct for mp 1*	3	B
	c	 At least three of one material only, and no other material included At least three of one cross-sectional area only 5 different lengths of 2.5 mm^2 cross-sectional area silver only		3	B

	d	Independent variable is length ***or*** the only variable that should change is length ***or*** Silver is the only material with five different lengths ***or*** Five data points are required for sufficient data Material ***and*** cross-sectional area should be controlled	*WTTE*	**2**	**B**
	e	 All correct	*Switch and ammeter acceptable in either position*	**1**	**B**
	f	Evidence of using R = V/I Correct answer: 6.25 or 6.3 (Ω)	*Seen or implied* *Award 2 marks for a correct result*	**2**	**C**
	g	Data point plotted correctly (100, 6.3) Line of best fit has data points above and below line and correctly models the data	*On 100 on the x axis and between 6.2 and 6.4* *Proportional relationship, judge by eye, intercept at (0,0) not required to be seen*	**2**	**C**

	h	***A suggestion of a reasonable source of error, for example [max 1]*** • wires may heat up which changes the resistance/resistivity of wire. • voltage and current readings may fluctuate • voltmeter or ammeter may be inaccurate • measurement of length was inaccurate • clipping on probes/leads of voltmeter and ammeter may not be at exact length • diameter of wire may not be consistent throughout wire length ***A correctly linked comment about the effect on resistance [max 1]*** • resistance will increase (at increased temperature) • calculated values of resistance will be inaccurate • resistance will not be calculated for correct length • calculated resistance will not be reliable	*Do **not** accept increase the number of trials* *Award second point for a comment correctly linked to MP1*	**2**	**C**

4	a	(The law of conservation of) <u>energy</u>		**1**	**A**
	b	Magnetic force drawn horizontally to the right (any length) Normal force vertically up and weight force vertically down Normal force and weight force are equal in magnitude ***and*** no additional forces added either horizontally or vertically 	*Arrows must align with the center of the ball to be accepted* *Arrows can be directed into the ball or away from the ball* *Only award MP3 if MP2 has been awarded*	**3**	**A**
	c	Magnetic force increases as the ball approaches the magnet ***or*** magnetic field is stronger closer to the magnet Acceleration increases		**2**	**C**
	d	A		**1**	**A**
	e	A reference to magnetic energy being released ***or*** changes in the magnetic field cause additional kinetic energy		**1**	**C**

4	**f**		**11**	B

	1 mark	2 marks	3 marks	4 marks	*Notes*
1.V	Identifies height as IV ***or*** maximum height as DV	Identifies initial height as IV ***and*** maximum height as DV	Identifies initial height as IV ***and*** maximum height as DV ***and*** one appropriate CV		*Only requirement is to state using the terminology of IV, DV and CV. No need to explain further.* ***Accept*** *h1 and h2 in place of initial height and maximum height for IV and DV, maximum can be implied for the DV* ***Accept*** *for CV – strength of magnet, angle of incline of plane, material/mass/size of balls* ***Do not accept*** *"keeping equipment the same", "type of balls", "magnet", "temperature", "pressure", "acceleration due to gravity" as a CV.*
2.H	Attempt at a hypothesis linked to height	Testable hypothesis linked to initial height ***and*** maximum height	Testable hypothesis linked to initial height ***and*** maximum height with an attempted explanation	Testable hypothesis linked to initial height ***and*** maximum height and with an explanation linking to the conservation of energy or conversion of kinetic energy or (gravitational) potential energy	***Accept*** *a scientific explanation that correctly uses conservation of momentum to explain the hypothesis* *The hypothesis does not need to be correct to receive credit but full credit can only be awarded to logical answers based on scientific reasoning*
3.M	Attempt at a method linked to the collision between the balls	Method to change initial height and measure final height is outlined but is not detailed enough to be followed by another student	Complete method is described with measurements of initial height and maximum height, detailed enough to be followed by another student		*A method that does not include how to vary the IV is incomplete.* *Details on the number of trials and number of increments is not needed to award full credit*

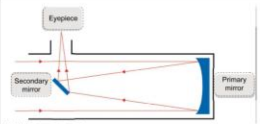
4.S	Mentions a relevant precaution linked to a specific hazard				***Do not accept*** *general considerations not linked to the specific investigation, e.g. wear a mask, tie hair back* ***Do not accept:*** *handle magnets carefully as this is not linked to a hazard, wear gloves unless this is linked to prevention of trapping fingers etc* *Accept: taking care not to trap fingers between the colliding balls/magnets* *Precautions regarding heavy balls rolling off the table onto feet/other objects*

4	g	Column headers for initial height and maximum exiting height including units Values for five increments of initial height shown Spaces for at least three trials of maximum height Column for average or mean maximum height	*Award marks for arrangement in columns or rows* *Values should be realistic, do not award MP2 if units in the column are repeated*	**4**	C

Initial Height of Ball / cm	Trial One Max Height / cm	Trial Two Max Height / cm	Trial Three Max Height / cm	Average Max Height of exiting ball / cm
5				
10				
15				
20				
25				

5	a	1.87 (s)		**1**	**C**
	b	$s=\frac{1}{2}at^2$ seen or implied 0.11(07266436) m s^{-2} ***or*** m/s^2 ***or*** 11(.07266436) cm s^{-2} ***or*** cm/s^2		**3**	**C** **D**
	c	Mass	*Do **not** accept weight*	**1**	**C**
	d	D		**1**	**B**
	e	***Accept any 2 statements from the list [max 2]*** • The line of best fit does not go through the origin • The line of best fit intercepts the x axis at 4A or there is no force when the current is 4A • The line of best fit intercepts the y axis at –2.7mN • Force is negative and positive ***or*** candidate uses 2 specific data points (to show that) doubling the current does not double the force ***or*** candidate uses 2 specific data points (to show that) F divided by I is not constant		**2**	**C**

	f	The rod will not move **or** The rod will not accelerate (because) there is no (net) force **or** (because) the force is not strong enough (to overcome friction)		2	C
	g	2.6 - 2.8 (mN)	*Accept a negative value for friction*	1	C

6	a	(White light is) made up of different frequencies **or** (White light is) made up of different wavelengths (different frequencies/wavelengths) <u>refract</u> by different amounts **or** (different frequencies/wavelengths) have different <u>refractive indices</u> **or** (white light is) <u>dispersed</u>		2	D
	b	 All labels in correct location		1	D
	c	3		1	D
	d	Galaxies moving away **or** A reference to red shift **or** Increased wavelength/decreased frequency of light emitted from galaxies	*Accept reference to stars instead of galaxies*	1	D

	e	A reference to the atmosphere or air on Earth ***or*** In space the telescope is in vacuum ***A specific effect caused by the atmosphere, for example [max 1]*** • scattering • refraction • light pollution • weather conditions • absorption	*Do **not** accept references to being closer to space*	2	D

7	a		13	D

The scientific challenges of launching a telescope into space

Mark	Descriptor	Notes
1	A statement	***The main themes to explore are:*** 1. Requires great technological innovations, extensive testing to ensure it can work remotely 2. Issues due to location / distance from Earth, including communication issues and the danger of impact with other objects in space 3. Thermal issues 4. Deployment issues, including coordinating the launching process and navigating to the required location ***Examples of statements*** • repair of space telescopes is challenging • a large diameter mirror requires advanced scientific innovation • harsh conditions in space. Nothing to protect the telescope from extreme high and low temperatures • once in deep space, the telescope must operate autonomously for long periods • the launching process is complex and requires precise calculations and coordination ***Examples of scientific support*** • the JWST's remote location at L2 (from video) could not be physically repaired (maintenance) • folding and unfolding mechanisms for 18 hexagonal mirrors would need to be created to fit into the rocket. (OR reference to precision alignment of mirror segments) • metal parts of the telescope can fuse together due to temperatures causing cracks and damage to the telescope • during testing, simulated conditions must include complexities such as vacuums, intense vibrations, extremely loud sounds, dense dust, extreme temperatures • autonomous communication links with earth are difficult to establish since ... the position of the satellite relative to the earth will be changing ... obstacles may block communication lines, time lags of signals due to long distances.
2	A statement with further support ***or*** Two statements	
3	Two statements with further support for one	
4	Two statements with further support for both	

The social or cultural implications of observations made with telescopes

Mark	Descriptor	Notes
1	A statement	***The main themes to explore are*** 1. Expanding human knowledge 2. Religion / philosophical 3. Artistic / literary creativity 4. Collaboration internationally ***Examples of social or cultural implications*** • it can expand our understanding of the universe • it can improve international collaboration • images observed will contribute to humanity's collective cultural heritage... • artists can draw inspiration from these images to create pieces that depict the mystery and beauty of the universe • observations may go against or support certain religious beliefs or conspiracy theories. • it can stimulate interest in science amongst a new generation of young people ***Examples of support*** • by observing the formation of stars and galaxies in closer detail (with infrared sensors), we will be able expand our knowledge of cosmic evolution • space telescopes can involve collaboration between countries (as with the JWST), which would lead to greater unity amongst nations • deep space images have been incorporated in artwork displayed in museums, clothing designs and tattoos • images from space telescopes can be used in church or religious groups to portray the wonders of God or support beliefs that there is extra – terrestrial life
2	A statement with further support ***or*** Two statements	
3	Two statements with further support for one	

The economic implications of spending government funds on a space telescope

Mark	Descriptor	Notes
1	A statement	***The main themes to explore are*** 1. High costs / budget 2. Economic growth due to tech advancement, industry innovation, or scientific discoveries ***Examples of economic implication*** • a large government investment for a space telescope • the development of a space telescope would lead to new tech or industrial innovations helping society ***Examples of support (do not need to be linked to the JWST directly)*** • space telescopes require nations to budget carefully. These funds could be used for other services such as healthcare and education • advancement in materials, optics, and other engineering solutions (such as folding mirrors) could lead to other innovations and applications enhancing the economy • the budget of the JWST does not seem high when it is placed alongside the annual budget of the US military (750 billion) and this money was spent over the many years of the project • countries that develop space telescopes can attract the best and brightest scientists to work for them, some of these scientists will relocate from overseas
2	A statement with further support ***or*** Two statements	
3	Two statements with further support for one	
4	Two statements with further support for both	

A concluding appraisal giving your opinion on the impact of the JWST

Mark	Descriptor	Notes
1	A simple conclusion	***Characteristics of a simple conclusion*** • the candidate writes a statement saying they are in support/against JWST in simple terms without an attempt to balance the positive and negative aspects which are evident
2	A concluding appraisal with reference to issues raised	***Characteristics of an appraisal*** • the candidate recognises the fact that there are positive and negative aspects to the impact of the JWST but makes a case for why they are in support/against the development by weighing up both sides

7	b	***Accept any two reasonable benefits, for example [max 2]*** • planetary data that was not available previously • picks up wavelengths specific to biomolecules ***Accept any two reasonable limitations, for example [max 2]*** • technique is limited in scope – can only be used for planets around small number of stars • no direct evidence of existence of alien life • cannot be sure if molecules were formed biologically or geologically A simple conclusion Conclusion is linked to benefits and limitations	*WTTE*	6	D

NOVEMBER SESSIONS

November 2016

November 2017

November 2018

November 2019

November 2020

November 2021

November 2022

November 2023

November 2024

(couldn’t find it bbgs 😔)

Subject Reports

GC Related Years *(Scientific & Technical Innovation)*:
May 2017 [3 to 5]
November 2019 [ ]
November 2022 [ ]

MAY SESSIONS

May 2016

Physics

Overall grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 13	14 - 27	28 - 45	46 - 55	56 - 65	66 - 75	76 - 120

General comments

The feedback received from schools overwhelmingly indicates that teachers judged the difficulty of the Physics assessment to be appropriate and suitable for candidates in MYP5. While it was noted that greater clarity regarding the topic list would be appreciated, the majority of candidates proved that they were able to access the material. Teachers judged the questions to be clear and examiners found few insistences of candidates being unable to discern the focus of the questions raised. The examiners found that candidate responses included information shared using media and onscreen stimuli and teacher feedback was generally positive, although the length of some videos was challenged.

According to the evidence of the candidate responses to questions it is clear that candidates, on the whole, found the time to complete the exam adequate. However, the increasing occurrence of blank responses to questions towards the end of the exam suggests that some candidates were not able to complete all aspects of the assessment. The examiners would suggest that teachers review the structure of the assessment prior to the completion of the examination and encourage candidates to structure their time so as to allow them to attempt all questions.

The areas of the programme and examination which appeared difficult for the candidates

The on-screen examination is designed to directly examine the four sciences criteria, with each of the criteria receiving equal weighting and candidates directed in the questions using the language of the published criteria. The middle section of the assessment examined the candidate's experimental skills as described by criteria B and C. It was clear from the candidate responses that, although they were familiar with requirements of the command terms, the language of the criteria was not always so familiar; this was particularly evident in those questions addressing criteria B and C.

Where candidates were prompted to establish that sufficient relevant data had been collected it was evident that this was not always well understood. The examiners would encourage teachers when preparing candidates to plan investigations in class using the phase 'sufficient relevant data'. Consideration should be given to the range of data collected, the increment between data points and the number of trials of each data point collected. In this way the candidates should be ready to tackle questions examining this strand of criterion B in the environment of the on-screen examination.

The use of scientific language was also an area in which the examiners found candidates lacking in preparedness when attempting some questions. The range of responses provided by candidates when they attempted to accurately interpret data and explain results using correct scientific reasoning typifies this. It was common to see candidates incorrectly describe relationships displayed by curved graphs as "proportional". Candidates also used terms like "exponential" where it was not possible to determine such a relationship from the data provided. In addition, some candidates were unfamiliar with the language, common in experiments prepared to assess criterion B, surrounding the description of variables: controlled, independent and dependent. In some cases candidates incorrectly planned experiments with multiple independent variables which would lead to invalid results.

The areas of the programme and examination in which candidates appeared well prepared

The questions towards the end of the examination were designed to assess criterion D, and these questions naturally call upon candidates to offer longer, essay style, responses to the situations posed. Both question 10 (examining the role of satellite communications) and question 11e (medical uses of imaging technology) were consistently tackled by candidates in such a way as to demonstrate they were familiar with the Impacts of Science criterion D. Candidates were able to assess the relative merits and impacts of the use of physics and technology to solve problems, and the ways in which these interact with the various factors. Teachers should, however, remind candidates to review the stimulus material carefully and note the direction of the questions posed. Often candidates attempted to examine the impact of all relevant factors, or in the case of question 11e, review all imaging techniques. In the timed environment of the examination, this prevented candidates having sufficient time to write responses with the necessary depth of reasoning for a higher mark to be awarded.

The strengths and weaknesses of the candidates in the treatment of individual questions

Question 3

Many candidates were able to superficially appreciate the need to control variables, although many struggled to articulate their understanding of the concept of terminal velocity sufficiently to understand what variables would the need to be controlled in order for an experiment to investigate surface area to be completed.

Question 6

Question 6 highlighted an inconsistent understanding of the requirements of criterion B, in particular the need to collect sufficient relevant data across an appropriate range of the possible data set. Many candidates only addressed the need to take repeated readings of the dependent variable.

Question 7

Again question 7 highlighted the fact that many candidates did not understand the need to record results across the range of possible readings; although this was taken into consideration when assessing candidate performance, teachers should be encouraged to emphasise this during the assessment of criterion B.

Questions 8 and 11

Questions 8 and 11 required candidates to demonstrate their knowledge of the electromagnetic spectrum. Some teachers questioned whether it was fair to expect candidates to have detailed knowledge of the spectrum. However, given its inclusion on the topic list, the examining team consider it reasonable to assume that any teaching of this area of physics would include knowledge of the relative placement of the regions of the spectrum by decreasing wavelength. It was evident from candidate responses that this was a suitable area of assessment. Candidates were less successful at displaying their understanding of the concept of change through their descriptions of kinetic theory and resistance in question 8.

Question 9 and 10

While questions 9 and 10 required candidates to display their understanding of physics in a situation that was deliberately unfamiliar, it was clear from the responses that candidates were confidently able to do so although again, question 9 highlighted the need for a better understanding of common terminology used to describe variables. Question 10 required candidates to reflect upon the impact of satellite technology and responses showed that they clearly understood the requirements of criterion D.

Question 11

This question focused on ionisation radiation. Most candidates were able to successfully examine the impact of science and weigh up the relative merits of differing forms of medical imaging but only the strongest candidates were able to offer convincing explanations for the process of ionisation.

Questions 12 and 13

Questions 12 and 13 focused on the global context for this examination and it was pleasing that candidates were able to respond positively to the stimulus of the application of physics, although many candidate responses lacked clarity and depth.

Recommendations and guidance for the teaching of future candidates

Candidates who were familiar with the on-screen environment found the examination easy to approach and were able to respond more quickly to the questions posed. It is of the greatest importance that teachers allow time for candidates to complete the familiarization exercises and understand the full potential of the on-screen tools available to them.

The on-screen examination is written to address directly the requirements of the published MYP Year 5 criteria, and as such candidates who are familiar with the language of the assessment criteria and the requirements of the strands of the criteria have a significant advantage. Preparation for approaching those questions designed to assess criteria B and C is best done through the use of typical laboratory based activities. Teachers are strongly encouraged to highlight to candidates those aspects of lab reports that meet the needs of the strands of the criteria; in particular the need to control variables and describe the role of these variables in the scientific method.

The key common vocabulary of science needs to be addressed in classrooms so that candidates are able to describe scientific process using precise and correct language.

May 2017

Physics

Overall grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-15	16-31	32-46	47-56	57-67	68-77	78-120

General comments

The feedback received from schools indicated that again this year teachers judged the difficulty of the Physics assessment to be appropriate and suitable for candidates in MYP5. Although it was observed that certain aspects of the topic list received greater emphasis than others. The assessment cannot cover all elements of the topic list in a single session; the topic list is designed to give teachers an overview of the physics which will be drawn upon when assessing the concepts detailed in the Sciences guide. The nature of MYP science teaching is rooted in conceptual understanding; this feedback also showed that teachers strongly felt that the assessment allowed candidates to display their abilities and understanding of the key and related concepts in physics. This observation was supported by the examining team. While this

feedback was useful, only a small number of schools had shared their experiences following the assessment. The examining team would strongly encourage all teachers to take the time to complete the feedback in future years.

In May 2016 in was noted that there was an increasing occurrence of blank responses to questions towards the end of the assessment suggesting that some candidates were not able to complete all aspects of the assessment. It was pleasing that in the May 2017 session this occurred less often suggesting that candidates attempted the assessment at a more realistic pace. As the number of marks drops from 120 to 100 in May 2018 it is hoped that this trend will continue.

The areas of the programme and examination which appeared difficult for the candidates

When assessing knowledge and understanding, a question will often review material related to the topic list in a context which is unfamiliar to the candidates. As such, the questions will include background information to help ensure that all candidates are able to address the requirements of criterion A. However, it is important for success in these circumstances that teachers help their candidates to understand the application of the command terms as they apply to criterion A. This is illustrated in question two: many candidates were unable to score high marks on the question as they were simply rephrasing the information shared by the stimulus material, rather than explaining the ideas using the knowledge they have gained in their classes. It is important to ensure that candidates are not only familiar with the topic list but also the direction that the command terms give to the type of answer required.

When attempting to describe relationships between experimental variables, candidates were unable to demonstrate they understood the meaning of the terms dependant and inversely dependant; often incorrectly using these terms to describe relationships that in part are merely linear in nature. The examining team would encourage teachers to use those investigations in class that produce quantitative data to further develop candidates' understanding of scientific relationships and the scientific vocabulary used to describe them.

The areas of the programme and examination in which candidates appeared well prepared

It was pleasing to note that candidates this session where able to follow the command term *calculate* correctly: the formula, the numerical calculation, final numerical answer and corresponding unit all often appearing in responses. A significant number of candidates were also able to correctly give answers to an appropriate number of significant digits. Many candidates are appropriately using the screen print function from the on-screen calculator to show their numerical working. This is to be encouraged and demonstrates that candidates have an increasing familiarity with the assessment software.

Criterion D questions were well answered again this year. It was pleasing to note that candidates were correctly lead by the language of criterion D; demonstrating a clear understanding of the requirement to *evaluate* through examining the merits of various opposing viewpoints. Candidates need to be familiar with that all of the various factors associated with

the impacts of science and it was clear this year that they were able to distinguish between ethical and social implications when evaluating completions including athletes aided by prosthetics.

The strengths and weaknesses of the candidates in the treatment of individual questions

Question 2

As noted in part 2, many candidates were stating the information given in the stimulus material rather than using their knowledge and understanding to describe and explain the significance of Herschel's discoveries. In addition, there were many candidates who were unable to explain why objects exposed to infra-red radiation became hotter. There was also considerable evidence that candidates did not have the necessary scientific vocabulary to express their knowledge, with suggestions being offered such as the thermometers were "absorbing temperature".

Question 3

While the ray diagram associated with a reflecting telescope was an unfamiliar situation for the vast majority of candidates, the application of previously taught material allowed many candidates to provide correct, or partially correct, diagrams. As noted in section 3 numerical questions such as 3f and 3g were generally well answered; however, teachers should remind candidates that when expressing numbers in standard form x10 should be used with the appropriate numeral as a superscript rather than using the symbol ^.

Question 4

All candidates had a sufficient knowledge of astrophysics to understand the context for the ideas assessed in question 4, without direct experience of the unfamiliar situation represented by the Kepler observatory although few candidates were able to suggest why planets could not be directly observed as they are non-luminous objects. Most candidates were able to interpret the information shared in the stimulus material concerning the habitable zone surrounding a star, in relation to liquid water. However, many candidates interpreted the requirement to formulate a hypothesis incorrectly, giving instead a question rather than a prediction with a scientific explanation.

Question 5 and 6

Many candidates were able to relate to the circumstances represented by the scenario described in the question, a dynamics trolley and stopping distance. Candidates generally had a clear understanding of the difference between independent, dependant and controlled variables as they related to the scenario and successfully identified them. Many were also able to correctly interpret the information shared in the graph related to the minimum ramp height and the value of the x-axis intercept. Although as noted in section two, the general trend in the data was often described incorrectly as proportional. While it represents one of the strands of assessment in criterion C, few candidates were able to outline the validity of the hypothesis.

The examining team would recommend that this strand of the criterion, and the language of the criterion, be given greater emphasis during investigations.

Question 7

Almost all candidates were able to correctly formulate a results table and understood the importance of common conventions related to: table headers, units, decimal place, and the need for a logical ordering of data. This question also gave various opportunities to candidates to demonstrate their abilities to describe relationships and collected data. As noted in section two, this was an area of significant weakness for many candidates, with many describing curved graphs as proportional and misunderstanding the importance of the intercept through the origin of a graph.

Question 8

While Young's Modulus was unfamiliar to almost all candidates, it was clear that the concepts explored in question 8 were well understood by many and the they were able to correctly interpret the data shared and offer suggestions to the implications in the development of prosthetics.

Question 9 and 10

As noted in section three, candidates were able to fully engage with the requirements of criterion D as explored in these two situations. Many were able to share full and well observed answers related to prosthetics as applied to these two very different scenarios.

Recommendations and guidance for the teaching of future candidates

Familiarization with the on-screen environment is of the greatest importance for the success of candidates; of particular importance is the need for candidates to be able to navigate the sections of the eAssessment that are exclusive to the sciences. The use of the calculator tool and sharing the screen print as part of a coherent answer is of the greatest importance in the Physics assessment.

Candidates need to be familiar with all aspects of the topic list, but teachers should make it clear to candidates that many of the scenarios in which this material will introduced will be unfamiliar. The ability to share their understanding of the conceptual nature of thinking in physics is of the greatest importance; candidates need to be reassured that it is expected that they will meet topics in the assessment that have not been discussed in their classes.

The assessment is designed to allow candidates to show their abilities against all four criteria, giving each equal weighting. Candidates who are familiar with the language of the sciences guide and the requirements of the strands of the criteria have a significant advantage. Preparation for tackling those questions designed to assess criteria B and C is best done through the use of common laboratory based activities; with emphasis placed upon the importance of evaluating not only the results, but also the process by which these results have been obtained.

May 2018

Physics

Overall grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 13	14 - 26	27 - 40	41 - 50	51 - 59	60 - 69	70 - 100

General comments

Teacher comments and feedback overwhelmingly suggested that the exam was accessible to the candidates, with questions appropriately addressing the areas of the topic list at a suitable level of difficulty. This overwhelmingly positive feedback was in concordance with experience of the examination team. However, it was disappointing that so few teachers took the opportunity to share feedback. This feedback is of great importance, assisting in both the final determination of grade boundaries and the design of future tasks and it is hoped that a greater proportion of teachers share their thoughts in future sessions.

This session saw far fewer questions left unanswered by candidates and given responses showed a greater degree of detail. The slightly shorter format adopted this year for the exam is evidently more appropriate, giving candidates sufficient time to complete the assessment.

The areas of the programme and examination which appeared difficult for the candidates

Candidates found many of the questions using command term *explain* challenging. The responses given often lacked the depth required to demonstrate that they could use the science they had been taught to good effect. While scientific literacy was much in evidence throughout the three sections, there were significant misconceptions shown regarding the role that humans play in the enhanced greenhouse effect leading to climate change. The depletion and subsequent recovery of the ozone layer was often linked to climate change demonstrating significant misunderstandings regarding the impact that science can have on our environment. This session, candidates were not able to consistently meet the requirements of the criterion B strand in which they are required to justify the collection of sufficient, relevant data. Task three required the candidates to discuss and evaluate information regarding the impact of the Three Gorges dam in China. Again, the application of scientific knowledge to assist the evaluation of this information was lacking from candidate's responses.

The areas of the programme and examination in which candidates appeared well prepared

The three questions assessing scientific knowing and understanding showed that candidates had a good understanding of those areas of the published topic list that were most closely targeted. Questions requiring calculations often showed the necessary working and included appropriate units.

A good understanding of experimental procedures and routine lab protocols were also much in evidence. This session, candidates showed a better understanding of the need for hypotheses to contain relevant scientific justification and a quantitative element when appropriate. A good understanding of the different experimental variables was also in evidence, with candidates able to identify independent, dependent and control variables consistently.

Task three showed that candidates are now prepared to quickly evaluate information regarding the impact of science. While they are not always using science to justify their thinking, there was greater evidence of candidates being willing to state their own opinion on the matters addressed.

The strengths and weaknesses of the candidates in the treatment of individual questions

Question 1: It was clear from the responses that the topics of magnetism, electromagnetism and transformers were familiar to candidates. Overwhelmingly, candidates were able to select the correct diagram showing field lines around a bar magnet and were able to perform a simple calculation using the transformer equation. Candidates found the calculation used to determine the efficiency of a non-ideal transformer more challenging; although commonly those able to calculate the power of an electrical circuit were able to calculate efficiency. Given the familiarity of the topic to all candidates, it was surprising how few were able to offer a simple explanation as to the operation of a transformer in terms of a changing magnetic field and alternating current.

Question 2: Candidates found this question straightforward and the responses demonstrated a good understanding of energy, forces and Sankey diagrams. While most candidates were able to successfully identify the definition of velocity and kinetic energy, a significant number were unable to select the definition of mechanical power. This question also required candidates to *calculate* a value of gravitational potential energy and convert the answer into kilojoules. The command term *calculate* requires candidates *to show the relevant stages in the working*. It was surprising how poorly many candidates showed their working and how few candidates were able to understand that the conversion to kilojoules required an additional step.

Question 3: This question required candidates to explain their scientific knowledge. Most candidates were able to interpret the given information to identify convection as the process utilized in the scenario and were able to explain the underlying principles that explain convection. Far fewer candidates were able to apply the principles of kinetic theory to explain cooling by evaporation.

Question 4: Most candidates were able to successfully write a hypothesis, with many attempting to link the variables quantitatively using a scientific explanation. While identification of variables was also not a challenge to most candidates, few were able to describe the need to record results for at least three trials and at least five different increments of the independent variable. The final two parts of this question required the candidates to determine and use the constant

found from a graph. Most candidates were able to correctly state the constant, however, few were able to adequately demonstrate how this had been determined using data from the graph. While almost all candidates who had calculated a constant attempted to determine the area of the hole which would lead to a fill time of 90 seconds, most candidates miscalculated to produce an area of $8cm^2$, or greater. It is important that candidates are reminded of the importance of checking their answers against the likely outcome of the calculation. A quick check would have allowed them to realise that this answer is larger than any in the question and, as such, is significantly too large.

Question 5: Almost all the candidates were able to engage with the requirements of planning an experiment and there many well written responses. Most candidates were aware of the need to describe, rather than simply state, variables involved in the scenario. While candidates did offer equipment lists, few suggested equipment that would be precise enough for measurements to be made and fewer still justified their choice of equipment. Methods were generally reasonable and were judged to be easy for another candidate to follow, although candidates often tended to repeat themselves with long lists of rudimentary instructions. It was pleasing to note the overwhelming number of candidates who suggested that repeated trials were important in the process. It was clear that those candidates who offered the strongest responses were those for whom writing and preparing plans, assessed against criterion B, was common place. These candidates wrote well-structured responses, following a clearly understood procedure, which allowed them to meet all the requirements of this question.

Question 6: Almost all candidates engaged fully with the scenario and were able to attempt the questions asked. However, it was clear that there were profound weaknesses in candidates' understanding of data analysis. While most candidates were able to arrange the data from the experiment into a simple table, there were many recurring errors. The most common errors included inconsistent decimal place, results not recorded in the correct order and units appearing alongside the numerical values. Again this year, candidates were challenged when determining the type of relationship shown by the data. While many more candidates were able to state the characteristics of a proportional relationship, few were able to apply this knowledge to correctly identify and explain why data did not follow the given trend.

Question 7: In responses to this question, candidates showed significant misconceptions regarding the role that named gases have in relation to climate change. Many candidates discussed the concern that burning fossil fuels would release carbon dioxide consuming all of the world's available oxygen, in addition to the concern that carbon dioxide production damages the ozone layer. While these matters may not always fall into some aspects of day-to-day physics teaching, when designing tasks used to address the requirements of criterion D, the role of various gases and their contribution to climate change should be addressed to help alleviate these widespread misconceptions.

Question 8: This longer response question allowed candidates to engage with the May 2018 Global Context: orientation in space and time, targeting the impact that science has on natural and human landscapes and resources. The focus of this question was hydro-electric power and the implications of using this application of science to solve the problem of electricity generation. It was encouraging to note that candidates were able to fully engage with this situation and many showed a nuanced understanding of the situation and were able to support their arguments with the information shared. However, it was particularly evident this session that

some candidates were copying and pasting large sections of the information shared in the question, without engaging in the evaluation of the information or discussing the use of hydroelectric power as it pertained to the material. Questions such as this assess similar skills to those assessed in the classroom against criterion D. While candidates are not penalized in the assessment for copying data shared; they only receive marks where they have engaged in discussing and balancing the arguments raised by this material.

Recommendations and guidance for the teaching of future candidates

Candidates with experience and understanding of the four Sciences criteria are able to best perform across the three tasks in the assessment and future classroom teaching which has a focus on the MYP objectives is to be strongly encouraged.

Each question contains a commend term and candidates familiar with these are best placed to give the appropriate answer in the exam.

The language of the MYP Sciences criteria is drawn on throughout the assessment; classroom activities which also utilize these terms allow candidates to develop a thorough understanding of the requirements of the assessment.

Candidates need to be given the opportunity to explain complex scientific concepts using simple models. The example this session, where candidates where asked to use the kinetic theory to explain cooling by evaporation, would make an excellent starter activity to a class following the teaching of this concept. In this way candidates develop the experience of using ideas to explain everyday phenomenon.

Candidates need to develop a more sophisticated understand of the need for repeated trials, appropriate increments and range of data when designing an experiment. In this way they will be able to better explain whether or not sufficient data has been collected.

May 2019

Physics

Overall grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 31	32 - 43	44 - 52	53 - 62	63 - 71	72 - 100

General comments

Candidate and teacher feedback shared following the assessment session was overwhelmingly positive. Teachers considered the assessment accessible and the level of difficulty appropriate to the candidates in their schools. Candidates also found that the on screen environment and the increasingly familiar experience of the on-screen assessment allowed them to show their experience of the skills developed in their MYP physics class. This feedback was supported by the session's team of examiners. It was clear from responses that candidates are increasingly familiar with the command terms and using these to help guide their responses. Better use of the various on-screen tools is being displayed across the range of responses. This is resulting in more candidates correctly presenting their responses using the equation editor, incorporating scientific notation and accurately displaying information in tabular form. Schools are therefore encouraged to continue to allow candidates to familiarize themselves with the on-screen environment before the assessment session. However, the development of these skills needs also to be encouraged throughout the five years of the programme through formative and summative assessments of all four criteria.

The areas of the programme and examination which appeared difficult for the candidates

Again this year, the questions candidates found most difficult were those requiring them to use the commend term explain. While these questions inevitably target those skills assessed through the 7-8 band of the sciences criteria, few such questions went unanswered. However, candidates found it challenging to offer explanations that incorporated the use of correct scientific terminology, with explanations often being superficial, relying on generalizations and incorrect terminology. Justifications of hypotheses and deeper understanding of why experimental procedures are followed also proved difficult. While a broad coverage of those skills assessed by criteria B and C was evident, this did not extend to a thorough awareness of the reasoning behind the choices of experimental design and structure. The impacts of science on the broad range of factors included in the guide were not evident, the political factor was poorly addressed by candidates in comparison to the environmental. While candidates were able to address the environmental impact of science with more fluency, again this year many candidates framed a response that focused on climate change and the enhanced greenhouse effect, which was not the focus of the question.

The areas of the programme and examination in which candidates appeared well prepared

Aside from the evidently growing familiarity with the on-screen environment, it was clear that candidates had developed a thorough understanding of the topic list including the fundamental ideas and concepts. These included applying these concepts to contexts that were undoubtedly unfamiliar to the majority of candidates. Teachers are encouraged to continue to expose candidates to contexts that are unfamiliar when designing formative and summative assessments so that in the eAssessment environment they can tackle these questions with confidence. Experimental design and structure also proved an area of strength for candidates who were able to respond to questions that dealt with the broad spectrum of criteria B and C. Understanding that scientific developments have an impact on the world was broadly shown to also be a strength, particularly when considering the impact on the environment.

The strengths and weaknesses of the candidates in the treatment of individual questions

Question 1

It was clear from the answers shared by candidates that this was a familiar area of the topic list. Most candidates were able to identify the means of heat transfer from the direction of travel, although some candidates mistakenly assumed that a convection current would begin with warm air travelling at right angles to the heat source. Identification of kelvin or celsius as the unit of temperature was straight forward for most candidates, although joules as the unit of heat energy proved more difficult. The final part of this question required an explanation of insulation; while almost all candidates attempted this part of the question, many answers lacked the degree of specificity required by the command term explain. Few candidates were able to explicitly link

the features named in the question with the mechanism of heat transfer they were designed to prevent and corresponding explanations were often superficial.

Question 2

The action of a photocopier was an unfamiliar context to explore the action of electrostatics for the majority of candidates. While most candidates were able to build a simple Bohr model of a helium atom using protons, neutrons and electrons, few were able to identify the force holding the electrons in orbit around the nucleus. From responses given by candidates it was evident that, as with heat transfer, this was an area of the topic list with which candidates were familiar. However, explanations offered were often simplistic and lacked the correct scientific terms required. In addition, many candidates were challenged by part d, which required the annotation of a diagram with force vector arrows.

Question 3

Given that again much of this question was set in a context that would be unfamiliar to candidates, it was pleasingly answered by most. The recall of information related to the areas of the solar system and forces on the topic list. The overwhelming majority of candidates were able to label bodies in the solar system and to identify the equations needed to solve the associated mathematical problems indicating that candidates were familiar with the concepts encountered. However, as with question two, many candidates found it challenging to correctly equate the magnitude of a force arrow to its length. Many weaker candidates, while able to identify the correct equation, were unable to rearrange it successfully to determine the correct numerical answer.

Question 4

This question allowed the candidates to demonstrate their understanding of experimental design and focused on the procedural elements of a physics experiment that would generate good quality data. Almost all candidates were able to use the graph to interpret simple data, but a significant proportion of candidates chose to give their units using incorrect or calculation notation. Only those who presented units correctly received marks in this question. Most candidates were able to identify the three different types of variable and were able to draw a simple prediction based upon the stimulus material. However, it was noticeable that many candidates did not attempt to offer a scientific explanation to accompany this predication based on the familiar concept of balanced forces. Most candidates were able to explain why it was necessary to choose equipment that allows for the control variables to be managed. However, few were able to explain why the range of data collected is of equal importance. Most candidates also stated a reasonable number of trials for the experiment, a common feature of classroom experimental procedure. However, few candidates were able to correctly explain the significance of multiple trials. Those candidates that attempted to justify their choice often incorrectly stated that repeated readings would improve the accuracy of their data.

Question 5

This question allowed candidates to show their understanding of the way data can be used to test a hypothesis and, as with question four, it was clear that the fundamental routines of

experimental procedure were familiar to most candidates. The majority of candidates were able to form a data table and to transfer data into a recognised format; this included correctly labelling table headings and the correct presentation of numerical information. Fewer candidates were able to work with a given formula and justify the need to transform data to test a given hypothesis. It is important that candidates are exposed in class to relationships that need to be manipulated and that they develop an understanding of the importance of linearization in physics. Again, as with question four, few candidates had more than a superficial understanding how to improve the reliability of data with many equating reliability with accuracy.

Question 6

The first part of question six allowed candidates to further display their understanding of data and relationships and to demonstrate their understanding of the ways experimental design can be improved. While most candidates were able to state the format of the graph that should be drawn to display continuous data, only the most able candidates were able to describe the features of this graph with many candidates mistaking a line of best fit for a straight line. Many candidates struggled to offer improvements to the experimental design and there was often a clear misunderstanding of the difference between improvements and extensions. Those candidates that did offer improvements often gave perfunctory justifications for these improvements, as with question five, showing only a superficial understanding of the underlaying reasons for the choices they routinely make in laboratory experiments.

Question 7

The first two parts of question seven required candidates to apply their understanding of ionising radiation to its application in medicine. Most candidates where able to apply their knowledge of half-life and give reasons why long exposure is undesirable. The final part of question seven required candidates to examine the impact that a range of devices might have on the production of radioisotopes in a country of their choice. It was evident that candidates were able to describe both advantages and disadvantages of their chosen device in very general terms, however few candidates were able to share answers that applied this to a specific country. Many candidates did not offer any local context and those that did often failed to make links that were country specific. Better responses showed candidates planning out their answers and structuring them in such a way as to offer clear delineation of their thinking.

Question 8

It was evident that most candidates were comfortable tackling the extended response question examining nuclear medicine. However, it was clear that many candidates were not fully engaged with the requirements of the question and, as such, did not frame their answers to look at the use of nuclear medicine rather looking at the nuclear industry in general. Schools should encourage candidates to read the question carefully and ensure their response focuses on the requirements of the assessment. Many candidates focused their answers on chemotherapy which, while receiving no marks, is an understandable conceptual error. It was also clear that candidates were more comfortable focusing their answer on the environmental implications rather than the political implications, which could reflect the emphasis schools place on the environment when looking at the factors associated with criterion D. It was worrying

how many candidates focused their response on the incorrect environmental impact of nuclear medicine as a producer of CO_2 and the way it contributes to the enhanced greenhouse effect.

Recommendations and guidance for the teaching of future candidates

Candidates with experience and understanding of the four Sciences criteria are able to best perform across the three tasks in the assessment and future classroom teaching which has a focus on the MYP objectives is to be strongly encouraged. When addressing assessments in the classroom, the following are recommended:

- Formative assessment tasks that allow candidates to develop explanations of studied phenomena are encouraged. The commend term explain is one that candidates are familiar with, but not one they are able to correctly address.
- Teachers need to spend time ensuring that candidates are taught the reasoning behind the experimental method, rather than simply following standard procedures. While repeated results will improve the reliability of data collected, it will not alter the accuracy. Such distinctions may be subtle; however, they are not beyond the comprehension of MYP5 candidates. Candidates therefore need to be explicitly taught these concepts.
- Candidates need to be exposed to all of the factors listed on page 10 of the guide on which science may have an impact. While the environment may often be an obvious choice for candidates to examine in science, the other factors carry equal importance and time needs to be spent unpacking these if candidates are to have the confidence to employ these ideas in the assessment.

May 2020

May 2021

Physics

Overall grade boundaries

Please note, that the boundaries set during the May 2021 session reflect the exceptional circumstances and challenges faced by schools during the pandemic. If using this year's examination to determine future students' grades in mock examinations, we recommend you consult the boundaries that were set in previous sessions.

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 29	30 - 44	45 - 55	56 - 67	68 - 78	79 - 100

General comments

The feedback given by schools and teachers was overwhelmingly positive. Although some candidates referred to a lack of time to complete all of the questions, and to the difficulty of some of the elements of the exam, it should be noted that the majority of candidates were able to complete all of the elements required. The higher level of difficulty of some of the questions should be expected, as any assessment should include varying levels of demand.

Candidates showed familiarity with the tools of the on-screen exam and were able to present their work in the correct format throughout. It is expected that candidates will show equations and units in the correct format, this involves the use of superscripts when appropriate. It is also expected that candidates are able to access the formula sheet, the periodic table, and to use the on-screen calculator as part of the assessment.

The areas of the programme and examination which appeared difficult for the candidates

The organisation and presentation of data in tables seemed to cause problems for a number of candidates. This was slightly surprising as formatting tables is usually considered to be a low-level skill. However, the question in this year's assessment was slightly trickier than in previous years.

Relatively few candidates were able to apply scientific knowledge and understanding to explain a hypothesis at a complex level. Candidates found the explanation of why a ball accelerates down a ramp challenging. In addition to this, few candidates were able to explain changes to the force of air resistance when surface area increases by reference to the particle model.

Many candidates simply need more practice with the graphical analysis of relationships. If 'y is directly proportional to x', then the graph is a straight-line that goes through the origin. When a straight-line does not pass through the origin (hence, it has a significant y-intercept), the variables are only linearly related. Only the strongest candidates were able to make the link between the formula of a relationship and its representation on a graph. Not all relationships in Physics involve finding the gradient from a directly proportional relationship and in question 6 candidates were required to find the intercept from a relationship that was processed to a linear form. Similarly the processing of data and the deduction of units from unfamiliar relationships was found to be challenging by many.

The areas of the programme and examination in which candidates appeared well prepared

The majority of candidates gave a clear and structured plan for the scientific investigation that was the subject of question 5b. The standard of the extended response planning questions has improved, and it was pleasing to see how the structure of the candidate responses clearly matched the requirements of the task.

The extended responses for question 8 were also of a good standard on the whole. Most candidates were able to respond to the context of the question to give interesting insights and opinions on the use of drones in surveillance. The structure of these extended responses seems to be improving and are matched to the requirements of the task. The responses to 7b were similarly good.

Candidates, on the whole, seemed to be comfortable with the identification of the variables from a scientific investigation, as evidenced by question 4. Also, the suggestion of the variables for a follow-up investigation was well done.

Most candidates were comfortable in performing simple calculations involving the selection of the correct formula, for example when calculating kinetic energy of the moving car in question 3.

The strengths and weaknesses of the candidates in the treatment of individual questions

Question 1

1a was designed to be a low demand question but it was surprising how many candidates thought that radio waves travelled at a different speed to light waves in a vacuum. Also, identifying the phenomenon of diffraction in 1b was not done successfully by a number of candidates. The calculation of time in 1c was relatively well done on the whole but the use of scientific notation caused problems for some. 1d had a broad range of acceptable answers. Candidates that were familiar with the use of radio waves in technology were capable of answering this question comfortably although it seemed many candidates were not. Some candidates simply repeated the information given in the question to no avail.

Question 2

2a was relatively low demand and most candidates were successful in answering it. Some candidates selected 63 as the number of electrons seemingly without recognising the end of the sentence as being 'in the nucleus'. 2b had mixed levels of success. It seemed that a number of candidates were not familiar with beta emissions being high speed electrons. A number of candidates did not select the correct path for the radiation which meant that they couldn't get any marks for this question. 2c was well done and most candidates were able to use the graph to identify the half-life of the isotope correctly. The responses to 2d were a little mixed and some candidates mistook the question to be about imaging – this has been the subject of previous Physics MYP questions. However, the question specifically referred to the treatment of medical conditions such as cancer.

Question 3

3a was a low demand question and was very well done by the candidates. 3b was more challenging and fewer candidates were successful in this question. Further practice with the use of the kinematic equations may be of benefit here. Rounding the answer to 3 significant figures was not done successfully by all candidates, even if they had calculated the correct answer. The concept of wasted energy was not clearly communicated by all candidates in 3c despite different terminology being allowed - (energy not readily available for performing work, energy that cannot be used by the car, energy that is not useful etc.) The possibly unfamiliar context of 3d was challenging for some although on the whole this was done well. 3e required the candidates to state that the battery could be used to power the car but many candidates simply repeated that the battery was recharged without stating what purpose this was meant to serve. 3f had many responses including the correct reference to climate change but not all of these correctly linked the gas carbon dioxide to this phenomenon.

Question 4

4a and 4b were low demand questions. However, candidates should always read the questions carefully. It is clearly stated that the candidate decides to change the distance that the ball rolls and measure the time taken. Despite this, some candidates referred to the angle of the slope as the independent variable. 4c was not answered successfully by many candidates and this was surprising given the demand of the question. All that was required was a correct reference to Newton's laws and the identification of the unbalanced force that was present. Some candidates communicated that this situation was an example of a constant state of motion and referenced Newton's first law but this is clearly incorrect as acceleration is a changing state of motion. 4d was designed to be more challenging and some candidates did well here but it is clear that other candidates need more practice in the linearization of functions that would not normally give a straight-line graph. The distinction between a proportional function and a straight line or linear graph was made in the marking the question and candidates should be accurate with the terminology that they use here. For 4e, rounding caused problems as did using appropriate units, these are skills that should be routinely practised as part of practical work. 4f required a specific response to the limitations of the use of the water clock. Candidates that referred to a lack of accuracy or precision were given no credit as this is a stock response

which doesn't meet the requirements of the question. 4g and 4h were well done by the majority of candidates.

Question 5

For 5a the majority of candidates made a valid hypothesis that referred to air resistance as the explanation. However, relatively few candidates made a correct reference to particle theory to explain this hypothesis in detail. It should be emphasised that correct terminology should be used with an explanation so the idea of the collisions of air particles with the surface of the parachute is communicated clearly.

5b was well done on the whole and candidates were able to write down well-structured experimental plans with clear sections that met the requirements of the task. The best responses for 5b included valid justifications for the 2 control variables and quantitative information in the method that made it more detailed and descriptive. It should also be noted that if repeated trials are performed then it should be clear what is to be done with these measurements in the processing. There was one point awarded for a safety precaution but this had to be relevant to the situation – e.g. precautions when working at height or when using cutting equipment.

Question 6

Question 6 involved the collection of data and the processing of this data to determine the focal length of a lens. There is no requirement for the candidates to have prior experience of this investigation, or to have any knowledge about the phenomena involved, to complete the question. Some candidates seemed to be uncomfortable in attempting data collection for an investigation with which they may be unfamiliar but following instructions and the application of knowledge and skills to unfamiliar situations is a vital skill. In 6a a number of candidates gave the scale reading correctly (42.8cm) but didn't use this to find the distance the lens by subtracting 30cm from it. 6b involved the organization and presentation of data in a table. This is a basic skill and to make it non-trivial there were some things that needed to be corrected, such as mixed units and inconsistent decimal places. Relatively few candidates were able to get all the marks for this question. 6c involved some data processing. Most candidates wrote 5.87 but a number of candidates gave an incorrectly rounded version of f and incorrect units for the last column. Most candidates identified the anomaly in 6d. In 6e candidates needed to ignore the anomaly and to consider the numbers of points above and below the line to get the correct answer of C. 6f required the candidates to use the intercept of the graph to find f – this information was given in the question. Some candidates used a gradient calculation, even though this was not what was required. Relatively few candidates were able to achieve full marks for this last question.

Question 7

7a was generally well done. 7b was also well done on the whole, although some candidates failed to give a clear conclusion to the discussion. Also it was notable that the more detailed

responses here made specific reference to the situation of delivering medical supplies and the advantages and disadvantages linked to this particular situation.

Question 8

The use of drones in surveillance was a context that gave candidates the opportunity to respond in different ways. A number of candidates made interesting and insightful discussion points. Across the cohort there was a wide variety of responses and different ideas and opinions that were communicated. The best responses included specific and detailed references to how drones can be used in environmental monitoring. Some responses were not balanced in terms of positive and negative implications when it came to the social and political implications and this limited the points that were achieved by these candidates. Candidates should be reminded that a discussion should have two sides. Higher-level responses recognised the need for some kind of regulation regarding the use of drones in surveillance and suggested scenarios in which their use would be appropriate.

Recommendations and guidance for the teaching of future candidates

Some candidates seemed uncomfortable with the application of the skills of data collection, data processing and analysis when performing an investigation that they haven't seen before. There are a number of classic labs that are performed in physics classrooms around the world, for example; Hooke's law, the period of a pendulum, Ohm's law etc. but candidates should develop the skills required to be able to transfer to new situations rather than learning the process of performing certain investigations. Candidates should be given experience with different kinds of data and different kinds of relationships in order to practice their processing and presentation. The presentation of data in tables and graphs is something that is best learned through classroom experience and practice.

Explicitly teaching the skill of graphical analysis would benefit candidates. More specifically, teaching how to linearize data and the difference between a linear relationship that has a y-intercept and a proportional relationship that has no y-intercept. Not all relationships in Physics are direct proportion with a gradient that refers to a constant of proportionality. Candidates should be given practice with powered relationships and inverse proportion so that they can learn how to linearize different data sets. Graphical analysis should involve the analysis of an intercept as well as the calculation of a gradient. Candidates can be given a task similar to question 6 in which they collect data, process the data and find a result based on graphical analysis in a classroom activity.

Candidates will become stronger in their experimental design questions if teachers create an inquiry-based learning environment where teachers provide guidance and let candidates design/select their own procedures. Remind candidates that they need to list each piece of equipment that would be required to make measurements of the key variables. Candidates need to reflect on what kind of data they will record and what equipment is needed to make the appropriate measurements. Sometimes thinking of the end result data table is helpful before listing equipment.

The use of scientific knowledge and understanding to explain a hypothesis is something that requires practice. It is clear that candidates can formulate a testable hypothesis but the statement of 'what' is less challenging than making the link to 'why'. Candidates should be given the opportunity to explain certain phenomena, or stated hypotheses, without being told the principles that they should use to make this explanation. This is part of the development of the inquiry-based learning environment that was mentioned previously.

Sometimes candidates will answer questions with stock responses such as using the terms "accuracy" or "precision". It is fine to use these terms but they need to be specifically referenced to details about the experiment or scenario. Too often candidates fail to elaborate and apply their knowledge to the specific situation. In general, candidates need to work on justifying their claims with the evidence provided. For example, candidates will know which is the correct graph but struggle to provide the correct evidence for their choice.

Further practice with the use of the kinematic equations is suggested, together with developing an understanding of when these equations are appropriate.

Candidates should be reminded to elaborate beyond what is given in the question. Often candidates tend to restate given information but they need to elaborate and show comprehension of the concepts applied to the situations and give further details to be awarded credit.
With essay questions where candidates are required to discuss and evaluate the advantages or disadvantages of a scenario, candidates need to practice answering these types of questions and answer them correctly. Sometimes candidates restate facts that are given (recycling information that is already given in the video or script). Candidates need to realize that this gives minimal reward. Their responses need to show interpretation with appropriate justification. It is helpful for candidates to be taught the CER (Claim Evidence Reasoning) approach. They can use certain facts to make a claim but they need to justify their claim with evidence. The evidence is used to justify their claim with appropriate reasoning. It is crucial that candidates need to justify their identified advantages and disadvantages. It also helps when candidates write their responses in a logical order (a paragraph for the advantages and a paragraph for the disadvantages). Candidates need to practice explaining physical principles linking science to the scenario. Simply recycling information that is given in the question is not enough.

May 2022

Physics

Overall grade boundaries

Please note that the boundaries set during the May 2022 session reflect the exceptional circumstances and challenges faced by schools during the pandemic. If using this year's examination to determine future students' grades in mock examinations, we recommend you consult the boundaries that were set in previous sessions.

Grade:	1	2	3	4	5	6	7
Mark range:	0-13	14-27	28-44	45-55	56-65	66-75	76-100

General comments

The on-screen examination this year involved interesting and relevant contexts for the candidates to explore and apply their knowledge of Physics. It was pleasing to see the way in which the candidates responded to the material as they clearly engaged with the contexts. Most candidates were able to respond to all of the elements of the examination and to make meaningful contributions throughout. The aim of the examination is to give candidates the opportunity to showcase what they have learned about the subject and the skills that they have developed. There were some excellent examples of work produced by candidates, this is pleasing to see given the disruption that has taken place throughout the last couple of years.

The areas of the programme and examination which appeared difficult for the candidates

A number of candidates struggled with graphical analysis and the interpretation of relationships. Candidates seemed to have problems understanding how to justify an inverse relationship between two variables graphically. Many could only state that as one variable increases the other variable decreases. However, proving it mathematically through logical argumentation with numerical evidence was quite difficult for many candidates. Hence, some candidates had trouble evaluating the evidence provided by data sets. Many candidates did not recognize that a slope has units or don't know how to determine those units. In addition to this, the more fundamental skills of plotting points on a graph and reading data from a graph was seemingly challenging for a number of candidates. This was evident in question 4 where they had to plot a point and draw the line of best fit. It was also evident in question 1, where a pair of points was required to calculate the distance using data from the speed-time graph. Many candidates just used one data point or read the data from 2 points incorrectly.

When structuring their essay in response to question 8, relatively few candidates explained the technical challenges of planning a crewed mission to Mars using their scientific knowledge and understanding. Many candidates wrote extended sections in which political and economic discussions were presented but they wrote relatively little about the many physical considerations and challenges involved. Only the very strongest candidates could reference relevant challenges and relate these to ideas about forces, gravitational fields, waves and energy.

The mixing of ice cubes in salt water and regular water revealed a number of misconceptions about heat, convection, condensation, density, and buoyancy. A number of candidates struggled with applying the principles of convection currents (or lack of convection currents) due to the change of density of the fluid.

Some misconceptions were evident with the application of Newton's first law to question 1. Some candidates seemed to believe that the motion of the train is always in the direction of the net force applied to it. Many candidates did not explain that when the train was moving at a constant velocity, the net force is zero. Thus, the drag force and thrust force are equal.

Many candidates struggled with correctly explaining why high voltage can reduce power loss. There were all sorts of misconceptions such as assuming the resistance would increase when the voltage across the power line was increased. Candidates struggled to make the link between an increased in voltage leading to a decreased current, meaning fewer electrons dissipating less energy.

The areas of the programme and examination in which candidates appeared well prepared

Most candidates were familiar with the units for common quantities such as force and time. The conversion of units, such as seconds into minutes, was also quite well done.

The calculation of average values from a set of repeated measurements was well done.

The manipulation of animations to collect data was also well done.

Most candidates could perform calculations using kinematics equations (such as speed=distance/time) and normal mathematical routines such as finding the average of three values.

The majority of candidates displayed a clear structural understanding of how to plan a scientific investigation given a relevant context for an investigation. They were able to choose and classify the key variables (independent, dependent and control variables) and to outline a procedure for the collection of relevant data. Question 6(d) was generally well done; it was clear that candidates have been taught explicitly how to answer this kind of question and there was a logical structure present in the majority of candidate responses. However, this was noted to be less consistent with the French language responses, in particular when outlining variables.

The majority of candidates could organise and present data in a table although there were some common errors with rounding and the presentation of inconsistent decimal places in a column.

The extended response question relating to putting humans on Mars was well done and there were some very interesting and insightful responses in evidence. A large number of candidates were able to discuss implications by drawing on their knowledge and wider studies and to explore both sides of an argument before presenting a concluding appraisal.

The strengths and weaknesses of the candidates in the treatment of individual questions

Question 1

Most candidates correctly identified the units of force. Those candidates who got it wrong typically mixed up the units of energy (joule) with force (newton). The majority of candidates could label the forces acting on the train using a free body diagram. However, a number of candidates had challenges relating the concept of equilibrium of forces to motion at a new speed. Very few were able to recognize that the drag force and thrust force are equal when moving at a constant velocity. Some candidates thought the newly redesigned train was simply more efficient but didn't recognize the air resistance was smaller. In 1(d), most candidates understood what to do in order to calculate the distance travelled by using the speed-time graph, either by calculating the area under the graph or by utilising an appropriate kinematic equation. However, a number of candidates simply performed a speed x time calculation, which in this case is inaccurate due to the train undergoing deceleration in the tunnel. Two data points were required to obtain an accurate answer. 1(e) was generally well done.

Question 2

It seemed that a number of candidates found this question challenging. Some candidates were unable to respond to elements of the question and there were quite a few misconceptions evident in candidate responses. 2(a) was designed to be quite a low-demand question but a number of candidates did not know that 100% efficient means that the power input is equal to the power output. In 2(b), candidates were able to calculate the voltage of the output using the data in the table and a P=IV calculation, alternatively they were able to do a calculation using the numbers of turns shown in the diagram; both answers were accepted. The transformer equation and the power equation are given in the equations list as part of the on-screen examination package. It would be helpful to remind candidates to write down the relevant equations before the substitution phase in order to get partial credit in the case that they make errors with the calculations later on. A number of candidates performed a calculation that assumed that the primary coil and the secondary coil had equal resistances. This is a misconception which is based on flawed logic; therefore it received no credit. More candidates were able to perform the calculations required to answer 2(c). Question 2(d) was conceptually quite difficult for the candidates to grasp. Despite the earlier questions relating to efficiency and to power being conserved, a number of candidates stated that the high voltage of electricity meant that more power was delivered. Not many candidates could explain that the current is reduced when the voltage is increased and that this reduced energy loss in the wires.

Question 3

Candidates will have been taught about the processes of thermal energy transfer but a number of candidates encountered challenges in applying their knowledge to everyday observations that are best explained by these processes. The investigation that was the focus of this question could be performed quite easily in a home kitchen but this proved to be a surprisingly difficult question for the candidates to answer. 3(a) was well answered with few exceptions, showing that most candidates knew the definitions of radiation, convection, and conduction. For 3(b), a number of candidates chose A or B instead of D showing that some candidates didn't clearly understand that heat is always transferred from a high to a low temperature region. For 3(c), a number of candidates could identify the correct process of condensation but this was not as many as was expected. This point in the question showed that not all of the candidates were following the logic of what was happening during the investigation. Parts (d) and (e) were not particularly well done on the whole and a lot of misconceptions were evident. Some answers tried to explain the observations using diffusion, specific heat capacity and chemical reactions. It is possible that the context, which involved a convection current being set-up by a cold fluid falling to be replaced by warmer fluid at the bottom of the beaker, was not consistent with other convection currents that have been studied, which usually involve fluids being heated from below. Some candidates got close to the answer by discussing the difference in density of salt water and pure water but failed to connect this with the water at the top being colder.

Question 4

Most candidates could state an appropriate research question [4(a)] and could identify the tubes required to address this research question [4(b)]. 4(c) was not meant to be a challenging question but not all candidates explicitly stated that material and diameter needed to be controlled in order to have a fair test. Also, the identification of length as the independent variable needed to be made explicitly. The majority of the responses for 4(d) did not go into the required depth to be awarded 3 marks. Candidates were required to perform a test for inverse proportionality using a pair of points but many candidates just stated that an increased length corresponds to a decreased frequency without any analysis. 4(e) was generally well done but there were a small number of errors with rounding. The last parts of the question related to graphing and graphical analysis. There were some errors with the placement of the data point in 4(f); candidates should always check the scale of the axes carefully.

Question 5

This was generally well done by the majority of the candidates but not all candidates were able to suggest valid extensions to the investigation being studied. For question 5(a), candidates often forgot to convert grams to kilograms. They should be reminded that the kilogram, not the gram, is the base unit in science. A number of candidates didn't write down the equation that they selected to use in their calculation. This would be worth 1 mark, even if the answer was incorrect. The variables in 5(b) were generally well done but some candidates should be more specific when stating these. For example, if 'material of wire' is stated as a control variable for 1 mark, then 'type of wire' is not good enough to be awarded a second mark – the control

variables suggested should be clearly distinct. Question 5(c) was usually well answered with candidates usually getting 2-3 marks. The most common error was with rounding measurements. Candidates should not add zeroes to the measurements they are given. If some measurements have more decimal places than others these should be removed through rounding to give consistent columns of data. Questions 5(e) and 5(f) led to a number of candidates losing marks as they simply gave the same variables as the original experiment they should have been extending. The question clearly asked for a different investigation and as such these responses received no credit. A few candidates didn't realise that the hanging mass of the weights is the same as the tension in the string. Candidates need to be reminded that changing the equipment for an investigation does not constitute a new investigation. Also, they should not state the names of equipment as control variables. Some candidates chose to list the distance between the string and electronic tuner being a control variable but this was not given any credit as it would have no influence on frequency. Lastly, candidates should be reminded that when explaining a hypothesis they should use scientific reasoning. Simply stating the expected relationship between the variables does not constitute an explanation.

Question 6

This question was generally well answered by candidates, the extended planning question in particular showed a clear and logical structure. 6(a) was generally well answered, showing that candidates understood the purpose of taking 3 trials (and not just to take an average). However, a number of candidates said that it would improve the accuracy without further justification. This is not necessarily true. So, it is important to discuss the concepts of reliability and anomalies in relation to data collection. 6(b) was well answered by most candidates. Only a few made rounding errors by quoting the average to a number of decimal places instead of rounding to the nearest whole number which was consistent with the data. Question 6(c) was a bit more challenging and candidates had to analyse the pattern in the data to get the correct answer. Some candidates didn't quite recognize the pattern. A common incorrect answer was 103 dB. For question 6(d), which was an extended planning question, candidates showed that that on the whole they have been well prepared for these kinds of questions. Some weaker candidates confused frequency with the loudness of a buzzer. Also, some weaker responses did not include a method for the collection of data but this was clearly stated as a requirement of the question. Only the very strongest responses gave clear justification for the control variables – *eg* distance should be controlled as an increased distance would decrease the sound intensity level measured. And relatively few responses contained a hypothesis that was explained using relevant scientific knowledge. The requirement for the collection of sufficient data seems clear to most candidates.

Question 7

Question 7 was relatively challenging for a number of candidates. For 7(a), it was clear that most candidates were familiar with the heliocentric and geocentric models but not many candidates correctly explained why the observed motion of Mars as viewed from Earth was not consistent with the geocentric model. A number of candidates simply stated the details of the heliocentric model without addressing the requirements of the question or referencing the animation. 7(b) was answered successfully by the majority of candidates. Usually, candidates could calculate the time using the speed = distance/time formula. A number of candidates could also convert the value to minutes although a few candidates made errors here and didn't round the final answer to the nearest minute. 7(c) was conceptually quite challenging for candidates as they had to consider the movement of Earth and Mars as well as the time taken for the rocket to travel. It should be seen as logical that a launch date would be proposed so that the travel time between the two planets would be minimised but some candidates had a different argument.

Question 8

There were a large number of interesting and insightful responses to this question and candidates clearly engaged with the context. Many candidates showed great insight into the economic and political implications of attempting to put humans on Mars. It was nice to read some of the historical context that was given by candidates who talked about the political background to the space race of the 20th Century and how the landscape had changed since then. Some candidates gave too much focus to the activities of private companies, whereas the question asked specifically about governments. A large number of responses didn't go far enough into the exploration of the technical challenges of the journey to Mars. In this element it was expected that the candidates would reference relevant Physics principles in talking about the challenges of the journey. Only a small number of responses did this very well. Weaker candidates failed to give more details beyond what was given in the information of the question. Some candidates just repeated facts and responses like this will receive very little credit. Other candidates used information from question 9 and thought the question was asking about people living on Mars rather than the journey to and from Mars when discussing the technical challenges.

Question 9

This was an interesting question that really stretched candidates to apply their own understanding of the challenges of living on Mars. There were two parts to the question: the challenges and the solutions to the problems. A number of candidates failed to describe the effects of low temperature, high radiation, and low gravity. They simply talked about the solutions. Other candidates described the effects without proposing solutions. Candidates should be reminded that the solutions they propose should be grounded in scientific principles and not science fiction. Some candidates talked about making artificial gravity without giving any details. A few candidates had some misconceptions about the reduced gravitational field strength on Mars by saying that everything would just float away. Other candidates talked about having heating and air conditioning like we have on Earth without really understanding the extreme cold temperatures that exist on Mars and how that would be a threat to life.

Recommendations and guidance for the teaching of future candidates

Candidates should be given opportunities to practice laboratory work in an open inquiry format. Inquiry-based laboratory investigations are integral to the MYP Physics program. Inquiry-based investigations allow candidates to apply scientific practices as they identify the questions they want to answer, design experiments to test hypotheses, conduct investigations, collect and analyse data, and communicate their results.

A hypothesis does not have to be correct to receive credit in the examination, but there should be an attempt to explain the hypothesis using scientific reasoning. Without an attempted explanation, the hypothesis is incomplete and would be considered to be a prediction.

When calculating a slope or area under the curve for a graph, remind candidates to use two data points (that are at least ⅔ length apart on the line of best fit). The acquisition of accurate data requires candidates to be familiar with the scale being used so they should pay attention to this. Remind candidates to show their work for part marks and to include appropriate units whenever a calculation is performed. Sometimes candidates lose marks because they don't show any work (such as an appropriate equation before substitution) so they don't receive any partial credit for an incorrect final answer.

When answering questions regarding how variable x affects variable y, tell candidates to use terms such as increases, decreases or remains the same. If they say simply "it changes", this response will rarely receive credit. A response that references a specific mathematical relationship between x and y variables, such as direct or inverse proportionality, is even better.

Remind candidates to read questions carefully and answer the question that was asked. For example in question 8, a number of candidates used information from question 9 to answer it. However, the question wasn't about living on Mars but about the journey to Mars. Candidates should be made familiar with the MYP command terms as they have precise meanings and are used to communicate specific requirements.

Teach candidates to use scientific terms correctly. They should know the difference between reliable, precise and accurate data. Some candidates seem to use these terms interchangeably without recognizing their specific meanings.

May 2023

Overall grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-32	33-46	47-58	59-69	70-81	82-100

Physics On-screen examination Subject Report

General comments

The on-screen examination included real-world and contemporary contexts, alongside the exploration of some classic physics principles. Although the lab-based investigations were probably unfamiliar to many students, they linked to established physics concepts in the form of Newton's laws and the gas laws. Elements of the lab-based investigations would be appropriate for conducting in class activities with relatively simple equipment, stimulating the application of physics in order to explain relatively simple phenomena. The real-world contexts involved an exploration of the spread of misinformation through the internet, and the issues related to location tracking technology that is related to the widespread use of mobile phone technology. There are excellent news articles on the internet that relate to both of these themes, and it is hoped that these kinds of topics are explored within the classroom in line with the expectations of the MYP physics programme. This year, as in all years previously, the top-level responses were a pleasure to read through. Students were able to apply their knowledge and understanding to produce insightful and thoughtful comments alongside the ability to solve complex and unfamiliar problems.

The areas of the programme and examination which appeared difficult for the candidates

Students struggled to apply Newton's laws to explain the motion of a balloon when the air was released from it. A number of students knew that Newton's 3rd law applied to the situation but had difficulty identifying action/reaction force pairs. Some could recite the laws, such as "For every action, there is an equal and opposite reaction," but had difficulty applying them to this specific scenario. Some did not realize that a net or unbalanced force causes acceleration. Some stated that "motion requires a force," although this commonly held conceptual knowledge statement is wrong. A deep understanding of these concepts is shown when students are able to apply them to different situations and contexts as part of a detailed scientific explanation.

Although most students were familiar with the phenomenon of dispersion, not many students could extend to an explanation involving the amounts of refraction undergone by the different colours of visible light. Only the most able students could explain the refraction of light fully in terms of changes in speed and wavelength and how a prism produces a visible light spectrum.

A number of students had difficulties when performing relatively straightforward calculations that required the conversion of units as part of the processing. For example, 1a required the conversion of minutes to hours and 2d required the conversion of nm to m. Some students simply put in the values that were given to them in the question without considering the units that would be required as an input.

The kinetic theory model was an area where students had some understanding but also had misunderstandings as to how microscopic motions are related to the macroscopic phenomena of temperature and pressure.

A number of students struggled to analyse graphs where the same data was represented in different forms after being processed in some way. The graphs in 6e could clearly be used to address the student's hypothesis but many students were unfamiliar with the kind of processing that had been performed.

Higher level analysis requires students to identify the form of the relationship, beyond a simple analysis such as: 'as one variable increases, the other increases'. The notion of proportionality is still unclear to many students. Students should learn how to choose the type of graph that can best fit their data or explain the relationship between the mathematical equation and the experimental graph.

Organizing data into a table is a fundamental skill but there are many errors in the student responses such as inconsistent decimal places, repeated units and a lack of ordering of the data.

A number of students misinterpreted the essay prompts and wrote responses that would not be graded favourably as a result. For example, in question 7b, students were prompted to describe the positive and negative security implications of location-tracking technology for a country. The point of view of a country (nation) was the focus of this strand, so any students talking about the security implications for an individual would not receive credit for this. For question 8, a number of students wrote about the advantages and disadvantages of sharing scientific information, or about the internet as a medium of communication in general. However, the question was focused on discussing the benefits and limitations of controlling scientific information shared via the internet with the example of the rise in popularity of conspiracy theories such as the 'flat-Earth theory' in recent times.

The areas of the programme and examination in which candidates appeared well prepared

The questions involving straightforward calculations were, on the whole, done well by students. Students were able to calculate quantities such as speed, work done, resultant force and pressure using the correct formulae and were able to perform simple manipulations of the formulae in order to obtain the required quantities. The increased number of students using the online tools to present their working clearly and logically was pleasing to see.

Most students could determine the atomic structure of a nucleus given the atomic number and atomic mass number. Most students were also able to represent changes to the composition of the nucleus through the use of appropriate decay equations.

Most students showed familiarity with the kinetic theory and understood that gases have moving molecules that increase in motion as temperature increases.

The extended planning question was generally well-answered. Most students could write an appropriate research question, identify the independent and dependent variables, and construct a method that was easy to follow. Most students also developed a method that would lead to the collection of sufficient data and could suggest relevant safety precautions that would need to be taken during the collection of data.

Most students could describe a relationship in simple terms given graphical information to analyse, such as when one variable increases, the other decreases.

Most students understood that for an ideal gas during a constant temperature process, as pressure increases, the volume decreases.

The strengths and weaknesses of the candidates in the treatment of individual questions

Question 1

In part a, most students knew that the formula speed = distance/time was required, but some had difficulty with unit conversions. Writing out calculations in full and the inclusion of units in the calculations can help to minimise these kinds of errors.
Parts b and c were not particularly demanding questions that were, on the whole, answered well.
Part d was not meant to be a demanding question but the number of incorrect answers was quite high. There seemed to be some misconceptions about the energy transformations that were taking place when the horse was running up a hill. This was possibly due to the unfamiliar nature of the context of the question as physics questions can generally focus on inanimate objects when exploring energy transformations.
Part e was more difficult and different approaches were credited towards getting an answer. Either the change in GPE or the work done against gravity was valid for the first step. A significant number of students did not do this first step correctly but they were credited with other marks in the question by the application of error carried forward. Stronger students were able to achieve full marks for this question.
Part f was generally well done, although some students did round their answer incorrectly following a correct calculation.

Question 2

The performance of students on this question was generally quite mixed and only the more able students got a high number of marks.
Part a was not meant to be challenging but it showed that some students could not correctly identify the phenomenon of dispersion.
In part b students had difficulty explaining the process of dispersion of white light in the glass and not many students achieved full marks for this question. A few students incorrectly discussed diffraction instead of dispersion. A few students attempted to use the refractive index in their reasoning. Most knew that the wavelength of red light changed.
In part c, most students were able to state a difference between IR and red light but some got the relative order of wavelengths or frequencies mixed up e.g. by incorrectly saying that red light had a longer wavelength than IR, or similar. Also, statements such as 'the wavelength is different' were seen from some students and these kinds of vague responses were not given credit.
Most students correctly identified the wave equation for use in part d but relatively few students correctly converted the length given in the question to m (from nm) in order to get a correct answer to the calculation.

Question 3

Most students could correctly state the atomic number and the mass number in part a.
In part b a number of students answered the question by referring to mass number and atomic number but the question was about the similarities and differences of the nucleus. A more specific response to the numbers of protons and neutrons was required here. A small number of students referred to numbers of electrons, which is clearly not relevant in this context.
Responses to part c were quite mixed, with a number of students getting 1 mark instead of 2. Some students got X-rays and gamma rays the wrong way around on the diagram (which received partial credit). Other students picked incorrect options from the draggable items, however, inspection of the options should show that only 2 are electromagnetic rays, as is required.
Part d was generally well done, although some students incorrectly picked the positive beta symbol to complete the equation.
Part e was slightly more challenging as students needed to be specific with their terminology and refer to the terms 'nucleus' and 'neutron' in their answer. Responses such as; Uranium-238 is changing into

Uranium-239 were commonly seen but were not insightful enough to receive credit as this was mere repetition of the formula shown.

Question 4

Parts a and b showed that the vast majority of students could write a research question and identify the independent and dependent variables. However, there was some confusion as a limited number of students confused the 'Amount of air in the syringe' with the 'volume of air'. The volume is defined as the space occupied by the air particles. However, the amount of air is usually thought to be the number of molecules or moles of air.
In part d, most students could calculate the weight force using mg with the exception of some students who used incorrect mass units in the calculation (e.g. by using g instead of kg). The use of P=F/A was generally well done following the result of the first part. However, the last marking point was challenging for many students who didn't calculate the absolute or total pressure through the addition of atmospheric pressure to the result of their calculation.
In part e, most students correctly identified that the pressure increased as the volume decreased. However, there were some difficulties using the correct wording for the relationship. Some stated that pressure and volume were 'indirectly proportional' instead of 'inversely proportional.'
There were some vague responses to part f that did not receive credit. For example, some students simply stated that Boyle's law was supported. The question asked for specific reference to the graph so reference to the gradient, the trend shown, or to specific data points was required prior to making a judgement about whether Boyle's law was supported, or not.
Part g was relatively challenging due to the requirement to read the value of the product of pressure and volume from the graph and then to divide this by the pressure to get the volume. However, a number of students were able to do this successfully. Some students wrote 11200 but it should be clear that this is not the correct answer given the range of volumes given in the question.

Question 5

Part a showed that many students had a foundational understanding of the kinetic theory model. However, many of them struggled to get the full 3 marks. Many students made the connection between increased temperature leading to increased kinetic energy, or speed, of molecules. Some students also stated that the frequency of collisions with one another increased but struggled to make the connection that it was the collisions with the balloon walls that led to greater pressure. Some students stated that the molecules would 'vibrate more', confusing the motion of the particles of a gas with a solid.

The experimental design question 5b was generally well answered. Most students could write an appropriate research question and could identify the independent and dependent variables. In the equipment section, many students failed to mention a piece of equipment that could be used to measure temperature, thinking that setting the temperature in the oven was good enough. Most students struggled to get full marks on the method section since many chose unrealistic temperature ranges. For example, an oven heats to temperatures above room temperature, or a balloon will likely melt or pop at temperatures above 100-120 degrees Celsius. A number of students seemed to think that the oven could be used to cool the balloon to temperatures that were below room temperature, which is physically impossible. The safety was generally well answered, but some did not relate to the actual experiment and just had general safety points like wearing a lab coat or having an instructor around without attempting to relate to the actual experiment done.

Question 6

Not many students achieved full marks on part a. It exposed some conceptual misunderstandings around forces and Newton's laws. Many students knew that Newton's 3rd law applied to the situation but had difficulty identifying action/reaction force pairs. They sometimes matched two forces acting on the same object. Some also thought that motion requires a force and didn't think about unbalanced forces. Some students incorrectly referred to Newton's 1st law to try and explain the observations.
Most students answered b and c well, although some students did not include the unit for part c and therefore did not get the mark.
Part d assessed the student's ability to present data in a table, which should be quite a fundamental skill at this level. However, the question demonstrated some frequent and basic errors. These included not rounding data to a consistent number of decimal places, not putting data in a logical order (ascending or descending) and putting units with values in the cells of the table.
In part e, it was clear that some students understood the question well, and others struggled with only achieving 1 mark. Some students seemed to think that the graphs were contradictory, seemingly without understanding that the same data had been processed in different ways before being presented. This was a more challenging analysis question so it was to be expected that only the most able students would achieve full credit.

Question 7

Part a was quite difficult for students. Many tried to use the wave equation without realising that the relationship between period and frequency was required to answer the question.
Parts b and c were generally well done.
Part d showed a variety of outcomes. Some students who put the time and effort into their responses were able to produce some excellent work, which showed a deep level of insight into the issues and had exceptional breadth and depth, covering all of the aspects required. Weaker students showed more disorganization and a general lack of support for the points made in their answers. Discussing the advantages and disadvantages of location-tracking mobile phones concerning the individual was probably the best-answered part. Many discussed safety and security issues along with navigation and convenience for advantages. Quite a few students discussed privacy breaches and data security as disadvantages. The economic benefits for the company were sometimes confused. Those who achieved well in this area discussed targeted marketing, location-based services with Apps, and even a few noted improvements in tracking shipment logistics. For the security of a country, unfortunately, several students discussed this from the perspective of an individual and did not get any marks for this part. Some statements were too broad, and it was difficult to tell whether it was connected to the security of a country.

Question 8

Some students produced excellent responses to this question, while others, unfortunately, did not answer the question stated in the prompt. Some students answered the question from the perspective of the advantages and disadvantages of sharing scientific information on the internet and did not address the key aspect of the benefits and limitations of controlling this scientific information.
The stronger responses referenced some interesting discussion points such as the dangers of misinformation vs. the problems of limiting free speech. Also, the question of who would decide what was correct or accurate, was raised repeatedly in student responses and this showed a good level of insight into the issues. Some students included an interesting discussion but did not end the response with a concluding statement.

Recommendations and guidance for the teaching of future candidates

Developing a deep conceptual understanding of Newton's laws takes explicit instruction and practice with the techniques of identifying interaction forces. Students need opportunities to use Newton's laws to reason their way to an explanation of observed phenomena.

Students should be advised to identify the main words in a question before tackling it in order not go off topic. Practice criterion D style assessments should have a specific context that the students have to respond to, as student responses are often too open-ended to show any engagement with the topic of debate.

One of the key areas that students struggle with on the 'discuss and evaluate' questions is the ability to come up with good arguments to support their answers. They should practise writing well developed paragraphs that contain a main point with support and examples, connecting back to the issue being discussed. They should also practise writing concluding appraisals that encapsulate the points raised in their arguments.

Graphical analysis techniques can be developed authentically by processing data from labs in order to obtain the specific form of a relationship. Students should realise that saying 'as one variable increases, the other decreases' is not a satisfactory outcome for a physics investigation. A mathematical description of a relationship is generally what physicists strive for, and even terms such as 'direct proportion' or 'inverse proportion' have a specific and quantifiable interpretation.

May 2024

Overall grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-11	12-23	24-38	39-50	51-62	63-74	75-100

General comments

This year, as in previous years, it was a real pleasure to read through the student responses to the on-screen examination questions. There were some very high-quality responses and excellent examples of work from many students. Students are challenged in different ways through the course of the examination and the way in which they have responded to these challenges should be lauded.

The authors of the examinations in physics have made a conscious attempt to move the exam more in line with the true nature of the subject. This means that physics principles run through all areas of the exam, including the planning exercises and the essay-based questions where students are reflecting on the impact of physics in the real world. As such, to be successful, students need to have a good conceptual understanding of physics principles that can be applied in different situations and contexts.

Throughout the course of the examination, students encountered questions on the majority of the content areas that would comprise any middle school physics course (in this exam; energy, thermal physics, nuclear physics, electricity, mechanics, magnetism, motion, waves and astrophysics were all covered to some extent). There is always a conscious attempt to provide a broad-based coverage of different content areas during the examination at the authoring stage. However, it should be evident that, due to the number of questions that can be asked, not everything that a school has covered in its own course will be the subject of a question in the exam.

The areas of the programme and examination which appeared difficult for the students

Nuclear reactions and the components of the nucleus

A surprising number of students were unable to correctly identify the number of protons and neutrons in a nucleus of uranium-235. Possibly linked to this, many students found it challenging to explain the behaviour of protons and neutrons during a uranium nuclear fission reaction. It is important that students have the foundational knowledge relating to subatomic particles so that they can understand the more complicated processes that take place during nuclear reactions.

Explaining macroscopic phenomena using the microscopic scale

A significant number of students struggled with the microscopic explanation of how the resistance of a wire increases with length. They often overlooked the concept of electron flow, failing to describe how electrons encounter more collisions and obstacles over a longer distance, leading to increased resistance. In addition to this, the changes that take place on the microscopic scale during changes of state, or increased temperature were not clearly outlined by a number of students.

Forces and free body diagrams

For question 4, many students had difficulty correctly labelling the forces acting on the ball as it approached the magnet through the production of a free-body force diagram. These diagrams have conventions which students should be familiar with but a number of responses did not follow these conventions.

Kinematics calculations

Surprisingly, there were numerous errors in solving kinematics problems where distance and time were given. This area revealed a variety of misconceptions, indicating a need for further emphasis on foundational kinematics concepts in the curriculum.

The areas of the programme and examination in which students appeared well prepared

Students performed well on questions involving simple calculations. The majority of students were able to calculate the resistance of a wire correctly. Students were also reasonably successful in calculating output power using the efficiency formula. This showed a level of competence in the manipulation of simple formulae and the application of mathematical relationships to solve physics problems.

The majority of students were able to correctly identify the independent, dependent and control variables for the extended planning task. The plans were generally well written and clearly structured, indicating that students had practiced these procedures beforehand.

Most students showed a good fundamental understanding of magnetic field patterns, correctly identifying the magnetic field around a bar magnet.

Most students were able to select suitable wires to explore the relationship between length and resistance.

Almost all students were able to label the coal-fired power plant correctly. The majority of students were also able to label the components of the reflecting telescope.

Most students were able to respond to the context of the question and engage in discussion, providing interesting opinions on the development of the JWST. The structure of these extended responses for the majority of students matched the requirements of the task.

The strengths and weaknesses of the students in the treatment of individual questions

Question 1

Almost all students were able to label the components of the coal-fired power station in question 1a. However, questions 1b and 1c, which involved kinetic theory, were more challenging for students. Students were required to answer the questions by referring to behaviour on the microscopic scale but a number of students referred to changes on the macroscopic scale, which was insufficient. It was also evident that there were misconceptions relating to kinetic energy and potential energy on the microscopic scale. Some students incorrectly referred to collision theory when attempting to answer the questions.

The majority of students were able to perform the correct calculation for question 1d but errors in rounding were commonly observed. Students were required to round their answer to 2 significant figures to receive full credit and this is something that was not seen consistently.

Students performed well on the efficiency calculation in question 1e and the majority of students presented their answer in the correct format (including units). Students struggled with the energy flow

diagram analysis related to coal burning and responses were quite mixed, although this was intended to be a more challenging question.

For question 1g, responses were quite mixed. Some students merely stated that increased heat leads to more extreme weather events without adding any explanatory points. This was information that was given in the question and as such was not worthy of credit. Successful students were correctly able to link a thermal physics phenomenon such as melting of ice, convection currents or evaporation of water to observed weather effects.

Question 2

Question 2a, in which students were required to identify the number of protons and neutrons in a nucleus of U-235, was seen to be more challenging for students than anticipated. As this is foundational knowledge in the area of nuclear physics, it followed on that relatively few students showed evidence of understanding how protons and neutrons are affected during nuclear fission.

Question 2b showed a lack of understanding of the conservation of nucleon number (protons and neutrons combined) and conservation of charge (number of protons) during this reaction.

In question 2c, most students could explain the general concept of a chain reaction and some students could link this to neutrons being both produced and required for the fission reaction.

Question 2d was generally well answered by students, the majority of students understood the consequences of an uncontrolled chain reaction in nuclear power station but not all students linked this to the concept of too much energy being released.

Performance on question 2e was quite mixed; some students struggled with basic analysis and the extraction of data from the half-life graph. Some students got the correct value from the graph but did not provide a unit with their answer.

Question 2f was reasonably well done by students, although some students often repeated facts provided in the prompt without adding new information.

Question 3

In question 3a, most students could state an appropriate research question.

In question 3b, the majority of students were able to formulate a testable hypothesis but many students struggled to explain their hypothesis by relating this to the concept of electron flow. Responses where students said simply that resistance increases with length, which was intended by the student as an explanation, were common. This is a statement of fact, not a scientific explanation. The more detailed responses indicated a good level of understanding of electron and lattice ion interaction in the metallic structure of the wire.

For question 3c many students were able to select appropriate wires to investigate the relationship between resistance and length, although some did not select enough lengths or failed to control variables such as cross-sectional area and material.

Question 3e was generally well answered with students correctly placing the ammeter and voltmeter in the circuit.

The vast majority of students answered question 3f correctly by calculating resistance using the values of voltage and current.

The majority of students were able to place the data point in the correct place on the graph for question 3g, although some students had difficulty interpreting the scale on the y-axis. The addition of the line of best fit was less successful for this question part with a number of students neglecting to do this. Some students added the line incorrectly by having an unbalanced number of data points above and below the line.

In question 3h, many students provided generic responses about taking more trials or mentioning random or systematic errors without relating these errors to the experiment's context. A lack of repeated trials is not a source of error. Specific identification of experimental errors impacting resistance measurement was expected for credit.

Question 4

A proportion of students were able to identify conservation of energy as the relevant principle in question 4a, although this was more challenging than had been anticipated when devising the task.

Question 4b was challenging for a number of students, who were seemingly unfamiliar with the conventions of a free-body force diagram. A number of students placed force arrows floating in free space, not aligned with the centre of the ball. Other students included incorrect forces, or had the forces acting in the wrong direction.

Question 4c was well done by the more able students who would link together the increasing force and its effect on the acceleration of the ball. The question highlighted a gap in understanding for some students who confused acceleration with velocity. For instance, while describing the ball's motion near the magnet, many students noted the ball got faster but did not explicitly state that the acceleration was increasing.

Question 4d was well done as most students could correctly identify the shape of the magnetic field around a bar magnet.

A small number of students were able to answer 4e successfully but this question was designed to be challenging. The fact that the kinetic energy of the outgoing ball is greater than the incoming ball is an unfamiliar context to the majority of students and is difficult to explain.

On question 4f the majority of students were able to correctly identify the relevant variables for the investigation. The experimental procedures were generally well-written and the format of the extended responses were logical and well presented. Some students wrote general safety considerations such as wearing goggles or lab coats, whereas only specific precautions that were relevant to the procedure being undertaken (e.g. take care not to trap fingers between the colliding balls) were credited with a mark. Also, only the more able students were able to provide a scientific explanation to support their hypothesis, although the majority of students were able to formulate a hypothesis that was testable.

Question 4g showcased a good range of responses, with students creating data tables to show how they would collect data, reflecting well on schools that provide opportunities for students to organise their data collection during laboratory investigations.

Question 5

For question 5a, a surprisingly large number of students did not correctly measure the time it took for the rod to travel 16 cm due to a failure to subtract the initial time when the rod started moving.

In question 5b, many students struggled with the kinematics calculation, making common errors such as mixing equations, ignoring that the initial velocity was zero, or misapplying the concept of average

velocity. This question was an effective discriminator between the levels as it was done well by the more able students.

Question 5c was quite well done on the whole, with students correctly identifying that mass was needed to calculate the force when given the acceleration.

Question 5d was well answered in terms of identifying a graph showing a directly proportional relationship. However, students struggled to outline why the data graph in question 5e was not directly proportional, often failing to reference the data in their explanations. They did not discuss whether the line of best fit went through the origin or use specific data points to demonstrate proportionality.

Question 5f was generally well answered, though a few students who understood that the force was zero did not explicitly state that the rod would not move/not accelerate due to no net force acting on it.

Question 5g was challenging for students, although the more able students noted that the y-intercept represented the frictional force and were able to read off the value from the graph.

Question 6

For question 6a, the more able students were able to link the colour fringes observed with refracting telescopes to the phenomenon of dispersion. The level of detail of the responses were mixed as some students forgot to state that white light entering a refracting telescope is composed of different frequencies and wavelengths and that these refract by different amounts due to having different refractive indices.

For question 6b, the majority of the students correctly labelled the different parts of a reflecting telescope by interpreting the information in the question correctly. However, fewer students were able to indicate that a ray of light underwent three separate reflections by interpreting the ray diagram provided in question 6c, with some erroneously stating that there were as many as eight reflections.

Question 6d was well answered by students who remembered the concept of 'red shift' in explaining why the universe is expanding, making it somewhat of a memory recall question.

Question 6e was quite well done by a good proportion of students correctly noting associated problems with the Earth's atmosphere for ground-based telescopes compared to space telescopes. A common mistake was students referring to a space telescope having clearer observations due to its greater proximity to objects in space, which is incorrect as the relative difference in distances is negligible.

Question 7

Question 7a led to some interesting responses from students who demonstrated a good understanding of the JWST's significance and challenges. However, there is room for improvement in depth, clarity and balance to achieve a more thorough and convincing analysis. Specifically, for scientific challenges, most responses identified issues such as the inability to repair the telescope once deployed, the difficulty of launching a telescope into space and the need for precise engineering. These points were clearly stated by many students but relatively few students were able to elaborate on the points and to give supporting information. Regarding social and cultural implications, responses frequently mentioned the positive impact of space telescopes on education and public knowledge, highlighting how discoveries can inspire and educate the public. For economic implications, most responses correctly addressed the significant financial investment required for projects like the JWST, often comparing it to other government expenditures such as military spending. Relatively few students referenced the economic positives that these projects involve, such as job creation and increased innovation in the technology sector. In the concluding appraisal, several responses provided a balanced view, considering both the positive impacts and the challenges or limitations associated with the JWST. However, a common weakness was that many responses repeated information provided in the prompt or the video script without adding new insights or interpretations, which limited the depth of the analysis. Some responses included vague or generalized statements without clear explanations or specific examples, weakening the argument. Additionally, a few responses showed misunderstandings or inaccuracies in scientific concepts, affecting the credibility of the analysis.

For question 7b, the responses demonstrated a good understanding of the mid-infrared instrument's ability to detect life-sustaining substances, as this information was provided in the prompt, reflecting a clear grasp of its primary scientific purpose. However, a common weakness was the repetition of information from the prompt without adding new insights or interpretations, indicating a need for more critical thinking and elaboration. Many responses included general statements about the JWST rather than focusing specifically on the mid-infrared instrument, showing a lack of specificity. Some insights referred to the general capabilities of the JWST rather than the specific capabilities of the mid-infrared instrument on the JWST.

Recommendations and guidance for the teaching of future students

Four recommendations for the teaching of future students are, as follows;

Emphasize conceptual understanding over memorization

Students that grasp the principles and concepts in physics at a deep level are able to apply these principles in different situations and contexts. For example, the question on telescopes required knowledge of refraction and reflection, which are standard wave phenomena. However, some students struggled to see how the principles were applied in this context. Incorporating activities and discussions that focus on understanding how physics applies in different situations and contexts will ensure that students learn these fundamental concepts at a deeper level.

Provide hands-on laboratory experiences to enhance practical and experimental skills

The on-screen exam aims to replicate what students would do in school-based lab activities. Questions involving experimental setups, such as placing ammeters and voltmeters correctly (question 3e) and drawing free-body diagrams (question 4b), highlighted the need for more practice. Also, when students were suggesting safety precautions (question 4f), some students made generic statements that didn't show awareness of prior lab experience. Schools should design labs that require students to set up experiments, collect and analyse data and write detailed lab reports. The labs in this exam could be replicated in a school setting.

Improve data interpretation and graphical analysis skills

Focus on teaching students how to interpret data accurately and construct and analyse graphs correctly. Many students struggled with proportional relationships and referencing data in their explanations (question 5d). Adding a data point and a line of best fit to a graph (question 3g) is quite a basic skill that some students struggled with. Schools should provide regular practice with different types of data sets and graphing exercises to build these critical skills. These skills are developed as part of an effective programme of lab work.

Develop student's critical thinking and analytical abilities

Encourage students to think critically and provide insightful analysis beyond what is given in the prompt. It was surprising to see how many students got question 5a wrong due to simply reading the time from the stopwatch, rather than realising that the timing started beyond zero seconds and making the required correction. In the longer, essay-based questions (question 7a and 7b), many responses repeated information without adding new insights or interpretations. The use of questions and projects that require students to analyse, synthesize and evaluate information in order to respond to a specific context or situation will help to develop these skills. The use of unfamiliar situations/contexts in school exams help students to be able to apply their knowledge and shows that effective physics learning does not rely on the memorisation of facts.

NOVEMBER SESSIONS

November 2016

November 2017

November 2018

November 2019

November 2020

November 2021

November 2022

November 2023

November 2024

Formula Sheet

dis

Kinetic energy	kinetic energy $= \frac{1}{2} \times$ mass $\times$ (velocity)^2	$E_k = \frac{1}{2} m v^2$
Gravitational field strength	gravitational field strength $= \frac{\text{force}}{\text{mass}}$	$g = \frac{F}{m}$
Gravitational potential energy	change in gravitational potential energy = mass $\times g \times$ change in height	$\Delta E_p = mg\, \Delta h$
Efficiency	efficiency $= \frac{\text{useful energy out}}{\text{total energy in}} \times 100$	
Power	power $= \frac{\text{work done}}{\text{time}}$	$P = \frac{W}{t}$
Current	current $= \frac{\text{flow of charge}}{\text{time}}$	$I = \frac{\Delta Q}{t}$
Power	power = voltage $\times$ current	$P = IV$
Voltage	voltage = current $\times$ resistance	$V = IR$
Transformers	$\frac{\text{primary voltage}}{\text{secondary voltage}} = \frac{\text{turns on primary coil}}{\text{turns on secondary coil}}$	$\frac{V_p}{V_s} = \frac{N_p}{N_s}$
Wave speed	wave speed = frequency $\times$ wavelength	$v = f\lambda$
Time period	time period $= \frac{1}{\text{frequency}}$	$T = \frac{1}{f}$

Metric multipliers

The following information about metric multipliers will be provided in the on-screen examination for all sciences subjects.

Prefix	Abbreviation	Value
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

MYP physics formula sheet

Density	$\text{density} = \dfrac{\text{mass}}{\text{volume}}$	$\rho = \dfrac{m}{V}$
Force	$\text{force} = \text{mass} \times \text{acceleration}$	$F = ma$
Motion	$\text{final velocity} = \text{initial velocity} + (\text{acceleration} \times \text{time})$	$v = u + at$
	$\text{distance} = (\text{initial velocity} \times \text{time}) + \dfrac{1}{2} \times \text{acceleration} \times (\text{time})^2$	$s = ut + \dfrac{1}{2}at^2$
	$(\text{final velocity})^2 = (\text{initial velocity})^2 + 2 \times \text{acceleration} \times \text{distance}$	$v^2 = u^2 + 2as$
	$\text{distance} = \dfrac{(\text{final velocity} + \text{initial velocity}) \times \text{time}}{2}$	$s = \dfrac{(v+u)t}{2}$
Momentum	$\text{momemtum} = \text{mass} \times \text{velocity}$	$p = mv$
Pressure	$\text{pressure} = \dfrac{\text{force}}{\text{area}}$	$p = \dfrac{F}{A}$
Work	$\text{work} = \text{force} \times \text{distance}$	$W = Fs$

Questions Page Numbers:

-
-
-
-
-

Answers Page Numbers:

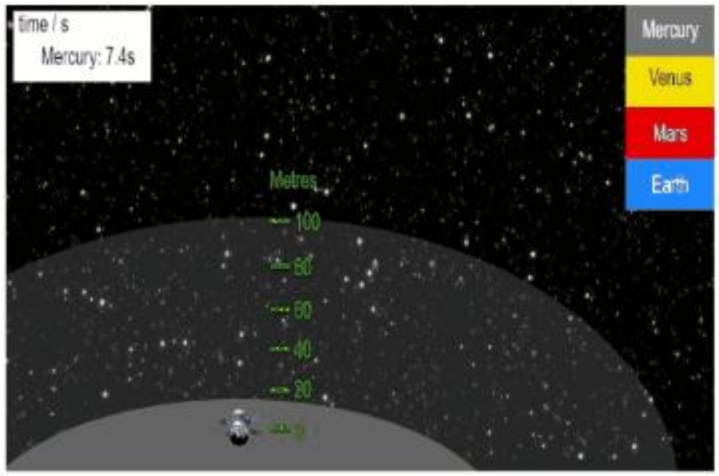
-
-
-

Questions

Pages:

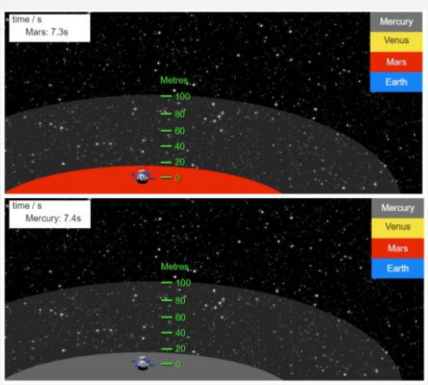
Question 1 : Physics – Gravitational Field Strength and Energy [11 marks]

A robotic probe collects data from Mercury, Mars, and Venus by dropping a test object from 100.0 m, measuring fall times to study gravitational effects. The experiment extends to Jupiter's moons Io and Ganymede, exploring energy transformations.



a Calculate the acceleration due to gravity on Mercury and Mars. [3 marks]

Use the data provided to calculate gravitational acceleration.



Calculation space:

Mercury: g= ___________ m/s²

Mars: g= ___________ m/s²

Answers / Explainations

Question 1a -

Solution:

Use the free-fall equation: $d = \frac{1}{2}gt^2$, rearranged to $g = \frac{2d}{t^2}$, where $d = 100.0\,\mathrm{m}$.

Mercury:

Time $t = 7.4\,\mathrm{s}$

$$g_{\text{Mercury}} = \frac{2\times100.0}{7.4^2} = \frac{200.0}{54.76} \approx 3.65\,\mathrm{m/s}^2$$

Mars:

Time $t = 7.3\,\mathrm{s}$

$$g_{\text{Mars}} = \frac{2\times100.0}{7.3^2} = \frac{200.0}{53.29} \approx 3.75\,\mathrm{m/s}^2$$

Final Answer:

Mercury: $g \approx 3.7\,\mathrm{m/s}^2$

Mars: $g \approx 3.8\,\mathrm{m/s}^2$

Key Concept:

Gravitational acceleration is derived from free-fall time using kinematic equations, assuming negligible friction.