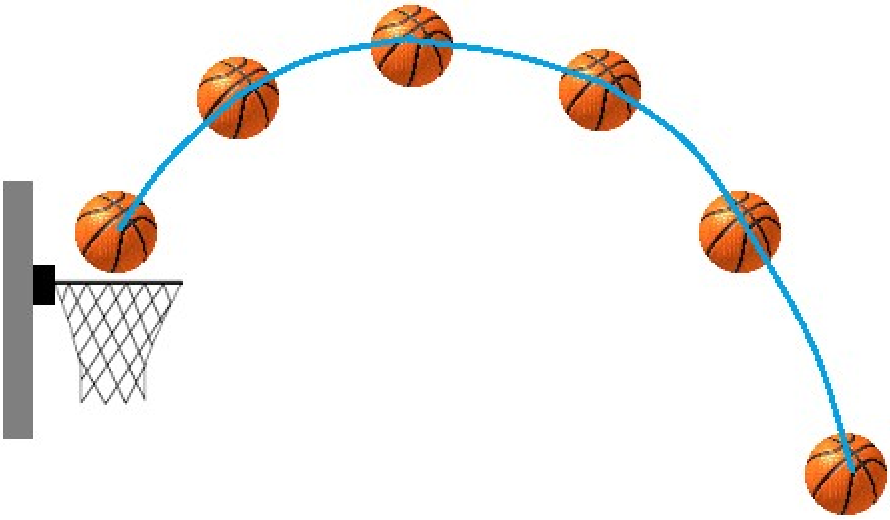
Year 11 Physics
Motion



https://www.introduction-to-physics.com/images/Projectile-motion.png

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SCSA ATAR Syllabus
https://senior-secondary.scsa.wa.edu.au/syllabus-and-support-materials/science/physics

Science Understanding

- distinguish between vector and scalar quantities, and add and subtract vectors in two dimensions
- uniformly accelerated motion is described in terms of relationships between measurable scalar and vector quantities, including displacement, speed, velocity and acceleration

This includes applying the relationships

$v_{av} = \frac{s}{t}$ $a = \frac{v-u}{t}$ $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$

- representations, including graphs, vectors, and equations of motion, can be used qualitatively and quantitatively to describe and predict linear motion
- vertical motion is analysed by assuming the acceleration due to gravity is constant near Earth's surface
- Newton's three Laws of Motion describe the relationship between the force or forces acting on an object, modelled as a point mass, and the motion of the object due to the application of the force or forces
- free body diagrams show the forces and net force acting on objects, from descriptions of real-life situations involving forces acting in one or two dimensions

This includes applying the relationships

$resultant\ F = ma$ $F_{weight} = mg$

- momentum is a property of moving objects; it is conserved in a closed system and may be transferred from one object to another when a force acts over a time interval

This includes applying the relationships

$p = mv$ $\sum mv_{before} = \sum mv_{after}$ $mv - mu = \Delta p = F\Delta t$

- energy is conserved in isolated systems and is transferred from one object to another when a force is applied over a distance; this causes work to be done and changes the kinetic (E_k) and/or potential (E_p) energy of objects

This includes applying the relationships

$E_k = \frac{1}{2}mv^2$ $E_p = mg\Delta h$ $W = Fs$ $W = \Delta E$

- collisions may be elastic and inelastic; kinetic energy is conserved in elastic collisions

This includes applying the relationship

$\sum \frac{1}{2}mv^2_{before} = \sum \frac{1}{2}mv^2_{after}$

- power is the rate of doing work or transferring energy

This includes applying the relationship

- $P = \frac{W}{t} = \frac{\Delta E}{t} = Fv_{av}$

Science as a Human Endeavour

Safety for motorists and other road users has been substantially increased through application of Newton's laws and conservation of momentum by the development and use of devices, including:

- helmets, seatbelts, crumple zones, airbags, safety barriers.

Proposed timeline

Wk	#	Topic	PowerPoint	STAWA Questions
2	1	Scalars and vectors	1-9	
2	2	Measuring motion	10-12	Set 14
2	3	Vector addition	13-18	
2	4	Vector subtraction	19-20	
2	5	Vector subtraction	19-20	
3	1	Vector components	21-23	
3	2	Vector components	21-23	
3	3	Acceleration down a slope	24-25	
3	4	Acceleration down a slope	24-25	
3	5	**Inclined plane investigation**		
4	1	Graphing motion	26-30	
4	2	Graphing motion	26-30	
4	3	Vertical motion	31-33	
4	4	Vertical motion	31-33	Set 15
4	5	Forces	34	
5	1	Newton's 1st law	35-40	
5	2	Newton's 2nd law	41-45	
5	3	Newton's 3rd law	46-54	
5	4	Elevator problems	46-54	Set 16
5	5	**Hockey slapshot analysis**		
6	1	Staff PL		
6	2	Momentum	55-58	
6	3	Momentum	55-58	
6	4	Impulse	59-64	
6	5	Impulse	59-64	Set 17
7	1	Energy	65-74	
7	2	Energy	65-74	
7	3	Work	75	
7	4	Efficiency	76-77	
7	5	Power	78-79	
8	1	Power	78-79	Set 18
8	2	Revision		
8	3	Revision		
8	4	Revision		
8	5	**Motion Topic Test**		

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Glossary

Word	Definition
Scalar	
Vector	
Distance	
Displacement	
Speed	
Velocity	
Acceleration	
Mass	
Weight	
Momentum	
Impulse	
Work	
Power	
Force	
Elastic collision	
Inelastic collision	
Efficiency	

Initial definitions

- Distance: total length of space
- Displacement (s): straight-line length of space between two points with the direction
- Speed: rate of change of distance
- Velocity (v): rate of change of displacement, including direction
- Acceleration (a): rate of change of velocity, including direction

Scalars vs Vectors

- Scalars have magnitude (size) only
- Vectors have magnitude (size) and direction

Examples of scalars:

Examples of vectors:

Distance vs Displacement

- Distance is how far an object has travelled from its starting point. (Scalar: magnitude)
- Displacement is how far an object is from its starting point with the direction. (Vector: magnitude with direction)
- Displacement is the straight line distance from start to finish.
- E.g. swimmer having done 1,2,3 laps of a 50m pool.

- E.g. athlete running around a 400m circuit track.

Speed vs Velocity

- Speed is the rate of change of distance (scalar)
- Velocity is the rate of change of displacement (vector)

Consider Damian, an athlete performing a training routine by running back and forth along a straight stretch of running track. He jogs 100 m north in a time of 20 s, then turns and walks 50 m south in a further 25 s before stopping.

a Calculate Damian's average speed as he is jogging.
b What is his average velocity as he is jogging?
c What is the average speed for this 150 m exercise?
d Determine the average velocity for this activity.
e What is Damian's average velocity in km h^{-1}?

Instantaneous vs average speed/velocity

- Instantaneous speed/velocity refers to how fast an object is moving at a specific moment in time
- Average speed/velocity refers to how fast an object completed a journey

Measuring Speed/Velocity

- Multiflash photography: flash exposure of 20Hz
- Photogate: light source and sensor trigger an electronic timing device as object breaks beams.
- Ultrasonic motion sensor: emit high frequency sound pulses that reflect off moving objects giving instantaneous speed

Ticker Timers

- Hammer vibrates with a frequency of 50 Hz
- Time between dots = 1/50s = 0.02s
- Distance travelled = length of tape between dots
- Dots close together = slow movement
- Dots far apart = fast movement

Representation of Vectors

- Use an arrow
- Draw to scale (include scale)
- Directions
    - True bearings: from North clockwise
    - Compass bearings: <u>N/S</u> <u>°</u> <u>W/E</u>
    - Left, right, up, down, forwards, backwards

Addition of Vectors

- Vectors are added head to tail and the resultant (R) goes from the tail of the first to the head of the last.
- The resultant can be determined by calculation or scaled diagram.

A train travels 250 km North, then stops and returns 100 km South, then travels 25km North.

a) What is the train’s displacement from its starting point?

b) What distance did the train cover?

Vector addition in two dimensions

- Draw a rough vector diagram
- Use Pythagoras to find the magnitude (requires a right angle)
- Use tangent function to find the direction.

E.g. If a person travels 4 km E, then 3 km N, what is their resultant displacement?

- If the vectors are not perpendicular, must use the cos or sin rules

Cos rule:

Sin rule:

Sally and Ken kick a stationary ball simultaneously with forces of 100 N South and 150 N South-East respectively. What is the resultant force on the ball?

Vector Subtraction

- To subtract one vector from another the first vector is made negative then added normally

$$A - B = A + (-B)$$

- To make a vector negative reverse it's direction

A pool ball moving at 4 m s^{-1} strikes the table edge at a 45° angle measured clockwise from the edge and rebounds at 3.2 m s^{-1} at a 45° angle measured counterclockwise from the edge. Find the change in velocity:

Resolution of vectors

- Any vector in two-dimensional space can be thought of as having an influence in two perpendicular directions.
- Each part of a two-dimensional vector is known as a component.
- A vector can be resolved into its component parts.
- Components are typically at right angles to one another.
- A vector is equal to the sum of its component.

Vector components

- The vector 'A' can be thought of as being made of components 'B' and 'C'
- Components can be determined using trigonometry
- E.g. C = A sin θ
- E.g. B = A cos θ

A chain pulls up on a dog at a 40° from horizontal with a force of 60 N. Find the horizontal and vertical components of this force.

Acceleration down a slope

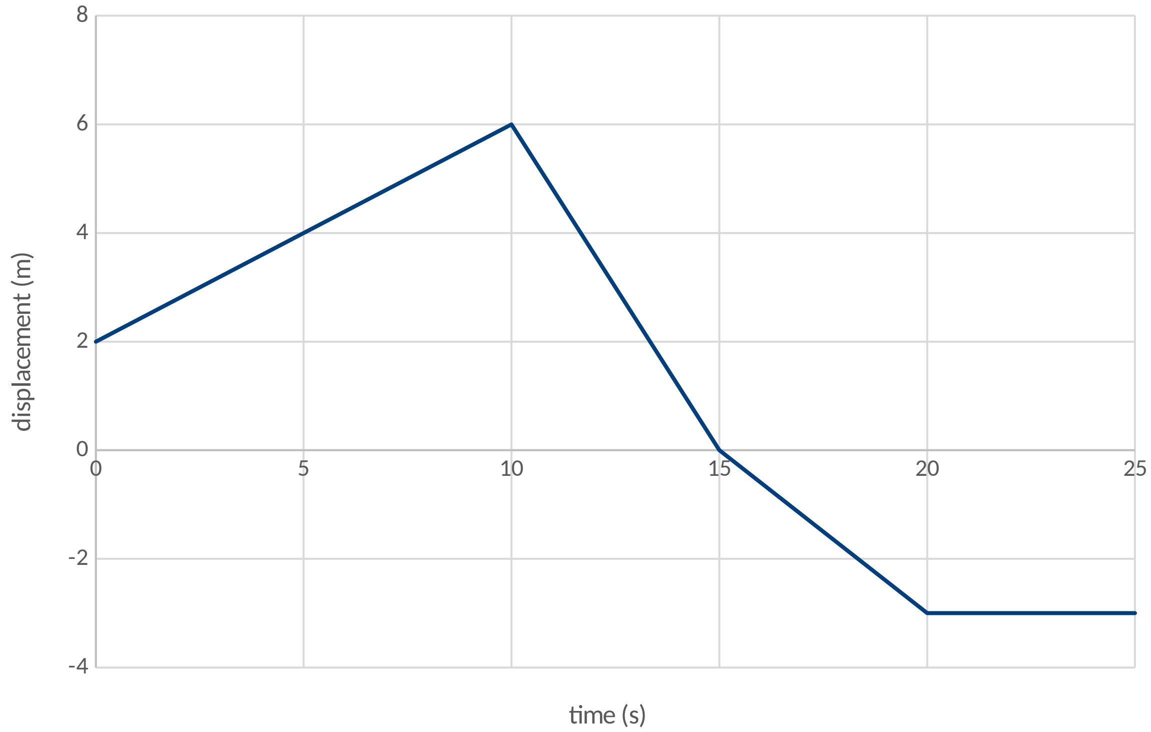
- An object in freefall on Earth is said to fall at 9.8 ms^{-2}
- An object on a slope will fall at a smaller rate
- The acceleration down a slope due to gravity is the component of gravity acting parallel to the slope (ignore friction)
- The acceleration down the slope is the component of gravitational acceleration acting parallel to the slope

$$g_{\parallel} = g \sin\theta$$

- Should always be less than 9.8 ms^{-2}

Displacement-time graphs

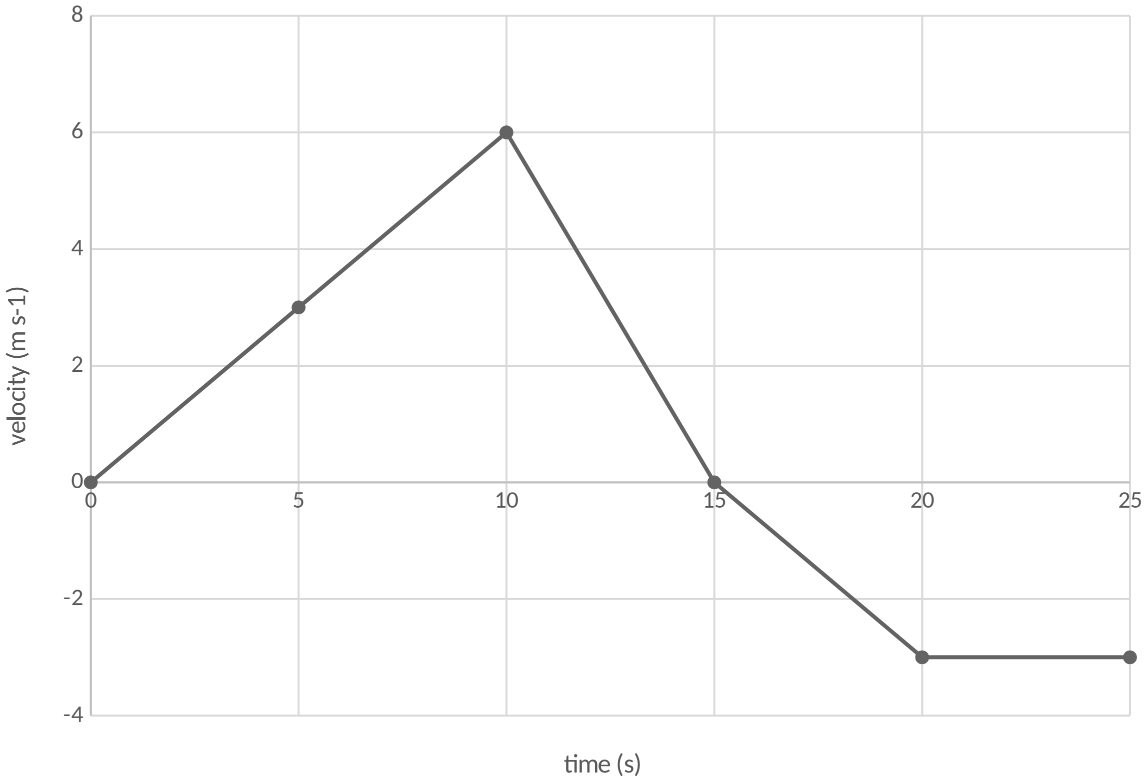
- Plots position of an object relative to a reference point (0 on the y-axis)
- Gradient = velocity
- Straight line = constant velocity



1. Describe the motion of the object
2. Determine the velocity at 5 s
3. Determine the total distance travelled

Velocity-time graphs

- Plots velocity of an object over time
- Gradient = acceleration
- Straight line = constant velocity
- Area under the curve = displacement



1. Describe the motion of the object
2. Determine the acceleration at 12 s
3. Determine the final displacement

Vertical Motion

- Assume that gravitational acceleration near the surface of the Earth is constant and that it is 9.8 ms^{-2}
- Recognise that the vertical component of an objects velocity becomes 0 at the peak of its flight
- Ignore air resistance
- Time up = time down (if distance up = distance down)
- Apply equations of motion as normal
- Up is positive, down is negative

A ball is fired upwards from the ground with an initial velocity of 15ms^{-1}, how high does it reach? How long does it take to hit the ground?

A ball is fired upwards off a 4m cliff with an initial velocity of 15ms^{-1} up, how high does it reach? How long does it take to hit the ground at the base of the cliff?

Forces

- Are pushes or pulls
- Measured in Newtons (N) or kg m s^{-2}
- Vectors, so include both magnitude and direction
- Described by Newton's Laws

1st Law – Law of inertia

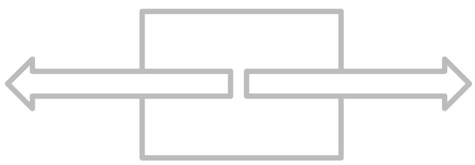
- An object in motion will remain in motion unless acted on by an unbalanced force
- An object at rest will remain at rest unless acted on by an unbalanced force

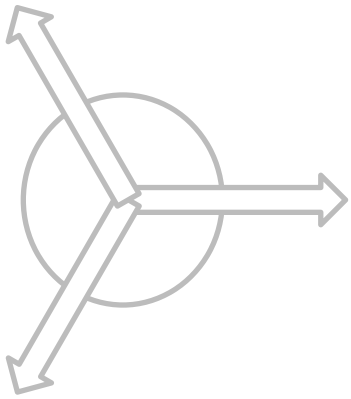
Inertia

- The property of mass to resist changes to its state of motion
- Proportional to mass

Balanced Forces

- The forces acting on an object are considered balanced if the vector sum of the forces is 0
- If the forces acting on an object are not balanced the object will accelerate





Free body diagrams

- Show relative size and direction of all forces acting on an object
- Labelled to show the types of forces
- Size of arrow indicates magnitude of force
- If on Earth always include weight force
- If moving on Earth always include friction force (friction, drag, air resistance)
- If resting on a surface include normal force

A cyclist pedals so she travels with a constant velocity of 8.0 m/s west. If the frictional forces applied to her are 60N, what force must be supplied by the rear wheel of the bicycle?

2nd Law

$$a = \frac{\Sigma F}{m}$$

- The acceleration of an object is directly proportional to the net force acting on the object and inversely proportional to the mass of the object

$$a = acceleration\left(m s^{-2}\right)$$
$$\Sigma F = net\left(total\right)force\left(N\right)$$
$$m = mass\left(kg\right)$$

- Commonly written: F=ma
- 1 Newton is the force that causes 1kg to accelerate at 1 ms^{-2}

(Σ is the capital Greek letter sigma, it means sum or total)

Determine the size of the force required to accelerate an 80 kg athlete from rest to 12 ms^{-1} in 5.0 s.

A 150g hockey ball is simultaneously struck by 2 hockey sticks. If the sticks supply a force of 15 N north and 20 N east respectively, determine the acceleration of the ball and direction it will travel.

A freestyle swimmer whose mass is 75kg applies a force of 350N. The water opposes her efforts with a 200N force. What is her initial acceleration?

A 780 kg car is travelling up a slope at a constant 60 km/h. The angle of the slope is 10^0 and the driving force is 3 000N Determine :
a) the friction forces on car
b) the normal

Mass and Weight

Mass

- Measured in kg
- Measure of quantity of matter
- Measure of inertia
- Constant for a given object regardless of location

Weight

- Measured in N
- Measure of force acting on an object due to the gravitational field it is in
- Varies according to local gravitational acceleration
- Product of mass and gravitational acceleration
- $W = mg$

3rd Law

- For every action force there is an equal and opposite reaction force
- E.g. If object A exerts a force of 10N right on object B, then object B also exerts a force of 10N left on object A

The two forces:

- Are equal in magnitude
- Opposite in direction
- Act on different objects
- Are the same type
- Act for the same duration

Normal force – apparent weight

- An object resting on a surface experiences a normal force opposing its weight force
- The normal force is always perpendicular to the surface, even if the surface is inclined
- Responsible for the sensation of weight, in freefall you feel ‘weightless’ because you are not experiencing a normal force
- A scale can be though of as measuring the normal force

Elevator problems

Can ask for the normal force experienced by a person in an elevator:

- While stationary
- While moving up/down at constant velocity
- While accelerating upwards
- While accelerating downwards

For each scenario, from personal experience, do you feel heavier, lighter or normal? This should inform your answers to calculations

- What normal force does a 60 kg woman experience standing on the ground?
- What normal force does a 60kg woman experience standing in a lift accelerating upwards at 5 ms^{-2}?

- What normal force does a 60 kg woman experience standing on the ground?
- What normal force does a 60kg woman experience standing in a lift accelerating downwards at 6 ms^{-2}?

- What normal force does a 60 kg woman experience standing on the ground?
- What normal force does a 60kg woman experience standing in a lift accelerating downwards at 16 ms^{-2}?

Elevator shortcut

- If you are very strict with treating upwards vectors as positive and downwards as negative you can simply use:

$$F_{normal} = ma - mg$$

$$F_{normal}=m(a-g)$$

Momentum

$$p=mv$$

- Mass in motion
- Measured in kg m s^{-1} or N s
- Related to how difficult it would be to stop the object moving

Conservation of momentum

- The total momentum of a system is constant assuming no external forces are acting on it

$$m_1u_1+m_2u_2=m_1v_1+m_2v_2$$

- Remember that momentum is a vector, be strict with positive and negative to denote direction

General formula:

$$m_1u_1+m_2u_2=m_1v_1+m_2v_2$$

If two objects start together (‘explosion’)

$$(m_1+m_2)u=m_1v_1+m_2v_2$$

If two objects end together (‘collision’)

$$m_1u_1+m_2u_2=(m_1+m_2)v$$

A skater (80kg) skating in a straight line with a velocity of 6.0m s^{-1} while another mass 70kg also with a speed of 6.0ms^{-1} approaches her in an opposite direction.
a) What will happen to lighter skater if 2 collide and the heavier one is brought to a stop.
b) What would happen if skaters stuck together after collision.

Impulse

$$\Delta p = p_f - p_i = Ft$$

- Change in momentum
- Product of force and time
- An object with 20 kg m s^{-1} of momentum could be stopped by a 20 N force acting for 1 s, a 10 N force acting for 2 s, a 4 N force acting for 5 s etc.

A footballer (80kg) running at 8.2 m s^{-1} collides with a goal post and comes to rest while trying to take a mark. He is brought to a standstill in 0.1s

- a) Determine the footballers change in momentum
- b) Determine the average force he experienced during the collision.

A tennis ball (58g) travelling at 55ms^{-1} is struck by a tennis racquet.

- a) Find the change in momentum as ball is momentarily brought to a halt.
- b) Find magnitude of impulse.
- c) Find average force applied to stop ball in 0.15s

A tennis ball (58g) travelling at 55ms^{-1} is struck by a tennis racquet, sending it back the opposite direction at 35 ms^{-1}.

- a) Find the change in momentum.
- b) Find magnitude of impulse.
- c) Find average force applied to hit ball for 0.15s

Crumple zones

- Longer time force is applied, the less the force required.
- Change in momentum will be the same.
- Ft = m(v-u)

Eg: cars crumple zone, egg packaging, bend knees on landing, high jump cushion, airbags, sport shoe design

A person weighs 60kg and lands on a concrete surface after jumping from a height of 6.0m.
The impact time when landing with locked knees is 0.002s and with bent knees is 0.050s.
Will the person's tibia bone fracture?
Assume cross sectional area of tibia is 3.0 cm^2
Bone strength is 170N mm^{-2}

Energy

- Energy: the capacity to do work, measured in Joules (J)
- Work: work is done when energy is transformed or transferred, measured in Joules (J)

Types of energy

Associated with motion

- Kinetic
- Electrical
- Mechanical
- Thermal
- Electromagnetic (light)

Stored

- Gravitational potential
- Electrostatic potential
- Nuclear potential
- Elastic potential
- Magnetic potential

Conservation of energy

- Energy can never be created of destroyed, only transformed or transferred

Gravitational potential energy

$$E_P = mgh$$

- Gravitational potential energy is energy held by mass raised off the ground

Kinetic energy

$$E_K = \frac{1}{2} m v^2$$

- Kinetic energy is energy held by mass in motion

Elastic vs inelastic collisions

- When two objects collide, the collision may be elastic or inelastic
- In an elastic collision the total kinetic energy held by the two objects doesn't change
- In an inelastic collision some of the kinetic energy is lost to other forms such as heat and sound

A 1.5×10^3 kg car is moving to the right at 20 m s^{-1} while a 5.0×10^3 kg truck is moving to the left at 10 m s^{-1} . The car and truck collide and move off as one mass stuck together. What is the velocity of the wreckage immediately after the collision.
How much kinetic energy is lost as heat or sound when the car and truck collide?

Total mechanical energy

- Sum of kinetic energy and gravitational potential energy
- Energy held by mass due to its position in and motion through a system

Calculate the kinetic energy and hence the velocity required for a pole vaulter to pass over a 5.0m high bar. Assume the vaulter reaches a maximum height equivalent to the level of the bar with a horizontal velocity of 1.2 m/s. Use g = 9.8 ms^{-2}. Mass of man is 75kg.

A climber abseiling down a cliff uses friction between gloved hands and the climbing rope to slow down. If a climber with mass of 75 kg abseils down a cliff of 45.0 m reaches a velocity of 5.20 m/s by the time he reaches the ground, determine the average frictional force applied by his hands on the rope.

Work

$$W = Fs$$

- Work is done when a force moves an object through a displacement parallel to the force
- Work is not done if the force is perpendicular to the displacement
- Work is done when energy is transformed or transferred

Degradation of energy

- When energy is converted into an unuseful form of energy.
- Energy transformations are rarely perfect, often transform some energy into 'waste' energy
- E.g. to heat due to friction and air resistance.
- Minimise frictional force by:
  - Lubrication
  - Bearings, rollers
  - Streamlining

Efficiency

$$efficiency = \frac{useful\ output}{total\ input} \times 100$$

- The effectiveness of an energy conversion can be measured by its efficiency
- The percentage of input energy that becomes the desired useful output energy

Power

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

- Rate of doing work
- Measured in J s^{-1}, known as watts (W)

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

W=Fs, so:

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

s/t=v so:

$$P = Fv$$

- Power needed to maintain an object moving at constant velocity

Work and Power Experiment

Aim : To determine: i) the work done by the fan to move the cart 1m and
ii) the power of the fancart when using the slow speed

Equipment: fancart, 1m ruler, stopwatch, scale

SAFETY: Safety glasses to be worn and fancart to operated on floor ONLY.

In groups of 2 or 3 decide on the procedure and do the necessary calculations. Show your teacher.

Motion revision

1. A fireworks rocket is shot vertically off the bridge over the canning at 50m/s.

a) How high does it go?
b) How long does it take to fall into the river that is 15m below the bridge? Total time?
c) What is the total distance covered by the rocket?
d) What is the rocket's velocity as it strikes the water .
d) Draw in all the forces acting on the rocket when it is:
    a) at the top of its journey
    b) half way down
    c) Draw a v/t and a/t graph of its motion (rough sketch)

2. A boy is dragging a 4kg cart along with a string making 25^0 to the horizontal and the tension in the string is 140N. There is a frictional force of 20N
a) What force is causing the cart to accelerate?
b) What is the acceleration of the cart?
c) How much work is done to move the cart 10m?

3. A 500kg car going at 60km/h collides head on with a 1 tonne truck going in the opposite direction at 80km/h. If the car bounces back after the collision at 10km/h determine:
a) the velocity of the truck after the collision.
b) the change in momentum of the car.
c) the impulse the car experienced?
d) If the crash occurred during 5ms, what average force did the car experience?
e) List and explain the safety features of a car that would have minimized the injury ot the driver.

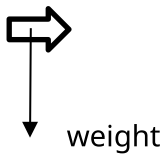
4. A car travels 200km due east and then changes direction and travels 50km South.

a) What is the resultant displacement of the car?
b) In which direction much he head to return to his starting point?

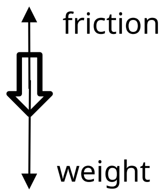
5. A 800kg car is traveling down a 20^0 slope at 50km/h at a constant speed applying brakes as it goes. Assume braking includes frictional forces.
a) Draw a free body diagram of all the forces acting on the car.
b) Determine the size of the braking force.
c) Determine the size of the normal.

Motion revision solutions

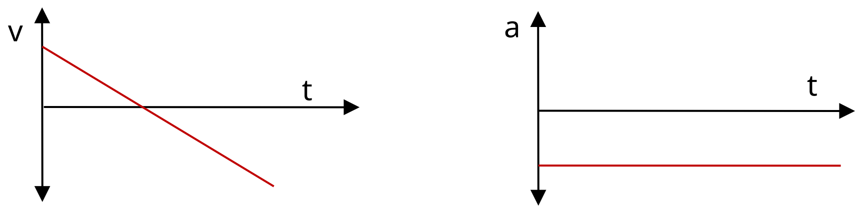
1.
   a. 128 m
   b. 10.5 s
   c. 270 m
   d. 52.9 m s^{-1}
   e.
      i.



      ii.

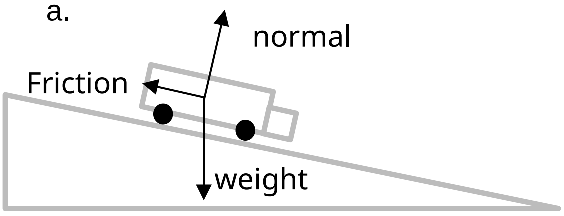


      iii.



2.
   a. The horizontal component of the pull on the string; 127 N
   b. 26.7 ms^{-2}
   c. 1270 N
3.
   a. 45 km h^{-1} in its original direction
   b. 9720 N s
   c. 9720 Ns
   d. 1940000 N
   e.
      i. Seatbelt
      ii. Airbag
      iii. Crumple zone

4.
    a. 206 km 104°
    b. 284°
5.
    a.



    b. 2680 N
    c. 7370 N