AS physics EOS 重难点精选

Table of content

1.1 Physics quantities

QUANTITY	SI BASE UNIT	SYMBOL
MASS	KILOGRAM	kg
LENGTH	METRE	m
TIME	SECOND	s
CURRENT	AMPERE	A
TEMPERATURE	KELVIN	K
AMOUNT OF SUBSTANCE	MOLE	mol

Figure 1: SI base units

A scalar is a quantity which only has a magnitude (size)

A vector is a quantity which has both a magnitude and a direction

1.2 Measurement and units

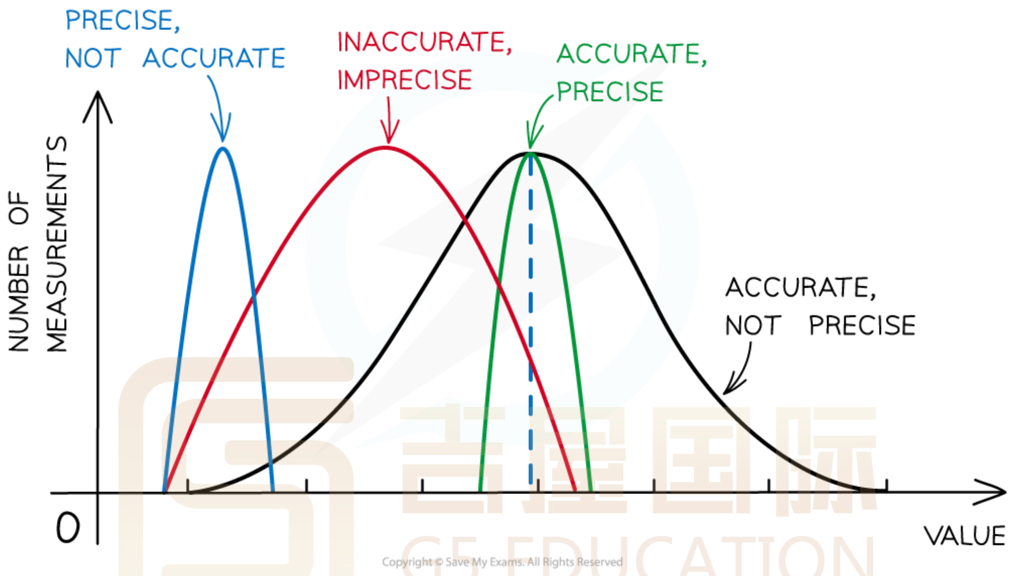
Errors

Random error

- Random errors cause unpredictable fluctuations in an instrument's readings as a result of uncontrollable factors, such as environmental conditions
- This affects the **precision** of the measurements taken, causing a wider spread of results about the mean value
- To **reduce** random error: **repeat** measurements several times and calculate an average from them

Systematic error

- Systematic errors arise from the use of faulty instruments used or from flaws in the experimental method
- This type of error is repeated every time the instrument is used or the method is followed, which affects the **accuracy** of all readings obtained
- To **reduce** systematic errors: instruments should be **recalibrated** or the technique being used should be corrected or adjusted



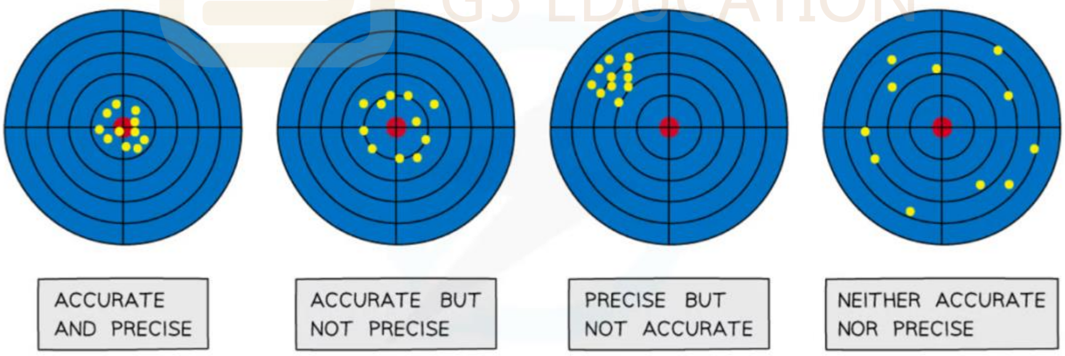
Representing precision and accuracy on a graph

Zero error

- This is a type of systematic error which occurs when an instrument gives a reading when the **true reading is zero**
- This introduces a fixed error into readings which must be accounted for when the results are recorded

Precision and accuracy

- **Precision of a measurement:** this is how close the measured values are to each other; if a measurement is repeated several times, then they can be described as precise when the values are very similar to, or the same as, each other
- The precision of a measurement is reflected in the values recorded - measurements to a greater number of decimal places are said to be more **precise** than those to a whole number
- **Accuracy**: this is how close a measured value is to the true value; the accuracy can be increased by repeating measurements and finding a mean average



Uncertainties

Absolute Uncertainty: where uncertainty is given as a fixed quantity
Fractional Uncertainty: where uncertainty is given as a fraction of the measurement
Percentage Uncertainty: where uncertainty is given as a percentage of the measurement

- **The uncertainty in a reading:** ± half the smallest division
- **The uncertainty in a measurement:** at least ±1 smallest division
- **The uncertainty in repeated data:** half the range i.e. ± ½ (largest - smallest value)
- **The uncertainty in digital readings:** ± the last significant digit unless otherwise quoted

1. Four students measure the same length of string and their results are as follows:

$$\ell_1 = 38.6cm,\ \ell_2 = 38.7cm,\ \ell_3 = 38.6cm,\ \ell_4 = 38.5cm$$

What is the average or *mean* measurement?

$$\ell_{ave} = \frac{\ell_1 + \ell_2 + \ell_3 + \ell_4}{n_\ell} = \frac{38.6cm + 38.7cm + 38.6cm + 38.5cm}{4} = \frac{154.4cm}{4} = 38.6cm$$

What is the *range* of measured values?

$$R = \ell_{\max} - \ell_{\min} = 38.7cm - 38.5cm = 0.2cm$$

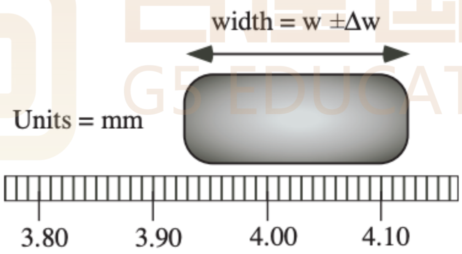
Repeated measurement of the same quantity can improve the overall acceptable value of that measurement. What is the *mean* and its *absolute uncertainty* for the length of string?

$$\Delta\ell_{ave} = \frac{R}{n} = \frac{\ell_{\max} - \ell_{\min}}{4} = \frac{0.2cm}{4} = \pm 0.05cm$$

but we have only 0.1 decimal place, hence $\Delta\ell_{ave} = \pm 0.1cm$

Therefore: $\ell \pm \Delta\ell = (38.6 \pm 0.1)cm$

2. What is the *width* and its *absolute uncertainty* of the object being measured in the sketch below?

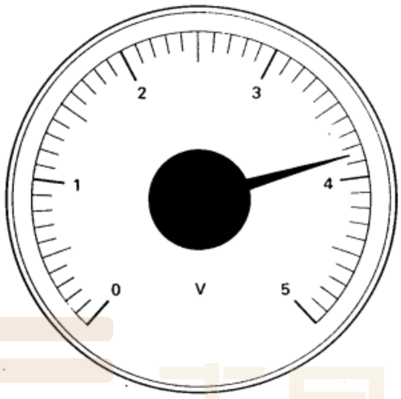


SOLUTION: $w = w_2 - w_1 = 4.12mm = 3.93mm = 0.19mm$

Smallest division is $\Delta w = 0.01mm$

$$w \pm \Delta w = 0.19mm \pm 0.01mm = (0.19 \pm 0.01)mm$$

3. The analogue voltmeter below measures a voltage on a scale of zero to 5 volts. What is the measured *voltage* and what is the *absolute uncertainty* shown here?



SOLUTION: Scale reads $V = 3.85V$

We can discern one half the smallest division so $\Delta V = \pm(0.5 \times 0.1V) = \pm 0.05V$

$$V \pm \Delta V = (3.85 \pm 0.05)V$$

4. The digital stopwatch was started at a time $t_0 = 0$ and then was used to measure ten swings of a simple pendulum to a time of $t = 17.26s$.

1	7	. 2	6

If the time for ten swings of the pendulum is $17.26s$ what is the *minimum absolute uncertainty* in this measurement?

SOLUTION: $\Delta(10T) = \pm 0.01s$

What is the *time* (period T) *of one complete pendulum swing* and its *absolute uncertainty*?

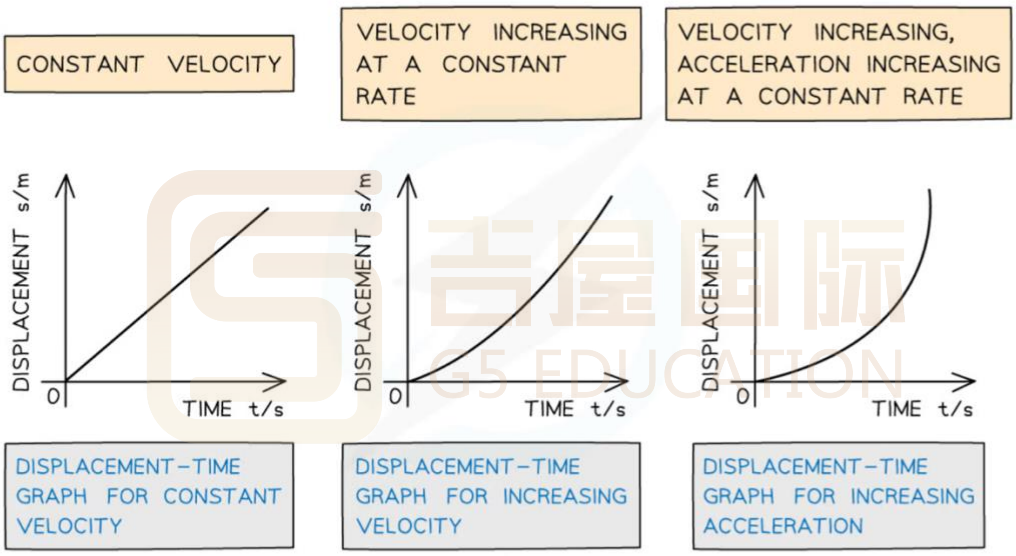
SOLUTION:

$$10T = (17.26 \pm 0.01)s \;\rightarrow\; T \pm \Delta T = \frac{(17.26 \pm 0.01)s}{10} = (1.726 \pm 0.001)s$$

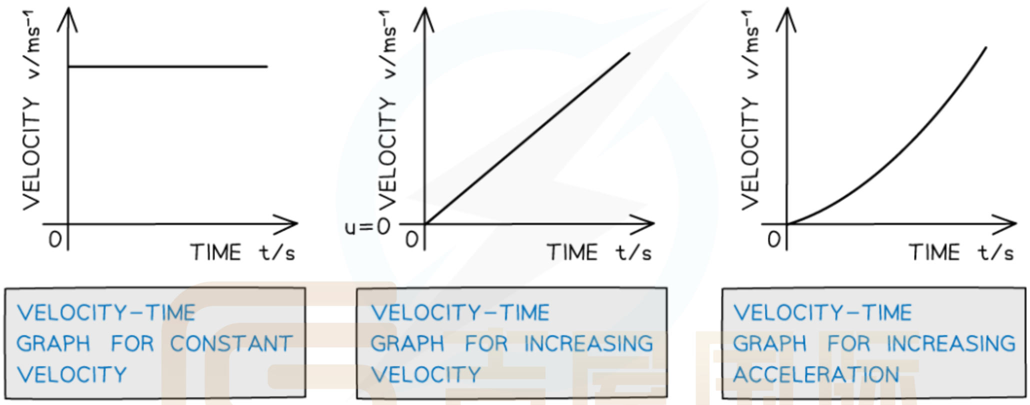
2 Kinematics

Motion graphs

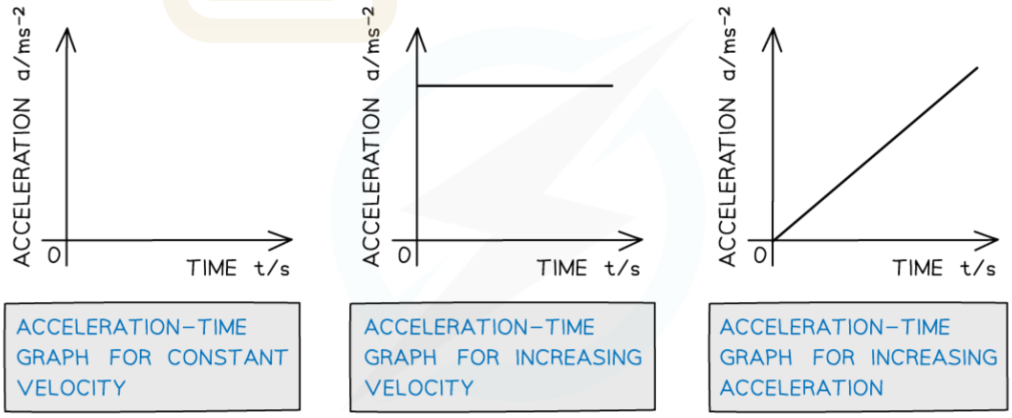
d-t diagram



v-t diagram



a-t diagram



Area under v-t diagram: displacement
Gradient of v-t diagram: acceleration
Gradient of d-t diagram: velocity

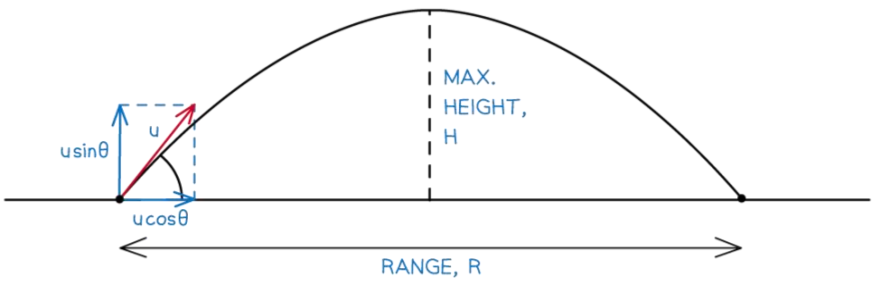
Equations of motion

$$v = u + at \qquad s = ut + \frac{1}{2}at^2$$

$$s = \frac{(v+u)}{2}t \qquad v^2 = u^2 + 2as$$

s = displacement
u = initial velocity
v = final velocity
a = acceleration
t = time interval

Projectile



VERTICAL MOTION (↑)

INITIAL SPEED, $u = u\sin\theta$

ACCELERATION, $a = 9.81\ \mathrm{ms^{-2}}$

DISPLACEMENT = 0

TIME OF FLIGHT

$u = u\sin\theta \quad v = 0 \quad a = -g \quad t = ?$

THE EQUATION THAT RELATES THESE QUANTITIES IS

$v = u + at$

$0 = u\sin\theta - gt$

$t = \dfrac{u\sin\theta}{g}$

$2t = \dfrac{2u\sin\theta}{g}$

IF THE TIME TO MAXIMUM HEIGHT IS t, THEN THE TIME OF FLIGHT IS 2t

MAXIMUM HEIGHT ATTAINED

$u = u\sin\theta \quad v = 0 \quad a = -g \quad H = ?$

THE EQUATION THAT RELATES THESE QUANTITIES IS

$v^2 = u^2 + 2as$

$0 = (u\sin\theta)^2 - 2gH$

$2gH = (u\sin\theta)^2$

$H = \dfrac{(u\sin\theta)^2}{2g}$

HORIZONTAL MOTION (→)

INITIAL SPEED, $u = u\cos\theta$

ACCELERATION, $a = 0$

DISPLACEMENT = R

RANGE (R)

$u = u\cos\theta \quad t = \dfrac{2u\sin\theta}{g} \quad a = 0 \quad R = ?$

THE EQUATION THAT RELATES THESE QUANTITIES IS

DISTANCE = SPEED × TIME

$R = (u\cos\theta)t$

$R = \dfrac{2u^2\sin\theta\cos\theta}{g}$

$R = \dfrac{u^2\sin 2\theta}{g}$

USING THE TRIG IDENTITY:

$2\sin\theta\cos\theta = \sin 2\theta$

3. Dynamics

Newton’s law of motion

Newton's 1st law - An object will remain at rest or travelling at a constant velocity, until it experiences a resultant force

Newton's 2nd law - The acceleration of an object is proportional to the resultant force experienced by the object: $F = ma$ where **F** is the resultant force, **m** is the object's mass and **a** is its acceleration.

It is important to note that the **resultant force and acceleration are always in the same direction**.

Newton's 3rd law - For each force experienced by an object, the object exerts an equal and opposite force.

Momentum

momentum = mass x velocity

conservation of momentum:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

There are two types of collision:

Elastic - where **both** momentum and kinetic energy are conserved

Inelastic - where **only** momentum is conserved, while some of the kinetic energy is converted into other forms (e.g heat, sound, gravitational potential) and may be larger or smaller after a collision

4. Force, density and pressure

Equilibrium of force (moment and torque):

Moment

The **moment** of a force about a point is the force multiplied by the perpendicular distance from the line of action of the force to the point.

Moment = Force X Perpendicular distance to line of action of force from the point

Couple and torque

A **couple** is a pair of coplanar forces (meaning they are forces within the same plane), where the two forces are equal in magnitude but act in opposite directions. A couple tends to only produce **rotation**.

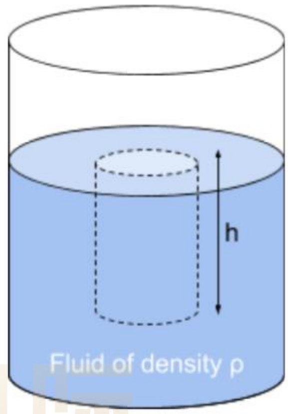
To find the **torque of a couple**, you multiply one of the forces by the perpendicular distance between the lines of action of the forces.

Moment of a couple = Force X Perpendicular distance between the lines of action of forces

Equilibrium

Note that a system is in **equilibrium** if there is no resultant force **and** no resultant torque.

Pressure



volume:

$Volume = A \times h$

$Mass = \rho \times A \times h$ As $Weight = mg$, you can calculate the weight of this fluid as shown below:

$Weight = \rho \times A \times h \times g$

Finally you can calculate pressure using the equation shown above:

$$p = \frac{Weight}{Area} = \frac{\rho \times A \times h \times g}{A} = \rho hg$$

Therefore,

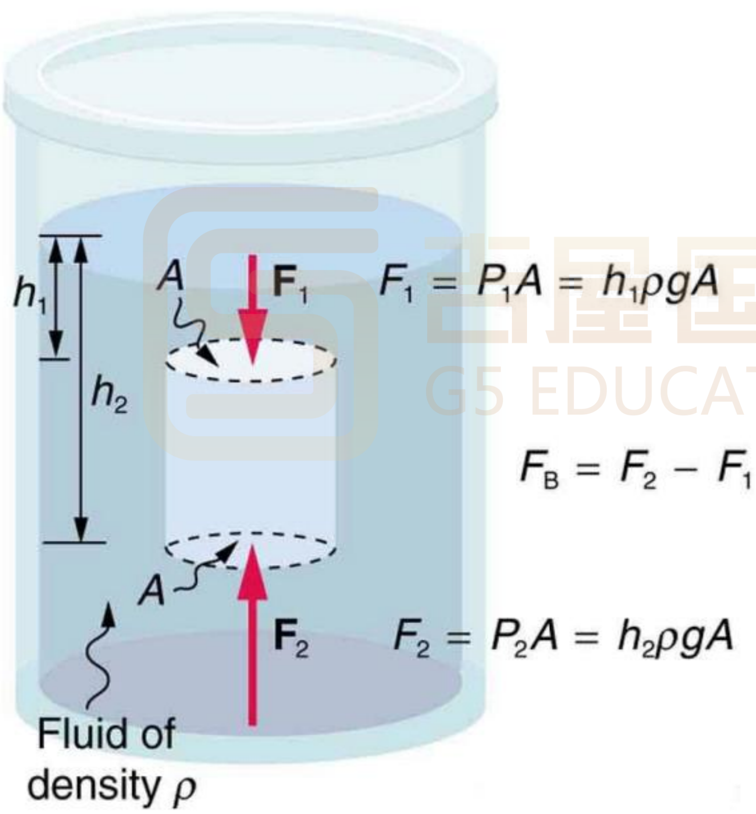
$$\Delta p = \rho g \Delta h$$

Note: this equation does not give you a value of total pressure.

Total pressure is the sum of the pressure exerted by the fluid and atmospheric pressure.

buoyant force (upthrust)

Archimedes' Principle states that the weight of the fluid displaced by a submerged body equals the upthrust force exerted on the body. As such the buoyant force F can be written as where F = ρgV ρ is the density of the fluid, g is the gravitational acceleration, and V is the volume of fluid displaced by the object.



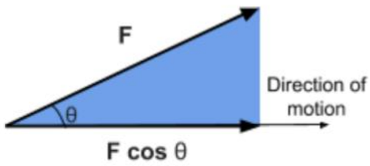
5. Work, energy and power

Work done of a force

Energy is defined as the capacity to do work.
Work done (W) is defined as the force causing a motion multiplied by the distance travelled in the direction of the motion.

$$W = Fs\cos\theta$$

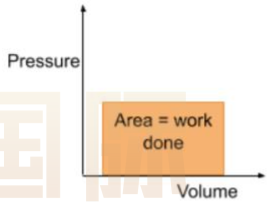
Where s is the distance travelled and θ is the angle between the direction of the force and the direction of motion.



Work is done on a gas to change its volume when it is at **constant pressure**, (this is usually done through the transfer of thermal energy) the value of work done can be calculated using the formula:

$$Work\ done = p\Delta V$$

Where p is the pressure and ΔV is the change in volume.



Energy conservation

The **principle of conservation of energy** states that energy cannot be created or destroyed, but can be transferred from one form to another. Therefore, the total energy in a closed system stays constant.

$$Total\ energy\ in = Total\ energy\ out$$

Power

Power (P) is the rate of energy transfer (energy transferred per unit time). As work is a measure of energy transfer, the rate of doing work = the rate of energy transfer, therefore:

$$P = \frac{\Delta W}{\Delta t} = \frac{F \times \Delta s}{\Delta t} = Fv \text{ as } v = \frac{\Delta s}{\Delta t}$$

It is important to note that you can calculate the work done by an electrical appliance of power P in t seconds, by finding the product of power and time passed.

$$Energy\ transferred = P \times \Delta t$$

Efficiency

Efficiency is a measure of how efficiently a system transfers energy. It is calculated by dividing the useful power output by the total power input.

$$Efficiency = \frac{useful\ output\ power}{input\ power} \qquad Efficiency\ (percentage) = \frac{useful\ output\ power}{input\ power} \times 100$$

If you multiply the value of efficiency by 100, you receive the value of efficiency as a percentage.

The efficiency of a system is never 100%, meaning that the energy input into a system is always greater than the **useful** energy output. This is because energy is always lost due to various forms of friction, for example, where two parts of the system make contact kinetic energy will be transferred to internal, and sound energy (which is usually undesirable).

GPE and KE

You can calculate the **kinetic energy (E_k)** of an object using the following equation:

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

You can calculate the change in **gravitational potential energy (ΔE_p)** of an object using the following equation, if it is close to the Earth's surface. This is because the Earth's gravitational field can be modelled as uniform close to its surface.

$$\Delta E_p = mg\Delta h$$

6. deformation of solid

Stress and strain

Tensile stress - Force applied per unit cross-sectional area.

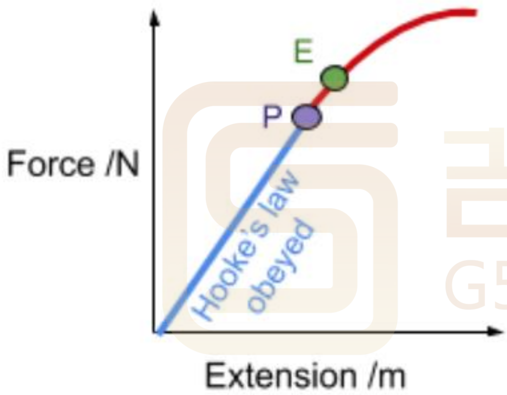
Tensile strain - This is caused by tensile stress, and is defined as the extension over the original length L.

$$Stress = \frac{F}{A}$$

$$Strain = \frac{x}{L}$$

Hooke' s law

Springs (as well as many other materials) follow Hooke's law. **Hooke's law** states that extension is directly proportional to the force applied, given that the environmental conditions (e.g temperature) are kept constant. This can be shown by the straight part of the force-extension graph shown to the right. A straight line graph through the origin shows that the force and extension are directly proportional.



The **limit of proportionality (P)** is the point after which Hooke's law is no longer obeyed. The **elastic limit (E)** is just after the limit of proportionality and if you increase the force applied beyond this, the material will deform plastically (be permanently stretched).

Young’s modulus

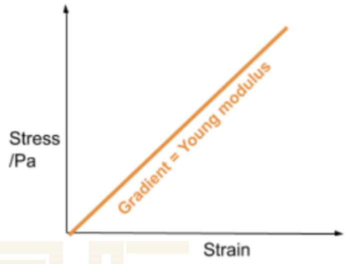
The **Young modulus** is a value which describes the stiffness of a material. It is known that up to the limit of proportionality, for a material which obeys Hooke’s law, stress is proportional to strain, therefore the value of stress over strain is constant. This value is the Young modulus.

$$Young\ Modulus\ (E) = \frac{Tensile\ Stress}{Tensile\ strain}$$

Using the formulas from above, this can be rewritten as:

$$E = \frac{FL}{xA}$$

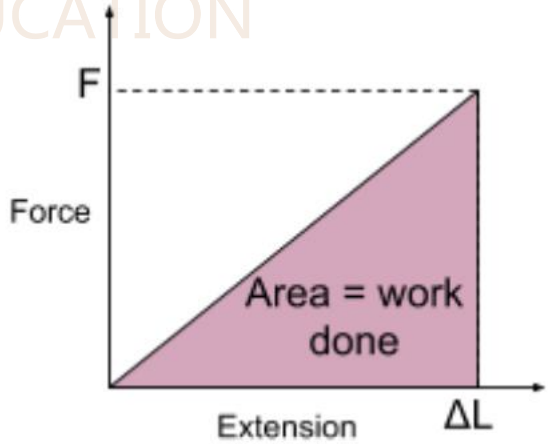
You can find the Young modulus of a material from a stress-strain graph by finding the **gradient** of the straight part of the graph.



Elastic strain energy

When work is done on a material to stretch or compress it, this energy is stored as elastic strain energy. This value cannot be calculated using the formula W = Fs cos θ because the force is variable, however you can find it by calculating the area under a force-extension graph. Therefore, elastic strain energy:

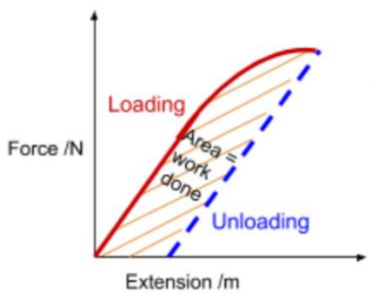
$$\frac{1}{2}Fx = \frac{1}{2}kx^2$$



Force-extension graphs can show the properties of a specific object. There are two main behaviours that a material can exhibit on a force-extension graph:

- **Plastic** - This is where a material will experience a large amount of extension as the load is increased, especially beyond the elastic limit
- **Brittle** - This is where a material will extend very little, and therefore is likely to fracture (break apart) at a low extension.

Once a material is stretched beyond its **elastic limit**, a force-extension graph showing loading and unloading will not return to the origin, however the loading and unloading lines will be parallel because the material’s stiffness is constant, as shown on the graph. The area between the loading and unloading line is the **work done to permanently deform the material.**



7. electricity

Current

Electric current (I) is the flow of charge (Q) per unit time (*t*), or the **rate of flow of charge**. Charge is carried by **charge carriers** in **quantised** amounts. Typically the charge carriers are **electrons**, which each carry the **elementary charge** $e = 1.60 \times 10^{-19}$ **C (coulombs)**.
As suggested by the definition of electric current, the equation for the charge carried by a conductor is:

$$Q = It$$

For example, a conductor delivering a current of 5 amps for 10 seconds equals a total transferred charge of 50 coulombs.

Imagine a current carrying conductor (such as a wire) with a **cross-sectional area (A)**, with particles carrying charges of q with a **number density (n),** and mean **drift velocity (v)**. The current (I) being carried by the conductor is as follows:

$$I = Anvq$$

Potential difference and emf

Potential difference (V) - the **energy** transferred **per unit charge** from electricity to other forms.
E.m.f (V) – the energy transferred per unit charge from other forms to electricity.

$$V = \frac{W}{Q}$$

Electric power and energy

Power (P) is the energy transferred over time (rate of transfer of energy). $P = \frac{E}{t}$ where **E** is energy transferred and **t** is time. Another formula for power is $P = VI$, which can be combined with the formula $V = IR$, to form two variations:

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

Power is the energy transferred over time, so the product of power and time is the energy transferred, therefore $E = VIt$.

Resistance and resistivity

Resistivity, ρ is a measure of how easily a material conducts electricity. It is defined as the product of resistance and the cross-sectional area, divided by the length of the material. Resistivity will give the value of resistance through a material of length 1 m and cross-sectional area 1 m^2 which is useful when you need to compare materials even though they may not be the same size, however resistivity is also dependent on environmental factors, such as temperature.

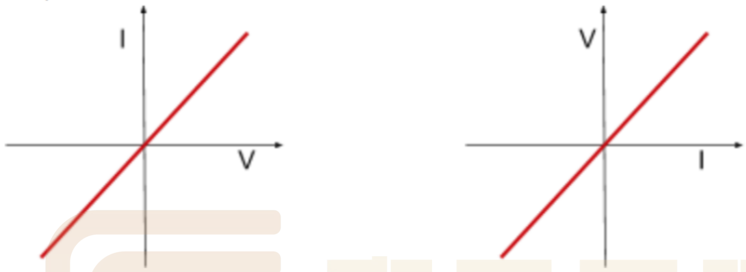
$$\rho = \frac{RA}{L}$$

Ohm's law

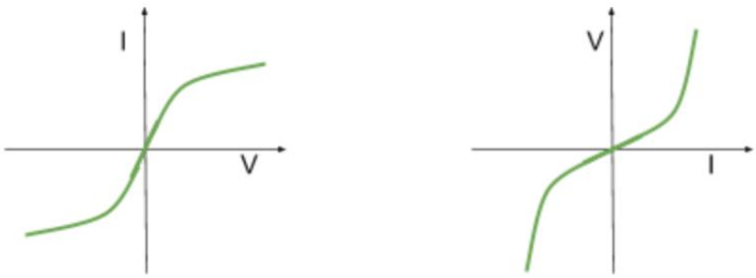
Ohm's law states that for an **ohmic conductor**, **current is directly proportional to the potential difference** across it, given that physical conditions (e.g temperature) are kept **constant**.

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

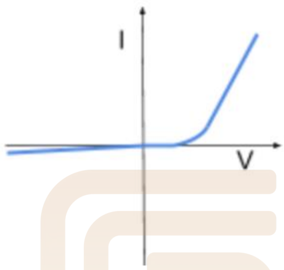
Ohmic conductor - this component **follows Ohm's law,** therefore its current-voltage graph will look like a straight line through the origin (provided that physical conditions are kept constant).

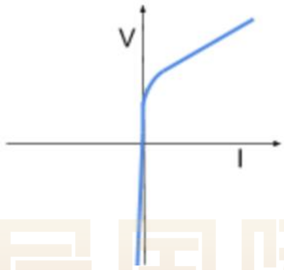


Filament lamp - this component contains a length of metal wire, which heats up as current increases, therefore the resistance of this component increases as current increases. At low currents the metal wire will not heat up significantly, therefore for very **low currents**, **Ohm's law is obeyed**. However, as the magnitude of the current increases, the graph begins to curve due to the increasing resistance.



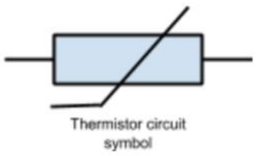
Semiconductor diode - when looking at the current-voltage graph of this component you must consider its forward and reverse bias. The forward bias of a diode is the direction in which it will allow current to flow easily past the **threshold voltage**, which is the smallest voltage needed to allow current to flow. In the direction of the reverse bias, the resistance of the diode is extremely high meaning that only a very small current can flow.

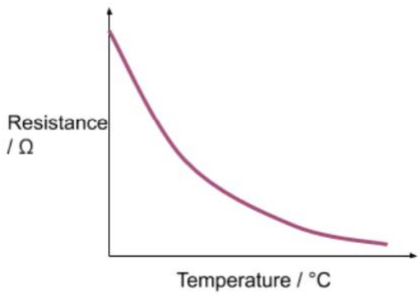




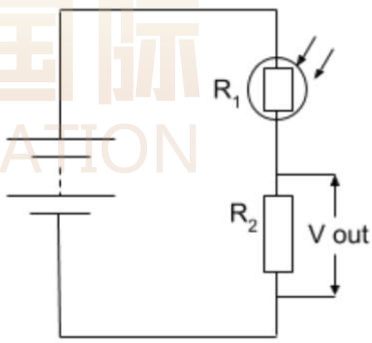
Thermistor and LDR (light dependent resistor)

When the **temperature of a metal conductor increases, its resistance will increase**. This is because the atoms of the metal gain kinetic energy and move more, which causes the charge carriers (electrons) to collide with the atoms more frequently, causing them to slow down. Therefore, as temperature increases, current decreases and so resistance increases ($R = \frac{V}{I}$).





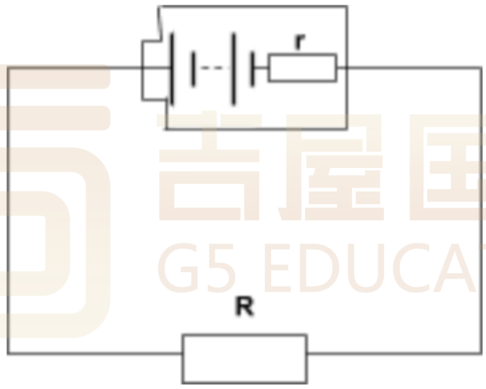
A **light dependent resistor (LDR)** is one whose resistance decreases with **increasing light intensity**. These types of sensors can be used to **trigger certain events**, for example in the circuit on the next page, a light dependent resistor is used. If the light intensity falls, resistance across R_1 will increase. This will cause the total circuit resistance to increase and so the circuit current will decrease. Using Ohm's law (**V = IR**), you can see that this means that the voltage across R_2 decreases, so the p.d out decreases. If you want this effect to be **reversed**, you can **switch the position of the LDR and resistor**, meaning that the p.d out would increase as light intensity decreases. This circuit, for example, could be used to switch on a light bulb depending on the light intensity of its environment, due to a certain threshold voltage (from p.d. out) being met.



8. D.C circuit

Internal resistance in practical circuit

Batteries have an **internal resistance (r)** which is caused by electrons colliding with atoms inside the battery, as this results in some energy being lost before electrons even leave the battery. It is represented as a small resistor inside the battery.



And so the emf is the product of the total resistance and the current of the circuit, because $V = IR$.

$$\varepsilon = IR + Ir \qquad \varepsilon = I(R + r)$$

The p.d. across the load resistance R, is known as the **terminal p.d. (V)**, whereas the p.d. across the internal resistance r, is known as **lost volts (v)** because this value is equal to the energy wasted by the cell per coulomb of charge.

$$V = IR \qquad v = Ir$$

Therefore, emf is the sum of the terminal p.d. and lost volts: $\varepsilon = V + v$.

Kirchhoff's law

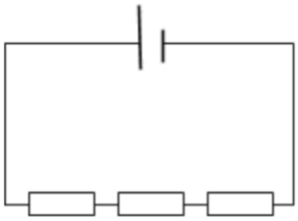
In DC circuits, charge and energy are **always** conserved. Kirchhoff's two laws describe how this is achieved:

Kirchhoff's first law - the total current flowing into a junction is **equal** to the current flowing out of that junction. This shows that no charge is lost at any point in the circuit.

Kirchhoff's second law - the **sum** of all the voltages in a **series** circuit is **equal** to the **battery voltage** (or the sum of all the voltages in a loop is zero). This shows that no energy is lost at any point in a circuit.

In a **series** circuit,

- The current is the **same** everywhere in the circuit.
- The battery p.d. is shared across all elements in the circuit, therefore the **total sum of the voltages** across all elements is **equal** to the **supply p.d**.



When joining together battery cells, you can use either a **series** or **parallel** configuration. When joined **in series**, the total voltage across the cells is equal to the sum of the individual voltages of the cells:

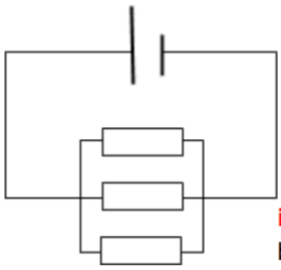
$V_T = V_1 + V_2 + V_3 + \ldots$

Following from this, the **combined resistance** of several resistors **in series** is:

$R_T = R_1 + R_2 + R_3 + \ldots$

In a **parallel circuit**,

- The **sum** of the currents in each parallel set of branches is **equal** to the **total current**.
- The potential difference across each branch is the **same**.



When **identical cells** are joined **in parallel**, the total voltage is equal to the voltage of one cell. This is because the current is split equally between branches, therefore the overall potential difference is the same as if the total current was flowing through a single cell:

$V_T = V_1 = V_2 = V_3 = \ldots$

Following from this, the **combined resistance** of several resistors **in parallel** is:

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$

Potential divider

A **potential divider** is a circuit with several resistors in series connected across a voltage source, used to produce a required **fraction** of the source potential difference, which remains constant.
You can also make a potential divider supply a **variable** potential difference by using a **variable resistor** as one of the resistors in series, therefore by varying the resistance across it, you can vary the potential difference output.

For example, in the diagram below, if the resistance across R_1 increases, the output p.d. will decrease as circuit current has decreased and V=IR.