Physics Notes 2016 / 2017

Secondary 3 / 4

EOY: Chapters 1 to 13

Consol: Chapters 1 to 14

MYE: Chapters 1 to 21.2

Note to mobile users: Download as PDF / Word to view hidden equations

THEME 1: GENERAL PHYSICS

Chapter 1: Measurements

Physical Quantities: Quantities that can be measured, consists of a *numerical magnitude* and a *unit*.

Prefixes:

10^9: giga- (G)	10^6: mega- (M)	10^3: kilo- (k)	10^{-1}: deci- (d)
10^{-2}: centi- (c)	10^{-3}: milli- (m)	10^{-6} : micro- (μ)	10^{-9}: nano- (n)

Useful Info:

÷3.6

km/h → m/s

km/h ← m/s

×3.6

Sizes of well-known objects:

Radius of Earth: 6378000m (6.378×10^6)

Size of atom: 0.0000000001m (10^{-10})

Vernier Calipers

Precision: 0.01cm

Reading: Read the main scale until the immediate left of the zero mark on the vernier scale, then add the marking which coincides with the marking on the main scale.

Zero Errors:

Positive: the zero mark of Vernier is slightly to the right of the main scale

Negative: the zero mark of Vernier is slightly to the left (READ SCALE FROM LEFT)

Micrometre Screw Gauge

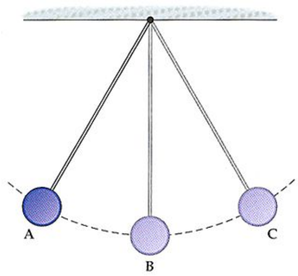
Precision: 0.01mm

Reading: Read main scale, then read thimble reading

Zero Errors:

Positive: Zero marking on thimble scale is below datum (centre) line

Negative: Zero marking on thimble scale is above datum line



Pendulums:

Oscillation: One complete to-and-fro motion (A->C->A)/(B->C->B->A->B)

Period: Time taken for one complete oscillation

Chapter 2: Kinematics

Scalar Quantities: Quantities with only magnitude

(Distance, Speed, Mass, Energy, Time)

Vector Quantities: Quantities with both magnitude and direction

(Displacement, Velocity, Acceleration, Force)

Distance: Total distance travelled

Displacement: Total distance travelled in a straight line

Speed: The distance moved per unit time (m/s)

Velocity: The rate of change of *displacement* (m/s)

Acceleration: The rate of change of velocity (m/s^2)

Uniform Acceleration: constant rate of change of velocity

Acceleration

$$a = \frac{v-u}{t_v-t_u}$$

where v = initial velocity (m/s)

u = final velocity (m/s)

t_u = time at *u* (s)

t_v = time at *v*

Important Information

The gradient of a displacement-time graph of an object is its velocity.

The gradient of a velocity-time graph of an object is its acceleration.

The area under a velocity-time graph of an object is its displacement.

Acceleration due to Gravity: $9.81 m/s^2$ ($10.0 m/s^2$)

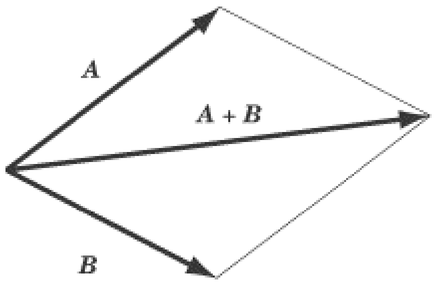
Reducing air resistance: Reduce surface area

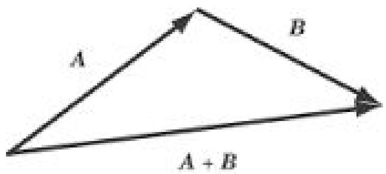
Skydiver question: He could fall head or feet first in order to reduce his surface area to fall faster.

Chapter 3: Forces

Forces – S.I. Unit = Newton (N)

Vector Diagrams: Parallelogram and tip-to-tail methods





- When asked to calculate a of arrow, given force F_1 on arrow and mass m, resultant force is not F_1 but F_1 -10m (See AHS Prelim 2017)

NEWTON's LAWS OF MOTION

First Law: every object will continue in its state of *rest or uniform motion in a straight line* unless a resultant force acts on it.

Second Law: when a resultant force acts on an object of constant mass, the object will accelerate in the direction of the resultant force. The product of the mass and acceleration of the object gives the resultant force.

TL; DR

$$F = ma$$

Where F = resultant force (N), m = mass (kg), a = acceleration (m/s^2)

Third Law: if body A exerts a force F_{AB} on body B, then body B will exert an equal and opposite force F_{BA} on body A.

Friction: the contact force that *opposes or tends to oppose* motion between surfaces in contact.

Reducing friction: Wheels, Ball bearings, Lubricants, Air Cushions

Increasing friction: Treads, Parachute, Chalk

Stuff to note

1. **In a vector diagram, if all 3 arrows form a complete loop, the forces are in equilibrium.**

Chapter 4: Mass, Weight and Density

Mass (kg): the amount of matter in a body.

Weight (N): the gravitational force, or gravity, acting on an object.

Gravitational field: a region in which a mass experiences a force due to gravitational attraction.

Gravitational field strength: the gravitational force acting per unit mass.

Relation between mass and weight:

$$W = mg$$

where W = weight (N),

M = mass (kg),

g = gravitational field strength (N/kg)

Mass vs Weight:

Measured with beam balance vs measured with spring balance

Inertia: the reluctance of the object to change its state of motion due to its mass.

Density (kg/m^3):

$$\rho = \frac{m}{V}$$

where ρ = density,

V = volume of object

Chapter 5: Turning effect of Forces

Moments

Moment of a force (torque, Nm): the product of the force F and the perpendicular distance from the pivot to the line of action of the force.

$$Moment\ of\ a\ force = F \times d$$

where F = force (N)

d = perpendicular distance from the pivot (m)

Moments are vector quantities, thus must specify both magnitude and direction.

Principle of Moments: when a body is in equilibrium, the sum of clockwise moments about a pivot is equal to the sum of anticlockwise moments about the same pivot.

Centre of Gravity: the point through which its whole weight seems to act.

Stability: the measure of an object's ability to return to its original position after it is slightly displaced.

Equilibrium: stable, unstable, neutral

Tightrope walking question: the long pole helps to lower the C.G. of the tightrope walker below the rope

Stuff to note

1. **Moment of a force is always calculated by the force multiplied by the perpendicular distance from the line of action of the force to the pivot**

Chapter 6: Energy, Work and Power

Energy (J): Energy is the capacity to do work.

Principle of Conservation of Energy: energy cannot be created or destroyed, but can be converted from one form to another. The total amount of energy in an isolated system is constant.

Efficiency:

$$\frac{\textit{useful energy output}}{\textit{total energy input}} \times 100\%$$

Work done by a constant force on an object is the product of the *force* and the *distance moved* by the object *in the direction of the force.*

i.e.

$$W = F \times s$$

where W = work done by a constant force F (J)

F = constant force (N)

s = distance moved by the object in the direction of the force.

Work Done = Energy Transformed

Kinetic Energy E_k (KE)

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

where E_k = kinetic energy (J)

m = mass of the body (kg)

v = speed of the body (m/s)

Gravitational Potential Energy E_p (GPE)

$$E_p = mgh$$

where E_p = gravitational potential energy (J)

m = mass of the body (kg)

g = gravitational field strength (m/s^2)

h = height (m)

Power: the rate of work done / energy conversion

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

where P = power (W)

W= work done (J)

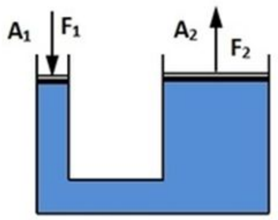
E = energy converted (J)

t = time taken (s)

Chapter 7: Pressure

Pressure (N/m^2 or Pa): Pressure is defined as the force acting per unit area.

$$p = \frac{F}{A} \ (solids)$$



where p = pressure (Pa)

F = force (N)

A = area (m^2)

$$p = h\rho g \ (liquids)$$

where h = height (m)

ρ = density (kg/m^3)

g = gravitational field strength (N/kg)

$$F_1 \times d_1 = F_2 \times d_2$$

Stuff to note:

1. **Test for vacuum in a simple mercury barometer: Tilt the tube until the closed end is below xx cm Hg. Absence of space will indicate that there is a vacuum**

THEME II: THERMAL PHYSICS

Chapter 8: Temperature

Temperature (K) refers to how hot or cold an object is.

Heat (J) refers to the amount of thermal energy that is being transferred from a hotter to a colder region.

Qualities of a Quality Thermometer

1. An easy-to-read-scale
2. Responsive to temperature changes
3. Sensitive to small temperature changes
4. Can measure a wide range of temperatures

Thermometric substances: have *physical properties* that vary *continuously and linearly* with temperature for the range of temperatures measured

Physical Property	Example of thermometer
The volume of a fixed mass of liquid	Mercury-in-glass thermometer, Alcohol thermometer
Electromotive force or electrical voltage	Thermocouple thermometer
Electrical resistance of a piece of metal	Resistance thermometer

Constructing a Thermometer

1. Choose an appropriate thermometric substance to be used in the thermometer
2. Choose two fixed points which are easily obtainable and reproducible. Usually, the temperature of pure melting ice at one atmosphere and the temperature of steam from boiling water at one atmosphere are used as fixed points
3. Record the values of the substance level in the thermometer stem at these fixed points
4. Divide the interval between these two fixed points in 100 equal parts
5. Each of these equal parts on the scale represents a measure of 1 ºC

Ice point: The temperature of pure melting ice at one atmospheric pressure, 0ºC

Steam point: The temperature of steam from boiling water at one atmospheric pressure, 100ºC

Calibrating thermometers – Precautions

1. Ice point: Use crushed ice to ensure good contact between the bulb and ice, use a

funnel to allow melted ice to flow away so that the thermometer only measures the temperature of the melting ice.

2. Steam point: Use a manometer to check if the pressure inside the apparatus is the same as the atmospheric pressure outside.

a. If the pressure is not equal, adjust the flame accordingly

Calculating temperature (Celsius scale) GENERAL EQUATION =

$$\theta = \frac{X_\theta - X_\delta}{X_N - X_\delta} \times (T_N - T_\delta) + T_\delta$$

Where:

Theta = Unknown Temperature

X theta = Value of thermometric property at unknown temperature

X delta = Smaller value of thermometric property at given temperature

X N = Larger value of thermometric property at given temperature

T N = Higher temperature relating to X n

T delta = Lower Temperature relating to X delta

Essentially,

$$\theta = \frac{Change\ in\ TP\ due\ to\ unknown}{Change\ in\ TP\ due\ to\ known} \times (Difference\ of\ 2\ known\ temp) + Lower\ known\ Temp$$

e.g. if melting point resistance = 700, boiling point resistance = 850, unknown resistance = 750,

$$\theta = \frac{750 - 700}{850 - 700} \times (100) + 0$$

- Only applicable when given temperatures are 0ºC and 100ºC
- Change (100) according to range of temperatures measured

Stuff to note

1. **Bubbles only appear at the source of heating and rise to the top during boiling**

Chapter 9: Kinetic Model of Matter

Kinetic model of matter states that the tiny particles that make up matter are always in continuous random motion.

Brownian Motion: a phenomenon that provides evidence for the continuous and random motion of tiny particles.

1. Examples: The random motion of pollen grains in water and smoke particles in air.
2. Smoke cells:
   a. Light: To allow smoke particles to reflect light and be seen as bright specks
   b. Choice of smoke particles: Smoke particles are large enough to be visible, yet light enough to be affected by air particles
3. Drawing of Brownian Motion
   a. Alter the length and direction of the lines
   b. Must have at least 5 lines
   c. Add arrows

Gas Pressure question: How is pressure produced by gases in containers?

Gas pressure in a container is produced by the collision of gas particles with *the walls of the container.* When a gas particle hits a container wall, it *exerts a force* on the wall. Since pressure is the force per unit area, pressure is produced. Gas pressure is defined as the *average* force per collision between gas particles and the container's walls.

Relationship between pressure, volume and temperature

$$V \propto T \text{ at constant pressure}$$

At higher temperatures, gas particles have higher *kinetic* energies. If volume is constant, the **frequency of collisions**, and hence, pressure will increase. In order for the pressure to remain constant, the **distance between the walls of the container** must *increase* so that the **average time between each collision** is increased. Therefore, at constant pressure, the volume of a gas increases with increasing temperature.

$$p \propto \frac{1}{V} \text{ at constant temperature}$$

When volume is increased, the distance between the walls of the container is *increased*. This causes the average time between each collision of the gas particles to *increase,* and the frequency of collisions to *decrease*. Therefore, at constant temperature, the pressure of a gas *decreases* with increasing volume.

$$p \propto T \text{ at constant volume}$$

When temperature increases, the gas particles have greater *kinetic* energies and move faster. They collide with the walls of the container more frequently and with *greater average* force. This causes the pressure in the container to *increase.* Therefore, at constant volume, the pressure of a gas *increases* with increasing temperature.

Ideal Gas Law

$$p_1 v_1 = p_2 v_2$$

- Where p_1 and p_2 are the initial and final pressures respectively, and v_1 and v_2 are the initial and final volumes respectively
- Derived from the relationship between pressure and volume

Chapter 10: Transfer of Thermal Energy

Thermal energy always flows from a region of higher temperature to a region of lower temperature. Net flow of thermal energy occurs only when there is a difference in temperature.

Conduction: the transfer of thermal energy by molecular vibration through a medium *without any flow of the medium*, i.e. solids

1. Particles, when heated, **gain kinetic energy** and **vibrate vigorously about their fixed positions**. They **collide with neighbouring particles, making them vibrate more vigorously**. The **neighbouring regions** of the object (rod) becomes hot. Eventually, the **particles at the other end of the rod** are also set into vigorous vibration.
   a. Free electron diffusion (metals only): The free electrons at the heated end **absorb thermal energy**, and hence gain **kinetic energy**. The free electrons that gain kinetic energy **move at greater speeds**, and move to the **cooler regions of the rod**. As these electrons move, they **collide with the atoms in the cooler parts of the rod**, making them **vibrate more vigorously**. Thermal energy is transferred via the **motion of the free electrons**. The cooler end of the rod becomes hot.
2. Speed: Solid > Liquid > Gas
   a. Distance between particles is inversely proportionate with the frequency of collisions

Convection: the transfer of thermal energy by means of *convection currents* in a fluid, due to a difference in density, i.e. liquids and gases.

1. Involves the bulk movement of the fluid that carries the thermal energy.
   a. When the flask is heated, the water molecules at the bottom of the flask gain **thermal energy through conduction**, and thus **speed up and expand**, hence **decreasing in density**. As these molecules are *less dense than the surrounding water above*,

they **rise**. As the upper region of the water is **more dense, it sinks to displace the hot water molecules**. Hence a convection current is set up, and thermal energy is transferred throughout the water.

b. Hence heating elements should be placed at the bottom of containers

Radiation: the transfer of thermal energy in the form of electromagnetic waves such as infrared radiation without the aid of a medium, i.e. in vacuum.

Thermal energy from infrared radiation is called radiant heat. All objects emit radiant heat.

Factors affecting radiation:

Colour and texture of the surface: Dull and black better emitters/absorbers of radiant heat

Surface temperature: The higher the surface temperature in comparison with the surroundings, the higher the rate of emission.

Surface area: Objects with larger surface area emit/absorb at a higher rate than objects with smaller surface areas

Stuff to note

1. **Conduction occurs in air as well. Conduction only does not occur in vacuum.**
2. **Design of a vacuum flask:**

- Plastic stopper: Conduction, Convection, evaporation
- Trapped air: Conduction
- Vacuum: Conduction and Convection
- Silvered surfaces: Radiation
- Cork: Conduction

Chapter 11: Thermal Properties of Matter

Internal Energy: The sum of molecular kinetic and potential energies of the particles of a substance

Heat capacity (C): the amount of thermal energy required to raise the temperature of a substance by 1K or 1°C

$$C = \frac{Q}{\Delta\theta} \text{ or } Q = C\Delta\theta \text{ or } C = mc$$

where Q = thermal energy (J)

$\Delta\theta$= change in temperature (K / °C)

S.I. unit = J/K or J/ °C

Specific Heat capacity (c): the amount of thermal energy required to raise the temperature of 1 kg of a substance by 1K or 1°C

$$c = \frac{C}{m} \text{ and } Q = mc(\Delta\theta) = C(\Delta\theta)$$

where C = heat capacity (J/K or J/ ºC)

Q = thermal energy required (J)

$\Delta\theta$= change in temperature (K / ºC)

m = mass of substance (kg)

S.I. unit = J/kg/K or J/kg/ ºC

Melting: Temperature remains constant as the thermal energy is absorbed to overcome the strong bonds between particles

1. Opposite: Solidification, temperature remains constant as there is no change in the kinetic energy of the molecules, as intermolecular bonds are formed during freezing and only the potential energy of the substance's molecules decreases.
2. Note this when drawing a melting curve

Boiling: Temperature remains constant as thermal energy is absorbed to break the intermolecular bonds between particles, provide energy for particles to push back on the surrounding atmosphere and increase the average spacing between particles

Latent Heat: Latent heat is the energy released or absorbed by a substance during a change of state, without a change in its temperature.

Latent Heat of fusion/vaporisation (L_f/L_v): the amount of thermal energy required to change a substance from solid state to liquid state/from liquid state to gaseous state without a change in temperature.

Specific Latent Heat of fusion/vaporisation (l_f/l_v): the amount of thermal energy required to change 1 kg of a substance from solid state to liquid state/from liquid state to gaseous state without a change in temperature.

*For vaporization the change in state is liquid ⇌ gas

$$L_f = l_f \times m \text{ or } L_v = l_v \times m$$

where m = mass of substance (kg)

S.I. unit = J/kg

Boiling	Evaporation
Occurs at particular temperature	Occurs at any temperature
Relatively fast	Relatively slow
Takes place throughout the liquid	Takes place only at liquid surface
Temperature remains constant	Temperature usually decreases
Bubbles are formed in the liquid	No bubbles formed in the liquid
External thermal energy source needed	External energy source not needed

- TEST PB (Test the prefectorial board; put them in hot water xD): Temperature for occurrence, Energy, Speed, Temperature Variation, Place, Bubbles

Process of evaporation:

Molecules of a liquid have different kinetic energies. When they constantly bombard each other, energy is being transferred. At the surface of the liquid, the most energetic molecules can overcome the downward attractive forces of other liquid molecules and the atmospheric pressure to escape from the surface of the liquid, hence evaporation occurs.

1. Cooling: (continued from above) As the less energetic molecules are left behind, the average kinetic energy of the molecules in the liquid decreases, hence the temperature of the liquid decreases.

Factors affecting rate of evaporation:

Surrounding temperature

Humidity

Pressure

Surface area

Heat capacity of liquid

Movement of surrounding air

Stuff to note:

1. During heating / cooling, only the kinetic energy of the molecules change.
2. During evaporation / solidification, only the potential energy of the molecules change.

THEME III: LIGHT, WAVES & SOUND

Chapter 12: Light

Normal: the perpendicular to the reflecting surface at the point of incidence

Laws of Reflection:

First Law: the incident ray, reflected ray and the normal at the point of incidence all lie in the same place.

Second law: the angle of incidence *i* is equal to the angle of reflection *r* (i.e. *i* = *r*)

Plane mirror images are:

Same size as object && laterally inverted && upright && virtual

Distance from the mirror = Distance of object from mirror

Refraction: the bending of light as light passes from one optical medium to another.

Laws of refraction:

Law 1: the incident ray, the normal and the refracted ray all lie in the same plane.

Law 2: for 2 given media, the ratio of sine of *i* to sine of *r* is a constant. (Snell's Law)

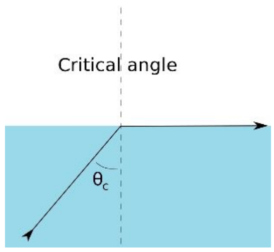
$$\frac{\sin i}{\sin r} = constant$$

Refractive index (n): the ratio of the speed of light in vacuum to the speed of light in medium

$$n = \frac{c}{v} = \frac{\sin i}{\sin r}$$

where c = speed of light in vacuum $(3.0 \times 10^{8} ms^{-1})$

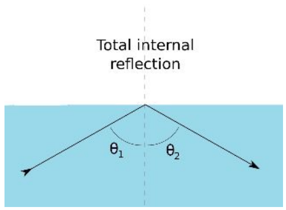
v = speed of light in the medium



Critical Angle (c): the angle of incidence in an optically denser medium for which the angle of refraction in the optically less dense medium is 90°.

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

Total Internal Reflection: the complete reflection of a light ray inside an optically denser medium at its boundary with an optically less dense medium.



2 conditions for total internal reflection:

1. The light ray in an optically denser medium strikes its boundary with an optically less dense medium
2. The angle of incidence is greater than the critical angle of the optically denser medium

Converging lenses

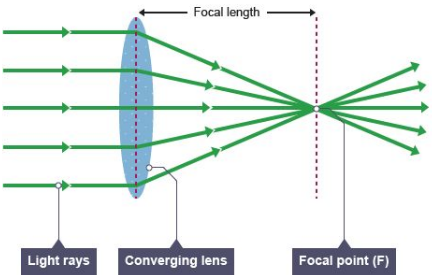
Focal Length (f): the distance between the optical centre and the focal point F.

Focal point F: the point at which all rays parallel to the principal axis converge after refraction.

Principal axis: the horizontal line perpendicular to the vertical plane of the lines passing through the optical centre.

Cases for images and lenses: If object distance (u) is …

Object Distance (u)	Type of Image	Image distance (v)	Uses
∞	Inverted, real, diminished	$v = f$	Object lens of a telescope
$u > 2f$	Inverted, real, diminished	$f < v < 2f$	Camera
$u = 2f$	Inverted, real, same size	$v = 2f$	Photocopier
$f < u < 2f$	Inverted, real, magnified	$v > 2f$	Projector
$u = f$	Upright, virtual, magnified	∞	Spotlights
$u < f$	Upright, virtual, magnified	Behind obj	Magnifying glass



Tips and things to remember for light:

Refraction and reflection both occur below the critical angle.

Focal point $\neq$ focal length

Ray diagrams: Virtual images / rays drawn must always be dotted

For $\frac{\sin i}{\sin r} = n$, $\sin i$ must always be bigger than $\sin r$

Stuff to note:

1. **Light entering or leaving a medium that has a different optical density with an angle of incidence of 0° will continue in a straight line**
2. **The angle of incidence / reflection / refraction is always measured from the normal of the medium to the ray**
3. **Blocking part of a convex lens which is forming an image will only decrease the intensity of the image formed. This is because light rays travel in all**

directions.

4. **For converging lenses, all virtual images are magnified**

Chapter 13: Waves

Wave: Made up of periodic motion.

Periodic motion: motion repeated at regular intervals.

Waves transfer kinetic energy without transferring the medium.

Waves transfer energy from one point to another.

- ➔ Particles do not move laterally, only vertically

The source of a wave is a vibration or an oscillation.

Waves transfer energy from one point to another.

Transverse wave: Waves that travel perpendicular to the direction of the vibration. (e.g. water waves, electromagnetic waves)

Longitudinal wave: Waves that travel parallel to the direction of the vibration. (e.g. sound)

Amplitude (A, m): the maximum displacement of a point from its rest position.

Wavelength (λ, m): the shortest distance between 2 points in phase.

Wavelength becomes shorter/longer upon entering a denser/less dense medium. However, frequency remains the same in both

$$\frac{V_1}{V_2} = \frac{\lambda_1}{\lambda_2}$$

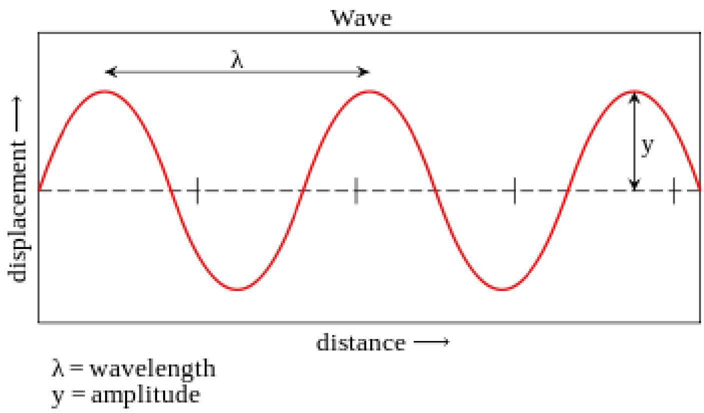
where v $= wave\ speed\ (ms^{-1})$

2 points are in phase if they have the same direction of motion, same speed and same displacement from rest position.

Displacement-distance graph:

Displays the displacements of all particles at a particular point in time.

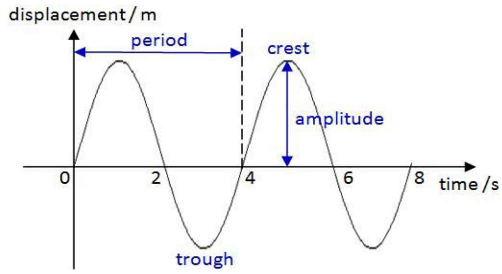
e.g. -> photograph of a wave



Displacement-time graph:

Displays the displacement of a particle over time

e.g. -> tracking of one particle



Period (T, s): the time taken to produce one complete wave.

Frequency (*f*): the number of complete waves produced per second.

$$f = \frac{1}{T}$$

S.I. unit: Hertz (Hz)

Wave speed (v): the distance travelled by a wave per second.

$$v = f\lambda$$

where λ: wavelength (m)

S.I. unit: ms^{-1}

Wavefront: Imaginary line on a wave that joins all adjacent points that are in phase.

The wavefront is always $90°$ to the direction the wave moves (wave's propagation)

Chapter 14: Electromagnetic Waves

Electromagnetic Spectrum: Made up of electromagnetic waves

From longest to shortest wavelength OR smallest to highest frequency:

Radio waves, Microwaves, Infrared Radiation, Visible light, ultraviolet, x-rays, gamma rays

- Note: The frequency overlaps for some waves
- EM song: https://www.youtube.com/watch?v=bjOGNVH3D4Y

Properties of electromagnetic waves:

1. They are transverse waves, comprising electric and magnetic fields oscillating 90° to each other
2. Can travel through vacuum
3. Travel at the speed of $3.0 \times 10^8\ ms^{-1}$ in vacuum
4. Transfer energy from one place to another
5. Wave speed equation $v = f\lambda$ is applicable to all electromagnetic waves
6. Wavelength and speed changes upon changing medium, but frequency does not
7. Electromagnetic waves obey the laws of reflection and refraction
8. Electromagnetic waves carry no electric charge

<u>Applications of electromagnetic waves</u>

Radio waves: Radios, over-the-air TV and communications

- AM, FM radio, submarine communication
- Chosen over microwaves as they have longer wavelengths and can hence diffract around obstructions on Earth's surface better that microwaves which have shorter wavelengths

Microwaves: Microwave ovens, satellite TV, GPS

- Chosen over Radio Waves as they have a higher frequency and can penetrate the atmosphere and travel through haze, light rain, snow, clouds and smoke to receivers.

Infrared radiation: Remote controls, ear thermometers and intruder alarms

Visible light: Optical fibres

Ultraviolet (UV) radiation: Sunbeds, equipment sterilisation

X-rays: Radiation therapy, imaging

Gamma rays: Radiation therapy

- Killing of cancer cells

Effects of electromagnetic waves

Infrared heating

- Infrared radiation from e.g. burning charcoal

Ionising radiation

- Radiation that has enough energy to remove electrons from atoms or molecules
- Can damage biological molecules (e.g. proteins or DNA) and lead to abnormal patterns of cell division
- Causes cancers such as leukemia, or deformation of foetuses

Stuff to note

1. **You cannot hear any form of electromagnetic waves whatsoever unless you're not from the planet Earth or you have dental fillings**

Chapter 15: Sound

Sound

1. Sound is a form of energy that is transferred from one point to another as a longitudinal wave.

In a sound wave,

1. Compressions are regions where air pressure is higher than the surrounding air pressure.
2. Rarefactions are regions where air pressure is lower than the surrounding air pressure.

Sound waves can be plotted using:

1. Pressure-distance graph
    a. Measures pressure over distance

    b. Instantaneous
2. Displacement-distance or displacement-time graph
    a. Measures displacement of particles
    b. Only one particle considered

Transmission of sound

1. Can only be transmitted through a medium
2. Cannot be transmitted through a vacuum
3. Speed of sound varies in each medium
4. Speed of sound in gas < Speed of sound in liquid < Speed of sound in solid

Reflection of sound

1. An echo is the repetition of a sound due to the reflection of sound.
2. Echoes largely obey the rules of light reflection
3. Used to measure large distances or detect the location of objects

Ultrasound

1. Sound with frequencies above the upper limit of the human range of audibility
    a. 20 Hz to 20000 Hz
2. Used for
    a. Quality control
    b. Prenatal scanning

Pitch

1. Pitch is related to the frequency of a sound wave, the higher the frequency, the higher the pitch

Loudness

1. Loudness is related to the amplitude of a sound wave, the larger the amplitude, the louder the sound

THEME IV: ELECTRICITY & MAGNETISM

Chapter 16: Static Electricity

Electric charges

1. **Like**-charged objects **repel** (positive + positive, negative + negative)
2. Unlike-charged objects attract (positive + negative, positive/negative + neutral)
3. Atoms become positively charged and negatively charged when electrons are removed or added respectively to form ions
- Only electrons (not protons) can be transferred, however positively charged atoms are mobile
4. Measured in coulombs
- Charge carried by an electron or proton is $\mathbf{1.6 \times 10^{-19}}$ **C**

Rationale for Charging Methods

	Electrical Insulators	Electrical conductors
Motion of charged particles	Not free to move about	Free to move about
Ability to conduct electricity	Low	High
Method of charging (As a result of the above factors)	Friction: When charged, the electrons remain at the surface where the material has been rubbed as they are unable to move freely within the material	Induction: When rubbed the electrons can be easily transferred to and away, leaving it electrically neutral

Electrostatics

1. The study of static electric charges

Charging by Friction

1. Before rubbing, the glass rod and the piece of silk are **electrically neutral**. As different materials have different **affinities** (extent of attraction) for electrons, *when* the glass rod and the piece of silk are rubbed together, the atoms at their surfaces are **disturbed** and some *electrons* from the atoms at the surface of the glass rod are *transferred* to the piece of silk. As the glass rod **loses electrons**, it becomes **positively charged**. As the piece of silk **gains electrons**, it becomes **negatively charged**.
- Prelim Points: Some **free electrons are transferred** from the rod to the cloth. There

are now **more positive charges than negative charges** on the rod.

Induction

1. The process of charging a conductor **without contact** between the *conductor* and the *charging body*
2. Charging 2 metal spheres
    a. Place the **2 conductors side by side** such that they are **touching each other**
    b. Bring a negatively charged rod **near but not touching** sphere A. This causes the **electrons** in both metal spheres to be repelled to the *far end of sphere B*. Now, **sphere A has excess positive charges** which **sphere B has excess negative charges**.
    c. While holding the **charged rod in place**, pull *sphere B away from sphere A*
    d. Remove the charged rod
    - Spheres A and B have an *equal number of opposite charges*
    - Note the inverse case if a positively charged rod is use
3. Charging a single Conductor
- Bring a **positively charged glass rod** near a metal conductor. The **free electrons** in the metal are **drawn towards** the positively charged glass rod. **Without removing** the glass rod, **earth the positively-charged end** of the metal conductor by **touching** it to **neutralise** the positive charges. With the glass rod still in place, **remove your hand** to stop the earthing and remove the **glass rod**. The negative charges will **redistribute** throughout the conductor to make it negatively charged

Discharging an Insulator

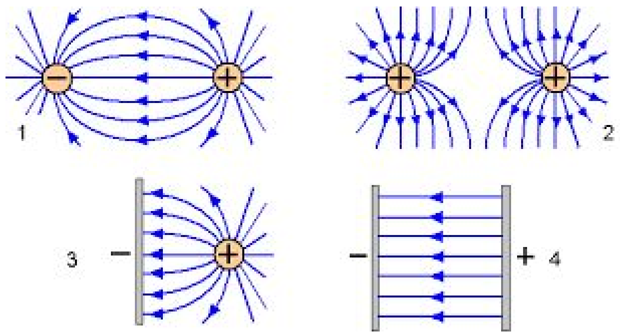
- Heat: Intense heat from flame ionises air particles which neutralise the excess charges on the insulator to discharge it
- Humidity: Water molecules in the air are conductors hence excess charges will be transferred to the water molecules on the surface of the insulator

Discharging a conductor: Earthing

1. Providing a path for excess electrons to flow
2. Providing a path for electrons to flow to the conductor

Electric Field

1. An electric field is a region in which an electric charge experiences an electric force
- An electric force is attractive or repulsive force that electric charges exert on one another
2. The direction of an electric field is the direction of that force that would act on a small positive charge
- Lines always go from the positive to the negative
- Lines are curved due to the resultant force exerted by the attraction and repulsion of both charges
3. Strength of the field is indicated by how close the field lines are to one another



4. Drawing:
- Repulsion: 7 x 2 lines
- 2 Plates: Top line must be curved
- Single Charge: 8 lines
- See pg 312 and 313

Hazards of electrostatics

1. Lightning: Friction between water molecules and air particles charges the thundercloud. The negative charges which tend to gather at the bottom of the cloud repels electrons on the Earth’s surfaces and renders it positively charged by induction. With enough charges the air particles near the cloud will be ionised, forming a conducting path for electrons in the cloud to reach Earth, which will form lightning.
- Tends to strike tall or isolated structures, therefore lightning rods are needed to provide a conducting path for the electrons to flow from the air to the earth to protect tall buildings
- A current of 0.1 A is sufficient to kill a person
2. Electrostatic discharge: Charges accumulated due to friction between roads and vehicles’ wheels may cause sparks and ignite flammable items when suddenly discharged
- Older trucks have a metal chain at the rear that hangs close to the ground to provide an earthing path for excess charges
- Antistatic packaging for electronics

Applications of electrostatics

1. Photocopiers
2. Electrostatic precipitators
3. Spray painting: Charges paint by friction, paint **spreads out** due to repulsion, attracted to earth object, hence forming a **uniform coat of paint**

Stuff to note

1. **Positive charges can never move**

Important Qns

- Workbook: 7, 8, 11c
- TYS: P1 7, 10, P2 3b,

Chapter 17: Current Electricity

Ampere: One ampere is the current produced when one coulomb of charge passes a point in the circuit in 1 second.

Electron flow is from the negative terminal of the battery to the positive terminal.

Conventional current is from the positive terminal of the battery to the negative terminal.

Electric Current: The rate of flow of electric charge

$$I = \frac{Q}{t}$$

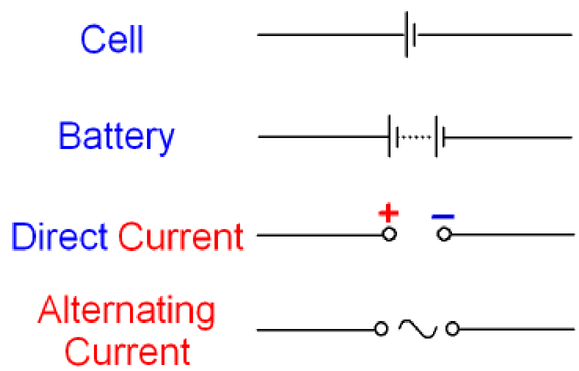
- Where I is the current in amperes (A), Q is the charge in coulombs (C) and t is the time taken (s)

Ammeter: Measure the strength of a current

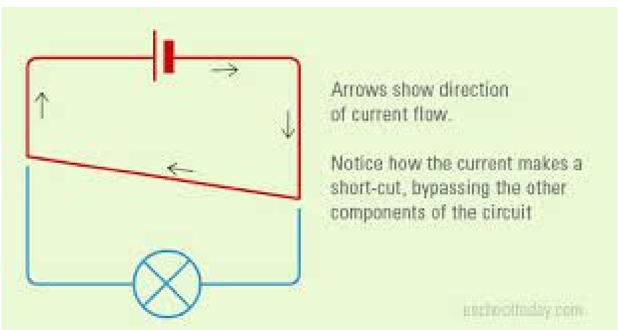
- Should be connected in series

Note the circuit symbols (p324 or below in chapter 18)

- May be tasked to draw circuit diagrams
- List of Tricky Symbols
- D.C./A.C. Power Supply
- Rheostat
- Fuse
- Transformer
- Thermistor



Short Circuit

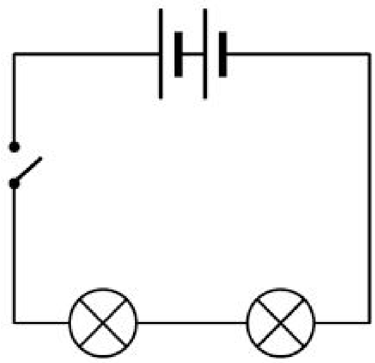
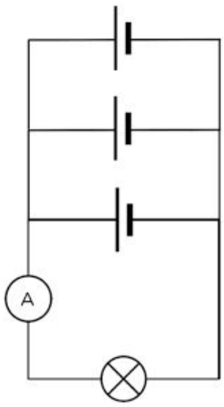


- Lamp does not light up

Electromotive force: The electromotive force of an electrical energy source is the *work done by the source in driving a unit charge around a complete circuit.*

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

- Where E is the electromotive force of the source (V), W is the work done by the source (J) and Q is the amount of charge (C)

Electromotive Force: Series vs Parallel	Series	Parallel
		
Resultant e.m.f	Sum of cells' e.m.f.	One cell's e.m.f
Battery Life	Cells last for a shorter time	Cells last for a longer time

Potential difference (V): The potential difference across a component in an electric circuit is the *work done to drive a unit charge through the component.*

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

- Where V is the electromotive force of the source (V), W is the work done by the source (J) and Q is the amount of charge (C)
- Measured by a Voltmeter
- Connected in parallel

Resistance (Ω): The resistance of a component is the ratio of the *potential difference V* across it to the current *I* flowing through it.

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

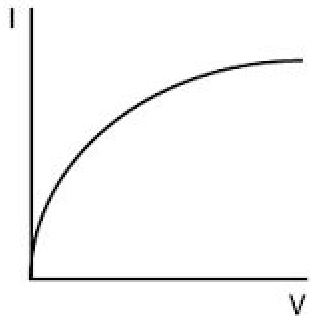
- Where R = Resistance (Ω), V = Potential Difference and I = Current (A)
- Therefore, R is directly proportional to V (p.d.) and inversely proportional to I

Ohm's Law: Ohm's law states that the current passing through a metallic conductor is *directly proportional* to the potential difference across it, provided that physical conditions (such as temperature) remains constant.

$I \propto V$

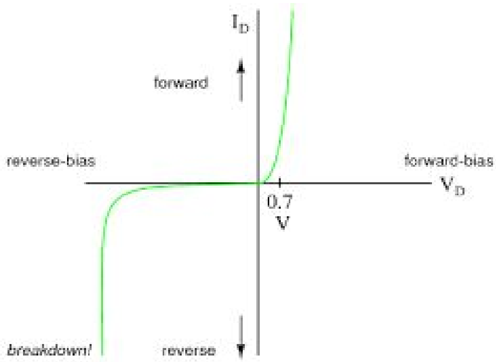
I/V graph: The conductor obeys Ohm's law IF and only IF

1. The gradient of the graph is constant
- Inverse of the resistance: As gradient increases, R decreases
2. The graph has an origin of 0 NOT LEGAL →



Non-ohmic Conductors

- As the current increases, devices generate more heat and thus their temperatures and the resistance of the device increases.
- Example: Filament lamp
- Diode: Allows current to flow in the forward direction only



Ammeter: Connected in series (negligible resistance)

Voltmeter: Connected in parallel (infinite resistance)

Why?

- Ammeter is connected in series to measure the amount of current flowing in the circuit. It has a negligible resistance so as to not increase the total amount of resistance in the circuit and cause the current reading to be inaccurate.
- Voltmeter is connected in parallel to measure the potential difference across a component. It has infinite resistance such that it does not draw any current, which may otherwise affect the value of the voltage.

Resistance of a wire: $R = \frac{\rho l}{A}$ where ρ is the resistivity (=/= resistance in Ωm) of the wire, in Ωm, l is the length of the wire (m), and A is the cross-sectional area of the wire (m^2).

Rewriting, we get:

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

- Note that A is usually πr^2 therefore resistance increases at an increasing rate as the radius of the wire increases
- Low Resistivity = Good conductor
- Can be used for wires
- High Resistivity = Poor Conductor
- Heating Coils in electric kettles (Nichrome): Produces a lot of thermal energy when a current passes through
- Light Bulbs (Tungsten)

For constant current, $R \propto V$

For constant voltage, $R \propto \frac{1}{I}$

Stuff to note

1. **Filament lamp is a non-ohmic conductor**
2. **LEDs produce more light than filament lamps**

Chapter 18: D.C. Circuits

Series circuits

1. Current at every point is the same
2. Sum of the potential difference across each component is equal to the p.d. across the whole circuit and the electromotive force of the battery
- Resistors of larger resistance will have a higher p.d. than resistors of smaller resistance
3. The effective resistance *R* is the sum of all the resistances

Parallel circuits

1. Sum of current in individual branches is equal to to the main current flowing in or out of the parallel branches
- Note WE18.2: Always check which currents contribute to the ammeter reading
- Branch with the least resistance has the largest current flowing through it
2. Potential difference across separate parallel branches and the total potential difference is the same
- Potential Difference = e.m.f of electrical energy source
3. Reciprocal of the effective resistances of resistors in parallel 1/R = the sum of the reciprocal of the individual resistors
- Use $x^{-1} = 1/x$ to aid in calculations
- Adding additional resistors to a circuit decreases the effective resistance due to the increased current.
    - This increases the energy requirement on the energy source (see water flow model)

Advantages of parallel circuits:

1. The **current flowing through each bulb** in a parallel circuit is larger than the current flowing through each bulb in a series circuit, hence bulbs connected in parallel **glow more brightly** than bulbs connected in series
2. When a bulb in a parallel circuit **blows**, the other bulbs in the circuit will **still work** as each **parallel branch forms a complete circuit.**

Disadvantage of parallel circuits

- The **current flowing through the electrical energy source** in a parallel circuit is higher than the current flowing through that of a series circuit. Hence the electrical energy source of a parallel circuit **provides more power** and is thus **depleted more quickly** than in a series circuit.

Potential divider

1. A line of resistors connected in series. Used to provide a fraction of the voltage of a source to another part of the circuit

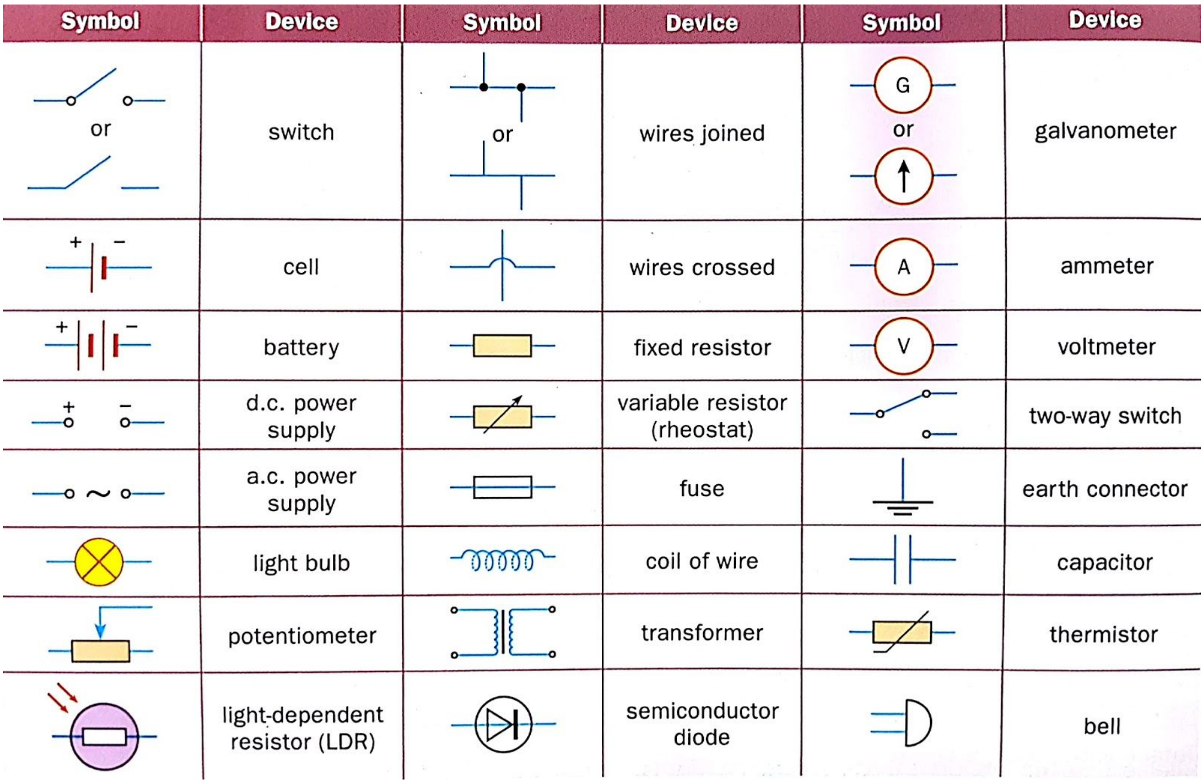
- $V_{out} = \frac{R_2}{R_2 + R_1} \times V_E$
- $V_{out} = \frac{l_2}{l_2 + l_1} \times V_E$

2. Rheostat vs Potentiometer

- An additional resistor (R_2) is added to prevent a large current from flowing through the circuit when the variable resistor's resistance is 0, which will cause appliances to overheat

Input transducers

1. Electronic devices that convert non-electrical energy to electrical energy
2. Thermistor, Light dependant resistor
    a. The higher the temperature / light level, the lower the resistivity



<u>Stuff to note</u>

1. **<u>Combined resistance of resistors in parallel always less than one resistor</u>**

<u>Chapter 19: Practical Electricity</u>

Renewable Energy: Energy from sources that can be replenished naturally

Non-renewable Energy: Energy from sources that cannot be replenished at a sustainable rate

Solar power	Advantage	It is a form of clean energy. The source of energy is free.
	Disadvantage	The generation of electricity is dependent on the availability of sunlight. Cost of infrastructure is high.
Wind power	Advantage	It is a form of clean energy. The source of energy is free.
	Disadvantage	The construction of wind farms requires large, open areas. It depends on the availability of wind.
Hydroelectric power	Advantage	It is an efficient method of generating electricity as water flow is easily controlled.
	Disadvantage	It disrupts ecosystems.
Nuclear power	Advantage	It is highly efficient as a small amount of uranium is sufficient to generate a large quantity of energy.
	Disadvantage	Nuclear waste may cause contamination of groundwater.
Fossil fuels	Advantage	Most countries have well-established technology and energy distribution systems.
	Disadvantage	Extensive mining has a negative impact on the ecosystem.

Electrical Power

1. Unit: Watt
2. 3 formulas
   a. $P = VI$
   b. $P = I^2R$: Good for series
   c. $P = V^2/R$: Good for parallel

3. Kilowatt hours
    a. (kW) x (time in hours)
    b. To convert to joules, (W) x (time in seconds)

Sources of electrical energy

1. Renewable: Energy from sources that can be replenished naturally
    a. Solar power
    b. Hydroelectric power
    c. Wind power
2. Non-renewable: Energy from natural sources that cannot be replenished at a sustainable rate.
    a. Nuclear power
    b. Fossil fuels

Dangerous Conditions for Electricity

- Damaged insulation
- Insulating materials can become worn with time, and expose the conducting wires inside
- The exposed conducting wires can cause electric shocks if touched
- Overheating of Cables: May cause fires
- Overloaded power sockets: With many appliances in a power socket in parallel, an unusually large current flows
- Inappropriate wires: Wires which are thin have a higher resistance and produce more heat. Hence when used with appliances which require a lot of power, the wires may overheat
- Damp environments
- Water provides a conducting path with a small resistance for the current to flow
- Leads to burns, uncoordinated contraction of heart muscles and death
    - Human body can only withstand an alternating current of 0.05 A

Circuit Breakers: Switch off energy supply when large current flows

- Can be reset
- Fault can be located easily without having to inspect each plug

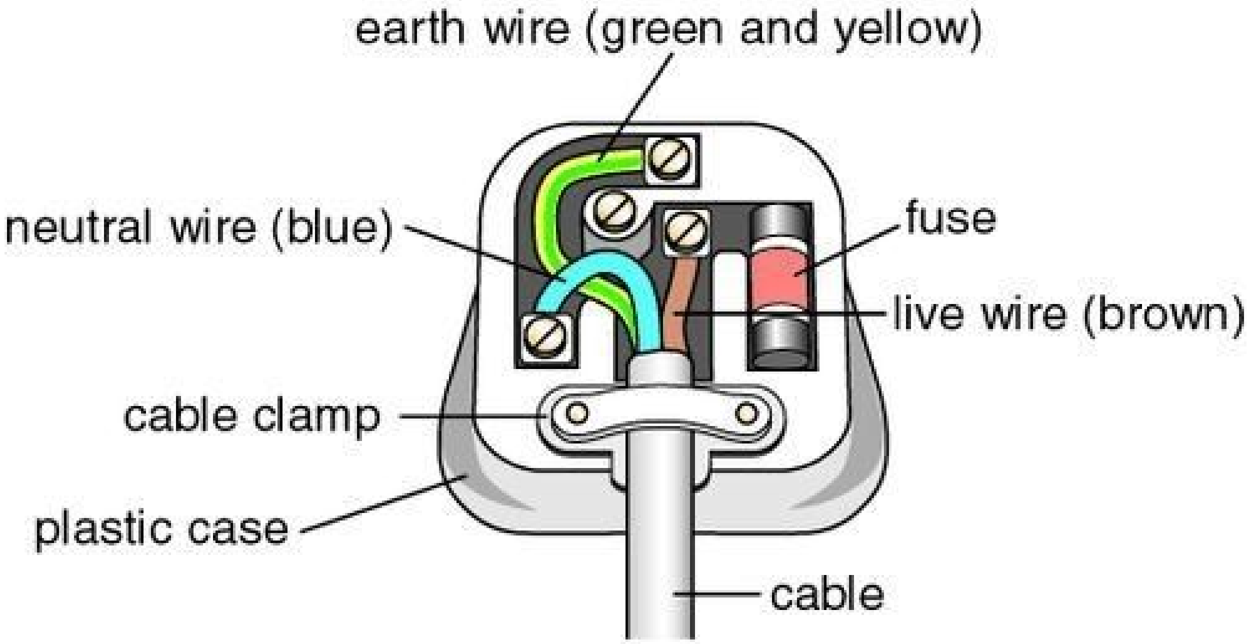
Fuses: Prevents excessive current flow

- Must be reset after tripping
- Thin short wire in a casing (∴ low resistance) blows when a large current passes through to open the circuit
- Considerations for fuses to avoid confusion
- Slightly higher rated value than normal current
- Connected to live wire
- Mains should be switched off before replacing
- Common fuse ratings: 1A, 3A, 5A, 7A, 10A, 13A

Switches

- Should be fitted to live wire
- If on Neutral: Live wire causes metal casing to have high voltage as it is still connected to the metal casing, hence a person will get an electric shock if he touches the casing and a large current flows through him to the earth
- If on Live: Casing will be disconnected from live wire, no current flows through person

Common Household Plug (Britain type only because British occupation!)



- Positioning: bLue, bRown, sTriped (Blue at left, Brown at right, Striped on top)
- Interesting video on plugs: https://www.youtube.com/watch?v=UEfP1OKKz_Q

Earthing

1. Earth wire is usually connected to the casing of appliances
2. Without earthing,
    a. Electrical fault results in live wire touching metal casing
    b. Metal casing is at high potential (open circuit)
    c. When a person touches the casing, circuit is complete and a large current flows through the person - person gets an electric shock
3. With earthing,
    a. Electrical fault results in live wire touching metal casing
    b. Large current **flows to the ground** through earth wire which has *much lower resistance than the person*, hence person does not suffer electric shock
    c. Large current exceeds rated value of fuse, hence fuse blows

- Fuse protects the circuit from overheating while Earthing protects users from electric shocks

When an electrical fault results in the *live wire touching the metal casing*, the large current *flows to the ground through the earth wire* which has a *lower resistan*ce than the person. The large current causes a *short circuit* and *exceeds the rated value of the fuse*, causing it to *blow*, hence *opening the circuit and cutting off the electricity supply to the appliance*.

Double Insulation: Two-Pin Plugs

- No Earth wire
- Two Levels of Insulation
- Electric Cables *insulated from* internal components of appliance
- Internal Components *insulated from* external casing (e.g. plastic casing)

Chapter 20: Magnetism

Magnetic Materials (CoINS)

1. Steel
2. Iron
3. Nickel
4. Cobalt

Identifying magnets

1. One side is attracted to a side of a known magnet, the other side is repelled from the side of the known magnet

Magnetic induction

1. The process whereby an object made of a magnetic material becomes a magnet when it is near or in contact with a magnet

Theory of Magnetism

- Every atom is a magnet

1. A magnetic domain consists of a group of atomic magnets pointing in the same direction

Magnetising magnetic materials

1. Stroking
    a. Unmagnetised steel bar is stroked several times in one direction with one of the poles of a permanent magnet
    b. Pole at the end of the steel bar where the strokes finish is opposite to the stroking pole used
2. Electrical method using a direct current

- Large direct current aligns the magnetic domains
    a. **Right-hand rule**
        i. Grip solenoid with right hand
        ii. Curl fingers in the direction of the current flow
        iii. Thumb points to the north pole

Demagnetising magnets

1. Heating in an **east-west** direction: Heat causes vigorous vibration of atoms hence causing the magnetic domains to lose their alignment
2. Hammering in an east-west direction: Alters the alignment of the magnetic domains
3. Electrical method using an alternating current
    a. Place the magnet inside a solenoid in an east-west direction
    b. Connect it to an a.c. supply
    c. Withdraw the magnet in an east-west direction while the solenoid is still on

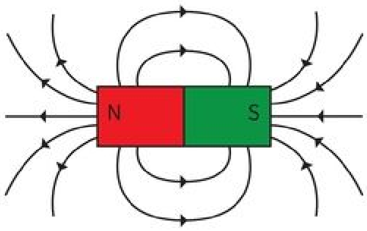
Magnetic fields

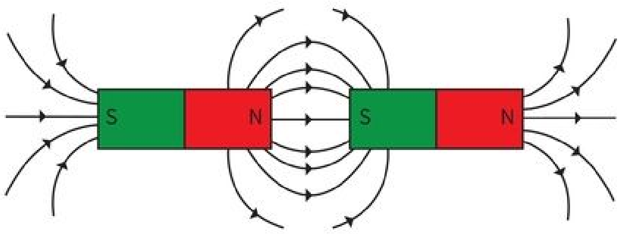
1. The region surrounding a magnet in which a body of magnetic material experiences a magnetic force

- Plotted with sprinkling iron filings/compass
- Closer lines = Stronger Magnetic Force
- Earth's geographical North is a magnetic South

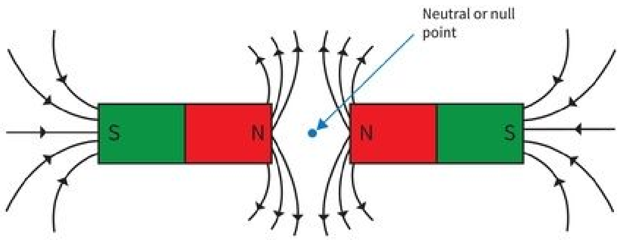
Magnetic Field Lines

Magnetic Field of a Bar Magnet





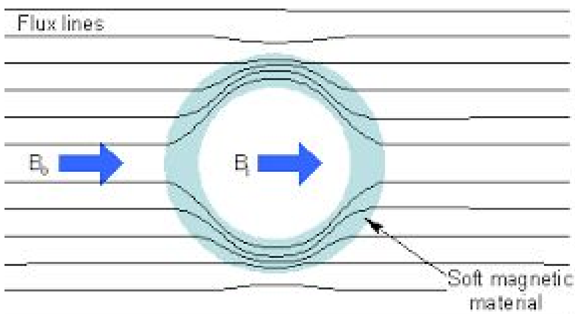
Attraction between opposite poles



Repulsion between like poles

- Drawn from North to South
- Neutral Point: No magnetic effect
- Note parallel case

Magnetic shielding



Soft magnetic materials

1. Iron

- Easily magnetised and demagnetised
- Stronger induced magnet

- Used to make temporary magnets and for shielding

Hard magnetic materials

1. Steel

- Difficult to magnetise and demagnetise
- Weaker induced magnet
- Used to make permanent magnets

Uses of magnets

- Magnetic Door Catches: P. Magnets keep door
- Moving-coil Loudspeakers: Movement of Diaphragm due to alteration between attraction and repulsion between temporary and permanent magnets due to current through a temporarily magnetic coil
- Moving-coil Ammeters: Current turns temporarily magnetic coil attached to pointer due extent of attraction to permanent magnet
- Electromagnets: Magnets formed when current flows, used for separation of magnetic materials from non-magnetic materials in scrapyards

Stuff to note

1. When magnetic materials are placed in an alternating current, **they become magnets and then switch poles when the current switches direction**

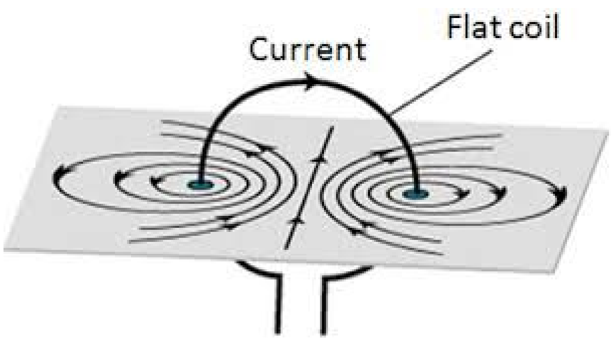
Important Questions

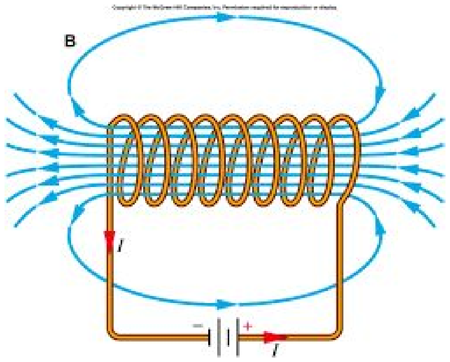
- WB: 4, 6a

Chapter 21: Electromagnetism

Electromagnetic Effects of a Current

1. A current-carrying conductor produces a magnetic field around it
2. **Right hand grip rule**
    a. Grip the wire such that your thumb points in the direction which the current is flowing in
    b. Direction in which fingers curl indicate whether the magnetic field is clockwise or anticlockwise
    c. Note: A cross indicates current flowing away, a dot indicates current flowing to you (Think of an arrow from a bow)
    - Not to be confused with the RHG rule for solenoids where the thumb points to the north pole and the other fingers indicate the flow of the current
3. Strength of magnetic field increases when the current increases
4. The direction of the magnetic field of a current-carrying wire is reversed when the direction of the current is reversed
5. Drawing: Magnetic Field lines should be further apart with increasing distance from the wire





These will come in handy:

1. Right-hand grip rule (Chapter 20): Fingers = current, Thumb = North
    a. To find out the poles of the solenoid: Acts like a bar magnet
    - Can be strengthened with a soft iron core, increased current/number of turns per unit length
    - Used in circuit breakers: Large Current → Strong Electromagnet → Attracts Latch → Releases Spring → Breaks Circuit
2. Right-hand grip rule #2: Fingers = Magnetic Field, Thumb = Direction of Current
    a. To find out the direction of a magnetic field around a wire
    - Conventional Current is used: Positive to Negative
3. Fleming's Left hand rule
    a. To find out the force when a wire is held between 2 poles of a magnet

Forces on a current-carrying conductor

1. When a current-carrying conductor is placed in a magnetic field, the conductor experiences a force. This effect on the conductor is called the <u>motor effect</u>.

<u>Fleming's left-hand rule</u>

1. Finding out the direction of the force acting on a current-carrying conductor
    a. Thumb → force
    b. Index finger → direction of magnetic field (From North to South
    c. Second finger → direction of current
    - Can deduce the direction of one given the other 2
    - Due to the combination of magnetic fields of current-carrying conductor and two magnetic poles that pushes it with a force from the stronger magnetic field to the weaker magnetic field (p413)

Forces between 2 parallel current-carrying conductors

1. Conductors carrying currents in opposite direction repel
2. Conductors carrying currents in the same direction attract

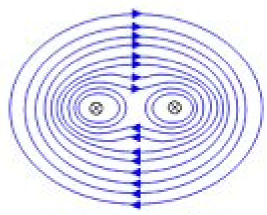


Figure 2(a)

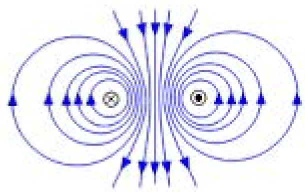


Figure 2(b)

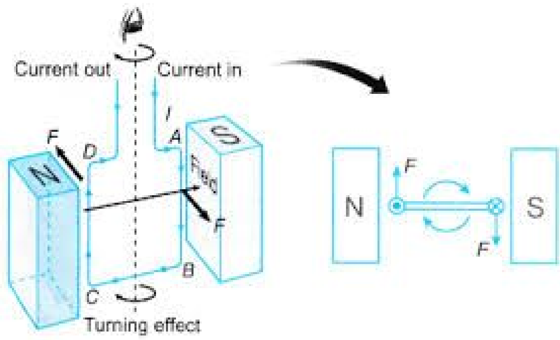
Forces acting on a beam of charged particles in a magnetic field (protons or electrons)

1. Direction of current flow is the direction of conventional current, i.e. direction of positive particle flow / opposite to direction of negative particle flow
- Point index finger in direction of magnetic field, point middle finger in the direction where the particle would move if undisturbed, resultant movement is between the thumb and middle finger

2. Reversing the direction of the current flow changes the direction of the force acting on the particle
3. Reversing the direction of the magnetic field also changes the direction of the force acting on the particle
4. Opposite Charge = reversed direction
5. Direction of movement of the particle is the resultant of the directions of the force, the current and the magnetic field

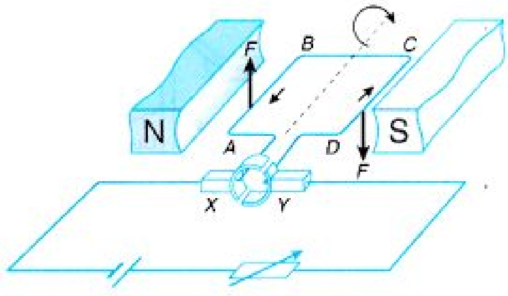
Current-Carrying Coil Conundrums

- Increasing Turning Effect
- Increasing number of turns per unit length
- Increasing current in coil



D.C. Motor

- Two Carbon Brushes at XY: Low friction + Path for current
- Addition of split-ring commutator: Hole cuts off the current when coil is vertical, momentum carries coil forward and allows for another cycle
- Reverses the direction of the current every half a revolution to allow it to continue spinning in one direction
- Force is greatest when horizontal
- Rheostat: Set at maximum R before switch is closed and decreased over time to prevent overheating due to large current through small R wire.
- Increasing Turning Effect
- Increasing number of turns per unit length
- Increasing current in coil
- Adding a soft iron core



(b) Second half-rotation: Current in the coil is along DCBA

Stuff to note

1. **If a particle is stationary, there are no forces acting on it at all. Hence, the particle will not move**

Chapter 22: Electromagnetic Induction

Electromagnetic induction

1. The process through which an induced e.m.f. is produced in a conductor due to a changing magnetic field.
- Note: It is e.m.f. which is induced which hence drives a current.
    - E.m.f: Work done by the source in driving a unit charge around a closed circuit

Faraday's law

1. Faraday's law of electromagnetic induction states that the **magnitude** of the **induced e.m.f.** in a circuit in **directly proportional** to the **rate of change of magnetic flux** (quantity of magnetic field) in the circuit.
2. Deals with magnitude, or strength, of the induced current

Ways to increase the magnitude of the induced e.m.f.

1. Increase number of turns per unit length of coil
    - Increases the number of magnetic field lines linked to the coil (magnetic flux linkage)
2. Increase the speed at which the magnet moves in / out of the coil.
3. Increase the strength of the magnet

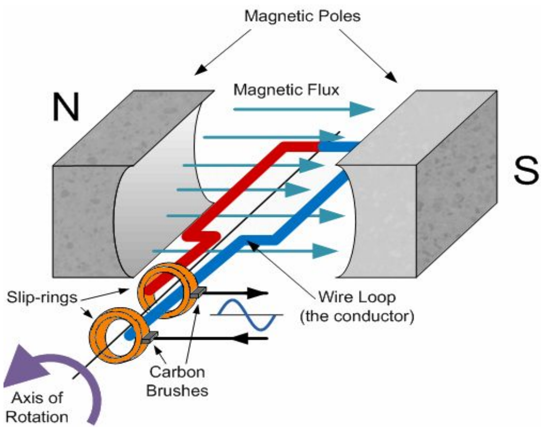
Lenz's law

1. Lenz's law states that the **direction of the induced e.m.f.**, and hence the **induced current** in a closed circuit, is always such that its **magnetic effect opposes the motion** or change producing it.
- If magnet enters solenoid south-first, south pole produced by current at end of entry to push away
- If magnet leaves solenoid south-first, north pole produced by current at end of entry to pull back
- Current acts in opposite direction of movement of magnet
- Galvanometer needle will be deflected in the direction of current
2. Deals with the direction of the induced current\

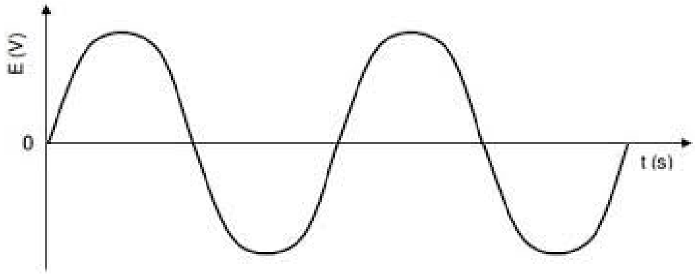
Key terms: Magnetic flux; rate of change of magnetic flux; magnetic flux linkage, Number of turns per unit length of coil

- IMPT: P429

Alternating Current generator (a.c.)



1. Transforms mechanical energy into electrical energy
2. Works on principle of electromagnetic induction
3. Current reverses direction, hence "alternating current"
4. Parallel Axel = Rate of Change of magnetic flux is maximum
5. When the coil **rotates**, it **cuts across** the **magnetic field lines** and there is a **change in magnetic flux** in the coil. By **Faraday's Law**, this change **induces an e.m.f.** in the coil



Fleming's right hand rule

- Similar to left-hand rule

1. Used to find out the direction of the current

Differences between left-hand and right-hand rule

Left-hand rule	Right-hand rule
Applies to d.c. motors	Applies to a.c. generators
Gives the direction of resultant force	Gives the direction of the induced current

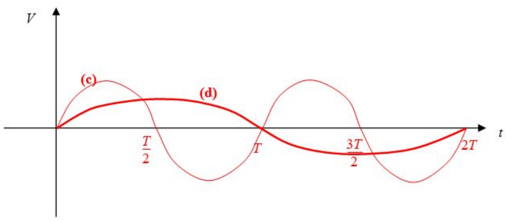
Slip rings

1. Ensure that the induced current in the coil is transferred to the external circuit

Ways to increase the magnitude of induced e.m.f

1. Increase number of turns per unit length of the coil
2. Increasing the strength of the permanent magnets
3. Increasing the frequency of rotations of the coil (results in (c))
4. Winding the coil around a soft iron core to strengthen the magnetic flux linking the coil

Effects of doing the above



1. Induced e.m.f is increased
    - Double number of turns per unit length of coil → Double the e.m.f
    - Twice the strength → double the e.m.f
2. Induced e.m.f. is increased, period is decreased
    - Twice the speed → double the e.m.f (rate of change of magnetic flux)
    - Twice the speed → half the period (less time to make one full rotation)

Fixed coil generator

1. An a.c. generator where magnets rotate instead of coils rotate
2. Bike dynamo

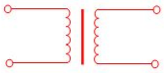
Practically, fixed coil generators are favoured because

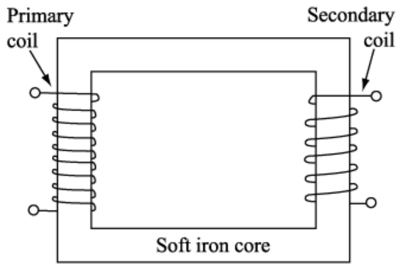
1. Does not require **carbon brushes**, which **wear out** easily and need to be **replaced**

frequently
2. Less likely to **break down from overheating**
    - Does not use slip rings and carbon brushes, eroded connection increases resistance which may cause overheating
3. More **compact**

Key terms: Slip rings, carbon brushes

Transformers

1. Symbol → 
2. A device that can change a high alternating voltage (at low current) to a low alternating voltage (at high current), or vice versa



- Used in electrical power transmission from power stations to households
- Used to regulate voltages for the proper operation of electrical appliances.
- A transformer is based on electromagnetic induction. An a.c. in the primary coil induces a varying magnetic field in the iron core which creates an alternating induced e.m.f in the secondary coil which generates an induced current

Features of a transformer

1. Laminated soft iron core
- Comprises of thin sheets of soft iron
    - Insulated by sheets of lacquer
- Soft iron is used because it is easily magnetised
    - Ensure better magnetic flux linkage
- Lamination reduces heat loss

Equation of power transmission → $$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

Types of transformers

1. Step up
    - Increases voltage, decreases current
    - Number of turns in the secondary coil is greater than that of the primary coil
2. Step down
    - Decreases voltage, increases current
    - Number of turns in the primary coil is greater than that of the secondary coil

$$V_S = \frac{N_S}{N_P} \times V_P$$

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

Power transmission → $$V_p I_p = V_s I_s$$

1. Ideal transformer → no power loss Equation to calculate efficiency
    - (outputpower / inputpower) x 100%
        - $\frac{V_S I_S}{V_P I_P}$
    - However IRL: Resistance of Coils, Leakage of Magnetic Flux in Transformers, hysteresis (?)

Why are transformers used to transmit electricity over distances?

1. Loss of power due to **Joule Heating** ($P = I^2R$)

- To reduce loss of power, decrease current through step-up
- Cannot increase diameter of cables due to increased construction costs
- Stepped-down at homes for suitable voltages
- Calculating loss of power: Find current, use I^2R where R is of cables to find P

Cathode Ray Oscilloscopes

- Shows a voltage-time graph
- X and Y axis have the unit V/div and ms/div
- One division is one tiny square
- Number of complete Cycles: $\frac{f_y}{f_x}$
- Below x-axis: Voltage in opposite direction
- Y-gain ∝ Amplitude of Graph: Stretching graph ↕, maximum values do not change
- Timebase ∝ 1/Period of Graph

Measuring the Speed of Sound

- Count the number of divisions between the two signals to count time between original and echo
- V = fλ

General stuff to note

Scalar Quantities	Vector Quantities
Mass	Displacement
Distance	Velocity
Time	Acceleration
Speed	Force
Volume	Weight
Density	Momentum
Pressure	Electric Field
Work done	Magnetic Field
Energy	
Power	
Electric charge	
Electric current (does not obey law of vector addition)	
Temperature	
Heat / Specific heat capacity	
Frequency	

1. Leave all answers to 3 or 2 significant figures
    a. Except angles (1 decimal place)
2. In MCQ, a maximum value of 10 does not mean its 10, it can mean 9.999 etc etc

Table of measurements and their S.I. units

Measurement	Name of S.I. unit	S.I. unit	Symbol if any
Period	seconds	s	T
Displacement	metres	m	s
Speed	metres per second	m/s	
Velocity	metres per second	m/s	v
Acceleration	metres per second per second	m/s/s or m/s^2	a
Force	newtons	N	F
Mass	kilograms	kg	m
Weight	newtons	N	W
Density	kilogram per metre cubed	kg/m^3	P
Gravitational field strength	newton per kg	N/kg	g
Moment	newton-metre	Nm	
Energy	joule	J	E
Efficiency	percent	%	
Work done	joule	J	W
Kinetic energy	joule	J	E_k
Gravitational potential energy	joule	J	E_p
Power	joules per second	J/s or W	P
Pressure (Solid)	pascal	P	P
Pressure (Fluid)	pascal	P	P

Temperature	degree Celsius	℃	T
Heat capacity	joules per degree Celsius	J/℃	C
Specific heat capacity	joules per kilogram per degree Celsius	J/kg/℃	c
Frequency	Hertz	Hz	f
Wave speed	metres per second	m/s	v
Wavelength	metres	m	λ
Electric current	ampere	A	A
emf or potential difference	volts	V	ε or V
Resistance	ohms	Ω	R
Energy usage	kilowatt-hours	kWh	E

Definitions (memorise)

Term	Definition
Period	time taken to complete one oscillation
Speed	distance travelled per unit time
Displacement	distance travelled in a straight line from start to finish
Velocity	rate of change of displacement
Acceleration	rate of change of velocity
Newton's 1st law	every object will remain in its state of rest or uniform motion in a straight line unless a resultant force acts on it
Newton's 2nd law	the force acting on an object is the product of the object's mass and its acceleration in the direction of the force
Newton's 3rd law	if body A exerts a force on body B, then body B will exert an equal but opposite force on body A
Friction	the contact force that opposes or tends to oppose motion between surfaces in contact
Mass	the amount of matter in a body
Weight	the gravitational force or gravity acting on it
Gravitational field	a region in which a mass experience a force due to gravitational attraction
Gravitational field strength	the gravitational force acting per unit mass
Inertia	the reluctance of an object to change its state of rest or motion, due to its mass
Moment	the product of the force and the perpendicular distance from the line of action of the force to the pivot
Principle of Moments	when a body is in equilibrium, the sum of anticlockwise moments about a pivot is equal to the sum of clockwise moments about the same pivot.
Centre of gravity	the point through which an object's whole weight seems to act
Stability	a measure of an object's ability to return to its original position after it is slightly displaced
Energy	the capacity to do work

Efficiency	the percentage ratio of output power to input power
Principle of Conservation of Energy	energy cannot be created or destroyed, but can be converted from one form to another. The total energy in an isolated system is constant.
Work	the amount of energy converted to other forms when a force applied moves an object by a particular distance
Work done	the product of the force and the distance moved by the object in the direction of the force
Power	the rate of work done or energy conversion
Pressure	the force acting per unit area
Temperature	how hot or cold an object is
Heat	the amount of thermal energy that is being transferred from a hotter to a colder region
Thermometric substance	a substance that has physical properties that vary continuously and linearly with temperature for the range of temperatures measured
Ice point	temperature of pure melting ice at one atmosphere
Steam point	temperature of steam from water boiling at one atmosphere
Kinetic model of matter	the tiny particles that make up matter are in constant random motion
Conduction	the transfer of thermal energy through a medium without any flow of the medium
Convection	the transfer of thermal energy by means of convection currents in a fluid due to difference in density.
Radiation	the transfer of thermal energy in the form of electromagnetic waves such as infrared radiation without the aid of a medium
Heat capacity	the amount of thermal energy required to raise the temperature of a substance by 1℃ or 1 K
Specific heat capacity	the amount of thermal energy required to raise the temperature of a unit mass of a substance by 1℃ or 1 K
Latent heat	the amount of energy released or absorbed by a substance during a change of state without any change in temperature
Specific latent heat	the amount of energy released or absorbed by a unit mass of a substance during a change of state without any change in temperature
1st law of reflection	the incident ray, the reflected ray and the normal at the point of reflection all lie in the same plane
2nd law of	the angle of incidence *i* is equal to the angle of reflection *r*

reflection	
Refraction	the bending of light as light passes from one optical medium to another
1st law of refraction	the incident ray, the normal and the refracted ray all lie in the same plane
2nd law of refraction/Snell's law	for any given media, the ratio of the sine of the angle of incidence to the angle of refraction is a constant.
Critical angle	the angle of incidence in an optically denser medium for which the angle of refraction in the optically less dense medium is 90°
Total internal reflection	the complete reflection of a light ray inside an optically denser medium at its boundary with an optically less dense medium
Refractive index	the ratio of the speed of light in vacuum to the speed of light in the medium
Focal length	the distance between the optical centre and the focal point
Transverse waves	waves that travel perpendicular to the direction of the vibration
Longitudinal waves	waves that travel parallel to the direction of the vibration
Amplitude	the maximum displacement of a point from its rest position
Wavelength	the shortest distance between any 2 points in phase
Period	time taken to produce one complete wave
Frequency	the number of complete waves produced per second
Wave speed	the distance travelled by a wave per second
Wavefront	an imaginary line that joins all points that are in phase
Sound	a form of energy that is transferred from one point to another as a longitudinal wave
Echo	the repetition of a sound due to the reflection of sound
Ultrasound	sound with frequencies above the human range of audibility
Ionising Radiation	radiation that has enough energy to remove electrons from atoms or molecules, thus creating ions
Induction	the process of charging a conductor without contact between the conductor and the charging body
Electric force	the attractive or repulsive force that electric charges exert on one another
Electric field	a region in which an electric charge experiences an electric force

Electric current	rate of flow of electric charge
Electromotive force	the work done by the source to drive a unit charge around a complete circuit
Potential difference	the work done to drive a unit charge through the component
Resistance	the ratio of the potential difference across it to the current flowing through it
Ohm's law	the current passing through a metallic conductor is directly proportional to the potential difference across it, provided that physical conditions such as temperature remain constant
Potential divider	a line of resistors connected in series, used to provide a fraction of the voltage of a source to another part of the circuit
Input transducer	electronic devices that convert non-electrical energy to electrical energy
Magnetic materials	materials that can be attracted to a magnet
Non-magnetic materials	materials that can not be attracted to a magnet
Magnetic induction	the process whereby an object made of a magnetic material becomes a magnet when it is near or in contact with a magnet
Magnetic field	the region surrounding a magnet in which a magnetic material experiences a magnetic force
Magnetic domain	consists of a group of atomic magnets pointing in the same direction
North pole	It is a north seeking pole or a pole that points towards the north when the magnet is freely suspended.
Motor effect	is the force experienced when a current-carrying conductor is placed in a magnetic field
Electromagnetic Induction	the process through which an induced e.m.f. is produced in a conductor due to a changing magnetic field
Faraday's Law	the magnitude of the induced e.m.f. in a circuit is directly proportional to the rate of change of magnetic flux in the circuit
Lenz's Law	the direction of the induced e.m.f., and hence the induced current in a closed circuit, is always such that its magnetic effect opposes the motion or change producing it
Alternating current generator	a mechanical device that uses electromagnetic induction to convert mechanical energy into electrical energy

Transformer	a device that can change a high alternating voltage (at low current) to a low alternating voltage (at high current), or vice versa

Newton’s First Law	every object will remain in it’s state of rest or uniform motion in a straight line until a resultant force acts on it.
Newton’s Second Law	the force acting on an object is the product of the object’s mass and its acceleration in the direction of the force.
Newton’s Third Law	if body A exerts a force on body B, then body B will exert an equal but opposite force on body A.
1st Law of reflection	the incident ray, the reflected ray and the normal at the point of reflection all lie on the same plane.
2nd Law of reflection	the angle of incidence *i* is always equal to the angle of reflection *r*.
1st Law of refraction	the incident ray, the refracted ray and the normal at the point of refraction all lie on the same plane.
2nd Law of refraction	for any given media, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.
Ohm’s Law	the current passing through a metallic conductor is directly proportional to the potential difference across it, provided that physical conditions such as temperature remain constant.
Faraday’s Law	the magnitude of an induced e.m.f. in a circuit is directly proportional to the rate of change of magnetic flux in the circuit.
Lenz’s Law	the direction of the induced e.m.f., and hence the induced current in a closed circuit, is always such that its magnetic effect opposes the motion or change of magnetic flux producing it

Formula list

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

$$F = ma$$

$$W = mg$$

$$\rho = \frac{m}{v}$$

$$Moment\ of\ a\ force = F \times d$$

$$Efficiency = \frac{useful\ energy\ output}{total\ energy\ input} \times 100\%$$

$$W = F \times s$$

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

$$E_p = mgh$$

$$P = \frac{WD}{t} = \frac{E}{t}$$

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

$$p = h\rho g$$

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

$$C = \frac{Q}{\Delta\theta} = mc$$

$$Q = mc$$

$$L_f = l_f \times m,\ L_v = l_v \times m$$

$$\frac{sin\ i}{sin\ r} = constant$$

$$n = \frac{c}{v} = \frac{sin\ i}{sin\ r}$$

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

$$\frac{V_1}{V_2} = \frac{\lambda_1}{\lambda_2}$$

$$f = \frac{1}{T}$$

$$v = f\lambda$$

$$I = \frac{Q}{t}$$

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

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

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

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

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

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

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