Enlightism

Spreading Inspiration

AS Physics

All Chapters

Contributed by Hassan Ilyas

Chapter 1: Kinematics

Distance (**d**): the length of the space between two points.

Speed (**v**): distance travelled per unit time.

$$\text{average speed (v)} = \frac{\text{distance (d)}}{\text{time (t)}}[\text{ms}^{-1}]$$

Speed the instant when you look at is known as instantaneous speed. If an objects speed is changing, then the equation gives us its average speed. Average speed is calculated over a period of time.

Displacement (**s**): distance moved by an object in a particular direction.

Velocity (**v**): rate of change of an object's displacement.

$$\text{velocity (v)} = \frac{\text{change in displacement (s)}}{\text{time taken (t)}}[\text{ms}^{-1}]$$

Displacement-Time Graphs:

The gradient (slope) of the graph is equal to its velocity. The steeper the slope is, the greater the velocity. If the gradient is 0, velocity is 0 and the object is stationary. If the slope is curved, then the velocity is changing. If the gradient is negative, the objects velocity is negative (it is moving backwards).

Scalar Quantities: only has magnitude; no direction.

Vector Quantities: has magnitude and direction.

Experiment to determine the acceleration of free fall using a falling object:

Method:
When the current to the magnet switches off, the ball drops and the timer starts. When the ball hits the trapdoor, the timer stops. The reading on the timer indicates the time it takes for the ball to fall a distance, *h.* This procedure is repeated several times for different values of *h*, in order to reduce random error. The distance, *h*, can be measured using a meter rule as it would be preferable to use for distances between 20 cm – 1 m.

To find g, use the same steps as in the problem solving section. The known quantities are: Displacement $s = h$, Time taken = t, Initial velocity $u = 0$, Acceleration $a = g$.

The equation that links these quantities is: $s = ut + \frac{1}{2}at^2$, $h = \frac{1}{2}gt^2$

Systematic error: residue magnetism after the electromagnet is switched off may cause the time to be recorded as longer than it should be

Random error: large uncertainty in distance from using a meter rule with a precision of 1mm, or from parallax error

<u>**Chapter 2: Accelerated motion**</u>

Acceleration (**a**): rate of change of velocity.

$$\text{acceleration (a)} = \frac{\text{change in velocity (v)}}{\text{time taken (t)}} \; [\text{ms}^{-2}]$$

Velocity-Time Graphs:

Acceleration is equal to the gradient of velocity-time graph: the greater the gradient the greater the acceleration. If the gradient is 0, acceleration is 0 (the object is moving at constant velocity). A straight line with a positive gradient shows constant acceleration. A negative gradient shows deceleration. If the slope is changing the acceleration is changing. Displacement/distance is equal to the area under the graph.

Equations of Motion:

- For motion in a straight line
- For an object with constant acceleration

Distance (s)	Initial Velocity (u)	Final Velocity (v)	Acceleration (a)	Time (t)

1) $v = u + at$
2) $s = \frac{(u+v)t}{2}$
3) $s = ut + \frac{1}{2}at^2$
4) $v^2 = u^2 + 2as$

Acceleration of Free Fall (**g**): acceleration gained by a body of non-relativistic mass during free fall under the influence of the gravitational force of earth.

$$g = (9.81 \text{ ms}^{-1})$$

Motion in Two Dimensions:

We can treat the ball's vertical and horizontal motions separately, because they are independent of one another. In the absence of air resistance, the horizontal component of velocity is constant while the vertical component of velocity increases at a rate of 9.81 ms^{-1}downwards.

Vectors such as forces can be resolved into components. Components at right angles to one another can be treated as independently of one another. For a velocity v at an angle θ to the x-direction, the components are:

$$\text{x-direction: } v\cos\theta$$

$$\text{y-direction: } v\sin\theta$$

Projectile Motion:

The trajectory of an object undergoing projectile motion consists of a vertical component and a horizontal component. These need to be evaluated separately. Time of flight: how long the projectile is in the air. Maximum height attained: the height at which the projectile is momentarily at rest. Range: the horizontal distance travelled by the projectile.

Chapter 3: Dynamics

Mass (m): the property of a body that resists change in motion.

Newton's Second Law: for a body of constant mass, its acceleration is directly proportional to the resultant force applied to it. ($a \propto F$) ($a \propto \frac{1}{m}$)

$$\text{force (F)} = \text{mass (m) x acceleration (a)[N]}$$

The mass of an object is a measure of its inertia, or its ability to resist any change in its motion. The greater the mass, the smaller the acceleration. Mass does not vary.

Newton (N): the force that will give a 1 kg mass an acceleration of 1 ms^{-2} in the direction of force.

Weight (W): force of gravity on an object (the effect of a gravitational field on a mass) (varies).

$$\text{product of mass and accel. of free fall} = \text{Weight (W)} = \text{mass (m) x acceleration of free fall (g)[N]}$$

Center of Mass: the point at the center of a distribution of mass in space that has the property that the weighted position vectors relative to this point sum to zero.

Newton's First Law: an object will remain at rest or in a state of uniform motion unless it is acted on by a resultant force.

Inertia: tendency of an object in motion to remain in motion, or an object at rest to remain at rest unless acted upon by a force. A larger mass has a larger amount of inertia.

We can calculate the resultant force by adding up two forces which act in the same straight line. We must take account of the direction of each force. When the backward and forward forces are balanced, an object can't go any faster – it has reached top speed.

Terminal Velocity: the velocity at which a falling body moves through a medium when the force of resistance of the medium is equal in magnitude and opposite in direction to the force of gravity. Drag force increases as speed increases.

Air resistance is just one example of the resistive or viscous forces which objects experience when they move through a fluid.

Newton's Third Law: when two bodies interact, the forces they exert on each other are equal in magnitude and opposite in direction. They act on different objects. They are forces of the same type.

Gravitational Field Strength: at a point is the gravitational force exerted per unit mass placed at that point is equal to the force experienced by a mass of 1 kg in that gravitational field (for situations where it is treated as an acceleration such as the acceleration of an object in free fall).

A fluid will exert a force upward on a body if it is partly or wholly submerged within it. This is because the deeper into a fluid you go, the greater the weight of it and so the greater the pressure. The up thrust on an object in a fluid is equal to the weight of the fluid displaced.

Homogeneous: when each term in an equation has the same base units.

Chapter 4: Forces

Center of Gravity: the point where an entire object's weight appears to act.

Moment: turning effect of a force. The greater the force, the bigger its moment. The further the force acts from the pivot, the greater its moment.

$$\text{moment} = \text{force } (F) \text{ x distance from pivot } (d)[\text{Nm}]$$

Principle of Moments: for any object that is in equilibrium, the sum of the clockwise moments about any point provided by the forces acting on the object equals the sum of the anticlockwise moments about that same point.

When there is no resultant force and no resultant torque, a system is in equilibrium.

Couple: a pair of forces, equal in magnitude, oppositely directed and displaced by perpendicular distance (d). A couple has a turning effect, but does not cause an object to accelerate. The two forces are parallel. A couple is a pair of forces that acts to produce rotation only.

Torque (τ): the turning effect or movement of a couple.

$$\text{torque } (\tau) = \text{force } (F) \text{ x perpendiculr distance } (d) \text{ [Nm]}$$

When we calculate the moment of a single force, the result depends on the point or pivot about which the moment acts. The further the force is from the pivot, the greater the moment. A couple is different; the moment of a couple does not depend on the point about which it acts, only on the perpendicular distance between the two forces. A single force acting on an object will tend to make the object accelerate (unless there is another force to balance it). A couple, however, is a pair of equal and opposite forces, so it will not make the object accelerate. This means we can think of a couple as a pure 'turning effect', the size of which is given by its torque.

For an object to be in equilibrium, two conditions must be met at the same time:

- The resultant force acting on the object is zero.
- The resultant moment is zero.

Chapter 5: Work, Energy and Power

Work (W): work done by a force is defined as the product of the force and the distance moved in the direction of the force.

$$\text{work (W)} = \text{force (F) x diplacement moved in the direction of force (s)[J]}$$

The bigger the force, and the further it moves, the greater the amount of work done. Work done defines what we mean by energy.

$$\text{work done} = \text{energy transformed}$$

Joule (J): amount of work done when a force of 1 Newton moves a distance of 1 meter (energy transferred).

Gases exert pressure on the walls of their container. If a gas expands, the walls are pushed outwards – the gas has done work on its surroundings. The work done by a gas at pressure when it expands:

$$\text{work (W)} = \text{pressure (p) x change in volume } (\Delta V)\text{[J]}$$

When an object of mass rises through a height in a uniform gravitational field, its gravitational potential energy increases by an amount:

$$\text{gravitational potential energy } E_P = \text{mass(m) x acceleration free fall (g) x height (h)[J]}$$

Gravitational potential energy increases as weight and height increases. Potential energy is energy that is stored in an object or substance. Elastic potential energy is energy stored in objects that can be stretched or compressed.

The kinetic energy of a body of a mass moving at speed:

$$\text{kinetic energy } (E_K) = \frac{1}{2}\text{mass (m) x speed}^2 (v^2)\text{[J]}$$

Energy is being transformed from gravitational potential energy to kinetic energy. Some energy is likely to be lost, usually as heat because of air resistance. However, if no energy is lost in the process:

$$\text{decrease in } E_P = \text{increase in } E_K$$

Many energy transfers are inefficient. That is, only part of the energy is transferred to where it is wanted. The rest is wasted, and appears in some form that is not wanted, or in the wrong place.

$$\text{efficiency } = \frac{\text{useful output}}{\text{total input}} \text{ x } 100\%$$

Principle of Conservation of Energy: for a closed system, energy cannot be created or destroyed. It can only be converted from one form to another.

Power (P): rate at which work is done (energy transferred).

$$\text{power (P)} = \frac{\text{work (W)}}{\text{time (t)}} \qquad \text{power (P)} = \text{force (F) x velocity (v)[J]}$$

Watt: rate of work done (energy transferred) of one joule per second.

Chapter 6: Momentum

Springy Collisions:

The moving ball stops dead. The ball initially at rest moves off with the same velocity as that of the original ball. The collision must be head-on and no spin must be given. In this collision the velocity between the two objects is swapped.

Sticky Collisions:

If a single moving ball collides with an identical stationary one, they both move off together. After the collision, the speed of the combined balls is half that of the original ball. In this collision the velocity between the two objects has been shared.

Linear Momentum: the product of the mass of the object and its velocity.

$$\text{momentum (p)} = \text{mass (m) x velocity (v)}[\text{kgms}^{-1}]$$

Conservation of Momentum: within a closed system, the total momentum in any direction is constant. Total momentum of objects before collision is equal to total momentum of objects after collision.

When two objects collide, they may crumple and deform. Their kinetic energy may also disappear completely as they come to a halt. This is an inelastic collision. Alternatively, they may spring apart, retaining all of their kinetic energy. This is a perfectly elastic collision. In practice, some energy is always transformed into other forms. Momentum is always conserved. Kinetic energy is usually not conserved, but total energy is always conserved. For a perfectly elastic collision, the relative speed of approach is equal to the relative speed of separation.

Momentum is a vector quantity and we have to consider the directions in which the objects travel. On the other hand, kinetic energy is a scalar quantity and direction of travel is irrelevant.

Relative Speed: the speed of one object measured relative to another. If two objects are travelling directly towards each other with speed v, as measured by someone stationary on the ground, then each object 'sees' the other one approaching with a speed of 2v. Thus if objects are travelling in opposite directions we add their speeds to find the relative speed. If the objects are travelling in the same direction then we subtract their speeds to find the relative speed.

Force: rate of change of momentum.

First Law: an object will remain at rest or keep travelling at constant velocity unless it is acted on by a resultant force.

Second Law: the resultant force acting on an object is directly proportional to the rate of change of the linear momentum of that object. The resultant force and the change in momentum are in the same direction.

$$\text{force (F)} = \frac{\text{change in momentum } (\Delta p)}{\text{time (t)}}[\text{N}]$$

Third Law: when two bodies interact, the forces they exert on each other are equal and opposite.

If $m_1 = m_2$ & $v_2 \neq 0$ then $v'_1 = v_2$ & $v'_2 = v_1$.

If $m_1 << m_2$ & $v_2 = 0$ then $v'_1 = -v$ & $v'_2 = 0$.

If $m_1 >> m_2$ & $v_2 = 0$ then $v'_1 = v_1$ & $v'_2 = 2v_1$.

Chapter 7: Matter and Materials

Density (ρ): mass per unit volume (constant).

$$\text{density } (\rho) = \frac{\text{mass (m)}}{\text{volume (v)}} [\text{kgm}^{-3}]$$

Pressure (P): normal force acting per unit cross-sectional area.

$$\text{pressure (P)} = \frac{\text{force (F)}}{\text{area (A)}} [\text{Pa/Nm}^{-2}]$$

The pressure in a fluid (a liquid or gas) increases with depth. The atmospheric pressure we experience down here on the surface of the Earth is due to the weight of the atmosphere above us, pressing downwards. It is pulled downwards by gravity. The pressure in a fluid depends on three factors: the depth, the density, and the acceleration due to gravity.

$$\text{pressure (P)} = \text{density } (\rho) \text{ x acceleration of free fall (g) x depth (h)[Pa]}$$

The upthrust acting on an object in a fluid is due to a difference in hydrostatic pressure.

Archimede's Principle states that a body immersed in a fluid experiences an upthrust equal to the weight of the fluid displaced, and this is fundamental to the equilibrium of a body floating in still water.

$$\text{Force (F)} = \text{density of fluid } (\rho) \text{ x acceleration of free fall (g) x volume of object (V) [N]}$$

Compressive Force: application of force against an object that causes it to become squeezed or compacted (deformed).

Tensile Force: force against an object that causes it to become stretched (deformed).

A pair of forces is needed to change the shape of a spring. When a wire is bent, some parts become longer and are in tension while other parts become shorter and are in compression.

Hooke's Law: extension produced in a spring is proportional to the applied force (load).

$$\text{force (F)} = \text{force constant (k) x extension (x) } (x \propto F) \ (k = \text{Nm}^{-2})$$

Elastic Limit: the force beyond which the spring becomes permanently deformed.

Strain (ε): the fractional increase in the original length of the wire (strain is a ratio; no units).

Stress (σ): the force applied per unit cross-sectional area of the wire.

Young Modulus (E): indication of the stiffness of the material.

$$\text{strain } (\varepsilon) = \frac{\text{extension (x)}}{\text{lenght (L)}}$$

$$\text{stress } (\sigma) = \frac{\text{force (F)}}{\text{area (A)}} [\text{Pa}]$$

$$\text{young modulus (E)} = \frac{\text{stress } (\sigma)}{\text{strain } (\varepsilon)} [\text{Pa}]$$

Elastic deformation: Elastic deformation refers to a temporary deformation of a material's shape that is self-reversing after removing the force or load. Elastic deformation alters the shape of a material upon the application of a force within its elastic limit.

Plastic deformation: permanent distortion that occurs when a material is subjected to tensile, compressive, bending, or torsion stresses that exceed its yield strength and cause it to elongate, compress, buckle, bend, or twist.

The area under a force-extension graph is equal to the work done by the force. Whenever you stretch a material, you are doing work. This is because you have to apply a force and the material extends in the direction of the force.

If the material has been strained elastically, the energy can be recovered. If the material has been plastically deformed, some of the work done has gone into moving atoms past one another, and the energy cannot be recovered. This change in shape is called deformation.

You can deduce the strain energy in a deformed material from the area under the force-extension graph. The limit of proportionality refers to the point beyond which Hooke's law is no longer true when stretching a material.

Elastic Potential Energy (**E**): stored as a result of deformation of an elastic object. It is equal to work done to stretch the spring.

$$\text{elastic potential energy (E)} = \frac{1}{2}\text{kx}^2 = \frac{1}{2}\text{Fx [J]}$$

To find the Young Modulus:
Measure the diameter of the wire with a micrometer screw gauge or digital calipers. Take at least 3 readings and find an average. Set up the apparatus so the wire is taut. No masses should be on the mass hanger just yet. Measure the original length of the wire using a meter ruler and mark a reference point with tape preferably near the beginning of the scale eg. at 1 cm. Record initial reading on the ruler of the reference point. Add a 100 g mass onto the mass hanger. Read and record the new reading of the tape marker from the meter ruler. Repeat this method by adding a 100 g mass (at least 5 – 10 times) and record the new scale reading from the meter ruler. Calculate the cross-sectional area of the wire. Multiply the gradient of load against extension graph by the ratio of the original length and cross-sectional area of the wire to calculate the Young Modulus.

Chapter 9: Electric Current

Conventional Current: the direction of current is from positive to negative.

Free Electrons: electrons not tied to any molecule or atom, and are free to move under the influence of an electric field.

In a typical metal, one electron from each atom breaks free to become a conduction electron. The atom remains as a positively charged ion. Since there are equal numbers of free electrons (negative) and ions (positive), the metal has no overall charge – it is neutral. When the cell is connected to the wire, it exerts an electrical force on the conduction electrons that makes them travel along the length of the wire. Since electrons are negatively charged, they flow away from the negative terminal of the cell and towards the positive terminal. This is in the opposite direction to conventional current. There is a current at all points in the circuit as soon as the circuit is completed. The cell produces an electric field in the wire; the field lines are along the wire, from the positive terminal to the negative. This means that there is a force on each electron in the wire, so each electron starts to move and the current exists almost instantly.

Current (I): a flow of electricity which results from the directional movement of electrically charged particles.

Electrolyte: a solution which conducts. It contains both positive and negative ions, which move in opposite directions when the solution is charged.

Charge Carriers: a particle that is free to move, carrying an electric charge and is measured in coulombs.

Electric Current (I): rate of flow of electric charge past a point.

$$\text{current (I)} = \frac{\text{charge (Q)}}{\text{time (t)}}[\text{A}]$$

$$\text{charge (Q)} = \text{current (I) x time } (\Delta t)[\text{C}]$$

Coulomb (C): the charge which flows past a point in a circuit in a time of 1s when the current is 1A.

Elementary Charge (e): the electric charge carried by a proton or the magnitude of the negative electric charge carried by a single electron. The charge is constant.

$$e = 1.6\text{x}10^{-19}\text{C}$$

Because electric charge is carried by particles, it must come in amounts that are multiple of e. We say that the charge is quantized.

Number Density (n): number of conduction electrons per unit volume.

Mean Drift Velocity (**v**): the average velocity attained by charged particles in a material due to an electric field.

$$\text{current (I)} = \text{number density (n) x cross area (A) x mean drift velocity (v) x electron charge (e)[A]}$$

$$\text{number of electrons} = \text{number density (n) x volume of area (v)}$$

$$\text{charge of electrons} = \text{number of electrons x electron charge (e)[Q]}$$

The conduction electrons are free to move around inside the metal. When the wire is connected to a battery or an external power supply, each electron within the metal experiences an electrical force that causes it to move towards the positive end of the battery. The electrons randomly collide with the fixed but vibrating metal ions. Their journey along the metal is very haphazard. The actual velocity of an electron between collisions is of the order of magnitude 10^5 m s^{-1}, but its haphazard journey causes it to have a drift velocity towards the positive end of the battery. Since there are billions of electrons, we use the term mean drift velocity of the electrons.

$$\text{mean drift velocity (v)} = \frac{\text{current (I)}}{\text{number density (n) x area (A) x electron charge (e)}}\ [\text{ms}^{-1}]$$

If the current increases, the drift velocity v must increase: $v \propto I$

If the wire is thinner, the electrons move more quickly for a given current. There are fewer electrons in a thinner piece of wire, so an individual electron must travel more quickly.

$$v \propto \frac{1}{A}$$

In a material with a lower density of electrons (smaller n), the mean drift velocity must be greater for a given current.

$$v \propto \frac{1}{n}$$

Electrical energy is transferred to the charge by the power supply. The charge flows round the circuit, transferring some of its electrical energy to heat in the first resistor, and the rest to heat in the second resistor. The voltmeter readings indicate the energy transferred to the component by each unit of charge. The voltmeter placed across the power supply measures the e.m.f. of the supply, whereas the voltmeters placed across the resistors measure the potential difference (p.d.) across these components. The terms e.m.f. and potential difference have different meanings. Potential difference is used when charges lose energy by transferring electrical energy to other forms of energy in a component. A power supply or a battery transfers energy to electrical charges in a circuit. The e.m.f. (E) of the supply is also defined as the energy transferred per unit charge.

Potential Difference (**V**): energy transferred per unit charge. The energy per unit charge as charge moves from point A to point B.

E.M.F. (**E**): energy transferred per unit charge. The total work done per unit charge when charge flows round a complete circuit.

The greater the potential difference, the greater the current. The greater the resistance, the smaller the current for a given potential difference.

Volt (V): the difference of potential that would carry one ampere of current against one ohm resistance.

Electrical Resistance (R): ratio of the potential difference to the current.

$$\text{resistance (R)} = \frac{\text{potential difference (V)}}{\text{current (I)}}\ [\Omega]$$

Ohm (Ω): the resistance of a component when a potential difference of 1 volt drives a current of 1 ampere through it.

Power (P): rate at which energy is transferred.

Power (P)	**Current** (I)	**Voltage** (V)
Resistance (R)	**Energy Transferred** (W)	**Charge** (Q)
	Time (t)	

$$P = \frac{W}{\Delta t} \qquad W = V\Delta Q \qquad P = \frac{V\Delta Q}{\Delta t} \qquad P = VI \qquad P = I^2R \qquad P = \frac{V^2}{R}$$

$$W = IV\Delta t \qquad V = IR$$

Fuses:

It is there to protect wiring from excessive currents. High currents cause wires to get hot, and this can lead to damaged wires, fumes from melting insulation and even fires. Inside the fuse cartridge is a thin wire which gets hot and melts if the current exceeds the current rating. This breaks the circuit and stops any hazardous current.

Current Rating: maximum current which a fuse will permit.

Chapter 10: Kirchhoff's laws

Kirchhoff's First Law: the sum of the currents entering any point in a circuit is equal to the sum of the currents leaving that same point.

$$\Sigma I_{in} = \Sigma I_{out}$$

The total amount of current remains the same after it splits. We would not expect some of the current to disappear, or extra current to appear from nowhere. Kirchhoff's first law is an expression of the conservation of charge. The idea is that the total amount of charge entering a point must exit the point.

Kirchhoff's Second Law: the sum of the e.m.f. around any loop in a circuit is equal to the sum of the p.d. around the loop.

$$\Sigma E = \Sigma V$$
$$E = IR_1 + IR_2$$

Kirchhoff's second law is an expression of the conservation of energy. Caution is necessary when applying Kirchhoff's second law. You need to take account of the ways in which the sources of e.m.f. are connected and the directions of the currents.

Conservation of Energy:

If a charge, say 1 C, moves around the circuit, it gains energy as it moves through each source of e.m.f. and loses energy as it passes through each p.d. If the charge moves all the way round the circuit, so that it ends up where it started, it must have the same energy at the end as at the beginning. E.M.F. in volts is simply the energy gained per 1 C of charge as it passes through a source. Similarly, a p.d. is the energy lost per 1 C as it passes through a component.

energy gained passing through source of emf = energy lost passing through component with pd

energy gained per coulomb around loop= energy lost per coulomb around loop

In Series:

Current is constant.

Ammeters have low resistance and are connected in series.

$$V = V_1 + V_2 \qquad R = R_1 + R_2$$

In Parallel:

P.d is constant.

Voltmeters have high resistance and are connected in circuit.

$$I = I_1 + I_2 \qquad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

When two or more resistors are connected in parallel, their combined resistance is smaller than any of their individual resistances. Because, by connecting the resistors in parallel, you are providing extra pathways for the current. Since the combined resistance is lower than the individual resistances, it follows that connecting two or more resistors in parallel will increase the current drawn from a supply. When components are connected in parallel, they all have the same p.d. across them. This means that you can often ignore parts of the circuit which are not relevant to your calculation. For resistors in parallel, you may be able to calculate the current in each one individually, and then add them up to find the total current.

Chapter 11: Resistance

The potential difference across a metal conductor can be altered using a variable power supply or by placing a variable resistor in series with the conductor. The current I am directly proportional to the voltage (V). By reversing the connections to the resistor, the p.d. across it will be reversed, i.e. negative. The current will flow in the opposite direction – it is also negative.

Ohm's Law: a conductor obeys Ohm's law if the current in it is directly proportional to the potential difference across its ends.

For the metallic conductor which's current in it is directly proportional to the p.d. across it. This means that its resistance is independent of both the current and the p.d. This is because the ratio $\frac{V}{I}$ is a constant. Any component which behaves like this is described as an ohmic component.

Non-Ohmic: a component that does not obey ohm's law.

For very small currents and voltages, p.d. is directly proportional to current. At higher voltages, the current is a bit less than we would have expected from an ohmic component. This suggests that the resistance has increased. You can also tell that the resistance has increased because the ratio V:I is larger for higher voltages than for low voltages. The resistance depends on the temperature of its conductor. The resistance may increase by a factor as large as ten between when it is cold and when it is brightest (when its temperature may be as high as 1750 °C).

Thermistors: components that are designed to have a resistance which changes rapidly with temperature.

Thermistors are made from metal oxides such as that of manganese and nickel. There are two distinct types of thermistors.

Negative Temperature Coefficient: resistance decreases with increasing temperature.

Positive Temperature Coefficient: resistance rises abruptly at a definite temperature (100-180°C).

Diodes: any component that allows electric current in only one direction.

When connected one way round (positively biased), the diode conducts and has a fairly low resistance. Connected the other way round (negatively biased), it allows only a tiny current and has almost infinite resistance. For positive voltages less than about 0.6V, the current is almost zero and hence the diode has almost infinite resistance. It starts to conduct suddenly at its threshold voltage. The resistance of the diode decreases dramatically for voltages greater than 0.6V. The resistance of a diode depends on the potential difference across it. From this we can conclude that it does not obey Ohm's law; it is a non-ohmic component. Diodes are used as rectifiers. They allow current to pass in one direction only and so can be used to convert alternating current into direct current.

The resistance of the pure metal increases linearly as the temperature increases from 0°C to 100°C.The resistance of an impure metal is greater than that of the pure metal and follows the same gradual upward slope. Temperature and the presence of impurities affect the resistance of a metal. In a metal, a current is due to the movement of free electrons. At low temperatures, they can move easily past the positive ions. However, as the temperature is raised, the ions vibrate with larger amplitudes. The electrons collide more frequently with the vibrating ions, and this decreases their mean drift velocity. They lose energy to the vibrating ions. If the metal contains impurities, some of the atoms will be of different sizes. Again, this disrupts the free flow of electrons. In colliding with impurity atoms, the electrons lose energy to the vibrating atoms. The resistance of the metal increases with the temperature of the wire because of the decrease in the mean drift velocity of the electrons.

Resistivity (ρ): a measure of the resisting power of a specified material to the flow of an electric current.

The resistance of a particular wire depends on its size and shape. The resistance of a wire also depends on the material. The relevant property of the material is its resistivity. Resistivity, like resistance, depends on temperature. For metal, resistivity increases with temperature.

At Constant Temperature:

$$\text{resistance} \propto \text{length}$$

$$\text{resistance} \propto \frac{1}{\text{cross−sectional area}}$$

$$\text{resistance} \propto \frac{\text{lenght}}{\text{cross−sectional area}}$$

$$\text{resistance (R)} = \frac{\text{resistivity } (\rho) \text{ x lenght (L)}}{\text{area (A)}} [\Omega]$$

understand that the resistance of a light-dependent resistor (LDR) decreases as the light intensity increases 8 understand that the resistance of a thermistor decreases as the temperature increases (it will be assumed that thermistors have a negative temperature coefficient)

explain that the resistance of a filament lamp increases as current increases because its temperature increases

Chapter 12: Practical Circuits

Internal Resistance: the opposition to the flow of current offered by the cell and batteries themselves resulting in the generation of heat.

$$E = I(R + r)$$
$$V = E - Ir$$

All sources of e.m.f. have an internal resistance. For a power supply, this may be due to the wires and components inside, whereas for a cell the internal resistance is due to the chemicals within it. Voltage across the terminals of the power supply depends on the circuit of which it is part. In particular, the voltage across the power supply terminals decreases if it is required to supply more current. The charges moving round a circuit have to pass through the external components and through the internal resistance of the power supply. These charges gain electrical energy from the power supply. This energy is lost as heat as the charges pass through the external components and through the internal resistance of the power supply. Power supplies and batteries get warm when they are being used. The reason for this heating effect is that some of the electrical potential energy of the charges is transformed to internal energy as they do work against the internal resistance of the cell. We cannot measure the e.m.f. E of the cell directly, because we can only connect a voltmeter across its terminals. This terminal p.d. V across the cell is always the same as the p.d. across the external resistor. This will be less than the e.m.f. E by an amount Ir. The quantity (Ir) is the potential difference across the internal resistor and is referred to as the lost volts. The 'lost volts' indicates the energy transferred to the internal resistance of the supply. If you short-circuit a battery with a piece of wire, a large current will flow, and the battery will get warm as energy is transferred within it.

$$\text{maximum current} = \frac{\text{e.m.f. (E)}}{\text{internal resistance (r)}}$$

The terminal p.d. of the battery depends on the resistance of the external resistor. For an external resistor of resistance 1.0 Ω, the terminal p.d. is 1.5 V – half of the e.m.f. The terminal p.d. approaches the value of the e.m.f. when the external resistance R is very much greater than the internal resistance of the battery. The more current a battery supplies, the more its terminal p.d. will decrease.

Potential Dividers: a simple circuit that uses resistors to supply a variable potential difference.

$$V_{out} = \left(\frac{R_2}{R_1 + R_2}\right) \text{x } V_{in}$$

Potentiometer: a device used for comparing potential differences.

Chapter 13: Waves

Vibrations produce waves of one type or another.

Progressive Waves: waves that move through a material (or a vacuum) and carries energy from one place to another.

Mechanical Waves: waves that are produced by vibrating objects and need a substance (medium) through which to travel.

Displacement (**x**): the distance of a point on the wave from its undisturbed position or equilibrium position.

Amplitude (**A**): the maximum displacement of any point on the wave from its undisturbed position.
The amplitude of a wave is measured in units of distance: the greater the amplitude of the wave, the louder the sound.

Wavelength (**λ**): the distance from any point on a wave to the next exactly similar point (e.g. crest to crest).
The wavelength of a wave on the sea is measured in units of distance, e.g. meters.

Period (**T**): the time taken for one complete oscillation of a point in a wave.
It is the time taken for a point to move from one particular position and return to that same position, moving in the same direction. It is measured in units of time, e.g. seconds.

Frequency (**f**): the number of oscillations per unit time of a point in a wave.
For sound waves, the higher the frequency, the higher is its pitch. Frequency is measured in hertz (Hz), where 1 Hz is equal to one oscillation per second. The frequency f of a wave is the reciprocal of the period T.

$$\text{frequency (f)} = \frac{1}{\text{period (P)}}[\text{Hz}]$$

There are two types of wave – longitudinal and transverse.

Longitudinal Waves: have vibrations parallel to the direction in which the wave travels.

Transverse Waves: have vibrations at right angles to the direction in which the wave travels.

In longitudinal waves, the particles of the medium vibrate parallel to the direction of the wave velocity. Sound waves are an example of a longitudinal wave. In longitudinal wave the material through which it is travelling is alternately compressed and expanded. This gives rise to high and low pressure regions, respectively. Longitudinal waves are represented as if it were a sine wave. The displacement referred to in the graph is the displacement of the particles in the wave. We can compare the compressions and rarefactions (or expansions) of the longitudinal wave with the peaks and troughs of the transverse wave. In transverse waves, the particles of the medium vibrate at right angles to the direction of the wave velocity. Light and all other electromagnetic waves are transverse waves.

Phase and Phase Difference:

All points along a wave have the same pattern of vibration. However, different points do not necessarily vibrate in step with one another. As one point on a wave vibrates, the point next to it vibrates slightly out-of-step with it. We say that they vibrate out of phase with each other – there is a phase difference between them. This is the amount by which one oscillation leads or lags behind another. Phase difference is measured in degrees. The phase difference between any other two points between A and B can have any value between 0° and 360°. A complete cycle of the wave is thought of as 360°.

Wave Energy:

For both types of mechanical wave, the particles that make up the material through which the wave is travelling do not move along – they only oscillate about a fixed point. It is energy that is transmitted by the wave. Each particle vibrates; as it does so, it pushes its neighbor, transferring energy to it.

Intensity (I): the rate of energy transmitted (i.e. power) per unit area at right angles to the wave velocity.

$$\text{intensity (I)} = \frac{\text{power (P)}}{\text{area (A)}}[\text{Wm}^{-2}]$$

The intensity of a wave generally decreases as it travels along. There are two reasons for this: the wave may 'spread out'. The wave may be absorbed or scattered. As a wave spreads out, its amplitude decreases. So, if one wave has twice the amplitude of another, it has four times the intensity. This means that it is carrying energy at four times the rate.

$$\text{intensity (I)} \propto \text{amplitude}^{2}\ (A^2)$$

Wave Speed (v): the speed with which energy is transmitted by a wave.

$$\text{wave speed (v)} = \text{frequency (f)x wavelength}(\lambda)[\text{ms}^{-1}]$$

For a given speed of wave, the greater the wavelength, the smaller the frequency and vice versa. The speed of sound in air is constant (for a given temperature and pressure). The wavelength of sound can be made smaller by increasing the frequency of the source of sound.

The Doppler Effect:

If the source is stationary, waves arrive at A and B at the same rate and so both observers hear sounds of the same frequency (f_s). If the source is moving towards A and away from B, the waves are squashed together in the direction of A and spread apart in the direction of B. Observer A will observe waves whose wavelength is shortened. More waves per second arrive at A, and so A observes a sound of higher frequency than f_s. Similarly, the waves arriving at B have been stretched out and B will observe a frequency lower than f_s. There are two different speeds involved in this situation. The source is moving with speed v_s. The sound waves travel through the air with speed v, which is unaffected by the speed of the source. The frequency and wavelength observed by an observer will change according to the speed v_s at which the source is moving. The wavelength observed by the observer is simply $\lambda_o=\frac{v}{f_s}$.The observed wavelength is now given by $\lambda_o=\frac{(v+v_s)}{f_s}$. The observed frequency is given by: $f_o=\frac{v}{\lambda_0}=\frac{f_s \times v}{(v+v_s)}$.

If the source is moving towards the observer, the f_s waves will be compressed into a shorter length equal to $v - v_s$, and the observed frequency will be given by: $f_o=\frac{v}{\lambda_0}=\frac{f_s \times v}{(v-v_s)}$.

We can combine these two equations to give a single equation for the Doppler shift in frequency due to a moving source: observed frequency $f_o=\frac{v}{\lambda_0}=\frac{f_s \times v}{(v \pm v_s)}$ (where the plus sign applies to a receding source and the minus sign to an approaching source).

The frequency f_s of the source is not affected by the movement of the source – it still emits f_s waves per second. The speed v of the waves as they travel through the air (or other medium) is also unaffected by the movement of the source. Note that a Doppler effect can also be heard when an observer is moving relative to a stationary source, and also when both source and observer are moving.

Electromagnetic Waves:

An electric current always gives rise to a magnetic field (this is known as electromagnetism). A magnetic field is created by any moving charged particles such as electrons. Similarly, a changing magnetic field will induce a current in a nearby conductor. A changing electric or magnetic field would give rise to waves travelling through space. Light is a wave, known as an electromagnetic wave that can travel through space (including a vacuum) as a disturbance of electric and magnetic fields.

Electromagnetic Radiation:

The speed (c) of electromagnetic radiation in a vacuum (free space) is independent of the frequency of the waves. In other words, all types of electromagnetic wave travel at the same speed in a vacuum. In the SI system of units, c has the value: c = 299 792 458 m s^{-1} (3.0 × 108 m s^{-1}). The wavelength λ and frequency f of the radiation are related by the equation: c = fλ. When light travels from a vacuum into a material medium such as glass, its speed decreases but its frequency remains the same, and so we conclude that its wavelength must decrease. We often think of different forms of electromagnetic radiation as being characterized by their different wavelengths, but it is better to think of their different frequencies as being their fundamental characteristic, since their wavelengths depend on the medium through which they are travelling. Light waves show the Doppler effect in the same way that sound waves do. The change in wavelength Δλ is simply given by $\Delta\lambda/\lambda = v_s/c$. The observed frequency of light from a moving source can be calculated using the same equation as for sound, $f_o = \frac{f\times c}{(c \pm v_s)}$ but there is an important condition. The speed of the source vs must be small compared to the speed of light c. For speeds approaching c, the equation must be altered to take account of the theory of relativity.

Orders of Magnitude:

There are no clear divisions between the different ranges or bands in the spectrum. The naming of subdivisions is also arbitrary. For example, microwaves are sometimes regarded as a subdivision of radio waves. The ranges of X-rays and γ-rays overlap. The distinction is that X-rays are produced when electrons decelerate rapidly or when they hit a target metal at high speeds. γ-rays are produced by nuclear reactions such as radioactive decay. There is no difference whatsoever in the radiation between an X-ray and a γ-ray of wavelength, say, 10^{-11} m.

Radiation	Wavelength range / m
radio waves	$>10^{6}$ to 10^{-1}
Microwaves	10^{-1} to 10^{-3}
Infrared	10^{-3} to 7×10^{-7}
Visible	7×10^{-7} (red) to 4×10^{-7} (violet)
Ultraviolet	4×10^{-7} to 10^{-8}
X-rays	10^{-8} to 10^{-13}
γ-rays	10^{-10} to 10^{-16}

Electromagnetic Waves:

An electromagnetic wave is a disturbance in the electric and magnetic fields in space. The electric field is shown oscillating in the vertical plane. The magnetic field is shown oscillating in the horizontal plane. These are arbitrary choices; the point is that the two fields vary at right angles to each other, and also at right angles to the direction in which the wave is travelling. This shows that electromagnetic waves are transverse waves.

By applying a filter we can polarize an unpolarised light (in all directions), light is emitted in one direction.

Chapter 14: Superposition of Waves

When two waves arrive together at the same place they pass straight through one another. This is very different from the behavior of particles. When two waves meet they combine, with the displacements of the two waves adding together. The resultant displacement is the algebraic sum of the displacements of waves A and B; that is, their sum, taking account of their signs (positive or negative).

Principle of Superposition: when two or more waves meet at a point, the resultant displacement is the algebraic sum of the displacements of the individual waves.

You should be aware that all waves can be reflected, refracted and diffracted.

Diffraction: the spreading of a wave as it passes through a gap or around an edge.

Diffraction effects are greatest when waves pass through a gap with a width roughly equal to their wavelength. When the gap width is larger than the wavelength, the wave passes through the gap and does not spread out much on the other side. When the gap size is smaller than the wavelength, more diffraction occurs and the waves spread out greatly. Diffraction is a wave effect that can be explained by the principle of superposition: in some directions the ripples add together while in other directions they cancel out.

Interference:

> Adding waves of different wavelengths and amplitudes results in complex waves. Where two waves arrive at a point in phase with one another so that they add up, we call this effect constructive interference. Where they cancel out, the effect is known as destructive interference. Where two waves have different amplitudes but are in phase, constructive interference results in a wave whose amplitude is the sum of the two individual amplitudes. Whether the waves combine constructively or destructively at a point depends on the path difference of the waves from the two sources.

Path Difference: the extra distance travelled by one of the waves compared with the other.

A path difference of 1 wavelength is equivalent to a phase difference of zero. A path difference of 0.5 wavelengths is equivalent to a phase difference of 180°. The waves interfere destructively because they are in antiphase. For constructive interference the path difference is a whole number of wavelengths: path difference$=n\lambda$. For destructive interference the path difference is an odd number of half wavelengths: path difference $= (n + \frac{1}{2})\lambda$.

Coherence:

> If two sources connected to different signal generators with slightly different frequencies, the waves might start off in phase with one another, but they would soon go out of phase. By connecting the two sources to the same signal generator, we can be sure that the waves that they produce are constantly in phase with one another. We say that they act as two coherent sources of waves (coherent means sticking together). Coherent sources emit waves that have a constant phase difference. Note that the two waves can only have a constant phase difference if their frequency is the same and remains constant.

Slit Separation (**a**): this is the distance between the centers of the slits

Fringe Separation (**x**): this is the distance between the centers of adjacent bright (or dark) fringes

Slit-To-Screen Distance (**D**): this is the distance from the midpoint of the slits to the central fringe on the screen.

$$\text{wavelenght } (\lambda) = \frac{\text{slit separation (a)} \times \text{fringe seperation (x)}}{\text{slit}-\text{to}-\text{screen distance (D)}}[\text{m}]$$

Diffraction Gratings:

A transmission diffraction grating consists of a large number of equally spaced lines ruled on a glass or plastic slide. Each line is capable of diffracting the incident light. There may be as many as 10 000 lines per centimeter. When light is shone through this grating, a pattern of interference fringes is seen. A reflection diffraction grating consists of lines made on a reflecting surface so that light is both reflected and diffracted by the grating. It is usual to measure the angle θ at which they are formed, rather than measuring their separation. With double slits, the fringes are equally spaced and the angles are very small. With a diffraction grating, the angles are much greater and the fringes are not equally spaced. The fringes are also referred to as maxima. The central fringe is called the zeroth-order maximum; the next fringe is the first-order maximum, and so on. The pattern is symmetrical, so there are two first-order maxima, two second-order maxima, and so on. As it passes through each slit, it diffracts into the space beyond. So now we have many overlapping beams of light, and these interfere with one another. It is difficult to achieve constructive interference with many beams, because they all have to be in phase with one another. By measuring the angles at which the maxima occur, we can determine the wavelength of the incident light. The wavelength λ of the monochromatic light is related to the angle θ by: $d \sin\theta = n\lambda$ (where d is the distance between adjacent lines of the grating and n is known as the order of the maximum; n can only have integer values 0, 1, 2, 3, etc). The distance d is known as the grating element or grating spacing. A diffraction grating can be used to split white light up into its constituent colors (wavelengths). This splitting of light is known as dispersion, a series of spectra appear, with violet closest to the centre and red furthest away. We can see why different wavelengths have their maxima at different angles if we rearrange the equation

$$\sin\theta = \frac{n\lambda}{d}[°]$$

From this it follows that the greater the wavelength λ, the greater the value of sin θ and hence the greater the angle θ. Red light is at the long wavelength end of the visible spectrum, and so it appears at the greatest angle.

Chapter 15: Stationary Waves

Progressive Waves: they start from a source and travel outwards, transferring energy from one place to another.

Stationary Waves: a wave which oscillates in time but whose peak amplitude profile does not move in space. The peak amplitude of the wave oscillations at any point in space is constant with time, and the oscillations at different points throughout the wave are in phase.

There are points along the wave that remain (almost) motionless while points on either side are oscillating with the greatest amplitude. The points that do not move are called the nodes and the points where the wave oscillates with maximum amplitude are called the antinodes. At the same time, it is clear that the wave profile is not travelling along the length of the spring. Hence we call it a stationary wave or a standing wave. The wave appears as a series of loops, separated by nodes. The phase difference between points A and B is 180°. Hence the sections of spring in adjacent loops are always moving in antiphase; they are half a cycle out of phase.

Formation of Stationary Waves:
Imagine a string stretched between two fixed points, pulling the middle of the string and then releasing it produces a stationary wave. There is a node at each of the fixed ends and an antinode in the middle. Releasing the string produces two progressive waves travelling in opposite directions. These are reflected at the fixed ends. The reflected waves combine to produce the stationary wave. A stationary wave is formed whenever two progressive waves of the same amplitude and wavelength, travelling in opposite directions, superpose. This cycle repeats itself, with the long spring showing nodes and antinodes along its length. The separation between adjacent nodes or antinodes tells us about the progressive waves that produce the stationary wave. The separation between adjacent nodes or antinodes is related to the wavelength (λ) of the progressive wave. The important conclusions are:

- separation between two adjacent nodes (or between two adjacent antinodes) $= \frac{\lambda}{2}$
- separation between adjacent node and antinode $= \frac{\lambda}{4}$.

The wavelength λ of any progressive wave can be determined from the separation between neighboring nodes or antinodes of the resulting standing wave pattern. (This separation is = λ/2.) This can then be used to determine either the speed v of the progressive wave or its frequency f by using the wave equation: $v = f\lambda$. It is worth noting that a stationary wave does not travel and therefore has no speed. It does not transfer energy between two points like a progressive wave. When the string is plucked half-way along its length, it vibrates with an antinode at its midpoint. This is known as the fundamental mode of vibration of the string. The fundamental frequency is the minimum frequency of a standing wave for a given system or arrangements, the sounds that are produced are made up of several different stationary waves having different patterns of nodes and antinodes. For example, a guitar string may vibrate with two antinodes along its length. This gives a note having twice the frequency of the fundamental, and is described as a harmonic of the fundamental. The musician's skill is in stimulating the string or air column to produce a desired mixture of frequencies. The frequency of a harmonic is always a multiple of the fundamental frequency. Since we know that adjacent nodes (or antinodes) of a stationary wave are separated by half a wavelength, we can use this fact to determine the wavelength λ of a progressive wave. If we also know the frequency f of the waves, we can find their speed v using the wave equation $v = f\lambda$.

Chapter 16: Radioactivity

Radioactivity the process whereby unstable nuclei emit radiation.

In the **nuclear model of the atom**, the protons and neutrons, which comprise nearly all of the mass of the atom, are located in the nucleus at the center of the atom. The electrons are distributed around the nucleus and occupy most of the volume of the atom. The **plum pudding model** is defined by electrons surrounded by a volume of positive charge, like negatively-charged “plums” embedded in a positively-charged “pudding”.

Geiger-Marsden α-scattering: A beam of α-particles is fired at thin gold foil. The α-particle source was encased in metal with a small aperture, allowing a fine beam of α-particles to emerge. Air in the apparatus was pumped out to leave a vacuum. One reason for choosing gold was that it can be made into a very thin sheet or foil. Rutherford’s foil was only a few hundreds of atoms thick. The α-particles were detected when they struck a solid ‘scintillating’ material. Each α-particle gave a tiny flash of light and these were counted by the experimenters (Geiger and Marsden).

An α-particle is deviated due to the repulsive force between the α-particle and the positive charge in the atom. Most α-particles have little or no deviation – so most of an atom is empty space. A very few α-particles are deviated more than 90° – so most of the mass of an atom is concentrated in a small space (the nucleus) and most of the atom is empty space.

Protons and neutrons make up the nucleus of the atom. The electrons move around the nucleus in a cloud. Protons and neutrons in a nucleus are collectively called nucleons. A specific combination of protons and neutrons in a nucleus is called a **nuclide**.

Isotopes are nuclei of the same element with different numbers of neutrons but same proton number.

Isotopes of the same element are identical, all have the same chemical properties but very different nuclear properties. The number of protons in the nucleus of an atom determines what element it is. The number of protons determines the chemical properties of the atom. The number of protons and the number of neutrons determine the nuclear properties.

Any atom is electrically neutral, so the number of electrons surrounding the nucleus must equal the number of protons in the nucleus of the atom. If an atom gains or loses an electron, it is no longer electrically neutral and is called an ion.

Protons carry positive charge +e; and neutrons are uncharged. You would expect electrostatic repulsions from all positively charged protons to blow it apart. This does not happen because of an attractive force called the strong nuclear force. It only acts over very short distances, and holds the nucleus together.

In a large nucleus the nucleons are not held together so tightly, and this can make the nucleus unstable. The more protons there are in a nucleus, the greater the electric forces between them, and we need a few extra neutrons to help ‘keep the protons apart’. This is why heavy nuclei have more neutrons than protons. Elements with a proton number greater than 83 all undergo radioactive decay.

Fundamental Particles:

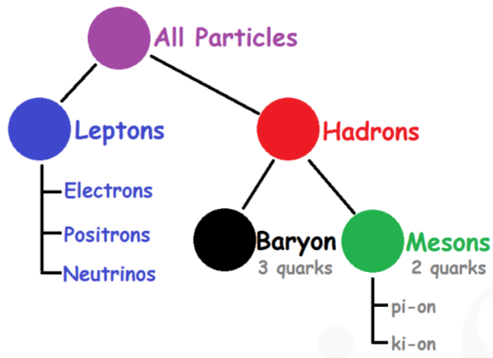
Protons, neutrons and electrons were thought of as fundamental particles, which could not be subdivided further. However, in the middle decades of the 20th century, physicists discovered many other particles with masses different from those of protons, neutrons and electrons suggesting that these were not fundamental particles. These new particles were found in two ways:

- by looking at cosmic rays, which are particles that arrive at the Earth from outer space
- by looking at the particles produced by high-energy collisions in particle accelerators

Today, sub-atomic particles are divided into two families:

- **Hadrons** (Heavy) these are all particles that are affected by the strong nuclear force.
- **Leptons** (Light) such as electrons. All particles that are unaffected by the strong nuclear force.

Murray Gell-Mann in 1964 proposed a new model of just a few different particles, which he called quarks. These are called the up (u), down (d) and strange (s) quarks. We have two families of fundamental particles, quarks and leptons.



Quark / Antiquark	Symbol		Charge/*e*	
up	u	$\bar{u}$	+2/3	-2/3
down	d	$\bar{d}$	-1/3	+1/3
charm	c	$\bar{c}$	+2/3	-2/3
strange	s	$\bar{s}$	-1/3	+1/3
top	t	$\bar{t}$	+2/3	-2/3
bottom	b	$\bar{b}$	-1/3	+1/3

There are two types of hadrons; baryons made up of three quarks, and mesons made up of two quarks (pi-on: quark + antiquark) (ki-on: any quark + any strange).

proton = (uud) **neutron = (udd)** **pi$^+$ meson = (u$\bar{d}$)** **phi meson = (s$\bar{s}$)**

Antiquarks account for the existence of antimatter. This is matter that is made of antiparticles; when a particle meets its antiparticle, they annihilate each other, leaving only photons of energy.

Radiation: takes place when nuclei of atom is unstable.

There are three types of radiations: **alpha beta** and **gamma**

Nuclei consist of protons and neutrons, and if the balance between these particles is too far to one side, the nucleus may emit α- or β-radiation as a way of achieving greater stability. γ-radiation is usually emitted after α- or β-decay, to release excess energy. There are two types of β-radiation. Beta-minus (β^-) radiation, which is an electron, with negative charge of −e. There are also many unstable nuclei that emit beta-plus (β^+) radiation. This radiation is in the form of positrons, similar to electrons in terms of mass but with positive charge of +e.

Positrons are a form of antimatter. When a positron collides with an electron, they annihilate each other. Their mass is converted into electromagnetic energy in the form of two gamma photons.

α- and β-radiation are particles of matter. A γ-ray is a photon of electromagnetic radiation, similar to an X-ray. (X-rays are produced when electrons are decelerated; γ-rays are produced in nuclear reactions.) An α-particle consists of two protons and two neutrons; it is a nucleus of helium-4. A β^--particle is simply an electron and a β^+-particle is a positron.

Radiation	Symbol	Mass (relative to proton)	Charge	Typical speed
α-particle	α, ^4_2He	4	+2*e*	'slow' ($10^6\,m\,s^{-1}$)
β^--particle	β, β^-, e, $^{0}_{-1}e$	$\frac{1}{1840}$	−*e*	'fast' ($10^8\,m\,s^{-1}$)
β^+-particle	β, β^+, e+, $^{0}_{+1}e$	$\frac{1}{1840}$	+*e*	'fast' ($10^8\,m\,s^{-1}$)
γ-ray	γ	0	0	speed of light ($3 \times 10^8\,m\,s^{-1}$)

β-particles are electrons coming from the nucleus of an atom. There are no electrons in the nucleus, so the process was pictured as the decay of a neutron to give a proton and an electron. It was noticed that β-particles were emitted with a range of speeds. It was deduced that some other particle must be carrying off some of the energy and momentum released in the decay. This particle is now known as the antineutrino, with symbol $\bar{\nu}$. They have very little mass (much less than an electron) and no electric charge. In β^+ decay, a proton decays to become a neutron and an electron neutrino (symbol ν). Weak nuclear force between quarks causes the changing of quarks.

beta-minus (β^-): $^1_0n \rightarrow {^1_1p} + {^{0}_{-1}e} + \bar{\nu}$ (d → u)   beta-plus (β^+): $^1_1p \rightarrow {^1_0n} + {^{0}_{+1}e} + \nu$ (u → d)

gamma (γ): $^{40}_{18}Ar_{higher} \rightarrow \gamma + {^{40}_{18}Ar_{lower}}$ alpha (α): $^{222}_{86}Rn \rightarrow {^{218}_{84}Po} + {^4_2\alpha}$

Nucleon number is conserved; there are as many nucleons after decay as there were before. In β^- decay, a neutron has become a proton so that the total number of nucleons is unchanged. In β^+ decay, a proton becomes a neutron. Proton number is also conserved. In β^- decay, we start with a neutron (Z = 0). After the decay, we have a proton (Z = +1) and a β– particle (Z = –1). Together these have Z = 0. In α decay, an alpha particle is emitted by a nucleus. Although these nucleons and protons are outside the nucleus, the total sum is still conserved. So nucleon and number is conserved.

You might expect mass to be conserved, but this is not so. The combined mass of the nucleus and the alpha particle is slightly less than that of the original nucleus. The 'lost' mass has become energy – this is where the fast-moving alpha particle gets its kinetic energy. So, instead of saying that mass is conserved in nuclear processes, we have to say that mass–energy is conserved.

The nucleus is held together by strong nuclear force, acting against repulsive electrostatic forces between protons. This force explains α decay, when a positively charged α-particle flies out of the nucleus, leaving it with less positive charge. However, the strong force cannot explain β decay. The weak interaction can, also known as the weak nuclear force. This is a force that acts on both quarks and leptons. The weak interaction is responsible for β decay.

Properties of Ionising Radiation:
Radiation affects the matter it passes through by causing ionisation. Both α- and β-particles are fast-moving charged particles, and if they collide with or pass close to atoms, they may knock or drag electrons away from the atoms. The resulting atoms are said to be ionised, and the process is called ionisation. In the process, the radiation loses some of its kinetic energy. After many ionisations, the radiation loses all of its energy and no longer has any ionising effect.

Alpha-radiation is the most strongly ionising, because the mass and charge of an α-particle are greater than those of a β-particle, and it usually travels more slowly. This means that an α-particle interacts more strongly with any atom that it passes, and so it is more likely to cause ionisation. Beta-particles are much lighter and faster, and so their effect is smaller. Gamma-radiation also causes ionisation, but not as strongly as α- and β-particles, as γ-rays are not charged.

Behaviour of radiations in electric and magnetic fields:
Because α-, β^-- and γ-radiations have different charges, or no charge, they behave differently in electric and magnetic fields. This can be used to distinguish one kind of radiation from another. A mixture of α-, β^-- and γ-radiations is passing through the gap between two parallel plates; the electric field in this space is uniform. Since α- and β^--particles are charged, they are attracted to the plate that has the opposite charge to their own. β^--particles are deflected more than α-particles, since their mass is so much less. Gamma-rays are undeflected since they are uncharged.

Alpha particles are deflected by a magnetic field confirming that they must carry a charge. The direction of deflection can be determined by Fleming's left hand rule. Beta particles are deflected by a magnetic field in an opposite direction to alpha particles. Gamma rays are unaffected by a magnetic field.

Radiation Penetration:
Because α-radiation is highly ionising, it cannot penetrate far into matter. A cloud chamber can be used to show the tracks of α-particles in air. The tracks are very dense, because of the dense concentration of ions produced, and they extend for only a few centimeters into the air. By the time the α-particles have travelled this far, they have lost virtually all of their kinetic energy. The α-particle, which is a nucleus of helium-4, grabs two drifting electrons in the air and becomes a neutral atom of helium gas.

α-radiation is absorbed by a thin sheet of paper or a few centimeters of air. β^--radiation is absorbed by a few millimeters of metal. γ-radiation is never completely absorbed but a few centimeters of lead, or several metres of concrete, greatly reduces the intensity.

The electronvolt (eV):
Alpha and beta particles move quickly; gamma photons travel at the speed of light. These types of radiation all have energy, but the energy of a single particle or photon is very small and far less than a joule. So we use another, much smaller unit of energy, the electronvolt, when considering the energy of individual particles or photons.

One electronvolt (1 eV) is the energy transferred when an electron travels through a potential difference of one volt.

understand that nucleon number and charge are conserved in nuclear processes

understand that an antiparticle has the same mass but opposite charge to the corresponding particle, and that a positron is the antiparticle of an electron

state that (electron) antineutrinos are produced during β^- decay and (electron) neutrinos are produced during β^+ decay 10 understand that α-particles have discrete energies but that β-particles have a continuous range of energies because (anti)neutrinos are emitted in β-decay

Enlightism

Spreading Inspiration

CONTACT US FOR QUERIES OR SUGGESTIONS

Email us at: contact@enlightism.com

FOLLOW US AT: @ENLIGHTISM

ENLIGHTISM.COM