MOJZA

AS Level

PHYSICS NOTES

9702

MOJZA

CONTENTS

MOJZA

Physical Quantities & Base Units

Physical Quantities

➜ All physical quantities consist of a numerical magnitude and a unit

SI Base Quantities

➜ There are seven base quantities with base units
➜ They can be used to derive every other quantity

Quantity	SI Base Unit	Symbol
Mass	Kilogram	kg
Length	Metre	m
Time	Second	s
Current	Ampere	A
Temperature	Kelvin	K

Derived Units
➜ Units of other quantities are derived from the base units
➜ The definition of quantities can be used to derive units
➜ For example, speed = distance/time = m/s

Homogeneity
➜ Both sides of a homogeneous equation have the same base units
➜ This can be used to find units of unknown quantities in an equation
➜ Homogeneity can be checked by calculating the units of both sides of an equation and comparing them to see if they are equal

MOJZA

Prefixes

Prefix	Value	Symbol
Tera	10^{12}	T
Giga	10^{9}	G
Mega	10^{6}	M
Kilo	10^{3}	k
Centi	10^{-2}	c
Milli	10^{-3}	m
Micro	10^{-6}	µ
Nano	10^{-9}	n
Pico	10^{-12}	p

Scalar and Vector Quantities

- Scalar quantities are those that have a magnitude only
- Vector quantities have a magnitude and a direction
- Distance is a scalar quantity; it is how much an object travels without considering direction
- Displacement is a vector quantity; it is the shortest distance between two points
- When an object returns to its starting position, the displacement is 0

Scalar Quantities	Vector Quantities
Distance	Displacement
Speed	Velocity
Mass	Force
Time	Acceleration
Energy	Momentum
Pressure	
Temperature	

MOJZA

Combining Vectors
➜ Vectors are represented by arrows pointing towards their direction
➜ Their length represents the magnitude
➜ Vectors can be combined by being added or subtracted

Triangle Method
➜ Place the tail of one vector at the head of the second vector
➜ Connect the the tail of the second vector to the head of the first vector to make the resultant vector

Parallelogram Method
➜ Place the tails of both vectors together
➜ Complete the parallelogram; the diagonal from both tails to both heads is the resultant

Equilibrium
➜ The vector triangles of coplanar forces form a closed triangle in equilibrium
➜ In equilibrium, all forces meet at a point

Resolving Vectors
➜ A single vector can be represented by two vectors; the original vector is a resultant of these two vectors
➜ Vectors have components; horizontal and vertical
➜ When a vector of magnitude F is at an angle θ to the horizontal, its vertical component is Fsinθ and its horizontal component is Fcosθ
➜ The component adjacent to the angle is Fcosθ and the component opposite to the angle is Fsinθ

Errors and Uncertainties

➜ It is impossible to find the true value of any quantity
➜ There are always uncertainties in measurement
➜ Uncertainty is the difference between the true value and the measurement

Random Error
➜ Random error refers to unpredictable fluctuations in measurements due to uncontrollable factors, such as environmental conditions
➜ This affects the precision of measurements
➜ There is a wider spread of results about the mean value
➜ Take several readings and calculate average to reduce random error

Systematic Error

➜ It is caused by faulty instruments and flaws in experimental methods
➜ The error is repeated every time the instrument is used
➜ This affects the accuracy of the measurements
➜ Recalibrate the instrument or modify the experimental method to reduce systematic error

Zero Error

➜ A type of systematic error
➜ The instrument gives a reading when the true value is zero
➜ This has a fixed error which can be countered by calculation in the results

Precision and Accuracy

➜ Precision is how close measured values are to each other
➜ Accuracy is how close measured values are to the true value

Calculating Uncertainty

➜ The uncertainty is a range of values where the true value is expected to lie
➜ It is an estimate
➜ It can be represented in three ways
➜ Absolute uncertainty, given as a fixed quantity
➜ Fractional uncertainty; uncertainty given as a fraction of the measurement
➜ Percentage uncertainty, given as a percentage of the measurement

➜ The uncertainty in a reading is ± half the smallest division
➜ The uncertainty in a measurement is at least ± the smallest division
➜ The uncertainty in repeated data is ± half of the range
➜ The uncertainty in digital readings is ± the last significant digit

Combining Uncertainties

➜ While adding or subtracting values, the uncertainties are always added
➜ While multiplying or dividing, the fractional uncertainties are added
➜ While raising to a power, the uncertainty is multiplied by the power

MOJZA

Kinematics

Graphs of Motion

➜ Distance-time graphs

➜ The gradient of a distance-time graph tells us the speed
➜ It shows how the distance of an object from a point varies over time
➜ The gradient of a tangent at a given time on a distance-time graph gives us the speed at that specific time
➜ A horizontal line in the distance-time graph shows that the object is at rest
➜ A straight line with a constant gradient represents constant speed
➜ Increasing acceleration is represented on a distance-time graph by a curve of increasing gradient - rising curve
➜ Decreasing acceleration is represented on a distance-time graph by a curve of decreasing gradient - falling curve

➜ Speed-time graphs

➜ The gradient of a speed-time graph gives us the acceleration
➜ The gradient of a tangent on a speed-time graph gives the acceleration at that given time
➜ The area under the graph of a speed-time graph represents the distance travelled
➜ A straight line represents constant acceleration
➜ A rising curve shows increasing acceleration
➜ A falling curve shows decreasing acceleration
➜ A horizontal line shows constant speed
➜ A flat line at 0 speed shows an object at rest

➜ Finding the distance

➜ Find the shapes under the curve
➜ Apply the formula for their area
➜ Find the base and height through the graph provided
➜ Add up all the areas

Equations of Motion

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

Deriving Equations

$v = u + at$

- ➜ Can be derived from a velocity-time graph
- ➜ The gradient represents acceleration
- ➜ The y intercept represents initial speed
- ➜ Finding the straight line equation gives us $v = u+at$
- ➜ It can also be derived by rearranging $a= (v-u)/t$

$s = (v+u)t/2$

- ➜ displacement = average velocity x time
- ➜ average velocity = $(v+u)/2$

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

- ➜ Can be derived by a velocity-time graph
- ➜ The area under the graph represents displacement
- ➜ The equation can be derived by finding the area under the graph
- ➜ It can also be derived by substituting $v = u+at$ into $s=(v+u)t/2$

$2as = v^2 - u^2$

- ➜ Can be derived by substituting $t=(v-u)/a$ into $s=(v+u)t/2$

Calculations with Equations of Motion

- ➜ Write down all the known and unknown variables in question
- ➜ Choose the equation that has all the variables
- ➜ Substitute values and solve for the required variable

Free Fall Experiment

- ➜ It requires a ball bearing, metre rule, electromagnet, electronic timer, and trapdoor
- ➜ The ball drops when the current in the magnet switches off and the timer starts
- ➜ The timer stops when the ball hits the trapdoor
- ➜ It is repeated for different heights to reduce random error
- ➜ The height can be measured using a metre rule
- ➜ The acceleration of free fall can then be calculated using the equations of motion

MOJZA

Projectile Motion

➜ Projectile motion is the movement of an object with only the force of gravity acting on it
➜ The motion consists of a vertical component and a horizontal component

For projection at an angle

	Vertical Motion	Horizontal Motion
Initial Speed	usinθ	ucosθ
Acceleration	g ($9.81ms^{-2}$)	0
Total Displacement	0	x

For vertical projection downwards from the top

	Vertical Motion	Horizontal Motion
Initial Speed	0	0
Acceleration	g ($9.81ms^{-2}$)	0
Total Displacement	h	0

For vertical projection upwards from the bottom

	Vertical Motion	Horizontal Motion
Initial Speed	u	0
Acceleration	-g ($-9.81ms^{-2}$)	0
Total Displacement	h (or 0 if returns to ground)	0

For horizontal projection

	Vertical Motion	Horizontal Motion
Initial Speed	0	u
Acceleration	g ($9.81ms^{-2}$)	0
Total Displacement	h	x

Dynamics

Newton's First Law
➜ A body at rest will remain at rest and a body in motion will remain in motion unless an unbalanced force acts upon it
➜ An object with no resultant force will keep travelling at constant speed

Newton's Second Law
➜ The force acting on an object is equal to the product of its mass and acceleration
➜ F = ma

Newton's Third Law
➜ If object A exerts a force on object B, then object B exerts an equal and opposite force of the same type on object A

Linear Momentum
➜ Momentum is the product of mass and velocity
➜ p = mv
➜ It is a vector quantity
➜ The SI unit for momentum is kg ms^{-1}
➜ The direction of momentum is represented by its sign

Force
➜ Force is the rate of change of momentum
➜ F = change in momentum/change in time
➜ It is a vector quantity; its sign represents direction

Resistive Forces
➜ Resistive forces oppose the motion of an object
➜ For example: friction and air resistance
➜ They increase with speed

Terminal Velocity
➜ A body in free fall experiences acceleration due to gravity only
➜ Air resistance increases as the body accelerates
➜ This causes the resultant force and acceleration to decrease
➜ When the air resistance is equal to the weight, the body will reach terminal velocity
➜ The body falls at this constant velocity, since there is no resultant force

Principle of Conservation of Momentum
➜ The total momentum of a system remains conserved if no external force acts on it

External and Internal Forces

➜ External forces act on a body from the outside, such as friction
➜ Internal forces are exchanged by particles in the system, such as tension
➜ A closed or isolated system has no external forces

Elastic and Inelastic Collisions

➜ In elastic collision, kinetic energy is conserved; the objects do not stick and move in opposite directions
➜ In inelastic collision, kinetic energy is not conserved; the objects may stick together
➜ The kinetic energy is transferred into other forms of energy in inelastic collisions

Collisions

➜ The total momentum before collision = the total momentum after collision
➜ The sign of the momentum is dependant upon direction
➜ Consider one direction positive and the opposite direction negative

Collision Cases	**Equation**
Remain separate after collision	$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
Stick together after collision	$m_1u_1 + m_2u_2 = v(m_1+m_2)$
Explosion	$(m_1+m_2)u = m_1v_1 + m_2v_2$

Forces, Density and Pressure

Centre of Gravity

➜The point at which all the weight of an object seems to act
➜ For symmetrical objects, it is located at the point of symmetry
➜ An object is stable when the centre of gravity is above its base
➜ The lower the centre of mass, the more stable an object is
➜ The wider the base, the more stable an object is
➜ The object will topple over if the centre of mass is not above the base

Moment

➜ Moment is the turning effect of a force
➜ Moments occur when a force causes an object to rotate about a pivot
➜ Moment = Force x Perpendicular distance from pivot
➜ The SI unit is Newton metre (Nm)

Principle of Moments

➜ For a system to be in equilibrium, the sum of clockwise moments must be equal to the sum of anticlockwise moments about the same point
➜ $F_1d_1 = F_2d_2$

Couple

➜ A pair of forces acting to produce rotation only
➜ Depends only on the perpendicular distance between two forces
➜ Couple forces are equal in magnitude, opposite in direction, and perpendicular to the distance between the two
➜ They have zero resultant force
➜ They do not accelerate
➜ The size of the turning effect is given by torque

Torque

➜ Torque is the moment of a couple
➜ Torque = One force x Perpendicular distance between forces

Equilibrium

➜ When all forces are balanced in a system, it is in equilibrium
➜ There is no resultant force or torque
➜ Coplanar forces in equilibrium are represented by a closed vector triangle
➜ The vectors form a closed path when joined together
➜ Coplanar forces in equilibrium act on a single point

MOJZA

Density

- ➜ It is the mass per unit volume of an object
- ➜ The units of density can be g/cm^3 or kg/m^3, depending on the units of mass and volume
- ➜ Density = Mass/Volume

Pressure

- ➜ Pressure is the force per unit area
- ➜ P = F/A
- ➜ Pressure is inversely proportional to area
- ➜ The unit of pressure is Pascal (Nm^{-2})
- ➜ It is a scalar quantity

Liquid Pressure

- ➜ Hydrostatic pressure is the pressure exerted by a fluid at equilibrium at any given point in the fluid due to gravity
- ➜ $P = \rho gh$
- ➜ The change in pressure is proportional to the change in height
- ➜ **$\Delta P = \rho gh$**
- ➜ Total Pressure = Hydrostatic pressure + Atmospheric pressure

Upthrust

- ➜ A force that pushes upwards on objects submerged in fluids
- ➜ It is due to the difference between hydrostatic pressure at the top and bottom of an object
- ➜ It is directly proportional to the pressure
- ➜ The force on the bottom of the object is greater than that on the top of the object
- ➜ The resultant pressure causes the upward force upthrust
- ➜ If the upthrust is greater than the weight of an object, it will rise up
- ➜ If the object has lesser density than the fluid, it will float

Archimedes' Principle

- ➜ The principle states that an object submerged in a fluid at rest has upthrust equal to the weight of the fluid displaced by the object
- ➜ $F = \rho gV$

Work, Energy and Power

Work

- Work done = Force in direction of displacement x Displacement (W=F x d)
- It is the energy transferred from one an object to another
- The unit of work is Joules (J)

Principle of Conservation of Energy

- Energy can not be created or destroyed; it can only be transferred from one form to another
- The total energy in a closed system remains constant

Types of Energy

- Kinetic energy is the energy possessed by an object due to its motion
- Gravitational potential energy is due to an object's height
- Internal/Thermal energy is energy due to an object's temperature
- Chemical energy is the energy in a chemical substance
- Nuclear energy is energy contained in the nucleus of an atom
- Elastic energy is possessed by a stretched spring or elastic band (strain energy)

Gravitational Potential Energy

- The energy stored in a mass due to its position in a gravitational field
- When an object is lifted, work is done against the force of gravity
- Energy is transferred to the object
- The equation is derived from work done
- The work is done is weight or mg, and the displacement is h
- W = F x d
- GPE = mgh
- The relationship between height and GPE is linear

Kinetic Energy

- Kinetic energy is the energy due to an object's motion
- Work is done by the force to make the object accelerate
- Energy is transferred to the object
- The equation is derived from work done
- Kinetic energy = $\frac{1}{2} mv^2$
- The faster an object moves, the greater the kinetic energy
- Objects gain kinetic energy as they gain speed while falling

MOJZA

Energy Dissipation

- During energy transfer, some energy can be transferred to unuseful forms
- Dissipation is how energy is wasted
- Energy not transferred to useful energy stores will be lost to the surroundings
- Energy is lost in the form of heat, light and sound energy
- The requirements of a system determine what energy is considered wasted

Work-Energy Equation

- Work done by driving force - Work done by resistive force = Change in energy
- Change in energy can be gain or loss, and can vary in different scenarios
- For example, gain in kinetic energy - loss in potential energy

Efficiency

- The ratio of useful energy output to the total energy input of a system
- Efficiency = Useful Energy Output/Total Energy Input x 100
- Efficiency = Useful Power Output/Total Power Input x 100

Power

- Power is the rate of energy transfer
- Since energy transferred is work done, it is also the work done per unit time
- The SI unit is Watt (W)
- $P = E/t$ or $P = W/t$
- For an object moving at constant velocity due to a constant force: $P = Fv$

MOJZA

Deformation of Solids

Tensile Force

➜ Forces can change the shape and size of an object
➜ It is known as deformation
➜ Forces acting in opposite directions on an object can stretch or compress it
➜ When forces are stretching an object, they are called tensile
➜ Tensile strength is the amount of load a material can handle without breaking

Hooke's Law

➜ When a force is applied to a spring, it extends
➜ Hooke's law says that the extension is directly proportional to the load attached
➜ Not all objects obey Hooke's law
➜ The limit of proportionality is the point where an object stops obeying Hooke's law
➜ The graph of force against extension produces a straight line for objects obeying the law
➜ At the limit of proportionality, the graph begins to curve
➜ The gradient of the line gives the spring constant k
➜ F = kx

Spring Constant

➜ The spring constant is the measure of the stiffness of an object
➜ It is defined as force per unit extension
➜ The SI unit is Nm^{-1}

Combinations of Springs

➜ Springs can be attached end-to-end in series or side-by-side in parallel
➜ The effective spring constant depends on the combination
➜ For series: $\frac{1}{kf} = \frac{1}{k1} + \frac{1}{k2}$
➜ For parallel: $k_F = k_1 + k_2$

Stress

➜ Tensile stress (σ) is the force applied per unit cross sectional area of a material
➜ σ = F/A
➜ The unit of stress is Pascal (Pa)
➜ The ultimate tensile stress is the maximum stress possible without the material breaking

Strain

➜ It is the extension per unit length
➜ It is dimensionless, as it is a ratio of lengths
➜ ε = x/L

Young's Modulus

➜ It is the measure of the stiffness of a material
➜ It tells us the elasticity of a material
➜ It is the ratio of stress and strain
➜ Young Modulus = Stress/Strain
➜ E = FL/Ax
➜ The unit is the same as stress, Pascal (Pa)
➜ Stress and strain are directly proportional to each other for a material
➜ The gradient of a stress-strain graph is the young modulus
➜ Young modulus remains same for a specific material

Elastic and Plastic Deformation

➜ In elastic deformation, the object returns to its original shape after the load is removed
➜ In plastic deformation, the object does not return to its original shape after removing the load
➜ Elastic limit is the point after which an object does not return to its original shape
➜ On a force-extension graph, the straight line represents elastic deformation
➜ Plastic deformation occurs when the graph curves

Brittle and Ductile Materials

➜ Brittle materials have little to no plastic deformation; the material breaks when stretched
➜ For example: glass and concrete
➜ Ductile materials have more plastic deformation; they can stretch before breaking
➜ For example: rubber and copper
➜ On a graph, brittle materials are represented by a straight line with little to no curve
➜ Ductile materials are represented by straight line which then curves towards the x axis

Elastic Potential Energy

➜ The work done to stretch a material is force x extension
➜ The area under a force-extension graph represents the work done
➜ This work done is known as elastic potential energy
➜ This is true for materials that do not obey Hooke's law as well
➜ Elastic potential energy is the energy stored in a material when it is stretched or compressed
➜ For an object obeying Hooke's law, EPE = $\frac{1}{2} kx^2$

Loading and Unloading Graphs

➜ The unloading curve always lies below the loading curve
➜ The area between the loading and unloading curves represents the net work done or thermal energy dissipated
➜ The total area is the minimum energy required to stretch the material to that extension

Waves

Progressive Waves

Oscillations and Vibrations

➜ Energy is transferred in waves through oscillations or vibrations
➜ In transverse waves, the vibrations are perpendicular to the direction of the wave
➜ In longitudinal waves, the vibrations are parallel to the direction of the wave

Wave Properties

➜ Displacement of a wave is the distance from the mean position
➜ Amplitude is the maximum displacement of a wave from its mean position
➜ Wavelength is the distance between two same points on consecutive oscillations
➜ The time period is time taken for one complete oscillation
➜ Speed is the distance a wave travels per unit time
➜ Frequency is the number of oscillations per unit time
➜ Frequency is measured in Hertz (Hz)
➜ $f = 1/T$

Phase

➜ Phase difference tells how far apart two points on a wave are
➜ It can be found from the position of crests or troughs for waves of the same frequency
➜ If two crests align, the waves are in phase
➜ If a crest and trough align, the waves are out of phase
➜ Phase difference can be measured in wavelengths, degrees or radians
➜ In phase waves have a phase difference of 360° or 2π radians
➜ Out of phase waves have a phase difference of 180° or π radians

Wave Energy

➜ Waves transfer energy without transferring matter
➜ Waves that transfer energy are progressive waves
➜ Waves that do not transfer energy are stationary waves

Cathode Ray Oscilloscope

➜ It is an instrument to display, measure and analyse waveforms of electrical circuits
➜ A.C current is represented as a transverse wave on the CRO
➜ The x axis represents time and the y axis represents voltage
➜ The timebase can be used to calculate time period
➜ Timebase is how many seconds a division represents
➜ It is measured in s div^{-1} or s cm^{-1}
➜ Dividing the total time by the number of wavelengths displayed gives time period

The Wave Equation

$v = f\lambda$

Wave speed = Frequency x Wavelength

Wave Intensity

➜ Intensity is the power per unit area
➜ The amount of energy passing through a unit area per unit time
➜ I = P/A
➜ Intensity is directly proportional to $frequency^2$
➜ Intensity is directly proportional to $1/r^2$
➜ Intensity is directly proportional to $amplitude^2$

Doppler Effect

➜ A change in frequency due to the relative motion between a source of sound or light and an observer results in the doppler effect
➜ When both the source and observer are stationary, the frequency is the same for both
➜ When the source moves towards the observer, the wavelength decreases and the frequency appears higher for the observer
➜ When the source moves away from the observer, the wavelength increases and the frequence appears lower for the observer
➜ observed frequency = source frequency x wave velocity/(wave velocity ± source velocity)
➜ $f_0 = f_s V / (V \pm V_s)$
➜ The sign is positive when the source is moving away and negative when the source is moving towards

Electromagnetic Waves

➜ All electromagnetic waves are transverse
➜ They can all travel in a vacuum
➜ They all travel at the speed of light in a vacuum
➜ They consist of electric and magnetic fields oscillating perpendicular to each other

MOJZA

Electromagnetic Spectrum

➜ The electromagnetic spectrum consists of seven components
➜ Radiowaves, microwaves, infrared, visible light, ultraviolet, x-rays and gamma rays
➜ The frequency increases from radio waves to gamma rays
➜ The wavelength decreases from radio waves to gamma rays
➜ The energy increases from radio waves to gamma rays

Radiation	Wavelength range / m
Radiowaves	10^{3}
Microwaves	10^{-2}
Infra-red	10^{-5}
Visible	10^{-6}
Ultra-violet	10^{-8}
X-Rays	10^{-10}
Gamma Rays	10^{-12}

Polarisation

➜ Transverse waves oscillate perpendicular to the direction of travel
➜ The oscillations can be in any plane
➜ They can be restricted to one direction by polarisation
➜ After a wave is polarised, it only vibrates in one plane
➜ Polarisation occurs in transverse waves only
➜ Longitudinal waves cannot be polarised since they oscillate parallel to direction
➜ A polariser or polarising filter is used to polarise waves in a particular direction
➜ Only unpolarised waves can be polarised

Malus' Law

➜ Polarisation reduces the intensity of waves
➜ The intensity of transmitted polarised light is half of the unpolarised light
➜ Unpolarised waves are passed through a polariser, and then an analyser filter
➜ If the orientation of the analyser and polariser are the same, the light transmitted by the analyser is of the same intensity that is incident on it
➜ Malus' law is applied when the orientation is different
➜ Intensity of transmitted light = maximum intensity x $\cos^2\theta$
➜ $I = I_0\cos^2\theta$
➜ At angles 0° and 180°, the intensity transmitted will be maximum
➜ At angles 90° and 270°, the intensity transmitted will be 0

Superposition

Superposition Principle
➜ When two or more waves of the same frequency travelling in opposite directions overlap, the resultant displacement is the sum of displacements of each wave
➜ When two waves have same frequency and amplitude, they can have constructive or destructive interference
➜ When the waves are in phase, crests line up with crests and troughs line up with troughs, they undergo constructive interference
➜ The resultant wave has double the amplitude
➜ When the waves are out of phase and crests line up with troughs, they undergo destructive interference
➜ The resultant wave has no amplitude

Stationary Waves
➜ Stationary waves are produced when two waves of the same frequency and amplitude travelling in opposite directions superpose
➜ The two waves are commonly a travelling wave and its reflection
➜ When they superpose, the resultant wave's crest and trough do not move

Nodes and Anti Nodes
➜ Stationary waves consist of nodes and anti nodes
➜ Nodes are where there is no vibration or zero amplitude
➜ Antinodes are where vibrations are at maximum amplitude
➜ Nodes are fixed and anti nodes only move vertically
➜ All points between nodes are in phase

Two Fixed Ends
➜ The simplest wave pattern is a single loop with two nodes and an antinode
➜ This is known as the fundamental mode or first harmonic frequency
➜ The frequency of the stationary waves in the string depend on its length and speed

One Open End
➜ The fundamental mode has a quarter of a wavelength with one node and antinode
➜ The next harmonic frequencies have an additional node or antinode

Two Open Ends
➜ Fundamental mode has one node and two anti nodes

Column Type	Length	Frequency	n (harmonic)
Two fixed ends	$L = n\lambda/2$	$f = nv/2L$	n = 1,2,3…
One open end	$L= n\lambda/4$	$f = nv/4L$	n = odd
Two open ends	$L = n\lambda/2$	$f = nv/2L$	n = 1,2,3…

Diffraction

➜ Diffraction is the spreading of waves due to an obstruction, such as a slit
➜ The diffraction depends on the width of the gap in comparison to the wavelength
➜ Diffraction is maximum when the width of the slit is equal to the wavelength
➜ Only the wave's amplitude changes during diffraction
➜ Some energy is dissipated during diffraction
➜ Any type of wave can be diffracted
➜ The greater the wavelength, the greater the diffraction
➜ The lesser the width of the slit, the greater the diffraction

Interference

➜ Interference is the overlapping of waves to produce a resultant wave with displacement which is the sum of displacements of each wave
➜ Constructive interference occurs when the waves are in phase
➜ The amplitude of the resultant wave is double
➜ Destructive interference occurs when the waves are out of phase
➜ The resultant wave has zero amplitude

Coherence

➜ Coherent waves have equal frequency and constant phase difference
➜ An observable interference pattern forms only for coherent waves
➜ Laser light produces coherent light waves

Two source interference

➜ For light waves, an interference pattern is seen on the screen
➜ For it to be observed, the waves must be coherent and monochromatic
➜ The interference depends on the phase difference between two waves
➜ It is proportional to the path difference
➜ Constructive interference occurs when the difference is an integer value
➜ Constructive interference forms bright fringes
➜ The centre fringe has the highest intensity; it decreases further from the centre
➜ Destructive interference occurs when the difference is an integer plus half
➜ Destructive interference forms dark fringes
➜ They have zero intensity

MOJZA

Young's Double Slit Experiment

- ➜ Demonstrates how light waves form an interference pattern
- ➜ A light source is placed behind a single slit which diffracts it
- ➜ The diffracted light passes through a double slit
- ➜ The sources at each slit are coherent since they have the same primary source
- ➜ After passing through the double slit, the waves create an interference pattern
- ➜ Bright and dark fringes are seen on the screen
- ➜ fringe separation = wavelength x distance between slits and screen / slit separation
- ➜ $x = \lambda D/a$

Diffraction Grating

- ➜ It is a plate made up of a large number of slits
- ➜ When monochromatic light passes through it, a pattern of fringes is seen
- ➜ order of maxima x wavelength = distance between slits x sin θ(angle between maxima)
- ➜ $n\lambda = d\sin\theta$
- ➜ d = length of grating / no of lines
- ➜ $d = 1/N$
- ➜ The angle θ is from the centre
- ➜ The difference between angles of the two orders can be found by subtraction
- ➜ The maximum angle to see orders is 90
- ➜ The maximum order visible can be calculated by $n=d/\lambda$

Electricity

Current
- ➜ It is the flow of charges
- ➜ It is measured in Amperes
- ➜ In wires, current is the flow of electrons
- ➜ Negatively charged electrons flow from the negative terminal to the positive terminal
- ➜ Conventional current is the flow of positive charges from the positive to negative terminal
- ➜ Current is measured with an ammeter
- ➜ Ammeters are always connected in series
- ➜ Current can also be defined as the charge passing through a circuit per unit time
- ➜ $I = Q/t$

Quantisation of Charge
- ➜ Charge can be quantised
- ➜ It depends on the number of protons and electrons present
- ➜ The charge of an electron is -1.60×10^{-19} C
- ➜ The charge of a proton is 1.60×10^{-19} C
- ➜ This is known as the elementary charge
- ➜ It is represented by e

Drift Velocity
- ➜ In conductors, current is due to the movement of charge carriers
- ➜ Charge carriers can be negative or positive
- ➜ Current always has the same direction
- ➜ Charge carriers are free electrons in conductors
- ➜ Drift speed is the average speed of the charge carriers in the conductor
- ➜ Current = number density of charge carriers x Area x charge of each carrier x drift speed
- ➜ $I = nAqv$

Potential Difference
- ➜ The energy transferred per unit charge
- ➜ Energy is transferred from electrical energy to other forms
- ➜ It is also the work done per unit charge
- ➜ It is measured in Joules
- ➜ In a series circuit, the potential difference of the power supply is shared across all components
- ➜ In a parallel circuit, the potential difference across all branches is equal
- ➜ Potential difference is measured by a voltmeter
- ➜ The voltmeter is always connected in parallel to the component

➜ $V = W/Q$

Power

➜ Power is the rate of doing work
➜ $P = IV$
➜ or $P = I^2R$ or $P = V^2/R$

Resistance

➜ It is the opposition to current
➜ The higher the resistance, the lesser the current
➜ $R = V/I$
➜ It is measured in Ohms

Ohm's Law

➜ At constant temperature, the current is directly proportional to the potential difference
➜ $V = IR$
➜ The I-V graph of a conductor that obeys Ohm's law is a straight line through the origin
➜ The gradient represents the resistance

Filament Lamp

➜ Filament lamps do not obey Ohm's law
➜ As the current increases, the temperature of the filament increases
➜ Higher temperature results in higher resistance
➜ The higher resistance causes the current to decrease
➜ This produces a curved I-V graph bending towards the voltage

Resistivity

➜ All materials show some resistance to current
➜ Free electrons collide with ions while flowing through a wire
➜ This causes the transfer of kinetic energy and produces electrical heat
➜ Resistance is caused by the ions resisting the flow of charge
➜ Resistance depends on resistivity, length of wire, and cross sectional area
➜ $R = \rho L/A$
➜ The longer the wire, the greater the resistance
➜ The greater the area of the wire, the lesser the resistance

LDR

➜ The resistance of a light dependent resistor changes according to the intensity of light
➜ As the light intensity increases, the resistance decreases

Thermistor

➜ The resistance depends on the temperature
➜ As the temperature increases, the resistance decreases

DC Circuits

Electromotive Force

➜ It is the energy transformed from chemical to electrical energy per unit charge
➜ It is measured in Volts
➜ It is also the potential difference across a battery when no current is flowing

Internal Resistance

➜ All power supplies have resistance between their terminals, known as internal resistance
➜ It causes some electrical energy to dissipate from the power supply
➜ It causes a loss of voltage
➜ Terminal potential difference (V_R) is the voltage across the components of a circuit
➜ $V_R = IR$
➜ When current passes through the cell, voltage produces across the internal resistance
➜ The voltage is not available to the rest of the circuit and is known as lost volts (V_r)
➜ $V_r = Ir$
➜ $V_r = E - V_R$
➜ $E = IR + Ir$

Kirchhoff's First Law

➜ The sum of currents entering a junction is equal to the sum of currents leaving the junction
➜ This is due to the conservation of charge

Kirchhoff's Second Law

➜ The sum of e.m.f.s in a closed circuit is equal to the sum of potential differences across individual components
➜ This is due to the conservation of energy
➜ In series circuit, voltage splits across components depending on the resistance
➜ The total e.m.f. is equal to the sum of voltages
➜ In a parallel circuit, the voltage across each loop is same
➜ The sum of voltages in each closed loop is equal to the total e.m.f.

Resistors in Series

➜ In series circuist, the total resistance is the sum of all individual resistances
➜ The equation is derived through Kirchhoff's laws

$V = V_1 + V_2$

$IR = IR_1 + IR_2$

$\mathbf{R = R_1 + R_2}$ **...**

Resistors in Parallel

➜ In parallel circuits, the reciprocal of the total resistance is equal to the sum of the reciprocal of the individual resistances
➜ The equation is derived through Kirchhof's laws
$I = I_1 + I_2$
$V/R = V/R_1 + V/R_2$
$1/R = 1/R_1 = 1/R_2 \ldots$

For two resistors: $R = R_1R_2/(R_1+R_2)$

Potential Dividers

➜ Potential difference is divided across two resistors connected in series
➜ Potential dividers produce an output voltage as a fraction of the input voltage
➜ $V_{out} = \frac{R_2}{R_1+R_2}V_{in}$
➜ The V_{out} is measured across R_2
➜ The resistor with the larger resistance will have greater potential difference
➜ If a resistor's resistance is increased, it will get more potential difference and the other will get lesser
➜ Variable resistors such as LDRs and thermistors can be used to vary the output voltage

Potentiometer

➜ It is a variable resistor
➜ It is used in potential dividers to give variable output voltages
➜ The symbol has an arrow with the resistor
➜ It consists of a coil of wire with a sliding contact
➜ Moving the slider changes the length of the coil the current passes through and thus, the resistance

Galvanometer

➜ It is a sensitive instrument to detect electric current
➜ It is used in a potentiometer to measure the e.m.f. between two points
➜ It has an arrow/needle which deflects in the direction of the current
➜ If the arrow is facing upwards, there is no current, or null deflection
➜ According to Ohm's law, there will be no current when there is no voltage
➜ The potential difference across the galvanometer will be zero when the potential on both sides of it is equal
➜ This occurs when the position of the sliding contact produces a voltage equal to the e.m.f.
➜ The potential of the cell should oppose the e.m.f. in the circuit
➜ Positive terminals should be connected together
➜ The sliding contact is adjusted till the galvanometer gives null reading
➜ There is no current due to the opposing equal voltage and e.m.f.
➜ $V_1/L_1 = V_2/L_2$

Particle Physics

Rutherford Scattering

➜ The α-particle scattering experiment helped understand the structure of an atom
➜ Alpha particles are fired at a thin gold foil
➜ A detector is placed on the other end to record the deflection of particles
➜ Alpha particles are positively charged particles, similar to the nucleus of a helium atom
➜ In the experiment, majority of the α-particles went straight through the foil
➜ This shows that most of the atoms are empty space
➜ Some α-particles were deflected at small angles of less than 10°
➜ This shows there is a positively charged nucleus at the centre that deflected the positive particles
➜ Only a small number of particles were deflected back at angles greater than 90°
➜ This shows that the nucleus is very small
➜ The mass and charge of the atom is concentrated in the centre
➜ Hence, the experiment shows that atoms consist of small, dense, positively charged nuclei surrounded by negatively charged electrons

Atomic Structure

➜ Atoms are made up of protons, neutrons and electrons
➜ Protons have the charge +1, neutrons have 0 and electrons have -1
➜ Protons and neutrons have a mass of 1, while electrons have negligible mass
➜ A stable atom is neutral and has no charge
➜ A stable atom has equal protons and electrons to balance the charges

Antimatter

➜ All matter particles have antiparticle counterparts
➜ Antimatter particles are identical to matter counterparts except with opposite charge
➜ Other than electrons, antiparticles have same name with the 'anti-' prefix
➜ Neutral particles are their own antiparticle

Matter	Charge	Antimatter	Charge
Proton	+1	Antiproton	-1
Neutron	0	Anti-neutron	0
Electron	-1	Positron	+1

Atomic Mass Unit

➜ The unified atomic mass unit (u) is approximately equal to the mass of a proton or neutron
➜ $1u = 1.66 \times 10^{-27}$ kg
➜ It is equal to 1/12 of the mass of a carbon-12 atom
➜ The mass of an atom in a.m.u is roughly equal to its nucleon number

Isotopes

➜ Isotopes are atoms of the same element with the same number of protons but different number of neutrons
➜ The nucleon number or mass number is also different
➜ Due to the imbalance of protons and electrons, isotopes are unstable
➜ They decay and emit radiation to achieve a stable form
➜ It can take from a few nanoseconds to thousands of years

Conservation of Nucleon number and Charge

➜ In nuclear equations, the nucleon number and charge is always conserved
➜ The sum of nucleons and charge on the left side must equal the sum on the right side

Alpha Particles (α)

➜ Alpha particles are high energy particles
➜ They have 2 protons and 2 neutrons
➜ It is the same as a helium nucleus
➜ They are emitted by large, unstable nuclei with too many protons
➜ Can only travel a few centimetres in air
➜ Can be stopped by paper
➜ During α decay, the proton number decreases by 2 and the nucleon number decreases by 4

Beta Particles (β)

➜ Beta particles are high energy electrons
➜ They are emitted by nuclei with too many neutrons
➜ It is moderately ionising
➜ It has a charge of +1e
➜ It has moderate penetrating ability
➜ They have a range of 20cm - 3m in air
➜ They can be stopped by a few millimetres of aluminium foil
➜ β- decay occurs when a neutron turns into proton, emitting electron and anti-electron neutrino
➜ The proton number increases by 1
➜ β+ decay occurs when a proton turns into a neutron, emitting a positron and electron neutrino
➜ The proton number decreases by 1

Gamma Rays (γ)
➜ Gamma rays are high energy electromagnetic waves
➜ They are emitted by nuclei to lose energy
➜ They have a high ionising ability
➜ They can travel infinitely in air
➜ They can be reduced by a few centimetres of lead

Neutrino
➜ An electron neutrino is a type of subatomic particle
➜ It has no charge and has negligible mass
➜ It is also emitted from the nucleus
➜ Its antiparticle is an anti-neutrino
➜ Electron anti-neutrinos are emitted during β- decay
➜ Electron neutrinos are emitted during β+ decay

Energy of Alpha and Beta Decay
➜ On a graph of the number of α-particles against kinetic energy, there are clear spikes
➜ They have only certain energy values
➜ The graph for β particles produces a curve
➜ It has a range of energy values
➜ This is because energy is shared between beta particles and neutrinos
➜ This was one of first clues for the existence of neutrinos
➜ The principle of conservation of momentum and energy applies to the decay of alpha and beta particles

Fundamental Particles - Quarks
➜ Quarks are fundamental particles
➜ They make up other subatomic particles like protons and neutrons
➜ Protons and neutrons are hadrons
➜ Hadrons are any particles made up of quarks
➜ Fundamental particles are not made up of any other particles
➜ Quarks are only observed in pairs or groups of three
➜ There are six types/flavours of quarks
➜ Each flavour has a relative charge
➜ The charge of a hadron is the sum of the charges of its quarks
➜ Protons are made up of two up quarks and a down quark
➜ Neutrons are made up of one up quark and two down quarks
➜ Quarks have antiparticles known as anti-quarks
➜ They are identical except for having opposite charges

Quark	Charge	Anti-quark	Charge
Up	$+\frac{2}{3}$ e	Anti-up	$-\frac{2}{3}$ e
Down	$-\frac{1}{3}$ e	Anti-down	$+\frac{1}{3}$ e
Charm	$+\frac{2}{3}$ e	Anti-charm	$-\frac{2}{3}$ e
Strange	$-\frac{1}{3}$ e	Anti-strange	$+\frac{1}{3}$ e
Top	$+\frac{2}{3}$ e	Anti-top	$-\frac{2}{3}$ e
Bottom	$-\frac{1}{3}$ e	Anti-down	$+\frac{1}{3}$ e

Fundamental Particles - Leptons

➜ Leptons are a group of fundamental particles
➜ They are not made up of any other particles
➜ There are six leptons
➜ Electron, muon, tau, electron neutrino, muon neutrino, tau neutrino
➜ Muon and tau are similar to electrons, but with slightly larger masses
➜ Electrons, muon and tau all have +1e charge
➜ They have a mass of 0.0005u
➜ Neutrinos are the most abundant leptons
➜ They have no charge and negligible mass
➜ Leptons do not interact with the strong force
➜ They only interact weakly with electromagnetic and and gravitational forces

Baryons and Mesons

➜ Hadrons can be classified into baryons and mesons
➜ Baryons have three quarks
➜ Mesons have a quark and antiquark pair
➜ Anti-hadrons can be anti-baryons with 3 antiquarks or anti-mesons with a quark and antiquark pair
➜ All baryons have integer charges
➜ Baryons can not be a combination of quarks and antiquarks

Quark Composition

➜ β- decay occurs when a down quark turns into an up quark, converting a neutron into a proton

$$\mathbf{d} \rightarrow \mathbf{d} + \beta^- + \bar{\nu}_e$$

➜ β+ decay occurs when an up quark turns into a down quark, converting a proton into a neutron

$$\mathbf{u} \rightarrow \mathbf{d} + \beta^+ + \nu_e$$

A Note from Mojza

These notes for Physics (9072) have been prepared by Team Mojza, covering the content for AS Level 2022-24 syllabus. The content of these notes has been prepared with utmost care. We apologise for any issues overlooked; factual, grammatical or otherwise. We hope that you benefit from these and find them useful towards achieving your goals for your Cambridge examinations.

If you find any issues within these notes or have any feedback, please contact us at support@mojza.org.

Acknowledgements

Authors:
Hussain Ahmed Moghal

Proofreaders:
Hadiya Farrukh
Zoella Ahmad

Designers:
Hussain Ahmed Moghal