Chapter 1: Physical Quantities and Units

1. **Physical Quantity:** A quantity that comprises of a numerical magnitude and a unit.
2. **Base Quantities:** Quantities that are not defined in terms of other physical quantities
3. **Derived Quantities:** Derived from the product and quotient of base quantities
4. **Scalar quantities:** Quantities that have only magnitude but have no direction
5. **Vector quantities**: Quantities that have both magnitude and direction

Chapter 2: Measurement Techniques

1. **Systematic errors:** Errors of measurements which yield a consistent over-estimation or under-estimation of the true value
2. **Random errors:** Random errors result in a scatter of readings about a mean value.
3. **Precision:** Precision refers to the extent or limit of sensitivity of a given measuring instrument to obtain the readings of the physical quantity being measured. For example, a metre rule can be used to obtain length measurements with the precision of up to 0.1 cm, while a micrometer screw gauge has a precision of up to 0.001 cm. Obviously, a micrometer screw gauge is a more precise instrument compared to a metre rule. Precision can also refer to the degree of scattering of the data. If the differences between the readings taken are very small, the data can be said to be precise.
4. **Accuracy:** Accuracy refers to the value of a measured quantity. The higher the percentage uncertainty, the less accurate the data is. Accuracy can also be defined as how close the data obtained is to the actual value.

Chapter 3: Kinematics

1. **Distance:** Total length covered by a moving object irrespective of the direction of motion. Scalar quantity.
2. **Displacement:** Distance from a reference point in a specific direction. Vector quantity.
3. **Speed:** Total distance traveled per unit time. Scalar quantity
4. **Velocity:** Rate of change of displacement. Vector quantity
5. **Acceleration:** Rate of change of velocity.
6. **Weight of a body**= the gravitational force acting on a body. W=mg

Chapter 4: Dynamics

A. Newton's Law of Motion

1. **Newton's First Law**
   A body will remain in its state of rest or uniform motion in a straight line unless a net external force acts on it to change that state.

2. **Newton's Second Law**
   The rate of change of momentum of a body is directly proportional to the net force acting on it and takes place in the direction of the force.

$$F_{net}=(mv-mu)/t$$

Therefore, force can be defined as the rate of change of momentum.

3. **Newton's Third Law**
   When two bodies interact, they exert equal and opposite forces on 1 another

B. Mass and Inertia

1. **Inertia**
   The property of a body which resists changes to its state of motion.

2. **Mass**
   Mass is a measure of inertia where inertia is the property of a body which resists changes to its state of motion.

C. Differences between Mass and Weight

Mass	Weight
A measure of body's resistance, (i.e. inertia) to changes in motion	Gravitational force acting on a body / effect of gravitational field on a body
Its value is constant regardless where it is.	Its value varies with gravitational field it is located.
Scalar quantity.	Vector quantity.
Measured in kilogram (kg).	Measured in Newton (N).
Measured with top pan balance.	Measured with spring balance.

D. Momentum

1. **Momentum**
   The product of the mass of an object and its velocity.

2. **Principle of Conservation of Momentum**
   For any collision in an isolated system, the sum of the momentum before any event is equal to the sum of the momentum after the event provided no external resultant force acts on it.

E. Elastic & Inelastic Collision

Elastic Collision	Inelastic Collision
Relative speed of approach is equal to relative speed of separation.	Relative speed of approach is different from relative speed of separation.
Total Kinetic Energy is conserved.	Total Kinetic Energy is not conserved
Total momentum is conserved.	Total momentum is conserved.
Total energy of system is conserved	

Note:- For ***completely inelastic collision***, in addition to the points for inelastic collision, objects also stick together after collision.

Chapter 5: Forces

1. **Upthrust**
   It is a vertical upward force acting on a body immersed partially / wholly in a fluid due to difference in pressure of the fluid.

2. **Two conditions for Equilibrium**
   1. The sum of forces in any direction must be equal to zero.
   2. The sum of moments about any point must be equal to zero.

3. **Centre of Gravity**
   The point through which the whole weight of the body is considered to act.

4. **Moment of a Force**
   The product of the force and the perpendicular distance between the pivot and the line of action of the force.

Is joule(J) the unit for Moment?
Joule is the unit for energy which is the ability of doing work.
Though the dimension of Nm is equivalent to joule but Moment and energy are different by definition.
Therefore, one cannot use joule for Moment.

5. **Couple & Torque**
   a) Couple of forces
   - a pair of parallel forces
   - equal magnitude & opposite direction
   - separated by a distance
   - produce only turning effect.

   b) **Torque of a couple**: Product of one the forces and the perpendicular distance between them.

Chapter 6: Work, Energy & Power.

1. **Work**
   the product of the exerted force and the distance moved in the direction of the force.

2. **Power**
   Rate of doing work/ Rate of change of energy.

Law of Conservation Of Energy:
Energy can neither be created nor destroyed in any process. It can be transformed from one form to another and transferred from one body to another but the total amount remains constant.

Chapter 9: Phases of Matter

1. Density,ρ : The density of a substance is defined as its **mass per unit volume**

$\rho = m/v$ Unit – kgm^{-3} (SI) ; gcm^{-3}

2. Comparison of Characteristics of the 3 Phases of Matter :

	Solid	Liquid	Gas
Spacing of Particles	Close (Not for water)	Slightly Apart (Not for water)	Further apart Separated by empty space
Ordering of Particles	Long range order	Short range order/disorder	Disorder
Motion of Particles	Vibrational and Rotational	Restricted, translational motion	Free and random motion
Density	High	High	Low
Compressibility	Not compressible	Almost incompressible	Easily compressible
Volume and Shape	Fixed & Definite	Fixed volume, Assumes shape of container	Not fixed

3. Comparison between Evaporation and Boiling:

Evaporation	Boiling
Happens at any temperature	Occurs only at boiling point
Temperature may change	Temperature remains constant while boiling
Causes cooling of the liquid	Absorbs heat from the outside
Happens only at liquid surface	Takes place throughout liquid
Rate is influenced by temperature of liquid and concentration of vapour molecules near the surface	Begins when vapour pressure is equal to atmospheric pressure
Change of state from liquid to gas	

4. Crystalline and Non-Crystalline Solids :

A crystal is defined as a collection of atoms or molecules in which each atom is placed precisely in a definite pattern with respect to its neighbours.

Metal	Polymers	Amorphous
- All metals (except mercury) are crystalline solids. - Atoms arranged in regular pattern - Well defined planes - Basic repeating unit is unit cell - Structure has high and definite melting point - Eg : Copper	- Organic materials consisting of long chains of carbon bonded to hydrogen and other atoms. - Some are crystalline solids, some aren't. - Basic identical unit is the monomer. Eg : ethylene (monomer) forms polyethylene (polymer) - Eg Natural : protein, cellulose Eg Synthetic : Nylon, Polyethylene	- Non crystalline solids - Molecules not arrange orderly - No regular shape or well defined planes. - No definite melting point - Eg : Glass, Ceramic

Pressure, P : Pressure is defined as **Force acting normally per unit area**

$P = F/A$

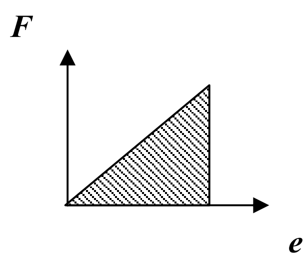
Unit – Nm^{-2} or Pascal

Chapter 10: Deformation of Solids

1. **Tensile force** causes an object to increase in length
2. **Compressive force** reduces the object in length.
3. **Hooke's Law**
   This law states that within the limit of proportionality, the extension produced in a material is directly proportional to the load applied.
4. **Tensile Stress**=force acting per unit cross-sectional area of a material. Is NOT pressure.
5. **Strain=**Ratio of the extension to the original length.
6. **Young Modulus, E (or stiffness or modulus of elasticity)** = Ratio of stress to strain

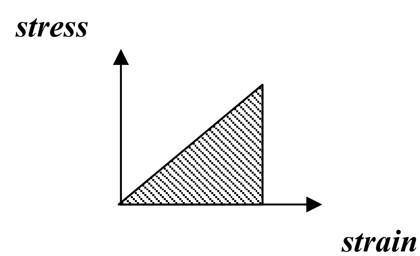
$$\textbf{E= stress/strain=} \frac{F/A}{\Delta l / l}$$

7. **Elastic deformation-** The material will return to its original shape and size once the deforming force is removed.
   All elastic potential energy is recovered when the force is removed.
8. **Plastic deformation-** The material suffers a permanent deformation once the deforming force is removed.
   NOT all elastic potential energy is recovered when the force is removed. Some is lost during loading process to permanently displace the molecules.
9. **Brittle material vs. ductile material?**
   Brittle material: Suffers little or no plastic deformation before fracture.
   Ductile material: Able to suffer permanent deformation before fracture.
10. **Proportionality limit vs. elastic limit?**
    Proportionality limit is lower in position than elastic limit in the graph of force-extension for a stretched material. Up to proportionality limit, the material still obeys Hooke' law, i.e. the extension is proportional to the force exerted. And it is elastic. After proportional limit, it is still elastic but no longer obeys Hooke's law. After elastic limit is exceeded, for ductile material it performs plastic deformation.
11. **Ultimate tensile stress =** the maximum stress (= F_{max}/area) a material can withstand before breaking.



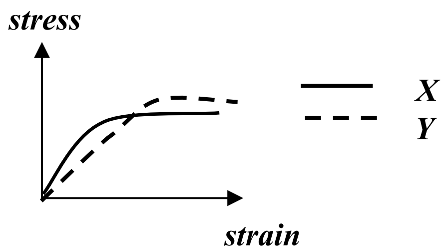
Gradient = F/e = spring constant k: force per unit extension

Area = strain energy/ elastic PE



Gradient = stress/ strain = young modulus : a measure of stiffness
The larger the gradient, the stiffer the material is.

Area = strain energy per unit volume



- Both materials have the same dimensions and break at the end of the graph.
- Y is stronger as the max stress it can withstand breaking is larger.
- X is stiffer as it's gradient, i.e. Young modulus= stress/ strain is larger

Chapter 15: Waves

1. **Progressive wave**
   A wave where the wave profile moves and energy is transmitted from one point to another.
2. **Displacement of particle, y**=instantaneous displacement of a particle from equilibrium position
3. **Amplitude, A**= Maximum displacement of a particle from equilibrium position.
4. **Wavelength, λ**= Shortest distance between two points that are in phase.
5. **Period, T**=Time taken for one complete oscillation.
6. **Frequency, f**= Number of complete oscillations per unit time.
7. **Speed, v**= distance traveled per second by its wave crests.
8. **Relationship between wave speed and wavelength, $v = f\lambda$**
9. **Intensity of a wave, I**= energy per unit time per unit area
   $\mathbf{I} = \dfrac{energy}{time \times area}$; unit Wm^{-2}
   Intensity I is proportional to square of amplitude but inversely proportional to the square of distance from source, r. $\mathbf{I \propto A^2}$ **and** $\mathbf{I \propto r^2}$

$$\frac{I_1}{I_2} = \frac{{A_1}^2}{{A_2}^2} = \frac{{r_2}^2}{{r_1}^2}$$

10.

Longitudinal wave	Transverse wave
waves where the direction of oscillation of particles is in the same direction as the direction of wave travel. E.g. sound wave	waves where the direction of oscillation of particles is at right angles to the direction of travel. E.g. EM waves.
Cannot be polarized.	Can be polarized.

11. Electromagnetic(EM) Spectrum:

Electromagnetic waves are joint electric and magnetic fields which travel through space without the need for a medium to carry them

- speed 3 x 10^8 ms^{-1} in vacuum

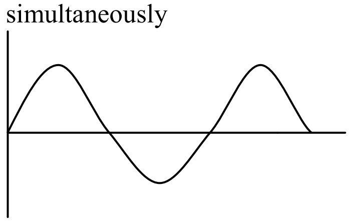
Range of wavelengths:

Radio: 10-10^3
Micro: 10^{-2}-10^{-4}
Infrared: 10^{-4}-10^{-7}
Visible light: 10^{-7} (400-700nm)
Ultraviolet: 10^{-7}-10^{-9}
X-rays: 10^{-8}-10^{-11}
Gamma: <10^{-9}

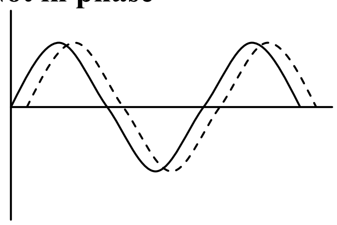
12. phase

a) In phase: -

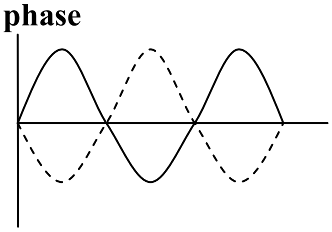
-reach max and min displacement simultaneously



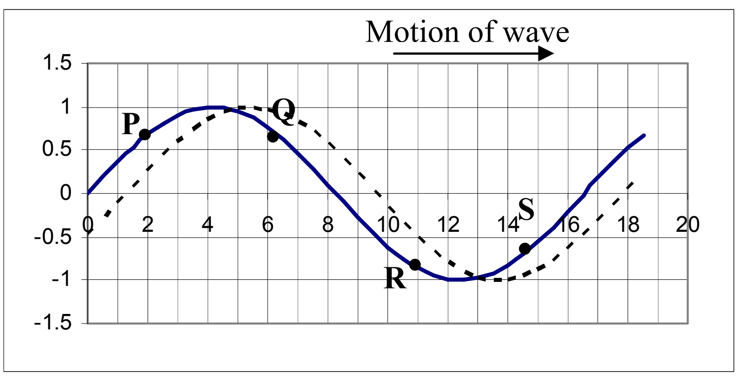
b) Not in phase



c) Antiphase/180 ^{o}out of phase



13. Movement and displacement of particles in the medium of wave propagation



	displacement	movement
P	upwards	downwards
Q	upwards	upwards
R	downwards	upwards
S	downwards	downwards

<u>Chapter 16: Superposition</u>

1. **Principle of Superposition**
   At a point where two or more waves meet, the instantaneous displacement is the vector sum of the individual displacements due to each wave at that point

2. **Stationary Wave**
   Wave where the wave profile does not move and energy is not transmitted from one point to another.

3. **Diffraction**
   When a wave passes through a small opening or blocked by an object, it will spread into the shadow regions.

Note: Max diffraction when size of gap = wavelength

4. Interference
When two or more waves simultaneously and independently travel through the same medium at the same time, their effects are superpositoned. The result of that superposition is called interference.

5. Constructive interference occurs when two waves superimpose in phase, their amplitudes reinforce each other, building a wave of maximum amplitude.

$\frac{\Delta x}{\lambda} = 1, 2, ..$

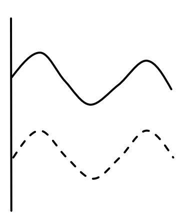
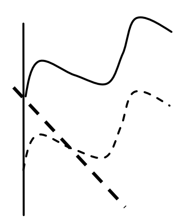
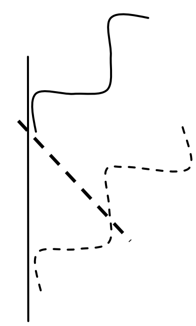
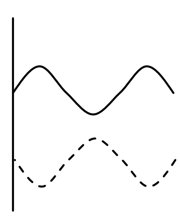
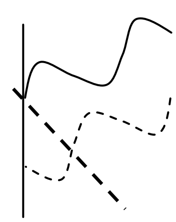
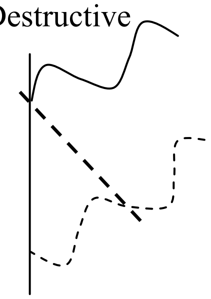
phase difference = 2π, 4π , 6π …

6. Destructive interference occurs when two waves of superimpose anti-phase, their amplitudes oppose each other, resulting in waves of zero or minimum amplitude.

$\frac{\Delta x}{\lambda} = ½ , 3/2, 5/2, …$

phase difference = π, 3π, 5π …

14. Wave generators S_1 and S_2 generate sinusoidal waves of equal frequency and amplitude

If S_1 and S_2 operate with	At a point where the path difference is		
	Zero, i.e. at the centre	$\lambda/2$	λ
zero phase difference	Constructive 	Destructive 	Constructive 
a phase difference of π radian	Destructive 	Constructive 	Destructive 

7. Two coherent sources
- Sources that have constant phase difference.

8. Conditions for interference to occur between two waves

- the waves must meet at a point
- they must be the same type of waves. e.g. EM waves
- they must be polarised in the same direction

9. Conditions for clear interference pattern

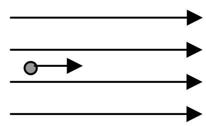
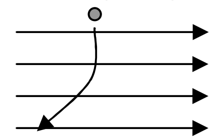
- The waves must be coherent
- The waves must have equal amplitudes.

10. progressive waves vs. stationary waves

	Progressive waves	***Stationary waves***
Energy	1. Energy is transferred along the direction of propagation.	1. Energy is confined in a region, i.e. between two nodes. It is not transferred along the direction of wave propagation.
Wave profile	2. Wave profile moves.	2. Wave profile doesn't move.
amplitude	3. Every point has the same amplitude.	3. Points between two nodes have different amplitude.
Displacement	4. Each point is displaced.	4. There are some points which always have zero displacement, i.e. known as nodes.
Phase	5. Neighbouring points are not vibrating in phase.	5. Points between two nodes are vibrating in phase. Points on either side of a node are in antiphase.

Chapter 17: Electric fields

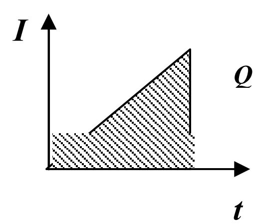
Electric field – A region where a charge experiences a force.
Electric field strength at a point is defined as the force per unit positive charge placed at the point.
$E = F/ Q$
E for uniform electric field $E = V/d$

<table>
<tr><th colspan="3">Two motions of charged particle in electric field:</th></tr>
<tr><td>a) charged particle moves in alignment with the electric field strength
Parallel to E
</td><td colspan="2">b) charged particle moves into a uniform electric field at right angles with u_x
At the right angles to E
</td></tr>
<tr><td colspan="3">- kinematics equations for linear constant acceleration are applied.
$$a = \frac{F}{m} = \frac{(EQ)}{m} = \left(\frac{V}{d}\right)\frac{Q}{m}$$</td></tr>
<tr><td>- it ‘ll be accelerated if it moves along the direction of E</td><td colspan="2">Projectile motion (parabolic path)</td></tr>
<tr><td>- it ‘ll be decelerated if it moves against the direction of E</td><td>Horizontal motion</td><td>Vertical motion</td></tr>
<tr><td rowspan="2"></td><td>$u_x = d/ t$</td><td>$S = ½ at^2$</td></tr>
<tr><td colspan="2">$S = ½ a(d/ u_x)^2$</td></tr>
</table>

Chapter 19 : Current of Electricity

1. Charge - Unit of charge is coulomb. One coulomb is the charge that flows past a point when a current of 1 ampere flows for one second.

Current – Rate of flow of charge



Q = area under graph

$Q = I \times t$

Charge = current x time

2. p.d. Vs. e.m.f.

Potential difference between two points	**e.m.f. of a source**
the amount of electrical energy changed to other forms of energy per unit charge flowing between them.	the amount of energy converted into electrical energy per unit charge passing through it
What is meant by a p.d. between two points of 12V? **12 J** of electrical energy is used to move one **coulomb** charge passes between the two points.	What is meant by an e.m.f. of a source of 12V? **12 J** of electrical energy is transferred by the source in driving one **coulomb** charge round a complete circuit.

3. Resistance –Ratio of the potential difference to the current.

Resistivity ρ of a material is defined by the equation $\rho = (RA) / L$, the resistance per unit length per unit cross-sectional area of the material.

Ohms' law= The current flowing in a metallic conductor is proportional to the potential difference applied across it, provided that the physical conditions (such as temperature, stress, etc) are constant

Chapter 20: D.C Circuits

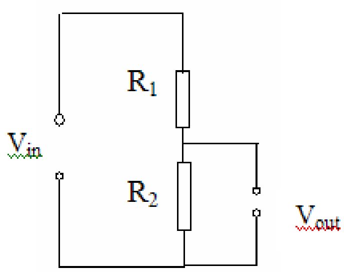
Kirchhoff's 1st Law:

- At a junction, the total current entering a junction is equal to the total current leaving the junction
- Conservation of charge

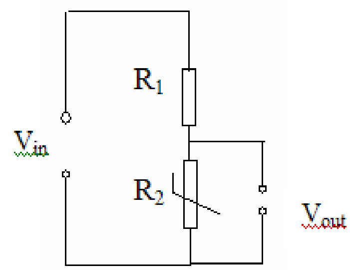
Kirchhoff's 2nd Law:

- The net e.m.f round a circuit loop is equal to the sum of the p.d.s around the loop.
- Conservation of energy

Potential Divider:



$V_{out}=[R_2/(R_1+R_2)]\ X\ V_{in}$

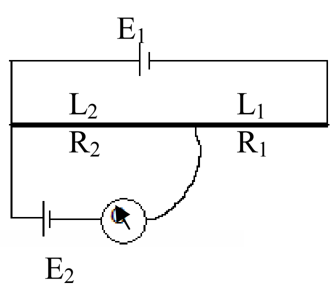


$V_{out}=[R_2/(R_1+R_2)]\ X\ V_{in}$
As T increases, R_2 decreases. Therefore, $[R_2/(R_1+R_2)]$ decreases.
Since V_{in} is a constant, V_{out} drops.

For light dependent resistor:
$V_{out}=[R_2/(R_1+R_2)]\ X\ V_{in}$
When no light, R_2 increases. Therefore, $[R_2/(R_1+R_2)]$ increases.
Since V_{in} is a constant, V_{out} increases.

For thermistor:

Potentiometer:



$V\ \alpha\ l$
When galvanometer shows zero,
E_2/ E_1
$=L_2 / (L_1+L_2)$
$= R_2 / (R_1+R_2)$
- Any resistance connected in series with E_2 will not affect the measurement.
- Resistance connected in series with E_1 will affect the measurement. Longer wire is needed to balance the same E_2.

Chapter 27: Nuclear Physics

Isotopes:

- Isotopes are atoms with the same proton number but with different nucleon number
-may have slight differences in physical and nuclear properties but have identical chemical properties

Radioactive Decay:

-a process in which an unstable nucleus disintegrates into a more stable nucleus with the emission of alpha, beta and gamma radiation and releasing energy.
-rate of decay is measured using Geiger-Muller tube with ratemeter.
-a *spontaneous* and *random* process
a) Spontaneous: Decay of atom is independent of **physical conditions**, e.g. temperature, pressure.
b) Random: Impossible to predict when an individual nucleus will decay or Constant probability that an individual nucleus will decay per unit time interval.

Particles	Alpha	Beta	Gamma
Nature	High-speed particles Helium nucleus Positive charge +2	High-speed electron About1/1850 mass of a proton Negative charge -1	Electromagnetic radiation of shorter wavelength No mass No charge
Ionising power	Highest ionising power due to its large mass	Reasonable ionising power. Weaker than Alpha	Weakest ionising power
Penetration power	Lowest penetration power. 5-6 cm of air or 10^2 mm Al	Reasonable penetration power. A few mm of Al	Extremely high penetration power. 10 m concrete
Motion in magnetic and electric fields	Deflected slightly	Large deflection because of small mass	No deflection

Show the derivations for the following formulas:

a) $v = u + at$, $v^2 = u^2 + 2as$,
$s = ut + (1/2)at^2$
b) $KE = ½ mv^2$
c) $GPE = mgh$
d) Power, $P = Fv$
e) Upthrust, $U = m_f g = \rho_f V_f g$
f) Pressure, $p = \rho hg$
g) Resistors in series and parallel