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MISCELLANEOUS

1. TYPES OF QUESTIONS

1.1 Part A (Classification)

- A set of choices is provided and the next few questions refer to those choices.
- Each choice may be used once, more than once or not at all in each set.

1.2 Part B (5 Choice Completion)

- **Type 1:** may not always look for correct option.
- **Type 2:** are multiple Roman numeral combinations.
- **Type 3:** present experimental data.

2. PROBLEM SOLVING

- **Clarify:** by separating problem into facts, conditions and requirement.
- **Organize:** information and apply yourself.
- **Select a strategy:** plugging in, elimination, trial-and-error, knowledge, etc.
- **Solve:** using strategy & review.

3. MATH SKILLS

3.1 Exponents

$a^0 = 1$	$(a^x)(a^y) = a^{x+y}$	$(ab)^x = a^x b^x$
$a^1 = a$	$a^x/a^y = a^{x-y}$	$(a^x b^y)^z = a^{xz} b^{yz}$
$a^{-x} = 1/a^x$	$(a^x)^y = a^{xy}$	$\sqrt[y]{a^x} = a^{x/y}$

- Powers of ten, (sometimes replaced by prefixes) are used in scientific notation.

POWER OF TEN	PREFIX	SYMBOL
-12	Pico	p
-9	Nano	n
-6	Micro	μ
-3	Mili	m
-2	Centi	c
-1	Deci	d
1	Deca	D
2	Hecto	H
3	Kilo	k
6	Mega	M
9	Giga	G
12	Tera	T

BASE QUANTITY	BASE UNIT	SYMBOL
LENGTH	Meter	m
MASS	Kilogram	kg
TIME	Second	s
TEMPERATURE	Kelvin	K
AMOUNT OF TIME	Mole	mol
ELECTRIC CURRENT	Ampere	A
LUMINOUS INTENSITY	Candela	C

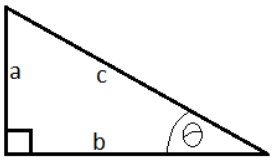
- All other units are derived from SI base units of the metric system.

3.2 Graphing

- **Linear graphs:** occur when 2 quantities are proportional to each other. Where m = gradient & c = y – intercept;
- $y = mx + c$, i.e. $y - y_1 = \{(y_2 - y_1)/(x_2 - x_1)\}(x - x_1)$.
- **Area under a curve:** equals the product of the quantities on the 2 axes and come in the form of triangle [bh/2], rectangle [bh] & trapezium $[(h/2)(b_1 + b_2)]$.
- **Parabolic graphs:** result when one quantity is proportional to the square of the other, e.g. when $s = gt^2/2$, the s-t graph forms an inverted parabola; while the $s\text{-}t^2$ graph is a straight line through the origin with gradient g/2.

3.3 Trigonometry

Sin θ = a/c
Cos θ = b/c
Tan θ = sin θ/cos θ = a/b
$c^2 = a^2 + b^2$



θ	0	30	45	60	90
SIN	√0/2	√1/2	√2/2	√3/2	√4/2
COS	√4/2	√3/2	√2/2	√1/2	√0/2
TAN	0	1/√3	1	√3	∞

3.4 Scalars & Vectors

- A **scalar**, e.g. mass, has only magnitude, while a **vector**, e.g. force, also has direction.
- Vectors can be added from tip-to-tail or separated into perpendicular components using trigonometry and then added to find resultant.

MECHANICS

1. KINEMATIC

1.1 SUVAT

	DIST. (D)	SPEED (SP)	DISP. (S)	VELOCITY (V)	ACC. (A)
TYPE OF QTY	Scalar	Scalar	Vector	Vector	Vector
DEFN.	Length moved	Rate of Δd	Change in posn.	Rate of Δs	Rate of Δv
GRAD. OF GRAPH	N/A	d-t	N/A	s-t	v-t
AREA BELOW GRAPH	sp-t	a-t	v-t	a-t	N/A

- At constant acceleration;

$$v = \frac{s}{t} \text{ or } sp = \frac{d}{t}$$
$$v^2 = u^2 + 2as$$
$$s = ut + \frac{at^2}{2}$$

$$s = \left(\frac{t}{2}\right)(u + v)$$
$$v = u + at$$
$$s = vt - \frac{at^2}{2}$$

1.2 Projectile Motion

- It is 2D; but, movement along each axis is independent of each other.
- Air resistance is negligible.
- Trigonometry must be applied.
- At x-axis: $a = 0$ & at y-axis $a = g = 10$ (freefall)
- Range:

$$x_{max} = \frac{u^2 \sin 2\theta}{g}$$

- Trajectory:

$$y = x \tan\theta - \frac{gx^2}{2u^2 \cos^2\theta}$$

- Max. height:

$$y_{max} = \frac{u^2 \sin^2\theta}{2g}$$

2. DYNAMICS

2.1 Newton's laws of motion

1. Every system will continue at its state of rest or uniform velocity unless acted upon by a resultant force.
2. Rate of change of momentum is directly proportional to the resultant force on a body in the direction of force.
3. To every action there is an equal yet opposite reaction.

2.2 Basic Applications

- 2nd law can be written as F = ma
- W=mg, so weight is gravitational force pulling an object to another.
- **Tension (T)** from spring/string and **Reaction force (R)** from a surface includes common reactions to weight.
- **Friction** is a resistive force that opposes motion and occurs between 2 surfaces that rub each other. It is of **2** types: **Static** & **dynamic**. Static friction is larger.

  $f \propto R$; $f = \mu R$, where μ is co-efficient of friction
- Applying trigonometry and drawing free body force diagrams are essential as questions include pulleys, inclined planes, etc.

3. MOMENTUM & IMPULSE

3.1 Momentum

- It is product of an object's mass and velocity; It is a vector;

$$p = mv$$

3.2 Impulse

- This vector quantity is defined as the product of force acting and the time for which it acts. It is equal to change in momentum.

$$F = ma = \left(\frac{m}{t}\right)(v - u) \therefore I = Ft = mv - mu$$

3.3 Conservation of Linear Momentum

- From Newton's laws of motion it can be derived that momentum before and after collision/explosion are equal.
- There are 2 types of collisions: **elastic** and **inelastic**.
- Relative velocity of approach and separation are equal in elastic collisions, so kinetic energy is conserved. Converse is true for inelastic collisions.

4. WORK & ENERGY

4.1 Work

- It is defined as the scalar product of force and displacement;

$$W = Fs\cos\theta$$

4.2 Power

- It is defined as the rate of doing work;

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

4.3 Energy

- **Energy:** is the ability to do work. It can neither be created nor be destroyed. It can only be converted from one form to another.
- **Work done = Energy converted**
- **Potential energy:** is possessed by a system due to its position (**gravitational** = mgh) or configuration (**elastic** = $Fx/2$ or $kx^2/2$).
- **Kinetic energy** ($mv^2/2$): is possessed by a system due to its motion.

5. Circular Motion & Rotation

5.1 Uniform Circular Motion

- **Centripetal force:** is the center seeking force that causes an object to follow a circular path.
- **Centrifugal force:** is the non-existent force caused by the center-fleeing perception of inertia.
- **Period (T):** is time taken for one revolution.
- **Frequency (f):** is rate of revolutions.
- **Angular velocity (ω):** is rate of change of **angular displacement (θ)**.

$f = 1/T$	$\omega = \theta/t = 2\pi r/T = 2\pi rf$
$v = r\omega$	$F = ma = mv^2/r = mr\omega^2$

5.2 Moment and Angular Momentum

- **Moment** is the turning effect of a force. It is the product of force and its perpendicular distance from pivot; $\tau = Fd$
- Since at equilibrium, resultant moment must be zero, clockwise and anti-clockwise moments must be equal.
- **Angular momentum** ($L = mvr$) of an object in uniform circular motion is also conserved

6. Vibrations

6.1 Hooke's Law

- It states that change in length of spring is directly proportional to the force applied on it. $F \propto x \therefore F = kx$, where k is stiffness constant.

6.2 Harmonic Motion

- An object is moving with **harmonic/vibrational motion** if it follows a repeated path at constant time intervals.
- **Amplitude (A)** of oscillations is maximum displacement from **equilibrium** (mean) position.
- **Restoring force** always acts towards equilibrium,

$$\therefore a \propto -x$$

Total energy of system = GPE + KE + EPE = constant

STATE	VELOCITY	ACCELERATION AND FORCE
EQUILIBRIUM	Maximum	Nil
EXTREMES	Nil	Maximum

7. Gravity

7.1 Newton's Law of Universal Gravitation

- $F = GMm/r^2 \therefore g = GM/r^2$, where $G = 6.67 \times 10^{-11} Nm^2kg^{-2}$

7.2 Summing up

QUANTITY	CHANGE	EXPLANATION
RADIUS	Increases	Initial change
GRAVITATIONAL FORCE	Decreases	Inverse square law
SPEED	Decreases	r↑ & F↓
ANGULAR MOMENTUM	Constant	Conservation of angular momentum
K.E.	Decreases	v↓
G.P.E.	Increases	r↑ > g↓
TOTAL ENERGY	Constant	Conservation of energy

Electricity & Magnetism

1. Electric Fields Forces & Potentials

1.1 Charge

- **The electron** is the fundamental carrier of charge (of $-1.6 \times 10^{-19}C$). 1 Coulomb is 1.6×10^{18} electrons.
- **Conductors** (e.g. metals) have mobile valence electrons to carry charge, but **insulators** (e.g. wood) don't.
- Negative charge is an excess of electrons and positive charge is a lack of them.
- **The nucleus** consists of positively charged **protons** and uncharged **neutrons**.
- Charge is conserved during any process.

- **Law of charges:** Like charges repel and unlike charges attract.
- **Conduction:** is the transfer of charge by direct contact.
- **Induction:** is the charging of a neutral object due to the proximity of a charged object.
- **Coulomb's law:** $F = Kq_1q_2/r^2$, where $K = 9 \times 10^9\ Nm^2C^{-2}$

1.2 Electric Field

- It is the force per unit charge experienced by a positive charge in a region of space. PD/EMF is work done per unit charge.

$$E = F/q \ \& \ V = W/q = Fd/q,\ V/d = F/q \therefore E = V/d$$

2. Circuits

2.1 IVRP

- **Current:** is the rate of flow of positive charge; $I = q/t$
- **Resistance:** is the opposition to flow of current.
- **Ohm's law** states that: $V \propto I$ at constant temperature. $\therefore R = V/I$

$$P = W/t = Vq/t = IV = I^2R = V^2/R$$

2.2 Resistors & Capacitors

- **Capacitors** store charge in electric fields for later reuse.
- **Capacitance** is charge per unit voltage. Its value depends on geometry plates of capacitors. $C \propto A/d$, $C = q/V$.

Series circuit: is one where same current passes through each component.	**Parallel circuit:** is one where same PD passes through each component.
$V_T = V_1 + V_2$	$I_T = I_1 + I_2$ .....
$R_T = R_1 + R_2$	$1/R_T = 1/R_1 + 1/R_2$ .....
$1/C_T = 1/C_1 + 1/C_2$	$C_T = C_1 + C_2$ .....

3. Magnetic Fields & Forces

3.1 Magnetism

- **Magnetic fields:** are regions of space where the N-pole of a magnet experiences a force.
- **Domain:** is the cluster of atoms aligned magnetically by a strong external magnetic field during **magnetization**.
- Moving charges produce magnetic fields.
- **Right hand thumb rule:** Thumb for conventional current and other fingers for magnetic field.
- Current carrying wire in an external magnetic field experiences a force, where $F = BILsin\theta = qvBsin\theta$
- **Fleming's left hand rule: T**humb-**T**hrust, **F**irst finger-**F**ield & se**C**ond finger-**C**urrent.
- A charge moving across a magnetic field feels a centripetal force, where $F = qvB = mv^2/r$, $\therefore r = mv/qB$

3.2 Electromagnetic Induction

- It is the generation of current through a conductor as it cuts through magnetic fields. (Use Fleming's right-hand rule)

Waves

1. General Wave Properties

1.1 Basic Properties

- **Waves:** transfer energy by vibrations.
- **Mechanical waves** need media while **electromagnetic** ones don't.
- **Transverse waves** vibrate perpendicularly to propagation while **longitudinal** ones vibrate parallel.
- They possess **crests** and **troughs** or **compressions** and **rarefactions** respectively.
- **Wavelength**: is length of one complete oscillation.
- Speed of sound ≈ 340 m/s; (faster in denser media)
- $V = f\lambda = \lambda/T$
- **Doppler Effect** is the apparent and proportional change in frequency and wavelength owing to the relative motion between source and observer.
- $f_o = f_sv/(v \pm v_s)$

2. Geometric Optics

2.1 Reflection

- It is the bouncing of a wave from a barrier.
- **Law of reflection: Incident angle = Reflected angle**; as measured from normal (line perpendicular to barrier)

2.2 Refraction

- It is the change in direction, speed & wavelength as wave switches medium.
- **Snell's law:** $n_2/n_1 = sin\theta_2/sin\theta_1 = v_2/v_1 = \lambda_2/\lambda_1$, where n is refraction index & n of vacuum is 1.

- **Critical angle** is incident angle in denser medium for which refracted angle > 90^0, so beyond it **Total internal reflection** occurs.

2.3 Electromagnetic Waves

- These are vibrations of electric and magnetic fields through space at 3×10^8 m/s.

RADIATION	WAVELENGTH IN 10^x M
Γ	-14 to -12
X	-12 to -10
UV	-10 to -8
IR	-6 to -4
μ	-4 to -2
RADIO	-2 to 0

- Visible light: 400nm to 700nm as VBGYOR in 50nm blocks.
- White light is dispersed into a spectrum by a prism as lower wavelength light is refracted more.

3. PHYSICAL OPTICS

3.1 Diffraction & Interference

- Transverse waves are **polarized** when they vibrate in one plane.
- **Diffraction** is the spreading of a wave into a geometric shadow as it passes through an aperture.
- **Principle of superposition states that**: when waves **interfere**, (meet at same point in space) their resultant displacement is sum of their individual displacements.
- In phase, **constructive interference** (positive superposition) occurs.
- Out of phase, **destructive interference** (negative superposition) occurs.
- **Stationary waves**: occur due to interference of 2 **coherent**, (constant phase relation) progressive waves of same amplitude, travelling along same line in opposite direction, creating a series of **nodes** (zero amplitude) and **antinodes** (maximum amplitude).

3.2 Interference Patterns

- These are sustainable and observable if source(s) are monochromatic, polarized & coherent;
- **Width of central maxima ∝ wavelength.**

Single-slits: produce a series of maxima which dim towards screen edges.	**Young's double slits:** produce a series of alternating minima and maxima.
$a \sin\theta = n\lambda$	$ax = D\lambda$

4. RAY OPTICS

4.1 Mirrors (Reflectors) & Lenses (Refractrors)

TYPE	MIRRORS	LENS
CONCAVE	Converging	Diverging
CONVEX	Diverging	Converging

- **Focal length:** is distance from mirror/lens center to focal point of rays. It is equal to half of radius of curvature.

d_o	Image characteristics			
	Reality	Alignment	Size	d_i
Converging mirrors/lens				
> 2f	Real	Inverted	Smaller	f to 2f
2f	Real	Inverted	Same size	2f
f to 2f	Real	Inverted	Larger	> 2f
f	No image			
< f	Virtual	Erect	Larger	$< -d_o$
Diverging mirrors/lens				
Any	Virtual	Erect	Smaller	$> -d_o$

- Plane mirrors form virtual, erect, same size laterally reversed images where $d_i = d_o$

4.2 Calculations

$M = d_i/d_o = l_i/l_o \quad f = r/2 = d_i d_o/(d_i + d_o)$

THERMAL PHYSICS

1. HEAT, TEMPERATURE & THERMODYNAMICS

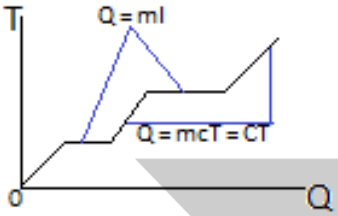
1.1 Heat & Temperature

- **Internal energy (U)** of a substance is sum of its **KE (due to its mass & motion)** and **PE (due to bonds).**
- **Heat** is the KE transferred from warmer substances to colder ones, by:
  - **Conduction** (Actual contact)
  - **Convection** (Bulk fluid movement)
  - **Radiation** (Electromagnetic infra-red wave)
- **Temperature** is a measure of mean KE of molecules. ($K = C^o + 273$)
- Solids undergo linear and volume thermal expansion, proportional to change in temperature.
- Change in length/volume = Co-efficient of expansion × Original length/volume × Change in temperature

1.2 Phase Changes & Calculations

- **Heat (Q)** raises KE and thus temperature, while **latent heat (L)** increase PE changing state.

PHASE	TO GAS	TO LIQUID	TO SOLID
FROM GAS	--------	Condensation	Deposition
FROM LIQUID	Boiling	---------	Freezing
FROM SOLID	Sublimation	Melting	---------



1.3 Thermodynamics

- It is the study of heat transfer, in 3 systems: isolated, closed and open.
- 1st law: $U = Q \pm W$
- 2nd law: Spontaneous processes raise **entropy** (disorder)
- % efficiency = $W/Q \times 100\%$

2. Gases & Kinetic Theory

2.1 Assumptions

- Molecules have:
- Negligible volume
- No intermolecular forces
- Continuous random motion
- Temperature $\propto$ KE & v^2

$\therefore$ Gases are ideal at low pressure and high temperature

2.2 Laws

LAW	FORMULAE
BOYLE'S	$P \propto 1/V$; $P_1V_1 = P_2V_2$
GUY LUSSAC'S	$P \propto T$; $P_1/T_1 = P_2/T_2$
CHARLES	$V \propto T$; $V_1/T_1 = V_2/T_2$
COMBINED GAS	$P_1V_1/T_1 = P_2V_2/T_2$
IDEAL GAS	$PV = nRT$

Modern Physics

1. Quantum Phenomena

1.1 Photons & Photoelectric Effect

- **Quantum** is the smallest particle of a quantity and quantized values occur in multiples of quanta.
- The **photon** is the quantum of light.
- $E = hf = hc/\lambda$; h (Max Planck's constant) = 6.63×10^{-34} J.
- The **photoelectric effect** results when light (photons) shined on a metal gives electrons enough KE to escape its surface.
- The minimum frequency at which this occurs is the **threshold frequency**.

1.2 Momentum of a Photon & Heisenberg Uncertainty Principle

$$p = h/\lambda$$

- **Werner Heisenberg's uncertainty principle states that** we can't simultaneously measure **position, speed or momentum** of a subatomic particle with complete accuracy. This is because even the smallest measuring device we have, **the photon**, has enough **momentum** to deviate subatomic particles.

1.3 Matter, Waves & the de Broglie Wavelength

- Subatomic particles also behave like waves and their $\lambda = h/p = h/mv$

2. Atomic Physics

2.1 Rutherford's Model of the Atom

- Rutherford corrected Thompson's '**plum pudding**' model of the atom (electrons floating in positive fluid), by his **alpha scattering** experiment, forming the '**planetary model**'.
  - Most particles passed through gold foil, so atom is mostly **empty space**.
  - Some of them were deflected by >90°, so there must be a dense positively charged core (**nucleus**) to repel them.

2.2 Bohr's Model of the Atom

- It placed electrons in **quantized** orbits around nucleus.
- **Electron energy levels** are placed in **electron-volts**.
- The lowest energy (in the orbit nearest to the nucleus) is called the **ground state**, and any above is **excited state**.

- When an electron absorbs/releases exactly enough energy, it jumps/drops to the higher/lower energy level.
- The energy exchange is in the form of **light (photons)**.

3. Nuclear and Particle Physics

3.1 Nuclear Structure

- Subscript is the number of protons **(Atomic no.)**; Superscript is the mass number of protons and neutrons **(Nucleon no.)**.
- **Isotopes** are atoms with same number atomic number, but different mass number.

PARTICLE	A_R	Q_R	LOCATION
PROTON	1	+1	Nucleus
NEUTRON	1	0	Nucleus
ELECTRON	1/1840	-1	Orbitals

3.2 Nuclear Binding Energy

- Mass is converted into **nuclear binding energy** to hold the nucleus together by **strong nuclear force** to overcome electrostatic repulsion between protons. ($E = mc^2$)
- Neutrons are composed of a proton and an electron, thus are neutral and able to dissipate some electrostatic repulsion between protons.

3.3 Radioactive Decay

- It is the random, spontaneous emission of particles/waves from nuclei to lose energy and become stable.
- Parent nuclide undergoes **radioactive transmutation** by α/β emission to form daughter nuclide.
- **Half-life** is the time taken for half atoms in a radioactive sample to decay on count rate to halven, following an exponential decay curve.
- **Fusion** is the combining of small nuclei into larger ones, emitting energy.
- **Fission** is the splitting of larger nuclei into smaller ones via bombardment by slow neutrons, releasing more neutrons and energy, initiating a chain reaction.

PROPERTY	α- PARTICLE	β-PARTICLE	γ-RADIATION
MASS	4	1/1840	0
CHARGE	+2	±1	0
NATURE	Helium nucleus (2p+2n)	Electron or positron	Short wavelength EM wave
SPEED	0.1c	>0.9c	c
PENETRATION	Few cm air	Few mm Al	Few cm PB
EM FIELD EFFECT	Little	Most	None
FORMATION	Nuclei Break-off	Breakup of p/n	Excess energy

4. Special Relativity

- All **inertial frames** (reference frame with constant velocity) are equal.
- The speed of light is constant for all observers.
- An observer watching an object moving at close to speed of light will see its:
  - length contracted in direction of motion.
  - clock slow down, i.e, **time dilation** occurs**.**
  - mass increase by equation $E = mc^2$.