Model Question Physics – 3

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Group – A

Give answers to the following questions either in **one word** or **one sentence.** (Alternatives are to be noted): 1 x 10 = 10

1.(a) 'A progressive wave carries energy in a plane perpendicular to the plane of wave front' — is the statement true ? 1

Ans: The statement is not true.

(b) Beats will be audible if the difference in frequencies of two superposing waves is not greater than ______________**.** 1

Ans: Beats will be audible if the difference in frequencies of two superposing waves is not greater than __15__ **.**

(c) The value of potential inside a hollow spherical conductor is ___________**.** 1

Ans: The value of potential inside a hollow spherical conductor is $\underline{\dfrac{Q}{4\pi \in_o R}}$,

R= radius of the conductor.

(d) Can it be possible to accelerate a neutron in a cyclotron accelerator ? 1

Ans. It is not possible to accelerate a neutron in cyclotron accelerator.

(e) Comment whether P–type semiconductor is positively charged or not ? 1

Ans. P–type semiconductor is not charged.

(f) Give an example where electron ejects photon. 1

Ans. In X–ray production electron ejects photon.

Group – B

2. (a) Why centrifugal force is termed as pseudo force ? 2

Ans. There is no existence of centrifugal force in an inertial frame of reference. The source of this force in a noninertial frame, cannot be find out. It appears not due to action–reaction like seal force. So it is termed as pseudo force.

(b) Degree of freedom of molecules of a gas is 5. Find the value of C_p / C_v 2

Ans. We know $\dfrac{C_p}{C_v} = \gamma$ and $\gamma = 1 + \dfrac{2}{f}$.

In this case f = degrees freedom = 5

$$\therefore \gamma = 1 + \frac{2}{5} = \frac{7}{5}$$

$$\therefore \frac{C_p}{C_v} = \gamma = \frac{7}{5}$$

(c) At equal temperature does r.m.s velocity of the molecules of Hydrogen and Oxygen will be same ? Give reason . 2

Ans. At equal temperature r.m.s. velocity of the molecules of Hydrogen and Oxygen will not be same. Because for Hydrogen

$(Cr.m.S)_{H_2} = \sqrt{\frac{3RT}{MH_2}}$ and for Oxygen

$(Cr.m.S)_{O_2} = \sqrt{\frac{3RT}{MO_2}}$. Since $MO_2 > MH_2$,

so $(Cr.m.S)_{O_2} < (Cr.m.S)_{H_2}$ i.e. r.m.s. velocity of Oxygen will be less than the r.m.s. velocity of Hydrogen.

(d) An electron when projected from rest through a potential difference of 60,000 v attains a velocity of 1,46 x 10^{10} cm/s. Find the ratio of charge and mass of electron. 2

Ans. Here v = velocity attained by the electron

= 1,46 x 10^{6} cm/s

= 1,46 x 10^{8} m/s

V = Potential difference through which the electron is allowed to move.

= 60,000 volt

m = mass of the electron is S.I.

e = charge of the electron in S.I.

So, $\frac{1}{2}mv^2 = ev$

Or, $\frac{e}{m} = \frac{v^2}{2V} = \frac{(146 \times 10^8)^2}{2 \times 60{,}000} = \frac{146 \times 146 \times 10^{16}}{12 \times 10^4}$ = 1776. 33 x 10^{8} coul/kg.

(e) A metal shows photoelectric effect in green light. Will it show photoelectric effect in violet light. Give reason to your answer. 2

Ans. Yes, the metal will show photo–electric effect in violet light also, because $\nu_v > \nu_G$ and hence $E_v > E_G$, where F = energy of E.M. radiation

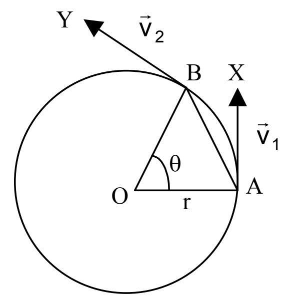
= h ν,

Group – C

3. a) What do you mean by centripetal acc^n ? Obtain the expression for centripetal acc^n of a point particle moving uniformly in a circular path. 1 + 3

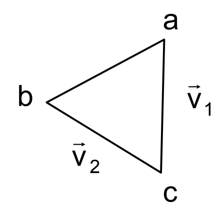
Ans. If a body moves in uniform circular motion, then the body has an acceleration towards the centre of the circle due to change of direction of it's velocity with time. This acceleration is called centripetal acceleration.

Consider a particle of mass 'm' moving along a circle of radius 'r' with uniform angular velocity 'w'. Let $\vec{v}_1$ and $\vec{v}_2$ be the instantaneous linear velocities of the particle at A and B respectively in a time interval Δt. Since angular velocity is constant, the magnitude of $\vec{v}_1$ and $\vec{v}_2$ be same. Therefore the particle's velocity changes due to change in direction only. Take a point c. Draw ca parallel to AX and cb parallel to BY.



Now $|\vec{v}_1| = |\vec{v}_2| = v$

i.e. ca = cb.



It is cleared that $\overrightarrow{ab} = \overrightarrow{\Delta v}$ = change of velocity $= \vec{v}_2 - \vec{v}_1$.

$\therefore$ The centripetal acceleration = $\frac{\Delta \vec{v}}{\Delta t} = \frac{\overrightarrow{ab}}{\Delta t}$.

If Δt is small then θ will also be small. Then the hard AB will be nearly equal to the arc AB. The ΔAOB and Δacb are similar.

$$\therefore \frac{ab}{AB} = \frac{ca}{OA}.$$

Or, $\frac{ab}{v\Delta t} = \frac{v}{r}$, because AB = v Δt ; ca = v; OA = r

Or, $\frac{ab}{\Delta t} = \frac{v^2}{r}$

Hence the acceleration,

$\vec{a} = \frac{\overrightarrow{ab}}{\Delta t} = \hat{n}\frac{v^2}{r}$, where $\hat{n}$ is the unit vector directed towards the centre.

So the acceleration is termed as centripetal acceleration.

b) An artificial satellite is moving in a circular orbit around the earth with a speed equal to the half of the magnitude of the escape velocity from the earth.

i) Determination the height of the satellite above the Earth surface.

ii) If the satellite is stopped suddenly in its orbit and allowed to fall freely on the earth, then determine the speed with which it hits the earth's surface. 2 + 2

Ans. Let the velocity of the artificial satellite be v, then $v = \sqrt{\frac{GM}{Rth}}$

Where M = Mass of the earth

R = Radius of the earth

h = Height of the artificial satellite from the surface of the earth.

Let v_e is the escape velocity then

$$v_e = \sqrt{\frac{2GM}{R}}$$

According to condition,

$$v = \frac{v_e}{2}$$

(i) Now, $v = \frac{v_e}{2}$

or, $\sqrt{\frac{GM}{Rth}} = \frac{1}{2}\sqrt{\frac{2GM}{R}}$

or, $\frac{GM}{Rth} = \frac{1}{4} \times \frac{2GM}{R}$

or, Rth = 2R

$\therefore \boxed{h = R}$

(ii) Let the speed of the satellite with which it hits the earth be V.

Now the total energy of the satellite when it is in orbit,

$$(E_T) = \frac{1}{2}mv^2 - \frac{GMm}{Rth}$$

$$= \frac{1}{2}m\frac{GM}{Rth} - \frac{GMm}{Rth}$$

$$= \frac{GMm}{2(Rth)} - \frac{GMm}{Rth}$$

$$= -\frac{GMm}{2(Rth)} \quad \ldots(1)$$

The total energy of the satellite when it just hits the surface,

$$\left(E_T^{/}\right) = \frac{1}{2}mv^2 - \frac{GMm}{R} \qquad \ldots(2)$$

Now $E_T^{/} = E_T$

Or, $\frac{1}{2}mv^2 - \frac{GMm}{R} = -\frac{GMm}{2(Rth)}$

Or, $\frac{mv^2}{2} = \frac{GMm}{R} - \frac{GMm}{Rth}$

Or, $v^2 = \frac{2GM}{R} - \frac{2GM}{Rth}$

$= 2GM\left(\frac{1}{R} - \frac{1}{Rth}\right)$

$= 2GM\left(\frac{1}{R} - \frac{1}{2R}\right)$, h = R

$= \frac{2GM}{2R} = \frac{GM}{R}$

$\therefore v = \sqrt{\frac{GM}{R}}$.

c) Show that in an adiabatic expansion, work done (W) by an ideal gas is $W = \frac{R}{1-\gamma}\left[T_2 - T_1\right]$ where temperature of the gas changes from T_1 to T_2. 4

Ans. We know that the work done 'dw' for expansion of a gas by an amount dv is given by

dw = p dv

In case of adiabatic expansion of ideal gas $pv^\gamma = K$ (say)

or, $P = \frac{K}{v^\gamma}$

so $dw = \frac{K}{v^\gamma}dv$

$\therefore dw \int_{v_1}^{v_2} \frac{K}{v^\gamma}dv$

$= \frac{K}{1-\gamma}\left[\frac{1}{v_2^{\gamma-1}} - \frac{1}{v_1^{\gamma-1}}\right]$

$$= \frac{1}{1-\gamma}\left[\frac{Kv_2}{v_2^{\gamma}} - \frac{Kv_1}{v_1^{\gamma}}\right]$$

$$= \frac{1}{1-\gamma}\left[P_2 v_2 - P_1 v_1\right]$$

$$= \frac{R}{1-\gamma}\left[T_2 - T_1\right]$$

d) which property of wave shows that sound wave is longitudinal ? Calculate the value of Young's modulus of steel if its density is 7.8 gm/cm^3 and if sound travels in it with a velocity of 5200 m/S. 1 + 3

Ans. Sound waves can propagate through liquid and gas medium like longitudinal waves. Polarisation of sound waves is not possible. Polarisation takes place only in case of transverse wave. So sound wave is longitudinal wave.

Velocity of sound wave through a rod or through a wire is give by,

$$v = \sqrt{\frac{y}{\rho}}$$

where v = velocity of sound wave

= 5200 m/S

= 520000 cm/S

ρ = density of the material

= 7.8 gm/cm^3

y = young modulus of the steel wire which has to be determined.

Now $520000 = \sqrt{\frac{y}{7.8}}$

Or $\frac{y}{7.8} = 52 \times 52 \times 10^8$

$\therefore$ y = $7.7 \times 52 \times 52 \times 10^8$

= 21091.2×10^8

= 2.1×10^{12} dyne/cm^2.

e) Two capacitor of capacitences C_1 = 2μF and C_2 = 8μF are connected in series and the resulting combination is connected across 300 volt. Calculate the charge, potential difference and energy stored in capacitor separately. 4

Ans. c_1 = 2μF, c_2 = 8μF

v = 300 volt. The two capacitors are connected in series.

Let the potential difference, charge and energy stored in the two given capacitors are v_1, q_1 E_1 and v_2, q_2, E_2 respectively. Since they are connected in series, so $q_1 = q_2 = q$ (say).

Now, $v_1 = \frac{q}{c_1}$ and $v_2 = \frac{q}{c_2}$

$$v = 300 \text{ volt} = \frac{q}{c_1} + \frac{q}{c_2}$$

$$= q\left(\frac{1}{c_1} + \frac{1}{c_2}\right)$$

$$= q\left(\frac{1}{2\mu F} + \frac{1}{8\mu F}\right)$$

$$= q\left(\frac{1}{2 \times 10^{-6}} + \frac{1}{8 \times 10^{-6}}\right)$$

$$= q \times 10^{6}\left(\frac{1}{2} + \frac{1}{8}\right)$$

$$= 10^{6} q \times \frac{5}{8}$$

$$\therefore = \frac{8}{5} \times \frac{300}{100}$$

$$= 480 \text{ x } 10^{-6} \text{ coul}$$

$$= 480 \ \mu \text{ coul}$$

So, $v_1 = \frac{q}{c_1} = \frac{480 \ \mu \text{ coul}}{2\mu F} = 240 \text{ volt}$

$$v_2 = \frac{q}{c_2} = \frac{480 \ \mu \text{ coul}}{8\mu F} = 60 \text{ volt}$$

$$E_1 = \frac{1}{2} q v_1 = \frac{1}{2} \times 480 \times 10^{-6} \times 240$$

$$= 57600 \text{ x } 10^{-6} \text{ Joule.}$$

$$= 0.0576 \text{ Joule}$$

$$E_2 = \frac{1}{2} q v_2 = \frac{1}{2} \times 480 \times 10^{-6} \times 60$$

$$= 0.0144 \text{ Joule.}$$

f) i) Define magnetic moment of a magnet. What is its unit ? 1 + 1

Ans. Combination of two isolated, equal and opposite magnetic poles separated by a small distance constitute a magnetic dipole. The product of pole strength (qm) and length (L) of dipole is called magnetic moment (M)

$$\therefore \vec{M} = q_m\vec{L}$$

In S.I. system its unit is Am^2.

ii) If a bar magnet of length L and magnetic moment M is bent into the form of a semicircle then find its magnetic moment. 2

Ans. Let the pole strength of the bar–magnet be q_m. So $M = q_m L$.

Now d be the diameter of the semicircle, then $L = \pi r = \pi\frac{d}{2}$

$$\text{Or } d = \frac{2L}{\pi}$$

In new condition, the magnetic moment $= q_m d$

$$= q_m \times \frac{2L}{\pi}$$

$$= \frac{2}{\pi}q_m L$$

$$= \frac{2M}{\pi}.$$

g) State Mosby's law. State two importance of Mosby's law. 2+2

Ans. Mosby's law states that the square root of the frequency of any particular spectral line is proportional to the atomic number of the target element i.e. $\sqrt{\nu}\alpha(z-b)$.

<u>Two importance of Mosby's Law</u>

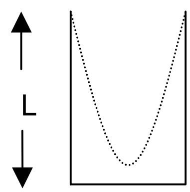
(i) Properties of an element do not depend upon it's atomic weight but upon it's atomic number. So atomic number is the fundamental quantity of an element.

(ii) A straight line graph between $\sqrt{\nu}$ and z indicates that atomic number increases regularly from one element to next element. Hence in the periodic table the elements should be arranged in the order of increasing atomic number.

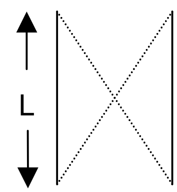
Group – D

4.a) i) Show that the fundamental frequency of an open pipe is twice that of a closed pipe if they are of same length.

Ans.



Closed Pipe



Open Pipe

One closed pipe and one open pipe both the same length 'L' are taken for consideration. Formation of fundamental tone in both cases are shown in the 'above fig'. For closed pipe frequency of the fundamental tone is given by,

$$n_o = \frac{v}{\lambda_o} = \frac{v}{4L} \quad \ldots(i)$$

and for open pipe that is given by

$$n_o' = \frac{v}{\lambda_o'} = \frac{v}{2L} \quad \ldots(ii)$$

$$= 2 \times \frac{v}{4L}$$

$$= 2 \times n_o$$

$$\boxed{n_o' = 2n_o}$$

i.e. the fundamental frequency of an open pipe is twice that of a closed pipe if they are same length.

ii) What are beats ?

Ans. Periodic variations of the intensity of wave resulting from the superposition of two waves of slightly different frequencies is known as the phenomenon of beats.

iii) The frequency of a tuning fork is 256 Hz and sound travels to a distance of 40m. While the fork executes 32 vibrations. Find the wave length of the note emitted by the form. 2 + 2 + 2

Ans. For 32 vibrations the distance traversed by sound wave is 40m. So the distance traversed by sound wave for 256 vibrations is $\frac{40}{32} \times 256$

$= 320$ meter.

$\therefore$ v = velocity of the wave

= 320 m/S.

$$\therefore \lambda \frac{320}{256} = \frac{5}{4} = 1.25\text{m}.$$

b) i) State Biot–Savart Law.

Ans. According to Biot–Savart's Law, the magnetic field $d\vec{B}$ at a point whose position vector $\vec{r}$ with respect to a current element $\overrightarrow{d\ell}$ of a wire carrying current I, is given by

$$d\vec{B} = \frac{\mu_o I}{4\pi}\left(\frac{\overrightarrow{d\ell} \times \vec{r}}{r^3}\right)$$

ii) By using this law find the magnetic induction B at a distance 'd' from an infinitely long straight conductor carrying current I. 2 + 4

Ans. Consider an element xy of a long straight conductor AB carrying current I in the direction from A to B. Let P be the observation point at a distance x from the centre of the element.

PM = r = normal distance of the point from the wire.

According Biot–Savart's Law

dB = magnetic intensity at P due the element xy

$$= \frac{\mu_o}{4\pi} \frac{I\, d\ell \sin\theta}{x^2} \qquad \sin\theta = \sin(\pi/2 - \alpha) = \cos\alpha$$

$$= \frac{\mu_o}{4\pi} \times \frac{I r \sec^2\alpha d\alpha \cos\alpha}{\frac{r^2}{\cos^2\alpha}} \qquad \text{from } \Delta \text{ O } \mu\rho$$

$$= \frac{\mu_o}{4\pi} \frac{I}{r} \cos\alpha\, d\alpha \qquad \cos\alpha = \frac{r}{x}$$

$$= \frac{\mu_o}{4\pi} \frac{I}{r} \cos\alpha\, d\alpha \qquad x = \frac{r}{\cos\alpha}$$

$$\tan\alpha = \frac{\ell}{r}$$

$$\ell = r \tan\alpha$$

$$d\ell = r \sec^2\alpha\, d\alpha.$$

$$\therefore B = \int_0^B dB = \frac{\mu_o I}{4\pi r} \int_{\alpha_1}^{\alpha_2} \cos\alpha \, d\alpha$$

$$= \frac{\mu_o}{4\pi r}\left(\sin\alpha_2 - \sin\alpha_1\right)$$