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IIT JEE PHYSICS PAPER SOLUTION
26 JUNE 2022
MORNING SHIFT

QUESTIONS BASED ON UNIT & DIMENSION, EMW,SCATTERING, DIODE & RL CIRCUIT WITH EMI ARE TRICKY

Q1: A expression for a dimensionless quantity P is given by $P = \frac{\alpha}{\beta}\log_e\left(\frac{kt}{\beta x}\right)$; where α and β are constants, x is distance; k is Boltzmann constant and t is the temperature. Then the dimensions of α will be:

(A) $[M^0L^{-1}T^0]$

(B) $[ML^0T^{-2}]$

(C) $[MLT^{-2}]$

(D) $[ML^2T^{-2}]$

ANS-1

$P = \frac{\alpha}{\beta}\log_e\left(\frac{kt}{\beta x}\right)$ ← Dimensionless

$\frac{kt}{\beta x} = M^0L^0T^0$

$\frac{ML^2T^{-2}}{\beta L} = M^0L^0T^0$

$\beta = MLT^{-2}$

P — Dimensionless (given)

$[\alpha] = [\beta] = MLT^{-2}$

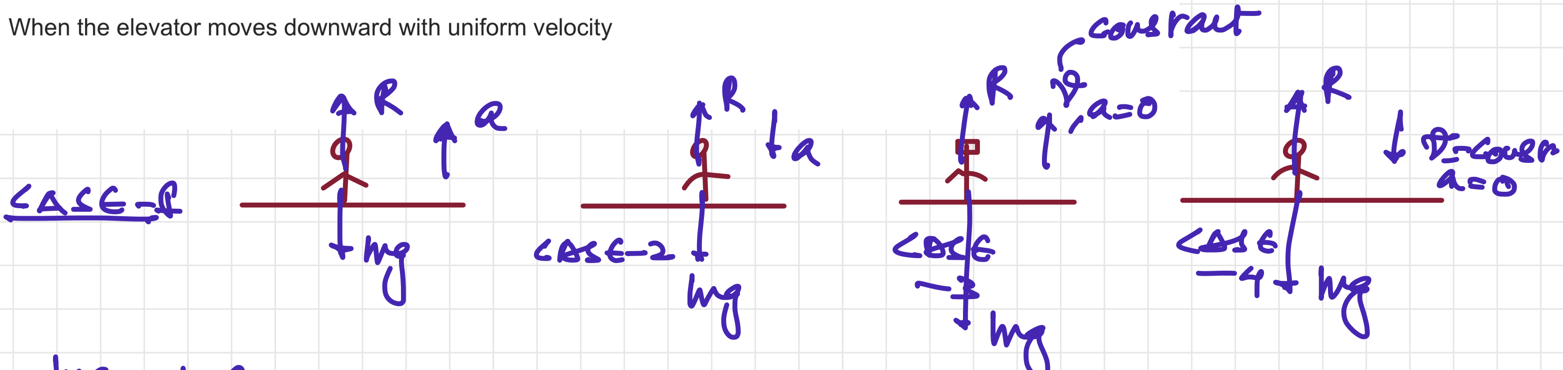
Q2: A person is standing in an elevator. In which situation, he experiences weight loss?

(A) When the elevator moves upward with constant acceleration

✓ (B) When the elevator moves downward with constant acceleration

(C) When the elevator moves upward with uniform velocity

(D) When the elevator moves downward with uniform velocity



$R - mg = ma$

$R = m(g+a)$

$mg - R = ma$

$R = m(g-a)$

Less than original weight

$R - mg = m(0)$

$R = mg$

$mg - R = m(0)$

$R = mg$

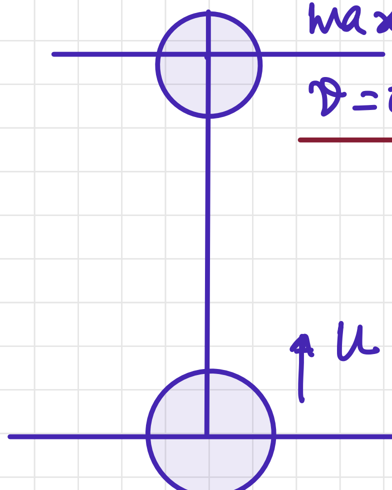
Q3: An object is thrown vertically upwards. At its maximum height, which of the following quantity becomes zero?

(A) Momentum ✓

(B) Potential energy

(C) Acceleration

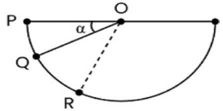
(D) Force



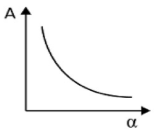
max height:

$v = 0$, $p = mv = 0$

Q4: A ball is released from rest from point P of a smooth semi-spherical vessel as shown in figure. The ratio of the centripetal force and normal reaction on the ball at point Q is A while angular position of point Q is α with respect to point P. which of the following graphs represented the correct relation between A and α when ball goes from Q to R?



(A)



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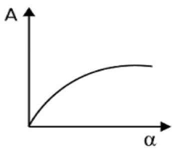
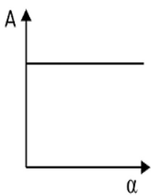
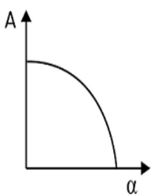
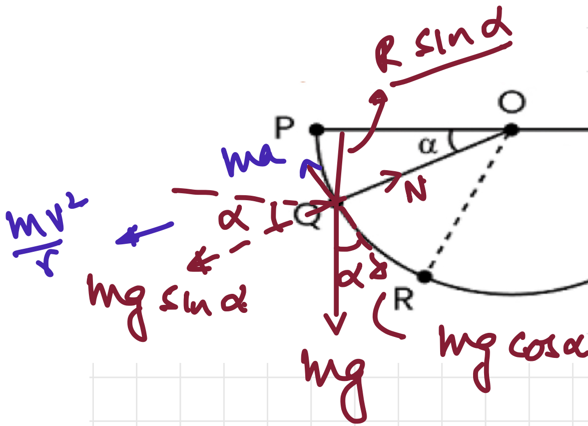


(C)



(D)





at point Q

$$A = \frac{mv^2/R}{N}$$

$$N = mg\sin\alpha + \frac{mv^2}{R}$$

$$ma = mg\sin\alpha$$

$$a = g\sin\alpha$$

$$\frac{1}{2}mv^2 = mg(R\sin\alpha)$$

$$v^2 = 2gR\sin\alpha$$

$$N = mg\sin\alpha + \frac{m}{R}(2gR\sin\alpha)$$

$$N = 3mg\sin\alpha \quad \text{— (1)}$$

$$\frac{mv^2}{R} = \frac{m}{R}(2gR\sin\alpha) \quad \text{— (2)}$$

$$= 2mg\sin\alpha$$

$$A = \frac{mv^2/R}{N} = \frac{2mg\sin\alpha}{3mg\sin\alpha}$$

$$A = 2/3$$

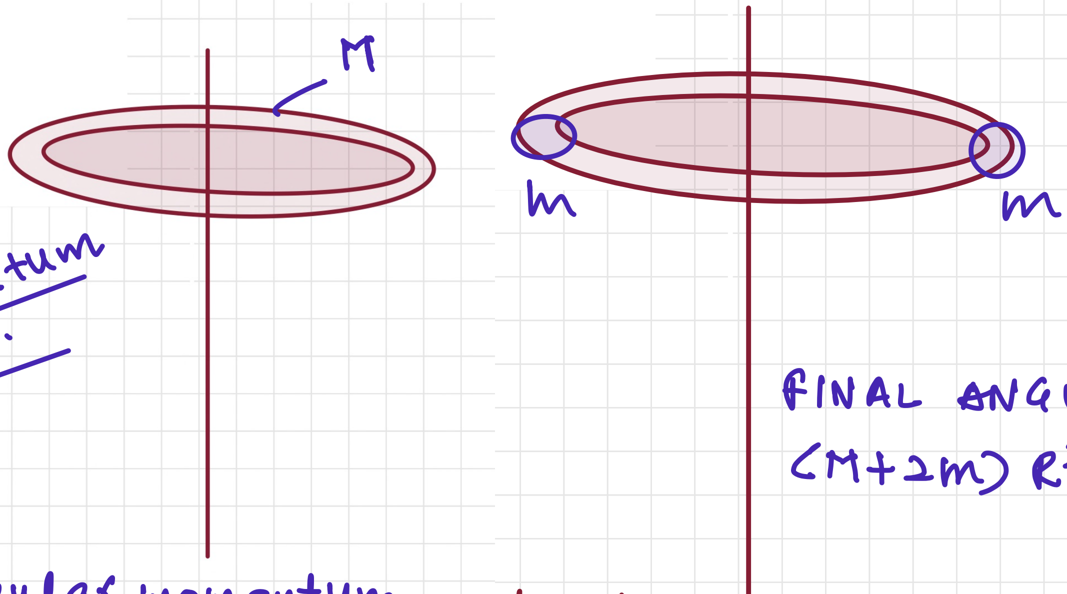
Q5: A thin circular ring of mass M and radius R is rotating with a constant angular velocity $2\,rad s^{-1}$ in a horizontal plane about an axis vertical to its plane and passing through the center of the ring. If two objects each of mass m be attached gently to the opposite ends of a diameter of ring, the ring will then rotate with an angular velocity (in $rad s^{-1}$)

(A) $\frac{M}{(M+m)}$

(B) $\frac{(M+2m)}{2M}$

(C) $\frac{2M}{(M+2m)}$ ✓

(D) $\frac{2(M+2m)}{M}$



No External torque hence angular momentum is conserved.

Initial angular momentum

$L_1 = I_1 \omega_1$

$L_1 = MR^2 \omega_1$

FINAL ANGULAR

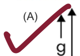
$(M+2m) R^2 \omega_2 = L_2$

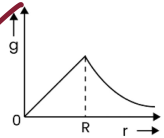
$L_1 = L_2$

$MR^2 \omega_1 = (M+2m) R^2 \omega_2$

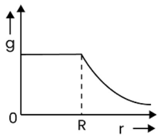
$\omega_2 = \frac{MR^2}{(M+2m)R^2}\omega_1 = \frac{2M}{(M+2m)}$

Q6: The variation of acceleration due to gravity (g) with distance (r) from the center of the earth is correctly represented by:
(Given R = radius of earth)

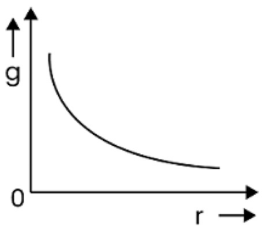
(A) 



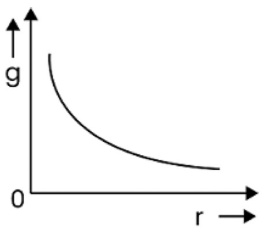
(B)



(C)



(D)



Inside

$r = a < R$

$r = R$ at surface

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

Inside

$g' = \frac{GM'}{a^2}$

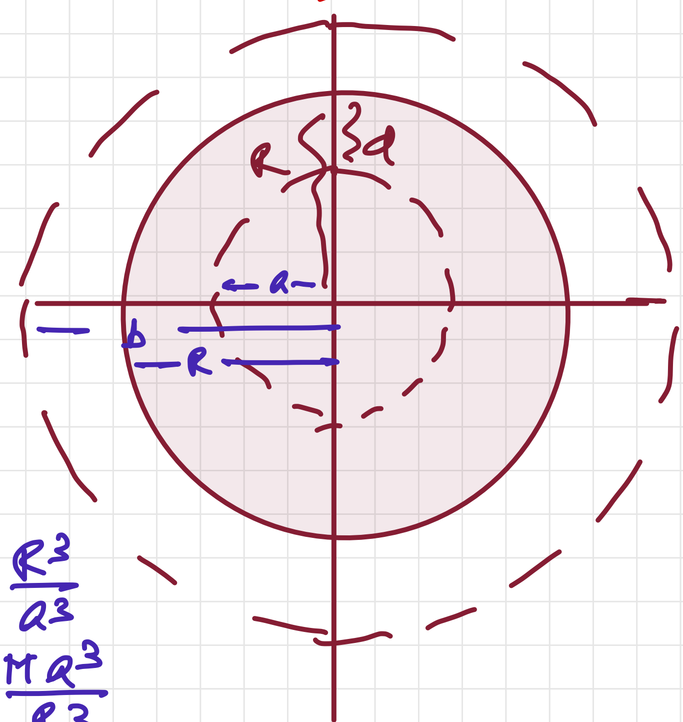
$M = \frac{4}{3}\pi R^3 \rho$

$M' = \frac{4}{3}\pi a^3 \rho$

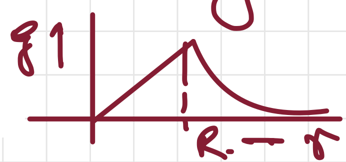
$\frac{M}{M'} = \frac{R^3}{a^3}$

$M' = \frac{M a^3}{R^3}$

$g = \frac{GM a^3}{R^3 a^2} = \frac{GM}{R^3} a$, $g \propto a \propto r$ – Inside



outside. $g = \frac{GM}{r^2}$ for $r > 0$



Q7: The efficiency of Carnot's engine, working between steam point and ice point, will be

(A) 26.81%

(B) 37.81%

(C) 47.81%

(D) 57.81%

$$\eta = 1 - \frac{T_2}{T_1}$$

$T_2 \rightarrow 0 + 273 = 273$

$T_1 \rightarrow 100 + 273 = 373$

$$= 1 - \frac{273}{373} = 0.268$$

26.8%

Q8: Time period of a simple pendulum in a stationary lift is 'T'. If the lift accelerates with $\frac{g}{6}$ vertically upwards then the time period will be:
(Where g = acceleration due to gravity)

(A) $\sqrt{\frac{6}{5}}T$

(B) $\sqrt{\frac{5}{6}}T$

(C) ✓ $\sqrt{\frac{6}{7}}T$

(D) $\sqrt{\frac{7}{6}}T$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$T' = 2\pi\sqrt{\frac{l}{g + g/6}}$$

$$T' = 2\pi\sqrt{\frac{6l}{7g}} = 2\pi\sqrt{\frac{6}{7}}\sqrt{\frac{l}{g}}$$

$$T' = \sqrt{\frac{6}{7}}\,(T)$$

$$\frac{T'}{T} = \sqrt{\frac{6}{7}}$$

Q9: A thermally insulated vessel contains an ideal gas of molecular mass M and ratio of specific heats 1.4. Vessel is moving with speed v and is suddenly brought to rest. Assuming no heat is lost to the surrounding and vessel temperature of the gas increases by:
(R = universal gas constant)

(A) $\frac{Mv^2}{7R}$

(B) $\frac{Mv^2}{5R}$

(C) $2\frac{Mv^2}{7R}$

(D) $7\frac{Mv^2}{5R}$

KE = Total work done

$\frac{1}{2}MV^2 = n\left(\frac{f}{2}R\right)\Delta T$

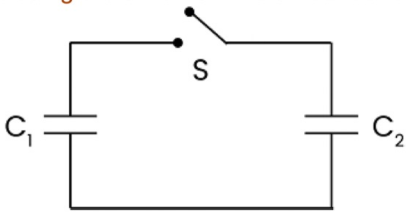
f → degree of freedom.

$n = 1$
$f = 5$

$\Delta T = \frac{MV^2}{5R}$

$\frac{C_p}{C_v} = 1.4 = \gamma$.

Q10: Two capacitors having capacitance C_1 and C_2 respectively are connected as shown in figure. Initially, capacitor C_1 is charged to a potential difference V volt by a battery. The battery is the removed and the charged capacitor C_1 is now connected to uncharged capacitor C_2 by closing the swich S. The amount of charge on the capacitor C_2, after equilibrium, is:

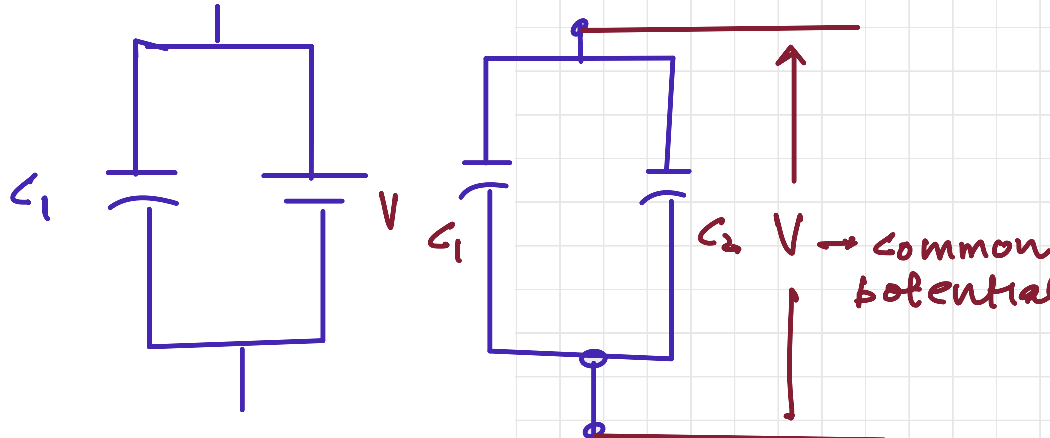


(A) $\frac{C_1C_2}{(C_1+C_2)}V$ ✓

(B) $\frac{(C_1+C_2)}{C_1C_2}V$

(C) $(C_1+C_2)V$

(D) $(C_1-C_2)V$



$q_1 = C_1 V$

$q_1' = C_1 V, \quad q_2' = C_2 V$

Total charge remains constant

$q_1 = q_1' + q_2'$

$C_1 V = (C_1 + C_2) V \Rightarrow V = \frac{C_1 V}{C_1 + C_2}$

$q_2' = C_2 V = C_2 \left(\frac{C_1 V}{C_1 + C_2} \right) = \left(\frac{C_1 C_2 V}{C_1 + C_2} \right)$

Q11: Given below two statements: One is labelled as Assertion (A) and other is labelled as Reason (R).

Assertion (A) : Non-polar materials do not have any permanent dipole moment. Reason (R) : When a non-polar material is placed in an electric field, the centre of the positive charge distribution of it's individual atom or molecule coincides with the centre of the negative charge distribution.

In the light of above statements, choose the most appropriate answer from the options given below.

(A) Both (A) and (R) are correct and (R) is the correct explanation of (A)

(B) Both (A) and (R) are correct and (R) is not the correct explanation of (A)

(C) (A) is correct but (R) is not correct ✓

(D) (A) is not correct but (R) is correct

Solution:

(A) is correct but (R) is not correct

IN- NONPOLAR MOLECULE

CENTRE OF POSITIVE CHARGE CENTRE OF NEGATIVE CHARGE Hence net dipole moment ZERO

when Non polar material is placed in external field, then centre of charge does not coincide, hence give non zero moment in field.

Q12: The magnetic flux through a coil perpendicular to its plane is varying according to the relation $\phi = (5t^3 + 4t^2 + 2t - 5)$Weber. If the resistance of the coil is 5 ohm, then the induced current through the coil at t =2 s will be,

(A) 15.6 A ✓

(B) 16.6 A

(C) 17.6 A

(D) 18.6 A

$$e = -\frac{d\phi}{dt}$$

$$= -\frac{d}{dt}(5t^3+4t^2+2t-5)$$

$$= -\frac{d}{dt}(5t^3) - \frac{d}{dt}(4t^2) - \frac{d}{dt}(2t) - \frac{d}{dt}(5)$$

$$= -15t^2 - 8t - 2 - 0$$

at t = 2sec | $|e| = |-15(2)^2 - 8(2) - 2| = 78$ Volt

$$I = \frac{|e|}{R} = \frac{78}{5} = 15.6 \text{ Amp}$$

Q13: An aluminium wire is stretched to make its length, 0.4% larger. The percentage change in resistance is:

(A) 0.4 %

(B) 0.2 %

(C) 0.8 %

(D) 0.6 %

$R_1 = \frac{\rho l_1}{A_1}$ — (1) | $R_2 = \frac{\rho l_2}{A_2}$ — (2)

$l_1 = l_2$ | $l_2 = \left(l + \frac{0.4}{100} l\right) = (1.004)\,l$

But volume will remain constant

$A_1 l_1 = A_2 l_2$

$\frac{A_1}{A_2} = \frac{l_2}{l_1} = \frac{1.004\,l}{l}$

equation (1) / equation (2)

$\frac{R_2}{R_1} = \frac{\rho l_2}{A_2} \times \frac{A_1}{\rho l_1} = \left(\frac{l_2}{l_1}\right)\left(\frac{A_1}{A_2}\right) = (1.004)(1.004)$

$\frac{R_2}{R_1} = (1.04)^2$

$\frac{R_2}{R_1} - 1 = (1.004)^2 - 1 = (1.004+1)(1.004-1)$

$= (2.004)(.004)$

$\left(\frac{R_2 - R_1}{R_1}\right) \times 100$

$= (2.004)(.004) \times 100$

$= 0.80\%$

Alternate method

$R = \frac{\rho L}{A}$, $LA = \text{constant}$

$A \propto 1/L$

$\frac{\Delta R}{R} \times 100 = 2\left(\frac{\Delta L}{L}\right) \times 100$

$= 2 \times 0.4 = 0.8\%$

Q14: A proton and an alpha particle of the same velocity enter in a uniform magnetic field which is acting perpendicular to their direction of motion. The ratio of the radii of the circular paths described by the alpha particle and proton is:

(A) 1 : 4

(B) 4 : 1

(C) 2 : 1

(D) 1 : 2

$$q v B = \frac{m v^2}{r}$$

$$r = \frac{mv}{qB}$$

proton	α-particle
m	4m
e	2e

$$\frac{r_p}{r_\alpha} = \frac{m_p v_p}{q_p B} \frac{q_\alpha B}{m_\alpha v_\alpha}$$

$$= \frac{m}{e} \times \frac{2e}{4m} = \frac{1}{2}$$

$$\frac{r_\alpha}{r_p} = \frac{2}{1}$$

Q15: If electric field intensity of a uniform plane electromagnetic wave is given as

$$E = -301.16\sin(kz-\omega t)\hat{a}_x + 452.4\sin(kz-\omega t)\hat{a}_y \frac{V}{m}$$

Then, magnetic intensity 'H' of this wave in Am^{-1} will be:

[Given: Speed of light in vacuum $c = 3\times 10^8 ms^{-1}$, permeability of vacuum $\mu_0 = 4\pi\times 10^7 NA^{-2}$

(A) $+0.8\sin(kz-\omega t)\hat{a}_y + 0.8\sin(kz-\omega t)\hat{a}_x$

(B) $+1.0\times 10^{-6}\sin(kz-\omega t)\hat{a}_y + 1.5\times 10^{-6}(kz-\omega t)\hat{a}_x$

(C) $-0.8\sin(kz-\omega t)\hat{a}_y - 1.2\sin(kz-\omega t)\hat{a}_x$

(D) ✓ $-1.0\times 10^{-6}\sin(kz-\omega t)\hat{a}_y - 1.5\times 10^{-6}\sin(kz-\omega t)\hat{a}_x$

$$\bar{E} = -301.16\sin(kz-\omega t)\hat{a}_x + 452.4\sin(kz-\omega t)\hat{a}_y$$

$(-\hat{i})$ for $\hat{a}_x$, $(\hat{j})$ for $\hat{a}_y$

$$\bar{B} = \frac{301.16}{3\times 10^8}\sin(kz-\omega t)(-\hat{j}) + \frac{452.4}{3\times 10^8}\sin(kz-\omega t)(-\hat{i})$$

(c) DIRECTION OF PROPOGATION $= \hat{k}$

$\vec{E} = (-\hat{i})$

$\vec{E}\times\vec{B} = \vec{c}$

$(-\hat{i})\times\vec{B} = \hat{k}$

$\bar{B} = (-\hat{j})$

$c = \hat{k}$

$E = \hat{j}$

$\vec{E}\times\vec{B} = \vec{c}$

$\hat{j}\times\bar{B} = \hat{k}$

$B = -\hat{i}$

Q16: In free space, an electromagnetic wave of 3 GHz frequency strikes over the edge of an object of size $\frac{\lambda}{100}$, where λ is the wavelength of the wave space. The phenomenon, which happens there will be:

(A) Reflection

(B) Refraction

(C) Diffraction

(D) Scattering ✓

$$f = 3 \times 10^9 \text{ Hz}$$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^9} = 0.1 \text{ mt}$$

Size of the particle $= \frac{\lambda}{100} = \frac{.01}{100} = .001 \text{ mt}$

here size of the particle <<< wavelength

hence phenomenon – scattering

Q17: An electron with speed v and a photon with speed c have the same de-Broglie wavelength. If the kinetic energy and momentum of electron are E_e and p_e and that of photon are E_{ph} and p_{ph} respectively. Which of the following is correct?

(A) $\frac{E_e}{E_{ph}} = \frac{2c}{v}$

(B) ✓ $\frac{E_e}{E_{ph}} = \frac{v}{2c}$

(C) $\frac{p_e}{p_{ph}} = \frac{2c}{v}$

(D) $\frac{p_e}{p_{ph}} = \frac{v}{2c}$

electron	photon
E_e	E_{ph}
p_e	p_{ph}
λ	λ

λ — same for both.

$$E_e = \frac{1}{2} m v^2$$

$$\lambda = \frac{h}{mv}$$

$$m = \frac{h}{\lambda v}$$

$$E_e = \frac{1}{2}\left(\frac{h}{\lambda v}\right) v^2$$

$$= \frac{1}{2}\frac{hv}{\lambda} \quad \text{--- (1)}$$

$$mc^2 = E_{ph}$$

$$mc = \frac{E_{ph}}{c} \Rightarrow p = \frac{E_{ph}}{c}$$

$$E_{ph} = (p_{ph})(c) \quad \text{--- (2)}$$

$$E_{ph} = \frac{hc}{\lambda}$$

equation (1) / equation (2)

$$\frac{E_e}{E_{ph}} = \frac{hv}{2\lambda} \times \frac{\lambda}{hc} = \frac{v}{2c}$$

Q18: How many alpha and beta particles are emitted when Uranium ${}_{92}U^{238}$ decays to lead ${}_{82}Pb^{206}$?

(A) 3 alpha particles and 5 beta particles

(B) 6 alpha particles and 4 beta particles

(C) 4 alpha particles and 5 beta particles

(D) ✓ 8 alpha particles and 6 beta particles

for α particle

$$\begin{array}{r} 238 \\ -206 \\ \hline 32 \end{array} \rightarrow 8 \times 4 \quad (He^4)$$

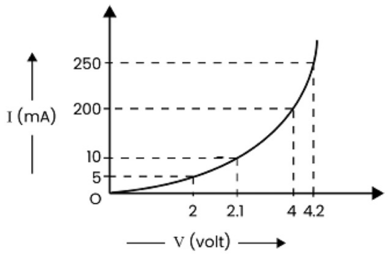
$${}_{92}U^{238} \longrightarrow {}_{82}Pb^{206} + 8\left({}_{2}He^{4}\right) + 6\left({}_{-1}\beta^{0}\right)$$

balanced equation

β:

$$92 = \underbrace{82 + 16}_{98} - 6$$

Q19: The I-V characteristics of a p-n junction diode in forward bias is shown in the figure. The ratio of dynamics resistance, corresponding to forward bias voltage of 2V and 4V respectively is:



(A) 1 : 2

(B) 5 :1

(C) 1: 40

(D) 20 : 1

Dynamic resistance

= Inverse of the slope

for 2. volt

$$r_1 = \frac{(2.1-2)}{(10-5)\times10^{-3}} = \frac{0.1\times10^3}{5} = \frac{100}{5} = 20\text{-ohm}$$

for 4 volt

$$r_2 = \frac{4.2-4}{(250-200)\times10^{-3}} = \frac{0.2\times10^3}{50} = \frac{0.2\times1000}{50} = 4$$

$$\frac{r_1}{r_2} = \frac{20}{4} = 5$$

Q20: Choose the correct statement for amplitude modulation:

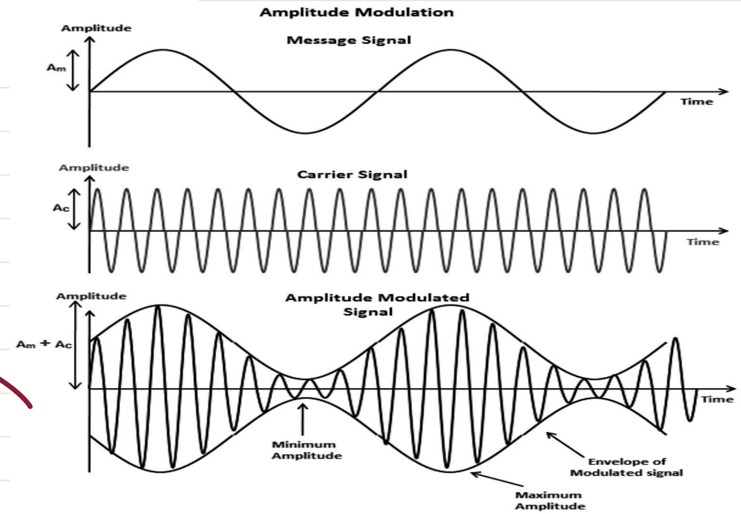
(A) Amplitude of modulating signal is varied in accordance with the information signal

(B) Amplitude of modulated signal is varied in accordance with the information signal

(C) Amplitude of carrier signal is varied in accordance with the information signal

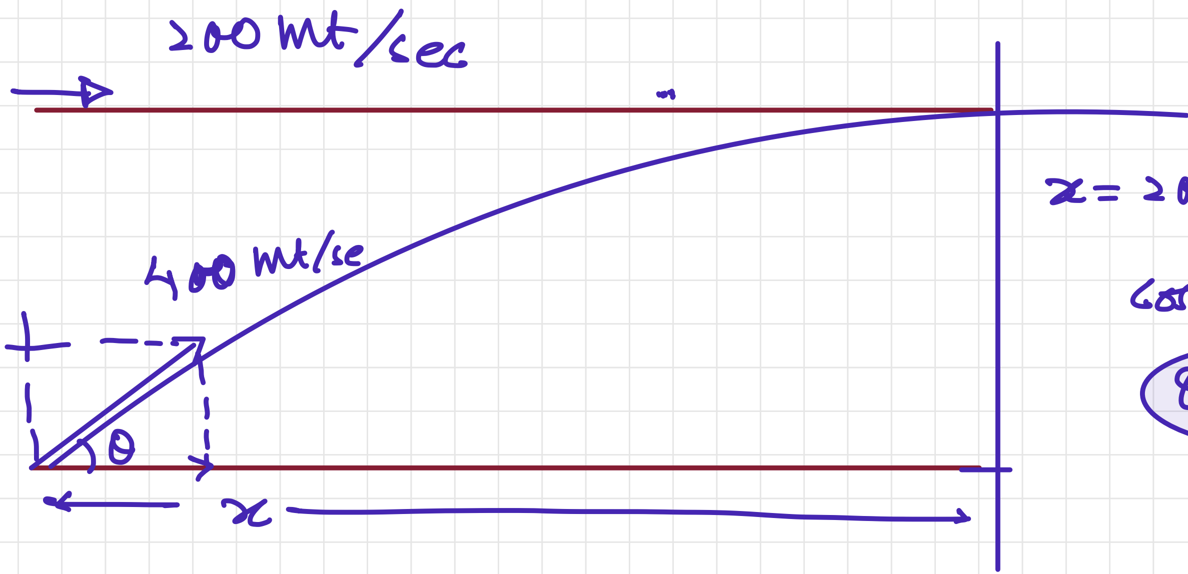
(D) ✓ Amplitude of modulated signal is varied in accordance with the modulating signal

Amplitude of modulated signal varies as per modulating or message signal



Q21: A fighter jet is flying horizontally at a certain altitude with a speed of $200\, ms^{-1}$. When it passes directly overhead an anti-aircraft gun, a bullet is fired from the gun, at an angle 0 with the horizontal, to hit the jet. If the bullet speed is 400 m/s, the value of θ will be _______ °.

60°



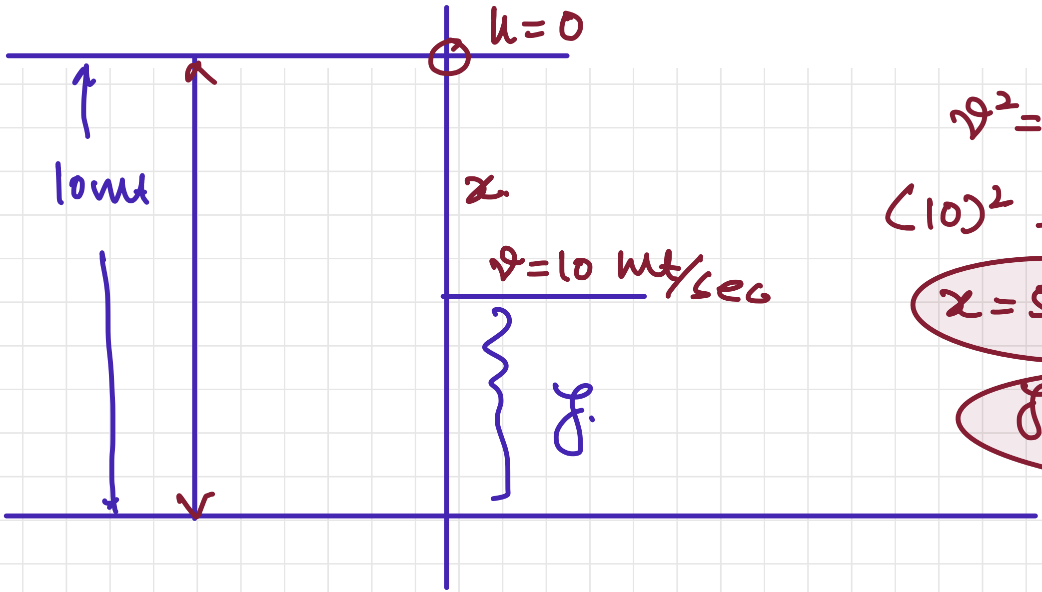
$x = 200(t) = 400 \cos\theta\,(t)$

$\cos\theta = 1/2$

$\theta = 60°$

Q22: A ball of mass 0.5 kg is dropped from the height of 10 m. The height, at which the magnitude of velocity becomes equal to the magnitude of acceleration due to gravity, is ______ m. [Use $g = 10\,m/s^2$]

10 mt



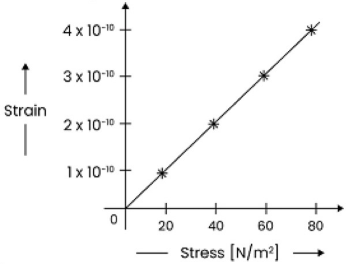
$v^2 = u^2 + 2as$

$(10)^2 = 0 + 2gx$

$x = 5$ mt

$y = 10 - 5 = 5$ mt

Q23: The elastic behaviour of material for linear stress and linear strain, in the figure. The energy density for a linear strain of 5×10^{-4} is 25 kJ / m^3. Assume that material is elastic upto the linear strain of 5×10^{-4}.



ENERGY DENSITY

$$= \frac{1}{2}(Y)(STRAIN)^2$$

$$= \frac{1}{2}\left(\frac{20}{10^{-10}}\right)(5 \times 10^{-4})^2$$

$$= 10^{11} \times 10^{-8} \times 25$$

$$= 25 \times 10^{3}\ J/mt^3$$

$$= 25\ KJ/mt^3$$

Q24: The elongation of a wire on the surface of the earth is $10^{-4} m$. The same wire of same dimensions is elongated by $6 \times 10^{-5} m$ on another planet. The acceleration due to gravity on the planet will be 6 ____ ms^{-2}. (Take acceleration due to gravity on the surface of earth $= 10\, ms^{-2}$)

6 ms^{-2}

$$Y = \frac{F/A}{\Delta l / l} \Rightarrow Y\left(\frac{\Delta l}{l}\right) = F/A$$

$$\Delta l = \frac{(F)(l)}{(A)(Y)} = \frac{\left(\frac{(mg+0)}{2}\right)(l_0)}{Y(A)} = \frac{mgl_0}{2YA}$$

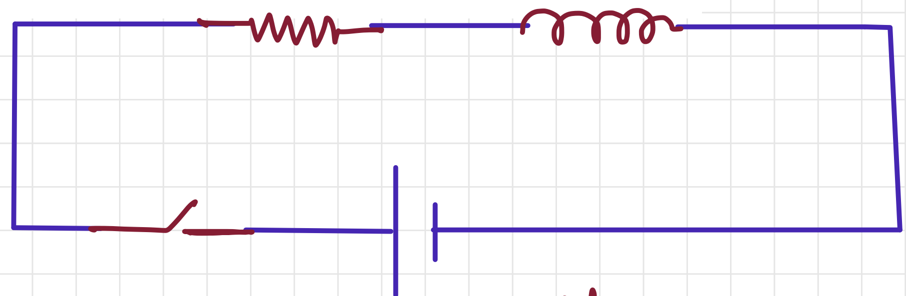
$$\Delta l \propto g$$

$$\frac{\Delta l_2}{\Delta l_1} = \frac{g_2}{g_1} = \frac{6 \times 10^{-5}}{10 \times 10^{-5}}$$

$$g_2 = \frac{6 g_1}{10} = 6\, ms^{-2}$$

Q25: A $10\Omega, 20mH$ coil carrying constant current is connected to a battery of 20V through a switch. Now after switch is opened current becomes zero in $100\mu s$. The average e.m.f. induced in the coil is 400 V.

400 Volt



$$e = -L\frac{dI}{dt}$$

$$= -20\times10^{-3}\frac{(I_f - I_i)}{100\times10^{-6}}$$

$$= -\frac{20}{1000}\frac{(0-2)}{100\times10^{-6}}$$

$$= \frac{20\times2}{10^{-1}} = 40\times10$$

$= 400$ Volt

Since switch is closed for long time then inductor will act as a short circuit (No role of inductor)

$I = \frac{20}{10} = 2$ Amp

Initial current