JEE Main 2020 Paper

Date : 5th September 2020

Time : 02 : 00 pm - 05 : 00 pm

Subject : Physics

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1. A ring is hung on a nail. It can oscillate, without slipping or sliding (i) in its plane with a time period T_1 and, (ii) back and forth in a direction perpendicular to its plane, with a period T_2. The ratio $\frac{T_1}{T_2}$ will be:

(1) $\frac{3}{\sqrt{2}}$ (2) $\frac{\sqrt{2}}{3}$ (3) $\frac{2}{\sqrt{3}}$ (4) $\frac{2}{3}$

SOl. **3**

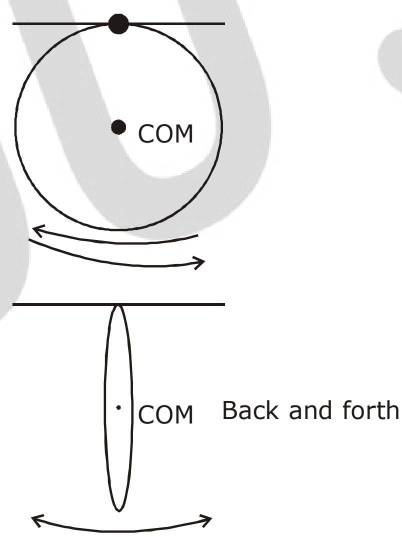
$$T_1 = 2\pi\sqrt{\frac{(mR^2 + mR^2)}{mgR}}$$

$$T_1 = 2\pi\sqrt{\frac{2R}{g}}$$

$$T_2 = 2\pi\sqrt{\frac{I}{mgL_{cm}}}$$

$$T_2 = 2\pi\sqrt{\frac{3mR^2/2}{mgR}} = 2\pi\sqrt{\frac{3R}{2g}}$$

$$\frac{T_1}{T_2} = \sqrt{\frac{4}{3}} = \frac{2}{\sqrt{3}}$$



2. The correct match between the entries in column I and column II are:

I Radiation	II Wavelength
(a) Microwave	(i) 100 m
(b) Gamma rays	(ii) 10^{-15} m
(c) A.M. radio waves	(iii) 10^{-10} m
(d) X-rays	(iv) 10^{-3} m

(1) (a) - (ii), (b)-(i), (c)-(iv), (d)-(iii)
(2) (a)-(iii), (b)-(ii), (c)-(i), (d)-(iv)
(3) (a)-(iv), (b)-(ii), (c)-(i), (d)-(iii)
(4) (a)-(i),(b)-(iii), (c)-(iv), (d)-(ii)

Sol. **3**

By theory

3. In an experiment to verify Stokes law, a small spherical ball of radius r and density ρ falls under gravity through a distance h in air before entering a tank of water. If the terminal velocity of the ball inside water is same as its velocity just before entering the water surface, then the value of h is proportional to : (ignore viscosity of air)

(1) r^4 (2) r (3) r^3 (4) r^2

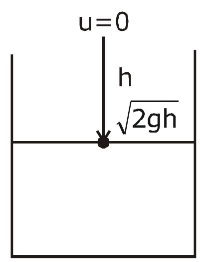
Sol. **1**

$V_T = \sqrt{2gh}$

$\frac{2}{9} r^2 \frac{(\rho - \sigma) g}{\eta} = \sqrt{2gh}$

$r^2 \propto \sqrt{h} \Rightarrow r^4 \propto h$

$h \propto r^4$



4. Ten charges are placed on the circumference of a circle of radius R with constant angular separation between successive charges. Alternate charges 1, 3, 5, 7, 9 have charge (+q) each, while 2, 4, 6, 8, 10 have charge (–q) each. The potential V and the electric field E at the centre of the circle are respectively: (Take V= 0 at infinity)

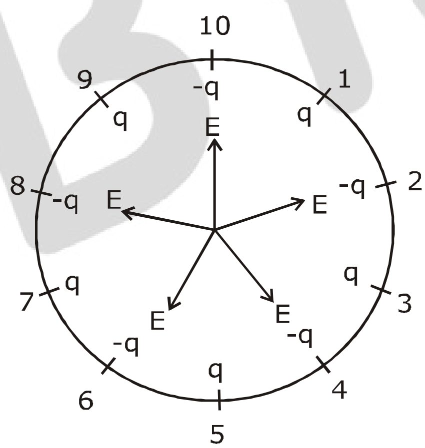
(1) V = 0; E = 0

(2) $V = \frac{10q}{4\pi\epsilon_0 R}; E = \frac{10q}{4\pi\epsilon_0 R^2}$

(3) $V = 0; E = \frac{10q}{4\pi\epsilon_0 R^2}$

(4) $V = \frac{10q}{4\pi\epsilon_0 R}; E = 0$

Sol. **1**



$v_{net} = 5\left(\frac{kq}{R}\right) + \left(\frac{5k(-q)}{R}\right)$

$v_{net} = 0$ [$Q_{net} = 0$]

$E_{net} = 0$ by symmetry

5. A spaceship in space sweeps stationary interplanetary dust. As a result, its mass increases at a rate $\frac{dM(t)}{dt}$ = bv^2 (t), where v(t) is its instantaneous velocity. The instantaneous acceleration of the satellite is :

(1) $-bv^3(t)$ (2) $-\frac{bv^3}{M(t)}$ (3) $-\frac{2bv^3}{M(t)}$ (4) $-\frac{bv^3}{2M(t)}$

Sol. **2**

$\frac{dM(t)}{dt} = -bv^2$

in free space
no external force
so there in only thrust force on rocket

$f_{in} = \frac{dM}{dt}(V_{rel})$

$Ma = \left(\frac{-bv^2}{(t)}\right)v$

$a = \frac{-bv^3}{M(t)}$

6. Two different wires having lengths L_1 and L_2, and respective temperature coefficient of linear expansion α_1 and α_2, are joined end-to-end. Then the effective temperature coefficient of linear expansion is:

(1) $\frac{\alpha_1 L_1 + \alpha_2 L_2}{L_1 + L_2}$ (2) $2\sqrt{\alpha_1\alpha_2}$

(3) $4\frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}\frac{L_2 L_1}{(L_2+L_1)^2}$ (4) $\frac{\alpha_1+\alpha_2}{2}$

Sol. **1**

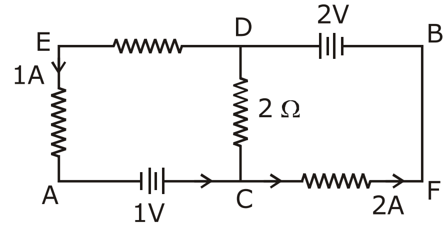
$L'_1 = L_1(1 + \alpha_1\Delta T)$
$L'_2 = L_2(1 + \alpha_2\Delta T)$
$L' + L_2' = L_1 + L_2 + L_1\alpha_1\Delta T + L_2\alpha_2\Delta T$

$= (L_1 + L_2)\left[1 + \left[\frac{L_1\alpha_1 + L_2\alpha_2}{L_1 + L_2}\right]\Delta T\right]$

$= (L_1 + L_2)[1 + \alpha_{eq}\Delta T]$

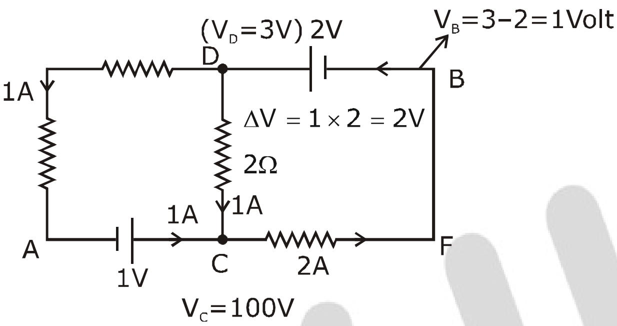
So, $\alpha_{eq} = \frac{L_1\alpha_1 + L_2\alpha_2}{L_1 + L_2}$

7. In the circuit, given in the figure currents in different branches and value of one resistor are shown. Then potential at point B with respect to the point A is:



(1) +2 V (2) −2 V (3) +1 V (4) −1 V

Sol. **3**



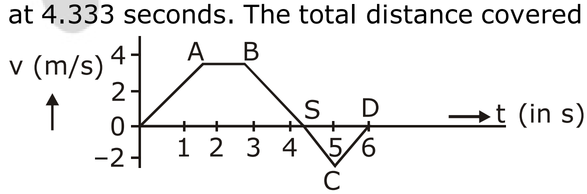
Let $V_A = 0$

applying KVL from A to B via ACDB

$V_A + 1 + 2 - 2 = V_B$

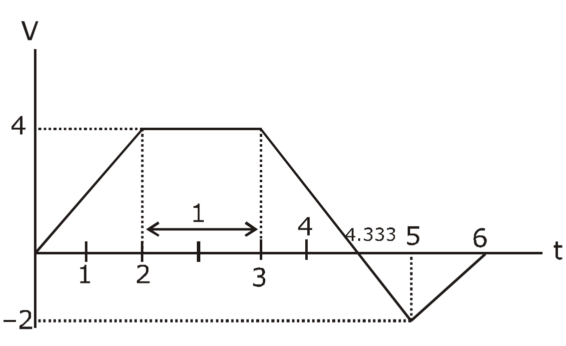
$V_B = 1V$

8. The velocity (v) and time (t) graph of a body in a straight line motion is shown in the figure. The point S is at 4.333 seconds. The total distance covered by the body in 6 s is:



(1) $\frac{37}{3}$m (2) $\frac{49}{4}$m (3) 12 m (4) 11 m

Sol. **1**



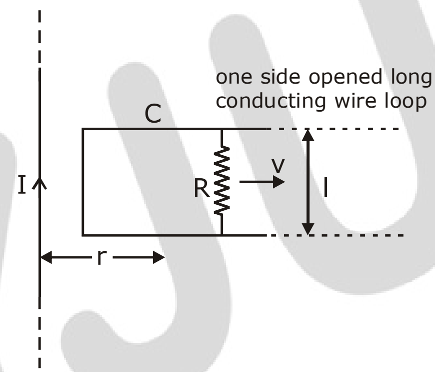
distance = area under graph

$= \frac{1}{2}(4)\left(\frac{13}{3}+1\right) + \left[\frac{1}{2}\left(6-\frac{13}{3}\right)\times 2\right]$

$= 2 \times \frac{16}{3} + \frac{5}{3}$

$= \frac{32}{3} + \frac{5}{3} = \frac{37}{3}$ m

9. An infinitely long straight wire carrying current I, one side opened rectangular loop and a conductor C with a sliding connector are located in the same plane, as shown in the figure. The connector has length l and resistance R. It slides to the right with a velocity v. The resistance of the conductor and the self inductance of the loop are negligible. The induced current in the loop, as a function of separation r, between the connector and the straight wire is:



(1) $\frac{\mu_0}{2\pi}\frac{Ivl}{Rr}$ (2) $\frac{\mu_0}{\pi}\frac{Ivl}{Rr}$ (3) $\frac{2\mu_0}{\pi}\frac{Ivl}{Rr}$ (4) $\frac{\mu_0}{4\pi}\frac{Ivl}{Rr}$

Sol. **1**

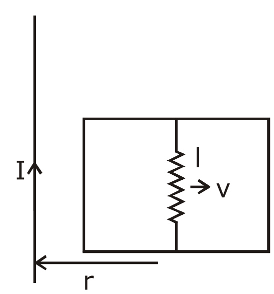
$B = \left(\frac{\mu_0 I}{2\pi r}\right)$

induced emf

e = Bvl

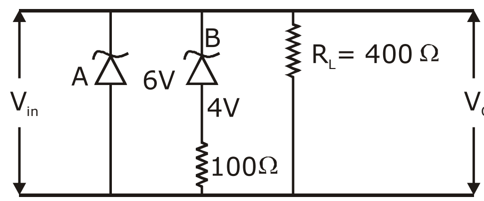
$= \frac{\mu_0 I}{2\pi r}$ V.l

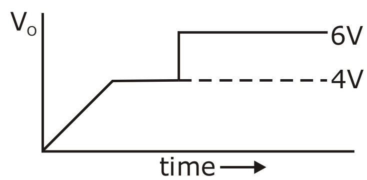
$= \frac{\mu_0 Ivl}{2\pi r}$

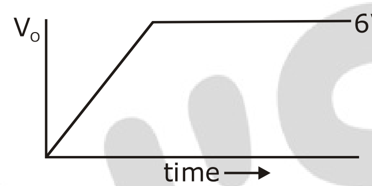


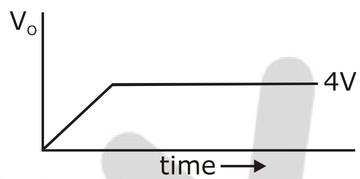
induced current $i = \frac{e}{R} = \frac{\mu_0 Ivl}{2\pi rR}$

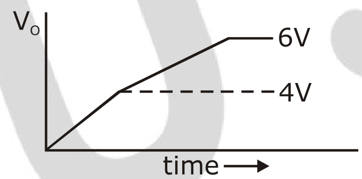
10. Two zener diodes (A and B) having breakdown voltages of 6 V and 4 V respectively, are connected as shown in the circuit below. The output voltage V_O variation with input voltage linearly increasing with time, is given by: (V_{input} = 0 V at t = 0)
(figures are qualitative)



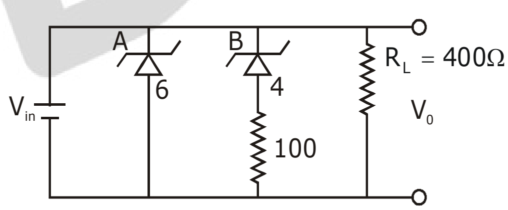
(1)


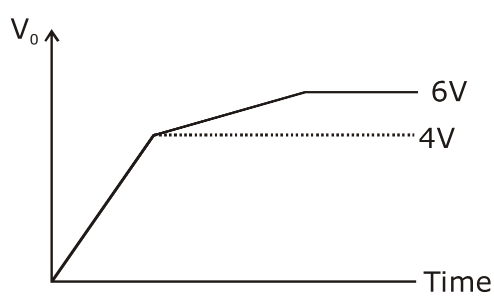
(2)


(3)


(4)


Sol. **(4)**
t = 0
$V_i = 0$
$V_i \propto t$
Given
$\because$ Zenerdiode maintains constant breakdown voltage.





11. In an adiabatic process, the density of a diatomic gas becomes 32 times its initial value. The final pressure of the gas is found to be n times the initial pressure. The value of n is:

(1) 32 (2) $\frac{1}{32}$ (3) 326 (4) 128

Sol. **4**

$PV^{\gamma} = \text{const.}$

$p\left(\rho^{-\gamma}\right) = \text{const.}$

$p_1\left(\rho_1^{-\gamma}\right) = p_2\left(\rho_2^{-\gamma}\right)$ $\gamma = \frac{7}{5}$ for diatomic

$p_0\rho_0^{-7/5} = (np_0)\,(32\rho_0)^{-7/5}$

$\rho_0^{-7/5} = \frac{n}{(32)^{7/5}}\,(\rho_0^{-7/5})$

$n = (2^5)^{7/5} = 2^7 = 128$

12. A galvanometer is used in laboratory for detecting the null point in electrical experiments. If, on passing a current of 6 mA it produces a deflection of 2°, its figure of merit is close to:

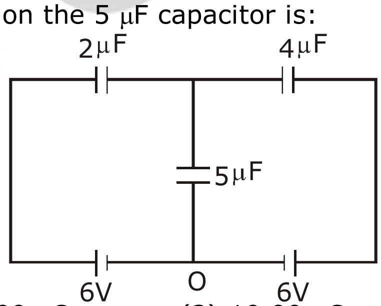
(1) 6×10^{-3} A/div. (2) 3×10^{-3} A/div. (3) 666° A/div. (4) 333° A/div.

Sol. **2**

figure of merit = $\frac{I}{\theta} \Rightarrow$ A/div.

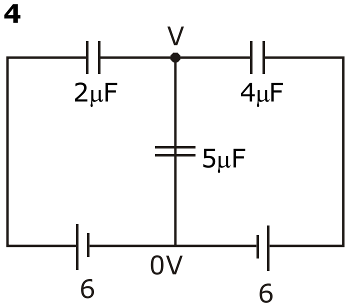
$= \frac{6 \times 10^{-3}}{2} = 3 \times 10^{-3}$ A/div.

13. In the circuit shown, charge on the 5 μF capacitor is:



(1) 5.45 μC (2) 18.00 μC (3) 10.90 μC (4) 16.36 μC

Sol. **4**



$(V - 6) \times 2 + (V - 0) \times 5 + (V - 6)\,4 = 0$

$2V - 12 + 5V + 4V - 24 = 0$

$11V = 36$

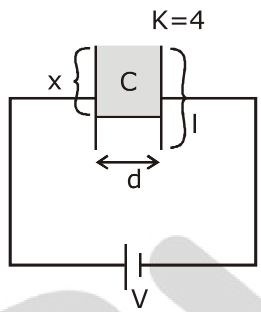
$V = \frac{36}{11}$

$q = CV = 5 \times \frac{36}{11} = 16.36\ \mu C$

14. A parallel plate capacitor has plate of length 'l', width 'w' and separation of plates is 'd'. It is connected to a battery of emf V.A dielectric slab of the same thickness 'd' and of dielectric constant k=4 is being inserted between the plates of the capacitor. At what length of the slab inside plates, will the energy stored in the capacitor be two times the initial energy stored?

(1) 2l/3 (2) l/2 (3) l/4 (4) l/3

Sol. **4**



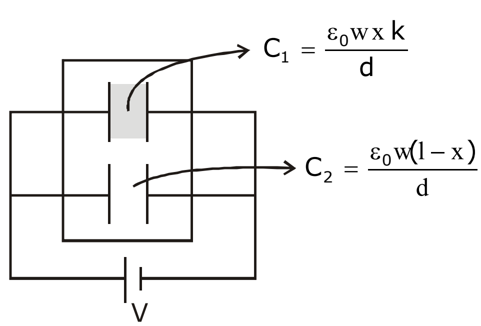
area of plate = lw

$$C = \frac{\varepsilon_0 A}{d} = \frac{\varepsilon_0 lw}{d}$$

$$U_1 = \frac{1}{2} cv^2 = \frac{\frac{1}{2}\varepsilon_0 l\omega}{d} v^2$$

$C_{eq} = C_1 + C_2$

When x length of the slab is inside the capacitor



$C_{eq} = \frac{\varepsilon_0 wxk}{d} + \frac{\varepsilon_0 w(l-x)}{d}$

$C_{eq} = \frac{\varepsilon_0 w}{d}[kx + l - x]$

$U_f = \frac{1}{2}C_{eq}V^2$

$U_f = 2U_i \Rightarrow \frac{1}{2}\frac{\varepsilon_0 w}{d}[kx + l - x]\, v^2 = 2 \times \frac{1}{2}\frac{\varepsilon_0 lw}{d}\, v^2$

$kx + l - x = 2l$

$4x - x = l$

$3x = l$

$x = \frac{l}{3}$

15. A radioactive nucleus decays by two different processes. The half life for the first process is 10 s and that for the second is 100 s. The effective half life of the nucleus is close to:

(1) 55 sec. (2) 6 sec. (3) 12 sec. (4) 9 sec.

Sol. **4**

$T_1 = 10$ sec $\lambda_1 = \frac{\ln 2}{T_1}$

$T_2 = 100s, \lambda_2 = \frac{\ln 2}{T_2}, \lambda_{eq} = \frac{\ln 2}{T_{eq}}$

we know

$\lambda_{eq} = \lambda_1 + \lambda_2$

$\frac{\ln 2}{T_{eq}} = \frac{\ln 2}{T_1} + \frac{\ln 2}{T_2}$

$\frac{1}{T_{eq}} = \frac{1}{10} + \frac{1}{100} = \frac{10+1}{100} = \frac{11}{100}$

$T_{eq} = \frac{100}{11} = 9$ s

16. A driver in a car, approaching a vertical wall notices that the frequency of his car horn, has changed from 440 Hz to 480 Hz, when it gets reflected from the wall. If the speed of sound in air is 345 m/s, then the speed of the car is:

(1) 24 km/hr (2) 36 km/hr (3) 54 km/hr (4) 18 km/hr

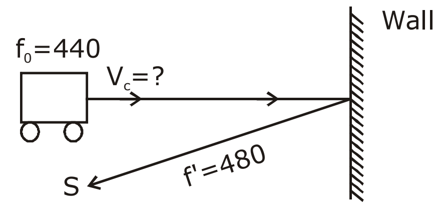
Sol. **3**

car as source, wall as observer

$f_1 = \left(\frac{v-0}{v-v_C}\right) f_0$ ....(i)

for reflected waves, wall is source, driver is observer

$480 = \left(\frac{v+v_c}{v-0}\right) f_1 \Rightarrow \left(\frac{v+v_c}{v}\right)\left(\frac{v}{v-v_c}\right) f_0$



$480 = (345 + V_C) \times \left(\frac{440}{345 - V_C}\right)$

$12 = \left(\frac{345 + V_C}{345 - V_C}\right) \times 11$

$12 \times 345 - 12 \times V_C = 345 \times 11 + 11\, V_C$

$23V_C = 4200 - 3850 = 345$

$V_C = \frac{345}{23}$ m

$V_C = \frac{345}{23} \times \frac{18}{5}$ km/h

$= \frac{70 \times 18}{23}$

$= 54.78$

$= 54$ km/hr

17. An iron rod of volume $10^{-3}m^3$ and relative permeability 1000 is placed as core in a solenoid with 10 turns/cm. If a current of 0.5 A is passed through the solenoid, then the magnetic moment of the rod will be:

(1) 0.5×10^2 Am² (2) 50×10^2 Am² (3) 5×10^2 Am² (4) 500×10^2 Am²

Sol. **3**

magnetic moment $\vec{M} = NIA(\mu_r - 1)$

$= (nl)\, IA\, (\mu_r - 1)$

$= nI\, (Al)\, (\mu_r - 1)$

$= 1000 \times 0.5 \times 10^{-3}\, (1000 - 1)$

$= 0.5 \times (999) = 499.5$

$= 500$

$= 5 \times 10^2$

$n = 10$ turns/cm

$= \frac{10}{10^{-2}}$ turn/m

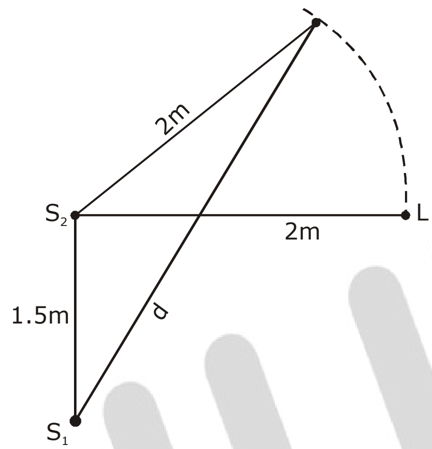
$= 1000$ turn/m

$V = 10^{-3}m^3 = Al$

$I = 0.5A,\ \mu_r$

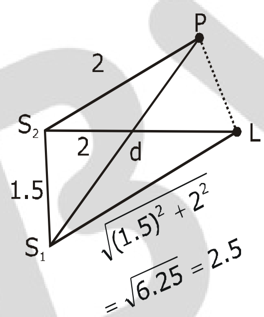
$N = nl$

18. Two coherent sources of sound, S_1 and S_2, produce sound waves of the same wavelength, λ = 1 m, in phase. S_1 and S_2 are placed 1.5 m apart (see fig). A listener, located at L, directly in front of S_2 finds that the intensity is at a minimum when he is 2 m away from S_2. The listener moves away from S_1, keeping his distance from S_2 fixed. The adjacent maximum of intensity is observed when the listener is at a distance d from S_1. Then, d is :



(1) 12 m (2) 2 m (3) 3 m (4) 5 m

Sol. **3**



For min at (L)

$S_1L - S_2L = \Delta x = \dfrac{\lambda}{2}$ (2n + 1);(n = 0, 12)

$2.5 - 2 = \dfrac{1}{2}$ (2n + 1)

$0.5 \times 2 = (2n + 1)$

2n = 0

n = 0 (first minima)

The adjacent maxima is the first maxima.

So at 'p' $\rightarrow$ first maxima

$\Rightarrow$ $S_1P - S_2P = \lambda$ [n = 1] for first maxima

S_1 P – 2 = 1

$S_1P = 1 + 2$

d = 3 m

19. The quantities $x = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$, $y = \frac{E}{B}$ and $z = \frac{L}{CR}$ are defined where C-capacitance, R-Resistance, L-length, E-Electric field, B-magnetic field and ϵ_0, μ_0 -free space permittivity and permeability respectively. Then:

(1) Only y and z have the same dimension
(2) x, y and z have the same dimension
(3) Only x and y have the same dimension
(4) Only x and z have the same dimension

Sol. **2**

$x = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ = (speed)

$[x] = LT^{-1}$ $\quad\quad$ $y = \frac{E}{B}$ = speed

$Z = \frac{l}{CR} = \frac{m}{sec}$ = m/s $\quad\quad$ $[y] = LT^{-1}$

[RC = T]

$[Z] = LT^{-1}$

So, x,y,z has same dimension

20. The acceleration due to gravity on the earth's surface at the poles is g and angular velocity of the earth about the axis passing through the pole is ω. An object is weighed at the equator and at a heigh h above the poles by using a spring balance. If the weights are found to be same, then h is : (h<<R, where R is the radius of the earth)

(1) $\frac{R^2\omega^2}{g}$ $\quad$ (2) $\frac{R^2\omega^2}{8g}$ $\quad$ (3) $\frac{R^2\omega^2}{4g}$ $\quad$ (4) $\frac{R^2\omega^2}{2g}$ \

Sol. **4**

$\because$ weight same at poles and at h (so $g_1 = g_2$)

$g_1 = g - R\omega^2$

$g_2 = g\left(1 - \frac{2h}{R}\right)$

$\because g_1 = g_2$

$g - R\omega^2 = g\left(1 - \frac{2h}{R}\right) \Rightarrow g - \frac{2gh}{R}$

$R\omega^2 = \frac{2gh}{R}$

$h = \frac{R^2\omega^2}{2g}$

21. Nitrogen gas is at 300° C temperature.The temperature (in K) at which the rms speed of a H_2 molecule would be equal to the rms speed of a nitrogen molecule, is _________. (Molar mass of N_2 gas 28 g).

Sol. **41**

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

$$V_{N_2} = \sqrt{\frac{3R(573)}{28}}$$

$$V_{H_2} = \sqrt{\frac{3RT}{2}}$$

$$V_{H_2} = V_{N_2}$$

$$\sqrt{\frac{3RT}{2}} = \sqrt{\frac{3R(573)}{28}}$$

$$\frac{T}{2} = \frac{573}{28}$$

T = 41 K

22. The surface of a metal is illuminated alternately with photons of energies E_1 = 4 eV and E_2 = 2.5 eV respectively. The ratio of maximum speeds of the photoelectrons emitted in the two cases is 2. The work function of the metal in (eV) is _________.

Sol. **2**

$$\frac{\frac{1}{2}mV_1^2}{\frac{1}{2}mV_2^2} = \frac{E_1 - \phi_0}{E_2 - \phi_0} = \frac{4 - \phi_0}{2.5 - \phi_0}$$

$$\left(\frac{V_1}{V_2}\right)^2 = \frac{4 - \phi_0}{2.5 - \phi_0}$$

$$(2)^2 = \frac{4 - \phi_0}{2.5 - \phi_0}$$

$10 - 4\phi_0 = 4 - \phi_0$
$3\phi_0 = 10 - 4 = 6$
$\phi_0 = 2eV$

23. A prism of angle A= 1° has a refractive index μ = 1.5. A good estimate for the minimum angle of deviation (in degrees) is close to N/10. Value of N is

Sol. **5**
A = 1°
$\delta = (\mu - 1) A$
$= (1.5 - 1) A$
$= 0.5 \times 1$

$$= \frac{5}{10} = \frac{N}{10} \text{ so } N = 5$$

24. A body of mass 2 kg is driven by an engine delivering a constant power of 1 J/s. The body starts from rest and moves in a straight line. After 9 seconds, the body has moved a distance (in m) ____________.

Sol. **18**

P = Fv = mav

$a = \frac{p}{mv}$

$\frac{dv}{dt} = \frac{p}{mv}$

$\int_0^u v dv = \frac{p}{m}\int_0^t dt$

$\frac{u^2}{2} = \frac{p}{m}t$

$u = \sqrt{\frac{2p}{m}}\ \sqrt{t}$

$\frac{dx}{dt} = \sqrt{\frac{2p}{m}}\sqrt{t}$

$\int_0^x dx = \sqrt{\frac{2p}{m}}\ \int_0^9 \sqrt{t}dt$

$x = \frac{2}{3}\left[(9)^{1/2}\right]^3$

$= \frac{2}{3} \times 27$

x = 18

II-method

$Pt = w = \frac{1}{2}\ mv^2 - 0$

$1\times t = \frac{1}{2} \times 2 \times u^2$

$u = \sqrt{t}$

$\frac{dx}{dt} = \sqrt{t} = \int_0^1 dx = \int_0^9 \sqrt{t}dt$

$x = \frac{\left[t^{3/2}\right]_0^9}{\frac{3}{2}} = 18\text{ m}$

25. A thin rod of mass 0.9 kg and length 1 m is suspended, at rest, from one end so that it can freely oscillate in the vertical plane. A particle of mass 0.1 kg moving in a straight line with velocity 80 m/s hits the rod at its bottom most point and sticks to it (see figure). The angular speed (in rad/s) of the rod immediately after the collision will be __________.

Sol. **20**

Applying COAM about the Pivot,

$L_i = L_f$

$0.1 \times 80 \times 1 = \dfrac{0.9 \times 1^2}{3} \times \omega + (0.1)\ 1^2\omega$

$8 = (0.3 + 0.1)\ \omega$

$8 = (0.4)\ \omega$

$\omega = \dfrac{80}{4} = 20$