JEE Main September 2020

Question Paper With Text Solution

5 September| Shift-2

PHYSICS

MATRIX

JEE Main & Advanced | XI-XII Foundation| VI-X Pre-Foundation

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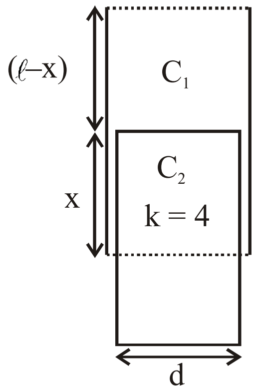
JEE MAIN SEP 2020 | 5 SEP SHIFT-2

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

Ans. (3)

Sol.



$$C_{eq} = C_1 + C_2 = \frac{\varepsilon_0(\ell - x)w}{d} + \frac{k\varepsilon_0 xw}{d}$$

$$\Rightarrow C_{eq} = \frac{\varepsilon_0 w}{d}(\ell + (k-1)x)$$

Energy stored $= \frac{1}{2}C_{eq}(V)^2 = 2$ (Energy initial)

$$\Rightarrow \frac{1}{2}C_{eq}V^2 = 2\left(\frac{1}{2}CV^2\right)$$

$$\Rightarrow C_{eq} = 2C$$

$$\Rightarrow \frac{\varepsilon_0 w}{d}(\ell + 3x) = 2\frac{\varepsilon_0 w\ell}{d}$$

$$\Rightarrow x = \frac{\ell}{3}$$

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

Ans. (2)

Sol. Time period of physical pendulum $T = 2\pi\sqrt{\frac{I}{mgd}}$ where d = R

$T_1 = 2\pi\sqrt{\frac{I_1}{mgd}}$ $\{I_1 = 2mR^2\}$

$T_2 = 2\pi\sqrt{\frac{I_2}{mgd}}$ $\left\{I_2 = \frac{3}{2}mR^2\right\}$

$\therefore \frac{T_1}{T_2} = \sqrt{\frac{I_1}{I_2}} = \frac{2}{\sqrt{3}}$

3. 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)-(iv), (b)-(ii), (c)-(i), (d)-(iii)

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

Ans. (2)

Sol. $E_\gamma > E_x > E_{micro} > E_{radio} \Rightarrow \lambda_\gamma < \lambda_x < \lambda_{micro} < \lambda_{radio}$

4. 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 current of 0.5 A is passed through the solenoid, then the magnetic moment of the rod will be

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

Ans. (3)

Sol. Magnetic susceptibility $\chi = \frac{M}{H}$

Where M = magnetic moment per unit volume $\left(\frac{\mu}{V}\right)$

H = nI (magnetic intensity of solenoid)

$\because\ \chi = (\mu_r - 1)$

$\Rightarrow (\mu_r - 1) = \frac{\mu / V}{H}$

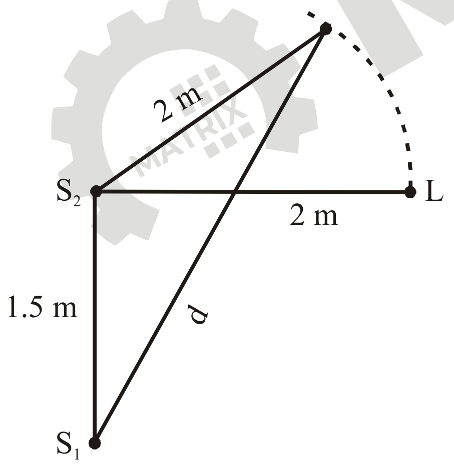
$\Rightarrow \mu = (\mu_r - 1)HV$

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

$\mu = 499.5$

$\mu \simeq 5 \times 10^2\ Am^2$

5. Two coherent sources of sound, S_1 and S_2, produce sound waves of the same wavelength, $\lambda = 1$ 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 distance d from S_1. Then, d is :



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

Ans. (3)

Sol. Initial path difference where minima is observed

$\Delta x_1 = \sqrt{2^2 + 1.5^2} - 2$

$\Delta x_1 = 0.5$ m

Path diffence at new postion where maxima is observed

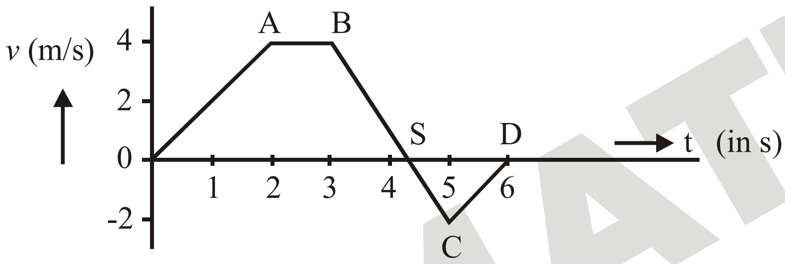
$\Delta x_2 = d - 2$

$\Delta x_2 - \Delta x_1 = \frac{\lambda}{2}$ (Path difference between adjacent maxima and minima is $\frac{\lambda}{2}$)

$\Rightarrow d - 2 - 0.5 = 0.5$

$\Rightarrow d = 3$m

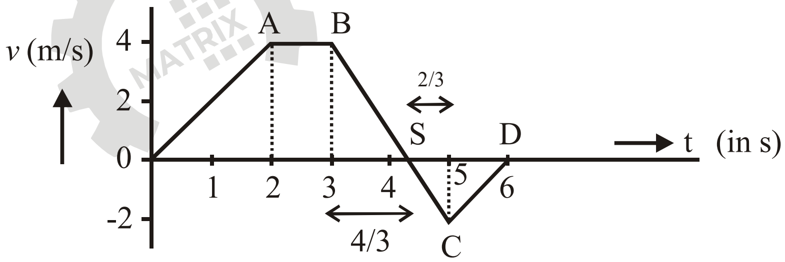
6. The velocity (v) and time (t) graph of a body in a straight line motion is shown in the figure. The point S is at 4.333 seconds. The total distance covered by the body in 6 s is :



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

Ans. (1)

Sol.



distance = sum of magnitude of area of each part in v-t curve.

$$= \frac{1}{2}(2\times 4) + 1\times 4 + \frac{1}{2}(4^2)\left(\frac{4}{3}\right) + \frac{1}{2}(2)\left(\frac{2}{3}\right) + \frac{1}{2}(2)(1)$$

$$= 4 + 4 + \frac{8}{3} + \frac{2}{3} + 1$$

$$= \frac{37}{3}\text{m}$$

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

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

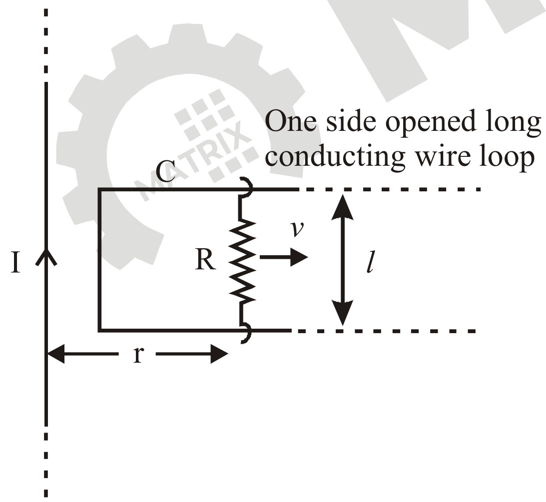
Ans. (3)

Sol. For simultaneous decay

$$\frac{1}{t} = \frac{1}{t_1} + \frac{1}{t_2}$$

$$\Rightarrow t = \frac{1000}{110} \simeq 9\,\text{sec}.$$

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

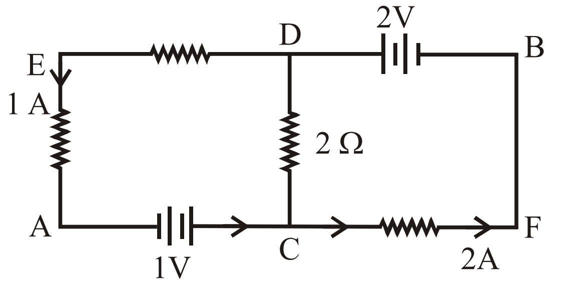
Ans. (1)

Sol. magnetic field due to wire at distance r is $\frac{\mu_0 I}{2\pi r}$

$\varepsilon_{ind} = Bv\ell = \frac{\mu_0 Iv\ell}{2\pi r}$

$I_{ind} = \frac{\varepsilon_{ind}}{R} = \frac{\mu_0}{2\pi}\frac{Iv\ell}{Rr}$

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



(1) -2V (2) +2V (3) +1V (4) -1V

Ans. (3)

Sol. Current in DC = 1A (from D to C using KCl at C)

Now move from A to B via C & D and write all potential changes.

$V_A + 1 + 2 \times 1 - 2 = V_B$

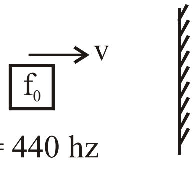
$\Rightarrow V_B - V_A = +1$

10. 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) 54 km/hr (2) 36 km/hr (3) 18 km/hr (4) 24 km/hr

Ans. (1)

Sol.



$f_0 = 440$ hz

f_1 (received by wall) = $f_0\left(\frac{345}{345 - v}\right)$

wall will act as source of frequency f_1

f_2 (received by driver) = $f_1\left(\frac{345+v}{345}\right)$

$\Rightarrow f_2 = f_0\left(\frac{345+v}{345}\right)\left(\frac{345}{345-v}\right)$

$\Rightarrow f_2 = f_0\left(1+\frac{2v}{345}\right)$

$\Rightarrow 480 = 440\left(1+\frac{2v}{345}\right)$ [if V is very small compared to 345]

$\Rightarrow v \simeq 15 m/s$

$\therefore v = 54$ km/hr

11. 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^2 (2) r^4 (3) r^3 (4) r

Ans. (2)

Sol. $v = \sqrt{2gh}$...............(i)

$v = \frac{2r^2 g(d-\rho)}{9\eta}$..............(ii)

from (i) and (ii)

$h = \frac{2r^4 g(d-\rho)^2}{81\eta^2}$

$h \propto r^4$

12. The quantities $x = \frac{1}{\sqrt{\mu_0 \in_0}}$, $y = \frac{E}{B}$ and $z = \frac{l}{CR}$ are defined where C-capacitance, R-Resistance, l-length, E-Electric field, B-magnetic field and $\in_0, \mu_0$, - free space permittivity and permeability respectively. Then :

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

(3) Only *y* and *z* have the same dimension (4) Only *x* and *y* have the same dimension

Ans. (2)

Sol. $x = \frac{l}{\sqrt{\mu_0 \varepsilon_0}}$ speed of light in vacuum

$\therefore [x] = [L^1T^{-1}]$

$y = \frac{E}{B}$ speed of EM wave

$\therefore [y] = [L^1T^{-1}]$

$Z = \frac{l}{RC} = \frac{\text{length}}{\text{time}}$

$\therefore [z] = [L^1T^{-1}]$

x,y,z have same dimensions

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

Ans. (2)

Sol. density becomes 32 times

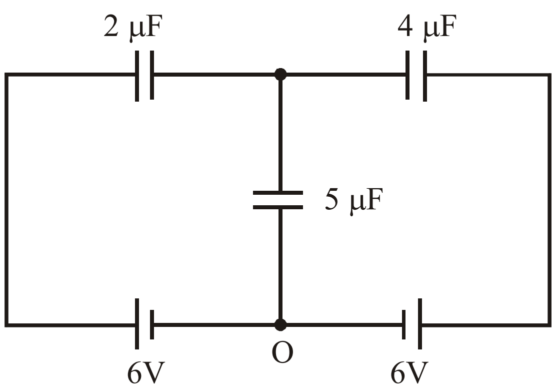
$\Rightarrow$ volume becomes $\frac{1}{32}$ times of initial volume

For adiabatic process

$P_iV_i^{\gamma} = P_fV_f^{\gamma}$ [$\gamma = \frac{7}{5}$ for diatomic gas]

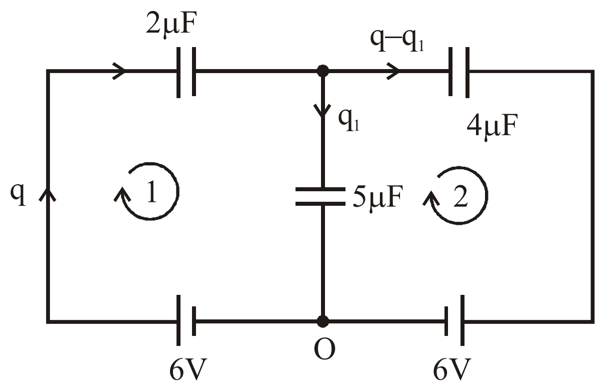
$\Rightarrow \frac{P_f}{p_i} = \left(\frac{V_i}{V_f}\right)^{\gamma} = (32)^{\frac{7}{5}} = 128$

14. In the circuit shown, charge on the 5 μ F capacitor is :



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

Ans. (1)



Applying KVL in loop 1

$$6-\frac{q}{2}-\frac{q_1}{5}=0...........(2)$$

Applying KVL in loop 2

$$-\left(\frac{q-q_1}{4}\right)-6+\frac{q_1}{5}=0...........(2)$$

from (1) and (2) q_1 = 16.36 μC

15. 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) $V=\frac{10q}{4\pi\in_0 R};E=0$

(2) $V=0;E=\frac{10q}{4\pi\in_0 R^2}$

(3) $V=\frac{10q}{4\pi\in_0 R}'E=\frac{10q}{4\pi\in_0 R^2}$

(4) $V=0;E=0$

Ans. (4)

Sol.

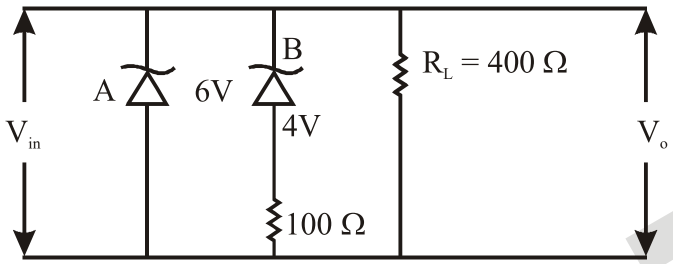
E (centre) due to +ve 5 charges = 0
E (centre) due to –ve 5 charges = 0
∴ E_{net} (centre) = 0
all charges are equidistant from centre

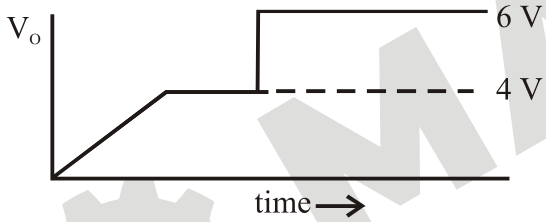
$\therefore V_{centre} = \frac{K(q_{total})}{R} = 0$

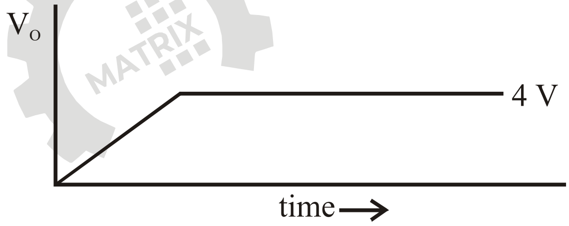
16. Two Zener diodes (A and B) having breakdown voltages of 6 V and 4 V respectively, are connected as shown in the circuit below. The output voltage V_o variation with input voltage linearly increasing with time, is given by :

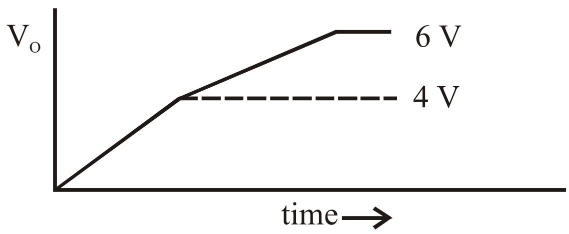
($V_{input} = 0$ V at t = 0)

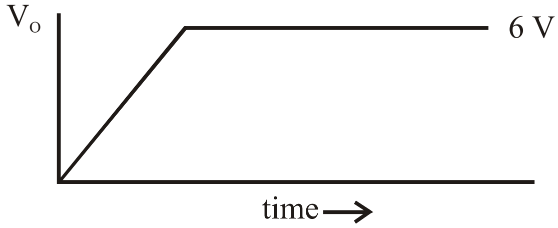
(figures are qualitative)



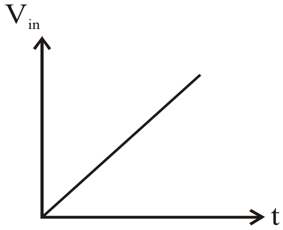
(1)


(2)


(3)


(4) 

Ans. (3)

Sol. 

For V < 4 both diodes are reverse biased but not working in zener region. Output voltage V_0 will be equal to input voltage.
For voltages higher than 4 A will not conduct current but B will work in Zener region and large current will flow through it. So potential will increase but some voltage drop will occur in connecting wires. So slope of V_o vs t will be reduced.
Once both diodes start working in zener region output voatge will become 6 V and will not change.

17. 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 height 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) $\frac{R^2\omega^2}{8g}$ (2) $\frac{R^2\omega^2}{g}$ (3) $\frac{R^2\omega^2}{2g}$ (4) $\frac{R^2\omega^2}{4g}$

Ans. (3)

Sol. At equator $g^1 = g - \omega^2 R$

At a height h above the poles $g^1 = g\left(1-\frac{2h}{R}\right)$

As weight is same so g^1 should be same

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

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

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

Ans. (1)

Sol. $\boxed{m} \xrightarrow{v}$ + dm → $\boxed{m+dm} \xrightarrow{} v + dv$

let us assume dm mass is attached in time dt, $dm = bv^2dt$

Applying conservation of momentum

$mv = (m + dm)(v + dv)$

$\Rightarrow mv = mv + mdv + dmv + dmdv$

$\Rightarrow mdv = -v(dm)$ [dmdv is negligible]

$\Rightarrow mdv = -v\, bv^2dt$

$$\Rightarrow \frac{dv}{dt} = \frac{-bv^3}{m}$$

$$\Rightarrow \text{acceleration} = \frac{-bv^3}{m}$$

19. 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) 666° A/div. (2) 3×10^{-3} A/div. (3) 6×10^{-3} A/div. (4) 333° A/div.

Ans. (2)

Sol. Figure of merit = $\frac{I}{\theta}$

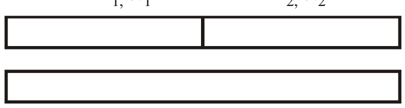
$$= \frac{6\times10^{-3}}{2}$$

$= 3 \times 10^{-3}$ A/degree

20. 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) $2\sqrt{\alpha_1\alpha_2}$ (2) $\frac{\alpha_1+\alpha_2}{2}$ (3) $\frac{\alpha_1L_1+\alpha_2L_2}{L_1+L_2}$ (4) $4\frac{\alpha_1\alpha_2}{\alpha_1+\alpha_2}\frac{L_2L_1}{(L_2+L_1)^2}$

Ans. (3)

Sol. 

α, $L = L_1 + L_2$

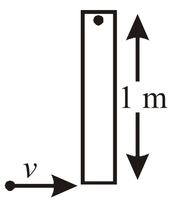
Change in length of equivalent wire = sum of change in length of each wire.

$\Delta L = \Delta L_1 + \Delta L_2$

$\Rightarrow L\alpha\Delta T = L_1 \alpha_1 \Delta T + L_2\alpha_2\Delta T$

$$\Rightarrow \alpha = \frac{\alpha_1 L_1 + \alpha_2 L_2}{L_1 + L_2}$$

21. 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 ______.



Ans. 20

Sol. 

Applying conservation of angular momentum about hinge

$$m_p v l = \left(m_p l^2 + \frac{m_r l^2}{3}\right)\omega$$

$\Rightarrow \omega = 20$ rad/s

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 ______.

Given __

Ans. 2

Sol. Let us assume work function = ϕ

$K_1(max) = 4 - \phi$

$K_2(max) = 2.5 - \phi$

$\because \frac{K_1(max)}{K_2(max)} = 4$ (given ratio of speeds is 2)

$\Rightarrow \frac{4-\phi}{2.5-\phi} = 4$

$\Rightarrow \phi = 2eV$

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 ______.

Ans. 5

Sol. For thin prism deviation

$\delta = (\mu - 1) A = 0.5$

$\therefore N = 5$

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) ______.

Ans. 18

Sol. Work = change in kinetic energy

$\Rightarrow$ Power × time = ΔK

$\Rightarrow 1 \times 9 = \frac{1}{2}(2)(v^2) \Rightarrow v = 3m/s$ (at t = 9s)

we can write $Fv = P \Rightarrow (ma)\,v = P \Rightarrow m\left(v\frac{dv}{ds}\right)v = P$

$\Rightarrow 2v^2dv = ds$

Integrating both sides

$\int_0^3 2v^2dv = \int_0^s ds \Rightarrow s = 18m$

25. 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)

Ans. 41

Sol. $V_{gas} \alpha \sqrt{\frac{T}{M}}$

$V_N \alpha \sqrt{\frac{T_N}{M_N}}$ and $V_H \alpha \sqrt{\frac{T_H}{M_H}}$

$\because V_N = V_H \Rightarrow \sqrt{\frac{T_N}{T_H}} = \sqrt{\frac{M_N}{M_H}}$

$\Rightarrow T_H = \frac{T_N M_H}{M_N} = 573 \times \frac{2}{28}$

$= 40.93$

$\simeq 41$