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NSEP 2026 DETAILED SOLUTION

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INDIAN ASSOCIATION OF PHYSICS TEACHERS

NATIONAL STANDARD EXAMINATION IN PHYSICS (NSEP) 2026

(QUESTION PAPER CODE 64)

Date : 22/11/2026 **Time : 120 Minute** **Maximum Marks: 216**

Write the question paper code (mentioned above) on YOUR OMR Answer Sheet (in the space provided), otherwise your Answer Sheet will NOT be evaluated, Note that the same Question paper code appears on each page of the question paper.

INSTRUCTIONS

1. Use of mobile phone, smart watches, and iPad during examination is STRICTLY **PROHIBITED.**
2. In addition to this question paper, you are given OMR Answer Sheet along with candidate's copy.
3. On the OMR sheet. make all the entries carefully in the space provided ONLY in BLOCK CAPITALS as well as by properly darkening the appropriate bubbles.
   Incomplete/ incorrect/ carelessly filled information may disqualify your candidature.
4. On the OMR Answer sheet, use only **BLUE or BLACK BALL POINT PEN** for making entries and filling bubbles.
5. Your **fourteen-digit roll number and date of birth** entered in the OMR Answer sheet shall remain your login credentials means login id and password respectively for accessing your performance result.
6. Question paper has two parts. In part A1 (**Q. No.1 to 48**) each question has four alternatives, out of which only one is correct. Choose the correct alternative (s) and fill the appropriate bubbles(s), as shown.

   Q.No.22 

   In part A2 (**Q. No. 49 to 60**) each question has four alternative out of which any number of alternative (s) (1, 2, 3, or 4) may be correct. You have to choose all correct alternative(s) and fill the appropriate bubbles(s), as shown

   Q.No.54 

7. For **Part A1,** each correct answer carries 3 marks whereas 1 mark will be deducted for each wrong answer. In **Part A2,** you get 6 marks. If all the correct alternative are marked. No negative marks in this part.
8. Rough work should be done only in the space provided. There are **49** printed pages in this paper.
9. Use of **non-programmable scientific** calculator is allowed
10. No candidate should leave the examination hall before the completion of the examination.
11. After submitting answer paper, take away the question paper & candidate's copy of OMR for your reference

    Please DO NOT make any mark other than filling the appropriate bubbles properly in the space provided on the OMR answer sheet.

    OMR answer sheets are evaluated using machine, hence CHANGE OF ENTRY IS NOT ALLOWED, Scratching or overwriting may result in wrong score.

    DO NOT WRITE ON THE BACK SIDE OF THE OMR ANSWER SHEET.

Name of Student :.....

Batch : .....

Enrolment No. | | | | | | | | | | | | | | | |

INDIAN ASSOCIATION OF PHYSICS TEACHERS

NATIONAL STANDARD EXAMINATION IN PHYSICS (NSEP) 2026

PAPER CODE-64

Date of Examination – 22nd November, 2026

SOLUTIONS

Attempt All Sixty Questions

(NSEP) PART : A–1

ONLY ONE OUT OF FOUR OPTIONS IS CORRECT, BUBLE THE CORRECT OPTION.

[Q.1] In order to form standing waves in a medium, the following two waves are superposed

$y_1 = A\sin\pi(5x + 100t + 0.8)$

$y_2 = A\sin\pi(5x - 100t)$

the variables x and y are in meter and t in second. The correct statement is that the

[A] positions of first two displacement nodes (for x > 0) are x = 2 cm and x = 22 cm respectively

[B] velocity amplitude is maximum at both the positions (for x > 0) x = 12 cm and x = 22cm

[C] pressure variation is maximum at both the positions (for x > 0) x = 22 cm and x = 32 cm

[D] positions of first two displacement antinodes (for x > 0) are x = 2 cm and x = 22 cm respectively

[ANS] **D**

[SOLN] $y_1 = A\sin(\pi 5x + 100\pi t + 0.8\pi)$

$y_2 = A\sin(\pi 5x - 100t)$

$y_R = y_1 + y_2 = 2A\sin(5\pi x + \pi\times 0.4)\cos(100\pi t + 0.4)$

$\text{Amplitude}(A_R)$

For, Nodel $A_R = 0$

$5\pi x + 0.4\pi = n\pi$

$x = \left[\frac{n - 0.4}{5}\right]$

For, $x > 0$,

$n = 1 \Rightarrow x = 12\,\text{cm}$

$n = 2 \Rightarrow x = 32\,\text{cm}$

And For anti-nodes

$5\pi x + 0.4x = (2n+1)\frac{\pi}{2}$

$x = \frac{n + 0.1}{5}\text{m, for } x > 0$

$n = 0, x = 2\,\text{cm}$

$n = 1, x = 22\,\text{cm}$

[Q.2] The density ρ of a solid sphere, of mass M and radius R, varies radially according $\rho = \rho_0\left(1-\frac{r}{2R}\right)$ where ρ_0 is a constant. The moment of inertia of this sphere about a diameter is $I = \alpha MR^2$ with α equal to

[A] 28/125 [B] 28/75 [C] 7/25 [D] 7/50

[ANS] **B**

[SOLN] $M = \int dM = \int_0^R \rho_0\left[1-\frac{r}{2R}\right]4\pi r^2 dr$

$$M = \rho_0 4\pi\left[\frac{R^3}{3}-\frac{R^3}{8}\right]$$

$$M = \frac{20\pi\rho_0 R^3}{24} \Rightarrow \rho_0\pi R^3 = \frac{24M}{20}$$

And $I = \int dI = \int_0^R \frac{2}{3}\rho_0\left(1-\frac{r}{2R}\right)4\pi r^2 - r^2 dr = \rho_0\frac{2}{3}\times 4\pi\int_0^R\left(r^4-\frac{r^5}{2R}\right)dr$

$$= \rho_0\frac{8\pi}{3}\times\left[\frac{R^5}{5}-\frac{R^5}{12}\right]$$

$$I = \rho_0\frac{8\pi}{3}\times R^5\times\frac{7}{60} = \frac{24M}{20}\times\frac{8}{3}\times\frac{7}{60}\times R^2$$

$$I = \frac{28}{75}MR^2$$

[Q.3] The magnetic field vector in a plane electromagnetic wave is given by $B = 2\times 10^{-7}\sin(kx+\omega t)\hat{j}T$. It is given that speed of wave is $c = 3.00\times 10^8\ ms^{-1}$ and $\omega = 1.50\times 10^{11}s^{-1}$

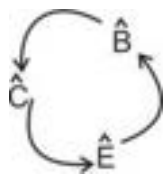
[A] The wavelength of the wave is 2 mm

[B] The frequency of the wave is nearly 2.39 GHz

[C] The electric field of the wave is $\vec{E} = 60\sin(kx-\omega t)\hat{k}\,Vm^{-1}$

[D] The electric field of the wave is $\vec{E} = 60\sin(\omega x+kx)\hat{k}\,Vm^{-1}$

[ANS] **D**

[SOLN] 

$$E = \hat{j}\times(-\hat{i}) = \hat{k}$$

$$\vec{B} = 2\times10^{-7}\sin(kx+\omega t)\hat{j}$$

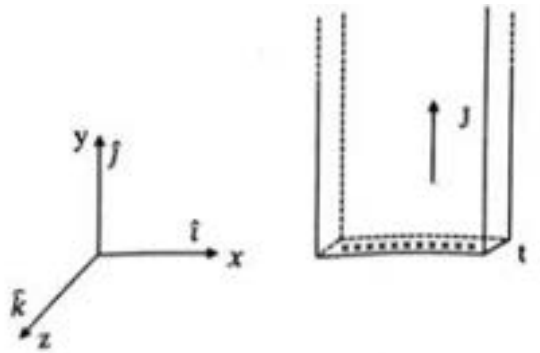
$$\vec{E} = 2\times10^{-7}C\sin(kx+\omega t)\hat{k}$$

$$= 60\sin(kx+\omega t)\hat{k}\ V/m \quad \Rightarrow c = \frac{\omega}{k},\ k = \frac{1.5\times10^{11}}{3\times10^{8}} = 500$$

$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{500} = 0.012m$$

$$f = \frac{\omega}{2\pi} = \frac{1.5\times10^{11}}{2\pi} = 0.238\times10^{11}Hz$$

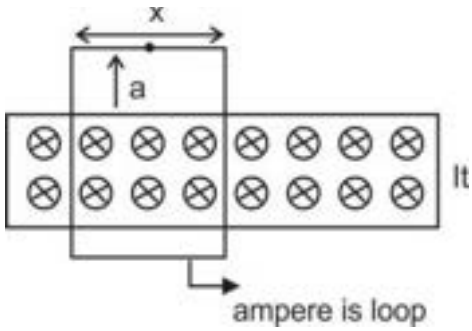
[Q.4] A thin metal plate of infinite length extending in positive y direction carries a current of current density J all along its length as shown. The very small thickness of the plate is t. The breadth (much larger than thickness) of the plate lies exactly along the x axis. The magnetic field produced at a small distance 'a' above and very close to the surface of the plate is



[A] $-\frac{\mu_0 Jt}{2}\hat{i}$ [B] $+\frac{\mu_0 Jt}{2}\hat{i}$ [C] $+\frac{\mu_0 Jt}{2a}\hat{k}$ [D] $+\frac{\mu_0 Jt}{a}\hat{i}$

[ANS] **B**

[SOLN] **Magnetic field due to plate.**



$$\int \vec{B}.\vec{dt} = \mu_0 i_{inside}$$

$$2Bx = \mu_0 J.x.t$$

$$B = \frac{\mu_0 J}{2}\hat{i}$$

[Q.5] An astronomical telescope is used to view an object of size 4 cm kept at a distance of 20 m. The focal lengths of the objective and the eyepiece are 80 cm and 5 cm respectively. The final image is 25 cm from the eyepiece (with the eye close to the eyepiece).

Statement 1: The size of the final image is 1.0 cm

Statement 2: The angular magnification is numerically 20

[A] Both statements 1 and 2 are wrong

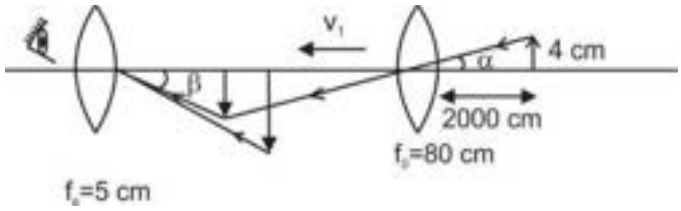
[B] Statement I is correct but statement 2 is wrong

[C] Statement 1 is wrong but statement 2 is correct

[D] Both statements 1 and 2 are correct

[ANS]

[SOLN]



$$\frac{1}{v_1}-\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{v_1}-\frac{1}{-2000}=\frac{1}{80}$$

$$\frac{1}{v_1}=\frac{1}{80}-\frac{1}{2000}=\frac{1}{80}\left[1-\frac{1}{25}\right]$$

$$\Rightarrow V_1=\frac{2000}{24}$$

Magnification of objective lens $=\frac{v_1}{-2000}=\frac{2000/24}{-2000}=\frac{-1}{24}$

And Magnification of eyepiece lens = $1+\frac{D}{fe}=1+\frac{25}{5}=6$

$$M_{net}=\frac{-1}{24}\times 6=\frac{-1}{4}$$

So, final height of image $H_I=M_{net}\times h_0=\frac{-4}{4}=-1\text{cm}$

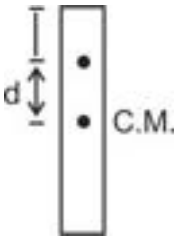
And angular magnification = $\left|\frac{\beta}{\alpha}\right|=\left|\frac{h_I/D}{\frac{4}{2000}}\right|=\frac{\frac{1}{25}}{4/2000}=20$

[Q.6]. A uniform rod of mass M and length L is hinged freely on a horizontal peg at a variable distance ξ one of its ends, so as to execute SHM with small angular amplitude in a vertical plane about the horizontal axis with time period T. If the minimum value of its time period $T_{min}=1.0\,\text{sec ond}$, the approximate value of L is

[A] 24.8 cm [B] 43.0 cm [C] 56.8 cm [D] 99.2 cm

[ANS] **B**

[SOLN]



$$T = 2\pi\sqrt{\frac{I_{cm} + Md^2}{mgd}} = 2\pi\sqrt{\frac{\frac{ML^2}{12d} + Md}{Mg}}$$

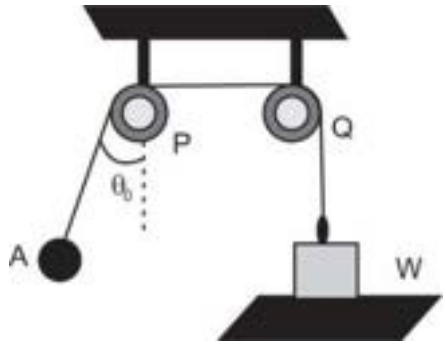
For, $T_{min}\ \frac{L^2}{12d} = d \Rightarrow d = \frac{L}{\sqrt{12}}$

And $T_{min} = 2\pi\sqrt{\frac{2d}{g}} = 1$

$$\Rightarrow \frac{2d}{g} = \frac{1}{4\pi^2}$$

$$\Rightarrow L = \sqrt{12}d = \sqrt{12} \times \frac{g}{8\pi^2} = 43\text{cm}$$

[Q.7] P and Q are two smooth weightless pulleys attached to the ceiling as shown. An un-stretchable, light string passes over both the pulleys. A weight W = 40 kg, resting on the floor, is tied to one end of the string. A ball of mass 20 kg is attached, at the other end A. The string PA is deflected by angle θ_0 when the ball A is released from rest. The ball at the end A is capable of just lifting up the weight W for the value of θ_0



[A] = 30° [B] = 45° [C] $\leq 53°$ [D] $\geq 60°$

[ANS] **D**

[SOLN] **To Lift block W**

$T \geq 40g$

No just capable is asking so, we must evaluate T at bottom that means,

$$T - m_A g = \frac{m_A v^2}{l} = 2m_A g(1 - \cos\theta)$$

And $\frac{1}{2}m_A V^2 = m_A gl(1-\cos\theta_0)$

$\Rightarrow T = m_A g(3-2\cos\theta) \geq 40g$

$\Rightarrow 20(3-2\cos\theta) \geq 40 \Rightarrow 3-2\cos\theta \geq 2$

$\cos\theta \leq \frac{1}{2} \Rightarrow \theta \geq 60°$

[Q.8] The position vector $\vec{r}$ of a particle of mass m moving in XY plane is given as a function of time by $\vec{r} = R(\omega t - \sin\omega t)\hat{i} + R(1-\cos\omega t)\hat{j}$ where R and ω are positive constants. The particle is momentarily at rest when

[A] $t = \frac{n\pi}{\omega}$ where n=1,3,5.....

[B] y component of $\vec{r}$ is $= 2R\hat{j}$

[C] the acceleration $\vec{a} = \omega^2 R\hat{j}$

[D] the acceleration $\vec{a} = -\omega^2 R\hat{j}$

[ANS] **C**

[SOLN] $\vec{r} = R(\omega t - \sin\omega t)\hat{i} + R(1-\cos\omega t)\hat{j}$

$\vec{v} = \frac{d\vec{r}}{dt} = R(\omega - \cos\omega t)\hat{i} + R(0+\omega\sin\omega t)\hat{j}$

Momentarily at rest, when $\vec{v} = 0$

$\omega t = 2n\pi$

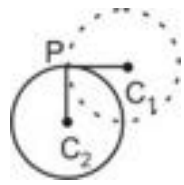
$t = \frac{2n\pi}{\omega} = 0, \frac{2\pi}{\omega}, \& \frac{4\pi}{\omega}, ...$

So, $t = 0, \frac{2\pi}{\omega}, \frac{4\pi}{\omega}, ...$

$\vec{a} = \frac{d\vec{v}}{dt} = R(+\omega^2\sin\omega t)\hat{i} + R(\omega^2\cos\omega t)\hat{j}$

$\vec{a} = \omega^2 R\hat{j}$ and $r_y = R(1-\cos\omega t)\hat{j} = 0$

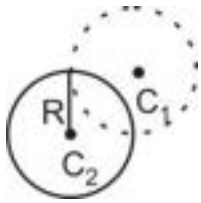
[Q.9] A thin circular disk of mass m and radius R can rotate freely in a vertical plane about a pivot P on its rim (as in the figure). It is released when its centre is at C_1 at the level of the pivot in a vertical plane. The speed of the lowest point of the disk when the centre is vertically below the pivot P at C_2 is



[A] $\sqrt{\frac{4gR}{3}}$ [B] $\sqrt{4gR}$ [C] $\sqrt{2gR}$ [D] $\sqrt{\frac{16gR}{3}}$

[ANS] **D**

[SOLN]



$$MgR = \frac{1}{2}\left(\frac{MR^2}{2} + MR^2\right)\omega^2$$

$$\omega = \sqrt{\frac{4gR}{3}},\ V_{lowest} = \omega(2R) = \sqrt{\frac{16gR}{3}}$$

[Q.10] A charge q is uniformly distributed over the surface of a thin circular disk of radius R. The disk rotates about its own axis with an angular velocity ω rad/s, maintaining its axis normal to a uniform magnetic field B. The magnitude of the torque acting on the charged disk is

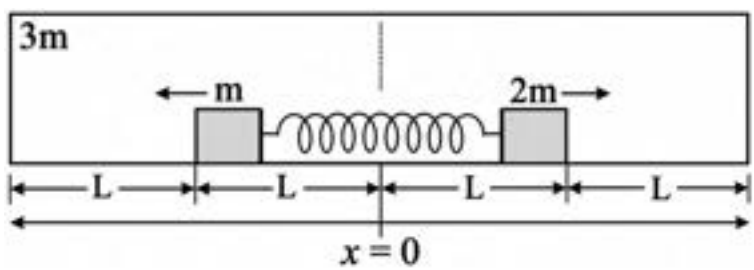
[A] zero [B] $\frac{q\omega R^4 B}{4}$ [C] $\frac{q\omega R^2 B}{4}$ [D] $\frac{q\omega R^2 B}{2}$

[ANS] **C**

[SOLN] $\mu = \left[\frac{q}{2m}\right]^{L} = \frac{q}{2m}\left[\frac{1}{2}Mr^2.\omega\right]$

$$\vec{\tau} = \vec{\mu} \times \vec{B} = \mu B \sin 90^\circ = \frac{q\omega R^2 B}{4}$$

[Q.11] Two rectangular blocks of masses m and 2m are held against a massless compressed spring within a box of mass 3m and length 4L. The box as well as the two blocks are free to move on a horizontal frictionless surface along the x-axis. Just when the blocks leave contact with the spring, each block is at a distance L from the wall of the box in front of it and the centre of the box is at origin x = 0 (see figure). When released, each block moves its own way, collides with the front wall and immediately sticks to it. The position of the centre of the box in the process shifts to



[A] $x = -\frac{L}{2}$ [B] $x = +\frac{L}{3}$ [C] $x = +\frac{L}{6}$ [D] $x = -\frac{L}{6}$

[ANS] **D**

[SOLN] Let's assume that box moves distance 'x' left side

So, by the conservation of Law of momentum.

$m_1\Delta x_1 + m_2\Delta x_2 + m_3\Delta x_3 = 0$

$2m(L - x) + m(-L - x) + 3m(-x) = 0$

$$x = \frac{mL}{2m + m + 3m} \Rightarrow x = \frac{L}{6}(\text{Left word})$$

[Q.12] ${}_1H^3$ and ${}_2He^3$ have almost same atomic mass. ${}_1H^3$ contains one proton, one electron and 2 neutrons while ${}_2He^3$ has two protons, two electrons and one neutron. Knowing that the mass of a neutron is slightly greater than that of the proton, the estimation of the nuclear binding energy in the two cases reveals that

[A] the binding energy of the nucleus of ${}_1H^3$ is equal to that of ${}_2He^3$ nucleus

[B] the binding energy of the nucleus of ${}_1H^3$ is less that that of ${}_2He^3$ nucleus

[C] the binding energy of the nucleus of ${}_1H^3$ is greater than that of ${}_2He^3$ nucleus

[D] the data is insufficient to predict any information about the binding energy

[ANS] **C**

[SOLN] Binding energy of ${}_1H^3 = [1\ m_p + 2m_n - m({}_1H^3)]C^2$

Binding energy of ${}_2He^3 = [2m_p + m_n - m({}_2He^3)]C^2$

Given that $m({}_1H^3) = m({}_2He^3)$

So, Now comparison is between $1\ m_p + 2m_n = m_p + m_n + m_n$

& $2m_p + m_n = (m_p + m_n + m_p)$

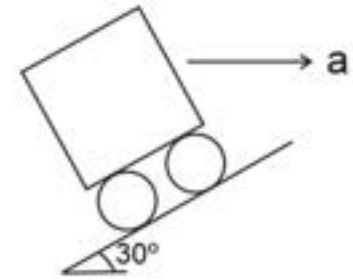
So, Clearly Binding energy of ${}_1H^3$ > Binding energy of ${}_2He^3$

[Q.13] A spherical bob of mass 0.20 kg and diameter 2.0 cm, having uniform density, is attached to the end of a string of length 100 cm. This pendulum so formed is suspended from the ceiling of an elevator. The elevator is moving upward with an acceleration of 5.4 ms^{-2} along an incline which makes an angle of 64 degree with vertical. The pendulum is made to oscillate about its mean position. Assuming that there is no aerial friction, the time period of oscillation of the pendulum is (given that acceleration due to gravity is 9.8 ms^{-2})

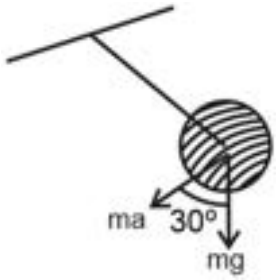
[A] 1.28 s [B] 1.26 s [C] 1.59 s [D] 1.79 s

[ANS] **D**

[SOLN]



$$T = 2\pi\sqrt{\frac{\ell}{geff}}$$



$$geff = \sqrt{a^2 + g^2 + 2ag\cos 60^\circ}$$

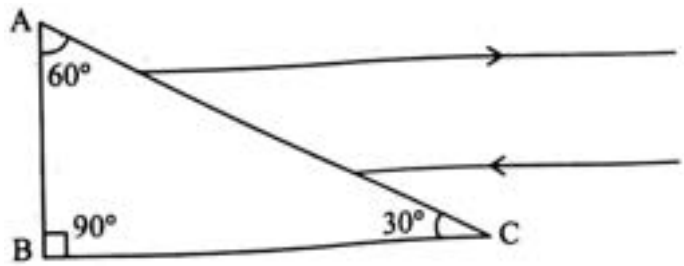
$$= \sqrt{(5.4)^2 + (9.8)^2 + 2\times 5.4\times 9.8\times \frac{1}{2}}$$

= 13.346

ℓ = 100cm + 1 cm $\approx$ 100 cm = 1 m

$$T = 2\pi\sqrt{\frac{1}{13.346}} \approx 1.79 \text{ sec}$$

[Q.14] When light is incident on an interface between two media at an angle greater than $\theta_c \equiv \sin^{-1}\frac{1}{\mu}$ (where μ is the relative refractive index of the two media), it is totally reflected –a phenomenon known as total internal reflection. If the angle of incidence is smaller than θ_c light is partly reflected and partly refracted. A ray of light incident, parallel to the base, on a 30º – 90º – 60º prism, as shown suffers two total internal reflections before emerging parallel but reversed in direction.

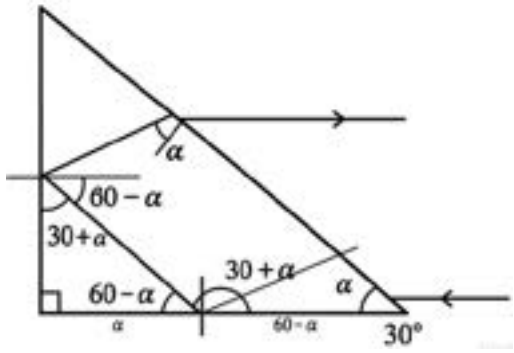


The condition on the critical angle for this to be possible is:

[A] $\tan\theta_c < \frac{\sqrt{3}}{1+\sqrt{3}}$ [B] $\tan\theta_c > \frac{\sqrt{3}}{1+\sqrt{3}}$ [C] $\sin\theta_c = \frac{\sqrt{3}}{1+\sqrt{3}}$ [D] $\sin\theta_c > \frac{\sqrt{3}}{1+\sqrt{3}}$

[ANS] **B**

[SOLN]



$$\sin 60^\circ = \mu \sin\alpha = \frac{\sqrt{3}}{2}$$

$$\sin(30+\alpha) \geq \frac{1}{\mu} \;\&\; \sin(60-\alpha) \geq \frac{1}{\mu}$$

$$\Rightarrow \sin\theta_c \geq \frac{\sin\alpha}{\frac{\sqrt{3}}{2}}$$

$$\sin\theta_c \geq \frac{2}{\sqrt{3}}\sin(\theta_c - 30^\circ)$$

$$\sin\theta_c \geq \frac{2}{\sqrt{3}}\left(\sin\theta_c \times \frac{\sqrt{3}}{2} - \cos\theta_c \times \frac{1}{2}\right)$$

$$\tan\theta_c \geq 1 - \frac{1}{\sqrt{3}}$$

$$\sin\theta_c \geq \frac{2}{\sqrt{3}}\sin(60-\theta_c)$$

$$\sin\theta_c \geq \frac{2}{\sqrt{3}}\left[\frac{\sqrt{3}}{2}\cos\theta_c - \frac{1}{2}\sin\theta_c\right]$$

$$\tan\theta_c \geq 1 - \frac{1}{\sqrt{3}}\tan\theta_c$$

$$\tan\theta_c\left[1 + \frac{1}{\sqrt{3}}\right] \geq 1$$

$$\tan\theta_c \geq \frac{\sqrt{3}}{1+\sqrt{3}}$$

[Q.15] A moving coil galvanometer has a coil with 175 turns and area 1 cm^2. It uses a torsion band of torsion constant 10^{-6} Nm/rad. The coil is placed in a magnetic field B parallel to its plane. The coil deflects by 1° for a current of 1 mA. The value of the magnetic field B (in Tesla) is approximately

[A] 10^{-2} [B] 10^{-3} [C] 10^{-1} [D] 10^{-4}

[ANS] **B**

[SOLN] $NIAB = C\theta$

$$B = \frac{C\theta}{NIA} = \frac{10^{-6} \times 1^{o} \times \frac{\pi}{180}}{175 \times 1 \times 10^{-3} \times 1 \times 10^{-4}} = 1 \times 10^{-3} T$$

[Q.16] Charge Q coulomb is uniformly distributed throughout the volume of a solid hemisphere of radius R meter. The potential at the centre 'O' of the hemisphere in volts is



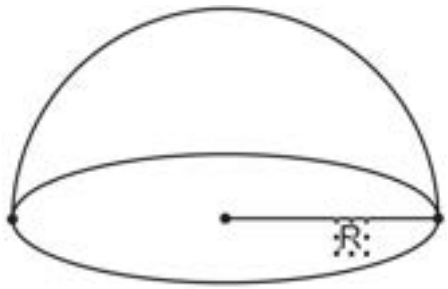
[A] $\frac{1}{4\pi\in_0}\frac{3Q}{2R}$ [B] $\frac{1}{4\pi\in_0}\frac{3Q}{4R}$ [C] $\frac{1}{4\pi\in_0}\frac{Q}{4R}$ [D] $\frac{1}{4\pi\in_0}\frac{Q}{8R}$

[ANS] **A**

[SOLN] for a solid sphere

$$V_C = \frac{9}{2} V_S$$

$$V_C = \frac{3}{2}\frac{K\theta \text{ total}}{R}$$



Solid Hemisphere has total

Charge = Q

For full S.S = 2Q

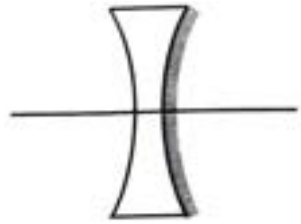
$$V_C = \frac{3}{2}\frac{K(2\theta)}{R}$$

$$= \frac{3K\theta}{R}$$

$\therefore$ due to solid Hemisphere $V_O = \frac{3}{2}\frac{K\theta}{R}$

$$= \left(\frac{3}{2}\frac{\theta}{R}\right)\frac{1}{4\varepsilon_0}$$

[Q.17] The rear surface of an equi-concave lens of radius of curvature R and refractive index μ has been silvered: the lens behaves as a mirror. The focal length and the nature of the resulting mirror are



[A] $\frac{R}{2(2\mu-3)}$ converging

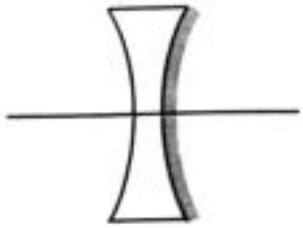
[B] $\frac{R}{2(2\mu-1)}$ converging

[C] $\frac{R}{2(2\mu+1)}$ diverging

[D] $\frac{R}{2(2\mu-1)}$ diverging

[ANS] **D**

[SOLN]



$P_{eq} = 2P_l + P_m$

$$P_{eq} = 2\left(\frac{-2(\mu-1)}{R}\right) - \frac{2}{R}$$

and $P_{eq} = -\frac{1}{f_{eq}}$

$$-\frac{1}{f_{eq}} = \frac{-2(2\mu-1)}{R}$$

$$\frac{1}{f_\ell} = (\mu-1)\left(\frac{1}{-R} - \frac{1}{R}\right)$$

$$\frac{1}{f_\ell} = \frac{-2(\mu-1)}{R}$$

$$P_\ell = \frac{-2(\mu-1)}{R}$$

$$P_m = \frac{-2}{R}$$

$$f_{eq} = \frac{R}{2(2\mu-1)}$$

[Q.18] In Milikan's oil drop experiment, a charged drop falls vertically down with a terminal velocity v. If an electric field E is applied vertically upward, it moves with terminal velocity 2v in the upward direction. If the electric field reduces to $\frac{E}{2}$ then the terminal velocity of the drop becomes

[A] v [B] 2v [C] $\frac{3}{2}$v [D] $\frac{v}{2}$

[ANS] **D**

[SOLN] When no E.Field

$f_V = 6\pi nrV_T$

$fV = k_V$ {where $K = 6\pi nr$ }

$\therefore$ $mg = kV$ ---------- (1)

Case – 1 when E ↑ (upward)

↑ qE $qE = mg + 2kV$

↓ ↓

Mg K(2V) $qE = 3kV$ ---------(2)

Case – 2

$E.f = \frac{E}{2}$

$fe = q\left(\frac{E}{2}\right) = \frac{3kV}{2}$

so,

$$\frac{qE}{2} = mg + KV^{I}$$

$$\frac{3kV}{2} = KV + KV^{I}$$

$$\frac{3}{2}V = V + V^{I}$$

$V' = 0.5\ V$

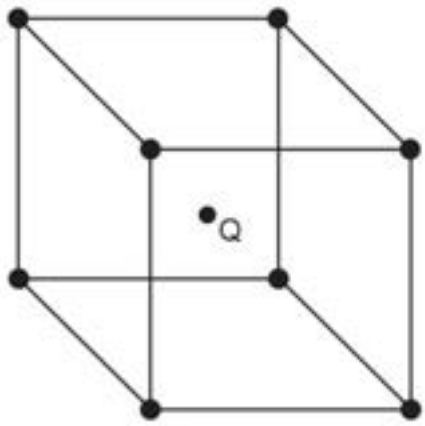
$$\boxed{V^{I} = \frac{V}{2}}$$

[Q.19] Seven equal positive charges of magnitude q each are placed at the seven comers of a cube of side ℓ. The force experienced by a charge Q placed at the centre of the cube is $\left(\text{given } K = \frac{1}{4\pi \in_0}\right)$

[A] Zero [B] $\frac{2KQq}{3\ell^2}$ [C] $\frac{4KQq}{3\ell^2}$ [D] $\frac{7KQq}{3\ell^2}$

[ANS] **C**

[SOLN]



Distance from centre to any corner = $\frac{\text{diagonal}}{2}$

IFF all corner have change then net force = 0

$\vec{F}_{\text{seven change}} + \vec{F}_{\text{missing}} = 0$

$\left|\vec{F}_{\text{seven change}}\right| = \left|-\vec{F}_{\text{due to 1 missing change}}\right|$

$= \frac{KQ \cdot q}{\left(\frac{\sqrt{3}\ell}{2}\right)^2}$

$= \frac{4KQq}{3\ell^2}$

[Q.20] The magnetic moment (p_m) and the moment of inertia (I) of a magnetic needle are $p_m = 8.7 \times 10^{-2}$ A.m^2 and I = 11.5×10^{-6} kg.m^2 respectively. The magnetic needle performs 10 complete oscillations in 6.70 s when suspended in a uniform horizontal magnetic field B. The magnitude of the magnetic field is

[A] 2.10 mT [B] 11.6 mT [C] 11.6 T [D] 1.5 T

[ANS] **B**

[SOLN] Given

$p_m = 8.7 \times 10^{-2}\ A.m^2$

$I = 11.5 \times 10^{-6}\ kg - m^2$

No of oscillation = 10

$\Rightarrow$ Time period = $\frac{6.70}{10} = 0.67$ sec

and $T = 2\pi\sqrt{\frac{I}{P_n B}}$

$T^2 = \frac{4\pi^2 I}{P_n B}$

$B = \frac{4\pi^2 I}{T^2 P_m} = \frac{4\times(3.14)^2 + 11.5\times 10^{-6}}{(0.67)^2 \times 3.7 \times 10^{-2}}$

= 0.0116 T

= 11.6 mT

[Q.21] Work function of metal A is equal to the ionization energy of the hydrogen atom in the first excited state. Work function of metal B is equal to the ionization energy of singly-ionised helium atom in the second orbit. Photons of the same energy E are incident on the two metals A and B. Maximum kinetic energy of photoelectron emitted from metal A is twice that of the photoelectrons emitted from metal B. The value of the photon energy E is

[A] 20.8 eV [B] 32.2 eV [C] 24.6 eV [D] 23.8 eV

[ANS] **D**

[SOLN] $\phi_A =$ I. E. of first excited state of hydrogen

$\phi_A = \frac{13.6\times(1)^2}{(2)^2}\text{eV} = 3.43\,\text{eV}$ $\phi_B = \frac{13.6\times(2)^2}{(2)^2}$ $\phi_B = 13.6\,\text{eV}$

Photons of same every strikes both (A & B)

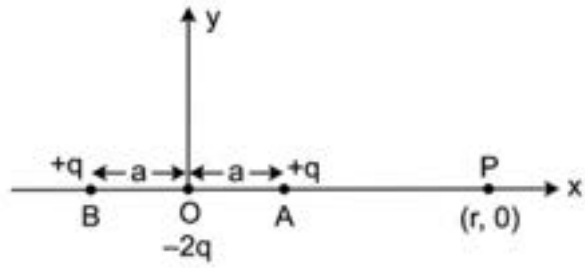
Given : $(K_{max})_A = 2(K_{max})_B$

$(E_{in} - \phi_A) = 2(E_{in} - \phi_B)$ $E - 3.4 = 2E - 27.2$ $E = 23.8$ eV

[Q.22] The figure shows an arrangement of charges [−2q at O (0, 0), +q at A (a, 0) and +q at B (−a, 0)]. The electric field E at point P (r, 0) can be expressed as (for r >> a) $\vec{E} = \frac{1}{4\pi \in_0} \frac{\alpha Q}{f^n} \hat{r}$

(where $Q = qa^2$)

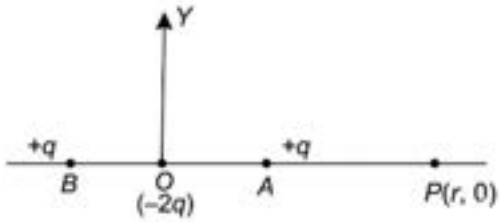
Choose the correct option



[A] α = 3, n = 3 [B] α = 3, n = 4 [C] α = 6, n = 3 [D] α = 6, n = 4

[ANS] **D**

[SOLN]



$$\vec{E}_q = \frac{1}{4\pi\varepsilon_0} \frac{\alpha Q}{r^n} \hat{r} \quad \{Q = qp^2\} \text{ Given.}$$

$$\vec{E}_q = \frac{1}{4\pi\varepsilon_0} \left[\frac{q}{(r-q)^2} - \frac{2q}{r^2} + \frac{q}{(r+q)^2} \right] \hat{r} \qquad r >> a$$

$$\vec{E}_q = \frac{q}{4\pi\varepsilon_0 r^2} \left[\left(1 - \frac{q}{r}\right)^{-2} - 2 + \left(1 + \frac{q}{r}\right)^{-2} \right] \hat{r}$$

$\because r >> a \qquad \frac{q}{r} << 1$

$$\vec{E}_p = \frac{q}{4\pi\varepsilon_0 r^2} \left[\left(1 + \frac{2q}{r} + \frac{3q^2}{r^2} + ..\right) - 2 + \left(\frac{1-2q}{r} + \frac{3q^2}{r^2} \right) \right]$$

$$\vec{E}_p = \frac{q}{4\pi\varepsilon_0 r^2} \left(\frac{6q^2}{r^2} \right) \hat{r} = \frac{1}{4\pi\varepsilon_0} \frac{6qn^2}{r^4} \hat{r} \qquad \alpha - = 6 \quad n = 4$$

[Q.23] During an excavation in the ancient volcanic caves, an archaeologist discovered a sample of a rare mineral trapped inside a sealed rock chamber. Laboratory analysis of the sample showed that the mineral originally contained a radioactive isotope X, which decays into a stable element Y. The radioactive isotope has a half-life T = 10^4 year. Due to contamination from underground water, 20% of the stable element got washed away before the sample was analysed. At the time of the analysis, the ratio of remaining (undecayed) radioactive isotope X to stable element Y in the sample is found to be 1 : 5.6. Assuming that no radioactive material X was lost from the sample, the archaeologist claimed that the actual age of the rock is

[A] 1×10^4 year [B] $\sqrt{3}\times10^4$ year [C] 3×10^4 year [D] $2\sqrt{3}\times10^4$ year

[ANS] **C**

[SOLN]



$T_{1/2}=10^4$ year $(N_y)_{remaing}=0.8(N_{tg})$total & $\frac{N_x}{(N_y)_{rem}}=\frac{1}{5.6}$ Given $\frac{N_x}{0.8(N_y)_t}=\frac{1}{5.6}$ n

$$\frac{N_x}{(N_y)_t}=\frac{1}{7} \quad ...(1)$$

Let No = total no radio active isotope X

No = N_x + (N_y) total

$$\frac{N_o}{N_x}=\frac{1+(N_y)t}{N_x}$$

$\frac{N_o}{N_x}=1+7$ $\left(\frac{1}{2}\right)^n=\frac{N_x}{N_o}=\frac{1}{8}$ $n=3$ $\frac{t}{T_{y_2}}=3,$ $t=3\times10^4$

[Q.24] Two identical particles of mass m each are moving in circular orbits under a central potential given by $V(r)=\frac{K}{r^n}$ where K is a constant. If the radii of their orbits are r_1 and r_2 while the time periods are T_1 and T_2, respectively, the correct mathematical relation is

[A] $T_1^2r_1^{-(n+2)}=T_2^2r_2^{-(n+2)}$ [B] $T_1^2r_1^{-3}=T_2^2r_2^{-3}$

[C] $T_1^2r_1^{-(2n-1)}=T_2^2r_2^{-(2n-1)}$ [D] $T_1^2r_1^{-(n-1)}=T_2^2r_2^{-(n-1)}$

[ANS] **A**

[SOLN] Central potential equ. $v(r)=\frac{K}{g^n}$

$$F(r)=-\frac{\delta V}{\delta r}=\frac{-\delta}{or}\left(Kr^{-n}\right)=nKr^{-(n+1)}=\frac{nK}{r^{n+1}}$$

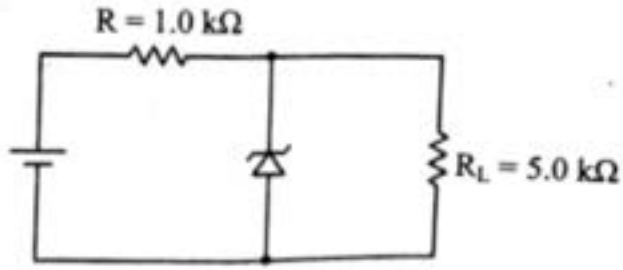
For particle of mass m moving in a circular orbit

$$F_c=mw^2r=m\left(\frac{2\pi}{r}\right)^2 r=\frac{4\pi^2 mr}{T^2}$$

Now $\frac{4\pi^2 mr}{T^2}=\frac{nK}{r^{n+1}}$ $\qquad T^2=\frac{4\pi^2 mr^{n+2}}{nK}$

$T^2 \propto r^{(n+2)}$

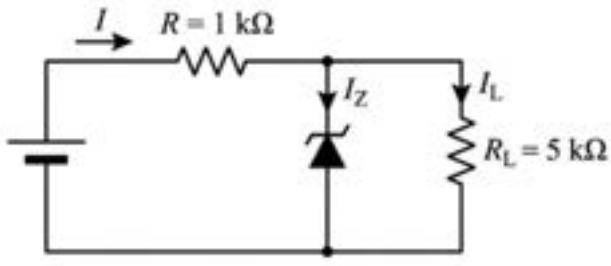
[Q.25] The figure represents a voltage regulator circuit using a zener diode. The breakdown voltage of the zener diode is 5.5 V and the load resistance is 5 kilo ohm. The series resistance R is 1 kilo ohm. If the battery voltage varies from 8 V to 14 V, what is the minimum and maximum value of current through the zener diode?



[A] 2.5 mA, 8.5 mA [B] 1.4 mA, 7.4 mA [C] 1.1 mA, 1.1 mA [d] 0.5 mA, 1.5 mA

[ANS] **B**

[SOLN]



Breakdown voltage of zene = 5.5 V

V_2 = 5.5 volt

So voltage across load = 5.5 V

$$I_L = \frac{V_2}{R_L} = \frac{5.5V}{5K\Omega} = 1.1\,mA$$

When 8v supply.

$$I = \frac{2.5\,volt}{1000\,\Omega} = 2.5\,mA$$

$$(I_2)_{min} = 2.5\,mA - 1.1\,mA = 1.4\ mA$$

When 14 v supply

$$I = \frac{14 - 5.5}{1k\Omega} = 8.5\ mA$$

$$(I_2)_{max} = 8.5\,mA - 1.1mA = 7.4\,mA$$

[Q.26] Two coherent electromagnetic plane waves, of exactly equal amplitude, propagating with a very small angle of divergence ψ, fall almost normally on a distant screen to produce interference fringes with a separation (fringe width) $\bar{x} = 1.0$ mm between neighbouring maxima. The wavelength of light is $\lambda = 6000\,Å$. The angle of divergence ψ

[A] is estimated to be ψ = 6.0 milliradians

[B] is estimated to be ψ = 0.6 milliradians

[C] is estimated to be ψ = 1.2 milliradians

[D] cannot be estimated from this data

[ANS] **B**

[SOLN] Given

Two EMW

$\rightarrow$ Equal amplitude

$\rightarrow$ $\bar{x} = 1.0$ mm (btw reig maxima)

$$\bar{x} = \frac{\lambda}{2\sin\left(\frac{\psi}{2}\right)} \text{ for small } \psi \quad \sin\frac{\psi}{2} \approx \frac{\psi}{2}$$

$\rightarrow$ ψ (very small)

$\lambda = 6000Å$

$$\bar{x} = \frac{\lambda}{\psi}$$

$$\psi = \frac{\lambda}{\bar{x}} = \frac{6\times10^{-7}}{1\times10^{-3}} = 6\times10^{-4} \text{ radian} = 0.6 \text{ milliradian}$$

[Q.27] In a line-of-sight radio communication, there is a distance of about 50 km between transmitting and receiving antennas. If the height of the receiving antenna is 70 m, then the minimum height of the transmitting antenna should be (Radius of the Earth = 6400 km)

[A] 20 m [B] 51 m [C] 32 m [D] 40 m

[ANS] **C**

[SOLN] d = 50 km h_R = 70 m R = 6.4 × 10^6 m h_r = ?

$$d = \sqrt{2Rhr + 2Rh_R}$$

$$50\times10^3=\sqrt{2Rh_r}+\sqrt{2\times6.4\times10^6\times70}$$

$$50\times10^3=\sqrt{2Rh_r}+30\times10^3$$

$$\sqrt{2Rh_r}=20\times10^3$$

$$h_r=31.25\,m$$

[Q.28] In an arrangement, three polarisers P, Q and S have been set up in sequence such that transmission axis of S is crossed with respect to that of P. The transmission axis of Q is inclined at 60° to the transmission axis of S. When a beam of unpolarised light of intensity I_0 is incident on P, the intensity of light transmitted by the three polarisers in succession is I. The ratio I : I_0 is equal to

[A] 1 : 16 [B] 3 : 16 [C] 3 : 32 [D] 10 : 18

[ANS] **C**

[SOLN] Angle between $P_2S = 90^o$

$Q_2S = 60^o$

$P_2Q = 30^o$

$$I_P=\frac{I_0}{2}$$

$$I_Q=I_P\cos^2\theta$$

$$I_Q=\frac{I_0}{2}\times\frac{3}{4}$$

$$I_Q=\frac{3I_0}{8}$$

$$I_S=I=I_Q\cos^2 60^o$$

$$=\frac{3I_0}{8}\times\frac{1}{4}$$

$$I=\frac{3I_0}{32}$$

$$\frac{I}{I_0}=\frac{3}{32}$$

[Q.29] A solid sphere of mass m and radius R rolls without slipping on a horizontal surface. It collides with a light spring of stiffness constant K with kinetic energy E. If the surface under the spring is smooth (frictionless), then the maximum compression of the spring is

[A] $\sqrt{\frac{2E}{K}}$ [B] $\sqrt{\frac{10E}{7K}}$ [C] $\sqrt{\frac{E}{K}}$ [D] $\sqrt{\frac{7E}{10K}}$

[ANS] **B**

[SOLN]



$E = \frac{1}{2}mv^2\left(1+\frac{K^2}{R^2}\right)$ $E = \frac{1}{2}mv^2\left(1+\frac{2}{5}\right)$ $E = \frac{7}{10}mv^2$

$E : E_t + E_r$ $\frac{7}{10}mv^2 = E_t + \frac{1}{2}\times\frac{2}{5}MR^2.\frac{v^2}{R^2}$ $\frac{7}{10}mv^2 - \frac{2}{10}mv^2 = E_t$

$E_{trans} = \frac{5}{10}mv^2$ $E_{trans} = \frac{5}{7}E$ $E_{trans} = \frac{1}{2}kx_{max}^2$

$\frac{5}{7}E = \frac{1}{2}kx^2$ $x = \sqrt{\frac{10E}{7K}}$

[Q.30] When a mass of 9.0 kg is suspended vertically from the free end of the wire of a sonometer, it resonates with a given tuning fork forming standing waves with five antinodes between the two bridges. When the 9.0 kg mass is replaced by another unknown mass M, the wire resonates with the same tuning fork forming three antinodes for the same positions of the bridges. The mass M is

[A] 5.4 kg [B] 15 kg [C] 25 kg [D] 35 kg

[ANS] **C**

[SOLN] For sonometer $f = \frac{2P}{2L}\sqrt{\frac{T}{\mu}}$

f = reasoned frequency T = mg P= antinodes μ = linear mass density

Same tunning took in

Both case

So, f = constant

$p\sqrt{m} = \text{const}$ $\quad p_1\sqrt{m_1} = p_2\sqrt{m_2}$ $\quad 5\sqrt{9} = 3\sqrt{m_2}$ $\quad 518 = 3\sqrt{m_2}$

$m_2 = 25\,\text{kg}$

[Q.31] A thin rectangular metal plate of surface area $0.1\ \text{m}^2$ is placed on a large horizontal table. There are a few drops of a liquid between the metal plate and the table forming a thin liquid layer of 0.3 mm thickness. The plate is pulled horizontally with the help of a string passing over a massless and frictionless fixed pulley. When a mass of 10 g is attached to the vertically hanging free end of the string, the plate is observed to move gently towards the pulley with a constant speed of $8.5\ \text{cms}^{-1}$. The coefficient of viscosity of the liquid is approximately

[A] 3.5 Pascal-s [B] 0.035 Pascal-s [C] 0.0035 pascal-s [D] 0.0025 Pascal-s

[ANS] **C**

[SOLN] $\eta A\dfrac{\Delta v}{\Delta z} = mg$

$$\eta = \frac{mg\Delta z}{A\Delta v} = \frac{0.098\text{N}\times\left(3\times10^{-4}\text{m}\right)}{0.1\ \text{m}^2\times0.085\ \text{m/s}} = 0.0035\ \text{Pa-s}$$

[Q.32] The Earth is revolving around the Sun in a circular orbit with a period of revolution equal to 1 year. Suppose that during its motion around the Sun, the mass of the Sun doubles suddenly, the time period of revolution of the Earth will then become

[A] $\dfrac{1}{\sqrt{2}}$ year [B] $\dfrac{2\sqrt{2}}{3\sqrt{3}}$ year [C] $\dfrac{2}{3\sqrt{3}}$ year [D] $\dfrac{1}{2\sqrt{2}}$ year

[ANS] **C**

[SOLN] $T_0 = 2\pi\sqrt{\dfrac{R^3}{GM}} = 1\ \text{year}$

$$v_0 = \sqrt{\frac{GM}{R}}$$

When mass suddenly becomes 2M, R & v_0 will not change instantaneously, but v_0 is lesser than the speed required for a circular orbit around 2M. At this point, Earth's position becomes aphelion (the farthest point) of the new elliptical orbit. New mechanical energy € will change immediately.

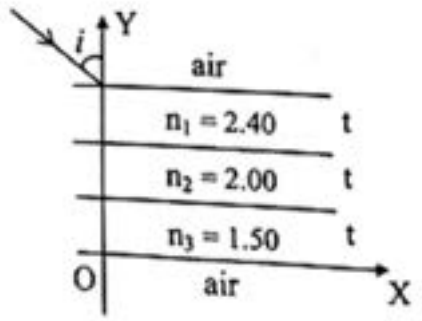
$$E = \frac{1}{2}mv_0^2 - \frac{G(2M)m}{R} \quad \left(\text{here } v_0^2 = \frac{GM}{R}\right)$$

$$E = -\frac{3GMm}{2R}$$

Time period then:

$$T = 2\pi\sqrt{\frac{a^3}{G(2M)}} = \sqrt{\frac{4}{27}}\times2\pi\sqrt{\frac{R^3}{GM}} = \sqrt{\frac{4}{27}}T_0 = \frac{2}{3\sqrt{3}}\ \text{year}$$

[Q.33] A beam of light in air is incident at an angle of incidence $i = 75°$ on a large block made of three parallel layers of different transparent materials stacked on top of each other, as shown. The thickness of each layer is t =10.0 cm. Refractive indices of the three successive layers with respect to air are n_1 = 2.40, n_2 = 2.00 and n_3 =1.50 respectively. The beam of light emerges from the third medium on the X axis at a distance ξ from O. The value of ξ is



[A] 30.3 cm [B] 23.4 cm [C] 18.3 cm [D] 9.02 cm

[ANS] **C**

[SOLN] Distance from origin:

$$\xi = t_1 \tan r_1 + t_2 \tan r_2 + t_3 \tan r_3$$

$$\mu_{air} \sin i = \mu_1 \sin r_1 = \mu_2 \sin r_2 = \mu_3 \sin r_3$$

Given $i = 75^o, \mu_{air} = 1,$

$t_1 = t_2 = t_3 = 10cm$

$$\mu_1 = 2.4, \mu_2 = 2, \mu_3 = 1.5, \sin 75^o = \frac{\sqrt{3}+1}{2\sqrt{2}} = 0.96 :$$

We get $\sin r_1 = 0.4 \Rightarrow \tan r_1 = 0.44$

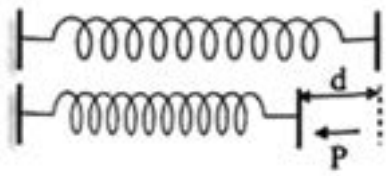
$\sin r_2 = 0.48 \Rightarrow \tan r_2 = 0.55$

$\sin r_3 = 0.64 \Rightarrow \tan r_3 = 0.84$

$\xi = t_1 \tan r_1 + t_2 \tan r_2 + t_3 \tan r_3 = 18.3cm$

Note : T.I.R. will not occure

[Q.34] A spring is in a compressed state under the action of a constant force P. Compression of the spring is d. Suppose direction of the force is reversed suddenly with its magnitude changed to 2P; the maximum extension of the spring will now be



[A] 2d [B] 3d [C] 4d [D] 5d

[ANS] **D**

[SOLN] For equilibrium $P = kd \Rightarrow k = \frac{P}{d}$

Now $W_{ext} + W_{spr} = k_f - k_i = 0$

$$2P(x+d) + \left[-\left(\frac{1}{2}kx^2 - \frac{1}{2}kd^2\right)\right] = 0 \quad \left(\text{herek} = \frac{P}{d}\right)$$

$\Rightarrow x^2 - 4dx - 5d^2 = 0$

$\Rightarrow x = 5d, -d$

Ans. : 5d

[Q.35] In a process, one mole of a monoatomic gas is heated from initial temperature 27°C, in such a way that its molar heat capacity is constant equal to 2R. During the process, volume of the gas is doubled. The final temperature of the gas becomes

[A] 108°C [B] 927°C [C] 527°C [D] 2127°C

[ANS] **B**

[SOLN] $C = C_v + \frac{R}{1-x}$

$2R = \frac{3R}{2} + \frac{R}{1-x}$

$\Rightarrow x = -1 \quad \Rightarrow pv^{-1} = \text{constant}$

$\Rightarrow Tv^{-2} = \text{constant}$

$\Rightarrow T \propto v^2$

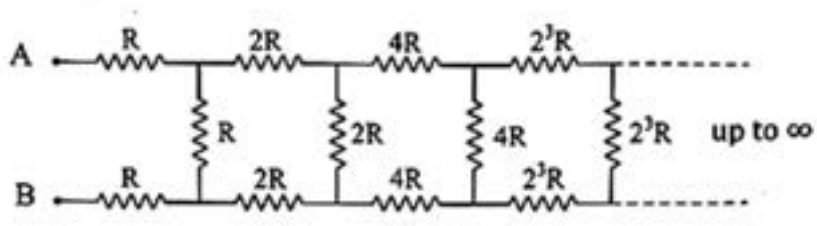
as $v_2 = 2v_1$

$T_2 = 4T_1 = 4 \times 300K$

$= 1200k$

$= 927^oC$

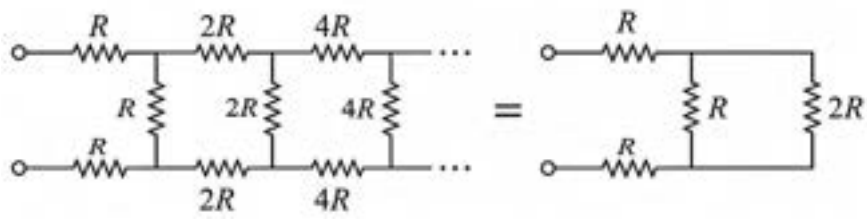
[Q.36] The resistance between the points A and B in the infinite circuit shown, in terms of R, is



[A] $\frac{5+\sqrt{41}}{4}R$ [B] $\frac{-5+\sqrt{41}}{4}R$ [C] $\frac{5+\sqrt{41}}{2}R$ [D] $\left(\sqrt{3}+1\right)R$

[ANS] **A**

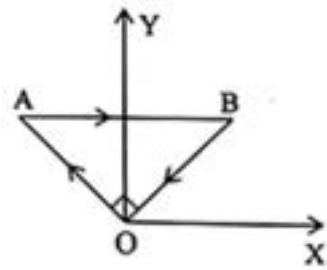
[SOLN] Let equivalent resistance between A & B be x:



$$\frac{2Rx}{2R+x}+R+R=x$$

this gives $x=\frac{5+\sqrt{41}}{4}R$

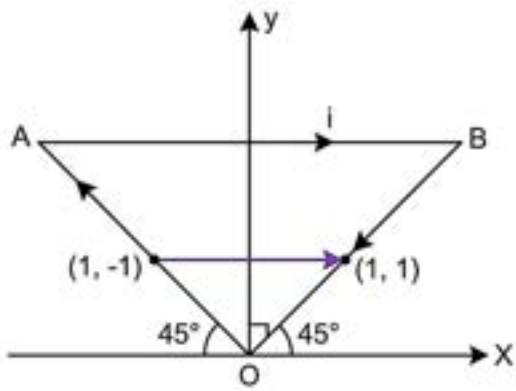
[Q.37] Three metallic wires form an isosceles right angled triangle AOB with wire AB parallel to x-axis and the vertex O at the origin. The length of the wire OA = length OB $=2\sqrt{2}$ m. A current of 10 A flows in the loop along OABO. A magnetic field $\vec{B}=2.5\left(\hat{i}-\hat{k}\right)$T exists in the region $y\geq 1$. The force acting on the triangle due to this field is



[A] $5\hat{j}$N [B] $50\left(\hat{i}+\hat{k}\right)$N [C] $50\left(\hat{j}+\hat{i}\right)$N [D] Zero

[ANS] **A**

[SOLN]



B exists for $y\geq 1$.

Effective length of wire for $y\geq 1$ is $L=2m$:

$L=2\hat{i}$

$B=2.5\left(\hat{i}-\hat{k}\right)$

$F=i(L\times B)=50\hat{j}$N

[Q.38] When placed in a liquid of density d_1, a solid sphere sinks displacing a volume V of the liquid. When placed in a second liquid of density d_2, the same sphere floats with half of its volume appearing over the surface of the liquid. When placed in a third liquid of density d_3, the same sphere floats with $\frac{1}{4}$th of its volume over the surface of the liquid. The buoyant force exerted by the liquid of density d_3 on the sphere is

[A] Vd_3g [B] $\frac{1}{2}Vd_3g$ [C] $\frac{1}{2}Vd_2g$ [D] $\frac{1}{4}Vd_3g$

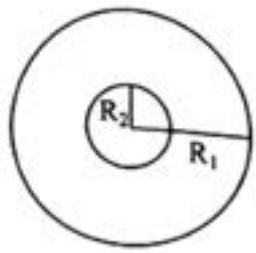
[ANS] **C**

[SOLN] Volume of sphere = V

$$\frac{V}{2}d_2g=\frac{3V}{4}d_3g\Rightarrow d_3=\frac{2}{3}d_2$$

$$F_{up}=\frac{3V}{4}\times d_3g=\frac{Vd_2g}{2}$$

[Q.39] There are two concentric and coplanar coils of radii R_1 and R_2 ($R_1 >> R_2$), and number of turns N_1 and N_2 respectively. The current in the second (smaller) coil is changing at a constant rate $\frac{dI_2}{dt}=k$. The magnitude of induced emf in the first (larger) coil will be



[A] $\frac{\mu_0\pi N_1N_2}{2}\sqrt{R_1R_2}K$ [B] $\mu_0\pi N_1^2N_2\frac{R_2^2}{2R_1}K$ [C] $\mu_0\pi N_1N_2\frac{R_1^2}{2R_2}K$ [D] $\mu_0\pi N_1N_2\frac{R_2^2}{2R_1}K$

[ANS] **D**

[SOLN] $$M=\frac{\phi_2}{i_1}=N_2\times\frac{N_1\mu_0i_1\times\pi R_2^2}{2R_1\times xi_1}$$

$$=\frac{\mu_0N_1N_2\pi R_2^2}{2R_1}$$

Now $$E_1=M\frac{di_2}{dt}=\frac{\mu_0N_1N_2\pi R_2^2K}{2R_1}$$

[Q.40] A concave mirror of radius of curvature R = 1.00 m is placed on the floor as shown. A small, light-weight ball falls from a height h=1.20 m vertically along the principal axis towards the mirror. If the ball loses 16% of its energy after each collision with the mirror, the distance between the ball and its image formed by the mirror, when the ball reaches its maximum height after the 2nd collision, is nearly



[A] 0.75 m [B] 0.66 m [C] 0.55 m [D] 0.37 m

[ANS] **C**

[SOLN] After 2nd collision

energy of ball $E_2 = 0.84\ mgh$

Now $(0.84)^2\ mgh = mgh_2 \Rightarrow h_2 = 0.847m$

For mirror $f = -0.5m$

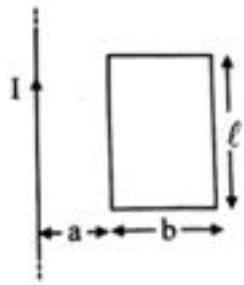
$U = -0.847\ m$

$$\frac{1}{v}+\frac{1}{-0.847}=\frac{1}{-0.5}$$

$$\Rightarrow v = 1.221\ m$$

Distance between image & object is 1.221 – 0.847 = 0.37 m

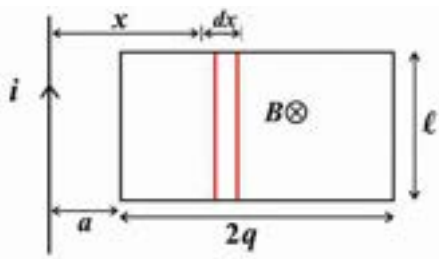
[Q.41] A flat rectangular $\ell \times$ b loop and a long straight wire lie in the same plane (see figure). Current in the wire varies according to $I = I_0 \sin \omega t$. The amplitude of emf induced in the loop is (Given b = 2a)



[A] $\left[\frac{\mu_0 \omega I_0 \ell}{2\pi} \ln 3\right]$ [B] $\left[\frac{\mu_0 \omega I_0 \ell}{2\pi} \ln 2\right]$ [C] $\left[\frac{3\mu_0 \omega I_0 \ell}{2\pi}\right]$ [D] $\left[\frac{\mu_0 \omega I_0 \ell}{\pi}\right]$

[ANS] **A**

[SOLN]



$$B = \frac{\mu_o i}{2\pi x} \Rightarrow d\phi = Bds = \frac{\mu_o i}{2\pi x}\ell dx$$

$$\phi = \int_{x=a}^{x=3a} d\phi = \frac{\mu_o i\ell}{2\pi}\ln 3$$

$$\Sigma_{ind} = \frac{d\phi}{dt} = \frac{\mu_o \ell \ln_3}{2\pi} \times I_o \omega \cos\omega t$$

$$(\Sigma_{ind})_{max} = \frac{\mu_o I_o \omega \ell \ln_3}{2\pi}$$

[Q.42] Speed of sound is measured in a confined gas and found to be 0.632 times the RMS velocity (v_{rms}) of the gas molecules as determined from the temperature. The degree of freedom f and molar heat capacity C_v at constant volume of the gas are

[A] f = 10, C_v = 5 R [B] f = 6, C_v = 3R [C] f = 5, $C_v = \frac{5}{2}R$ [D] f = 3, $C_v = \frac{3}{2}R$

[ANS] **A**

[SOLN] Speed of sound

$$V_S = \sqrt{\frac{mRT}{M}}, V_{ms} = \sqrt{\frac{3RT}{M}}$$

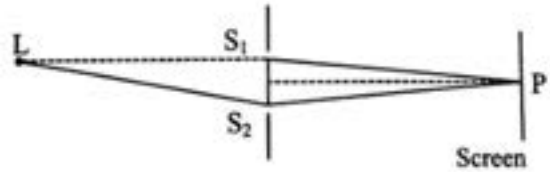
As $V_S = 0.632 V_{rms}$

$\psi \approx 1.2$

Now $\psi = 1 + \frac{2}{f} \Rightarrow f = 10$

& $C_V = \frac{fR}{2} = 5R$

[Q.43] A line source L (perpendicular to the plane of the paper) emitting light of wavelength 5625 Å is placed 1.00 m away directly in front of the slit S_1 in an opaque wall (see figure). A second slit S_2 in the same wall is parallel to slit S_1 and at distance \(d\) from it; both the slits are parallel to each other and to the line source L. Intensity of light is measured at the position P, equidistant from each of the slits S_1 and S_2 on the screen, for three different conditions. When S_2 is covered it is I_1, when S_1 is covered it is S_2. When both slits are open it is I. If $I = I_1 + I_2$, the distance d between the two slits is



[A] 0.75 mm [B] 0.53 mm [C] 1.06 mm [D] 1.50 mm

[ANS] **B**

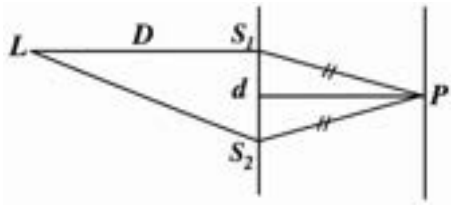
[SOLN] $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\theta$

Given $I = I_1 + I_2$

$\Rightarrow \cos\phi = 0$

$\phi = \frac{\pi}{2}, \frac{3\pi}{2}, ...$

Now $\Delta x = \frac{\lambda}{2\lambda} \times \phi = \frac{\lambda}{4}, \frac{3\lambda}{4}, ...$



$\Delta x = LS_2 - LS_1 = \sqrt{D^2 + d^2} - D$

$= D\left(1 + \frac{d^2}{D^2}\right)^{\frac{1}{2}} - D$

$= D\left(1 + \frac{d^2}{2D^2}\right) - D = \frac{d^2}{2D}$

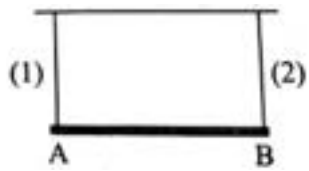
Now taking $\Delta x = \frac{\lambda}{4}(\text{min})$

$\frac{d^2}{2D} = \frac{\lambda}{4} \Rightarrow d = \sqrt{\frac{\lambda D}{2}} = \sqrt{\frac{5625 \times 10^{-10} \times 1}{2}}$

$= 5.3 \times 10^{-4}\,\text{m}$

$= 0.53\,\text{m m}$

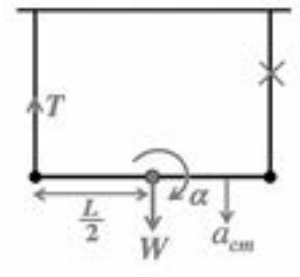
[Q.44] A uniform rod AB of weight W is symmetrically suspended with the help of two identical un-stretchable light strings (1) and (2) of equal length from a rigid horizontal support. The rod is horizontal. The tension in the string (I), immediately after the string (2) is burnt, would be



[A] W [B] $\frac{3W}{4}$ [C] $\frac{W}{2}$ [D] $\frac{W}{4}$

[ANS] **D**

[SOLN]



Force : $W - T = Ma_{cm}$ ..... (1)

Torque $\tau = W \times \frac{L}{2}$ ..... (2) W = mg

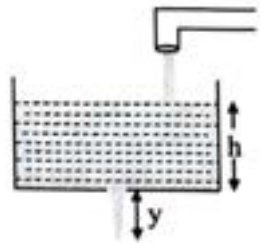
$$\alpha = \frac{\tau}{I} = \frac{W \times \frac{L}{2}}{\frac{ML^2}{3}} = \frac{3g}{2L}$$

$$a_{cm} = \frac{L}{2}\alpha = \frac{3g}{2}$$

Putting in (1)

$$T = \frac{W}{4}$$

[Q.45] In a wide container, Water is always filled up to a height h. There is a nozzle (hole) of radius r0 at its bottom. For some distance below the nozzle, water falls in a laminar stream. Radius r of stream as a function of y below the nozzle is expressed as [ignore the viscosity of water]



[A] $r = \frac{r_0}{\left(1+\frac{y}{h}\right)^{\frac{1}{2}}}$ [B] $r = \frac{r_0}{\left(1+\frac{y}{h}\right)^{\frac{1}{4}}}$ [C] $r = r_0\left(1+\frac{y}{h}\right)^{\frac{1}{4}}$ [D] $r = \frac{r_0}{\left(1+\frac{h}{y}\right)^{\frac{1}{4}}}$

[ANS] **B**

[SOLN] $V_e = \sqrt{2gh}$ ....(1)

For a displacement y of liquid d

$V^2 = V_o^2 + 2gh$ .....(2)

from (1) & (2) $V = \sqrt{2g(h+y)}$

Now use $A_1V_1 = A_2V_2$

$$\pi r_o^2 \times \sqrt{2gh} = \pi r^2 \sqrt{2g(h+y)}$$

$$\Rightarrow r = \frac{r_0}{\left(1+\frac{y}{h}\right)^{1/4}}$$

[Q.46] A point object of mass m starts moving from rest along x axis from the origin, under the action of a force which delivers a constant power P. The position x of the object at time t is

[A] $x = \left(\frac{8Pt^3}{9m}\right)^{\frac{1}{2}}$ [B] $x = \left(\frac{9Pt^3}{8m}\right)^{\frac{1}{2}}$ [C] $x = \left(\frac{8Pt^4}{27m}\right)^{\frac{1}{3}}$ [D] $x = \frac{2}{3}\left(\frac{Pt^3}{m}\right)^{\frac{1}{2}}$

[ANS] **A**

[SOLN] At $t = 0,\ v = 0,\quad x = 0$

Also, power = p (count)

F.V = P

$\Rightarrow$ m a.v = P

$$\Rightarrow a.v = \frac{p}{m}$$

$$\Rightarrow a = \left(\frac{p}{m}\right).\frac{1}{V}$$

$$\Rightarrow \frac{dv}{dt} = \left(\frac{p}{m}\right).\frac{1}{V}$$

$$\Rightarrow \int_o^v v.dv = \int_o^t \left(\frac{p}{m}\right).dt$$

$$\Rightarrow \frac{V^2}{2} = \frac{Pt}{m} \Rightarrow V^2 = \frac{2Pt}{m}$$

$$\Rightarrow V = \sqrt{\frac{2p}{m}} \times \sqrt{t}$$

$$\Rightarrow \frac{dx}{dt} = \sqrt{\frac{2p}{m}} \times t^{1/2}$$

$$\Rightarrow \int_o^x dx = \sqrt{\frac{2p}{m}} \times \int_o^t t^{1/2}\, dt$$

$$\Rightarrow x = \left(\frac{8Pt^3}{9m}\right)^{1/2} \rightarrow \text{(a) is correct}$$

[Q.47] A black body, maintained at absolute temperature T, is emitting radiations of wavelength λ with maximum (peak) intensity. The emitted photons are capable of exciting the electron in a Bohr-model hydrogen atom from ground state (E_g = –13.60 eV) to the third excited state. Using Wien's constant b = 2.90 x 10^{-3} mK, the estimated value of temperature T is nearly

[A] 2.98×10^3 K [B] 2.98×10^4 K [C] 2.83×10^4 K [D] 2.68×10^4 K

[ANS] **B**

[SOLN] For excitation

$$\Delta E = E_4 - E_1$$

$$= 13.6 \times \left(1 - \frac{1}{16}\right) = 12.75 \text{ ev}$$

$$\Rightarrow \frac{12400}{\lambda(\dot{A})} = 12.75$$

$$\Rightarrow \lambda \approx 972.5\dot{A}$$

From wien's displacement lamo

$$T = \frac{b}{\lambda} = \frac{2.9 \times 10^{-3}}{972.5 \times 10^{-10}} \approx 2.98 \times 10^4 k$$

$\longrightarrow$ (b) is correct.

[Q.48] In an experiment for determination of the focal length of a thin convex lens, the object distance is measured as 15 cm with 1% error and the image distance is measured as 30 cm with 2% error. From the given data, the focal length of the lens is estimated with n% error. The value of n is

[A] 1.33 [B] 3 [C] 0 [D] 2

[ANS] **A**

[SOLN] Using lens formula, $f = \frac{uv}{u+v}$

differentiatiny : $\frac{\Delta f}{f} = \left(\frac{v}{n+v}\right) \times \frac{\Delta n}{n} + \left(\frac{u}{u+v}\right) \times \frac{\Delta v}{v}$

$$\Rightarrow \frac{\Delta f}{f} = \frac{30}{45} \times 1\% + \frac{15}{15} \times 2\%$$

$$= \frac{2}{3} + \frac{2}{3} = \frac{4}{3}\%$$

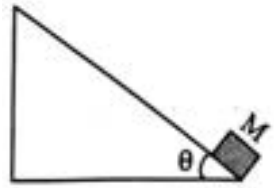
= 1.33% $\rightarrow$ (a) is correct.

(NSEA) PART : A–2

ANY NUMBER OF OPTIONS (4, 3, 2 or 1) MAY BE CORRECT

MARKS WILL BE AWARDED ONLY IF ALL CORRECT OPTIONS ARE BUBBLED AND NO INCORRECT.

[Q.49] A rectangular block of mass M projected up an inclined plane, set at an angle θ with the horizontal, comes to a stop at a certain height and slides back down the incline. The down trip takes exactly twice as long as the up trip. The observations reveal that



[A] coefficient of sliding friction between the block and the surface of the incline is 0.6 $\tan\theta$

[B] coefficient of sliding friction between the block and the surface of the incline is 0.6 $\sin\theta$

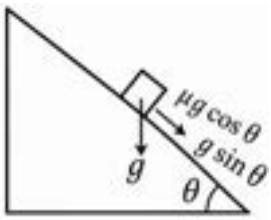
[C] about 75% of the original energy of projection has been lost to friction during the entire trip

[D] the acceleration of the block during its sliding down is 0.4 g $\sin\theta$

[ANS] **A, C, D**

[SOLN] Key input ∴ time taken in down trip = 2x time up

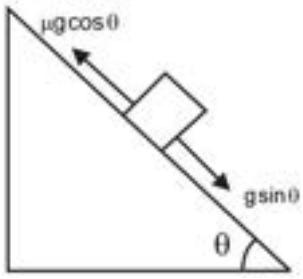
up-trip ∴



$$\begin{cases} a = +g(\sin\theta + \mu\ \text{con}\theta) \\ \text{displacement} = 3 \end{cases}$$

$$S = \frac{1}{2}g(\sin\theta + \mu\ \text{cons}\theta)t^2 \text{ up}$$

down-trip



$$a = g(\sin\theta - \mu\cos\theta)$$

displacement = 5

$$s = \frac{1}{2} g(\sin\theta - \mu\cos\theta).t^2_{down}$$

$$\frac{t_{down}}{t_{up}} = 2$$

$$\Rightarrow t^2_{down} \times (\sin\theta - \mu\cos\theta) = t^2_{up} \times (\sin\theta + \mu\cos\theta)$$

$$\Rightarrow \frac{t^2_{down}}{t^2_{up}} = \left(\frac{\sin\theta + \mu\cos\theta}{\sin\theta - \mu\cos\theta}\right) = 4$$

$$\Rightarrow \sin\theta + \mu\cos\theta = 4(\sin\theta - \mu\cos\theta)$$

$$\Rightarrow \tan\theta + \mu = 4(\tan\theta - \mu)$$

$$\Rightarrow 5\mu = 3\tan\theta$$

$$\Rightarrow \mu = \boxed{0.6\tan\theta} \rightarrow (a)$$

$$\therefore a_{down} = (g(\sin\theta - \mu\cos\theta))$$
$$= g(\sin\theta - 0.6\sin\theta)$$
$$= 0.4g\sin\theta \rightarrow (d)$$

$$\frac{V_{down}}{u_{up}} = \frac{a_{down} \times t_{down}}{a_{up} \times t_{up}} = 2 \times \frac{0.4g\cancel{\sin\theta}}{1.6g\cancel{\sin\theta}} = \frac{1}{2}$$

$$\therefore \frac{KE_{down}}{KE_{up}} = \frac{1}{4}$$

$\therefore$ loss is 75% $\rightarrow$(c)

[Q.50] A rocket is fired from Earth at 600 to the local vertical with an initial speed $v_0 = \sqrt{gR}$ where R is radius of the Earth and g is the acceleration due to gravity at the surface Of the Earth. Choose correct option(s) [Assume the Earth to be a uniform solid sphere. Also ignore the rotation of the Earth]

[A] The maximum distance reached by the rocket from the Earth's centre is 2R

[B] The maximum distance reached by the rocket from the Earth's centre is $\frac{3R}{2}$

[C] The minimum velocity of the rocket during the motion is $\sqrt{\frac{gR}{3}}$

[D] The maximum height attained by the rocket above the Earth's surface is $\frac{R}{3}$

[ANS] **B, C**

[SOLN] At the max^m height the radial component of velocity becomes O but the tangential comp. doesn't.

$\Rightarrow$ Energy con s^n:-

$$\frac{1}{2}\times m\times gR-\frac{GmM}{R}=\frac{1}{2}\times m\times V_t^2-\frac{GmM}{\gamma_{max}}$$

$$\Rightarrow \frac{1}{2}\times m\times\frac{GM}{R}-\frac{GmM}{R}=\frac{1}{2}mV_t^2-\frac{GmM}{\lambda_{max}}$$

$$\Rightarrow -\frac{GmM}{2R}=\frac{1}{2}mV_t^2-\frac{GmM}{\gamma_{max}} \longrightarrow (1).$$

Con s^n of angula momentum about centre of earth.

$$\Rightarrow \cancel{m}\times\sqrt{gR}\times\sin 60^o\times R=mV_t\, r_{max}$$

$$\Rightarrow V_t\times r_{max}=R\times\frac{\sqrt{3}}{2}\times\sqrt{\frac{GM}{R}} \longrightarrow (2).$$

Solving (1) & (2).

$$r_{max}=\frac{3R}{2}\longrightarrow \text{opton b}$$

Also, $v_t=\frac{\sqrt{3}R}{\cancel{2}}\times\sqrt{\frac{GM}{R}}\times\frac{\cancel{2}}{3R}=\sqrt{\frac{gR}{3}}$ $\rightarrow (c)$

[Q.51] A proton of mass m is released from rest at $x_o=\frac{\alpha}{\beta}$ and starts moving along x axis under the influence of conservative force F(x). Its potential energy is $U(x)=\frac{\alpha}{x^2}-\frac{\beta}{x}$, where α and β are positive constants. Rigorous calculation predict that

[A] The speed of the proton is maximum at $x=2x_o$

[B] The maximum speed of the proton is $v=\sqrt{\frac{\alpha}{mx_o^2}}$

[C] the force on the proton is zero at $x=2x_o$

[D] During its motion the proton can move in a region $x_o\le x\le\infty$

[ANS] **ACD**

[SOLN] $U(x)=\frac{\alpha}{x^2}-\frac{\beta}{x}$, at $t=0$, $x_o=\frac{\alpha}{\beta}$

$$F(x)=-\frac{du}{dx}=\frac{2\alpha}{x^3}-\frac{\beta}{x^2}$$

For equilibrium f(x) = 0 $\Rightarrow x = \frac{2\alpha}{\beta} = 2x_o \rightarrow C$

$\Rightarrow$ Since its conservative force, potential energy is minimum at speed (KE) Maximum at speed (KE) Maximum $\Rightarrow$ at $x = 2x_o$ minima U(x) of $\rightarrow$ a is correct.

Also, For V_{max}

$KE_{max} + U(2x_o) = E$

$For, E = U(x_o) = \frac{\alpha}{(\alpha/\beta)^2} - \frac{\beta}{(\alpha/\beta)} = \frac{\beta^2}{\alpha} - \frac{\beta^2}{\alpha} = 0$

$Now,\ KE(max) = 0 - U(2x_o) = 0 - \left[\frac{\alpha}{(2\alpha/\beta)^2} - \frac{\beta}{(2\alpha/\beta)}\right] = \frac{\alpha}{4x_o^2} = \frac{1}{2}mV_{max}^2 = \frac{\alpha}{4x_o^2}$

$\Rightarrow V_{max} = \sqrt{\frac{\alpha}{2mx_o^2}} \rightarrow 0$

Also $KE(x) + U(x) = 0$

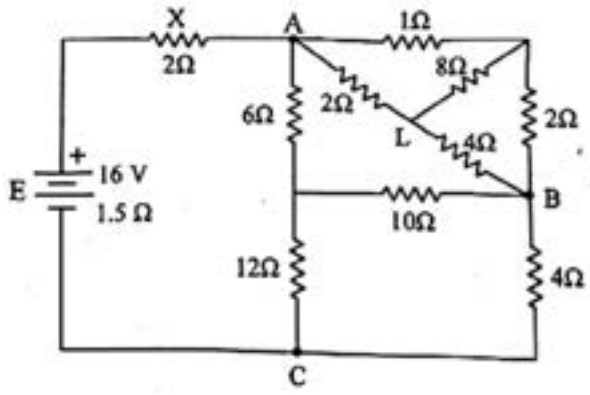
$\Rightarrow U(x) \le 0$

$\Rightarrow \frac{\alpha}{x^2} - \frac{\beta}{x} \le 0$

$\Rightarrow \alpha - \beta x \le 0$

$\Rightarrow x \ge \frac{\alpha}{\beta} \Rightarrow x \ge x_o \rightarrow (d)$ is correct.

[Q.52] In the given circuit, the emf E of the battery is 16 V and its infernal resistance is r =1.5 Ω . The correct option(s) is/are



[A] The potential difference across terminals of battery is 3 V

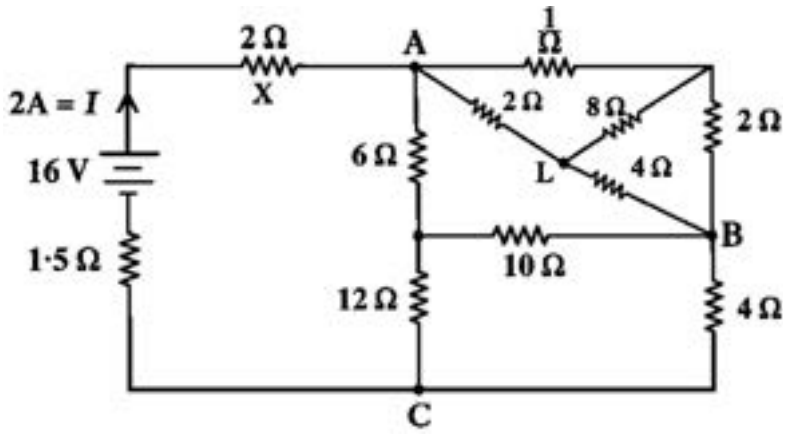
[B] The power dissipated in the resistance $X(=2\Omega)$ is 8 W

[C] The power dissipated in 12Ω resistance is 3W

[D] The potential difference across junctions A and B is 3 V

[ANS] **BCD**

[SOLN]



$\rightarrow 8\Omega$ has to be removed due to balanced wheat bridge

Bride $\rightarrow 10\Omega$ also removed (balanced W.B)

$\rightarrow$ Req for circuit $= 8\Omega$

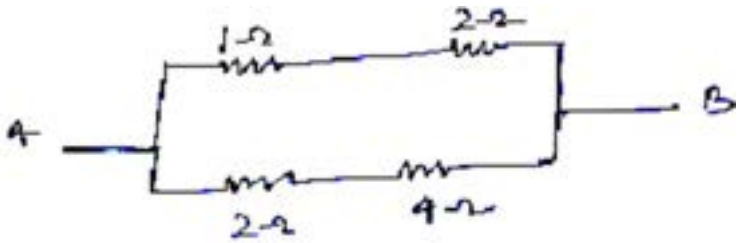
$\rightarrow$ Main current drawn, $I = \frac{16}{8} = 2A$

$\therefore$ Terminal voltage of battery 16 – 3 = 13 volt

$\rightarrow \text{Power (in x)} = I^2 \times 2 = 8\,\text{watt}$

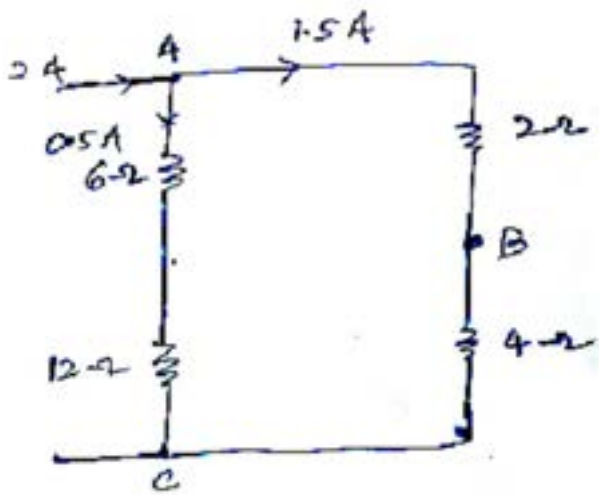
$\rightarrow \text{Power (in } 12-2) = I^2 (\text{across } 12-2) \times 12 = (0.5)^2 \times 12 = 3\,\text{Watt}$

Potential difference across AB



$$R_{AB} = \frac{3 \times 6}{9} = 2\Omega$$

$\Rightarrow$



$$V_{AB} = 1.5 \times 2 = 3\,V$$

[Q.53] Charge Q is distributed in non-uniform but spherically symmetric manner with charge density $\rho(r)$ such that

$$\rho(r) = \rho_o\left(1-\frac{r}{R}\right) \quad \text{for } r \le R$$

$$\rho(r) = 0 \quad \text{for } r \ge R$$

The correct statement is are:-

[A] The value of the constant ρ_o is $\frac{3Q}{2\pi R^3}$

[B] The electric field produced by the given charge has maximum value at $r = \frac{2R}{3}$

[C] The maximum electric field produced by this charge distribution is $E = \frac{1}{3\pi\in_o}\frac{Q}{R^2}$

[D] The maximum electric field produced is $E = \frac{1}{4\pi\in_o}\frac{Q}{R^2}$ is r = R.

[ANS] **BC**

[SOLN] Total charge (Sphere), $Q = \int_0^R \rho(r).dv$

$$= \int_0^R \rho\left(1-\frac{r}{R}\right).4\pi r^2.dr$$

$$= 4\pi\rho_o\left(\frac{R^3}{3}-\frac{R^3}{4}\right) = 4\pi\rho_o \times \frac{R^3}{12}$$

$$Q = \frac{\pi\rho_o R^3}{3} \Rightarrow \rho_o = \frac{3Q}{\pi R^3}$$

Electric field calculation $E(r)\times 4\pi r^2 = \frac{qin}{\varepsilon_o} = 4\pi\rho_o \times \left(\frac{r^3}{3}-\frac{r^4}{4R}\right) = \frac{Q\times 12}{R^3}\left(\frac{r^3}{3}-\frac{r^4}{4R}\right)$

$$\Rightarrow q_{in} = Q\left(\frac{4r^3}{R^3}-\frac{3r^4}{R^4}\right)$$

$$\Rightarrow E(r) = \frac{q_{in}}{4\pi\varepsilon_o r^2} = \frac{Q}{4\pi\varepsilon_o}\left(\frac{4r}{R^3}-\frac{3r^2}{R^4}\right)$$

For outside region $r \ge R$

$$E(r) = \frac{Q}{4\pi\varepsilon_o r^2}$$

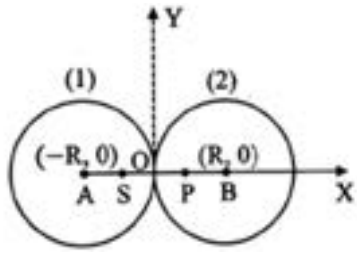
$\therefore$ for maximum electric field

$$\frac{dE_{in}}{dr} = 0 \Rightarrow \frac{Q}{4\pi\varepsilon_o}\left(\frac{4}{R^3}-\frac{6r}{R^4}\right) = 0$$

$\Rightarrow r = \frac{3R}{3} \rightarrow$ (b) is correct

$\therefore E_{max} = \frac{Q}{4\pi\varepsilon_o}\left[\frac{4}{R^3}\times\left(\frac{2R}{3}\right) - \frac{3}{R^4}\times\left(\frac{2R}{3}\right)^2\right] = \frac{1}{3\pi\varepsilon_o}\times\frac{Q}{R^2}$

[Q.54] Two non-conducting solid spheres (1) and (2), with uniformly distributed charge throughout their volumes, are held at positions A and B, as shown in the figure. Each sphere has radius R. The centers A and B of the spheres (1) and (2) lie on x axis with the point of contact O at the origin. Given that the total charge on sphere (1) is Q and the electric field E at point $P\left(\frac{R}{2},0\right)$ is zero. The correct statement(s) is/are



[A] The charge on sphere (2) is $Q_2 = \frac{8Q}{9}$

[B] The ratio of the magnitudes of the electric fields at O and at B is 4: 9

[C] The electric potential at B is $V_B = \frac{1}{8\pi\in_o}\frac{Q}{R}$ [taking V = 0 at infinity]

[D] The electric field at the point $S\left(-\frac{R}{2},0\right)$ is in positive x- direction

[ANS] **ABD**

[SOLN] At $\left(\frac{R}{2},0\right)$ $\vec{E}_1 + \vec{E}_2 = 0 \Rightarrow$ in magnitude $E_1 = E_2$

$\Rightarrow \frac{KQ}{(3R/2)^2} = \frac{K\times Q_2}{R^3}\times\left(\frac{R}{2}\right)$

$\Rightarrow Q_2 = \frac{Q}{9} \rightarrow$ a is correct

$\Rightarrow E_o = \frac{KQ}{R^2} - \frac{K\times 8Q}{9\times R^2}$ along + ve x.

$= \frac{KQ}{9R^2}$, $E_B = \frac{KQ}{(2R)^2} = \frac{KQ}{4R^2}$

$\therefore \frac{E_o}{E_B} = \frac{4}{9} \rightarrow$ (b) is correct

Potential at B: $V = V_1 + V_2 = \frac{KQ}{2R} + \frac{3}{2}\times\frac{K\times 8Q}{9\times R} = \frac{KQ}{2R} + \frac{4KQ}{3R} = \frac{KQ}{R}\left(\frac{1}{2}+\frac{4}{3}\right) = \frac{1}{4\pi\varepsilon_o}\times\frac{Q}{R}\left(\frac{3+8}{6}\right)$

$= \dfrac{11Q}{24\pi\varepsilon_o R} \rightarrow$ c is incorrect

= Electric field at S

$E_5 = \dfrac{KQ}{R^3} \times \dfrac{R}{2} - \dfrac{K \times 8Q}{9 \times (3R/2)^2} = \dfrac{KQ}{2R^2} - \dfrac{32KQ}{81R^2} \Rightarrow +ve\ volume \rightarrow along + ve\ x$

[Q.55] Two moles of a mixture of a monoatomic gas and a diatomic gas are being used as the working substance in a reversible Carnot cycle as shown in figure. For the mixture of gasses, the value of $\gamma_{mixture} = \dfrac{C_P}{C_V} = \dfrac{3}{2}$. The cycle operates between the source temperature 600 K and the sink temperature 300 K. The highest and lowest pressures during the cycle are 1600 kPa and 100 kPa. The correct statement(s) is/are

[A] If the minimum volume in the cycle is V, then the maximum volume is 8 V

[B] The working substance consists of one mole of monoatomic and one mole of diatomic gas

[C] Work done per cycle by the engine is 600 R ln 2

[D] The minimum volume of working substance is 6.23 L

[ANS] **ABCD**

[SOLN] n_1 moles $\rightarrow$ monoatomic $C_V = \dfrac{3R}{2}$

n_2 moles $\rightarrow$ diatomic $C_V = \dfrac{5R}{2}$

$\Rightarrow n_1 + n_2 = 2$ .....(1)

$CV_{mix} = \dfrac{n_1 CV_1 + n_2 CV_2}{n_1 + n_2}$

$\Rightarrow 2R = \dfrac{n_1 \times \dfrac{3R}{2} + n_2 \times \dfrac{5R}{2}}{n_1 + n_2}$

$\Rightarrow 3n_1 + 5n_2 = 8$.....(2)

Using 1 and 2

$n_1 = 1$ mole

$n_2 = 1$mole

Now for minimum volume $\rightarrow A(V_1)$

For maximum volume $\rightarrow C(V_3)$

$$P_1V_1 = nRT_1 \quad \Rightarrow \frac{P_1V_1}{P_3V_3} = \frac{T_1}{T_2} = \frac{1600\times V}{100\times V_3} = \frac{600}{300}$$

$= V_3 = 8V$

Also $v_1 = \frac{nRT_1}{P_1} = \frac{2\times 8.314\times 600}{1600\times 10^3} \approx 6.23$ Ltr $\rightarrow$ d is correct

For work done per cycle

$$W_{net} = nR(T_1 - T_2)\ln\left(\frac{V_2}{V_1}\right)$$

Where where, $\frac{V_2}{V_1} \Rightarrow$ expansion ratio

$\Rightarrow$ Calculation of expansion ratio

$\Rightarrow$ For adiabatic process to B to C

$T_1V_2^{r-1} = T_2V_3^{r-1}$

$\Rightarrow 600\times V_2^{1/2} = 300\times V_3^{1/2}$

$$\Rightarrow\left(\frac{V_3}{V_2}\right)^{1/2} = 2 \Rightarrow \frac{V_3}{V_2} = 4$$

Also, $V_3 = 8V_1 \Rightarrow \frac{V_2}{V_1} = 2$

$\therefore$ Work done per cycle $2\times R\times 300\times \ln 2$

$= 600\ln \rightarrow$ c is correct

[Q.56] A long horizontal thin metal wire under tension g attached at one end to a vibrator, transverse oscillations in the wire when the other end of the wire is fastened rigidly. The vibration produces a travelling wave in the wire, which is described by $y = y_o \sin\pi(\alpha t - \beta x)$, where x is measured in meter along the wire from the vibrator end. Here α and β are known positive constants. The linear density of the wire is μ kg / m. Then

[A] The tension in the wire is $T = \mu\frac{\alpha^2}{\beta^2}$

[B] the transverse wave propagates in the negative x direction with a speed $v = \frac{\alpha}{\beta}$

[C] the power supplied by the vibrator is $P = \frac{\mu\pi^2\alpha^3 y_o^2}{2\beta}$

[D] If the vibrator vibrates with double the frequency, delivering double power to the same wire under the same tension, the amplitude of the wave will reduce to half of the original value.

[ANS] **AC**

[SOLN] Given wave equation

$y = y_o \sin\pi(\alpha t - \beta x) = y_o \sin(\pi\alpha t - \pi\beta x)$

Comparing with $y = A\sin(\omega t - kx) \Rightarrow A = y_o \Rightarrow \omega = \pi\alpha \Rightarrow f = \frac{\alpha}{2} \Rightarrow k = \pi\beta \Rightarrow \frac{2\pi}{\lambda} = \pi\beta \Rightarrow \lambda = \frac{2}{\beta}$

$\therefore \upsilon = \frac{\alpha}{\beta}$, but propagating in + ve x direction

Also $\upsilon = \sqrt{\frac{T}{\mu}} \Rightarrow T = \mu v^2 = \frac{\mu\alpha^2}{\beta^2}$

Also, $P_{av} = 2\pi^2 A^2 F^2 \mu V$

$2\pi^2 \times y_o^2 \times \frac{\alpha^2}{4} \times \mu \times \frac{\alpha}{\beta} = \frac{4\pi^2\alpha^3 y_o^2}{2\beta}$

$P \propto A^2F^2$

$\Rightarrow \frac{P_1}{P_2} = \frac{A_1^2F^2}{A_2^2F_2^2} \Rightarrow \frac{1}{2} = \frac{A_1^2 \times f_1^2}{A_2^2 \times 4f_1^2} \Rightarrow A_2^2 = \frac{A_1^2}{2}$

$\Rightarrow A_2 = \frac{A_1}{\sqrt{2}}$

[Q.57] A train, moving in a straight line with an initial speed $u\ ms^{-1}$ at t = 0, is given a constant acceleration 'a' ms^{-2} to attain a maximum speed $V_m = \frac{7}{3}u$. The driver runs the train at that maximum speed for some duration and then decelerates at a rate of 'a' ms^{-2} to attain the same initial speed $u\ ms^{-1}$ at t = T. The average speed of the train for the entire journey (from time t = 0 to t = T) is 2u. Choose the correct statement (s)

[A] The train runs at the maximum speed for a duration of $T\sqrt{1-\frac{4u}{aT}}$

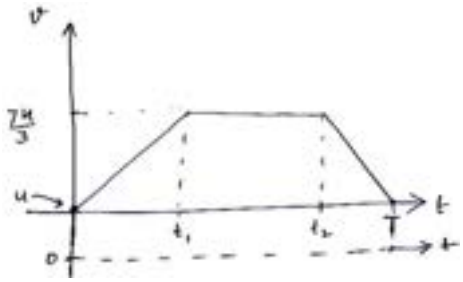
[B] The train runs at the maximum speed for a duration of $T\sqrt{1-\frac{2u}{aT}}$

[C] The train runs at the maximum speed for a duration of T/2

[D] The acceleration $a = \frac{16u}{3T}$

[ANS] **ACD**

[SOLN] According to question



b/w 0 to t_1 : $\frac{7u}{3} = u + a \times t_1$

$\Rightarrow at_1 = \frac{4u}{3} \Rightarrow t_1 = \frac{4u}{3a}$

$(T - t_2) = \left(\frac{4u}{3a}\right)\ T = \frac{8u}{3a} + (t_2 - t_1)$

$\Rightarrow (t_2 - t_1) = T - \frac{8u}{3a}$

Total distance covered area $= \frac{1}{2} \times [(t_2 - t_1) + T] \times \frac{4u}{3} + uT$

$\Rightarrow \text{Avg.speed} \times T = \frac{2u}{3}[T + (t_2 - t_1)] + \mu T$

$\Rightarrow (t_2 - t_1) = \frac{l}{2} \rightarrow \text{c is correct}\quad T - \frac{8u}{3a} = (t_2 - t_1)\ \Rightarrow T - \frac{8u}{3a} = \frac{l}{2}$

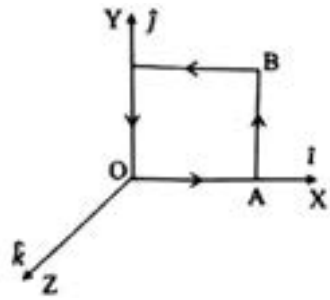
$\Rightarrow \frac{8u}{3a} = \frac{l}{2} \Rightarrow a = \frac{16u}{3T} \rightarrow \text{d is correct}$

Checking option A

$T\sqrt{1 - \frac{4u}{at}} = T\sqrt{1 - \frac{4u}{T} \times \frac{3T}{16u}} = T\sqrt{1 - \frac{3}{4}} = \frac{l}{2} \rightarrow \text{a is correct}$

$\therefore$ (b) is not correct

[Q.58] A wire loop OABC, with corners at O (0, 0), A (L, 0), B (L, L) and C (0, L) lying in XY plane, carries a current [In anti-clock wise direction as shown. The correct statement(s) is/are



[A] The magnetic field produced at the center of the loop is $\vec{B_1} = \frac{2\sqrt{2}\,\mu_o I}{\pi L}\hat{k}$

[B] The magnetic moment of the current loop is $\mu_o I L^2 \hat{k}$

[C] If a non-uniform magnetic field $\vec{B_2} = \left(\frac{B_o z}{L}\right)\hat{j} + \left(\frac{B_o y}{L}\right)\hat{k}$ is switched on, the magnetic force on the loop is $B_o I L\hat{j}$

[D] The magnetic force on the current carrying loop due to the magnetic field $\vec{B}_2$ is zero

[ANS] **AC**

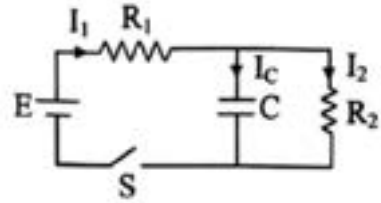
[SOLN] $\vec{B}_{centre} = \frac{\mu_o I}{4\pi\left[\frac{L}{2}\right]} \times \left[\sin 45^\circ \times 2\right] \times 4 = \frac{\mu_o I}{\pi L} \times 4 \times \frac{1}{\sqrt{2}} = \frac{\mu_o I.2\sqrt{2}}{\pi L}\hat{K}$

$\vec{\mu}_{loop} = I.L^2\hat{k} \quad \left(\vec{B} = \left(\frac{B_o z}{L}\right)\hat{j} + \left(\frac{B_o y}{L}\right)\hat{k} = \frac{B_o y}{L}\hat{k}\right.$

$\vec{F}_B = \vec{F}_{OA} + \vec{F}_{AB} + \vec{F}_{BC} + \vec{F}_{CO}$

$= 0 + \left(I\frac{B_o}{L}\int_0^2 y dy\right)\hat{i} + I\frac{B_o}{L}.L\,\hat{J} + \left(I\frac{B_o}{L}\int_0^2 y dy\right)(-\hat{i}) = IB_o L\hat{j}$

[Q.59] In the circuit shown, E is the emf of an ideal battery. Capacitor C is initially uncharged. Switch S is closed at time t = 0. The time dependent current through the resistance R_1 and R_2 are I_1 and I_2 respectively. At any moment t, the charging current through the capacitor is $I_C(t)$. Choose correct option (s)



[A] Current I_C charging the capacitor is given by $I_C = \frac{E}{R_1}e^{-\frac{t}{CR}}$ where $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

[B] Current I_C charging the capacitor is given by $I_C = \frac{E}{R_1}e^{-\frac{t}{CR}}$ where $R = R_1 + R_2$

[C] Soon after the switch S is closed (at t = 0), the currents are $I_1 = \frac{E}{R_1}$ and $I_2 = 0$

[D] Long time after the switch S is closed $(t \to \infty)$, charge on the capacitor is q = CE

[ANS] **AC**

[SOLN] $q_c(t) = q_{max}\left(1 - e^{\frac{-t}{t_{eq}}}\right)$

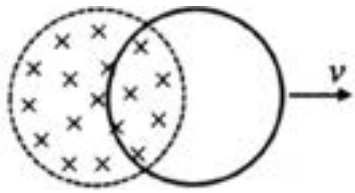
$T_{eq} = \left[\frac{R_1R_2}{R_1 + R_2}\right]C \;\&\; q_{max} = \left[\frac{E}{R_1 + R_2}\right]R_2 \times C \;, q_c(t) = \frac{ECR_2}{R_1 + R_2}\left(1 - e^{-\frac{(R_1+R_2)t}{R_1R_2C}}\right) - \frac{(R_1 + R_2)t}{R_1R_2C}$

$$I_C(t)=\frac{dq_c(t)}{dt}=\frac{ECR_2}{(R_1+R_2)}\times\frac{(R_1+R_2)}{R_1R_2C}=\frac{E}{R_1}e$$

At $t\to 0^+, I_1=\frac{E}{R_1}$

At $t\to\infty$, $q=\frac{ECR_2}{(R_1+R_2)}$

[Q.60] A uniform magnetic field B = 0.5 T exists in a circular region of radius R = 5 m. A wire loop of radius R =5 m completely encloses the magnetic field at t = 0. The loop is pulled at uniform speed $v=2ms^{-1}$ in the plane of the paper as shown



[A] The emf induced in the loop at time t = 3 s will be 8 V

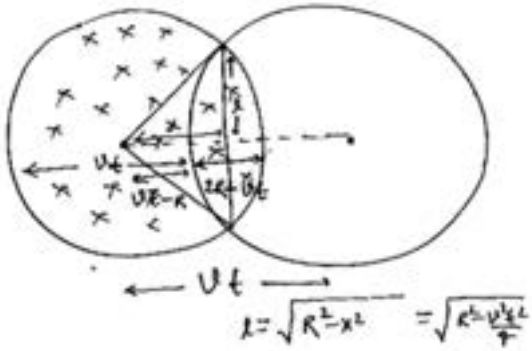
[B] The maximum emf induced in the loop will be 10 v

[C] The emf induced in the loop will be minimum at time t = 4

[D] The emf induced in the loop will be maximum just at start at the time t = 0 s

[ANS] **ABD**

[SOLN] At t = t



$\varepsilon=BV(2\ell)$

$$x=vt-R+\frac{2R-vt}{2}=\frac{Vt}{2}$$

$$(i)\varepsilon=BV\left(2\sqrt{R^2-\frac{v^2t^2}{4}}\right)=BV\sqrt{4R^2-v^2t^2}$$

At, $t=3, \varepsilon=0.5\times 2\times\sqrt{4\times 25-4\times 9}=8V$

$(ii)\varepsilon_{max}=BV.2R=0.5\times 2\times 2\times 5=10\,V$

$(iii)\varepsilon_{max}$ will be at $t=0$