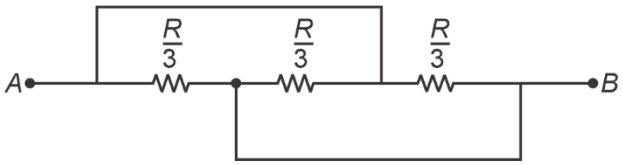
PHYSICS

SECTION - A

Multiple Choice Questions: This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

Choose the correct answer:

1. Find the equivalent resistance across *A* & *B*.

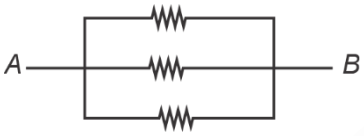


(1) R (2) $R/6$

(3) $R/3$ (4) $R/9$

Answer (4)

Sol. Equivalent circuit can be redrawn as



$$R_{eq} = \frac{1}{3}\left(R/3\right) = \frac{R}{9}$$

2. A uniform wire of linear charge density λ is placed along *y*-axis. The locus of equipotential surface is

(1) $x^2 + y^2 + z^2$ = constant

(2) $x^2 + z^2$ = constant

(3) xyz = constant

(4) $xy + yz + zx$ = constant

Answer (2)

Sol. Concentric cylinders are the equipotential surface.

3. Which of following reaction is correct?

(Where symbols have their usual meanings)

(1) $n \to p + e^- + \nu$ (2) $n \to p + e^+ + \nu$

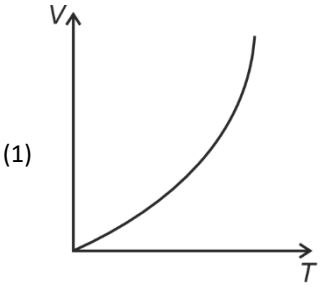
(3) $n \to p + e^+ + \bar{\nu}$ (4) $n \to p + e^- + \bar{\nu}$

Answer (4)

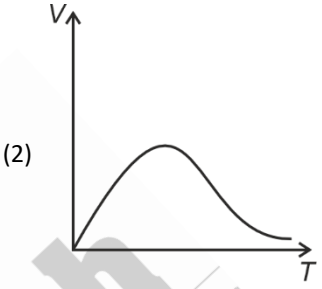
Sol. In 2, 3 charge conservation is not holding and in neutron decay, antineutrino $(\bar{\nu})$ is released.

4. The graph of root mean square velocity *v/s* temperature is

(1)



(2)



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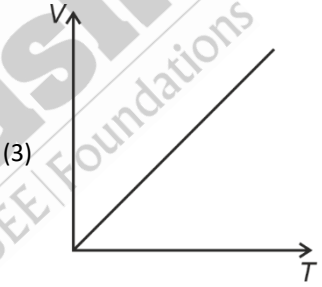
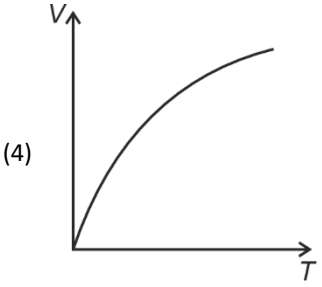


(4)

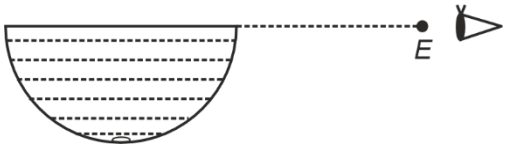


Answer (4)

Sol. We know $\frac{1}{2}MV_{Rms}^2 = \frac{3}{2}RT$

$$\Rightarrow V_{RMS} = \sqrt{\frac{3RT}{M}} \Rightarrow V_{RMS} \propto \sqrt{T}$$

5. A coin is placed at the bottom of a hemispherical container filled with a liquid of refractive index μ. Find the least refractive index if the coin is visible to an observer at *E*.

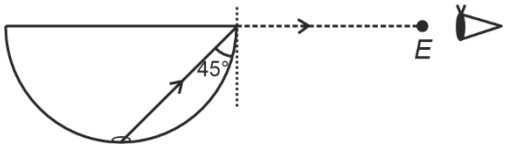


(1) $\sqrt{3}$ (2) $\sqrt{2}$

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

Answer (2)

Sol.

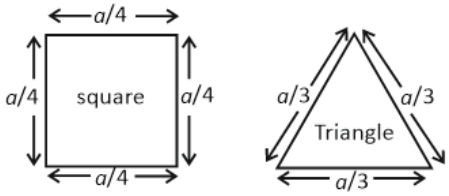


$\theta_c = 45°$

$$\sin 45° = \frac{1}{\mu}$$

$$\mu = \frac{1}{\sin 45°} = \sqrt{2}$$

6. In the given figure, the square and the triangle have same resistance per unit length. Find the ratio of their resistances about adjacent corners.



(1) $\frac{32}{27}$ (2) $\frac{27}{32}$

(3) $\frac{8}{9}$ (4) $\frac{9}{8}$

Answer (2)

Sol. Let the resistance per unit length be λ, then

For square,

$$R_{\text{Square}} = \frac{\left(\frac{3\lambda a}{4}\right)\left(\frac{\lambda a}{4}\right)}{\frac{3\lambda a}{4}+\frac{\lambda a}{4}} = \frac{3\lambda a}{16}$$

For triangle,

$$R_{\text{Triangle}} = \frac{\left(\frac{2\lambda a}{3}\right)\left(\frac{\lambda a}{3}\right)}{\frac{2\lambda a}{3}+\frac{\lambda a}{3}} = \frac{2\lambda a}{9}$$

$$\frac{R_{\text{Square}}}{R_{\text{Triangle}}} = \frac{3\lambda a}{16} \times \frac{a}{2\lambda a} = \frac{27}{32}$$

7. **Assertion :** Work done by central force is independent of path.

Reason : Potential energy is associated with every force.

(1) Both Assertion and Reason are correct

(2) Assertion is correct, Reason is incorrect

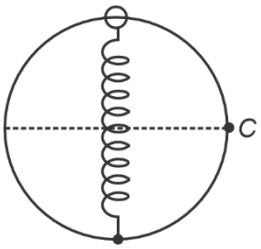
(3) Assertion is incorrect, Reason is correct

(4) Both Assertion and Reason are incorrect

Answer (4)

Sol. Not all central force/s are conservative so work done by central force might depend on path.

8. There is smooth ring of radius *R* in vertical plane. A spring of natural length *R* & elastic constant *K* is vertical along a diameter. The free end is connected to bead of mass *m* & when slightly disturbed it reaches point *C* with speed v where v is



(1) $\sqrt{\frac{KR^2\left(\sqrt{2}-1\right)+2mgR}{m}}$

(2) $\sqrt{\frac{2KR^2\left(\sqrt{2}-1\right)+2mgR}{m}}$

(3) $\sqrt{\frac{2KR^2\left(\sqrt{2}-1\right)+mgR}{m}}$

(4) $\sqrt{\frac{KR^2\left(\sqrt{2}-1\right)+mgR}{m}}$

Answer (2)

Sol. Loss in PE = gain in KE

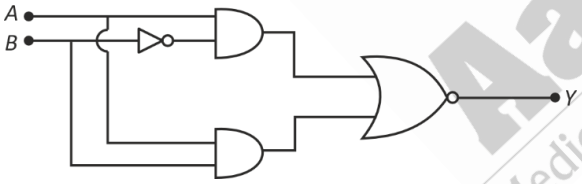
$$\frac{1}{2}K\left(R^2\right)-\frac{1}{2}K\left(\sqrt{2}-1\right)^2R^2+mgR=\frac{1}{2}mv^2$$

$$\frac{1}{2}KR^2\left\{1-2-1+2\sqrt{2}\right\}+mgR=\frac{1}{2}mv^2$$

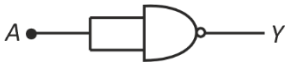
$$KR^2\left(\sqrt{2}-1\right)+mgR=\frac{1}{2}mv^2$$

$$\sqrt{\frac{2KR^2\left(\sqrt{2}-1\right)+2mgR}{m}}=v$$

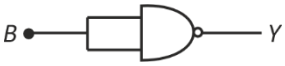
9. The equivalent logic gate for the circuit shown below is



(1) 

(2) 

(3) 

(4) 

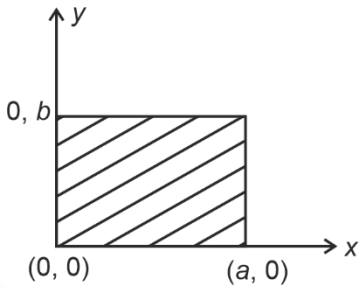
Answer (2)

Sol. $Y=\overline{A\bar{B}+AB}$

$$Y=\overline{A\left(\bar{B}+B\right)}$$

$$Y=\bar{A}$$

10. Surace mass density varies as $\sigma=\frac{\sigma_0 x}{ab}$ for the given plane sheet. Find the position of centre of mass for the distribution given



(1) $\frac{2a}{3},\frac{2b}{3}$ (2) $\frac{2a}{3},\frac{b}{2}$

(3) $\frac{a}{3},\frac{b}{2}$ (4) $\frac{a}{2},\frac{b}{2}$

Answer (2)

Sol. As there is no variation of mass density in *y* direction. So

$y_{cm}=\frac{b}{2}$.

Now for *x* direction

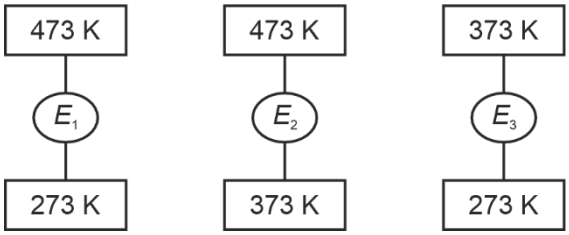
$$dm=\left(\frac{\sigma_0 x}{ab}\right)b.dx$$

$$x_{cm}=\frac{\int_0^a xdm}{\int_0^a dm}=\frac{\frac{\sigma_0}{a}\int_0^a x^2dx}{\frac{\sigma_0}{a}\int xdx}$$

$$\Rightarrow\quad x_{cm}=\frac{a^3\times 2}{3\times a^2}=\frac{2}{3}a$$

So $r_{cm}=\frac{2}{3}a,\frac{b}{2}$

11. η_1, η_2 and η_3 are the efficiencies of the three Carnot engines E_1, E_2 and E_3 operating between temperatures shown in the figure. Choose the correct option relating the efficiencies.



(1) $\eta_2 + \eta_3 > \eta_1$ (2) $\eta_2 + \eta_3 = \eta_1$

(3) $\eta_2 + \eta_3 < \eta_1$ (4) $\eta_1 + \eta_2 = \eta_3$

Answer (1)

Sol. $\eta_1 = 1 - \frac{273}{473} = \frac{200}{473}$

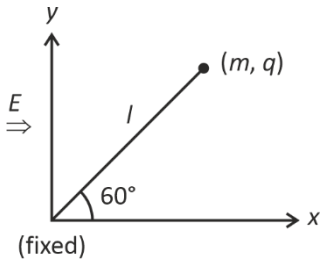
$\eta_2 = 1 - \frac{373}{473} = \frac{100}{473}$

$\eta_3 = 1 - \frac{273}{373} = \frac{100}{373}$

$\eta_1 - \eta_2 = \frac{100}{473} < \eta_3$

i.e., $\eta_2 + \eta_3 > \eta_1$

12. A simple pendulum of length l and bob of mass m is placed on smooth horizontal surface as shown. When electric field of strength E is switched on, the bob passes the x-axis with speed v then



(1) $v = \sqrt{\frac{2qEl}{m}}$ (2) $v = \sqrt{\frac{qEl}{m}}$

(3) $v = \sqrt{\frac{qEl}{2m}}$ (4) $v = 2\sqrt{\frac{qEl}{m}}$

Answer (2)

Sol. $W = \Delta K$

$qE(l - l\cos 60°) = \frac{1}{2}mv^2$

$\frac{qEl}{m} = v^2$

13. **Statement-I :** Velocity of sound in solids is more compared to that in gases.

Statement-II : Bulk modules of gas is more than that of solids.

(1) Statement-I is correct statement-II is correct

(2) Statement-I is correct statement-II is incorrect

(3) Statement-I is incorrect statement-II is correct

(4) Statement-I is incorrect statement-II is incorrect

Answer (2)

Sol. Speed of sound in medium depends on elastic and inertia properly of medium.

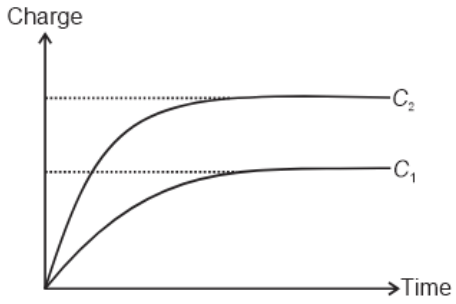
for gas $v = \sqrt{B/\rho}$

for solids $v = \sqrt{Y/\rho}$

The elastic properly of solids happens to be many fold greater than that of elastic properly of gases.

Bulk modulus of gas depends on the process, $B = \frac{-\Delta P}{\Delta V / V}$, which varies between 0 to ∞ therefore in general statement 2 is incorrect.

14. To capacitor C_1 and C_2 are connected across same battery and store energies U_1 and U_2 respectively at steady state. Choose the correct option by observing the graph of charge vs time shown below.



(1) $\begin{matrix} C_1 > C_2 \\ U_1 > U_2 \end{matrix}$ (2) $\begin{matrix} C_1 < C_2 \\ U_1 < U_2 \end{matrix}$

(3) $\begin{matrix} C_1 > C_2 \\ U_1 < U_2 \end{matrix}$ (4) $\begin{matrix} C_1 < C_2 \\ U_1 > U_2 \end{matrix}$

Answer (2)

Sol. Steady state

$\frac{C_1}{C_2} = \frac{Q_1}{Q_2} < 1$ (Connected across same potential difference)

$\frac{C_1}{C_2} = \frac{U_1}{U_2} < 1$

15. Energy of photon of wavelength λ is E_0 which is equal to kinetic energy of proton of mass m_p. The ratio of de Broglie wavelengths of proton and photon is

(1) $\frac{1}{c}\sqrt{\frac{2E_0}{m_p}}$ (2) $\frac{1}{c}\sqrt{\frac{E_0}{2m_p}}$

(3) $\frac{2}{c}\sqrt{\frac{E_0}{m_p}}$ (4) $\frac{1}{2c}\sqrt{\frac{E_0}{m_p}}$

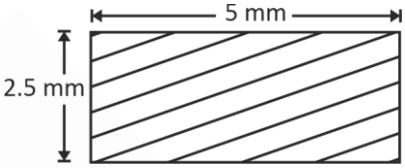
Answer (2)

Sol. $\frac{1}{2}m_p v^2 = E_0 \Rightarrow p = \sqrt{2m_p E_0}$ $\lambda_p = \frac{h}{\sqrt{2m_p E_0}}$

for photon $\frac{hc}{\lambda} = E_0 \Rightarrow \lambda_{ph} = \frac{hc}{E_0}$

$\Rightarrow \frac{\lambda_p}{\lambda_{ph}} = \frac{h}{\sqrt{2m_p E_0}} \times \frac{E_0}{hc} = \frac{1}{c}\sqrt{\frac{E_0}{2m_p}}$

16. The lengths of a rectangular sheet is measured from a screw gauge of pitch 0.75 mm and number of division on circular scale = 15. Find maximum possible error in measurement of area.



(1) 0.225 mm^2

(2) 0.375 mm^2

(3) 0.75 mm^2

(4) 0.30 mm^2

Answer (2)

Sol. Lest count of screw gauge

$= \frac{0.75}{15} = 0.05$ mm

Now, $S = lb$

$\Rightarrow \frac{\Delta S}{S} = \frac{\Delta l}{l} + \frac{\Delta b}{b}$

$\Rightarrow \frac{\Delta S}{S} = \left(\frac{0.05}{5}\right) + \frac{0.05}{2.5} = \frac{1}{100} + \frac{2}{100} = \frac{3}{100}$

$\Delta S = \left(\frac{3}{100}\right) \times 5 \times 2.5 = 0.375\ mm^2$

17. There are two prisms of refractive indices of 1.54 & 1.72 respectively. If ray is not deviating after passing through two prisms, then find prism angle of second prism if prism angle of first prism is 4°

(1) 2° (2) 3°

(3) 4° (4) 3.5°

Answer (2)

Sol. $S_1 = S_2$

$\Rightarrow (1.54 - 1)4° = (1.72 - 1)A.$

$\Rightarrow A = 3°$

18. The energy associated with a cylindrical region due to an EM wave $E = 100\sin(kx - \omega t)$ is U_0. Find the equation of EM wave for which a cylinder of same length and half the diameter (as previous one) contains same energy U_0.

(1) $200\sin(kx - \omega t)$ (2) $25\sin(\omega t - kx)$

(3) $50\sin(kx - \omega t)$ (4) $400\sin(\omega t - kx)$

Answer (1)

Sol. For EM wave $E = 100\sin(\omega t - kx)$

Energy density $\rho_{a_v} = \frac{1}{2}\epsilon_0 (E_0)^2$

Initial volume $v_0 = \pi R^2 l$

Volume in next situation = $v = \frac{\pi R^2 l}{4} = \frac{V_0}{4}$

So, $u_0 = \frac{1}{2}\epsilon_0 (E_0)^2 \times V_0 = \frac{1}{2}\epsilon_0 (E_1^2)\cdot\frac{V_0}{4}$

$\Rightarrow E_0^2 = \frac{E_1^2}{4} \Rightarrow E_1 = 2E_0 = 200$ V/m

So, required equation will have 200 V/m of amplitude.

19.

20.

SECTION - B

Numerical Value Type Questions: This section contains 5 Numerical based questions. The answer to each question should be rounded-off to the nearest integer.

21. The dimensions of Young's modules of elasticity per unit length is $M^aL^bT^c$ then $|a + b + c|$ is

Answer (3)

Sol. $\frac{Y}{L} = \frac{MLT^{-2}}{L^2}\frac{1}{L} = ML^{-2}T^{-2}$

$|1 - 2 - 2| = 3$

22. In a *YDSE*, the distance of the 10th bright fringe from the central maxima is 10 mm when light of wavelength used is 600 nm. Find the distance (in mm) of the 10th bright fringe from the central maxima if light of wavelength 660 nm is used instead.

Answer (11)

Sol. $y = 10\frac{\lambda D}{d}$

$\frac{y_2}{y_1} = \frac{\lambda_2}{\lambda_1}$

$y_2 = \frac{\lambda_2}{\lambda_1} \times y_1$

$= \frac{660\text{ nm}}{600\text{ nm}} \times 10\text{ mm}$

= 11 mm

23.

24.

25.