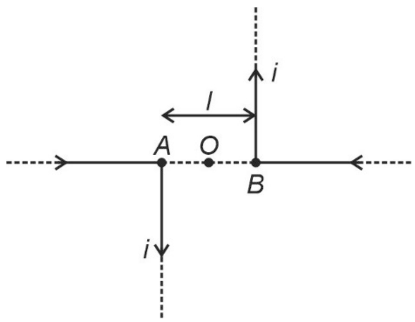
PHYSICS

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.



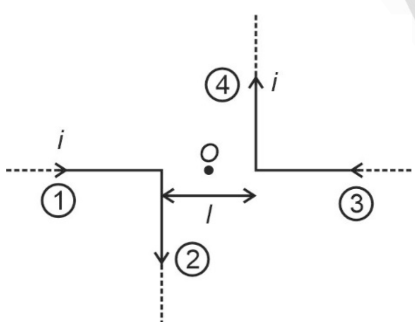
Point O and two long wires are kept in same plane such that point O lies at mid of line. Then magnetic field at point O due to the current i flowing in both the wires is equal to

(1) $\frac{\mu_0 i}{2\pi l}$ (2) $\frac{\mu_0 i}{\pi l}$

(3) $\frac{2\pi\mu_0 i}{l}$ (4) $\frac{\mu_0 i}{2l}$

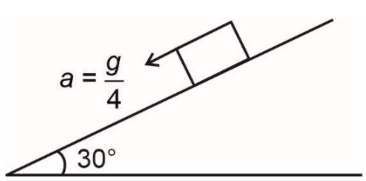
Answer (2)

Sol. Wire section 1 and 3 will not generate field at O but 2 and 4 does so



$$B = 2\times\frac{\mu_0 i}{4\pi\frac{l}{2}} = \frac{\mu_0 i}{\pi l}$$

2. A block is sliding down an inclined plane of inclination 30°, with an acceleration of $\frac{g}{4}$:



Find the co-efficient of friction between the block and incline.

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

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

Answer (2)

Sol. $mg\sin\theta - \mu mg\cos\theta = ma$

$$\Rightarrow \quad \frac{g}{4} = g\sin\theta - \mu g\cos\theta$$

$$\Rightarrow \quad \mu = \frac{1}{2\sqrt{3}}$$

3. A car is moving on a circular track of radius 50 cm with coefficient of friction being 0.34. On this horizontal track the maximum safe speed for turning is equal to (g = 10 m/s^2)

(1) 1.03 (2) 1.7

(3) 1.3 (4) 1.8

Answer (3)

Sol. Friction will provide required centripetal acceleration to move in the circle.

so,

$$\frac{mv^2}{R} = \mu mg$$

or $v = \sqrt{\mu g R}$

$$= \sqrt{0.34\times 10\times\frac{1}{2}}$$

= 1.3 m/s

4. Find the ratio of maximum wavelength of Lyman series of hydrogen atom to minimum wavelength of Balmer series of helium atom.

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

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

Answer (1)

Sol. For Lyman series, (for hydrogen atom)

λ_{max} then ΔE will be from n = 2 to n = 1

$$\Delta E = 13.6\times\left(1-\frac{1}{4}\right)\text{eV}$$

$$=\left(\frac{3}{4}\times 13.6\right)\text{eV}$$

$$\lambda_{max} = \frac{12400}{\left(\frac{3}{4}\times 13.6\right)}(\text{Å})$$

For λ_{min} in Balmer series, for He atom from $n = \infty$ to $n = 2$

$$\Delta E = 13.6\times 4\left(\frac{1}{4}\right) = 13.6\text{ eV}$$

$$\lambda_{min} = \frac{12400}{(13.6)}\text{Å}$$

$$\frac{\lambda_{max}}{\lambda_{min}} = \frac{(13.6)}{\left(\frac{3}{4}\times 13.6\right)} = \left(\frac{4}{3}\right)$$

5. If dimensional formula of pressure gradient is X, electric field has Y, energy density has W and latent heat has Z. Find dimensional formula of $\frac{[X][Y]}{[Z][W]}$ is

(1) $ML^{-2}T^{-1}A^{1}$ (2) $ML^{-2}T^{-1}A^{-1}$

(3) $M^{-1}L^{2}T^{-1}A^{-1}$ (4) $ML^{2}T^{-1}A^{-1}$

Answer (2)

Sol. $[X] = \left[\frac{\Delta P}{\Delta X}\right] = \frac{MLT^{-2}}{L^3} = [ML^{-2}T^{-2}]$

$[Y] = [E] = [MLT^{-3}A^{-1}]$

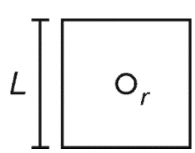
$$[W] = \left[\frac{MLT^{-2}}{L^2}\right] = [ML^{-1}T^{-2}]$$

$$[Z] = \left[\frac{ML^2T^{-2}}{M}\right] = [L^2T^{-2}]$$

$$\frac{[X][Y]}{[Z][W]} = \frac{[ML^{-2}T^{-2}][MLT^{-3}A^{-1}]}{[L^2T^{-2}][ML^{-1}T^{-2}]}$$

$= [ML^{-2}T^{-1}A^{-1}]$

6. A small circular loop of radius r is placed in the plane of a square loop of side length L ($r << L$). Circular loop is at the center of square as shown in the figure. Find mutual inductance.

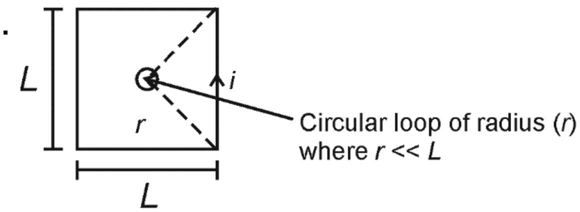


(1) $\frac{\mu_0 r^2}{\sqrt{2}L}$ (2) $\frac{\pi\mu_0 r^2}{2L}$

(3) $\frac{2\sqrt{2}\mu_0 r^2}{L}$ (4) $\frac{4\mu_0 r^2}{L}$

Answer (3)

Sol.



B_{at} centre of rectangular loop

$$= \frac{\mu_0 i}{4\pi\left(\frac{L}{2}\right)}\left[\frac{1}{\sqrt{2}}+\frac{1}{\sqrt{2}}\right]\times 4$$

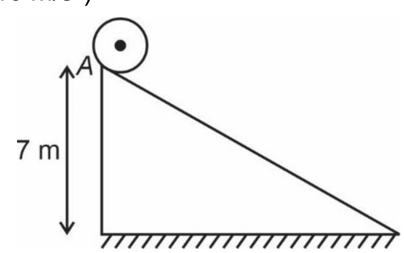
$$= \frac{\mu_0 i}{2\pi L}\left[\frac{2}{\sqrt{2}}\right]\times 4$$

$$= \frac{4\mu_0 i}{\sqrt{2}\pi L} = \left(\frac{2\sqrt{2}\mu_0 i}{\pi L}\right)$$

Flux in circular loop (ϕ) = $\pi r^2 x(B)$

Self inductance = $\frac{\phi}{i} = \left(\frac{2\sqrt{2}\mu_0 r^2}{L}\right)$

7. A solid sphere is released from point O at the top of an incline as shown. Find the value of velocity of centre of mass of sphere at the bottommost point of the incline after it reaches there doing pure rolling. (g = 10 m/s²)



(1) 3 m/s (2) 7 m/s

(3) 10 m/s (4) 0.7 m/s

Answer (3)

Sol. Using energy conservation.

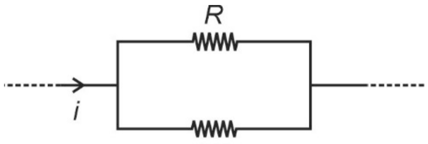
$$\frac{1}{2}mv_{cm}^2 + \frac{1}{2}\frac{2mR^2}{5}\left(\frac{v_{cm}}{R}\right)^2 = mgh$$

$$\frac{7}{10}mv_{cm}^2 = mgh$$

$$v_{cm} = \sqrt{\frac{10}{7}gh}$$

= 10 m/s

8. In the part of a circuit shown



find the ratio of rate of heat produced in R to that in $3R$.

(1) 1 : 9 (2) 1 : 3

(3) 3 : 1 (4) 9 : 1

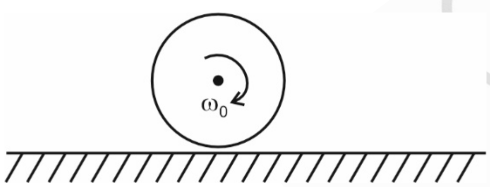
Answer (3)

Sol. $P = \frac{V^2}{R}$

Since V is same

$$\Rightarrow \text{Ratio} = \frac{\frac{1}{R}}{\frac{1}{3R}} = 3$$

9. A disk of radius R is given ω_0 angular speed and placed gently on a rough horizontal surface. Find the velocity of center of disk when pure rolling starts.

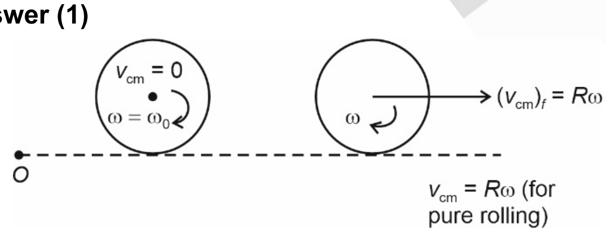


(1) $\frac{R\omega_0}{3}$ (2) $R\omega_0$

(3) $\frac{R\omega_0}{4}$ (4) $2R\omega_0$

Answer (1)

Sol.



Applying angular momentum conservation about point 'O'.

$$I_{cm}\omega_0 = \left(I_{cm} + MR^2\right)\omega$$

$$\frac{1}{2}MR^2\omega_0 = \frac{3}{2}MR^2\omega$$

$$\Rightarrow \boxed{\frac{R\omega_0}{3} = \left(v_{cm}\right)_f}$$

Finally velocity of centre of mass $= \left(\frac{R\omega_0}{3}\right)$

10. In a standard YDSE first minima is obtained in front of a slit for λ = 800 nm. If distance between the slit and screen is 5 m then separation between the slits is equal to

(1) 5×10^{-2} m (2) 5 mm

(3) 3 mm (4) 2 mm

Answer (4)

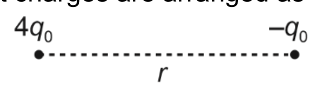
Sol. $\frac{d}{2} = \frac{\lambda D}{2d}$

$d = \sqrt{\lambda D}$

$= \sqrt{800 \times 10^{-9} \times 5}$

= 2 mm

11. Two point charges are arranged as shown:



Find the distance from $4q_0$ where net electric field is zero.

(1) $4r$ (2) $3r$

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

Answer (4)

Sol. $\frac{1}{4\pi\varepsilon_0}\frac{4q_0}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(x-r)^2}$

$\Rightarrow x = 2r$

12. Wavelength of shortest wavelength of Lyman series for hydrogen atom is λ_0, then longest wavelength of Balmer series for He^+ ion is equal to

(1) $\frac{17\lambda_0}{13}$ (2) $\frac{11\lambda_0}{7}$

(3) $\frac{9\lambda_0}{5}$ (4) $\frac{25\lambda_0}{19}$

Answer (3)

Sol. $\frac{1}{\lambda_0} = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$

(For Lyman series for hydrogen atom)

$\lambda_0 = \frac{1}{R}$

$\frac{1}{\lambda} = R \times 2^2\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$

(For Balmer series for He^+ ion)

$\frac{1}{\lambda} = 4R \times \frac{5}{36}$

$\lambda = \frac{9\lambda_0}{5}$

13. Find excess pressure inside a soap bubble of radius 'R' and surface tension 'T'.

(1) $\frac{T}{R}$ (2) $\frac{2T}{R}$

(3) $\frac{3T}{R}$ (4) $\frac{4T}{R}$

Answer (4)

Sol. $(\Delta P)_{\text{soap bubble}} = \left(\frac{4T}{R}\right)$

14. Two point masses (mass m each) are moving in a circle of radius R under mutual gravitational attraction. Find the speed of each mass.

(1) $\sqrt{\frac{Gm}{4R}}$ (2) $\sqrt{\frac{Gm}{2R}}$

(3) $\sqrt{\frac{Gm}{8R}}$ (4) $\sqrt{\frac{Gm}{R}}$

Answer (1)

Sol. $\frac{G(m)(m)}{(2R)^2} = \frac{mv^2}{R}$

$\Rightarrow v = \sqrt{\frac{Gm}{4R}}$

15. Find out work done in expanding the soap bubble from radius r_1 = 3.5 cm to r_2 = 7.0 cm.

(Given surface tension of soap solution, T = 0.03 N/m)

(1) 0.14 mJ (2) 1.4 mJ

(3) 0.7 mJ (4) 2.8 mJ

Answer (2)

Sol. Work done = change in surface energy of soap babble

Work done = $T(4\pi R^2 - 4\pi r^2)$

$= 4\pi T[7^2 - (3.5)^2] \times 10^{-4}$ J

$= 4\pi T[3.5 \times 10.5] \times 10^{-4}$ J

$= 1.4$ mJ

16. In an isochoric process on an ideal gas initial temperature is equal to 27°C with initial pressure being equal to 270 kPa. Now if final temperature is made equal to 36°C then final pressure is equal to approximately

(1) 298 kPa (2) 270 kPa

(3) 360 kPa (4) 278 kPa

Answer (4)

Sol. As the process is isochoric so

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{270 \times 10^3}{300} = \frac{P_f}{309}$$

$$P_f = 270 \times 10^3 \times \frac{309}{300}$$

$P_f = 278.1 \times 10^3$ Pa = 278.1 kPa

17. If half life of a sample is 30 minutes. Find the fraction of undecayed sample after 90 minutes.

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

(3) $\frac{1}{8}$ (4) $\frac{7}{8}$

Answer (3)

Sol. $N = N_0e^{-\lambda t}$

$$\lambda = \left(\frac{\ln 2}{t_{\frac{1}{2}}}\right)$$

N = Number of undecayed nuclie.

$N = N_0e^{-\lambda \times (90)}$

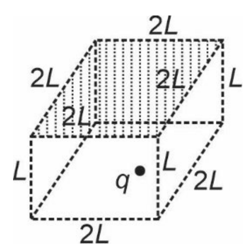
$= N_0e^{-\left(\frac{\ln 2}{30} \times 90\right)}$

$= N_0e^{-\ln(8)}$

$N = \left(\frac{N_0}{8}\right)$

Fraction undecayed $= \frac{N}{N_0} = \left(\frac{1}{8}\right)$

18. A charge q is placed at the centre of bottom face as shown:



Find the flux through the shaded surface.

(1) $\frac{2q}{7\varepsilon_0}$ (2) $\frac{q}{12\varepsilon_0}$

(3) $\frac{q}{4\varepsilon_0}$ (4) $\frac{q}{6\varepsilon_0}$

Answer (4)

Sol. Place a similar box at the bottom. We get a cube of side $2L$. charge q is then at the centre.

$$\Rightarrow \quad \phi = \frac{1}{6}\left(\frac{q}{\varepsilon_0}\right)$$

$$\Rightarrow \quad \phi = \frac{q}{6\varepsilon_0}$$

19. Two coherent waves of amplitude 8 cm each are superimposed on one another. If the amplitude of resultant wave is 8 cm then the phase difference between two waves is equal to

(1) $2\pi/3$ (2) $\pi/3$

(3) $\pi/4$ (4) $3\pi/4$

Answer (1)

Sol. $A_1 = A_2 = 8$ cm

$A_R = 8$ cm

$$A_R = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$$

$$8 = \sqrt{64 + 64 + 128\cos\phi}$$

$$\Rightarrow \quad \cos\phi = -\frac{1}{2}$$

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

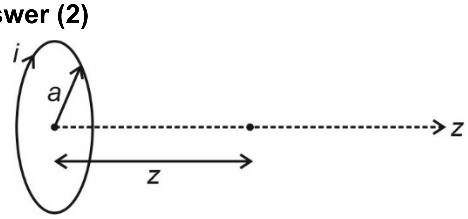
20. A current carrying loop of radius a is placed in X-Y plane with its center at origin. Find magnetic field on the point $(0, 0, a)$.

(1) $\frac{\mu_0 i}{2\sqrt{2}a}$ (2) $\frac{\mu_0 i}{4\sqrt{2}a}$

(3) $\frac{2\mu_0 i}{a}$ (4) $\frac{\mu_0 i}{4a}$

Answer (2)

Sol.



$$\vec{B} = \frac{\mu_0}{4\pi}\frac{2\vec{\mu}}{(a^2 + z^2)^{3/2}}$$

$$|\vec{\mu}| = (\pi a^2)i$$

$$B = \frac{\mu_0 a^2 i}{2(a^2 + z^2)^{3/2}}$$

as $z = a$

$$B = \frac{\mu_0 a^2 i}{2(2a^2)^{3/2}} = \left(\frac{\mu_0 i}{4\sqrt{2}a}\right)$$

SECTION - B

Numerical Value Type Questions: This section contains 10 questions. In Section B, attempt any five questions out of 10. The answer to each question is a **NUMERICAL VALUE.** For each question, enter the correct numerical value (in decimal notation, truncated/rounded-off to the second decimal place; e.g. 06.25, 07.00, –00.33, –00.30, 30.27, –27.30) using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.

21. A ball of mass 2 kg is dropped from a height of 9.8 m and rebounds to a height of 4.9 m. If it remains in contact with ground for 0.2 seconds, the average force on the ball by the ground is $x(\sqrt{2}+1)$ Newtons. Find x. (Take $g = 9.8$ m/s^2)

Answer (98)

Sol. $v_{\text{initial}} = \sqrt{2g(9.8)}\downarrow$

$v_{\text{final}} = \sqrt{2g(4.9)}\uparrow$

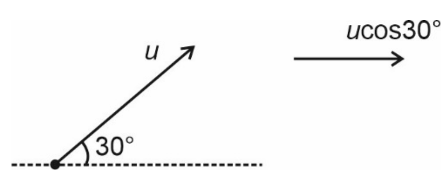
$\Rightarrow F \times \Delta t = m(v_{\text{final}} - v_{\text{initial}})$

$\Rightarrow F = 98(\sqrt{2}+1)$N

22. A stone is thrown at an angle 30° with the horizontal on a plane ground. The ratio of kinetic energy at maximum height to the kinetic energy at the point of projection is equal to

Answer (0.75)

Sol.



At the point of projection, speed is u so $KE_1 = \frac{1}{2}mu^2$

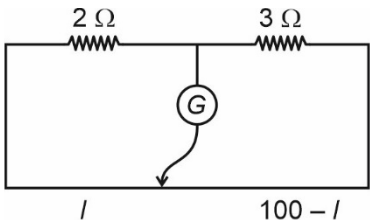
At maximum height, the speed is $u\cos 30°$

So, $KE_2 = \frac{1}{2}m(u\cos 30°)^2$

$= \frac{3}{8}mu^2$

So, $\frac{KE_1}{KE_2} = \frac{4}{3}$

23. Consider the meter bridge setup shown :



If a shunt resistance x Ω is added to 3 Ω resistor, balance point shifts by 22.5 cm. Find x.

Answer (2)

Sol. $\frac{2}{3}=\frac{l}{100-l}$

$\Rightarrow$ l = 40 cm

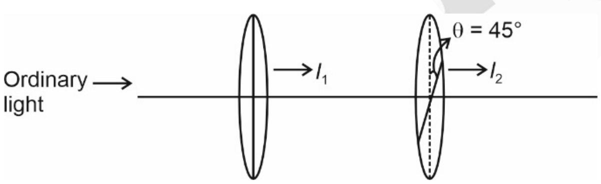
$\Rightarrow \frac{2}{R}=\frac{62.5}{37.5}$ where $R=\frac{3x}{3+x}$

$\Rightarrow \frac{3x}{3+x}=\frac{75}{62.5}$

$\Rightarrow x = 2\ \Omega$

24. Two polarizers P_1 & P_2 are placed such that their transmission axis are at 45° from each other. Ordinary light is passed through P_1 & I_1 intensity is observed. When this light is passed through P_2, I_2 intensity is observed.

Find $\frac{I_1}{I_2}$?



Answer (2)

$I_1=\frac{I}{2}$

$I_2=\frac{I}{2}\cos^2 45^\circ=\frac{I}{2}\times\frac{1}{2}=\frac{I}{4}$

so, $\frac{I_1}{I_2}=\frac{\frac{I}{2}}{\left(\frac{I}{4}\right)}=2$

25. Magnetic field through a circular loop is 0.8 T. The radius of the loop is expanding at 2 cm/s. The induced emf in the loop, when radius of the loop is 10 cm, is $x\pi \times 10^{-4}$ volts. Find x.

Answer (32)

Sol. $\phi = B(\pi r^2)$

$|r|=\left|\frac{-d\phi}{dt}\right|=\pi B\left(2r\frac{dr}{dt}\right)$

$=\pi\times 0.8\times 2\times\frac{10}{100}\times\frac{2}{100}$

$= 32\pi \times 10^{-4}$ volts

26. Consider the nuclear reaction:

$${}^{292}_{92}\text{X}\longrightarrow{}^{282}_{p}\text{Y}+2\alpha+{}^{0}_{1}e+2\,{}^{0}_{-1}e$$

Find the value of p.

Answer (89)

Sol. Conserving charge:

$p + 2 \times 2 + 1 + 2 \times (-1) = 92$

$\Rightarrow p = 89$

27. ??

28. ??

29. ??

30. ??