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. Choose the correct relationship between Poisson ratio (σ), bulk modulus (K) and modulus of rigidity (η) of a given solid object

(1) $\sigma = \frac{6K - 2\eta}{3K - 2\eta}$ (2) $\sigma = \frac{6K + 2\eta}{3K - 2\eta}$

(3) $\sigma = \frac{3K - 2\eta}{6K + 2\eta}$ (4) $\sigma = \frac{3K + 2\eta}{6K + 2\eta}$

Answer (3)

Sol. Poisson ratio (σ), bulk modulus (*K*) and modulus of rigidity (η) are related by

$\because \quad 2\eta(1 + \sigma) = 3K(1 - 2\sigma)$

$2\eta + 2\eta\sigma = 3K - 6K\sigma$

$$\sigma = \frac{3K - 2\eta}{2\eta + 6K}$$

2. A small object at rest, absorbs a light pulse of power 20 mW and duration 300 ns. Assuming speed of light as 3×10^8 m/s, the momentum of the object becomes equal to

(1) 2×10^{-17} kg m/s (2) 3×10^{-17} kg m/s

(3) 1×10^{-17} kg m/s (4) 0.5×10^{-17} kg m/s

Answer (1)

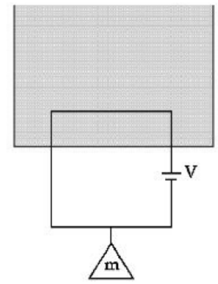
Sol. Assuming the small object as photon.

$$\text{Momentum } (p) = \frac{E}{C}$$

$$= \frac{20 \times 10^{-3} \times 300 \times 10^{-9}}{3 \times 10^8}$$

$= 2 \times 10^{-17}$ kg m/s

3. A massless square loop, of wire of resistance 10 Ω, supporting a mass of 1 g, hangs vertically with one of its sides in a uniform magnetic field of 10^3 G, directed outwards in the shaded region. A dc voltage *V* is applied to the loop. For what value of *V*, the magnetic force will exactly balance the weight of the supporting mass of 1 g? (If sides of the loop = 10 cm, $g = 10$ m/s²)



(1) 1 V (2) 10 V

(3) $\frac{1}{10}$ V (4) 100 V

Answer (2)

Sol. For balancing of force

$\therefore \quad F_{loop}$ = weight

$$\left(\frac{V}{R}\right)lB = mg$$

$$\left(\frac{V}{10}\right) \times \frac{10}{100} \times (10^3 \times 10^{-4}) = \left(\frac{1}{1000}\right) \times 10$$

V = 10 volts

4. The magnetic moment associated with two closely wound circular coils *A* and *B* of radius r_A = 10 cm and r_B = 20 cm respectively are equal if: (where N_A, I_A and N_B, I_B are number of turn and current of *A* and B respectively)

(1) $N_AI_A = 4N_BI_B$ (2) $2N_AI_A = N_BI_B$

(3) $N_A = 2N_B$ (4) $4N_AI_A = N_BI_B$

Answer (1)

Sol. $M_A = M_B$

$$I_AN_A\left(\pi r_A^2\right) = I_BN_B\left(\pi r_B^2\right)$$

$I_AN_A = 4I_BN_B$

5. A ball of mass 200 g rests on a vertical post of height 20 m. A bullet of mass 10 g, travelling in horizontal direction, hits the centre of the ball. After collision both travels independently. The ball hits the ground at a distance 30 m and bullet at a distance of 120 m from the foot of the post. The value of initial velocity of the bullet will be (if g = 10 m/s²)

(1) 60 m/s (2) 120 m/s

(3) 400 m/s (4) 360 m/s

Answer (4)

Sol. $\because$ Time of flight of each ball and bullet

$$= \sqrt{\frac{2H}{g}} = \sqrt{\frac{2 \times 20}{10}} = 2 \text{ s}$$

$\Rightarrow$ By applying linear momentum conservation

$$10u + 200(0) = 200\left(\frac{30}{2}\right) + 10\left(\frac{120}{2}\right)$$

u = 360 m/s

6. Two isolated metallic solid spheres of radii R and $2R$ are charged such that both have same charge density σ. The spheres are then connected by a thin conducting wire. If the new charge density of the bigger sphere is σ'. The ratio $\frac{\sigma'}{\sigma}$ is

(1) $\frac{5}{6}$ (2) $\frac{4}{3}$

(3) $\frac{5}{3}$ (4) $\frac{9}{4}$

Answer (1)

Sol. $\sigma = \frac{Q_1}{4\pi R^2} = \frac{Q_2}{4\pi(2R)^2}$

Now $Q_2' = Q_{\text{total}}\left[\frac{R_2}{R_1 + R_2}\right]$

$$= (Q_1 + Q_2)\left[\frac{2R}{3R}\right]$$

$$= \sigma(20\pi R^2)\frac{2}{3}$$

$$\therefore \quad \sigma_2' = \frac{Q_2'}{4\pi(2R)^2} = \frac{\sigma(20\pi R^2)\frac{2}{3}}{16\pi R^2}$$

$$= \frac{5}{4} \times \frac{2}{3}\sigma$$

$$= \frac{5}{6}\sigma$$

7. The pressure (P) and temperature (T) relationship of an ideal gas obeys the equation PT^2 = constant. The volume expansion coefficient of the gas will be

(1) $\frac{3}{T}$ (2) $\frac{3}{T^2}$

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

Answer (1)

Sol. PT^2 = constant

From $PV = nRT \Rightarrow \frac{T^3}{V}$ = constant

$T^3 \propto V$ ...(1)

$3T^2 dT \propto dV$ ...(2)

From (1) and (2)

$$\frac{3dT}{T} = \frac{dV}{V}$$

$$\therefore \quad \gamma = \frac{1}{V}\frac{dV}{dT} = \frac{3}{T}$$

8. Heat is given to an ideal gas in an isothermal process.

A. Internal energy of the gas will decrease.

B. Internal energy of the gas will increase.

C. Internal energy of the gas will not change.

D. The gas will do positive work.

E. The gas will do negative work.

Choose the correct answer from the options given below:

(1) C and E only (2) C and D only

(3) A and E only (4) B and D only

Answer (2)

Sol. Isothermal process $\Delta T = 0$

$$\Delta U = \frac{f}{2} nR\Delta T$$

$\Delta U = 0$

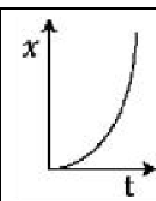
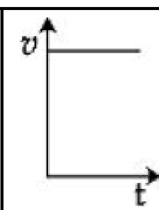
No change in internal energy

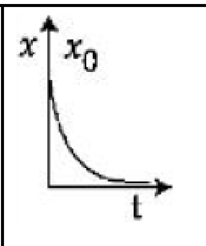
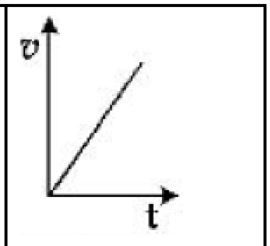
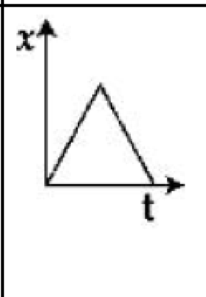
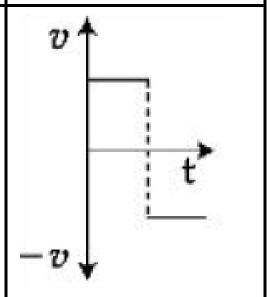
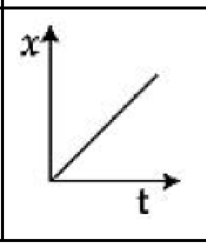
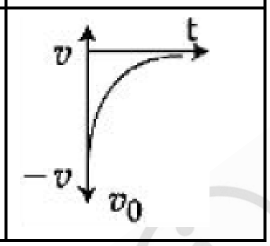
$\Delta Q = \Delta W$ (1st law)

ΔQ = +ve

ΔW = +ve

9. Match Column-I with Column-II :

Column-I (*x-t* graphs)		Column-II (*v-t* graphs)	
A.		I.	

B.		II.	
C.		III.	
D.		IV.	

Choose the correct answer from the options given below :

(1) A-I, B-III, C-IV, D-II

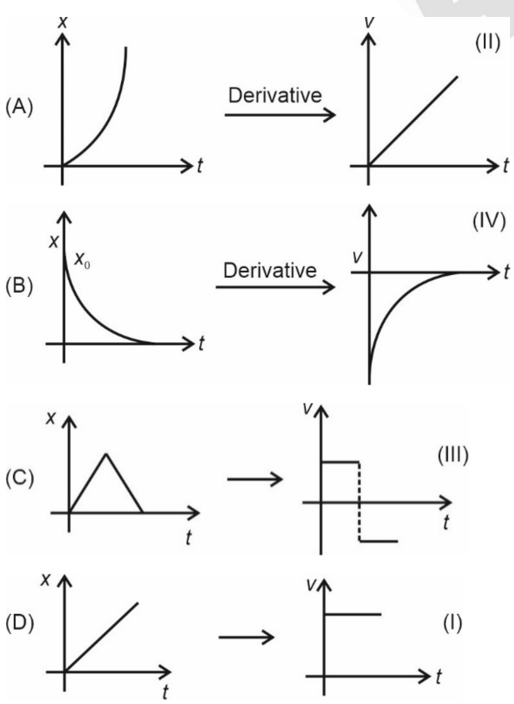
(2) A-II, B-III, C-IV, D-I

(3) A-I, B-II, C-III, D-IV

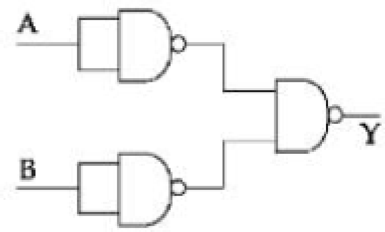
(4) A-II, B-IV, C-III, D-I

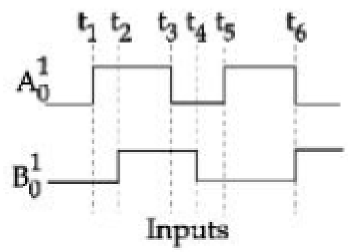
Answer (4)

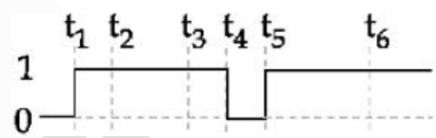
Sol.

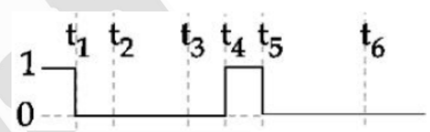


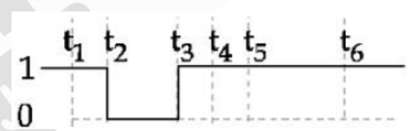
10. The output waveform of the given logical circuit for the following inputs A and B as shown below, is

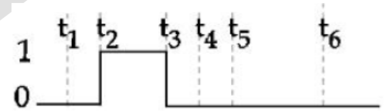




(1) 

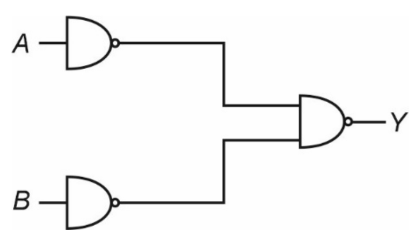
(2) 

(3) 

(4) 

Answer (1)

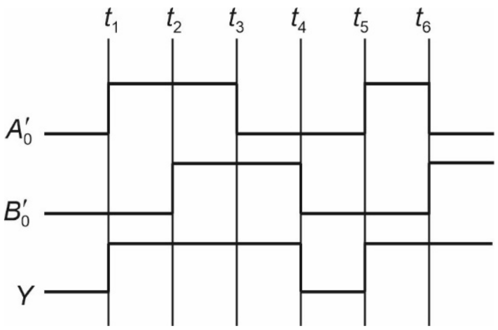
Sol.



Truth table

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

OR Gate



11. The charge flowing in a conductor changes with time as Q(t) = $\alpha t - \beta t^2 + \gamma t^3$. Where α, β and γ are constants. Minimum value of current is

(1) $\alpha - \frac{\gamma^2}{3\beta}$ (2) $\alpha - \frac{\beta^2}{3\gamma}$

(3) $\alpha - \frac{3\beta^2}{\gamma}$ (4) $\beta - \frac{\alpha^2}{3\gamma}$

Answer (2)

Sol. $Q(t) = \alpha t - \beta t^2 + \gamma t^3$

$i(t) = \alpha - 2\beta t + 3\gamma t^2$

$\frac{di}{dt} = -2\beta + 6\gamma t = 0$ (for max/min of i)

at $t = \frac{\beta}{3r}$ (i is minimum as i is an upward parabola)

$$i\left(\frac{\beta}{3\gamma}\right) = \alpha - 2\beta\left(\frac{\beta}{3\gamma}\right) + \frac{3\gamma\beta^2}{9\gamma^2}$$

$$= \alpha \frac{-\beta^2}{3\gamma}$$

12. The height of liquid column raised in a capillary tube of certain radius when dipped in liquid A vertically is, 5 cm. If the tube is dipped in a similar manner in another liquid B of surface tension and density double the values of liquid A, the height of liquid column raised in liquid B would be _______m.

(1) 0.20 (2) 0.05

(3) 0.5 (4) 0.10

Answer (2)

Sol. height of capillary rise $= \frac{2s\cos\theta}{\rho gR}$

When in A $5\ cm = \frac{2s_A\cos\theta}{\rho_A gR}$

When in B $h = \frac{2s_B\cos\theta}{\rho_B gR}$

$s_B = 2s_A$ and $\rho_B = 2\rho_A$

$$h = \frac{2\times 2s_A \times \cos\theta}{2\rho_A gR} = 5 \text{ cm}$$

13. A person has been using spectacles of power –1.0 dioptre for distant vision and a separate reading glass of power 2.0 dioptres. What is the least distance of distinct vision for this person

(1) 50 cm (2) 10 cm

(3) 30 cm (4) 40 cm

Answer (1)

Sol. u = 25 cm

$$f = \frac{1}{2}\text{m} = 50 \text{ cm}$$

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

$$\Rightarrow \frac{1}{v} + \frac{1}{25} = -\frac{1}{50}$$

$$\frac{1}{v} = -\frac{1}{50}$$

$\Rightarrow$ u = –50 cm

14. Speed of an electron in Bohr's 7th orbit for Hydrogen atom is 3.6 ×10^6 m/s. The corresponding speed of the electron in 3rd orbit, in m/s is

(1) (7.5 × 10^6) (2) (1.08 × 10^6)

(3) (8.4 × 10^6) (4) (3.6 × 10^6)

Answer (3)

Sol. $v \alpha \frac{z}{n}$

$$\frac{v_1}{v_2} = \left(\frac{n_2}{n_1}\right)$$

$$\Rightarrow \frac{3.6\times 10^6}{v_2} = \frac{3}{7}$$

$$\Rightarrow v_2 = \frac{7}{3}\times 3.6\times 10^6 \text{m/s}$$

= 8.4 × 10^6 m/s

15. Electric field in a certain region is given by $\vec{E} = \left(\frac{A}{x^2}\hat{i} + \frac{B}{y^2}\hat{j}\right)$. The SI unit of A and B are

(1) Nm^{3}C; Nm^{2}C

(2) Nm^{2}C; Nm^{3}C

(3) Nm^{2}C^{-1}; Nm^{2}C^{-1}

(4) Nm^{3}C^{-1}; Nm^{2}C^{-1}

Answer (3)

Sol. $\vec{E} = \left(\frac{A}{x^2}\hat{i} + \frac{B}{y^3}\hat{j}\right)$

$$\left[\frac{A}{x^2}\right] = [E] = \left[\frac{F}{q}\right] = \left[\frac{N}{C}\right] = NC^{-1}$$

$[A] = (Nm^2C^{-1})$

$[B] = Nm^3C^{-1}$

16. A sinusoidal carrier voltage is amplitude modulated. The resultant amplitude modulated wave has maximum and minimum amplitude of 120 V and 80 V respectively. The amplitude of each sideband is

(1) 10 V (2) 15 V

(3) 20 V (4) 5 V

Answer (1)

Sol. Amplitude of each side band $= \frac{A_{messsage}}{2}$

$A_{carrier} + A_{message} = 120$ ...(1)

$A_{carrier} - A_{message} = 80$ ...(2)

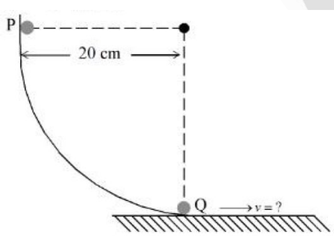
From (1) and (2)

$A_{message} = 20$ V

$\therefore$ Amplitude of each side band = 10 V

17. As per the given figure, a small ball P slides down the quadrant of a circle and hits the other ball Q of equal mass which is initially at rest. Neglecting the effect of friction and assume the collision to be elastic, the velocity of ball Q after collision will be

($g = 10$ m/s^2)

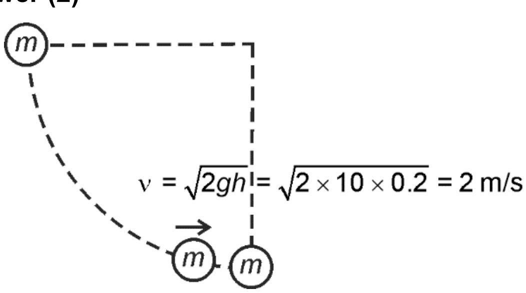


(1) 0.25 m/s (2) 2 m/s

(3) 0 (4) 4 m/s

Answer (2)

Sol.



Mass is same and elastic collision, so speed gets exchanged, $v = 2$ m/s

18. If the gravitational field in the space is given as $\left(-\frac{K}{r^2}\right)$. Taking the reference point to be at r = 2 cm with gravitational potential V = 10 J/kg. Find the gravitational potential at r = 3 cm in SI unit

(Given, that K = 6 Jcm/kg)

(1) 10

(2) 12

(3) 11

(4) 9

Answer (3)

Sol. $E = -\frac{K}{r^2}$

$$\Delta V = -\int_{r=2\,cm}^{3\,cm} E \cdot dr$$

$$= \int_2^3 \frac{k}{r^2} dr$$

$$= \left[-\frac{K}{r}\right]_2^3 = \left(\frac{K}{6}\right) = \frac{6}{6} = 1 \text{ J/kg}$$

$V_f - V_i = 1$

$\Rightarrow V_f - 10 = 1$

$V_f = 11$ J/kg

19. In a series LR circuit with $X_L = R$, power factor is P_1. If a capacitor of capacitance C with $X_C = X_L$ is added to the circuit the power factor becomes P_2. The ratio of P_1 to P_2 will be:

(1) 1 : 2

(2) 1 : 3

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

(4) 1 : 1

Answer (3)

Sol. $X_L = R$

$$\Rightarrow P_1 = \frac{R}{\sqrt{X_L^2 + R^2}} = \frac{1}{\sqrt{2}}$$

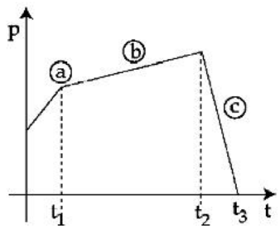
Now, $X_L = X_C = R$

$$\Rightarrow P_2 = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = 1$$

$$\Rightarrow \frac{P_1}{P_2} = \frac{1}{\sqrt{2}}$$

20. The figure represents the momentum time (p-t) curve for a particle moving along an axis under the influence of the force. Identify the regions on the graph where the magnitude of the force is maximum and minimum respectively?

If $(t_3 - t_2) < t_1$



(1) a and b (2) c and a

(3) c and b (4) b and c

Answer (3)

Sol. $F = \frac{dp}{dt}$

$\Rightarrow \quad |F| = \left|\frac{dp}{dt}\right| = |\text{slope of } p - t \text{ curve}|$

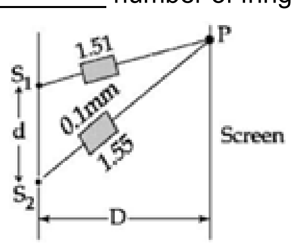
As we can see from graph,

$|F_c|$ is maximum and $|F_b|$ is minimum.

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. In Young's double slit experiment, two slits S_1 and S_2 are 'd' distance apart and the separation from slits to screen is D (as shown in figure). Now if two transparent slabs of equal thickness 0.1 mm but refractive index 1.51 and 1.55 are introduced in the path of beam (λ = 4000 Å) from S_1 and S_2 respectively. The central bright fringe spot will shift by _____________ number of fringes.



Answer (10)

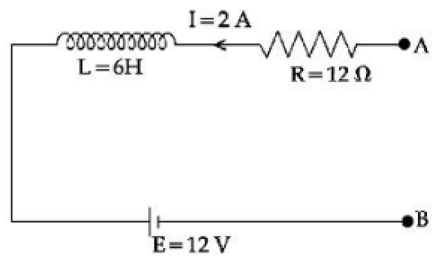
Sol. Path difference introduced by two slabs = $(\mu_2 - \mu_1)t$

$\Rightarrow \quad$ Number of shifts $= \frac{(\mu_2 - \mu_1)t}{\lambda}$

$= \frac{0.04 \times 0.1 \text{ mm}}{4000 \text{ Å}}$

$= \frac{4 \times 10^{-2} \times 10^{-4}}{4 \times 10^{-7}}$

= 10

22. 

As per the given figure, if $\frac{dI}{dt} = -1$ A/s then the value of V_{AB} at this instant will be ______V.

Answer (30)

Sol. From the circuit :

$V_A - iR - \frac{Ldi}{dt} - 12 = V_B$

$\Rightarrow \quad V_A - V_B = 2 \times 12 + 6(-1) + 12$ volts

= 30 volts

23. A horse rider covers half the distance with 5 m/s speed. The remaining part of the distance was travelled with speed 10 m/s for half the time and with speed 15 m/s for other half of the time. The mean speed of the rider averaged over the whole time of motion is $\frac{x}{7}$ m/s. The value of x is _______.

Answer (50)

Sol. Let S total distance

$\Rightarrow \quad t_1 = \frac{\frac{S}{2}}{5}$ ...(1)

Also, $\frac{S}{2} = \frac{10t_2}{2} + \frac{15t_2}{2}$

$\Rightarrow \quad t_2 = \frac{S}{25}$ ...(2)

$\Rightarrow \quad$ Mean speed $= \frac{S}{t_1 + t_2}$

$= \frac{S}{\frac{S}{10} + \frac{S}{25}} = \frac{250}{35}$ m/s $= \frac{50}{7}$ m/s

24. In an experiment for estimating the value of focal length of converging mirror, image of an object placed at 40 cm from the pole of the mirror is formed at distance 120 cm from the pole of the mirror. These distances are measured with a modified scale in which there are 20 small divisions in 1 cm. The value of error in measurement of focal length of the mirror is $\frac{1}{K}$ cm. The value of x is ________.

Answer (32)

Sol. $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ ...(1)

$\Rightarrow -\frac{1}{f^2}df=-\frac{1}{v^2}dv-\frac{1}{u^2}du$

$\Rightarrow \frac{df}{f^2}=\frac{dv}{v^2}+\frac{du}{u^2}$ ...(2)

From (1) : $-\frac{1}{120}-\frac{1}{40}=\frac{1}{f} \Rightarrow f = -30$ cm

Also, least count $=\frac{1\text{ cm}}{20}=0.05$ cm

$\Rightarrow df=\left[\frac{0.05}{120^2}+\frac{0.05}{40^2}\right]\times 30^2$

$=0.05\left[\frac{1}{16}+\frac{9}{16}\right]=\frac{5}{8}\times\frac{5}{100}=\frac{1}{32}$ cm

$\Rightarrow k = 32$

25. In a screw gauge, there are 100 divisions on the circular scale and the main scale moves by 0.5 mm on a complete rotation of the circular scale. The zero of circular scale lies 6 divisions below the line of graduation when two studs are brought in contact with each other. When a wire is placed between the studs, 4 linear scale divisions are clearly visible while 46th division the circular scale coincide with the reference line. The diameter of the wire is ________$\times 10^{-2}$ mm.

Answer (220)

Sol. Least count of screw gauge $=\frac{0.5}{100}$ mm $=\frac{1}{200}$ mm

Zero error of screw gauge $=+\frac{6}{200}$ mm $=+\frac{3}{100}$

$=0.03$ mm

Reading of screw gauge $=4\times 0.5+\frac{46}{200}$ mm

$=2+\frac{23}{100}$ mm = 2.23 mm

So diameter of wire = 2.23 mm – 0.03 mm

= 2.20 mm

= 220 × 10^{-2} mm

26. A capacitor of capacitance 900 μF is charged by a 100 V battery. The capacitor is disconnected from the battery and connected to another uncharged identical capacitor such that one plate of uncharged capacitor connected to positive plate and another plate of uncharged capacitor connected to negative plate of the charged capacitor. The loss of energy in this process is measured as x × 10^{-2} J. The value of x is

Answer (225)

Sol. $U_i=\frac{1}{2}CV^2=\frac{1}{2}\times 900\times 10^{-6}\times 100^2=4.5$ J

As the other capacitor is identical therefore charge is equally divided and potential difference across the capacitors becomes half. So

$U_f=\frac{1}{2}2C\left(\frac{V}{2}\right)^2=\frac{1}{2}\times 2\times 900\times 10^{-6}\left(\frac{100}{2}\right)^2$

$=\frac{9}{4}$ J $= 2.25$ J

So, loss in energy $\Delta U_{loss}=U_i-U_f$

= 2.25 J

= 225 × 10^{-2} J

27. A thin uniform of length 2 m, cross sectional area 'A' and density 'd' is rotated about an axis passing through the centre and perpendicular to its length with angular velocity ω. If value of ω in terms of its rotational kinetic energy E is $\sqrt{\frac{\alpha E}{Ad}}$ then value of α is ________.

Answer (3)

Sol. Kinetic energy of rod $E=\frac{1}{2}\frac{ml^2}{12}\omega^2$

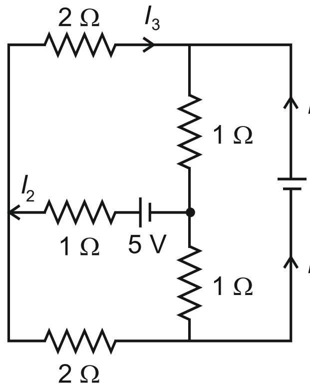
or $\omega=\sqrt{\frac{24E}{ml^2}}=\sqrt{\frac{24E}{d\times A\times l^3}}$

$\Rightarrow \omega=\sqrt{\frac{24E}{dA2^3}}$

$=\sqrt{\frac{3E}{Ad}}$

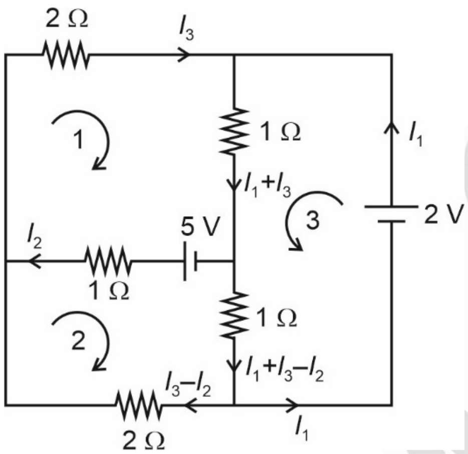
So, α = 3

28. In the following circuit, the magnitude of current I_1, is ________ A.



Answer (01.50)

Sol. The indicated diagram shows current flow diagram loops for writing Kirchhoff's law are also indicated, writing the equation



$2I_3 + I_1 + I_3 + I_2 = 5$

or $I_1 + I_2 + 3I_3 = 5$ ...(1)

$I_2 - 5 = 2(I_3 - I_2) + (I_1 + I_3 - I_2)$

or $I_1 - 4I_2 + 3I_3 = -5$ ...(2)

$(I_1 + I_3) + (I_1 + I_3 - I_2) = 2$

or $2I_1 - I_2 + 2I_3 = 2$ ...(3)

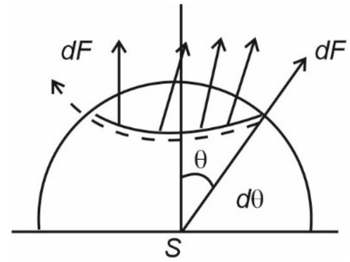
on solving $I_1 = \frac{3}{2}$A , I_2= 2, $I_3 = \frac{1}{2}$A

= 01.50

29. A point source of light is placed at the centre of curvature of a hemispherical surface. The source emits a power of 24 W. The radius of curvature of hemisphere is 10 cm and the inner surface is completely reflecting. The force on the hemisphere due to the light falling on it is ________ × 10^{-8} N.

Answer (4)

Sol.



$dA = 2\pi R \sin\theta R d\theta$

$= 2\pi R^2 \sin\theta d\theta$

So, $dF = 2\frac{IdA}{C}$

$= \frac{2\times 24}{4\pi R^2} \times \frac{2\pi R^2 \sin\theta d\theta}{C}$

$dF = \frac{24}{C}\sin\theta d\theta$

This dF force will be radially outward so the component of this force in vertical direction is

$dF_v = dF\cos\theta$

$\int_0^{F_v} dF_v = \frac{24}{C}\int_0^{\pi/2} \sin\theta\cos\theta d\theta$

$= \frac{24}{2C} = \frac{24}{2\times 3\times 10^8} = 4\times 10^{-8}$ N

30. The general displacement of a simple harmonic oscillator is x = Asinωt. Let T be its time period. The slope of its potential energy (U) – time (t) curve will be maximum when $t = \frac{T}{\beta}$. The value of β is

Answer (8)

Sol. $U = \frac{1}{2}m\omega^2 A^2 \sin^2 \omega t$

So, $\frac{dU}{dt} = \frac{m\omega^3 A^2}{2}\sin 2\omega t$

This value will be maximum when

$\sin 2\omega t = 1$

or $2\omega t = \frac{\pi}{2}$

$2\times \frac{2\pi}{T}t = \frac{\pi}{2}$

$\Rightarrow \quad t = \frac{T}{8}$

So β = 8