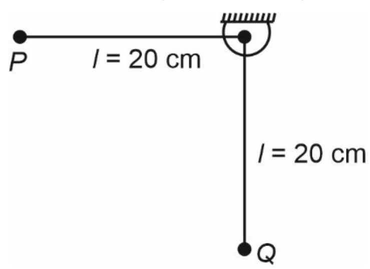
PHYSICS

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. Bob P is released from the position of rest at the moment shown. If it collides elastically with an identical bob Q hanging freely then velocity of Q, just after collision is (g = 10 m/s^2)



(1) 1 m/s (2) 4 m/s

(3) 2 m/s (4) 8 m/s

Answer (3)

Sol. Velocity of P just before collision is $= \sqrt{2gl}$

$= 2$ m/sec

As collision is elastic and the mass of P and Q is equal therefore just after collision velocity of P is 0 and that of Q is 2 m/sec.

2. Choose the option showing the correct relation between Poisson's ratio (σ), Bulk modulus (B) and modulus of rigidity (G).

(1) $\sigma = \dfrac{3B-2G}{2G+6B}$ (2) $\sigma = \dfrac{6B+2G}{3B-2G}$

(3) $\sigma = \dfrac{9BG}{3B+G}$ (4) $B = \dfrac{3\sigma-3G}{6\sigma+2G}$

Answer (1)

Sol. $E = 2G(1+\sigma)$ ....(1)

$E = 3B(1-2\sigma)$ ....(2)

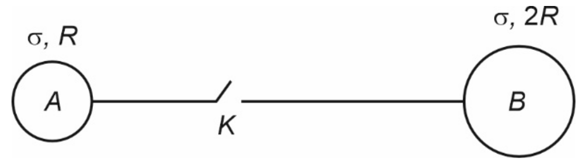
$$1 = \frac{2G}{3B}\left(\frac{1+\sigma}{1-2\sigma}\right)$$

$\Rightarrow 3B - 6B\sigma = 2G + 2G\sigma$

$\Rightarrow 3B - 2G = \sigma(2G + 6B)$

$$\sigma = \left(\frac{3B-2G}{2G+6B}\right)$$

3. Two conducting solid spheres (A & B) are placed at a very large distance with charge densities and radii as shown:



When the key K is closed, find the ratio of final charge densities.

(1) 4 : 1 (2) 1 : 2

(3) 2 : 1 (4) 1 : 4

Answer (3)

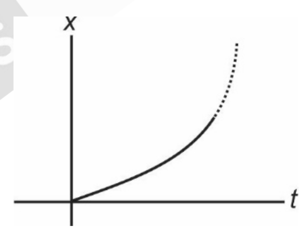
Sol. Final potential is same

$$\Rightarrow \frac{1}{4\pi\varepsilon_0}\frac{Q_1}{R} = \frac{1}{4\pi\varepsilon_0}\frac{Q_2}{2R} \quad ....(1)$$

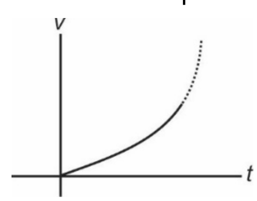
Also, $Q_1 + Q_2 = \sigma \cdot 4\pi R^2 + \sigma \cdot 4\pi(2R)^2$ .....(2)

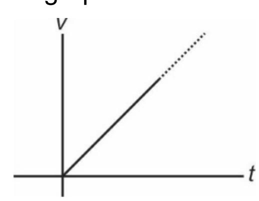
$$\Rightarrow \frac{\sigma_1}{\sigma_2} = 2.$$

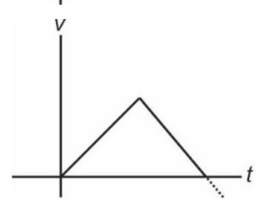
4. Position-time graph for a particle is parabolic and is as shown:

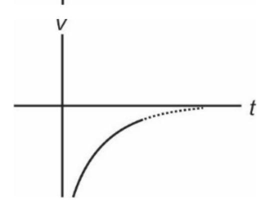


Choose the corresponding $v-t$ graph

(1)


(2)


(3)


(4)


Answer (2)

Sol. Since $x \propto t^2$

$$\Rightarrow \quad v = \frac{dx}{dt} \propto t'$$

$\Rightarrow$ Option 2 is correct

5. For a system undergoing isothermal process, heat energy is supplied to the system. Choose the option showing correct statements

(a) Internal energy will increase

(b) Internal energy will decrease

(c) Work done by system is positive

(d) Work done by system is negative

(e) Internal energy remains constant

(1) (a), (c), (e) (2) (b), (d)

(3) (c), (e) (4) (a), (d), (e)

Answer (3)

Sol. For isothermal process,

$dT = 0$

so, $dU = 0 \Rightarrow$ Internal energy remains same

$dQ = dW$

as dQ is positive,

so dW is positive

6. The heat passing through the cross-section of a conductor, varies with time 't' as $Q(t) = \alpha t - \beta t^2 + \gamma t^3$. ($\alpha$, β and γ are positive constants.) The minimum heat current through the conductor is

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

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

Answer (2)

Sol. Heat through cross section of rod

$Q = \alpha t - \beta t^2 + \gamma t^3$

so heat current $= \frac{dQ}{dt}$

heat current $= \frac{dQ}{dt} = \alpha - 2\beta t + 3\gamma t^2$

for heat current to be minimum

$$\frac{d^2Q}{dt^2} = -2\beta + 6\gamma t = 0$$

$$t = \frac{2\beta}{6\gamma} = \left(\frac{\beta}{3\gamma}\right)$$

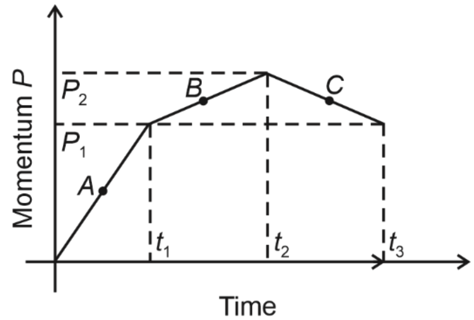
so minimum heat current

$$\left.\frac{dQ}{dt}\right|_{\text{minimum}} = \alpha - 2\beta \times \frac{\beta}{3\gamma} + 3\gamma \times \frac{\beta^2}{9\gamma^2}$$

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

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

7. Momentum-time graph of an object moving along a straight line is as shown in figure. If $(P_2 - P_1) < P_1$ and $(t_2 - t_1) = t_1 < (t_3 - t_2)$ then at which points among A, B and C the magnitude of force experienced by the object is maximum and minimum respectively.

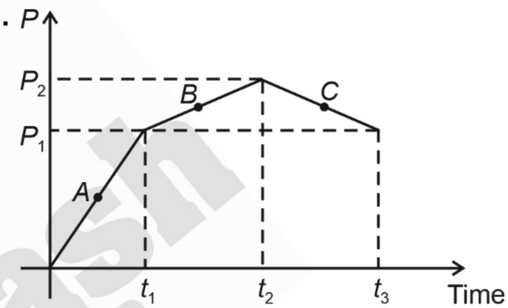


(1) A, B (2) A, C

(3) B, C (4) B, A

Answer (2)

Sol.



$$F_A = \frac{P_1}{t_1}$$

$$F_B = \frac{P_2 - P_1}{t_2 - t_1}$$

$$F_C = \frac{P_2 - P_1}{t_3 - t_2}$$

Therefore the maximum force is at A and minimum force is at C.

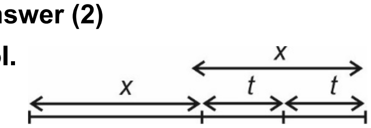
8. A particle moving in unidirectional motion travels half of the total distance with a constant speed of 15 m/s. Now first half of the journey time it travels at 10 m/s and second half of the remaining journey time it travels at 5 m/s. Average speed of the particle is

(1) 12 m/s (2) 10 m/s

(3) 7 m/s (4) 9 m/s

Answer (2)

Sol.



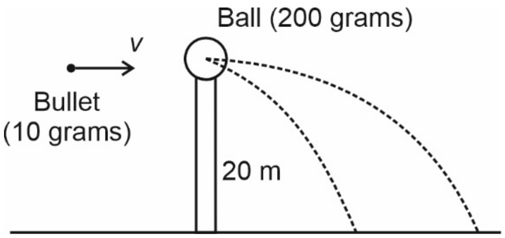
$$v_{av} = \frac{2x}{\frac{x}{15} + 2t}$$

$= \dfrac{2x}{\dfrac{x}{15} + \dfrac{2x}{10+5}}$

= 10 m/sec

9. A bullet strikes a stationary ball kept at a height as shown. After collision, range of bullet is 120 m and that of ball is 30 m. Find initial speed of bullet. Collision is along horizontal direction.

Take g = 10 m/s^2



(1) 150 m/s (2) 90 m/s
(3) 240 m/s (4) 360 m/s

Answer (4)

Sol. $m_1V + m_2(O) = m_1v_1' + m_2V_2'$ ...(1)

$\Delta t = \sqrt{\dfrac{2h}{g}} = 2s$ ...(2)

$\Rightarrow v_1' = \dfrac{120 \text{ m}}{2s} = 60 \text{ m/s}$

& $v_2' = \dfrac{30 \text{ m}}{2s} = 15 \text{ m/s}$

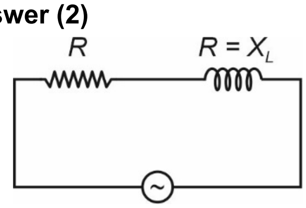
$\Rightarrow v$ = 360 m/s

10. If an inductor with inductive reactance, $X_L = R$ is connected in series with resistor R across an A.C voltage, power factor comes out to be P_1. Now, if a capacitor with capacitive reactance, $X_C = R$ is also connected in series with inductor and resistor in the same circuit, power factor becomes P_2. Find $\dfrac{P_1}{P_2}$

(1) $\sqrt{2}:1$ (2) $1:\sqrt{2}$
(3) 1 : 1 (4) 1 : 2

Answer (2)

Sol.

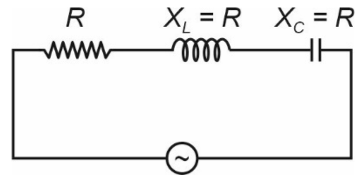


$Z = \sqrt{R^2 + R^2}$

$= \sqrt{2}R$

$P_1 = \cos\phi$ = power factor $= \dfrac{R}{Z} = \left(\dfrac{1}{\sqrt{2}}\right)$

When capacitor is also connected in series



The LCR circuit is in resonance stage

So, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = R$

$P_2 = \cos\phi$ = power factor $= \dfrac{R}{Z} = \dfrac{R}{R} = 1$

So, $\dfrac{P_1}{P_2} = \dfrac{\left(\dfrac{1}{\sqrt{2}}\right)}{1} = \dfrac{1}{\sqrt{2}}$

11. Electromagnetic wave beam of power 20 mW is incident on a perfectly absorbing body for 300 ns. The total momentum transferred by the beam to the body is equal to

(1) 2×10^{-17} Ns (2) 1×10^{-17} Ns
(3) 3×10^{-17} Ns (4) 5×10^{-17} Ns

Answer (1)

Sol. Total energy incident = Pt

So total initial momentum = $\dfrac{Pt}{c}$

Total final momentum = 0

Total momentum transferred $= \dfrac{Pt}{c}$

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

= 2×10^{-17} Ns

12. The velocity of an electron in the seventh orbit of hydrogen-like atom is 3.6×10^6 m/s. Find the velocity of the electron in the 3rd orbit.

(1) 4.2×10^6 m/s (2) 8.4×10^6 m/s
(3) 2.1×10^6 m/s (4) 3.6×10^6 m/s

Answer (2)

Sol. For hydrogen like atom,

$v \propto \dfrac{1}{n}$

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

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

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

= 8.4×10^6 m/s

13. Electric field in a region is given by $\vec{E} = \frac{a}{x^2}\hat{i} + \frac{b}{y^3}\hat{j}$, where x & y are co-ordinates. Find SI units of a & b.

(1) a – Nm^2C^{-1}
b – Nm^3C^{-1}

(2) a – Nm^3C^{-1}
b – Nm^2C^{-1}

(3) a – NmC^{-1}
b – Nm^2C^{-1}

(4) a – Nm^2C^{-1}
b – Nm^2C^{-1}

Answer (1)

Sol. E – NC^{-1}

x^2 – m^2

y^3 – m^3

$\Rightarrow$ a – Nm^2C^{-1}

& b – Nm^3C^{-1}

14. Coil A of radius 10 cm has N_A number of turns and I_A current is flowing through it. Coil B of radius 20 cm has N_B number of turns and I_B current is flowing through it. If magnetic dipole moment of both the coils is same then

(1) $I_AN_A = 4I_BN_B$

(2) $I_AN_A = \frac{1}{4}I_BN_B$

(3) $I_AN_A = 2I_BN_B$

(4) $I_AN_A = \frac{1}{2}I_BN_B$

Answer (1)

Sol. Magnetic dipole moment $\mu = NIA = NI\pi R^2$

So $\frac{\mu_A}{\mu_B} = \frac{N_AI_AR_A^2}{N_BI_BR_B^2} = 1$

$\frac{N_AI_A\,(10^2)}{N_BI_B\,(20^2)} = 1$

$N_AI_A = 4N_BI_B$

15. An ideal gas undergoes a thermodynamic process following the relation PT^2 = constant. Assuming symbols have their usual meaning then volume expansion coefficient of the gas is equal to

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

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

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

(4) $\frac{1}{T}$

Answer (2)

Sol. Volume expansion coefficient $= \frac{dV}{VdT}$

For PT^2 = constant

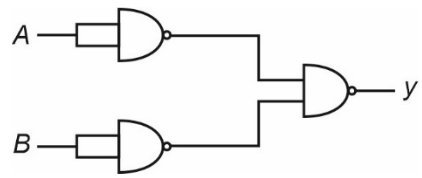
Or $\frac{T^3}{V}$ = constant

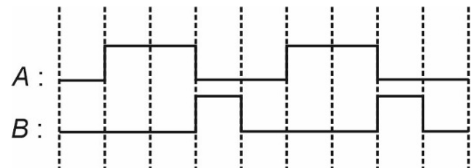
Or $\frac{dV}{dT} = (C)\,3T^2$

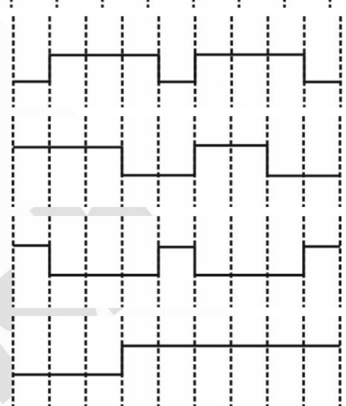
Or $\frac{dV}{VdT} = \frac{3T^2}{T^3}$

$\frac{dV}{VdT} = \frac{3}{T}$

16. Consider a combination of gates as shown :







Answer (1)

Sol. $y = (A'B')' = A + B$

$\Rightarrow$ OR gate

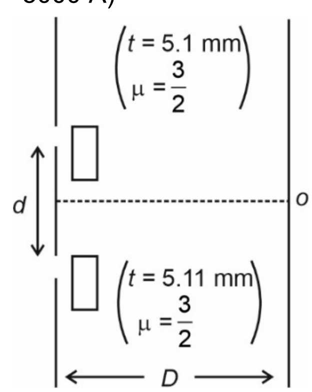
$\Rightarrow$ Option 1

17. For the given YDSE setup. Find the number of fringes by which the central maxima gets shifted from point O.

(Given d = 1 mm

D = 1 m

λ = 5000 Å)



(1) 10

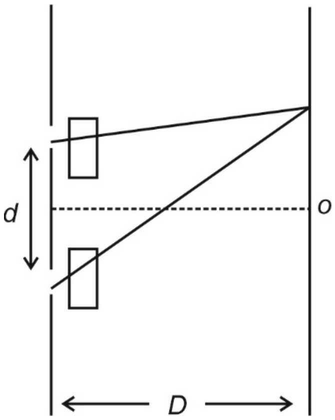
(2) 15

(3) 8

(4) 12

Answer (1)

Sol.



at central position, path difference, is,

$(\mu - 1)t_1 - (\mu - 1)t_2$

$\Delta x = (\mu - 1)\,(t_1 - t_2)$

$$\Delta x = \left(\frac{3}{2} - 1\right)(5.11 - 5.10)\text{ mm}$$

$$= \frac{1}{2} \times (0.01)\text{ mm}$$

= 0.005 mm

= 5×10^{-6} m

No. of fringes shifted = $\frac{\Delta x}{\lambda} = \frac{5 \times 10^{-6}\text{ m}}{5 \times 10^{-7}\text{ m}}$

= 10

18.

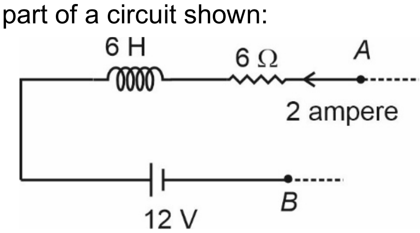
19.

20.

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 a part of a circuit shown:



Find $V_A - V_B$ in volts. It is given that current is decreasing at a rate of 1 ampere/s.

Answer (18)

Sol. $V_A - iR - L\frac{di}{dt} - 12 = V_B$

$\Rightarrow$ $V_A - V_B$ = +18 volts

22. A particle undergoing SHM follows the position-time equation given as $x = A\sin\left(\omega t + \frac{\pi}{3}\right)$. If the SHM motion has a time period of T, then velocity will be maximum at time $t = \frac{T}{\beta}$ for first time after t = 0. Value of β is equal to

Answer (03.00)

Sol. $x = A\sin\left(\omega t + \frac{\pi}{3}\right)$

$$\Rightarrow v = A\omega\cos\left(\omega t + \frac{\pi}{3}\right)$$

For maximum value of v

$$\cos\left(\omega t + \frac{\pi}{3}\right) = \pm 1$$

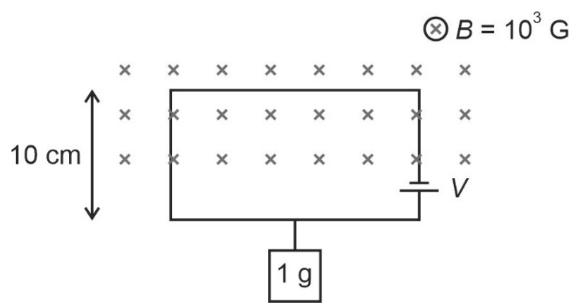
$$\Rightarrow \omega t + \frac{\pi}{3} = \pi \text{ (for nearest value of } t\text{)}$$

$$\omega t = \frac{2\pi}{3}$$

$$t = \frac{T}{3}$$

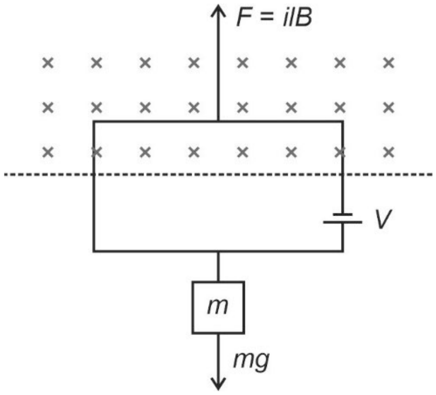
So β = 3

23. A block of mass 1 g is equilibrium with the help of a current carrying square loop which is partially lying in constant magnetic field (B) as shown. Resistance of the loop is 10 Ω. Find the voltage (V) (in volts) of the battery in the loop.



Answer (10.00)

Sol.



$ilB = mg$

$$i = \left(\frac{mg}{lB}\right) = \frac{(1\times10^{-3}\ \text{kg})\times(10\ \text{m/s}^2)}{(0.1\ \text{m})\times(0.1\ \text{T})}$$

$= 1 \times 10^{-3} \times 10^{3}$

$i = 1$ A

As resistance of loop = 10 Ω

$$i = \frac{V}{R} = 1\ \text{A}$$

$V = (1 \times 10)$ V

= 10 V

24. Initial volume of 1 mole of a monoatomic gas is 2 litres. It is expanded isothermally to a volume of 6 litres. Change in internal energy is xR. Find x.

Answer (00)

Sol. $\Delta U = nC_V\Delta T$

$= nC_V(0)$ $\quad$ ($\because$ isothermal)

$\Rightarrow \Delta U = 0$

25. An object is placed at a distance of 40 cm from the pole of a converging mirror. The image is formed at a distance of 120 cm from the mirror on the same side. If the focal length is measured with a scale where each 1 cm has 20 equal divisions. If the fractional error in the measurement of focal length is $\frac{1}{10\,k}$ Find k.

Answer (60.00)

Sol. $u = -40$ cm

$v = -120$ cm

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

$$\Rightarrow -\frac{1}{120} - \frac{1}{40} = \frac{1}{f}$$

$$\frac{1}{f} = \left(\frac{-1-3}{120}\right) = -\frac{4}{120}$$

$f = -30$ cm

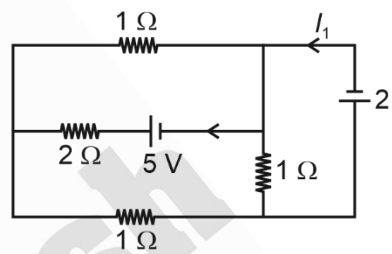
Least count of scale = $\left(\frac{1}{20}\right)$ cm

Fractional error = $\left(\frac{\frac{1}{20}}{30}\right) = \left(\frac{1}{600}\right)$

as $\frac{1}{10\,k} = \frac{1}{600}$

$k = 60$

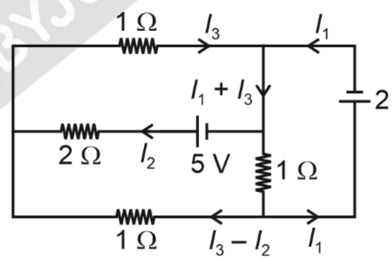
26.



In two circuit shown above the value of current I_1 (in amperes) is equal to $-\frac{y}{5}$ A . Value of y is equal to

Answer (11.00)

Sol.



Using Kirchoff's law.

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

$I_3 + 2I_2 = 5$ ...(ii)

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

$$\Rightarrow I_1 = -\frac{11}{5}\ \text{A}$$

$\Rightarrow y = 11$

27. ??

28. ??

29. ??

30. ??