JEE (Main) PHYSICS SOLVED PAPER

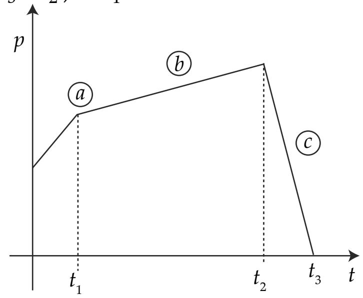
2023
30th Jan Shift 1

Section A

Q. 1. The magnetic moments 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) $4N_AI_A = N_BI_B$ **(2)** $N_A = 2N_B$
(3) $N_AI_A = 4N_BI_B$ **(4)** $2N_AI_A = N_BI_B$

Q. 2. 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) c and b **(2)** b and c
(3) a and b **(4)** c and a

Q. 3. 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 $\frac{\sigma'}{\sigma}$

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

(3) $\frac{5}{6}$ **(4)** $\frac{9}{4}$

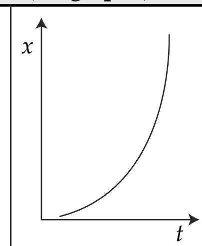
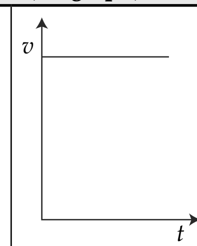
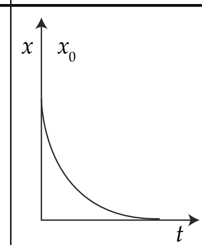
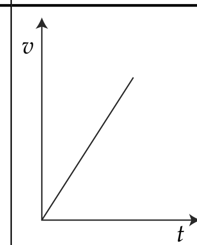
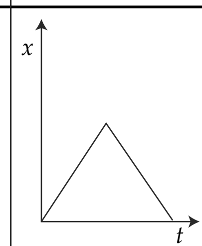
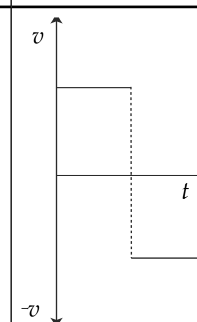
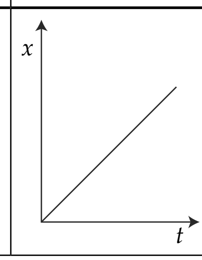
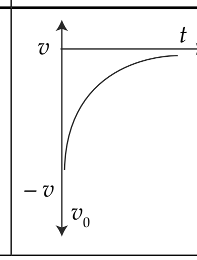
Q. 4. A person has been using spectacles of power −1.0 dioptre for distant vision and a separate reading glass of power 2.0 dioptres. What is the least distance of distinct vision for this person ?

(1) 40 cm **(2)** 30 cm
(3) 10 cm **(4)** 50 cm

Q. 5. A small object at rest, absorbs a light pulse of power 20 mW and duration 300 n s. Assuming speed of light as 3×10^8 m s^{-1}, the momentum of the object becomes equal to :

(1) 3×10^{-17} kg m s^{-1} **(2)** 2×10^{-17} kg m s^{-1}
(3) 1×10^{-17} kg m s^{-1} **(4)** 0.5×10^{-17} kg m s^{-1}

Q. 6. Match Column-I with Column-II

	Column-I (x-t graphs)		Column-II (v-t graph)
A.		I.	
B.		II.	
C.		III.	
D.		IV.	

Choose the correct answer from the options given below:

(1) A – I, B – II, C – III, D – IV
(2) A – II, B – III, C – IV, D – I
(3) A – I, B – III, C – IV, D – II
(4) A – II, B – IV, C – III, D – I

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

Q. 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 D only **(2)** C and E only
(3) A and E only **(4)** B and D only

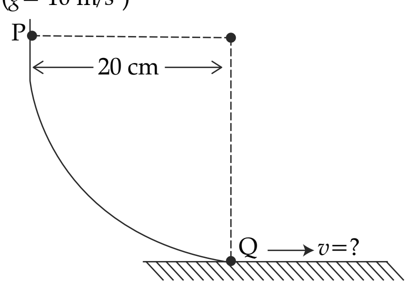
Q. 9. If the gravitational field in the space is given as $\left(-\frac{K}{r^2}\right)$ Taking the reference point to be at $r = 2$ cm with gravitational potential $V = 10$ J kg^{-1}. Find the gravitational potential at $r = 3$ cm in SI unit (Given: $K = 6$ J cm/kg^{-1})

(1) 9 **(2)** 10 **(3)** 11 **(4)** 12

Q. 10. 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 : 3 **(2)** 1 : 2 **(3)** $1 : \sqrt{2}$ **(4)** 1 : 1

Q. 11. 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)

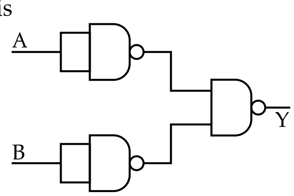


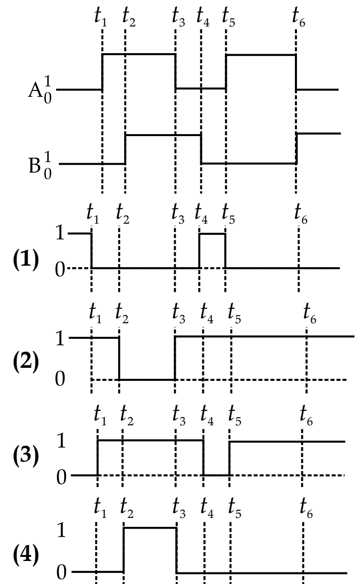
(1) 0 **(2)** 4 m s^{-1} **(3)** 2 m s^{-1} **(4)** 0.25 m s^{-1}

Q. 12. 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 the 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 s^{-2}):

(1) 360 m s^{-1} **(2)** 400 m s^{-1}
(3) 60 m s^{-1} **(4)** 120 m s^{-1}

Q. 13. The output waveform of the given logical circuit for the following inputs A and B as shown below, is





Q. 14. 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) $\alpha - \frac{3\beta^2}{\gamma}$ **(2)** $\alpha - \frac{\gamma}{3\beta}$ **(3)** $\alpha - \frac{\beta^2}{3\gamma}$ **(4)** $\beta - \frac{\alpha^2}{3\gamma}$

Q. 15. Choose the correct relationship between Poisson ratio (σ), bulk modulus (K) and modulus of rigidity (η) of a given solid object:

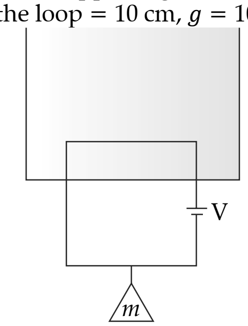
(1) $\sigma = \frac{3K + 2\eta}{6K + 2\eta}$ **(2)** $\sigma = \frac{3K - 2\eta}{6K + 2\eta}$

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

Q. 16. Speed of an electron in Bohr's 7th orbit for Hydrogen atom is 3.6×10^6 m s^{-1}. The corresponding speed of the electron in 3rd orbit, in m s^{-1} is:

(1) (1.8×10^6) **(2)** (3.6×10^6)
(3) (7.5×10^6) **(4)** (8.4×10^6)

Q. 17. 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 10^3G, 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 s^{-2})



(1) $\frac{1}{10}$ V **(2)** 100 V **(3)** 10 V **(4)** 1 V

Q. 18. 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) $N\,m^3\,C^{-1}$; $N\,m^2\,C^{-1}$ **(2)** $N\,m^2\,C^{-1}$; $N\,m^3\,C^{-1}$
(3) $N\,m^3\,C$; $N\,m^2\,C$ **(4)** $N\,m^2C$; $N\,m^3C$

Q. 19. 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) 0.05 **(2)** 0.10 **(3)** 0.20 **(4)** 0.5

Q. 20. 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) 20 V **(2)** 15 V **(3)** 10 V **(4)** 5 V

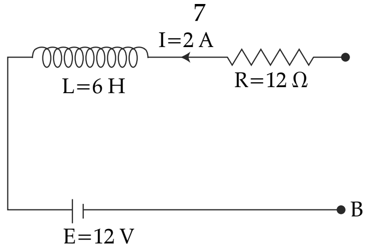
Section B

Q. 21. The general displacement of a simple harmonic oscillator is $x = A\sin\omega t$. 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______.

Q. 22. A thin uniform rod 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 _____.

Q. 23. A horse rider covers half the distance with 5 m s^{-1} speed. The remaining part of the distance was travelled with speed 10 m s^{-1} for half the time and with speed 15 m s^{-1} 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^{-1}. The value of x is ____.

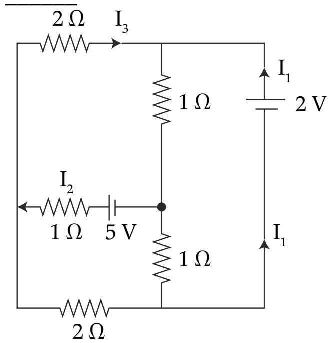
Q. 24.



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

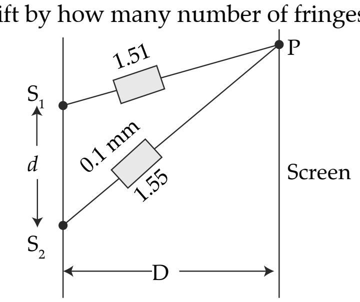
Q. 25. A point source of light is placed at the centre of curvature of a hemispherical surface. The source emits a power of 24 W. The radius of curvature of hemisphere is 10 cm and the inner surface is completely reflecting. The force on the hemisphere due to the light falling on it is _____ $\times 10^{-8}$ N

Q. 26. In the following circuit, the magnitude of current I_1, is ______ A.



Q. 27. 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 of the circular scale coincide with the reference line. The diameter of the wire is _______ $\times 10^{-2}$ mm

Q. 28. 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 = 4000Å) from S_1 and S_2 respectively. The central bright fringe spot will shift by how many number of fringes ?



Q. 29. 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 $x \times 10^{-2}$ J. The value of x is ______.

Q. 30. 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 K is___________.

●●●

Answer Key

Q. No.	Answer	Topic Name	Chapter Name
1	(3)	Magnetic moment	Magnetism and Matter
2	(1)	2^{nd} Law of Motion	Laws of Motion
3	(3)	Electric Potential	Electrostatic Potential and Capacitance
4	(4)	Power of Lens	Ray Optics
5	(2)	Conservation of Momentum	Work, Energy and Power
6	(4)	Graphical Representation of Motion	Motion in a Straight Line
7	(4)	Ideal Gas	Kinetic Theory of Gases
8	(1)	Laws of Thermodynamics	Thermodynamics
9	(3)	Gravitational Potential Energy	Gravitation
10	(3)	Power Factor	Alternating Current
11	(3)	Motion in a Verticle Circle	Laws of Motion
12	(1)	Projectile Motion	Motion in a Plane
13	(3)	Logic Gates	Semiconductor Electronics
14	(3)	Electric Current	Current Electricity
15	(2)	Relation Between Poisson Ratio, Bulk Modulus and Modulus of Rigidity	Thermal Propoerties of Matter
16	(4)	Bohr's Model	Atoms
17	(3)	Magnetic Force	Moving Charges and Magnetism
18	(2)	Electric Field	Electric Charges and Fields
19	(1)	Rise of Liquid in a Capillary Tube	Mechanical Properties of Fluids
20	(3)	Amplitude Modulation	Communication Systems
21	[8]	SHM	Oscillations
22	[3]	Rotational Kinetic Energy	System of Particles and Rotational Motion
23	[50]	Avergae Speed	Motion in a Straight Line
24	[30]	RLC Circuit	Alternating Current
25	[4]	Intensity of EMW	Electromagnetic Waves
26	[1.5]	Electric Circuit	Current Electricity
27	[220]	Screw Gauge	Practical Physics
28	[10]	Young's Double Slit Experiment	Wave Optics
29	[225]	Charging of Capacitor	Electrostatic Potential and Capacitance
30	[32]	Errors in Measurement	Units and Measurement

SOLUTIONS

Section A

1. Option (3) is correct.

Magnetic moment of a current carrying coil is given by $|\vec{m}| = NiA$

It is given that $|\vec{m}|_A = |\vec{m}|_B$

$$N_A i_A A_A = N_B i_B A_B$$

$$N_A i_A (\pi r_A^2) = N_B i_B (\pi r_B^2)$$

Putting $r_A = 10$ cm and $r_B = 20$ cm

$$N_A i_A (10)^2 = N_B i_B (20)^2$$

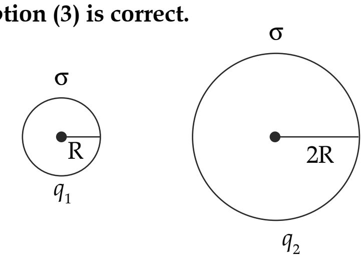
$$N_A i_A = 4 N_B i_B$$

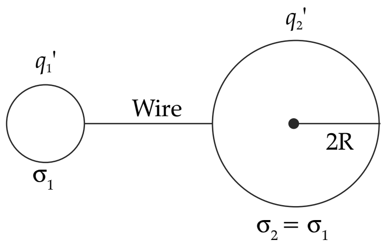
2. Option (1) is correct.

From Newton's 2^{nd} law of motion $|\vec{F}| = \dfrac{dp}{dt}$ = slope of (p-t) graph

As can be seen from the given graph, slope of curve c is the maximum and that of curve b is minimum.

3. Option (3) is correct.





Let q, and q_2 be the charges before connection, and q_1' and q_2' be the charges after connection.
Since total charge on the system is conserved
$q_1 + q_2 = \rho 4\pi(R^2 + 4R^2) = 20\pi\rho R^2 = q_1' + q_2'$ ….. (i)
Also after connection, the potentials of both spheres become identical

$$\frac{Kq_1'}{R} = \frac{Kq_2'}{2R}$$

$$\Rightarrow \quad q_1^1 = \frac{q_2^1}{2} \qquad \ldots\text{(ii)}$$

Putting value from eq. (ii) in (i), we get

$$\frac{q_2^1}{2} + q_2^1 = 20\rho R^2$$

$$q_2^1 = \frac{40}{3}\pi\sigma R^2$$

$$\rho_2 = \frac{q_2^1}{4\pi(2R)^2} = \frac{\frac{40}{3}\pi\sigma R^2}{16\pi R^2}$$

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

$$\frac{\sigma^1}{\sigma} = \frac{5}{6}$$

4. Option (4) is correct.

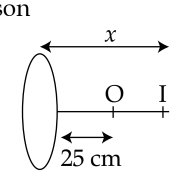
For distant vision $P_1 = -1$ D (concave lens)

$$f_1 = \frac{1}{P_1} = -1\text{ m} = -100\text{ cm}$$

For reading $P_2 = 2$ D (convex lens)

$$f_2 = \frac{1}{P_2} = \frac{1}{2} = 0.5\text{ m} = 50\text{ cm}$$

For an average human eye, least distance of distinct vision = 25 cm.
Let x be new least distance of distinct vision for the concerned person



Applying lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_2}$$

$$\frac{1}{-x} - \frac{1}{-25} = \frac{1}{50}$$

$$\frac{1}{-x} = \frac{1}{50} - \frac{1}{25} = \frac{-1}{50}$$

$$x = 50\text{ cm}$$

5. Option (2) is correct.

Applying conservation of momentum

$$\vec{0} = \vec{p_1} + \vec{p_2}$$

$$\vec{p_2} = -\vec{p_1}$$

$$|\vec{p_2}| = |\vec{p_1}|$$

where, $|\vec{p_1}|$ = momentum of the light pulse absorbed;

$|\vec{p_2}|$ = momentum of the object.

$$\therefore \quad |\vec{p_2}| = \frac{E}{C} = \frac{Pt}{C} = \frac{20\times10^{-3}\times300\times10^{-9}}{3\times10^{8}}$$

$$= 2\times10^{-17}\text{ kg m s}^{-1}$$

6. Option (4) is correct.

velocity $\quad v = \dfrac{dx}{dt}$ = slope of (x-t) graph

A. $\quad x = kt^2$ where k = const.

$$v = \frac{dx}{dt} = 2kt$$

A. → II.

B. $\quad x = x_0 e^{-kt}$ where k = const

$$v = \frac{dx}{dt} = -x_0 k e^{-kt}$$

B. → IV.

C. 1st half, $\quad x = kt$ where k = constant

$$v = \frac{dx}{dt} = k = \text{constant}$$

2nd half, $\quad x = k_0 - k't$ where k_0 and k' are constant

$$v = \frac{dx}{dt} = -k' = \text{constant}$$

C. → III.

D. $\quad x = kt$ where k = constant

$$v = \frac{dx}{dt} = k = \text{constant}$$

D. → I.

7. Option (4) is correct.

Given, PT^2 = constant

Coefficient of volume expansion,

$$\gamma = \frac{\Delta V}{V\Delta T}$$

For an ideal gas,

$$PV = RT$$

Putting $P = \dfrac{RT}{V}$ in PT^2 = constant, we get

$$\left(\frac{RT}{V}\right)T^2 = \text{constant}$$

$$\frac{T^3}{V} = \text{constant} = k\text{ (say)}$$

$$T^3 = kV$$

Differentiating both sides w.r.t. V, we get

$$3T^2\frac{\Delta T}{\Delta V} = k$$

$$\Rightarrow \quad k\frac{\Delta V}{\Delta T} = 3T^2$$

Putting for $k = \frac{T^3}{V}$, we get

$$\frac{T^3}{V}\frac{\Delta V}{\Delta T} = 3T^2$$

$$\frac{\Delta V}{V\Delta T} = \gamma = \frac{3}{T}$$

8. Option (1) is correct.

For an isothermal process (T = const), $\Delta U = nC_v\,\Delta T$ is zero i.e. U remains constant . Hence, $\Delta Q = \Delta W$

Since heat is given to the gas, ΔQ is positive. Hence, ΔW is also positive.

9. Option (3) is correct.

$$\Delta V_g = \int_A^B E_g\, dr$$

where, E_g is the gravitational field and V_g is the gravitational potential

$$V_3 - V_2 = -\int_2^3 -\frac{K}{r^2}dr$$

$$V_3 - 10 = K\left(-\frac{1}{r}\right)_2^3$$

$$V_3 = 10 - 6\left(\frac{1}{3}-\frac{1}{2}\right)$$

$$= 10 - 6\left(\frac{2-3}{6}\right)$$

$$= 10 + 1$$

$$= 11\ \text{J kg}^{-1}$$

10. Option (3) is correct.

Power factor,

$$\cos\phi = \frac{R}{Z}$$

For R – L circuit with $X_L = R$,

$$\cos\phi = P_1 = \frac{R}{\sqrt{R^2 + X_{L2}}} = \frac{1}{\sqrt{2}}$$

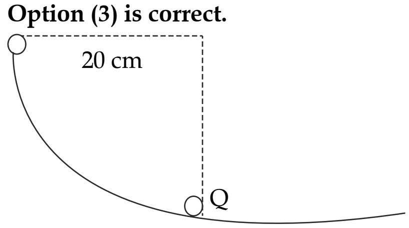
For R – L – C circuit with $X_c = X_L$.

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

$$= 1$$

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

11. Option (3) is correct.

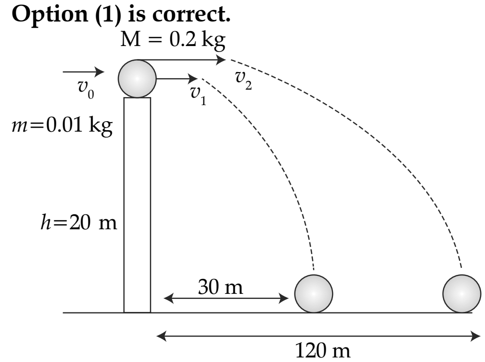


Velocity of ball P on reaching the bottom $= \sqrt{2gh}$

$v_p = \sqrt{2\times 10\times 0.2} = 2\ \text{m s}^{-1}$

Since masses of both balls are same and collision is elastic, both exchange their velocities after collision i.e $v_P{}' = 0$ and $v_Q{}' = v_P = 2\ \text{m s}^{-1}$

12. Option (1) is correct.



Let v_1 and v_2 be the velocities of the ball and the bullet after collision.

Both take the same time t to reach the ground.

$$h = \frac{1}{2}gt^2$$

$$t^2 = \frac{2h}{g} = \frac{2\times 20}{10} = 4$$

$$t = 2\ \text{s}$$

For the ball,

$$30 = v_1 t = v_1(2) \quad\Rightarrow\quad v_1 = 15\ \text{m/s}$$

For the bullet,

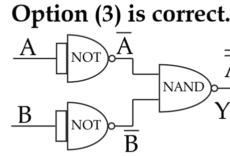
$$120 = v_2 t = v_2(2) \quad\Rightarrow\quad v_2 = 60\ \text{m/s}$$

Conservation of momentum gives (ball + bullet, system)

$$0.01v_0 = 0.01v_2 + 0.2v_1$$

$$v_0 = v_2 + 20v_1 = 60 + 20(15) = 360\ \text{m s}^{-1}$$

13. Option (3) is correct.



$\overline{\bar{A}.\bar{B}} = \bar{\bar{A}} + \bar{\bar{B}} = A + B$

De Morgan's law

$Y = A + B$ (OR gate)

Truth, Table for an OR gate is

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

From the given waveforms, we can see

	A	B	Y
$0 < t < t_1$	0	0	0
$t_1 < t < t_2$	1	0	1
$t_2 < t < t_3$	1	1	1
$t_3 < t < t_4$	0	1	1
$t_4 < t < t_5$	0	0	0
$t_5 < t < t_6$	1	0	1

14. Option (3) is correct.

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

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

For i_{min}, $\frac{di}{dt} = 0 = -2\beta + 6\gamma t$

$$t = \frac{\beta}{3\gamma}$$

Putting for t in the expression for i, we get

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

$$= \alpha - \frac{2}{3}\frac{\beta^2}{\gamma} + \frac{3\beta^2}{9\gamma}$$

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

15. Option (2) is correct.

From the relation, $Y = 3K(1 - 2\sigma) = 2\eta\,(1 + \sigma)$

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

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

16. Option (4) is correct.

$$v \propto \frac{z}{n}$$

where n is the orbit number

$$\frac{v_7}{v_3} = \frac{3}{7}$$

$$v_3 = \frac{7}{3}v_7 = \frac{7}{3} \times 3.6 \times 10^6$$

$$= 8.4 \times 10^6 \text{ m s}^{-1}$$

17. Option (3) is correct.

Current i in the loop $= \frac{V}{R} = \frac{V}{10}$

Magnetic force on the side of the loop in the magnetic field

$$\overrightarrow{F_m} = ilB(j)$$

which balances the hanging weight i.e. at equitibrium

$$ilB = mg$$

$$\frac{V}{10}lB = mg$$

and $IG = 10^{-4}$ Tesla

$$V = \frac{10mg}{lB} = \frac{10\times10^{-3}\times10}{0.1\times10^{3}\times10^{-4}} = 10 \text{ V}$$

18. Option (2) is correct.

$$\bar{E} = \frac{A}{x^2}\hat{\imath} + \frac{B}{y^2}\hat{\jmath}$$

Unit of $\vec{E}$ is $N\,C^{-1}$

Unit of A is $N\,m^2\,C^{-1}$

Unit of B is $N\,m^3\,C^{-1}$

19. Option (1) is correct.

Height of the liquid column

$$h = \frac{2T\cos\theta}{r\rho g}$$

where, r = radius of capillary

T = surface tension

ρ = density of liquid

$$h \propto \frac{T}{\rho}$$

$$\frac{h_1}{h_2} = \frac{T_1}{T_2} \times \frac{\rho_2}{\rho_1}$$

Given $T_2 = 2T_1$

$\rho_2 = 2\rho_1$

$$\frac{h_1}{h_2} = \frac{T_1}{2T_1} \times \frac{2\rho_1}{\rho_1} = 1$$

$$h_2 = h_1 = 5 \text{ cm} = 0.05 \text{ m}$$

20. Option (3) is correct.

$$V_{max} = V_m + V_c$$

$$V_{min} = V_c - V_m$$

where, V_m and V_c are the amplitudes of the modulating signal and the carrier respectively.

$$V_c = \frac{V_{max} + V_{min}}{2} = \frac{120 + 80}{2} = 100 \text{ V}$$

$$V_m = \frac{V_{max} - V_{min}}{2} = \frac{120 - 80}{2} = 20 \text{ V}$$

Modulation index,

$$\mu = \frac{V_m}{V_c} = \frac{20}{100} = 0.2$$

Amplitude of the side band $= \frac{\mu N_c}{2}$

$$= \frac{0.2 \times 100}{2}$$

$$= 10 \text{ V}$$

Section B

21. The correct answer is [8]

$$x = A\sin\omega t$$

Potential energy, $U = \frac{1}{2}kx^2$

$$= \frac{1}{2}kA^2\sin^2\omega t$$

Slope of U-t curve, $\frac{dU}{dt} = \frac{1}{2}kA^2(2\sin\omega t)(\omega\cos\omega t)$

$$= \frac{1}{2}KA^2\omega(\sin 2\omega t)$$

For slope to be maximum, $\frac{d^2U}{dt^2} = 0$

$$\frac{d^2U}{dt^2} = \frac{1}{2}KA^2\omega(2\omega\cos 2\omega t) = 0$$

$$\cos 2\omega t = 0$$

$$2\omega t = (2n+1)\frac{\pi}{2},\ n = 0, 1, 2, \ldots..$$

For $n = 0$, $2\omega t = \dfrac{\pi}{2}$

$$t = \frac{\pi}{4\omega} = \frac{\pi}{2\left(\frac{2\pi}{T}\right)} = \frac{T}{8} = \frac{T}{\beta} \text{ (given)}$$

On comparing, $\beta = 8$

22. The correct answer is [3]

Rotational $\quad \text{KE} = \dfrac{1}{2}I\omega^2 = E$

$$I_{\text{rod}} = \frac{M\ell^2}{12} = \frac{(Vd)\ell^2}{12} = \frac{(A\ell d)\ell^2}{12}$$

$$= \frac{Ad\ell^3}{12}$$

Hence $\quad E = \dfrac{1}{2}\left(\dfrac{Ad\ell^3}{12}\right)\omega^3$

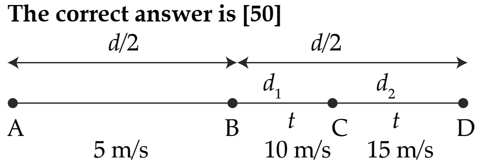
Given $\quad l = 2$ m

$$E = \frac{Ad\omega^2}{3}$$

$$\omega = \sqrt{\frac{3E}{Ad}} = \sqrt{\frac{\alpha E}{Ad}} \text{ (given)}$$

On comparing, $\alpha = 3$

23. The correct answer is [50]



$$t_{AB} = \frac{\frac{d}{2}}{5} = \frac{d}{10}$$

$$t_{BC} = t = \frac{d_1}{10} \rightarrow d_1 = 10t$$

$$t_{CD} = t = \frac{d_2}{15} \rightarrow d_2 = 15t$$

$$d_1 + d_2 = \frac{d}{2} = 25t$$

$$t = \frac{d}{50}$$

$$\text{Mean speed} = \frac{\text{total distance}}{\text{total time}}$$

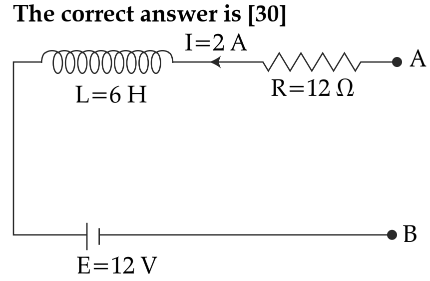
$$= \frac{d}{t_{AB} + t_{BC} + t_{CD}}$$

$$= \frac{d}{\frac{d}{10} + \frac{d}{50} + \frac{d}{50}} = \frac{d}{\frac{7d}{50}} = \frac{50}{7} \text{ m s}^{-1}$$

$$\frac{50}{7} = \frac{x}{7} \text{ (given)}$$

On comparing, $x = 50$

24. The correct answer is [30]



$$\frac{dI}{dt} = -1 \text{ A s}^{-1}$$

Applying Kirchoff's law from A to B round the loop, we get $V_{AB} - IR - L\dfrac{dI}{dt} - 12 = 0$

$$V_{AB} = V = IR + L\frac{dI}{dt} + 12$$

$$= (2 \times 12) + 6(-1) + 12$$

$$= 30 \text{ volt}$$

25. The correct answer is [4]

Pressure exerted by radiation on a reflecting surface $= \dfrac{2I}{C} = \dfrac{2P}{CA}$ where, I is the intensity of radiation.

$$I = \frac{P}{\text{Area}} = \frac{P}{4\pi r^2}$$

Force exerted = pressure × projected area (πr^2)

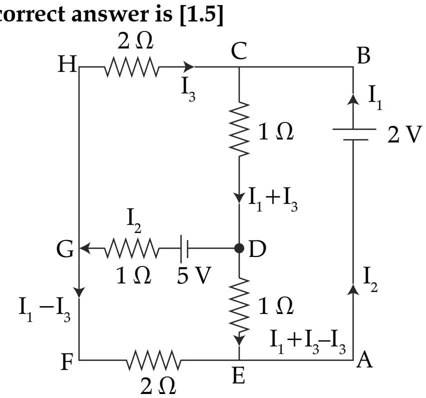
$$= \frac{2P}{C(4\pi r^2)} \times \pi r^2$$

$$= \frac{2P}{4C}$$

$$= \frac{P}{2C}$$

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

26. The correct answer is [1.5]



KVL in the loop ABCDEA gives,

$$2 - 1(I_1 + I_3) - 1(I_1 + I_3 - I_2) = 0$$

$$2 - 2I_1 + I_2 - 2I_3 = 0$$

$$2I_1 - I_2 + 2I_3 = 2 \quad \ldots \text{(i)}$$

KVL in the loop CHGDC gives,

$$2I_3 + 1I_2 - 5 + 1(I_1 + I_3) = 0$$

$$I_1 + I_2 + 3I_3 = 5 \quad \ldots \text{(ii)}$$

KVL in the loop DGFED gives,

$$5 - 1I_2 - 2(I_2 - I_3) + 1(I_1 + I_3 - I_2) = 0$$

$$I_1 - 4I_2 + 3I_3 = -5 \qquad \dots \text{(iii)}$$

On subtracting eq (iii) from eq. (ii), we get

$$5I_2 = 10$$

$$\Rightarrow \quad I_2 = 2\text{ A}$$

On putting value of I_2 in eq. (i) and (ii), we get

$$2I_1 + 2I_3 = 4$$

$$\Rightarrow \quad I_1 + I_3 = 2$$

$$\Rightarrow \quad I_3 = 2 - I_1$$

$$I_1 + 3I_3 = 3$$

$$\Rightarrow \quad I_1 + 3(2 - I_1) = 3$$

$$-2I_1 = -3$$

$$I_1 = \frac{3}{2} = 1.5\text{ A}$$

27. The correct answer is [220]

Given, pitch = 0.5 mm

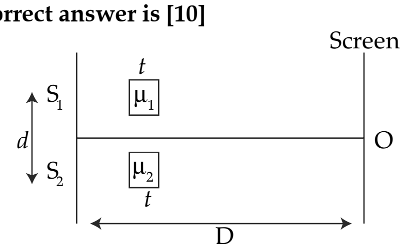
$$\text{Least count (L.C.)} = \frac{\text{Pitch}}{\text{No. of divisions on circular scale}}$$

$$= \frac{0.5}{100} = 0.005\text{ mm}$$

Zero error = 6 × (L.C.)
= 6 × 0.005
= 0.030 mm (positive)

Reading = main scale reading + coincident division × L.C (on circular scale) – Zero error
= 4(0.5) + 46(0.005) – 6(0.005).
= 2 + 40(0.005)
= 2 + 0.2
= 2.2 mm
= 220×10^{-2} mm

28. The correct answer is [10]



Shift in the position of the central fringe in the presence of two transparent plates, as shown above is given by

$$\frac{D}{d}[\mu_1 - \mu_2]\,t$$

Since $\mu_1 = 1.51$ and $\mu_2 = 1.55$,
Shift is negative i.e. below O.

Fringe width, $\beta = \frac{D\lambda}{d}$

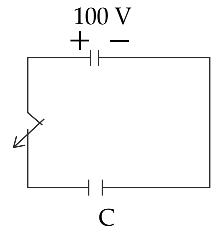
No. of fringes crossed, $n = \frac{|\text{shift}|}{\beta} = \frac{(\mu_1 - \mu_2)t}{\lambda}$

$$n = \frac{(1.55 - 1.51)0.1 \times 10^{-3}}{4 \times 10^{-7}}$$

$$= \frac{0.04 \times 0.1 \times 10^4}{4}$$

$$= 10$$

29. The correct answer is [225]



When equitibrium is attained i.e. both capacitor acquire the same potential,

$$\text{loss of energy} = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2} \therefore (V_1 - V_2)^2$$

Here $C_1 = C_2 = C = 900\,\mu$F
$V_1 = 100$ V
$V_2 = 0$

$$\text{Loss} = \frac{1}{2}\frac{C}{2}V_1^2$$

$$= \frac{900}{4} \times 10^4 \times 10^{-6}\text{ J}$$

$$= 2.25\text{ J}$$

$$= 225 \times 10^{-2}\text{ J}$$

$$= x \times 10^{-2}\text{ J} \qquad \text{(given)}$$

On comparing, $x = 225$

30.The correct answer is [32]

For the converging mirror

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

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

$$\frac{1}{f} = \frac{-4}{120} = \frac{-1}{30}$$

$f = -30$ cm (concave mirror)

Differentiating the mirror equation

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

$$df = f^2\left[\frac{du}{u^2} + \frac{dv}{v^2}\right]$$

Now $|du| = |dv| = \frac{1}{20} = 0.05$ cm

$$\therefore |df| = (30)^2\left[\frac{0.05}{(40)^2} + \frac{0.05}{(120)^2}\right]$$

$$= 9 \times 0.05\left[\frac{1}{16} + \frac{1}{144}\right]$$

$$= 0.45\left[\frac{10}{144}\right]$$

$$= \frac{4.5}{144}$$

$$= \frac{1}{32}\text{ cm} = \frac{1}{K} \qquad \text{(given)}$$

On comparing, K = 32