JEE (Main) PHYSICS SOLVED PAPER

2021

26th August Shift 1

Time : 1 Hour **Total Marks : 100**

General Instructions :

1. *In Chemistry Section, there are 30 Questions (Q. no. 1 to 30).*
2. *In Chemistry, Section A consists of 20 multiple choice questions & Section B consists of 10 numerical value type questions. In Section B, candidates have to attempt any five questions out of 10.*
3. *There will be only one correct choice in the given four choices in Section A. For each question for Section A, 4 marks will be awarded for correct choice, 1 mark will be deducted for incorrect choice questions and zero mark will be awarded for not attempted question.*
4. *For Section B questions, 4 marks will be awarded for correct answer and zero for unattempted and incorrect answer.*
5. *Any textual, printed or written material, mobile phones, calculator etc. is not allowed for the students appearing for the test.*
6. *All calculations / written work should be done in the rough sheet is provided with Question Paper.*

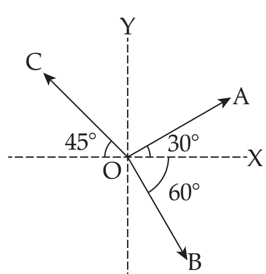
Physics

Section A

Q. 1 An inductor coil stores 64 J of magnetic field energy and dissipates energy at the rate of 640 W when a current of 8 A is passed through it. If this coil is joined across an ideal battery, find the time constant of the circuit in seconds:

(1) 0.4 **(2)** 0.8
(3) 0.125 **(4)** 0.2

Q. 2 The magnitude of vectors $\overrightarrow{OA}$, $\overrightarrow{OB}$ and $\overrightarrow{OC}$ in the given figure are equal. The direction of $\overrightarrow{OA}+\overrightarrow{OB}-\overrightarrow{OC}$ with x-axis will be :



(1) $\tan^{-1}\frac{(1+\sqrt{3}-\sqrt{2})}{(1-\sqrt{3}-\sqrt{2})}$ **(2)** $\tan^{-1}\frac{(\sqrt{3}-1+\sqrt{2})}{(1-\sqrt{3}+\sqrt{2})}$

(3) $\tan^{-1}\frac{(\sqrt{3}-1+\sqrt{2})}{(1+\sqrt{3}-\sqrt{2})}$ **(4)** $\tan^{-1}\frac{(1-\sqrt{3}-\sqrt{2})}{(1+\sqrt{3}+\sqrt{2})}$

Q. 3 A series LCR circuit deriven by 300 V at a frequency of 50 Hz contains a resistance R = 3 kΩ, an inductor of inductive reactance X_L = 250 πΩ and an unknown capacitor. The value of capacitance to maximize the average power should be:

(1) 4 μF **(2)** 25 μF
(3) 40 μF **(4)** 400 μF

Q. 4 In a Screw Gauge, fifth division of the circular scale coincides with the reference line when the ratchet is closed. There are 50 divisions on the circular scale, and the main scale moves by 0.5 mm on a complete rotation. For a particular observation, the reading on the main scale is 5 mm and the 20th division of the circular scale coincides with reference line. Calculate the true reading.

(1) 5.00 mm **(2)** 5.20 mm
(3) 5.15 mm **(4)** 5.25 mm

Q. 5 If E, L, M and G denote the quantities as energy, angular momentum, mass and constant of gravitation respectively, then the dimensions of P in the formula $P = EL^2M^{-5}G^{-2}$ are:

(1) $[M^0 L^1 T^0]$ **(2)** $[M^{-1} L^{-1} T^2]$

(3) $[M^0 L^0 T^0]$ **(4)** $[M^1 L^1 T^{-2}]$

Q. 6 Statement I:

By doping silicon semiconductor with pentavalent material, the electrons density increases.

Statement II:

The n-type semiconductor has net negative charge.

In the light of the above statements, choose the most appropriate answer from the options given below:

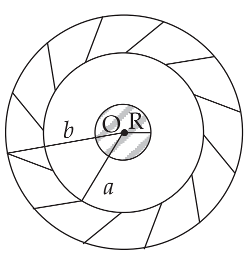
(1) Both Statement I and Statement II are true.

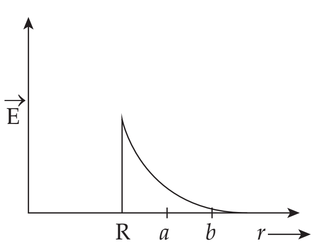
(2) Statement I is true but Statement II is false.

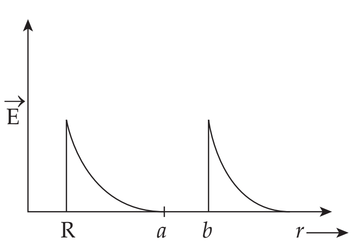
(3) Both Statement I and Statement II are false.

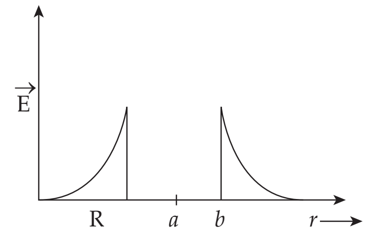
(4) Statement I is false but Statement II true.

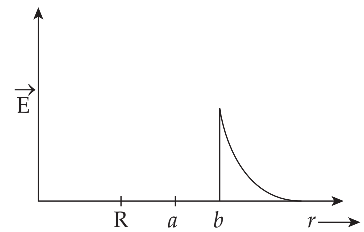
Q. 7 A solid metal sphere of radius R having charge q is enclosed inside the concentric spherical shell of inner radius a and outer radius b as shown in figure. The approximate variation of electric field $\vec{E}$ as a function of distance r from centre O is given by:



(1)


(2)


(3)


(4)


Q. 8 Two narrow bores of diameter 5.0 mm and 8.0 mm are joined together to form a U-shaped tube open at both ends. If this U-tube contains water, what is the difference in the level of two limbs of the tube.

[Take surface tension of water $T = 7.3\times10^{-2}\,Nm^{-1}$, angle of contact $= 0$, $g = 10\ ms^{-2}$ and density of water $= 1.0\times10^{3}\,kgm^{-3}$]

(1) 5.34 mm **(2)** 4.97 mm

(3) 2.19 mm **(4)** 3.62 mm

Q. 9 What equal length of an iron wire and a copper-nickel alloy wire, each of 2 mm diameter connected parallel to give an equivalent resistance of 3 Ω?

(Given resistivities of iron and copper-nickel alloy wire are 12 μΩ cm and 51 μΩ cm respectively)

(1) 82 m **(2)** 110 m

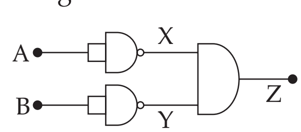
(3) 97 m **(4)** 90 m

Q. 10 The rms speeds of the molecules of Hydrogen, Oxygen and Carbon dioxide at the same temperature are V_{H}, V_O and V_{CO_2} respectively then:

(1) $V_H = V_O > V_{CO_2}$ **(2)** $V_{CO_2} > V_O > V_H$

(3) $V_H > V_O > V_{CO_2}$ **(4)** $V_H = V_O = V_{CO_2}$

Q. 11 Identify the logic operation carried out by the given circuit:



(1) NOR **(2)** OR

(3) NAND **(4)** AND

Q. 12 Car B overtakes another car A at a relative speed of 40 ms^{-1}. How fast will the image of car B appear to move in the mirror of focal length 10 cm fitted in car A, when the car B is 1.9 m away from the car A?

(1) 0.1 ms^{-1} **(2)** 0.2 ms^{-1}
(3) 4 ms^{-1} **(4)** 40 ms^{-1}

Q. 13 Inside a uniform spherical shell:

(a) the gravitational field is zero.

(b) the gravitational potential is zero.

(c) the gravitational field is same everywhere.

(d) the gravitational potential is same everywhere.

(e) all of the above.

Choose the most appropriate answer from the options given below:

(1) (a), (c) and (d) only
(2) (e) only
(3) (b), (c) and (d) only
(4) (a), (b) and (c) only

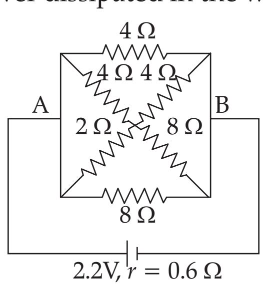
Q. 14 In a photoelectric experiment ultraviolet light of wavelength 280 nm is used with lithium cathode having work function $\phi = 2.5$ eV. If the wavelength of incident light is switched to 400 nm, find out the change in the stopping potential. $\left(h = 6.63\times10^{-34}\,\text{Js}, c = 3\times10^{8}\,\text{ms}^{-1}\right)$

(1) 1.9 V **(2)** 1.1 V
(3) 1.3 V **(4)** 0.6 V

Q. 15 A particular hydrogen like ion emits radiation of frequency 2.92×10^{15} Hz when it makes transition from $n = 3$ to $n = 1$. The frequency in Hz of radiation emitted in transition from $n = 2$ to $n = 1$ will be:

(1) 0.44×10^{15} **(2)** 4.38×10^{15}
(3) 6.57×10^{15} **(4)** 2.46×10^{15}

Q. 16 In the given figure, the emf of the cell is 2.2 V and if internal resistance is 0.6 Ω Calculate the power dissipated in the whole circuit:



(1) 2.2 W **(2)** 1.32 W
(3) 0.65 W **(4)** 4.4 W

Q. 17 The initial mass of a rocket is 1000 kg. Calculate at what rate the fuel should be burnt so that the rocket is given an acceleration of 20 ms^{-2}. The gases comes out at a relative speed of 500 ms^{-1} with respect to the rocket:

(1) 60 kg s^{-1} **(2)** 10 kg s^{-1}
(3) 6.0×10^2 kg s^{-1} **(4)** 500 kg s^{-1}

Q. 18 The fractional change in the magnetic field intensity at a distance 'r' from centre on the axis of current carrying coil of radius 'a' to the magnetic field intensity at the centre of the same coil is : (Take $r < a$).

(1) $\frac{3}{2}\frac{r^2}{a^2}$ **(2)** $\frac{3}{2}\frac{a^2}{r^2}$

(3) $\frac{2}{3}\frac{a^2}{r^2}$ **(4)** $\frac{2}{3}\frac{r^2}{a^2}$

Q. 19 An electric appliance supplies 6000 J/min heat to the system. If the system delivers a power of 90 W. How long it would take to increase the internal energy by 2.5×10^3 J?

(1) 4.1×10^1s **(2)** 2.4×10^3s
(3) 2.5×10^2s **(4)** 2.5×10^1s

Q. 20 The material filled between the plates of a parallel plate capacitor has resistivity 200Ωm The value of capacitance of the capacitor is 2 pF. If a potential difference of 40V is applied across the plates of the capacitor, then the value of leakage current flowing out of the capacitor is: (given the value of relative permitivity of material is 50)

(1) 9.0 μA **(2)** 0.9 μA
(3) 9.0 mA **(4)** 0.9 mA

Section B

Q. 21 Two spherical balls having equal masses with radius of 5 cm each are thrown upwards along the same vertical direction at an interval of 3 s with the same initial velocity of 35 m/s, then these balls collide at a height of __________m.

(take g = 10 m/s^2)

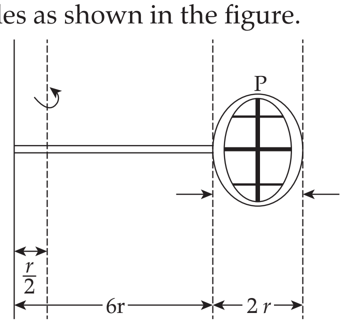
Q. 22 A source and a detector move away from each other in absence of wind with a speed of 20 m/s with respect to the ground. If the detector detects a frequency of 1800 Hz of the sound coming from the source, then the original frequency of source considering speed of sound in air 340 m/s will be ________ Hz.

Q. 23 White light is passed through a double slit and interference observed on a screen 1.5 m away. The separation between the slits is 0.3 mm. The first violet and red fringes are formed 2.0 mm and 3.5 mm away from the central white fringes. The difference in wavelengths of red and voilet light is ________ nm.

Q. 24 An amplitude modulated wave is represented by $C_m(t) = 10\,(1 + 0.2\cos 12560t) \times \sin\,(111\times10^4 t)$ volts. The modulating frequency in kHz will be ________.

Q. 25 Two travelling waves produces a standing wave represented by equation. $y = 1.0$ mm $\cos\,(1.57\text{ cm}^{-1})\,x\,\sin\,(78.5\text{ s}^{-1})\,t$. The node closest to the orgin in the region $x > 0$ will be at $x =$ ______ cm.

Q. 26 Consider a badminton racket with length scales as shown in the figure.



If the mass of the linear and circular portions of the badminton racket are same (M) and the mass of the threads are negligible, the moment of inertia of the racket about an axis perpendicular to the handle and in the plane of the ring at, $\frac{r}{2}$ distance from the end A of the handle will be ________ Mr^2.

Q. 27 A uniform chain of length 3 metre and mass 3 kg overhangs a smooth table with 2 metre laying on the table. If k is the kinetic energy of the chain in joule as it completely slips off the table, then value of k is ________. (Take g = 10 m/s^2)

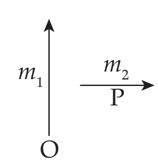
Q. 28 A soap bubble of radius 3 cm is formed inside the another soap bubble of radius 6 cm. The radius of an equivalent soap bubble which has the same excess pressure as inside the smaller bubble with respect to the atmospheric pressure is ________ cm.

Q. 29 The electric field in a plane electromagnetic wave is given by

$$\vec{E} = 200\cos\left[\left(\frac{0.5\times10^3}{\text{m}}\right)x - \left(1.5\times10^{11}\,\frac{\text{rad}}{\text{s}}\times t\right)\right]\frac{\text{V}}{\text{m}}\hat{j}$$

If the wave falls normally on a perfectly reflecting surface having an area of 100 cm^2. If the radiation pressure exerted by the E.M. wave on the surface during a 10 minute exposure is $\frac{x}{10^9}\frac{\text{N}}{\text{m}^2}$. Find the value of x.

Q. 30 Two short magnetic dipoles m_1 and m_2 each having magnetic moment of 1 Am^2 are placed at point O and P respectively. The distance between OP is 1 metre. The torque experienced by the magnetic dipole m_2 due to the presence of m_1 is ________ $\times 10^{-7}$ Nm.



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Answer Key

Q. No.	Answer	Topic Name	Chapter Name
1	4	RC Circuit	Alternating Current
2	4	Vectors	Vectors
3	1	Electrical Resonance	Alternating Current
4	3	Least Count and Zero Error	Errors and Measurement
5	3	Dimensions	Mesurement and Dimensions
6	2	N Type Semi Conductor	Semiconductors
7	2	Electric Field Inside The Shell	Charges and Fields
8	3	Surface Tension	Mechanical Properties of Fluids
9	3	Resistance	Current and Electricity
10	3	Rms Speed	Kinetic Theory of Gases
11	1	Logic Gates	Digital Circuits
12	1	Ray Optics	Ray Optics
13	1	Gravitational Potential	Gravitation
14	3	Photoelectric effect Effect	Photoelectric Effect
15	4	Transition	Atoms and Nuclei
16	1	Power	Current and Electricity
17	1	Rocket Propulsion	Laws of Motion
18	1	Magnetic Field on The Axis of The Coil	Moving Charges and Magnetic Field
19	3	First Law of Thermodynamics	Heat and Thermodynamics
20	4	Current Leakage	Capacitance
21	50	Motion Under Gravity	Kinematics 1D
22	2025	Doppler's Effect	Waves
23	300	Interference	Waves
24	2	Communication	Communication
25	1	Waves In A String	Waves
26	52	Moment of Inertia	Rigid Body
27	40	Friction	Laws of Motion
28	2	Surface Tension	Surface Tension
29	354	Em Waves	EM Waves
30	1	Magnetic Moment	Magnetism

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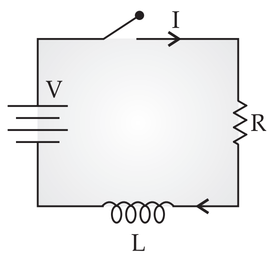
ANSWERS WITH EXPLANATIONS

Physics

Section A

1. Option (4) is correct.

Time constant, $\tau = \frac{L}{R}$?



Here, energy stored in inductor, $E = \frac{1}{2} LI^2$

Power, $P = I^2R$

So, $\frac{E}{P} = \frac{\frac{1}{2}I^2L}{I^2R}$

$= \frac{1}{2}\frac{L}{R} = \frac{\tau}{2}$

$\Rightarrow \quad \tau = \frac{2 \times E}{P}$

$= \frac{2 \times 64}{640}$ (Here, E = 64J and P = 540W)

$= \frac{2}{10}$

$= 0.2$ s

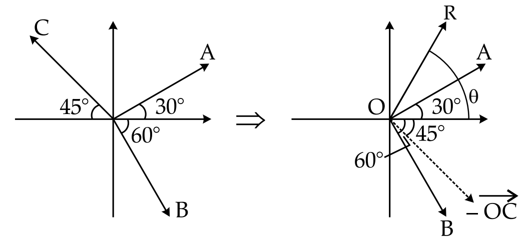
2. Option (4) is correct.

We need to find direction of

$$\vec{R} = \vec{OA} + \vec{OB} - \vec{OC}$$

$$= \vec{OA} + \vec{OB} + (-\vec{OC})$$

So to get $-\vec{OC}$ reverse direction of $\overline{OC}$



Now find ΣA_x and ΣA_y

$$\vec{R} = \Sigma R_x \hat{i} + \Sigma R_y \hat{j}$$

Direction, $\theta = \tan^{-1}\frac{\Sigma R_y}{\Sigma R_x}$

Summation of x-component of each

$\Sigma R_x = (1.\cos 30° + 1.\cos 45° + 1.\cos 60°)\hat{i}$

$\Sigma R_y = (1.\sin 30° - 1.\sin 45° - 1.\sin 60°)\hat{j}$

Here, we have considered unit length of each value

$$\Sigma R_x = \left(\frac{\sqrt{3}}{2} + \frac{1}{\sqrt{2}} + \frac{1}{2}\right)\hat{i}$$

$$\Sigma R_y = \left(\frac{1}{2} - \frac{1}{\sqrt{2}} - \frac{\sqrt{3}}{2}\right)\hat{j}$$

$$\tan\theta = \frac{\Sigma R_y}{\Sigma R_x} = \frac{\left(\frac{\sqrt{2} - 2 - \sqrt{6}}{2\sqrt{2}}\right)}{\left(\frac{\sqrt{6} + 2 + \sqrt{2}}{2\sqrt{2}}\right)}$$

$$= \frac{1 - \sqrt{2} - \sqrt{3}}{(\sqrt{3} + \sqrt{2} + 1)}$$

$$= \tan^{-1}\left(\frac{1 - \sqrt{3} - \sqrt{2}}{1 + \sqrt{3} + \sqrt{2}}\right)$$

3. Option (1) is correct.

Given V = 300 V, f = 50 Hz

$$R = 3k\,\Omega \qquad X_L = 250\pi\,\Omega$$

Here, average power in circuit is to be maximized.

In Series Resonance Circuit, the impedence is minimum, this way we can maximize power

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

$$Z = Z_{min} \qquad \text{if } X_L = X_C$$

$$X_L = X_C = \frac{1}{\omega C}$$

$$\Rightarrow \qquad C = \frac{1}{\omega X_L}$$

$$= \frac{1}{2\pi \times 50 \times 250\pi}$$

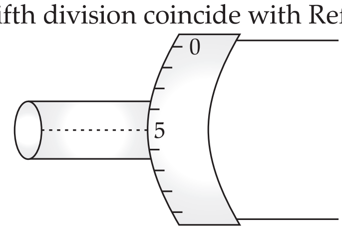
$$C = 0.04 \times 10^{-4}$$

$$= 4\,\mu F$$

4. Option (3) is correct.

$$\text{Least count} = \frac{0.5}{50}$$

Here fifth division coincide with Refrence line



This is the case of positive zero error, as zero error always subtracted from observed reading to get actual reading

True Reading = Observed – Zero Error

Observed Reading = 5 + L.C. × 20 – L.C × 5

$$= 5 + \frac{0.5}{50} \times 20 - \frac{0.5}{50} \times 5$$

$$= 5.15 \text{ mm}$$

5. Option (3) is correct.

Since,

The dimensions of energy

$$[E] = [ML^2T^{-2}]$$

The dimensions of angular momemtum

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

The dimensions of mass

$$[M] = [M]$$

The dimensions of gravitational constant

$$[G] = [M^{-1}L^3T^{-2}]$$

Given,

$$P = EL^2M^{-5}G^{-2}$$

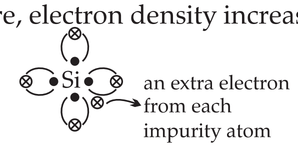
Thus, dimensions of P will be

$$[P] = [ML^2T^{-2}][ML^2T^{-1}]^2[M]^{-5}[M^{-1}L^3T^{-2}]^{-2}$$
$$= [ML^2T^{-2}][M^2L^4T^{-2}][M^{-5}][M^2L^{-6}T^4]$$
$$= [M^0L^0T^0]$$

6. Option (2) is correct.

Statement-I is true.

By doping silicon with pentavalent impurity, it gives an extra electron so called donor impurity. Therefore, electron density increases.

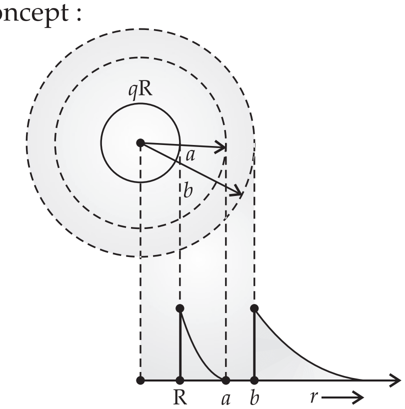


Statement-II is false.

Net charge on semiconductor on either of the type is zero.

7. Option (2) is correct.

Concept :



As we know there is no charge inside the conductor.

When we consider innermost sphere

For region or $0 < r < R$, E = 0

$$R < r < a, \; E \propto \frac{1}{r^2}$$

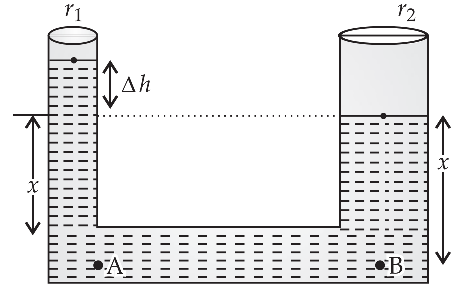
The shell is hollow. So, no charge is there inside the shell.

$$a < r < b \Rightarrow E = 0$$

For region, $r > b$,

$$E \propto \frac{1}{r^2}$$

8. Option (3) is correct.



The bore which is more fine (less radius) make the water to rise to greater height. So let Δh height of column is more than the other bore as shown in figure.

Consider two points A and B on the same level. So, the pressure will also be same

$$P_A = P_B$$

$$P_{atm} - \frac{2T}{r_1} + \rho g(\Delta h) + \rho g x = P_{atm} - \frac{2T}{r_2} + \rho g x$$

$$\Rightarrow \quad \rho g \Delta h = 2T\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

$$\Rightarrow \quad \Delta h = \frac{2T}{\rho g}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$\Rightarrow \Delta h = \frac{2 \times 7.3 \times 10^{-2}}{1 \times 10^3 \times 10}\left(\frac{1}{(2.5 \times 10^{-3})} - \frac{1}{(4 \times 10^{-3})}\right)$$

$$\Rightarrow \Delta h = 2.19 \times 10^{-3}\, m = 2.19 \text{ mm}$$

9. Option (3) is correct.

Given that both the wires are of same dimensions

i.e., $l_{Cu-Ni} = l_{Fe} = l$ and $A_{Fe} = A_{Cu-Ni} = \pi r^2$

From the relation, $R = \rho \frac{l}{A}$, ρ-Resistivity.

Given $\rho_{Fe} = 12\, \mu\Omega$ cm, $\rho_{Cu-Ni} = 15\, \mu\Omega$ cm, $R_{eq.} = 3\Omega$

$$\frac{1}{R_{eq}} = \frac{1}{R_{Fe}} + \frac{1}{R_{Cu\text{-}Ni}}$$

$$\Rightarrow \quad \frac{1}{3} = \frac{A}{\rho_{Fe} l} + \frac{A}{\rho_{CuNi} l}$$

$$l = 3A\left(\frac{1}{\rho_{Fe}} + \frac{1}{\rho_{Cu\text{-}Ni}}\right)$$

$$= 3\pi r^2\left(\frac{\rho_{Fe} + \rho_{Cu\text{-}Ni}}{\rho_{Fe} \times \rho_{Cu\text{-}Ni}}\right)$$

$$l = 3\pi \times (1 \times 10^{-3})^2 \left[\frac{12 \quad 51}{12 \times 51}\right]$$

$$= 97 \text{ m}$$

10. Option (3) is correct.

Root mean square velocity,

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

Temperature is same for all. So, $V_{rms} \propto \frac{1}{\sqrt{M}}$

So, the lighter gas has greater r.m.s. speed.

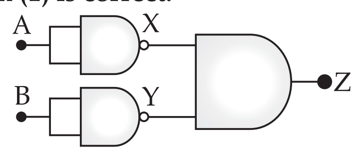
$$V_H : V_O : V_{CO_2} = \frac{1}{\sqrt{M_H}} : \frac{1}{\sqrt{M_O}} : \frac{1}{\sqrt{M_{CO_2}}}$$

$$= \frac{1}{1} : \frac{1}{\sqrt{16}} : \frac{1}{\sqrt{44}}$$

$$= \frac{1}{1} : \frac{1}{4} : \frac{1}{2\sqrt{11}}$$

$$V_H > V_O > V_{CO_2}.$$

11. Option (1) is correct.



From above diagram

$$X = \overline{A}$$

$$Y = \overline{B}$$

As X and Y are input of AND Gate

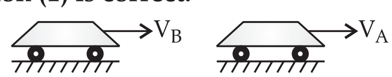
Thus, $\quad Z = \overline{A}.\overline{B}$

From Demorgan's theorem

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

So, NOR Gate

12. Option (1) is correct.



As,

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

On differentiating w.r.t. time 't', we get

$$-\frac{du}{dt}.\frac{1}{u^2} - \frac{dv}{dt}.\frac{1}{v^2} = 0$$

$$\Rightarrow \quad \frac{du}{dt} = \text{object speed, } (V_0)$$

$$\frac{dv}{dt} = \text{image speed, } (V_I)$$

$$V_I = -m^2 V_0 \;...(i) \quad \begin{Bmatrix} \because & u = -1.9 \text{ cm} \\ \because & f = 10 \text{ cm} \end{Bmatrix}$$

$$\text{Magnification, } m = \frac{v}{u} = \frac{f}{f-u}$$

$$m = \frac{10}{10-(-190)}$$

$$\Rightarrow \quad m = \frac{10}{200} = \frac{1}{20}$$

Putting values in equation (i)

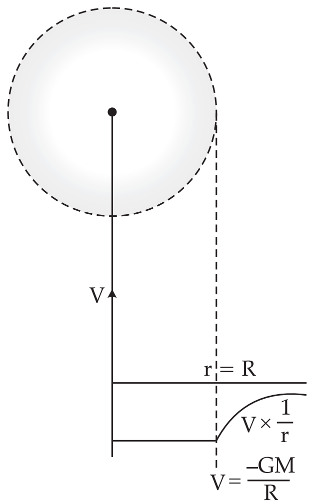
$$V_I = -\left(\frac{1}{20}\right)^2 \times 40$$

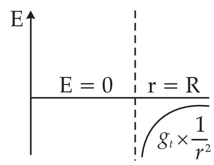
$$V_I = -0.1 \text{ m/s}$$

Hence, the can will appear to move with speed 0.1 m/s

13. Option (1) is correct.

Concept : Inside spherical shell





There is no effective mass so, intensity of gravitational field is zero.

And inside at all points gravitational field is zero so we can say intensity of gravitational field is zero.

Gravitational potential from surface to center of the shell is constant and same.

14. Option (3) is correct.

From Einstein equation

$$(eV_0)_1 = \frac{hc}{\lambda_1} - W \quad \text{...(i)}$$

and $$(eV_0)_2 = \frac{hc}{\lambda_2} - W \quad \text{...(ii)}$$

Substracting eqn (ii) from eqn (i)

$$e(V_{01} - V_{02}) = hc\left\{\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right\}$$

$$(V_{01} - V_{02}) = \frac{hc}{e}\left\{\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right\}$$

We are given $\lambda_1 = 280$ nm, $\lambda_2 = 400$ nm

Change in stopping potential in V

$$\left(\frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}}\right)\left[\frac{1}{280} - \frac{1}{400}\right]\times10^{9}$$

$$\Rightarrow \frac{12.43\times10^{2}\times120}{280\times400}$$

$$\Rightarrow (V_{01} - V_{02}) = 1.33 \text{ V}$$

15. Option (4) is correct.

Let the atomic no. of hydrogen like atom be z, and the transition taken place from n_1 to n_2

So, the wavelength in transition

$$\frac{1}{\lambda} = Rz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

For first transition, $n_1 = 3, n_2 = 1$

$$\frac{1}{\lambda} = Rz^2\left(\frac{1}{1} - \frac{1}{9}\right)$$

$$= \frac{8}{9}Rz^2$$

$$\because \quad c = f\lambda$$

$$\Rightarrow \quad f = \frac{8}{9}Rz^2.c \quad \text{...(i)}$$

Similarly for $n_1 = 2$ to $n = 1$

$$f' = Rz^2c\left(\frac{1}{1} - \frac{1}{4}\right)$$

$$= Rz^2c\times\frac{3}{4} \quad \text{...(ii)}$$

Dividing eqn (ii) by eqn (i), we get

$$\frac{f'}{f} = \frac{27}{32}$$

$$\Rightarrow \quad f' = \left(\frac{27}{32}\right)f$$

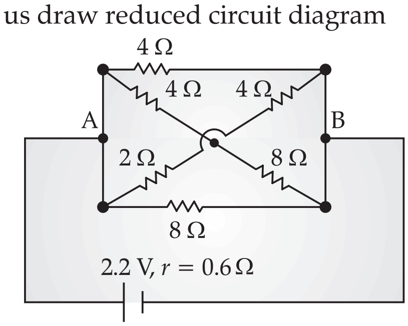
$$f' = \frac{27}{32}\times2.92\times10^{15} \text{ Hz}$$

$$= 2.46 \times 10^{15} \text{ Hz}$$

16. Option (1) is correct.

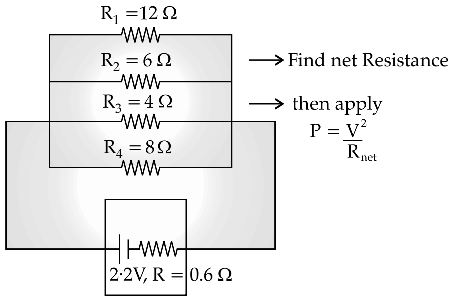
Concept :

Let us draw reduced circuit diagram



If we notice in this diagram that first end of each arm is connected to A, and second end is connected to end B. So, all arms are connected in parallel.

We can redraw as



Equivalent resistance for external resistance, R_{eq}

So, $$\frac{1}{R_{eq}} = \frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}$$

$$= \frac{1}{12}+\frac{1}{6}+\frac{1}{4}+\frac{1}{8}$$

$$R_{eq} = \frac{8}{5} = 1.6\Omega$$

$$R_{Net} = R_{eq} + 0.6$$

$$= 1.6 + 0.6$$

$$= 2.2\,\Omega$$

Now, dissipated power $= \dfrac{V^2}{R}$

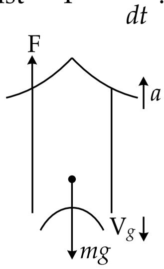
$$= \frac{(2.2)^2}{2.2}$$

$$= 2.2\text{ W}$$

17. Option (1) is correct.

Rocket is example of variable mass system. If rate of loss of mass be $\dfrac{dm}{dt}$ and the gas leaves rocket relative speed of V_g then

$$\text{Upthrust} = F = \frac{dm}{dt}.V_g$$



From free body diagram

$$F - mg = ma$$

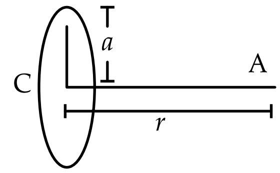
$$\Rightarrow \frac{dm}{dt}.V_g - mg = ma$$

$$\frac{dm}{dt} = \frac{m(g+a)}{V_g}$$

$$= \frac{1000(10+20)}{500}$$

$$\frac{dm}{dt} = 2 \times 30 = 60\text{ kg/s}$$

18. Option (1) is correct.



Let the intensity of magnetic field at centre be B_C and at axis by B_A

then the fraction change $= \dfrac{\Delta B}{B_C} = \dfrac{B_C - B_A}{B_A}$ ...(i)

at center $\quad B_C = \dfrac{\mu_0 I}{2a}$

at axis $\quad B_A = \dfrac{\mu_0 I a^2}{2(a^2+x^2)^{3/2}}$

Put in equation (i), we get

$$\frac{\Delta B}{B_C} = \frac{\frac{\mu_0 i}{2a} - \frac{\mu_0 i a^2}{2(1^2+x^2)^{3/2}}}{\frac{\mu_0 i}{2a}}$$

$$= 1 - \frac{1}{\left(1+\frac{x^2}{a^2}\right)^{3/2}}$$

$$\frac{\Delta B}{B_C} = 1 - \left(1+\frac{x^2}{a^2}\right)^{-\frac{3}{2}}$$

Using binomial $(1 + x)^n = 1 + nx + \ldots\ldots\ldots$ Neglecting higher degree terms as $r < a$

$$\frac{\Delta B}{B_C} = 1 - \left(1 - \frac{3}{2}\frac{x^2}{a^2}\right)$$

$$\frac{\Delta B}{B_C} = \frac{3x^2}{2a^2} \qquad \text{put } x = r$$

$$\frac{\Delta B}{B_C} = \frac{3r^2}{2a^2}$$

19. Option (3) is correct.

Given $\dfrac{\Delta Q}{\Delta t} = 6000\dfrac{J}{\text{min}} = \dfrac{6000}{60}\dfrac{J}{s}$

$$\frac{dW}{dt} = 90\text{ W},$$

let in time Δt internal energy increase by ΔU

So, $\quad \Delta U = 2.5 \times 10^3$ J

From first law of thermodynamics

$$\Delta U = Q - W$$

$$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} - \frac{\Delta W}{\Delta t}$$

Now putting the given values

$$\frac{2.5\times10^3}{\Delta t} = 100 - 90 = 10$$

$$\Delta t = 250 \text{ s} = 2.5 \times 10^1 \text{ s}$$

20. Option (4) is correct.

Current leakage is small current that flows through capacitor when voltage is applied.

Given,

$\rho = 200\ \Omega\text{m}$, $C = 2 \times 10^{-12}$ F, $V = 40$ V, $k = 50$

Leakage current as function of time

$$i(f) = i_0\, e^{\frac{-t}{\tau}} \qquad \text{...(i)}$$

Here, $i_0 = \dfrac{q_0}{\rho\, k\varepsilon_0}$ for maximum current.

Put in equation (i)

$$i = \frac{CV_0}{\rho k\varepsilon_0} e^{-t/k\varepsilon_0\rho}$$

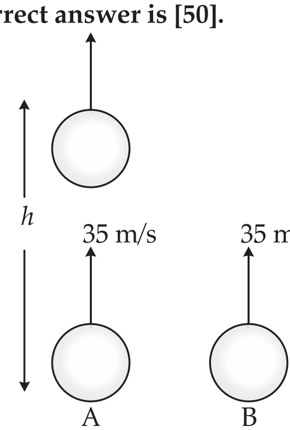
$$i_{\text{leakage}} = \frac{CV_0}{\rho\, k\varepsilon_0} \text{ as } t \to \infty$$

$$= \frac{2\times10^{-12}\times40}{200\times50\times8.85\times10^{-12}}$$

$$= 903\ \mu\text{A} = 0.9 \text{ mA}$$

Section B

21. The correct answer is [50].



Displacement of two balls are

$$S_1 = 35t - \frac{1}{2}gt^2$$

And $$S_2 = 35(t-3) - \frac{1}{2}g(t-3)^2$$

$$\Rightarrow \quad S_1 = S_2 = h$$

$$\Rightarrow \quad 35t - \frac{gt^2}{2} = 35(t-3) - \frac{g(t-3)^2}{2}$$

$$\Rightarrow \quad \frac{g}{2}\left[t^2 - (t-3)^2\right] = 105$$

$$\Rightarrow \quad (2t-3)(3) = \frac{210}{10}$$

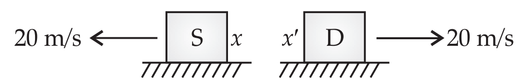
$$\Rightarrow \quad 2t = 10 \Rightarrow t = 5 \text{ s}$$

$$\Rightarrow \quad h = 35\times5 - \frac{10}{2}\times25$$

$$= 175 - 125$$

$$= 50 \text{ m}$$

22. The correct answer is [2025].



By applying Doppler formula

$$f_{app} = f_0\left(\frac{V - V_D}{V - V_S}\right)$$

Here using sign convention

$V_S = -20$ m/s (moving opposite to sound direction)

$V_D = 20$ m/s (moving in direction of sound)

$$f_{app} = f\left(\frac{340-20}{340+20}\right)$$

$$\Rightarrow \quad 1800 = f\left(\frac{320}{360}\right)$$

$$f = 2025 \text{ Hz}$$

23. The correct answer is [300].

Position of first bright fringe $= \dfrac{\lambda D}{d}$

So position of first red fringe $= Y_R = \dfrac{\lambda_R D}{d}$ ...(i)

Position of first violet fringe $= Y_V = \dfrac{\lambda_V D}{d}$ ...(ii)

From eqn (i) and eqn (ii)

$$Y_R - Y_V = (\lambda_R - \lambda_V)\frac{D}{d}$$

$$(Y_R - Y_V)\frac{d}{D} = \lambda_R - \lambda_V$$

$$\lambda_R - \lambda_V = \frac{(3.5-2)}{1.5} \times 0.3 \times 10^{-3} \text{ mm}$$

$$\lambda_R - \lambda_V = 0.3 \times 10^{-3} \text{ mm}$$

$$\Delta\lambda = \lambda_R - \lambda_V = 300 \text{ nm}$$

24. The correct answer is [2].

Concept : Comparing given equation of amplitude modulated wave by standard equation, we can get;

$$C_m = Ac\left(1 + \frac{A_m}{A_c}\cos 2xf_m t\right)\sin 2\pi f_c t$$

Given : $C_m = 10(1 + 0.2 \cos 12560t) \sin(111 \times 10^4 t)$

So, $\cos 2\pi f_m t = \cos 12560\, t$

$\Rightarrow$ $2\pi f_m = 12560$

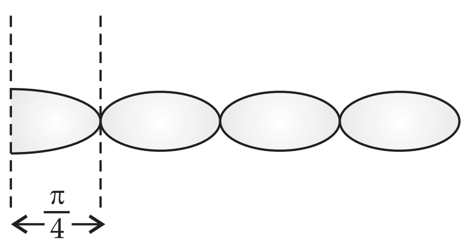
$\Rightarrow$ $f_m = \dfrac{12560}{2 \times 3.14} = 2000 = 2\text{kHz}$

25. The correct answer is [1].

Concept : By comparing given equation with equation of standing wave $y = 2A \cos kx \sin \omega t$

Amplitude $R = 2A \cos kx$

Given equation, $y = 1.0 \text{ mm} \cos(1.5 \text{ cm}^{-1})\, x \sin(78.5)\text{s}^{-1})\, t$



Comparing cos term

$$k = 1.57 = \frac{2\pi}{\lambda}$$

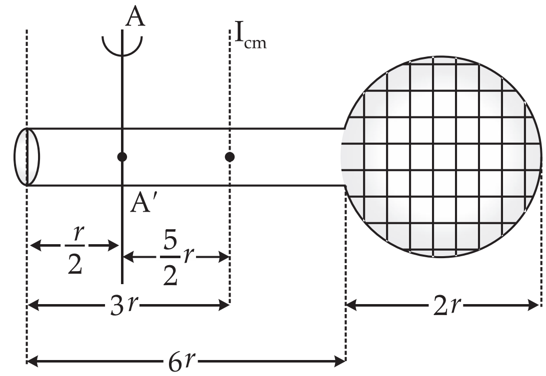
$$\lambda = \frac{2\pi}{1.57} \text{cm}$$

$$\text{Closest Node Position from origin} = \frac{\lambda}{4}$$

$$= \frac{2\pi}{4 \times 1.57} = 1 \text{ cm}$$

26. The correct answer is [52].

Concept : In this



Problem we have to use parallel axis theorem twice in order to get moment of inertia of linear and circular part.

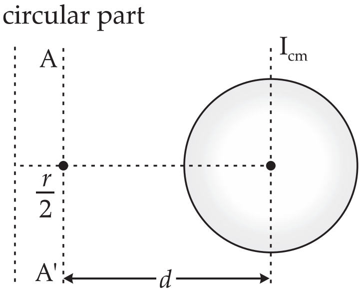
MI of linear part

$$I'_{AA} = I_{cm} + Md^2$$

$$= \frac{M(6r)^2}{12} + M\left(\frac{5}{2}r\right)^2$$

$$I'_{AA} = \frac{36Mr^2}{12} + \frac{25Mr^2}{4}$$

MI of circular part



$$I'_{AA} = I_{cm} + Md^2$$

$$= \frac{Mr^2}{2} + M\left(\frac{13}{2}r\right)^2$$

$$I'_{AA} = \frac{Mr^2}{2} + \frac{169}{4}Mr^2$$

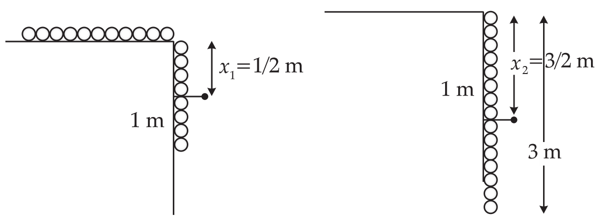
$$\text{Net M.I} = \underbrace{I_{AA}}_{\text{Linear Part}} + \underbrace{I_{AA'}}_{\text{Circular Part}}$$

$$\text{Net MI} = \left(\frac{36Mr^2}{12} + \frac{25}{4}Mr^2\right) + \left(\frac{Mr^2}{2} + \frac{169}{4}Mr^2\right)$$

$$\text{Net MI} = 52\, Mr^2$$

27. The correct answer is [40].

When the chain falls its center of mass goes down from $x_1 = \frac{1}{2}$ m to $x_2 = \frac{3}{2}$ m.



From conservation of Mechanical energy

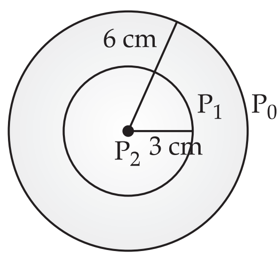
$$\Delta k = U_f - U_i$$

$$= \left(3 \times g \times \frac{3}{2}\right) - \left(1 \times g \times \frac{1}{2}\right)$$

$$= 45 - 5 = 40 \text{ J}$$

28. The correct answer is [2].

Concept : The formula for excess pressure for soap bubble, $\Delta P = \frac{4T}{R}$



So, applying this formula for interior, middle and exterior, surface, we can get result.

$$P_1 - P_0 = \frac{4T}{6}$$

and, $$P_2 - P_1 = \frac{4T}{3}$$

So, $$P_2 - P_0 = (P_1 - P_0) + (P_2 - P_1)$$

$$P_2 - P_0 = \frac{4T}{6} + \frac{4T}{3}$$

$$\Rightarrow \quad \frac{4T}{R} = \frac{4T}{6} + \frac{4T}{3}$$

$$\Rightarrow \quad \frac{1}{R} = \frac{1}{6} + \frac{1}{3}$$

$$R = 2 \text{ cm}$$

29. The correct answer is [354].

Concept : By comparing given equation with $E = E_0 \cos(kx - wt)$ we can find required parameter then use formula

Radiation pressure $= \frac{2I}{c}$

and $$I = \frac{1}{2}\varepsilon_0 E_0^2 c$$

$$\text{Radiation Pressure} = \frac{2I}{c} = \left(\frac{2}{c}\right)\left(\frac{1}{2}\varepsilon_0 E_0^2 c\right)$$

$$= \varepsilon_0 E^2$$

Here, $E = 200 \frac{V}{m}$ and $\varepsilon_0 = 8.85 \times 10^{-12}$

$$\text{Radiation Pressure} = 8.85 \times 10^{-12} \times (200)^2$$

$$= 354.0 \times 10^{-9} \text{ N/m}^2$$

30. The correct answer is [1].

Concept : Magnetic dipole (2) is laying in magnetic field of (1) so it will experience a torque

$$\tau = (m_2 \times B_1) \sin 90°$$

$$\tau = m_2 B_1$$

Magnetic Dipole (2) is lying in equatorial position of dipole (1)

So, $$B_1 = \frac{\mu_0}{4\pi} \times \frac{m_1}{r^3}$$

$$= \frac{\mu_0}{4\pi} \cdot \frac{1}{1^3}$$

The torque $$\tau = 1 \times \frac{\mu_0}{4\pi} . \times 1$$

$$= 1 \times 10^{-7} \text{ N.m}$$

❐❐❐