JEE (Main) PHYSICS SOLVED PAPER

2023
31^{st} Jan Shift 1

Section A

Q. 1. The maximum potential energy of a block executing simple harmonic motion is 25 J. A is amplitude of oscillation. At A/2, the kinetic energy of the block is:

(1) 18.75 J **(2)** 9.75 J **(3)** 37.5 J **(4)** 12.5 J

Q. 2. The drift velocity of electrons for a conductor connected in an electrical circuit is V_d. The conductor in now replaced by another conductor with same material and same length but double the area of cross section. The applied voltage remains same. The new drift velocity of electrons will be:

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

Q. 3. The initial speed of a projectile fired from ground is u. At the highest point during its motion, the speed of projectile is $\frac{\sqrt{3}}{2}u$. The time of flight of the projectile is:

(1) $\frac{2u}{g}$ **(2)** $\frac{u}{2g}$ **(3)** $\frac{\sqrt{3}u}{2}$ **(4)** $\frac{u}{g}$

Q. 4. The correct relation between $\gamma = \frac{C_p}{C_v}$ and temperature T is :

(1) $\gamma \propto T^0$ **(2)** $\gamma \propto T$

(3) $\gamma \propto \frac{1}{\sqrt{T}}$ **(4)** $\gamma \propto \frac{1}{T}$

Q. 5. The effect of increase in temperature on the number of electrons in conduction band (n_e) and resistance of a semiconductor will be as:

(1) Both n_e and resistance increase
(2) Both n_e and resistance decrease
(3) n_e decreases, resistance increases
(4) n_e increases, resistance decreases

Q. 6. The amplitude of 15sin $(1000\pi t)$ is modulated by 10sin $(4\pi t)$ signal. The amplitude modulated signal contains frequency(ies) of

A. 500 Hz **B.** 2 Hz
C. 250 Hz **D.** 498 Hz
E. 502 Hz

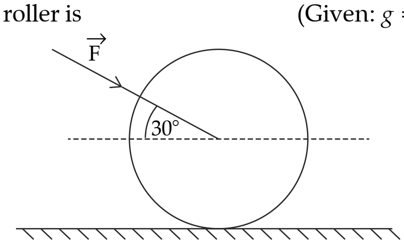
Choose the correct answer from the options given below:

(1) A only **(2)** B only
(3) A and B only **(4)** A, D and E only

Q. 7. Two polaroide A and B are placed in such a way that the pass-axis of polaroids are perpendicular to each other. Now, another polaroid C is placed between A and B bisecting angle between them. If intensity of unpolarized light is I_0 then intensity of transmitted light after passing through polaroid B will be:

(1) $\frac{I_0}{4}$ **(2)** $\frac{I_0}{2}$ **(3)** Zero (4) $\frac{I_0}{8}$

Q. 8. As shown in figure, a 70 kg garden roller is pushed with a force of $\vec{F} = 200$ N at an angle of 30° with horizontal. The normal reaction on the roller is (Given: $g = 10$ m s^{-2})

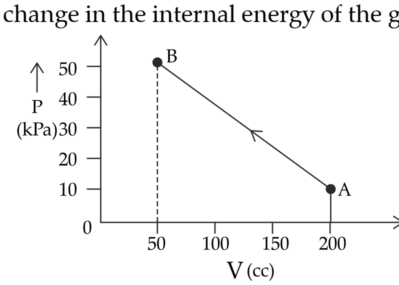


(1) $800\sqrt{2}$ N **(2)** $200\sqrt{3}$ N
(3) 600 N **(4)** 800 N

Q. 9. If 1000 droplets of water of surface tension 0.07 N m^{-1}, having same radius 1 mm each, combine to form a single drop. In the process the released surface energy is: $\left(\text{Take } \pi = \frac{22}{7}\right)$

(1) 8.8×10^{-5} J **(2)** 7.92×10^{-4} J
(3) 7.92×10^{-6} J **(4)** 9.68×10^{-4} J

Q. 10. The pressure of a gas changes linearly with volume from A to B as shown in figure. If no heat is supplied to or extracted from the gas then change in the internal energy of the gas will be



(1) – 4.5 J **(2)** zero **(3)** 4.5 J **(4)** 6 J

Q. 11. Given below are two statements: One is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: The beam of electrons shows wave nature and exhibit interference and diffraction.

Reason R: Davissons Germer Experimentally verified the wave nature of electrons.

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

(1) Both A and R are correct and R is the correct explanation of A

(2) A is not correct but R is correct

(3) A is correct but R is not correct

(4) Both A and R are correct but R is Not the correct explanation of A

Q. 12. A free neutron decays into a proton but a free proton does not decay into neutron. This is because

(1) proton is a charged particle

(2) neutron is an uncharged particle

(3) neutron is a composite particle made of a proton and an electron

(4) neutron has larger rest mass than proton

Q. 13. A spherical insulating ball and a spherical metallic ball of same size and mass are dropped from the same height. Choose the correct statement out of the following. (Assume negligible air friction)

(1) Insulating ball will reach the earth's surface earlier than the metal ball

(2) Metal ball will reach the earth's surface earlier than the insulating ball

(3) Both will reach the earth's surface simultaneously.

(4) Time taken by them to reach the earth's surface will be independent of the properties of their materials

Q. 14. If R, X_L, and X_c represent resistance, inductive reactance and capacitive reactance. Then which of the following is dimensionless :

(1) $\dfrac{R}{X_L X_C}$ **(2)** $\dfrac{R}{\sqrt{X_L X_C}}$

(3) $R\dfrac{X_L}{X_C}$ **(4)** $RX_L X_C$

Q. 15. 100 balls each of mass m moving with speed v simultaneously strike a wall normally and reflected back with same speed, in time t second. The total force exerted by the balls on the wall is:

(1) $\dfrac{100mv}{t}$ **(2)** $200mvt$ **(3)** $\dfrac{mv}{100t}$ **(4)** $\dfrac{200mv}{t}$

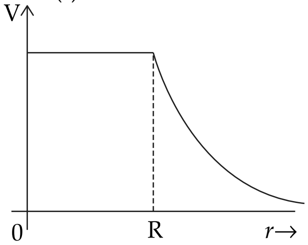
Q. 16. If a source of electromagnetic radiation having power 15 kW produces 10^{16} photons per second, the radiation belongs to a part of spectrum is: (Take Planck constant, $h = 6 \times 10^{-34}$ J s)

(1) Micro waves **(2)** Ultraviolet rays

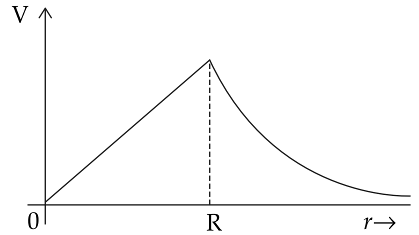
(3) Gamma rays **(4)** Radio waves

Q. 17. Which of the following correctly represents the variation of electric potential (V) of a charged spherical conductor of radius (R) with radial distance (r) from the centre?

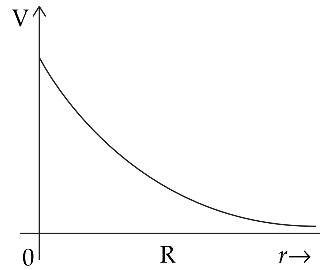
(1)



(2)



(3)



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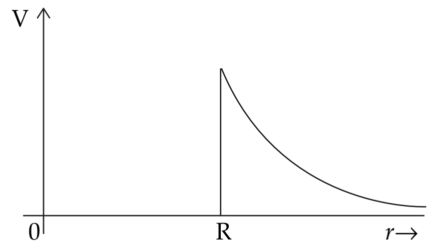


Q. 18. A bar magnet with a magnetic moment 5.0 A m^2 is placed in parallel position relative to a magnetic field of 0.4 T. The amount of required work done in turning the magnet from parallel to antiparallel position relative to the field direction is:

(1) 1 J **(2)** 4 J

(3) 2 J **(4)** zero

Q. 19. At a certain depth "d" below surface of earth, value of acceleration due to gravity becomes four times that of its value at a height 3R above earth surface. Where R is Radius of earth (Take R = 6400 km). The depth, d is equal to:

(1) 4800 km **(2)** 2560 km

(3) 640 km **(4)** 5260 km

Q. 20. A rod with circular cross-section area 2 cm^2 and length 40 cm is wound uniformly with 400 turns of an insulated wire. If a current of 0.4 A flows in the wire windings, the total magnetic flux produced inside windings is $4\pi \times 10^{-6}$ Wb. The relative permeability of the rod is (Given : Permeability of vacuum $\mu_0 = 4\pi \times 10^{-7}$ N A^{-2})

(1) $\dfrac{5}{16}$ **(2)** 12.5 **(3)** 125 **(4)** $\dfrac{32}{5}$

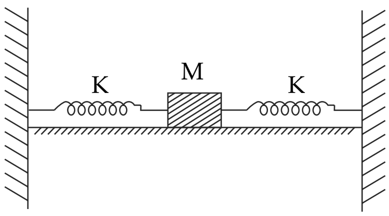
Section B

Q. 21. In a medium the speed of light wave decreases to 0.2 times to its speed in free space.The ratio of relative permittivity to the refractive index of the medium is x : 1. The value of x is ______. (Given: speed of light in free space = 3×10^8 m s^{-1} and for the given medium $\mu_r = 1$)

Q. 22. A solid sphere of mass 1 kg rolls without slipping on a plane surface. Its kinetic energy is 7×10^{-3} J. The speed of the centre of mass of the sphere is ________ cm s^{-1}.

Q. 23. A lift of mass M = 500 kg is descending with speed of 2 m s^{-1}. Its supporting cable begins to slip thus allowing it to fall with a constant acceleration of 2 m s^{-2}. The kinetic energy of the lift at the end of fall through to a distance of 6 m will be _______ kJ.

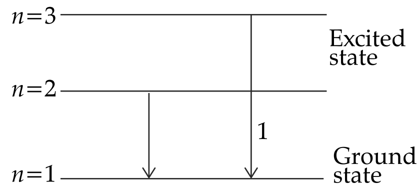
Q. 24. In the figure given below, a block of mass M = 490 g placed on a frictionless table is connected with two springs having same spring constant (K = 2 N m^{-1}). If the block is horizontally displaced through 'x' m then the number of complete oscillations it will make in 14π seconds will be ________.



Q. 25. An inductor of 0.5 mH, a capacitor of 20 μF and resistance of 20 Ω are connected in series with a 220 V AC source. If the current is in phase with the emf, the amplitude of current of the circuit is $\sqrt{x}$ A. The value of x is:

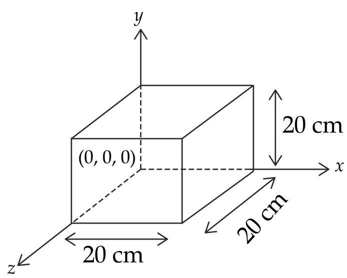
Q. 26. The speed of a swimmer is 4 km h^{-1} in still water. If the swimmer makes his strokes normal to the flow of river of width 1 km, he reaches a point 750 m down the stream on the opposite bank. The speed of the river water is _______ km h^{-1}.

Q. 27. For hydrogen atom, λ_1 and λ_2 are the wavelengths corresponding to the transitions 1 and 2 respectively as shown in figure. The ratio of λ_1 and λ_2 is $\frac{x}{32}$. The value of x is _______ .



Q. 28. Two identical cells, when connected either in parallel or in series gives same current in an external resistance 5 Ω. The internal resistance of each cell will be ______ Ω.

Q. 29. Expression for an electric field is given by $\vec{E}$ = 4000 $x^2\hat{i}$ Vm^{-1}. The electric flux through the cube of side 20 cm when placed in electric field (as shown in the figure) is _____ V cm.



Q. 30. A thin rod having a length of 1 m and area of cross-section 3×10^{-6} m^2 is suspended vertically from one end. The rod is cooled from 210°C to 160°C. After cooling, a mass M is attached at the lower end of the rod such that the length of rod again becomes 1 m. Young's modulus and coefficient of linear expansion of the rod are 2×10^{11} N m^{-2} and 2×10^{-5} K^{-1}, respectively. The value of M is _____ kg. (Take g = 10 m s^{-2})

Answer Key

Q. No.	Answer	Topic Name	Chapter Name
1	(1)	energy in SHM	SHM
2	(1)	Drift velocity	Electric current
3	(4)	Projectile motion	2D motion
4	(1)	Specific heat	Kinetic theory of gases
5	(4)	Energy band	Semiconductor
6	(4)	Modulation	Communication systems
7	(4)	Polarisation	Wave optics
8	(4)	Newton's first law	Newton's law of motion
9	(2)	Surface energy	Viscosity
10	(3)	First law of thermodynamic	Thermodynamics
11	(1)	de-Broglie matter wave	Dual nature of matter
12	(4)	Radioactive Decay	Nuclear Physics
13	(1)	Induction	Magnetism
14	(2)	Dimentional formula	Units & Dimentions
15	(4)	Momentum	Newton's law of motion
16	(3)	Electromagnetic spectrum	Photoelectric effect

17	**(1)**	Electric potential	Electrostatics
18	**(2)**	Magnetic Dipole	Magnetism
19	**(1)**	Variation in g	Gravitation
20	**(1)**	Solenoid	Magnetism
21	**[5]**	Visible light	EM Waves
22	**[10]**	Rotational Kinetic Energy	Rotational Motion
23	**[7]**	Kinetic energy	Work energy & power
24	**[20]**	Spring block system	SHM
25	**[242]**	LRC circuit	Alternating Current
26	**[3]**	Relative velocity	Motion in plane
27	**[27]**	Emission spectrum	Atoms
28	**[5]**	Grouping of cells	Current electricity
29	**[640]**	Electric flux	Gauss law
30	**[60]**	Hook's law	Bulk Modulus

SOLUTIONS

Section A

1. Option (1) is correct.

The total energy associated with the body executing SHM,

$$K = \frac{1}{2}\, m\omega^2 A^2$$

Given that $\quad E = \frac{1}{2} m\omega^2 A^2 = 25\text{ J} \quad \ldots \text{(i)}$

Potential energy $U = \frac{1}{2} m\omega^2 x^2$

Here, $\quad x = \frac{A}{2} \quad$ (given)

$$U = \frac{1}{2} m\omega^2 \left(\frac{A}{2}\right)^2 \quad \ldots \text{(i)}$$

Total energy, $\quad E = K + U$

$$\Rightarrow \quad \frac{1}{2} m\omega^2 A^2 = K + \frac{1}{2}\, m\omega^2 \left(\frac{A}{2}\right)^2$$

$$\Rightarrow \quad K = \frac{1}{2}\, m\omega^2 A^2 - \frac{1}{2} m\omega^2\, \frac{A^2}{4}$$

$$\Rightarrow \quad K = \frac{1}{2} m\omega^2 A^2 \left(1 - \frac{1}{4}\right) = 25 \times \frac{3}{4}$$

$$= 18.75\text{ J}$$

2. Option (1) is correct.

Given, $\quad A_1 = A$

$A_2 = 2A$

Same materials means same resistivity

$V = \text{Constant} = V$

$I = V_d\, ne\, A$

From Ohm's law $\; V = IR$

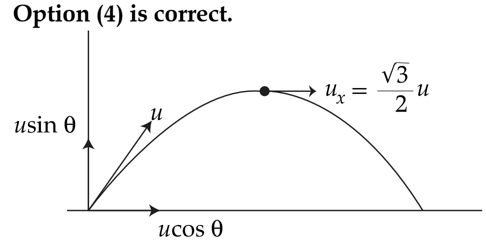
Since voltage is constant

$$V = I_1 R_1 = I_2 R_2$$

$$\Rightarrow \quad V_{d1} neA \times \rho \frac{I}{A} = V_{d2} ne \times 2A \times \rho \frac{I}{2A}$$

$$\Rightarrow \quad V_{d_1} = V_{d_2} = V_d$$

3. Option (4) is correct.



At the highest point the velocity along y-axis becomes zero.

Velocity along x-axis $= u\cos\theta$

As there is no acceleration acting along x-axis, so $u\cos\theta$ remains constant, along the same axis,

$$u\cos\theta = \frac{\sqrt{3}}{2}\, u \Rightarrow \cos\theta = \frac{\sqrt{3}}{2}$$

$$\theta = 30^\circ$$

the time period will be given by,

$$T = \frac{2u\sin\theta}{g} = \frac{2u\sin 30}{g} = \frac{24 \times \frac{1}{2}}{g} = \frac{u}{g}$$

4. Option (1) is correct.

C_p = Specific heat capacity at constant pressure.

C_v = Specific heat capacity at constant volume

where,

$$C_P = \frac{f}{2} R + R \text{ And } C_v = \frac{f}{2} R$$

So, $\quad \gamma = \frac{C_P}{C_V} = 1 + \frac{2}{f}$

Here γ is independent of T.

Therefore $\gamma \propto T^0$ is the correct option.

5. Option (4) is correct.

The conductivity of a conductor decreases as temperature is increased. This is because as the temperature increases the random collisions of the free electrons with the particle become more frequent. In case of semiconductor, the increase in temperature leads to more current as the more number of electrons jumps to conduction band from valence band.

$E_g \sim 1\ eV \Rightarrow$ Energy gap in Semiconductor

$\boxed{T\uparrow R\downarrow n_e\uparrow}$

6. Option (4) is correct.

Let, $C = A_c \sin \omega_c t$ represent carriers wave

& $S = A_s \sin \omega_s t$ represents signal wave

Here, $\omega_c - \omega_s$ represent lower side frequency

& $\omega_c + \omega_s$ represent upper side frequency.

Now $\omega_c = 1000\pi$

& $\omega_s = 4\pi$

Now the associated frequency will be

$$f_c = \frac{\omega_c}{2\pi} = \frac{1000\pi}{2\pi} = 500 \text{ Hz}$$

$$f_s = \frac{\omega_s}{2\pi} = \frac{4\pi}{2\pi} = 2 \text{ Hz}$$

$$\text{LSF} = 500 - 2 = 498 \text{ Hz}$$

$$\text{USF} = 500 + 2 = 502 \text{ Hz}$$

7. Option (4) is correct.

Intensity of unpolarised light $= I_0$

From Malus law $I = I_0\cos^2\theta$

Intensity after A, $I_A = I_0\cos^2\theta = I_0\cos^2 45$

$$I_A = I_0 \times \frac{1}{2} = \frac{I_0}{2}$$

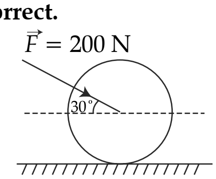
Intensity after C, $I_C = I_A\cos^2\theta$

$$\Rightarrow \quad I_C = \frac{I_0}{2}\cos^2 45 = \frac{I_0}{2}\times\frac{1}{2} = \frac{I_0}{4}$$

Intensity after B, $I_B = I_C\cos^2 45$

$$= \frac{I_0}{4}\times\frac{1}{2} = \frac{I_0}{8}$$

8. Option (4) is correct.



Here the forces which are acting on the Roller are:

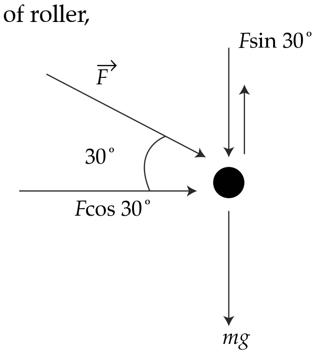
(1) Weight

(2) Applied external force

(3) Normal Reaction from ground

(4) Friction

From FBD of roller,



Equation long,

y-axis, $N = mg + F\sin 30°$

$$= 70 \times 10 + 200 \times \frac{1}{2}$$
$$= 700 + 100$$
$$= 800 \text{ N}$$

9. Option (2) is correct.

When 1000 droplets of radius 1 mm is combined to form single drop, then the volume of 1000 droplets would be same as the volume of one drop

So,

$$1000 \times \frac{4}{3}\pi r^3 = 1 \times \frac{4}{3}\pi R^3$$

$$\Rightarrow \quad R = 10r$$

Now the released surface energy would be

$$\Delta U = T.\Delta A$$

$$\Rightarrow \quad \Delta U = T(1000 \times 4\pi r^2 - 4\pi R^2)$$
$$= T \times 4\pi(1000r^2 - R^2)$$

$$\Rightarrow \quad \Delta U = 4 \times \frac{22}{7} \times 0.07(1000r^2 - 100r^2)$$

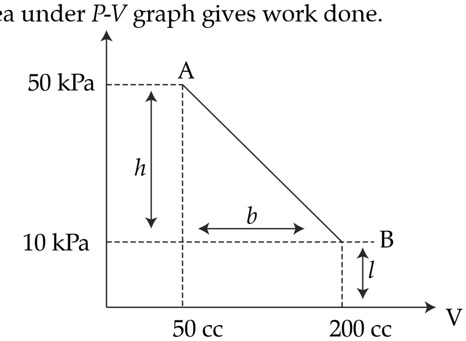
$$= 4 \times \frac{22}{7} \times \frac{7}{100} \times 900r^2$$

$$= \frac{4\times 22}{100} \times 900 \times 10^{-6}$$

$$= 7.92 \times 10^{-4} \text{ J}$$

10. Option (3) is correct.

Area under P-V graph gives work done.



$P_1 = 50 \text{ kPa} = 50 \times 10^3 \text{ Pa}$

$P_2 = 10 \text{ kPa} = 10 \times 10^3 \text{ Pa}$

$V_1 = 50 \text{ cc} = 50 \text{ cm}^3 = 50 \times 10^{-6} \text{ m}^3$

$V_2 = 200 \text{ cc} = 200 \text{ cm}^3$

$= 200 \times 10^{-6} \text{ m}^3$

W = area under P-V graph

$$= \frac{1}{2} \times b \times h + b \times l$$

$$= \frac{1}{2} \times (200-50) \times 10^{-6} \times (50-10) \times 10^3$$
$$+ 10 \times 10^3 \times (200 - 50) \times 10^{-6}$$

$$\Rightarrow \quad W = -\frac{150}{2} \times 40 \times 10^{-3} + 10^4 \times 150 \times 10^{-6}$$

$$= -75 \times 4 \times 10^{-2} + 150 \times 10^{-2}$$

$$= -450 \times 10^{-2} = -4.5 \text{ J}$$

Now from first law of thermodynamies

$$Q = \Delta U + W$$

As no heat transfer takes place

$$\Rightarrow \quad \Delta U = W = 4.5 \text{ J}$$

11. Option (1) is correct.

The beam of electrons shows wave nature given by de-Broglie. He suggested that a particle of mass m moving with speed v behaves in same way like waves of wavelength λ.

The wave nature of particle is obtained by Davisson-Germer experiment.

In this experiment the electron shows wave nature and exihibit interference and diffraction.

12. Option (4) is correct.

A free neutron can decay into proton through the weak nuclear force. In this process, a neutron decay into a proton, an electron, and an antineutrino.

On the other hand, a free proton does not decay into neutron because it would violate conservation of mass-energy and momentum as the rest mass of neutron is greater than that of proton.

13. Option (1) is correct.

When metallic ball is passing through magnetic field, eddy current is produced and it opposes the motion, so it takes more time than insulated ball.

14. Option (2) is correct.

The resistance, inductive reactance and capacitive reactance have same units and dimensions.

$$R = \frac{V}{I} = \frac{\left[ML^2T^{-3}A^{-1}\right]}{[A]} = \left[ML^2T^{-3}A^{-2}\right]$$

$$X_C = [ML^2T^{-3}A^{-2}]$$
$$X_L = [ML^2T^{-3}A^{-2}]$$

Now putting the values in second option,

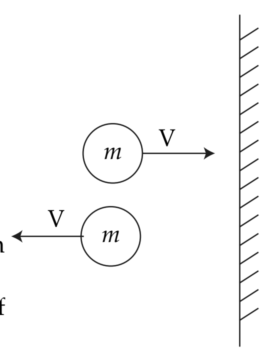
$$\frac{R}{\sqrt{X_L X_C}} = \frac{\left[ML^2T^{-3}A^{-2}\right]}{\sqrt{\left[ML^2T^{-3}A^{-2}\right]\left[ML^2T^{-3}A^{-2}\right]}}$$

$$= \frac{\left[ML^2T^{-3}A^{-2}\right]}{\left[ML^2T^{-3}A^{-2}\right]} = [M^0L^0T^0A^0]$$

15. Option (4) is correct.

From Newton's second law,

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



dp = Change in momentum

$p_i = mv$ = Initial momentum of one ball

p_f = Final momentum of one ball $= mv$

$$dp = p_f - p_i = mv - (-mv) = 2\,mv$$

Force exerted due to one ball

$$F_{avg} = \frac{dp}{dt} = \frac{2mv}{dt}$$

Force exerted by 100 balls

$$F_{avg} = 100 \times \frac{2mv}{t} = \frac{200mv}{t}$$

16. Option (3) is correct.

$$P = n\frac{E}{t} = n\frac{hc}{\lambda}$$

where, P = power $= 15 \times 10^3$ W

$$n = 10^{16}$$
$$h = 6 \times 10^{-34}\text{ J s}$$
$$c = 3 \times 10^8\text{ m s}^{-1}$$

Substituting above values,

$$P = n\frac{hc}{\lambda}$$

$$\Rightarrow \quad 15 \times 10^3 = 10^{16} \times \frac{6 \times 10^{-34} \times 3 \times 10^8}{\lambda}$$

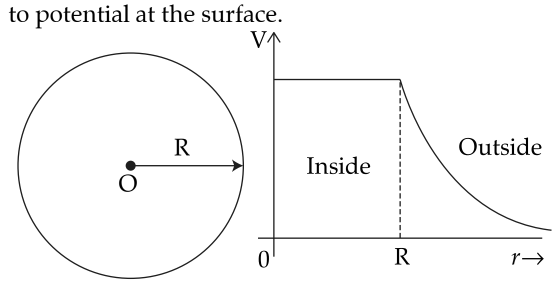
$$\Rightarrow \quad \lambda = \frac{6 \times 3 \times 10^{24-34}}{15 \times 10^3}$$

$$\Rightarrow \quad \lambda = 1.2 \times 10^{-13}\text{ m} = 0.0012\text{ Å}$$

Which belongs to gamma ray.

17. Option (1) is correct.

Potential inside the sphere is constant which is equal to potential at the surface.



$$V_{inside} = V_{surface} = \frac{1}{4\pi\varepsilon_0}\frac{q}{R} \text{ and } V_{outside} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

18. Option (2) is correct.

Work done in turning a magnet of magnetic moment M placed in magnetic field B is given by

$$W_{\theta_1-\theta_2} = MB(\cos\theta_1 - \cos\theta_2)$$

Here,
$$M = 5.0\text{ A m}^2$$
$$B = 0.4\text{ T}$$
$$\theta_1 = 0^\circ$$
$$\theta_2 = 180^\circ$$

$$W_{\theta_1-\theta_2} = MB(\cos\theta_1 - \cos\theta_2)$$
$$= 5 \times 0.4(1 + 1) = 2 \times 5 \times 0.4$$
$$= 4\text{ J}$$

19. Option (1) is correct.

Value of g above the surface of earth is given by

$$g'_h = \frac{g}{\left(1+\frac{h}{R}\right)^2}$$

And the value of g below the surface of earth is given by

$$g'_d = g\left(1 - \frac{d}{R}\right)$$

According to the question,

$$g\left(1 - \frac{d}{R}\right) = 4 \times \frac{g}{\left(1+\frac{h}{R}\right)^2}$$

$$\Rightarrow 1 - \frac{d}{R} = \frac{4}{(1+3)^2} = \frac{4}{16} = \frac{1}{4} \Rightarrow \frac{d}{R} = 1 - \frac{1}{4} = \frac{3}{4}$$

$$\Rightarrow \quad d = \frac{3}{4}R = \frac{3}{4} \times 6400 = 4800\text{ km}$$

20. Option (1) is correct.

Given, $A = 2\text{ cm}^2 = 2 \times 10^{-4}\text{ m}^2$

$l = 40\text{ cm} = 40 \times 10^{-2}\text{ m}$

$I = 0.4\text{ A}$

$\phi = 4\pi \times 10^{-6}\text{ Wb}$

$\mu_0 = 4\pi \times 10^{-7}\text{ NA}^{-2}$

$N = 400$

Magnetic field by solenoid is given by,

$B = \mu n I$

where, $\mu = \mu_0\mu_r$

and, n/l = number of turns per meter

$$n = \frac{N}{l} \text{ So, } B = r_0\mu_r\frac{N}{l}I$$

Now the magnetic flux $\phi = N(B.A)$

$$\Rightarrow \quad \phi = N(\mu_0\mu_r\frac{N}{l}\ I.A) \Rightarrow \mu_r = \frac{\phi \times l}{N\mu_0 NIA}$$

$$\Rightarrow \quad \mu_r = \frac{4\pi\times10^{-6}\times0.4}{400\times4\pi\times10^{-7}\times400\times0.4\times2\times10^{-4}}$$

$$\Rightarrow \quad \mu_r = \frac{10}{32} = \frac{5}{16}$$

Section B

21. The correct answer is [5].

Refractive index, $n = \dfrac{c}{v}$

$$\Rightarrow \quad n = \frac{c}{0.2\times c} \Rightarrow n = \frac{10}{2} = 5$$

Now,

$$n = \sqrt{\mu_r\varepsilon_r} \Rightarrow 5 = \sqrt{1\times\varepsilon_r}$$

$\Rightarrow \quad \varepsilon_r = 25$

According to the question,

$$\frac{\varepsilon_r}{n} = \frac{x}{1} \Rightarrow \frac{25}{5} = \frac{x}{1} \Rightarrow \frac{5}{1} = \frac{x}{1}$$

$\Rightarrow \quad x = 5$

22. The correct answer is [10].

Given, $m = 1\text{ kg}$

$\text{K.E.} = 7 \times 10^{-3}\text{ J}$

$KE_{total} = KE_{translational} + KE_{rotational}$

$$\Rightarrow \quad \text{K.E.} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{2}{5}mR^2\right)\left(\frac{v}{R}\right)^2$$

where, $\omega = \dfrac{V}{R}$ and $I = \dfrac{2}{5}mR^2$

$$\Rightarrow \quad \text{K.E.} = \frac{1}{2}mv^2\left(1+\frac{2}{5}\right)$$

$$\Rightarrow \quad 7\times10^{-3} = \frac{1}{v}\times1\times v^2\left(\frac{7}{5}\right)$$

$$\Rightarrow \quad 7\times10^{-3} = \frac{7}{10}\times v^2$$

$\Rightarrow \quad v^2 = 10^{-2}$

$\Rightarrow \quad v = 10^{-1}\text{ m s}^{-1}$

$= 10\text{ cm s}^{-1}$

23. The correct answer is [7].

Given, $M = 500\text{ kg}$

$u = 2\text{ m s}^{-1}$

$a = 2\text{ m s}^{-2}$

$s = 6\text{ m}$

Final velocity can be calculated by

$v^2 = u^2 + 2as$

$\Rightarrow \quad v^2 = (2)^2 + 2 \times 2 \times 6$

$\Rightarrow \quad v^2 = 4 + 24 = 28\text{ m s}^{-1}$

Now $\quad \text{K.E.} = \dfrac{1}{2}mv^2 = \dfrac{1}{2} \times 500 \times 28$

$= 7000\text{ J} = 7\text{ kJ}$

24. The correct answer is [20].

Given, $m = 490\text{ g} = 0.49\text{ kg}$

$K_1 = K_2 = K = 2\text{ N m}^{-1}$

Here, the equivalent force constant

$K_e = K_1 + K_2$

$K_e = K + K = 2K$

Now the time period is

$$T = 2\pi\sqrt{\frac{m}{K_e}} = 2\pi\sqrt{\frac{m}{2K}}$$

$$\Rightarrow \quad T = 2\pi\sqrt{\frac{0.49}{2\times2}}$$

$$\Rightarrow \quad T = 2\pi \times \frac{0.7}{2} = 0.7\pi$$

Now the number of oscillations in 14π seconds

$$= \frac{14\pi}{0.7\pi} = \frac{10\times14\pi}{7\pi} = 20$$

25. The correct answer is [242].

Impedance in LCR circuit is given by,

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

According to the question the current is in phase with emf.

Then, $X_L = X_C$

So $|Z| = R$

Now, $I_{rms} = \dfrac{V_{rms}}{R}$

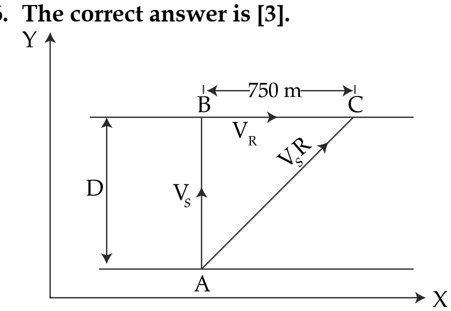
$$\Rightarrow \quad I_{rms} = \frac{220}{20} \Rightarrow I_{rms} = 11\text{ A}$$

Since, $I_0 = \sqrt{2} \times I_{rms}$

$I_0 = \sqrt{2} \times 11 = \sqrt{242}\text{ A}$

Comparing, we get $x = 242$

26. The correct answer is [3].



Given, $D = 1\text{ km}$

$V_S = 4\text{ km h}^{-1}$

V_R = Speed of river water

V_{SR} = Speed of swimmer W.r.t. river

Along Y-axis, $D = V_s \times t$

$$t = \frac{D}{V_s} = \frac{1}{4}\text{ h}$$

In the same time the swimmer reaches at point C.

Along X-axis,

$$D = V_R \times t$$

$$\Rightarrow \quad \frac{750}{1000} = V_R \times \frac{1}{4}$$

$$\Rightarrow \quad V_R = \frac{4 \times 750}{1000}$$

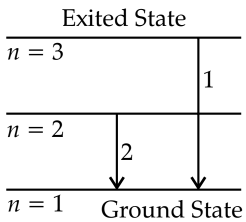
$$V_R = 3\text{ km h}^{-1}$$

27. The correct answer is [27].

Wavelength of photon emitted during excitation is given by

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

Now,



$$\frac{1}{\lambda_1} = R\left(\frac{1}{1^2} - \frac{1}{3^2}\right)$$

$$\Rightarrow \frac{1}{\lambda_1} = R\left(1 - \frac{1}{9}\right) \Rightarrow \frac{1}{\lambda_1} = \frac{8R}{9}$$

$$\Rightarrow \quad \lambda_1 = \frac{9}{8R}$$

Similarly,

$$\frac{1}{\lambda_2} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \Rightarrow \lambda_2 = \frac{4}{3R}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\frac{9}{8R}}{\frac{4}{3R}} = \frac{9 \times 3R}{8R \times 4} \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{27}{32}$$

On comparing, $x = 27$

28. The correct answer is [5].

Given, $R = 5\,\Omega$

In parallel grouping,

$$i = \frac{\text{Net emf}}{\text{Total resistance}} \Rightarrow i = \frac{E}{R + \frac{r}{n}}$$

where, $n = 2$ (no. of resistance)

$$i_1 = \frac{E}{R + \frac{r}{2}} \quad \text{... (i)}$$

In series grouping,

$$\Rightarrow \quad i_2 = \frac{nE}{nr + R} = \frac{2E}{2r + R} \quad \text{...(ii)}$$

According to the question,

$$i_1 = i_2$$

$$\Rightarrow \quad \frac{E}{R + \frac{r}{2}} = \frac{2E}{2r + R}$$

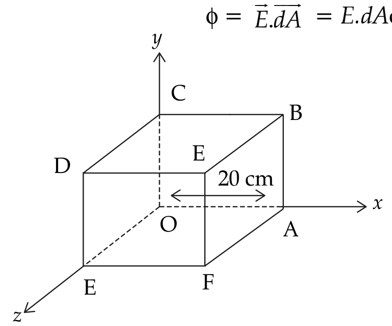
$$\Rightarrow \quad 2r + R = 2R + r$$

$$\Rightarrow \quad R = r$$

$$\Rightarrow \quad r = 5\,\Omega$$

29. The correct answer is [640].

$$\phi = \vec{E}.\vec{dA} = E.dA\cos\theta$$



Given,

$$\vec{E} = 4000x^2\,\hat{i}\text{ V m}^{-1}$$

Here the electric field is directed towards x-axis

So, the flux along y and z-axis would be zero, as E and A are perpendicular

$\phi_{DCBE} = \phi_{DEGF} = \phi_{COAB} = \phi_{GOFA} = 0$

$\phi_{GODC} = 0$ as $\vec{E}$ depends on x.

And $x = 0$ for surface $GODC$

Now for surface $AFEB$

$$\begin{aligned}\phi_{AFEB} &= \vec{E}.\vec{dA}\\ &= 4000x^2 \times (0.2)^2\\ &= 4000 \times (0.2)^2 \times (0.2)^2\\ &= 6.4\text{ V m} = 640\text{ Vcm}\end{aligned}$$

30. The correct answer is [60].

Given,

Length (l) = 1 m

Area of cross-section (A) = 3×10^{-6} m^2

$T_1 = 210^\circ$C

$T_2 = 160^\circ$C

$Y = 2 \times 10^{11}$ N m^{-2}

$\alpha = 2 \times 10^{-5}$ K^{-1}

From Hook's law,

$$\Rightarrow \quad \frac{F}{A} = \gamma\frac{\Delta l}{l} \Rightarrow F = \gamma = \gamma A\frac{\Delta l}{l}$$

Here the force applied on the rod is equal to weight of attached object.

$$\Rightarrow \quad Mg = Y\frac{A\,\Delta l}{l} \quad \text{...(i)}$$

Putting the value of $\Delta l = l\alpha\Delta T$ in equation (i)

$$\Rightarrow \quad Mg = \frac{YAl\alpha\Delta T}{l}$$

$$\Rightarrow \quad Mg = YA\alpha\Delta T$$

$$\Rightarrow \quad M \times 10 = 2 \times 10^{11} \times 3 \times 10^{-6} \times 2 \times 10^{-5} \times (210 - 160)$$

$$\Rightarrow \quad M \times 10 = 12 \times 50$$

$$\Rightarrow \quad M = 60\text{ kg}$$

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