PART I : PHYSICS

SECTION 1 (Maximum Marks: 15)

- This section contains **FIVE** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories:

Full Marks	: +3	If only the bubble corresponding to the correct option is darkened.
Zero Marks	: 0	If none of the bubbles is darkened.
Negative Marks	: –1	In all other cases.

Q.1 In a historical experiment to determine Planck's constant, a metal surface was irradiated with light of different wavelengths. The emitted photoelectron energies were measured by applying a stopping potential. The relevant data for the wavelength (λ) of incident light and the corresponding stopping potential (V_0) are given below :

λ (μm)	V_0 (Volt)
0.3	2.0
0.4	1.0
0.5	0.4

Given that $c = 3 \times 10^8$ m s^{-1} and $e = 1.6 \times 10^{-19}$ C, Planck's constant (in units of J s) found from such an experiment is

(A) 6.0×10^{-34} (B) 6.4×10^{-34} (C) 6.6×10^{-34} (D) 6.8×10^{-34}

Space for rough work

Answers for the above questions

Ans for Q.1: (B)

Q.2 A uniform wooden stick of mass 1.6 kg and length l rests in an inclined manner on a smooth, vertical wall of height $h(<l)$ such that a small portion of the stick extends beyond the wall. The reaction force of the wall on the stick is perpendicular to the stick. The stick makes an angle of 30° with the wall and the bottom of the stick is on a rough floor. The reaction of the wall on the stick is equal in magnitude to the reaction of the floor on the stick. The ratio h/l and the frictional force f at the bottom of the stick are

($g = 10$ m s^{-2})

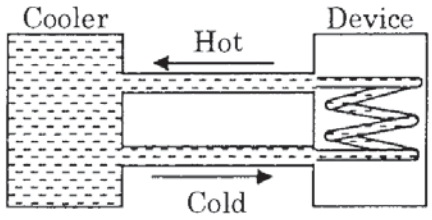
(A) $\frac{h}{l}=\frac{\sqrt{3}}{16}$, $f=\frac{16\sqrt{3}}{3}$N

(B) $\frac{h}{l}=\frac{3}{16}$, $f=\frac{16\sqrt{3}}{3}$N

(C) $\frac{h}{l}=\frac{3\sqrt{3}}{16}$, $f=\frac{8\sqrt{3}}{3}$N

(D) $\frac{h}{l}=\frac{3\sqrt{3}}{16}$, $f=\frac{16\sqrt{3}}{3}$N

Q.3 A water cooler of storage capacity 120 litres can cool water at a constant rate of P watts. In a closed circulation system (as shown schematically in the figure), the water from the cooler is used to cool an external device that generates constantly 3 kW of heat (thermal load). The temperature of water fed into the device cannot exceed 30 °C and the entire stored 120 litres of water is initially cooled to 10 °C. The entire system is thermally insulated. The minimum value of P (in watts) for which the device can be operated for 3 hours is



(Specific heat of water is 4.2 kJ kg^{-1} K^{-1} and the density of water is 1000 kg m^{-3})

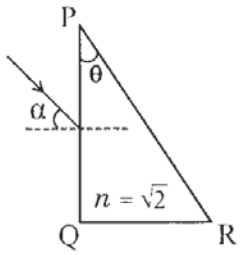
(A) 1600 (B) 2067 (C) 2533 (D) 3933

Space for rough work

Answers for the above questions

Ans for Q.2: (D)	Ans for Q.3: (B)

Q.4 A parallel beam of light is incident from air at an angle α on the side PQ of a right angled triangular prism of refractive index $n=\sqrt{2}$. Light undergoes total internal reflection in the prism at the face PR when α has a minimum value of 45°. The angle θ of the prism is



(A) 15° (B) 22.5° (C) 30° (D) 45°

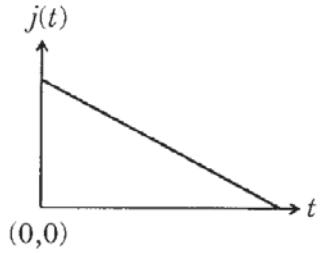
Space for rough work

Answers for the above questions

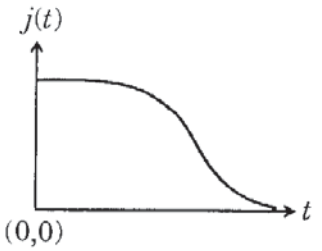
Ans for Q.4: (A)

Q.5 An infinite line charge of uniform electric charge density λ lies along the axis of an electrically conducting infinite cylindrical shell of radius R. At time $t = 0$, the space inside the cylinder is filled with a material of permittivity ε and electrical conductivity σ. The electrical conduction in the material follows Ohm's law. Which one of the following graphs best describes the subsequent variation of the magnitude of current density $j(t)$ at any point in the material?

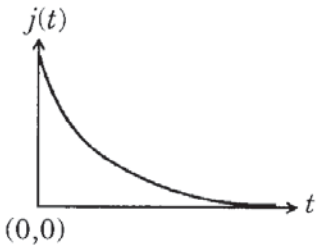
(A)



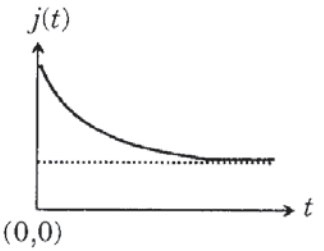
(B)



(C)



(D)



Space for rough work

Answers for the above questions

Ans for Q.5: (C)

SECTION 2 (Maximum Marks: 32)

- This section contains **EIGHT** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct.
- For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS.
- For each question, marks will be awarded in one of the following categories:

Full Marks	: +4	If only the bubble(s) corresponding to all the correct option(s) is(are) darkened.
Partial Marks	: +1	For darkening a bubble corresponding **to each correct option**, provided NO incorrect option is darkened.
Zero Marks	: 0	If none of the bubbles is darkened.
Negative Marks	: –2	In all other cases.

- For example, if (A), (C) and (D) are all the correct options for a question, darkening all these three will result in +4 marks; darkening only (A) and (D) will result in +2 marks; and darkening (A) and (B) will result in –2 marks, as a wrong option is also darkened.

Q.6 Highly excited states for hydrogen-like atoms (also called Rydberg states) with nuclear charge Ze are defined by their principal quantum number n, where $n \gg 1$. Which of the following statement(s) is(are) true?

(A) Relative change in the radii of two consecutive orbitals does not depend on Z

(B) Relative change in the radii of two consecutive orbitals varies as $1/n$

(C) Relative change in the energy of two consecutive orbitals varies as $1/n^3$

(D) Relative change in the angular momenta of two consecutive orbitals varies as $1/n$

Space for rough work

Answers for the above questions

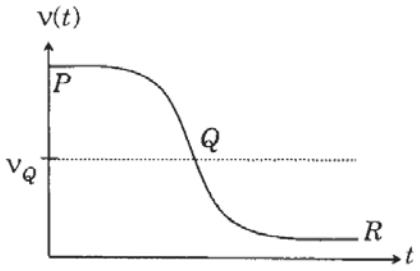
Ans for Q.6: (A), (B), and (D)

Q.7 Two loudspeakers M and N are located 20 m apart and emit sound at frequencies 118 Hz and 121 Hz, respectively. A car is initially at a point P, 1800 m away from the midpoint Q of the line MN and moves towards Q constantly at 60 km/hr along the perpendicular bisector of MN. It crosses Q and eventually reaches a point R, 1800 m away from Q. Let $\nu(t)$ represent the beat frequency measured by a person sitting in the car at time t. Let ν_P, ν_Q and ν_R be the beat frequencies measured at locations P, Q and R, respectively. The speed of sound in air is 330 m s^{-1}. Which of the following statement(s) is(are) true regarding the sound heard by the person?

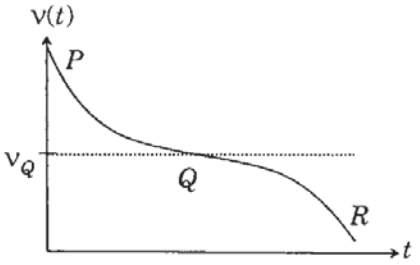
(A) $\nu_P + \nu_R = 2\,\nu_Q$

(B) The rate of change in beat frequency is maximum when the car passes through Q

(C) The plot below represents schematically the variation of beat frequency with time



(D) The plot below represents schematically the variation of beat frequency with time



Space for rough work

Answers for the above questions

Ans for Q.7: (A), (B), and (C)

Q.8 An incandescent bulb has a thin filament of tungsten that is heated to high temperature by passing an electric current. The hot filament emits black-body radiation. The filament is observed to break up at random locations after a sufficiently long time of operation due to non-uniform evaporation of tungsten from the filament. If the bulb is powered at constant voltage, which of the following statement(s) is(are) true?

(A) The temperature distribution over the filament is uniform

(B) The resistance over small sections of the filament decreases with time

(C) The filament emits more light at higher band of frequencies before it breaks up

(D) The filament consumes less electrical power towards the end of the life of the bulb

Q.9 A plano-convex lens is made of a material of refractive index n. When a small object is placed 30 cm away in front of the curved surface of the lens, an image of double the size of the object is produced. Due to reflection from the convex surface of the lens, another faint image is observed at a distance of 10 cm away from the lens. Which of the following statement(s) is(are) true?

(A) The refractive index of the lens is 2.5

(B) The radius of curvature of the convex surface is 45 cm

(C) The faint image is erect and real

(D) The focal length of the lens is 20 cm

Space for rough work

Answers for the above questions

Ans for Q.8: (C) and (D)	Ans for Q.9: (A) and (D)

Q.10 A length-scale (l) depends on the permittivity (ε) of a dielectric material, Boltzmann constant (k_B), the absolute temperature (T), the number per unit volume (n) of certain charged particles, and the charge (q) carried by each of the particles. Which of the following expression(s) for l is(are) dimensionally correct?

(A) $l = \sqrt{\left(\frac{nq^2}{\varepsilon k_B T}\right)}$

(B) $l = \sqrt{\left(\frac{\varepsilon k_B T}{nq^2}\right)}$

(C) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{2/3} k_B T}\right)}$

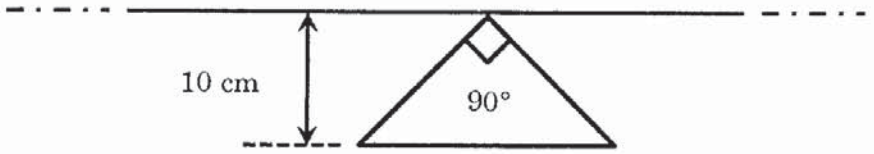
(D) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{1/3} k_B T}\right)}$

Space for rough work

Answers for the above questions

Ans for Q.10: (B) and (D)

Q.11 A conducting loop in the shape of a right angled isosceles triangle of height 10 cm is kept such that the 90° vertex is very close to an infinitely long conducting wire (see the figure). The wire is electrically insulated from the loop. The hypotenuse of the triangle is parallel to the wire. The current in the triangular loop is in counterclockwise direction and increased at a constant rate of 10 $A\,s^{-1}$. Which of the following statement(s) is(are) true?



(A) The magnitude of induced *emf* in the wire is $\left(\frac{\mu_0}{\pi}\right)$ volt

(B) If the loop is rotated at a constant angular speed about the wire, an additional *emf* of $\left(\frac{\mu_0}{\pi}\right)$ volt is induced in the wire

(C) The induced current in the wire is in opposite direction to the current along the hypotenuse

(D) There is a repulsive force between the wire and the loop

Space for rough work

Answers for the above questions

Ans for Q.11: (A) and (D)

Q.12 The position vector $\vec{r}$ of a particle of mass m is given by the following equation

$$\vec{r}(t)=\alpha t^3 \hat{i}+\beta t^2 \hat{j},$$

where $\alpha=10/3$ m s^{-3}, $\beta=5$ m s^{-2} and $m=0.1$ kg. At $t=1$ s, which of the following statement(s) is(are) true about the particle?

(A) The velocity $\vec{v}$ is given by $\vec{v}=(10\hat{i}+10\hat{j})$ m s^{-1}

(B) The angular momentum $\vec{L}$ with respect to the origin is given by $\vec{L}=-(5/3)\hat{k}$ N m s

(C) The force $\vec{F}$ is given by $\vec{F}=(\hat{i}+2\hat{j})$N

(D) The torque $\vec{\tau}$ with respect to the origin is given by $\vec{\tau}=-(20/3)\hat{k}$ N m

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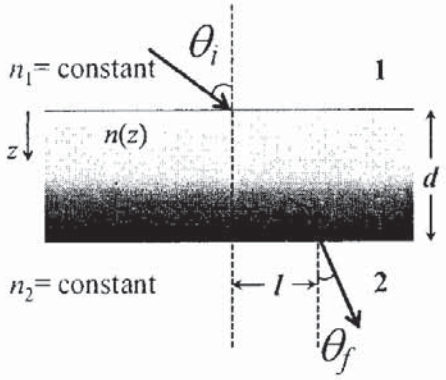
Space for rough work

Answers for the above questions

Ans for Q.12: (A), (B) and (D)

Q.13 A transparent slab of thickness d has a refractive index $n(z)$ that increases with z. Here z is the vertical distance inside the slab, measured from the top. The slab is placed between two media with uniform refractive indices n_1 and $n_2 (> n_1)$, as shown in the figure. A ray of light is incident with angle θ_i from medium 1 and emerges in medium 2 with refraction angle θ_f with a lateral displacement l.



Which of the following statement(s) is(are) true?

(A) $n_1 \sin\theta_i = n_2 \sin\theta_f$

(B) $n_1 \sin\theta_i = (n_2 - n_1)\sin\theta_f$

(C) l is independent of n_2

(D) l is dependent on $n(z)$

Space for rough work

Answers for the above questions

Ans for Q.13: (A), (C) and (D)

SECTION 3 (Maximum Marks: 15)

- This section contains **FIVE** questions.
- The answer to each question is a **SINGLE DIGIT INTEGER** ranging from 0 to 9, both inclusive.
- For each question, darken the bubble corresponding to the correct integer in the ORS.
- For each question, marks will be awarded in one of the following categories:

  Full Marks : +3 If only the bubble corresponding to the correct answer is darkened.

  Zero Marks : 0 In all other cases.

Q.14 A metal is heated in a furnace where a sensor is kept above the metal surface to read the power radiated (P) by the metal. The sensor has a scale that displays $\log_2(P/P_0)$, where P_0 is a constant. When the metal surface is at a temperature of 487 °C, the sensor shows a value 1. Assume that the emissivity of the metallic surface remains constant. What is the value displayed by the sensor when the temperature of the metal surface is raised to 2767 °C?

Q.15 The isotope $^{12}_{5}B$ having a mass 12.014 u undergoes β-decay to $^{12}_{6}C$. $^{12}_{6}C$ has an excited state of the nucleus ($^{12}_{6}C^{*}$) at 4.041 MeV above its ground state. If $^{12}_{5}B$ decays to $^{12}_{6}C^{*}$, the maximum kinetic energy of the β-particle in units of MeV is
(1 u = 931.5 MeV/c^2, where c is the speed of light in vacuum).

Space for rough work

Answers for the above questions

Ans for Q.14: (9)	Ans for Q.15: (8) OR (9)

Q.16 A hydrogen atom in its ground state is irradiated by light of wavelength 970 Å. Taking $hc/e = 1.237 \times 10^{-6}$ eV m and the ground state energy of hydrogen atom as –13.6 eV, the number of lines present in the emission spectrum is

Q.17 Consider two solid spheres P and Q each of density 8 gm cm^{-3} and diameters 1 cm and 0.5 cm, respectively. Sphere P is dropped into a liquid of density 0.8 gm cm^{-3} and viscosity $\eta = 3$ poiseulles. Sphere Q is dropped into a liquid of density 1.6 gm cm^{-3} and viscosity $\eta = 2$ poiseulles. The ratio of the terminal velocities of P and Q is

Q.18 Two inductors L_1 (inductance 1 mH, internal resistance 3 Ω) and L_2 (inductance 2 mH, internal resistance 4 Ω), and a resistor R (resistance 12 Ω) are all connected in parallel across a 5 V battery. The circuit is switched on at time $t = 0$. The ratio of the maximum to the minimum current (I_{max} / I_{min}) drawn from the battery is

END OF PART I : PHYSICS

Space for rough work

Answers for the above questions

Ans for Q.16: (6)	Ans for Q.17: (3)	Ans for Q.18: (8)

PART I : PHYSICS

SECTION 1 (Maximum Marks: 18)

- This section contains **SIX** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories:

Full Marks	:	+3	If only the bubble corresponding to the correct option is darkened.
Zero Marks	:	0	If none of the bubbles is darkened.
Negative Marks	:	–1	In all other cases.

Q.1 The electrostatic energy of Z protons uniformly distributed throughout a spherical nucleus of radius R is given by

$$E=\frac{3}{5}\frac{Z(Z-1)e^2}{4\pi\varepsilon_0 R}$$

The measured masses of the neutron, ${}^{1}_{1}\mathrm{H}$, ${}^{15}_{7}\mathrm{N}$ and ${}^{15}_{8}\mathrm{O}$ are 1.008665 u, 1.007825 u, 15.000109 u and 15.003065 u, respectively. Given that the radii of both the ${}^{15}_{7}\mathrm{N}$ and ${}^{15}_{8}\mathrm{O}$ nuclei are same, 1 u = 931.5 MeV/c^2 (c is the speed of light) and $e^2/(4\pi\varepsilon_0)=1.44$ MeV fm. Assuming that the difference between the binding energies of ${}^{15}_{7}\mathrm{N}$ and ${}^{15}_{8}\mathrm{O}$ is purely due to the electrostatic energy, the radius of either of the nuclei is

(1 fm = 10^{-15} m)

(A) 2.85 fm (B) 3.03 fm (C) 3.42 fm (D) 3.80 fm

Q.2 An accident in a nuclear laboratory resulted in deposition of a certain amount of radioactive material of half-life 18 days inside the laboratory. Tests revealed that the radiation was 64 times more than the permissible level required for safe operation of the laboratory. What is the minimum number of days after which the laboratory can be considered safe for use?

(A) 64 (B) 90 (C) 108 (D) 120

Space for rough work

Answers for the above questions

Ans for Q.1: (C)	Ans for Q.2: (C)

Q.3 A gas is enclosed in a cylinder with a movable frictionless piston. Its initial thermodynamic state at pressure $P_i = 10^5$ Pa and volume $V_i = 10^{-3}$ m^3 changes to a final state at $P_f = (1/32) \times 10^5$ Pa and $V_f = 8 \times 10^{-3}$ m^3 in an adiabatic quasi-static process, such that P^3V^5 = constant. Consider another thermodynamic process that brings the system from the same initial state to the same final state in two steps: an isobaric expansion at P_i followed by an isochoric (isovolumetric) process at volume V_f. The amount of heat supplied to the system in the two-step process is approximately

(A) 112 J (B) 294 J (C) 588 J (D) 813 J

Q.4 The ends Q and R of two thin wires, PQ and RS, are soldered (joined) together. Initially each of the wires has a length of 1 m at 10 °C. Now the end P is maintained at 10 °C, while the end S is heated and maintained at 400 °C. The system is thermally insulated from its surroundings. If the thermal conductivity of wire PQ is twice that of the wire RS and the coefficient of linear thermal expansion of PQ is 1.2×10^{-5} K^{-1}, the change in length of the wire PQ is

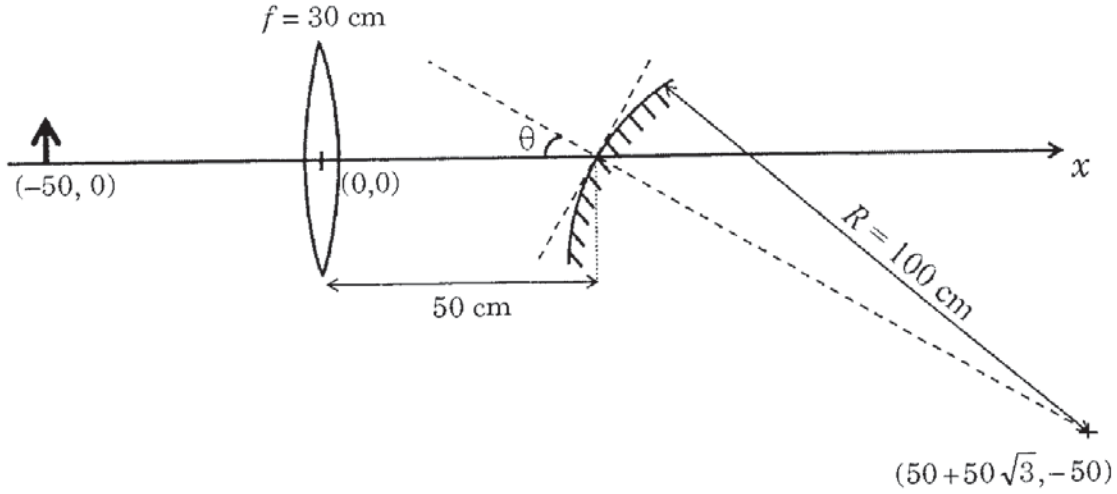
(A) 0.78 mm (B) 0.90 mm (C) 1.56 mm (D) 2.34 mm

Space for rough work

Answers for the above questions

Ans for Q.3: (C)	Ans for Q.4: (A)

Q.5 A small object is placed 50 cm to the left of a thin convex lens of focal length 30 cm. A convex spherical mirror of radius of curvature 100 cm is placed to the right of the lens at a distance of 50 cm. The mirror is tilted such that the axis of the mirror is at an angle $\theta = 30°$ to the axis of the lens, as shown in the figure.



If the origin of the coordinate system is taken to be at the centre of the lens, the coordinates (in cm) of the point (x, y) at which the image is formed are

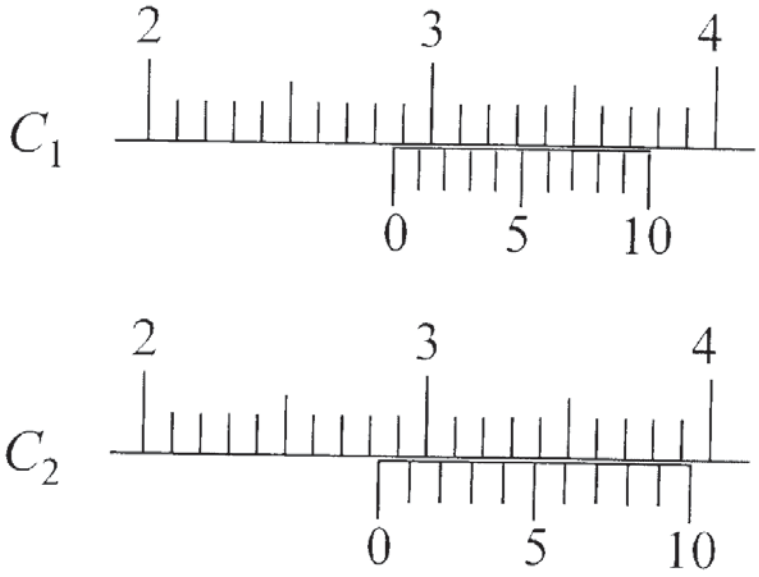
(A) $(0, 0)$ (B) $(50 - 25\sqrt{3}, 25)$ (C) $(25, 25\sqrt{3})$ (D) $(125/3, 25/\sqrt{3})$

Space for rough work

Answers for the above questions

Ans for Q.5: (C)

Q.6 There are two Vernier calipers both of which have 1 cm divided into 10 equal divisions on the main scale. The Vernier scale of one of the calipers (C_1) has 10 equal divisions that correspond to 9 main scale divisions. The Vernier scale of the other caliper (C_2) has 10 equal divisions that correspond to 11 main scale divisions. The readings of the two calipers are shown in the figure. The measured values (in cm) by calipers C_1 and C_2, respectively, are



(A) 2.85 and 2.82 (B) 2.87 and 2.83 (C) 2.87 and 2.86 (D) 2.87 and 2.87

Space for rough work

Answers for the above questions

Ans for Q.6: (B)

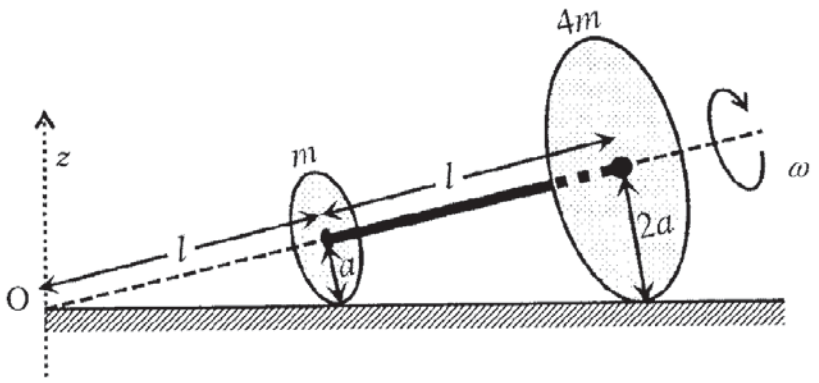
SECTION 2 (Maximum Marks: 32)

- This section contains **EIGHT** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct.
- For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS.
- For each question, marks will be awarded in one of the following categories:

Full Marks	: +4	If only the bubble(s) corresponding to all the correct option(s) is(are) darkened.
Partial Marks	: +1	For darkening a bubble corresponding **to each correct option**, provided NO incorrect option is darkened.
Zero Marks	: 0	If none of the bubbles is darkened.
Negative Marks	: –2	In all other cases.

- For example, if (A), (C) and (D) are all the correct options for a question, darkening all these three will result in +4 marks; darkening only (A) and (D) will result in +2 marks; and darkening (A) and (B) will result in –2 marks, as a wrong option is also darkened.

Q.7 Two thin circular discs of mass m and $4m$, having radii of a and $2a$, respectively, are rigidly fixed by a massless, rigid rod of length $l = \sqrt{24}\,a$ through their centers. This assembly is laid on a firm and flat surface, and set rolling without slipping on the surface so that the angular speed about the axis of the rod is ω. The angular momentum of the entire assembly about the point 'O' is $\vec{L}$ (see the figure). Which of the following statement(s) is(are) true?



(A) The center of mass of the assembly rotates about the z-axis with an angular speed of $\omega/5$

(B) The magnitude of angular momentum of center of mass of the assembly about the point O is $81ma^2\omega$

(C) The magnitude of angular momentum of the assembly about its center of mass is $17ma^2\omega/2$

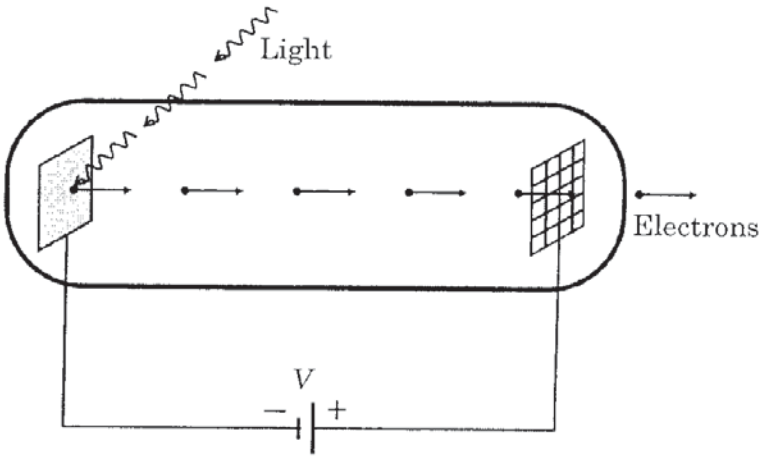
(D) The magnitude of the z-component of $\vec{L}$ is $55ma^2\omega$

Space for rough work

Answers for the above questions

Ans for Q.7: (A) OR (A) and (C)

Q.8 Light of wavelength λ_{ph} falls on a cathode plate inside a vacuum tube as shown in the figure. The work function of the cathode surface is ϕ and the anode is a wire mesh of conducting material kept at a distance d from the cathode. A potential difference V is maintained between the electrodes. If the minimum de Broglie wavelength of the electrons passing through the anode is λ_e, which of the following statement(s) is(are) true?



(A) λ_e decreases with increase in ϕ and λ_{ph}

(B) λ_e is approximately halved, if d is doubled

(C) For large potential difference ($V \gg \phi/e$), λ_e is approximately halved if V is made four times

(D) λ_e increases at the same rate as λ_{ph} for $\lambda_{ph} < hc/\phi$

Space for rough work

Answers for the above questions

Ans for Q.8: (C)

Q.9 In an experiment to determine the acceleration due to gravity g, the formula used for the time period of a periodic motion is $T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$. The values of R and r are measured to be (60 ± 1) mm and (10 ± 1) mm, respectively. In five successive measurements, the time period is found to be 0.52 s, 0.56 s, 0.57 s, 0.54 s and 0.59 s. The least count of the watch used for the measurement of time period is 0.01 s. Which of the following statement(s) is(are) true?

(A) The error in the measurement of r is 10%

(B) The error in the measurement of T is 3.57%

(C) The error in the measurement of T is 2%

(D) The error in the determined value of g is 11%

Q.10 Consider two identical galvanometers and two identical resistors with resistance R. If the internal resistance of the galvanometers $R_C < R/2$, which of the following statement(s) about any one of the galvanometers is(are) true?

(A) The maximum voltage range is obtained when all the components are connected in series

(B) The maximum voltage range is obtained when the two resistors and one galvanometer are connected in series, and the second galvanometer is connected in parallel to the first galvanometer

(C) The maximum current range is obtained when all the components are connected in parallel

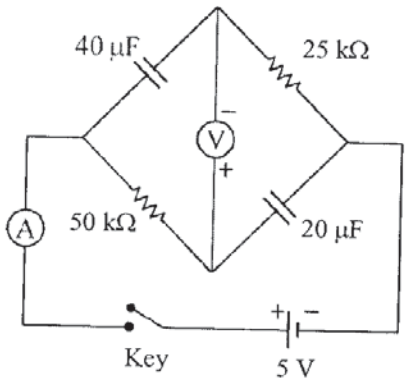
(D) The maximum current range is obtained when the two galvanometers are connected in series and the combination is connected in parallel with both the resistors

Space for rough work

Answers for the above questions

Ans for Q.9: (A), (B) and (D)	Ans for Q.10: (B) and (C)

Q.11 In the circuit shown below, the key is pressed at time $t = 0$. Which of the following statement(s) is(are) true?



(A) The voltmeter displays -5 V as soon as the key is pressed, and displays $+5$ V after a long time

(B) The voltmeter will display 0 V at time $t = \ln 2$ seconds

(C) The current in the ammeter becomes $1/e$ of the initial value after 1 second

(D) The current in the ammeter becomes zero after a long time

Q.12 A block with mass M is connected by a massless spring with stiffness constant k to a rigid wall and moves without friction on a horizontal surface. The block oscillates with small amplitude A about an equilibrium position x_0. Consider two cases: (i) when the block is at x_0; and (ii) when the block is at $x = x_0 + A$. In both the cases, a particle with mass $m (< M)$ is softly placed on the block after which they stick to each other. Which of the following statement(s) is(are) true about the motion after the mass m is placed on the mass M?

(A) The amplitude of oscillation in the first case changes by a factor of $\sqrt{\frac{M}{m+M}}$, whereas in the second case it remains unchanged

(B) The final time period of oscillation in both the cases is same

(C) The total energy decreases in both the cases

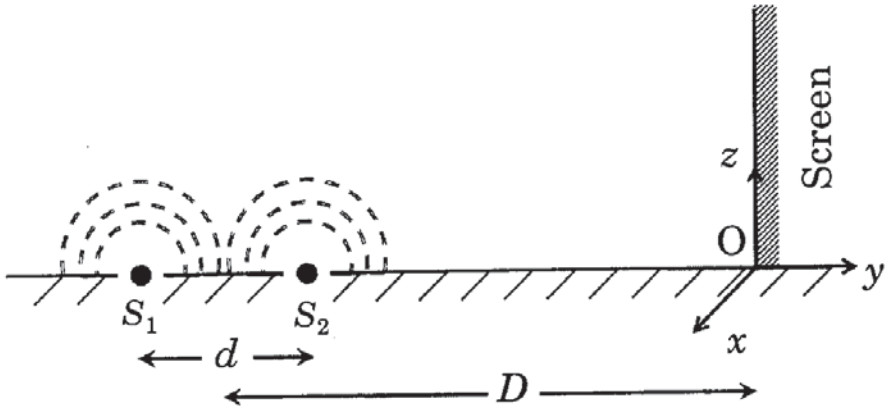
(D) The instantaneous speed at x_0 of the combined masses decreases in both the cases

Space for rough work

Answers for the above questions

Ans for Q.11: (A), (B), (C) and (D)	Ans for Q.12: (A), (B) and (D)

Q.13 While conducting the Young's double slit experiment, a student replaced the two slits with a large opaque plate in the x-y plane containing two small holes that act as two coherent point sources (S_1, S_2) emitting light of wavelength 600 nm. The student mistakenly placed the screen parallel to the x-z plane (for $z > 0$) at a distance $D = 3$ m from the mid-point of S_1S_2, as shown schematically in the figure. The distance between the sources $d = 0.6003$ mm. The origin O is at the intersection of the screen and the line joining S_1S_2. Which of the following is(are) true of the intensity pattern on the screen?



(A) Straight bright and dark bands parallel to the x-axis

(B) The region very close to the point O will be dark

(C) Hyperbolic bright and dark bands with foci symmetrically placed about O in the x-direction

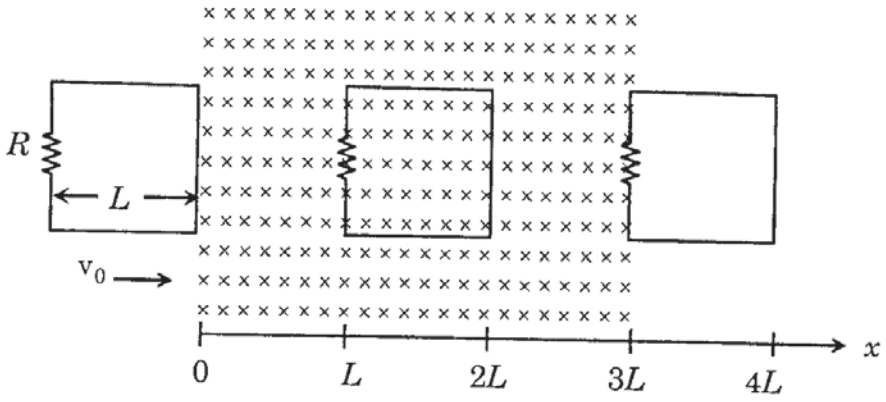
(D) Semi circular bright and dark bands centered at point O

Space for rough work

Answers for the above questions

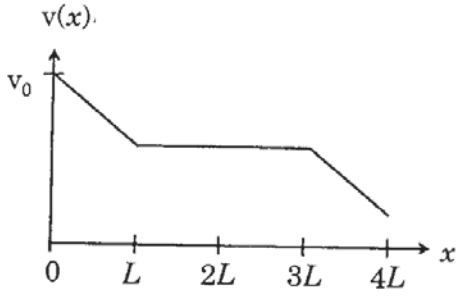
Ans for Q.13: (B) and (D)

Q.14 A rigid wire loop of square shape having side of length L and resistance R is moving along the x-axis with a constant velocity v_0 in the plane of the paper. At $t = 0$, the right edge of the loop enters a region of length $3L$ where there is a uniform magnetic field B_0 into the plane of the paper, as shown in the figure. For sufficiently large v_0, the loop eventually crosses the region. Let x be the location of the right edge of the loop. Let $v(x)$, $I(x)$ and $F(x)$ represent the velocity of the loop, current in the loop, and force on the loop, respectively, as a function of x. Counter-clockwise current is taken as positive.

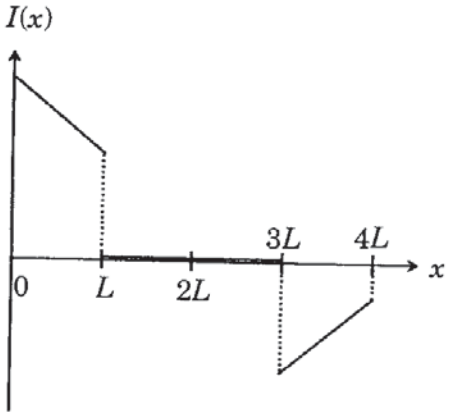


Which of the following schematic plot(s) is(are) correct? (Ignore gravity)

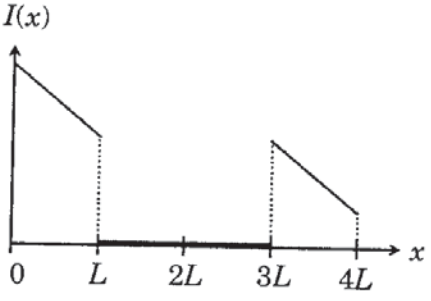
(A)



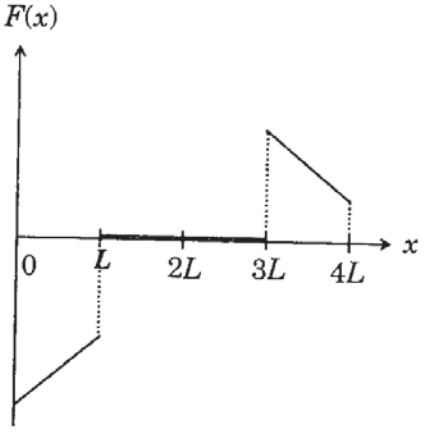
(B)



(C)



(D)



Space for rough work

Answers for the above questions

Ans for Q.14: (A) and (B)

SECTION 3 (Maximum Marks: 12)

- This section contains **TWO** paragraphs.
- Based on each paragraph, there are **TWO** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories:

  Full Marks : +3 If only the bubble corresponding to the correct option is darkened.

  Zero Marks : 0 In all other cases.

Space for rough work

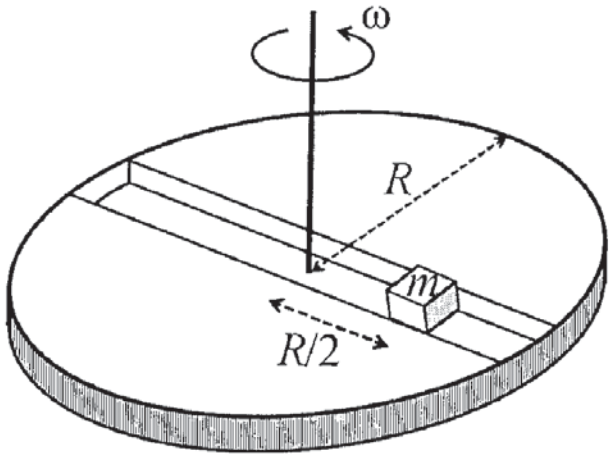
PARAGRAPH 1

A frame of reference that is accelerated with respect to an inertial frame of reference is called a non-inertial frame of reference. A coordinate system fixed on a circular disc rotating about a fixed axis with a constant angular velocity ω is an example of a non-inertial frame of reference. The relationship between the force $\vec{F}_{\text{rot}}$ experienced by a particle of mass m moving on the rotating disc and the force $\vec{F}_{\text{in}}$ experienced by the particle in an inertial frame of reference is

$$\vec{F}_{\text{rot}} = \vec{F}_{\text{in}} + 2m(\vec{v}_{\text{rot}} \times \vec{\omega}) + m(\vec{\omega} \times \vec{r}) \times \vec{\omega},$$

where $\vec{v}_{\text{rot}}$ is the velocity of the particle in the rotating frame of reference and $\vec{r}$ is the position vector of the particle with respect to the centre of the disc.

Now consider a smooth slot along a diameter of a disc of radius R rotating counter-clockwise with a constant angular speed ω about its vertical axis through its center. We assign a coordinate system with the origin at the center of the disc, the x-axis along the slot, the y-axis perpendicular to the slot and the z-axis along the rotation axis ($\vec{\omega} = \omega\hat{k}$). A small block of mass m is gently placed in the slot at $\vec{r} = (R/2)\hat{i}$ at $t = 0$ and is constrained to move only along the slot.



Q.15 The distance r of the block at time t is

(A) $\frac{R}{4}(e^{\omega t} + e^{-\omega t})$ (B) $\frac{R}{2}\cos\omega t$ (C) $\frac{R}{4}(e^{2\omega t} + e^{-2\omega t})$ (D) $\frac{R}{2}\cos 2\omega t$

Q.16 The net reaction of the disc on the block is

(A) $\frac{1}{2}m\omega^2 R(e^{2\omega t} - e^{-2\omega t})\hat{j} + mg\hat{k}$ (B) $\frac{1}{2}m\omega^2 R(e^{\omega t} - e^{-\omega t})\hat{j} + mg\hat{k}$

(C) $-m\omega^2 R\cos\omega t\,\hat{j} - mg\hat{k}$ (D) $m\omega^2 R\sin\omega t\,\hat{j} - mg\hat{k}$

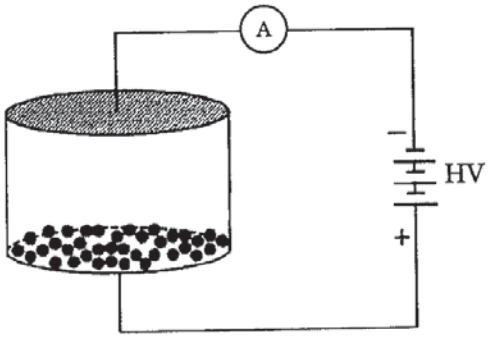
Space for rough work

Answers for the above questions

Ans for Q.15: (A)	Ans for Q.16: (B)

PARAGRAPH 2

Consider an evacuated cylindrical chamber of height h having rigid conducting plates at the ends and an insulating curved surface as shown in the figure. A number of spherical balls made of a light weight and soft material and coated with a conducting material are placed on the bottom plate. The balls have a radius $r \ll h$. Now a high voltage source (HV) is connected across the conducting plates such that the bottom plate is at $+V_0$ and the top plate at $-V_0$. Due to their conducting surface, the balls will get charged, will become equipotential with the plate and are repelled by it. The balls will eventually collide with the top plate, where the coefficient of restitution can be taken to be zero due to the soft nature of the material of the balls. The electric field in the chamber can be considered to be that of a parallel plate capacitor. Assume that there are no collisions between the balls and the interaction between them is negligible. (Ignore gravity)



Q.17 Which one of the following statements is correct?

(A) The balls will stick to the top plate and remain there

(B) The balls will bounce back to the bottom plate carrying the same charge they went up with

(C) The balls will bounce back to the bottom plate carrying the opposite charge they went up with

(D) The balls will execute simple harmonic motion between the two plates

Q.18 The average current in the steady state registered by the ammeter in the circuit will be

(A) zero

(B) proportional to the potential V_0

(C) proportional to $V_0^{1/2}$

(D) proportional to V_0^2

END OF PART I : PHYSICS

Space for rough work

Answers for the above questions

Ans for Q.17: (C)	Ans for Q.18: (D)