

IIT-JEE-Physics-1997

Time : Three hour

Max. Marks : 100

Instructions

1. Answer all question in the languages of your choice as shown in your admit card.
2. The paper consists of eight printed pages (16 questions).
3. Answer to next question should start after drawing a separating horizontal line with a space of 3 cm.
4. All sub-question should be answered at one place in the same order as in the question paper.
5. There is no negative marking.
6. Use of calculators is prohibited.
7. Use of Logarithmic Tables is permitted.

Useful Data :

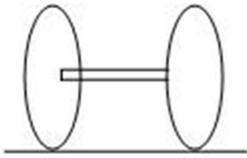
acceleration due to gravity $g=9.8 \text{ m/s}^2$
Velocity of light in vacuum $c=3.0 \times 10^8 \text{ m/s}$
Planck's constant $h=6.63 \times 10^{-34} \text{ J s}$
Mass of electron $m_e=9.1 \times 10^{-31} \text{ kg}$
Electronic charge $e=1.6 \times 10^{-19} \text{ C}$
Electron binding energy in H atom = 13.6 eV
1 eV = $1.6 \times 10^{-19} \text{ J}$

1. A cart is moving along x direction with a velocity of 4 m/s. A person on the cart throws a stone with a velocity of 6 m/s relative to himself. In the frame of reference of the cart the stone is thrown in y-z plane making an angle of 30° with vertical z axis. At the highest point of its trajectory the stone hits an object of equal mass hung vertically from branch of a tree by means of a string of length L. A completely inelastic collision occurs in which the stone gets embedded in the object. Determine :
 - (i) The speed of the combined mass immediately after the collision with respect to an observer on the ground.
 - (ii) The length L of the string such that the tension in the string becomes zero when the string becomes horizontal during the subsequent motion of the combined mass.
2. Two blocks of mass $m_1 = 10 \text{ Kg}$ and $m_2 = 5 \text{ Kg}$ connected to each other by a massless inextensible string of length 0.3 m are placed along a diameter of turn table. The coefficient of friction between the table and m_1 is 0.5 while there is no friction between m_2 and the table. The table is rotating with an angular velocity of 10 rad/s about a vertical axis passing through its centre O. The masses are placed along the diameter of the table on either side of the centre O such that the mass m_1 is at a distant of 0.124 m from O. The masses are observed to be at rest with respect to an observer on the turn table.
 - (i) Calculate the frictional force on m_1 .
 - (ii) What should be the minimum angular speed of the turn table so that the masses will slip from this position.
 - (iii) How should the masses be placed with the string remaining taut so that there is no frictional force acting on the mass m_1 .
3. Two thin circular discs of mass 2 Kg and radius 10 cm each are joined by a rigid massless rod of length 20 cm. The axis of the rod is along the perpendicular to the planes of the disk through their centres. This object is kept on a truck in such a way that the axis of the object is horizontal and perpendicular to the direction of motion of the truck. Its friction with the floor of the truck is large enough so that the object can roll on the truck without slipping.

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Take x-axis as the direction of motion of the truck and z-axis as the vertically upwards direction. If the truck has an acceleration 9 m/s^2 , calculate:

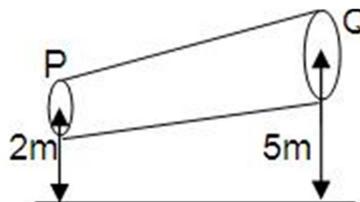


- (i) the force of friction on each disk.
- (ii) the magnitude and direction of the frictional torque acting on each disk about the centre of mass O of the object. Express the torque in the vector form in terms of unit vectors i , j and k in x , y and z directions.

4. In the following column I lists some physical quantities and the column II gives approximate energy of them. Choose the appropriate value of energy from column II for each of the physical quantities in column I and write the corresponding letters A, B, C etc. against the number (i), (ii) and (iii) etc. of the physical quantity. In the answer books in your answer the sequence of column I should be maintained.

Column I	Column II
(i) Energy of thermal neutron	(A) 0.025 eV
(ii) Energy of X-Ray	(B) 0.5 eV
(iii) Binding energy per nucleon	(C) 3 eV
(iv) Photoelectric threshold of a metal	(D) 20 eV
	(E) 10 keV
	(F) 8 MeV

5. A non viscous liquid of constant density 1000 Kg/m^3 flows in a streamline motion along a tube of variable cross section. The tube is kept inclined in the vertical plane as shown in the figure. The area of cross-section of the tube at two points P and Q at heights of 2 meters and 5 meters are respectively $4 \times 10^{-3} \text{ m}^2$ and $8 \times 10^{-3} \text{ m}^2$. The velocity of the liquid at point P is 1 m/s . Find the work done per unit volume by the pressure and the gravity forces as the fluid flows from point P to Q.

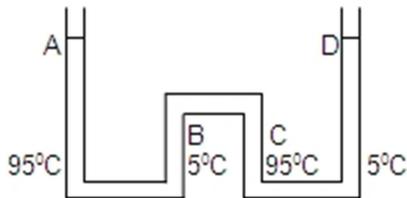


6. A band playing music at a frequency f is moving towards a wall at a speed V_b . A motorist

is following the band with a speed V_m . If V is the speed of sound, obtain an expression for the beat frequency heard by the motorist.

7. One mole of a diatomic ideal gas ($\gamma = 1.4$) is taken through a cyclic process starting from point A. The process A→B is an adiabatic compression. B→C is isobaric expansion, C→D an adiabatic expansion and D→A is isochoric. The volume ratios are $V_A/V_B = 16$ and $V_C/V_D = 2$ and the temperature at A is $T_A = 300$ K. Calculate the temperature of the gas at the point B and D and find the efficiency of the cycle.

8. The apparatus shown in figure consists of four glass columns connected by horizontal sections. The height of two central column B and C are 49 cm. each. The two outer columns A and D are open to the atmosphere. A and C are maintained at a temperature of 95°C while the columns B and D are maintained at 5°C. The height of the liquid in A and D measured from the base line are 52.8 cm and 51 cm respectively. Determine the coefficient of thermal expansion of the liquid.



9. In each sub-section of this question, FOUR alternatives are given of which only ONE alternative is correct/best answer. Select the correct/best alternative and write down the corresponding letter A, B, C or D in your answer book against the sub-question number. In your answers, the sequence of the sub-question should be the same as given in the question paper.

(i) The average translational kinetic energy of O_2 (molar mass 32) molecules at a particular temperature is 0.048 eV. The translational kinetic energy of N_2 (molar mass 28) molecules in eV at the same temperature is:

- (A) 0.0015 (B) 0.003
(C) 0.048 (D) 0.768

(ii) A vessel contained 1 mole of O_2 gas (molar mass 32) at a temperature T . The pressure of the gas is P . An identical vessel containing one mole of the gas (molar mass 4) at a temperature $2T$ has a pressure of:

- (A) $P/8$ (B) P
(C) $2P$ (D) $8P$

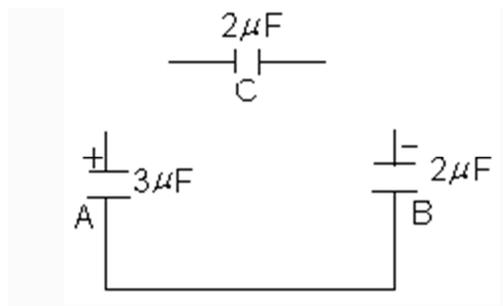
(iii) A proton, a deuteron and an α -particle having the same kinetic energy are moving in circular trajectories in a constant magnetic field. If r_p , r_d and r_α denote respectively the

energy 6 e fall on it is 4 eV. The stopping potential in volts is:

- (A) 2 (B) 4
(C) 6 (D) 10

10. Two capacitors A and B with capacities 3mF and 2mF are charged to a potential difference of 100V and 180V respectively. The plates of the capacitors are connected as shown in the figure with one wire of each capacitor free. The upper plate of A is positive and that of B is negative. An uncharged 2mF capacitor C with lead wires falls on the free ends to complete the circuit. Calculate:

- (i) the final charge on the three capacitors, and
(ii) the amount of electrostatic energy stored in the system before and after completion of the circuit.



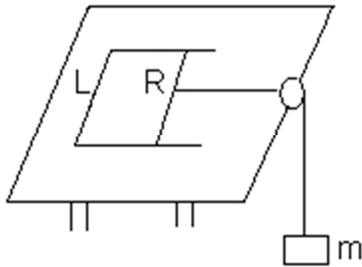
11. Three infinitely long thin wires, each carrying current i in the same direction are in the x - y plane of a gravity free space. The central wire is along the y -axis while the other two are along $x = \pm d$.

- (i) Find the locus of the points for which the magnetic field B is zero.
(ii) If the central wire is displaced along the z direction by a small amount and released, show that it will execute simple harmonic motion. If the linear density of the wires is l , find the frequency of oscillation.

12. A pair of parallel horizontal conducting rails of negligible resistance shorted at one end is fixed on a table. The distance between the rails is L . A conducting massless rod of resistance R can slide on the rails frictionlessly. The rod is tied to a massless string which passes over a pulley fixed to the edge of the table. A mass m tied to the other end of the string hangs vertically. A constant magnetic field B exists perpendicular to the table. If the system is released from rest, calculate:

- (i) the terminal velocity achieved by the rod, and

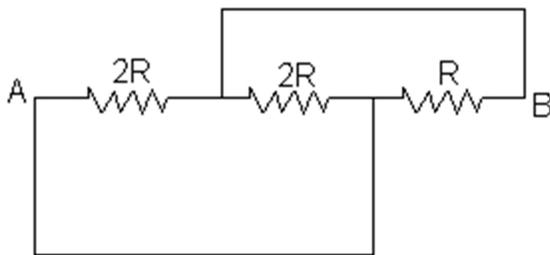
(ii) the acceleration of the mass at the instant when the velocity of the rod is half the terminal velocity.



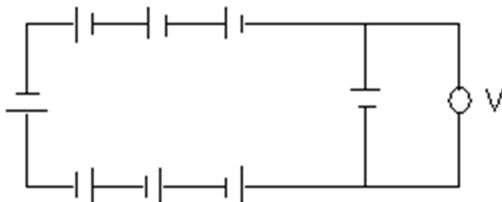
13. Fill in the blanks in the following. In your answer book, write down the sub-question number (i), (ii) etc. and your answer(s) against it corresponding to each blank. Do not write the full statement. Your answer should be in the same sequence as given in the question paper.

(i) A rod of weight W is supported by two parallel knife edges A and B and in equilibrium in a horizontal position. The knives are at a distance d from each other. The centre of mass of the rod is at distance x from A . The normal reaction on A is and on B is

(ii) The equivalent resistance between points A and B of the circuit given below is



(iii) In the circuit shown alongside, each battery is $5V$ and has an internal resistance 0.2 ohm. The reading in the ideal voltmeter V is V .



(iv) A light of wavelength 6000\AA in air, enters a medium with refractive index 1.5. Inside the medium its frequency is Hz and its wavelength is A.

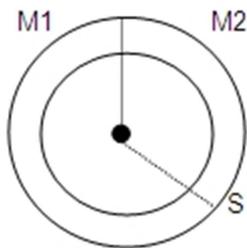
(v) Two thin lenses, when in contact, produce a combination of power +10 dioptres. When they are 0.25 m apart, the power reduces to + 6 dioptres. The focal length of the lenses are ... m and m.

(vi) The equation of state of a real gas is given by—

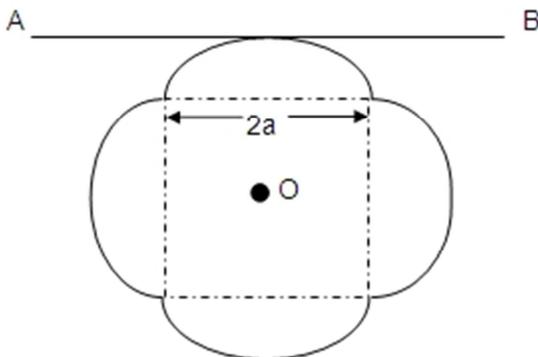
$$(P + a/V^2) (V - b) = RT$$

where P , V and T are pressure, volume and temperature respectively and R is the universal gas constant. The dimensions of the constant a in the above equation is

(vii) A ring shaped tube contains two ideal gases with equal masses and molar masses $M_1 = 32$ and $M_2 = 28$. The gases are separated by one fixed partition and another movable stopper S which can move freely without friction inside the ring. The angle α as shown in the figure is degrees.



(viii) A symmetric lamina of mass M consists of a square shape with a semicircular section over each of the edge of the square as shown in figure. The side of the square is $2a$. The moment of inertia of the lamina about an axis through its centre of mass and perpendicular to the plane is $1.6 Ma^2$. The moment of inertia of the lamina about the tangent AB in the plane of the lamina is



(ix) A particle is projected vertically upward from the surface of earth (radius R) with kinetic energy equal to half of the minimum value needed for it to escape. The height to which it rises above the surface of earth is

(x) Earth received 1400W/m^2 of solar power. If all the solar energy falling on a lens of area 0.2 m^2 is focused onto a block of ice of mass 280 grams, the time taken to melt the ice will be Minute. (latent heat of fusion of ice = $3.3 \times 10^5\text{ J/kg}$).

(xi) A ray of light is incident normally on one of the face of a prism of apex angle 30° and refractive index $\sqrt{2}$. The angle of deviation of the ray is degree.

14. In a Young's experiment, the upper slit is covered by a thin glass plate of refractive index 1.4, while the lower slit is covered by another glass plate, having the same thickness as the first one but having refractive 1.7. Interference pattern is observed using light of wavelength 5400Å . It is found that the point P on the screen, where the central maximum ($n=0$) fall before the glass plates were inserted, now has $3/4$ the original intensity. It is further observed that what used to be the fifth maximum earlier lies below the point P while the sixth minima lies above P. Calculate the thickness of glass plate. (Absorption of light by glass plate may be neglected).

15. Assume that the de Broglie wave associated with an electron can form a standing wave between the atoms arranged in a one dimensional array with nodes at each of the atomic sites. It is found that one such standing wave is formed if the distance d between the atoms of the array is 2λ . A similar standing wave is again formed if d is increased to 2.5λ but not for any intermediate value of d . Find the energy of the electron in eV and the least value of d for which the standing wave of the type described above can form.

16. The element curium $^{248}_{96}\text{Cm}$ has a mean life of 1013 seconds. Its primary decay modes are spontaneous fission and α -decay, the former with a probability of 8% and the latter with a probability of 92%. Each fission releases 200 MeV of energy. The masses involved in decay are as follows: $^{248}_{96}\text{Cm} = 248.072220\text{ u}$, $^{244}_{94}\text{Pu} = 244.064100\text{ u}$ and $^4_2\text{He} = 4.002603\text{u}$, Calculate the power output from a sample of 10^{20} Cm atoms. ($1\text{u} = 931\text{MeV}/c^2$)