

## IIT-JEE-1999

### PHYSICS

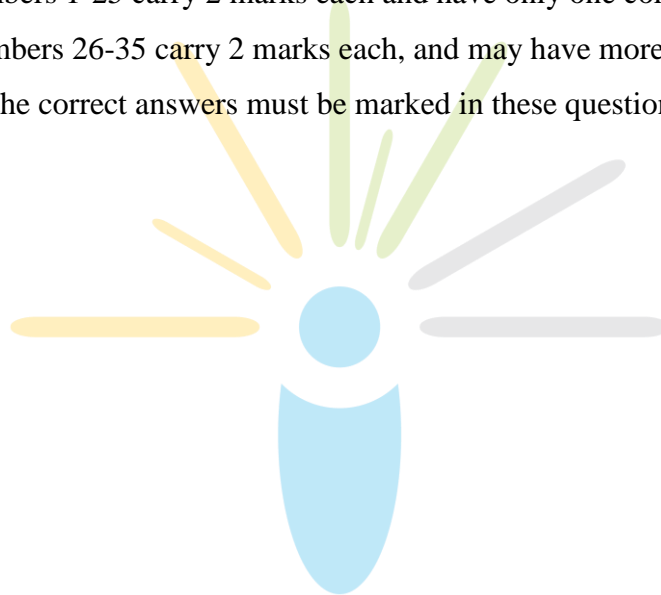
[Time allowed: 3 hours] [Maximum Marks: 200]

#### General Instructions :

1. Do not break the seal of the question paper before you are instructed to do so by the invigilator.
2. This question paper is in two sections. Section I has 35 objective type questions. Section II has 12 regular questions.
3. Answer Section I only the special machine-graded OBJECTIVE RESPONSE SHEET (ORS) that is inserted in this booklet. Questions of Section I will not be graded if answered anywhere else.
4. Answer problems of Section II in the answer-book.
5. Without breaking the seal of this booklet, take out the Response Sheet (ORS) for Section I. Make sure that the ORS has the SAME QUESTIONPAPER CODE, printed on its as on the top of this page.
6. Write your name, registration number and name of the Centre at the specified locations on the right half of the ORS for Section I.
7. Using a soft HB pencil darken the appropriate bubble under each digit of your registration number.
8. The Objective Response Sheet will be collected back after 75 minutes have expired from the start of the examination. In case you finish Section I before the expiry of 75 minutes, you may start answering Section II.

## **INSTRUCTIONS FOR SECTION I**

1. Questions are to answered by darkening with a soft HB pencil the appropriate bubble (marked A, B, C and D) against the question number on the left-hand side of the Objective Response Sheet.
2. In case you wish to change an answer, erase the old answer completely using a good soft eraser.
3. The answer sheet will be collected back after 75 minutes from the start of the examination.
4. There is no negative marking.
5. Question numbers 1-25 carry 2 marks each and have only one correct answer.
6. Question Numbers 26-35 carry 2 marks each, and may have more than one correct answers. All the correct answers must be marked in these questions to get any credit.



**SECTION I**

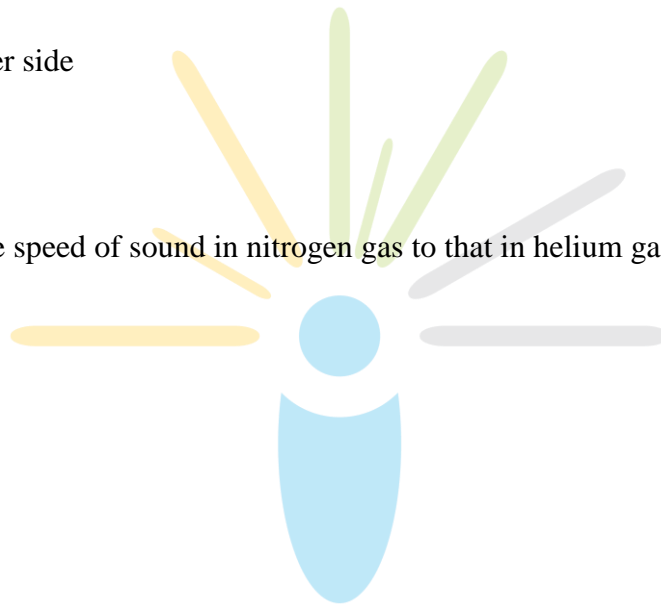
**Directions** — Select the most appropriate alternative a, b, c or d in question 1–25.

1. A closed compartment containing gas is moving with some acceleration in horizontal direction. Neglect effect of gravity. Then the pressure in the compartment is:

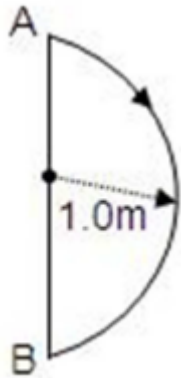
- (A) same everywhere
- (B) lower in front side
- (C) lower in rear side
- (D) lower in upper side

2. The ratio of the speed of sound in nitrogen gas to that in helium gas at 300K is:

- (A)  $\sqrt{2/7}$
- (B)  $\sqrt{1/7}$
- (C)  $\sqrt{3/5}$
- (D)  $\sqrt{6/5}$

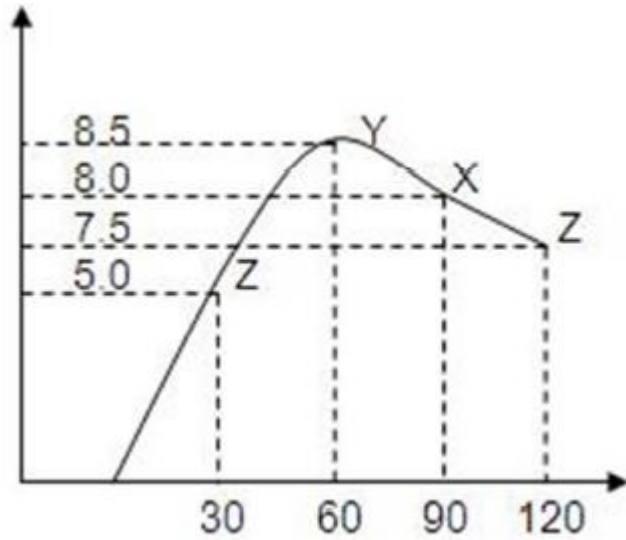


3. In  $1.0\text{S}$ , a particle goes from point  $A$  to point  $B$ , moving in a semicircle (see figure). The magnitude of the average velocity is:



- (A)  $3.14\text{m/s}$
- (B)  $2.0\text{m/s}$
- (C)  $1.0\text{m/s}$
- (D) zero
4. A charged particle is released from rest in a region of steady and uniform electric and magnetic fields which are parallel to each other. The particle will move in a :
- (A) straight line
- (B) circle
- (C) helix
- (D) cycloid

5. Binding energy per nucleon Vs mass number curve for nuclei is shown in figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is:



- (A)  $Y \rightarrow 2Z$
- (B)  $W \rightarrow X + Z$
- (C)  $W \rightarrow 2Y$
- (D)  $X \rightarrow Y + Z$

6. Order of magnitude of density of uranium nucleus is ( $m_p = 1.67 \times 10^{-27} \text{ kg}$ ):

- (A)  $10^{20} \text{ kg/m}^3$
- (B)  $10^{17} \text{ kg/m}^3$
- (C)  $10^{14} \text{ kg/m}^3$
- (D)  $10^{11} \text{ kg/m}^3$

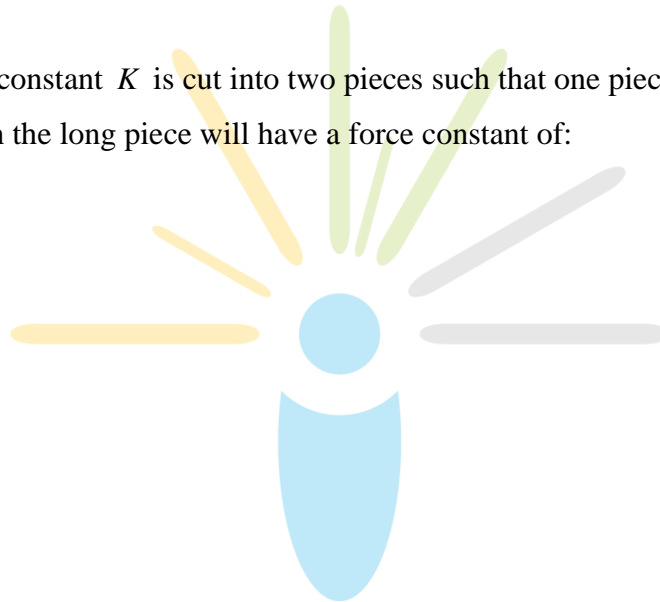
7. Two identical circular loops of metal wire are lying on a table without touching each other.

Loop  $A$  carries a current which increases with time. In response, the loop  $B$  :

- (A) remains stationary
- (B) is attracted by the loop  $A$
- (C) is repelled by the loop  $A$
- (D) rotates about its  $CM$  , with  $CM$  fixed

8. A spring of force constant  $K$  is cut into two pieces such that one piece is double the length of the other. Then the long piece will have a force constant of:

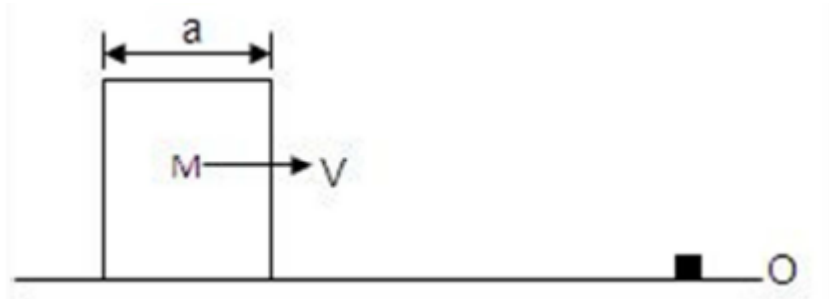
- (A)  $\frac{2}{3} K$
- (B)  $\frac{3}{2} K$
- (C)  $3 K$
- (D)  $6 K$



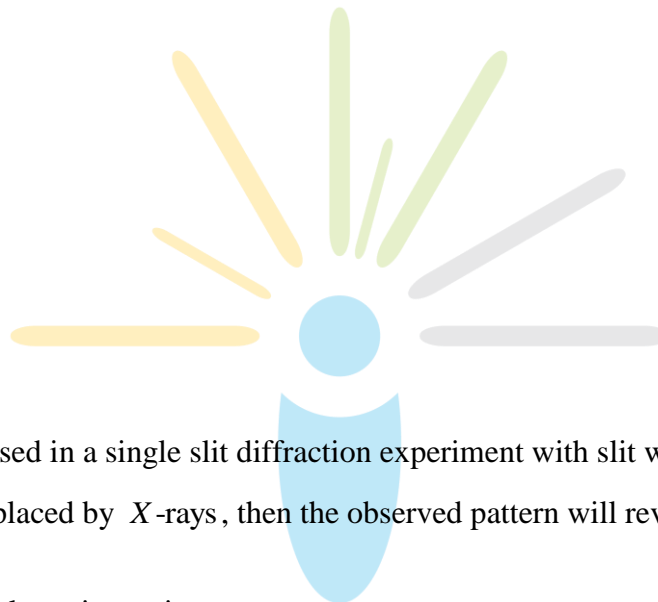
9.  $^{22}\text{Ne}$  nucleus, after absorbing energy, decays into two  $\alpha$ - particles and an unknown nucleus. The unknown nucleus is:

- (A) nitrogen
- (B) carbon
- (C) boron
- (D) oxygen

10. A cubical block of side  $a$  moving with velocity  $V$  on a horizontal smooth plane as shown. It hits a ridge at point  $O$ . The angular speed of the block after it hits  $O$  is:



- (A)  $3V/4a$
- (B)  $3V/2a$
- (C)  $\sqrt{3}V/\sqrt{2}a$
- (D) zero



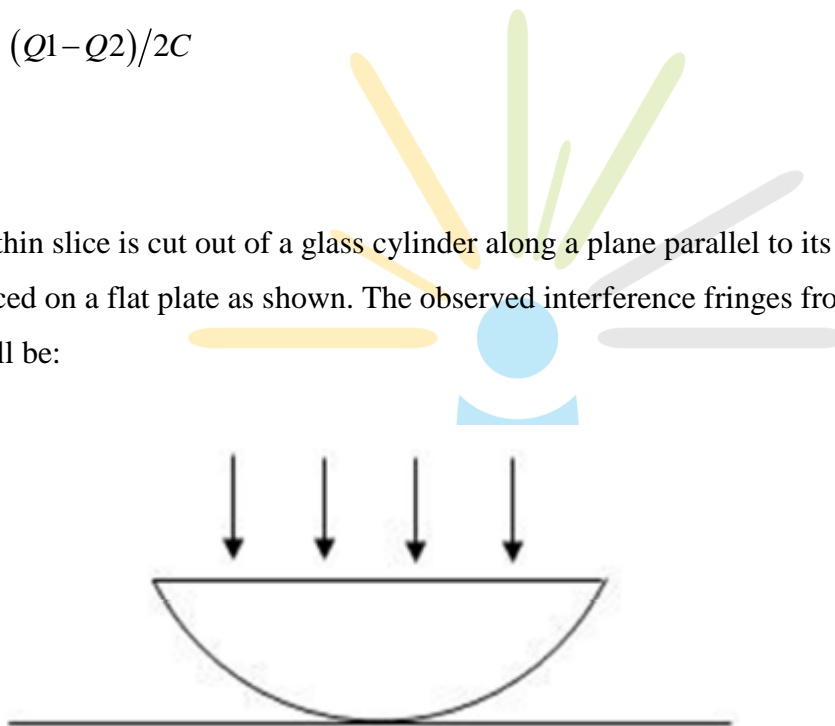
11. Yellow light is used in a single slit diffraction experiment with slit width of  $0.6\text{ mm}$ . If yellow light is replaced by  $X$ -rays, then the observed pattern will reveal:

- (A) that the central maximum is narrower
- (B) more number of fringes
- (C) less number of fringes
- (D) no diffraction pattern

12. Two identical metal plates are given positive charges  $Q_1$  and  $Q_2$  ( $< Q_1$ ) respectively. If they are now brought close together to form a parallel plate capacitor with capacitance  $C$ , the potential difference between them is:

- (A)  $(Q_1 + Q_2)/2C$
- (B)  $(Q_1 + Q_2)/C$
- (C)  $(Q_1 - Q_2)/C$
- (D)  $(Q_1 - Q_2)/2C$

13. A thin slice is cut out of a glass cylinder along a plane parallel to its axis. The slice is placed on a flat plate as shown. The observed interference fringes from this combination shall be:



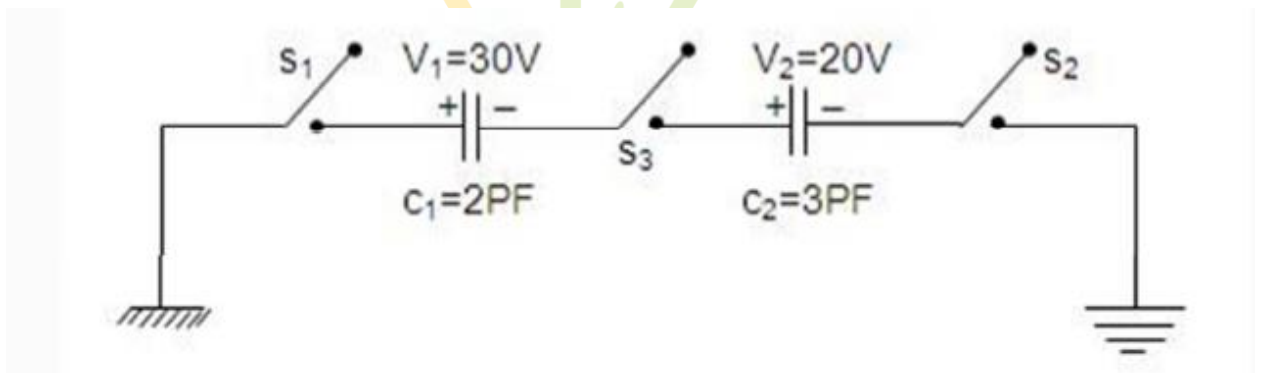
- (A) straight
- (B) circular
- (C) equally spaced
- (D) having fringe spacing which increases as we go outwards.



14. A coil of inductance  $8.4\text{mH}$  and resistance  $6\Omega$  is connected to a  $12\text{V}$  battery. The current in the coil is  $1.0\text{A}$  at approximately the time:

- (A)  $500\text{ s}$
- (B)  $20\text{ s}$
- (C)  $35\text{ ms}$
- (D)  $1\text{ ms}$

15. For the circuit shown, which of the following statements is true:



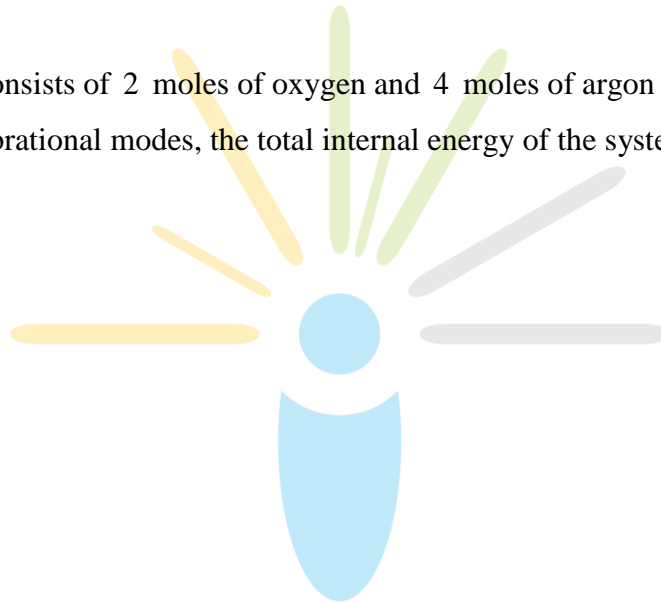
- (A) With  $S_1$  closed,  $V_1 = 15\text{V}$ ,  $V_2 = 20\text{V}$
- (B) With  $S_3$  closed,  $V_1 = V_2 = 25\text{V}$
- (C) With  $S_1$  and  $S_2$  closed,  $V_1 = V_2 = 0$
- (D) With  $S_1$  and  $S_3$  closed,  $V_1 = 30\text{V}$ ,  $V_2 = 20\text{V}$

16. A concave lens of glass, refractive index 1.5 has both surface of same radius of curvature  $R$ . On immersion in a medium of refractive index 1.75, it will behave as a:

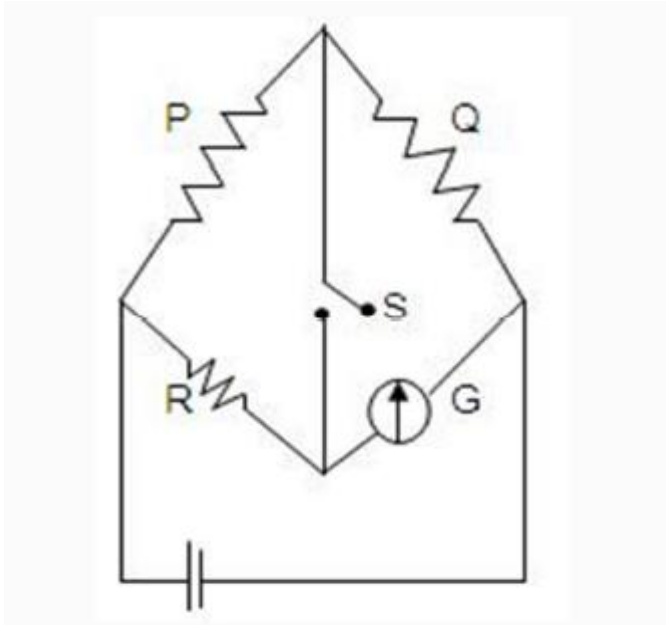
- (A) convergent lens of focal length  $3.5 R$
- (B) convergent lens of focal length  $3.0 R$
- (C) divergent lens of focal length  $3.5 R$
- (D) divergent lens of focal length  $3.0 R$

17. A gas mixture consists of 2 moles of oxygen and 4 moles of argon at temperature  $T$ . Neglecting all vibrational modes, the total internal energy of the system is:

- (A)  $4 RT$
- (B)  $15 RT$
- (C)  $9 RT$
- (D)  $11 RT$



18. In the circuit shown  $P^1R$ , the reading of galvanometer is same with switch  $S$  open or closed. Then:



- (A)  $IR = IG$
- (B)  $IP = IG$
- (C)  $IQ = IG$
- (D)  $IQ = IR$

19. A smooth sphere  $A$  is moving on a frictionless horizontal plane with angular velocity  $w$  and centre of mass velocity  $v$ . It collides elastically and head on with an identical sphere  $B$  at rest. Neglect friction everywhere. After the collision, their angular speeds are  $w_A$  and  $w_B$  respectively. Then:

(A)  $w_A < w_B$

(B)  $w_A = w_B$

(C)  $w_A = < w$

(D)  $w_B = w$

20. In hydrogen spectrum the wavelength of  $H\alpha$  line is  $656\text{ nm}$ ; whereas in the spectrum of a distant galaxy  $H\alpha$  line wavelength is  $706\text{ nm}$ . Estimated speed of galaxy with respect to earth is:

(A)  $2 \times 10^8\text{ m/s}$

(B)  $2 \times 10^7\text{ m/s}$

(C)  $2 \times 10^6\text{ m/s}$

(D)  $2 \times 10^5\text{ m/s}$

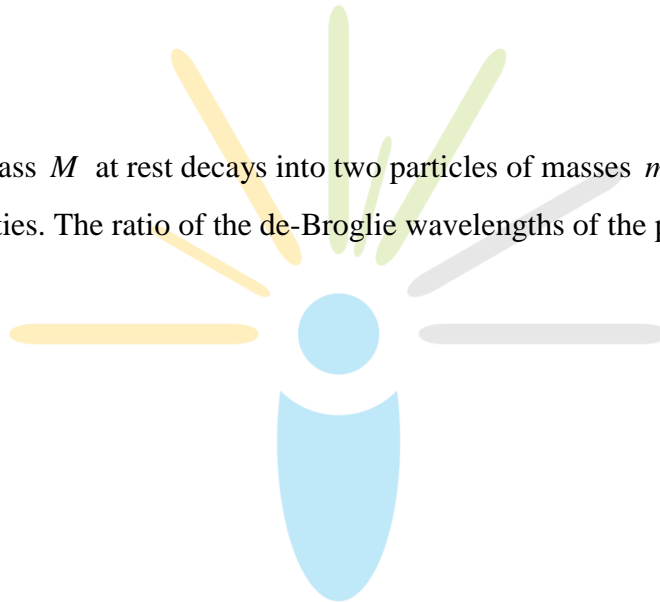
21. A particle free to move along the  $x$ -axis has potential energy given by

$U(x) = K[1 - \exp(-x^2)]$  for  $-\mu \leq x \leq \mu$  where  $K$  is a positive constant of appropriate dimensions. Then:

- (A) At points away from the origin, the particle is in unstable equilibrium
- (B) For any finite non-zero value of  $x$ , there is a force directed away from the origin.
- (C) If its total mechanical energy is  $K/2$ , it has its minimum kinetic energy at the origin.
- (D) For small displacements from  $x = 0$ , motion is simple harmonic

22. A particle of mass  $M$  at rest decays into two particles of masses  $m_1$  and  $m_2$  having non-zero velocities. The ratio of the de-Broglie wavelengths of the particles  $\lambda_1/\lambda_2$  is:

- (A)  $m_1/m_2$
- (B)  $m_2/m_1$
- (C) 1.0
- (D)  $\sqrt{(m_2/m_1)}$

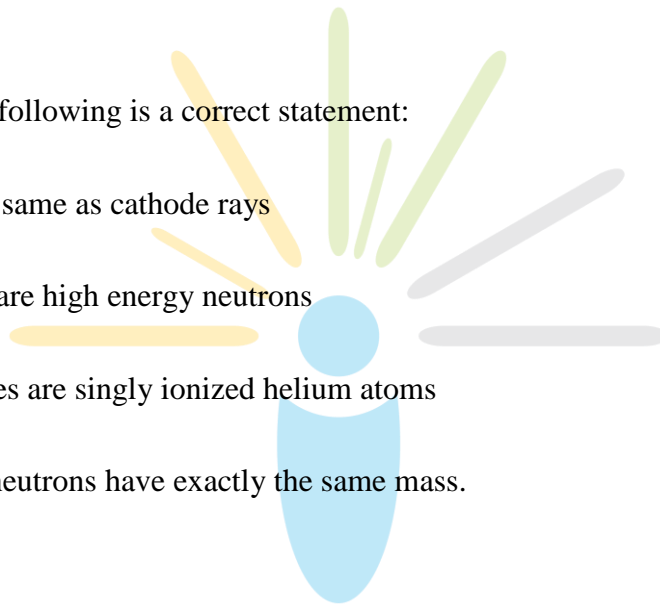


23. A circular loop of radius  $R$ , carrying current  $I$ , lies in  $x - y$  plane with its centre at the origin. The total magnetic flux through  $x - y$  plane is:

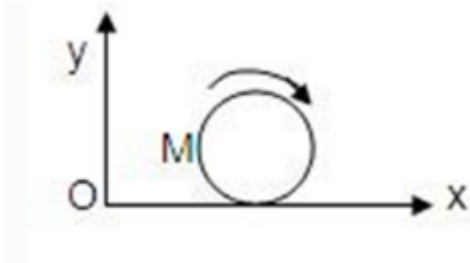
- (A) directly proportional to  $I$
- (B) directly proportional to  $R$
- (C) directly proportional  $R^2$
- (D) zero

24. Which of the following is a correct statement:

- (A) Beta rays are same as cathode rays
- (B) Gamma rays are high energy neutrons
- (C) Alpha particles are singly ionized helium atoms
- (D) Protons and neutrons have exactly the same mass.



25. A disc of mass  $M$  and radius  $R$  is rolling with angular speed  $\omega$  on a horizontal plane as shown. The magnitude of angular momentum of the disc about the origin  $O$  is:



- (A)  $(1/2)Mr^2\omega$
- (B)  $Mr^2\omega$
- (C)  $(3/2)Mr^2\omega$
- (D)  $2Mr^2\omega$

**Directions:** Questions numbers 26-35 carry 3 marks each and may have more than one correct answers. All correct answers must be marked to get any credit in these questions.

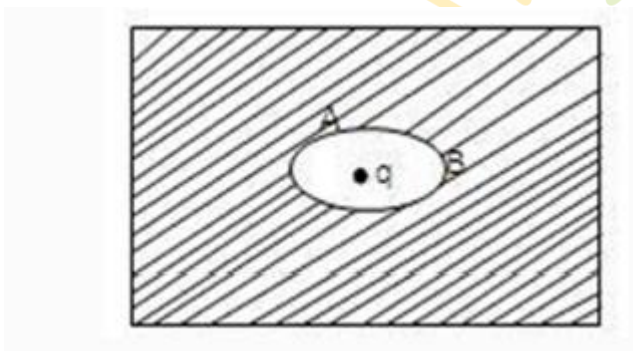
26. The coordinates of a particle moving in a plane are given by  $x(t) = a \cos(pt)$  and  $y(t) = b \sin(pt)$  where  $a, b (< a)$  and  $p$  are positive constants of appropriate dimensions. Then:

- (A) the path of the particle is an ellipse
- (B) the velocity and acceleration of the particle are normal to each other at  $t = p/2p$
- (C) the acceleration of the particle is always directed towards a focus
- (D) the distance travelled by the particle in time interval  $t = 0$  to  $t = p/2p$  is  $a$ .

27. The half-life period of a radioactive element  $X$  is same as the mean life time of another radioactive element  $Y$ . Initially both of them have the same number of atoms. Then:

- (A)  $X$  and  $Y$  have the same decay rate initially
- (B)  $X$  and  $Y$  decay at the same rate always
- (C)  $Y$  will decay at a faster rate than  $X$
- (D)  $X$  will decay at faster rate than  $Y$

28. An elliptical cavity is carved within a perfect conductor. A positive charge  $q$  is placed at the centre of the cavity. The points  $A$  and  $B$  are on the cavity surface as shown in the figure. Then:



- (A) electric field near  $A$  in the cavity = electric field near  $B$  in the cavity
- (B) charge density at  $A$  = charge density at  $B$
- (C) potential at  $A$  = potential at  $B$
- (D) total electric field flux through the surface of the cavity is  $q/\hat{\epsilon}_0$ .



29. Three simple harmonic motions in the same direction having the same amplitude and same period are superposed. If each differ in phase from the next by  $45^\circ$ , then:

- (A) the resultant amplitude is  $(1 + \sqrt{2})a$
- (B) the phase of the resultant motion relative to the first is  $90^\circ$ .
- (C) the energy associated with the resulting motion is  $(3 + 2\sqrt{3})$  times the energy associated with any single motion
- (D) the resulting motion is not simple harmonic

30. As a wave propagates

- (A) the wave intensity remains constant for a plane wave
- (B) the wave intensity decreases as the inverse of the distance from the source for a spherical wave
- (C) the wave intensity decreases as the inverse square of the distance from the source for a spherical wave
- (D) total intensity of the spherical wave over the spherical surface centered at the source remains constant at all times

31. A bimetallic strip is formed out of two identical strips – one of copper and the other of brass. The coefficients of linear expansion of the two metals are  $aC$  and  $aB$ . On heating, the temperature of the strip goes up by  $DT$  and the strip bends to form an arc of radius of curvature  $R$ . Then  $R$  is:

- (A) proportional to  $DT$
- (B) inversely proportional to  $DT$
- (C) proportional to  $|aB - aC|$
- (D) inversely proportional to  $|aB - aC|$

32. When a potential difference is applied across, the current passing through:

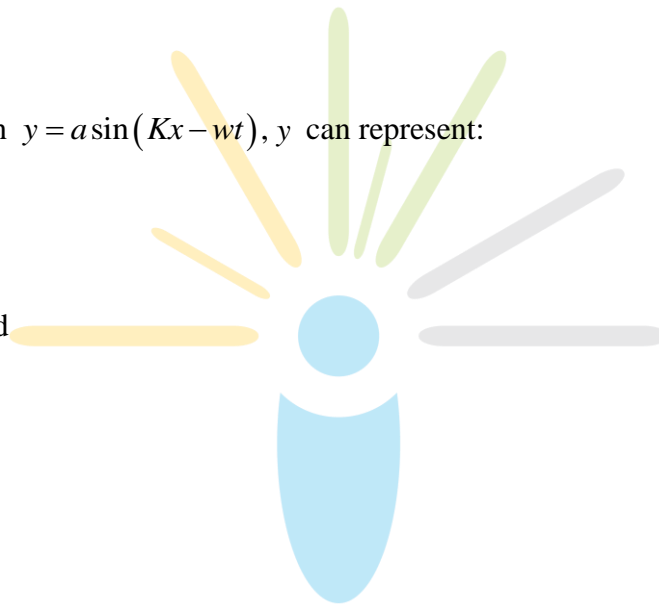
- (A) an insulator at  $0\text{ K}$  is zero
- (B) a semiconductor at  $0\text{ K}$  is zero
- (C) a metal at  $0\text{ K}$  is finite
- (D) a  $p-n$  diode at  $300\text{ K}$  is finite if it is reverse biased.

33.  $Y(x,t) = 0.8/\sqrt{(4x+5t)^2+5}$  represents a moving pulse where  $x$  and  $y$  are in metres and  $t$  in second. Then:

- (A) pulse is moving in positive  $x$  direction
- (B) in  $2s$  it will travel a distance of  $2.5$  m
- (C) its maximum displacements is  $0.16$  m
- (D) it is a symmetric pulse

34. In a wave motion  $y = a \sin(Kx - \omega t)$ ,  $y$  can represent:

- (A) electric field
- (B) magnetic field
- (C) displacement
- (D) pressure



35. Standing waves can be produced:

- (A) on a string clamped at both ends
- (B) on a string clamped at one end and free at the other
- (C) when incident wave gets reflected from a wall
- (D) when two identical waves with a phase difference of  $\pi$  are moving in the same direction.

## SECTION II

1. Two moles of an ideal monoatomic gas initially at pressure  $P_1$  and volume  $V_1$  undergo an adiabatic compression until its volume is  $V_2$ . Then the gas is given heat  $Q$  at constant volume  $V_2$ :

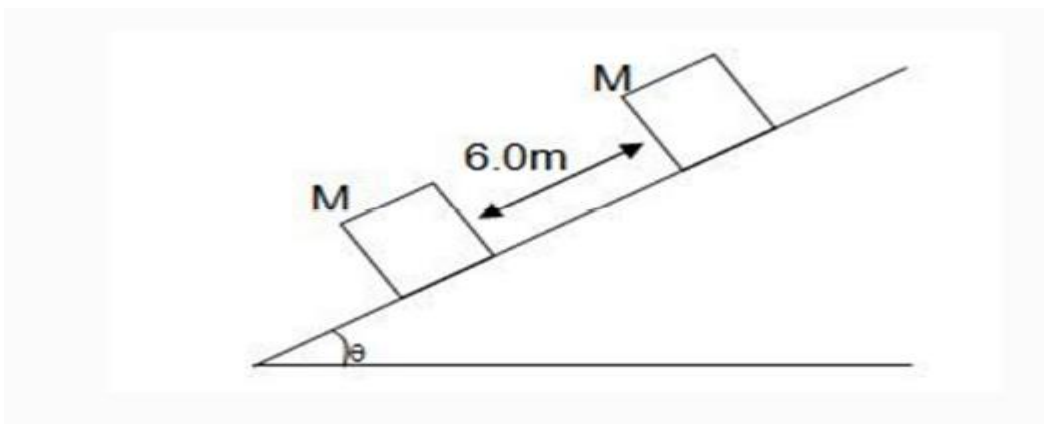
(A) Sketch the complete process on a  $P$ - $V$  diagram.

(B) Find the total work done by the gas, the total change in internal energy and the final temperature of the gas.

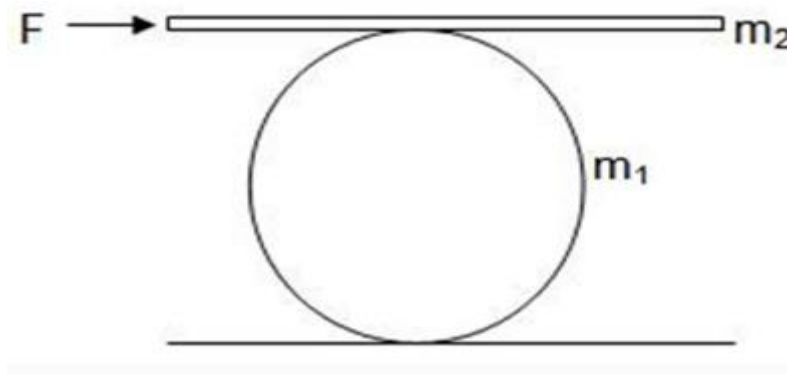
[Give your answer in terms of  $P_1:V_1:V_2:Q$  and  $R$ ]

2. Two blocks of mass  $2\text{ kg}$  and  $M$  are at rest on an inclined plane and are separated by a distance of  $6.0\text{ m}$  as shown. The coefficient of friction between each block and the inclined plane is  $0.25$ . The  $2\text{ kg}$  block is given a velocity of  $10.0\text{ m/s}$  up the inclined plane. It collides with  $M$ , comes back and has a velocity of  $1.0\text{ m/s}$  when it reaches its initial position. The other block  $M$  after collision moves  $0.5\text{ m}$  up and comes to rest. Calculate the coefficient of restitution between the blocks and the mass of the block  $M$ .

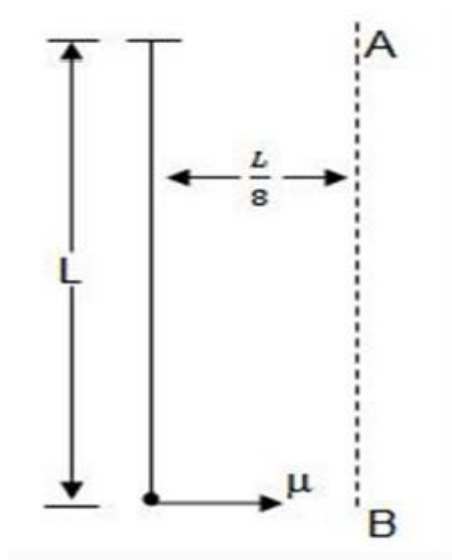
[Take  $\sin q = \tan q = 0.05$  and  $g = 10\text{ m/s}^2$ ]



3. A man pushes a cylinder of mass  $m_1$  with the help of a plank of mass  $m_2$  as shown. There is no slipping at any contact. The horizontal component of the force applied by the man is  $F$ . Find:



- (A) the accelerations of the plank and the centre of mass of the cylinder and  
 (B) the magnitudes and directions of frictional forces at contact points.
4. A particle is suspended vertically from a point  $O$  by an inextensible massless string of length  $L$ . A vertical line  $AB$  is at a distance of  $L/8$  from  $O$  as shown. The object is given a horizontal velocity  $u$ . At some point, its motion ceases to be circular and eventually the object passes through the line  $AB$ . At the instant of crossing  $AB$ , its velocity is horizontal. Find  $u$ .



5. A wooden stick of length  $L$ , radius  $R$  and density  $p$  has a small metal piece of mass  $m$  (of negligible volume) attached to its one end. Find the minimum value for the mass  $m$  (in terms of given parameters) that would make the stick float vertically in equilibrium in a liquid of density  $s (> p)$ .
6. A long wire  $PQR$  is made by joining two wires  $PQ$  and  $QR$  of equal radii.  $PQ$  has a length 4.8 m and mass 0.06 Kg.  $QR$  has length 2.56 m and mass 0.2 Kg. The wire  $PQR$  is under a tension of 80N. A sinusoidal wave pulse of amplitude 3.5cm is sent along the wire  $PQ$  from the end  $P$ . No power is dissipated during the propagation of the wave pulse. Calculate: (a) the time taken by the wave pulse to reach the other end  $R$  and (b) the amplitude of the reflected and transmitted wave pulse after the incident wave pulse crosses the joint  $Q$ .
7. A non-conducting disc of radius  $a$  and uniform positive surface charge density  $s$  is placed on the ground with its axis vertical. A particle of mass  $m$  and positive charge  $q$  is dropped, along the axis of the disc from a height  $H$  with zero initial velocity. The particle has  $q/m = 4\hat{I}0 g/s$ .
- (a) Find the value of  $H$  if the particle just reaches the disc.
- (b) Sketch the potential energy of the particle as a function of its height and find its equilibrium position.

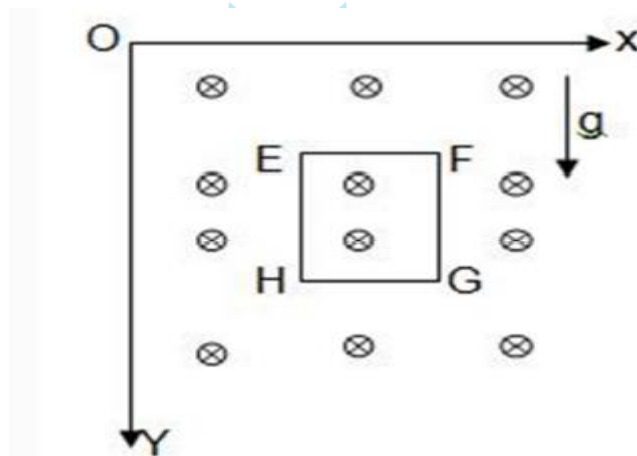
8. The region between  $x = 0$  and  $x = L$  is filled with uniform steady magnetic field  $B_0k$ . A particle of mass  $m$ , positive charge  $q$  and velocity  $V_0i$  travels along  $x$ -axis and enters the region of the magnetic field.

Neglect the gravity throughout the question.

(a) Find the value of  $L$  if the particle emerges from the region of magnetic field with its final velocity at an angle  $30^\circ$  to its initial velocity.

(b) Find the final velocity of the particle and the time spent by it in the magnetic field, if the magnetic field now expands upto  $2.1L$ .

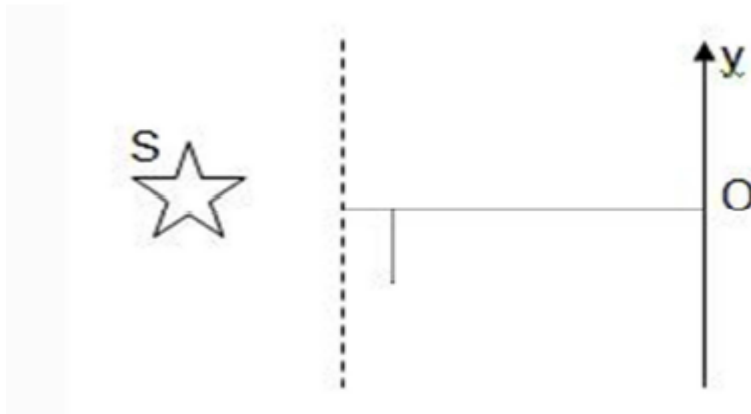
9. A magnetic field  $B = (B_0y/a)k$  is acting into the paper in the  $+z$  direction.  $B_0$  and  $a$  are positive constants. A square loop  $EFGH$  of side  $a$ , mass  $m$  and resistance  $R$  in  $x$ - $y$  plane starts falling under the influence of gravity. Note the directions of  $x$  and  $y$



in the figure. Find:

- the induced current in the loop and indicate its direction
- the total Lorentz force acting on the loop and indicate its direction
- an expression for the speed of the loop  $v(t)$  and its terminal velocity.

10. The young's double slit experiment is done in a medium of refractive index  $4/3$ . A light of  $600\text{nm}$  wavelength is falling on the slits having  $0.045\text{mm}$  separation. The lower slit  $S_2$  is covered by a thin glass sheet of thickness  $10.4\text{mm}$  and refractive index screen placed  $1.5\text{m}$  front the slits as shown.



- Find the location of central maximum (bright fringe with zero path difference) on the  $y$ -axis.
- Find the light intensity at point  $O$  relative to the maximum fringe intensity.
- Now if  $600\text{nm}$  lights is replaced by white light of range  $400$  to  $700\text{nm}$ , find the wavelengths of the light that form maxima exactly at point  $O$ .

[All wavelengths in the problem are for the given medium of refractive index  $4/3$ . Ignore dispersion]

11. The  $x$ - $y$  plane is the boundary between two transparent media. Medium-1 with  $z > 0$  has a refractive index  $\sqrt{2}$  and medium-2 with  $z \leq 0$  has a refractive index  $\sqrt{3}$ . A ray of light in medium-1 given by vector  $A = 6\sqrt{3}i + 8\sqrt{3}j - 10k$  is incident on the plane of separation. Find the unit vector in the direction of the refracted ray in medium-2.



12.(a) A quarter cylinder of radius  $R$  and refractive index 1.5 is placed on a table. A point object  $P$  is kept at a distance of  $mR$  from it. Find the value of  $m$  for which a ray from  $P$  will emerge parallel to the table as shown in figure.

(b) Photoelectrons are emitted when  $400\text{nm}$  radiation is incident on a surface of work function  $1.9\text{eV}$ . These photoelectrons pass through a region containing  $\alpha$ -particle. A maximum energy electron combines with an  $\alpha$ -particle to form a  $\text{He}^+$  ion, emitting a single, photon in this process.  $\text{He}^+$  ions thus formed are in their fourth excited state. Find the energies in eV of the photons lying in the  $2$  to  $4\text{eV}$  range, that are likely to be emitted during and after the combination.

[Take  $h = 4.14 \times 10^{-15} \text{eV} \cdot \text{s}$ ]

