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S. No. of Question Paper : **8619**

Unique Paper Code : **32221102** **J**

Name of the Paper : **Mechanics**

Name of the Course : **B.Sc. (Hons.) Physics**

Semester : **I**

Duration : **3 Hours** Maximum Marks : **75**

(Write your Roll No. on the top immediately on receipt of this question paper.)

Question No. **1** is compulsory and carriers **19** marks.

Answer any *four* of the remaining six, each carrying **14** marks, attempting any *two* parts out of three from each question.

1. Attempt all parts of this question :

(*i*) Calculate the percentage contraction of a rod moving with a velocity 0.8c in a direction inclined at 45° to its own length. 3

(*ii*) A particle slides back and forth on a frictionless track whose height as a function of horizontal position x is given by $y = ax^2$, where $a = 0.92\ m^{-1}$. If the particle's maximum speed is 8.5 m/s, find the turning points of its motion. 3

(*iii*) · A space traveller weighs 80 kg on earth. Find the weight of the traveller on another planet whose radius is twice that of the earth and whose mass is 3 times that of the earth. 3

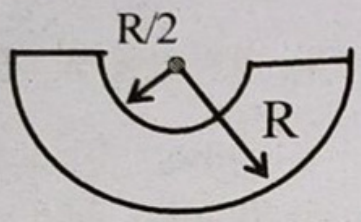
(*iv*) A rigid body is rotating about its axis of symmetry, its moment of inertia about the axis of rotation being 1 kg m^2 and its rate of rotation 2 rev/s. What is it angular momentum about the given axis ? Wha additional work will have to be done to double its rat of rotation ?

(*v*) A particle, moving in a straight line with S.H.M. o period $2\pi/\omega$ about a fixed point O, has a velocity $\sqrt{3}b\omega$ when at a distance b from O. Calculate its amplitud and the time it takes to cover the rest of its distance.

(*vi*) A 4800 kg elephant is standing at one end of a 1500 kg rail car, which is at rest all by itself, on a frictionle horizontal track. The elephant walks 19 m towar the other end of the car. How far does the c move ?

2. (*i*) (*a*) Find the location of the center of mass of a solid hemisphere of uniform density and radius R.

(*b*) Mass in the shape of a hemisphere of radius R/2 is removed from the hemisphere in part (*a*), as shown in the figure. Where is the center of mass of the remaining mass ? 4+3



(*ii*) Two particles having masses m_1 and m_2 move so that their relative velocity is v and the velocity of their centre of mass is v_{cm}. Prove that the total kinetic energy of the system is $(Mv_{cm}^2 + \mu v^2)/2$, where M is the total mass and μ is the reduced mass of the system. 7

(*iii*) An empty freight car of mass 500 kg starts from rest under an applied force of 100 N. At the same time sand begins to run into the car at a steady rate of

20 kg/s from a hopper at rest on the track. Find the speed of the car when 100 kg of sand has been transferred. 7

3. (*i*) Obtain an expression for the moment of inertia of a solid cylinder about an axis through its centre and perpendicular to its axis of cylindrical symmetry. 7

(*ii*) A ring of mass 0.3 kg and radius 0.1 m and a solid cylinder of mass 0.4 kg and of the same radius are given the same kinetic energy and released simultaneously on a flat horizontal surface such that they begin to roll as soon as released towards a wall which is at the same distance from the ring and the cylinder. Assuming that the rolling friction in both cases is negligible, find out which object reaches the wall first ? 7

(*iii*) A uniform rod of mass M and length L lies on a smooth horizontal plane. A particle of mass m moving at a speed v perpendicular to the length of the rod strikes it a distance L/4 from the centre and stops after the collision. Find :

(*a*) The velocity of the centre of the rod.

(*b*) The angular velocity of the rod about its centre just after collision. 4+3

4. (*i*) Derive the expression for the gravitational potential due to a spherical shell of radius R and mass M at a point outside the shell and also at a point inside the shell. Give its graphical representation. 7

(*ii*) A bead of mass m slides without friction on a smooth rod along the x-axis. The rod is equidistant between two spheres of mass M. The spheres are located at $x = 0$, $y = \pm a$ and attract the bead gravitationally :

(*a*) Find the potential energy of the bead.

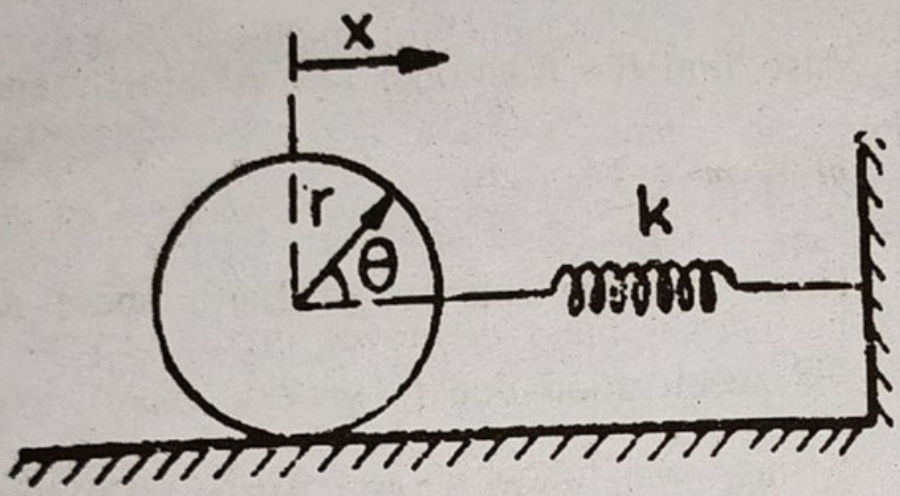
(*b*) The bead is released at $x = 3a$ with velocity v_0 towards the origin. Find the speed as it passes the origin.

(*c*) Find the frequency of small oscillations of the bead about the origin. 3+2+2

(*iii*) A particle of mass m moves in the central force field with the force function $f(r) = -Kr$, with $K > 0$. Find the effective potential energy and hence show that all the orbits are bounded. Find the radius and period of circular orbits, if any. 7

5. (*i*) What do you understand by 'logarithmic decrement', 'relaxation time' and 'quality factor' of a weakly damped harmonic oscillator ? Show that the average energy of a weakly damped harmonic oscillator decays exponentially with time. 3+4

(*ii*) A circular solid cylinder of radius r and mass m is connected to a spring of spring constant k as shown in the figure below.



Determine the frequency of horizontal oscillations of the system if the cylinder :

(*a*) Slips on the surface without rolling.

(*b*) Rolls on the surface without slipping.

Neglect friction. 3+4

(*iii*) A particle of mass m with velocity v_0 collides elastically with another particle of mass M at rest, and is scattered through angle θ in the centre of mass frame. Show that

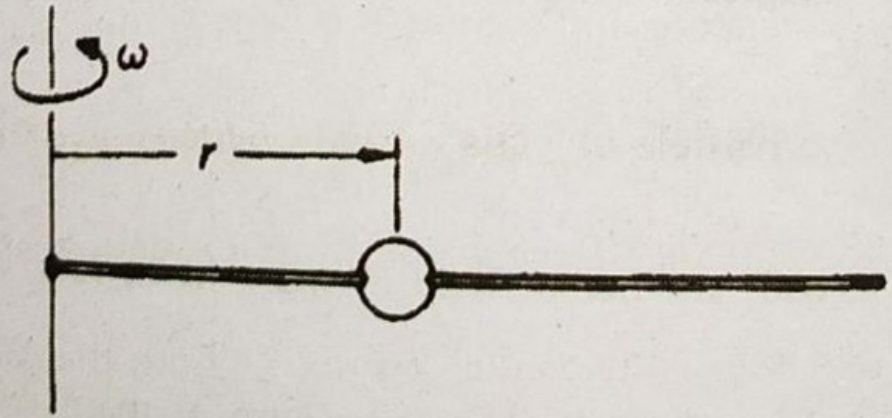
the final velocity of mass m in the laboratory frame is :

$$v_f = \left(\frac{v_0}{m+M}\right)(m^2 + M^2 + 2mM\cos\theta)^{1/2}$$

Also find the fractional loss of kinetic energy of mass m if $m = M$. 7

6. (*i*) How does the rotation of Earth about its axis affect the acceleration due to gravity experienced by a body at rest at a point on the surface of earth ? Support your answer with a suitable derivation and diagram. 7

(*ii*) A bead of mass 'm' slides without friction on a rigid wire rotating at constant angular speed ω as shown in the figure. Find an expression for the force exerted by the wire on the bead that is initially at rest at a distance r_0 from the axis. 7



(iii) The space and time coordinates of two events as measured in frame S are :

Event 1 : $x_1 = x_0,\ t_1 = x_0/c,\ y_1 = z_1 = 0,$

Event 2 : $x_2 = 2x_0,\ t_2 = x_0/c,\ y_2 = z_2 = 0.$

Find the velocity of another frame S' in which the second event occurs by time $x_0/2c$ before the first event. 7

7. (i) Derive the expression for relativistic Doppler's effect. 7

(ii) A particle with a rest mass m_0 and kinetic energy $3m_0c^2$ makes a completely inelastic collision with a stationary particle of rest mass $2m_0$, without any radiation loss and the two particles forming a composite particle. What is the rest mass of the composite particle and its speed ? 7

(iii) (a) Suppose that a particle moves relative to O' with a constant velocity of $c/2$ in the $x'y'$-plane such that its trajectory makes an angle of 60° with the x'-axis. If the velocity of O' with respect to O is $0.6c$ along the x-x'-axis, find the equations of motion of the particle as determined by O.

(*b*) Define proper time. What is time dilation ? With what velocity should a rocket move so that as observed from Earth every year spent on the rocket corresponds to 4 years on Earth ? 4+3

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