This question paper contains **4** printed pages]

Roll No. | | | | | | | | | | |

S. No. of Question Paper : **842**

Unique Paper Code : **222103** **G**

Name of the Paper : **PHHT-102 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.)

Attempt *five* questions in all including

Question No. **1** which is compulsory.

1. Attempt any *five* of the following :

   (*a*) Find the position of the center of mass of a semi-circular wire of mass M and radius R.

   (*b*) An object of mass *m* lies at a distance *r* from the center of the Sun. It is to be ejected perpendicular to the direction towards the Sun. What speed should it be ejected with so that it acquires a parabolic orbit ?

   (*c*) Find the ratio of the radii of gyration of a solid disk of mass M and radius R spinning about an axis through its center and perpendicular to its plane and a solid sphere of the same mass and radius spinning about its diameter.

   (*d*) Prove that under the influence of a central force, the motion of a particle is always confined to a plane.

   (*e*) Show that the theoretical limiting values of Poisson's ratio are – 1 and 0.5.

P.T.O.

(*f*) A cosmic ray proton has energy 10^{13} MeV and travels across our Galaxy of size 10^5 light years. How long does it take to cross the galaxy in its own rest-frame ? Assume the rest mass of the proton is 10^3 MeV.

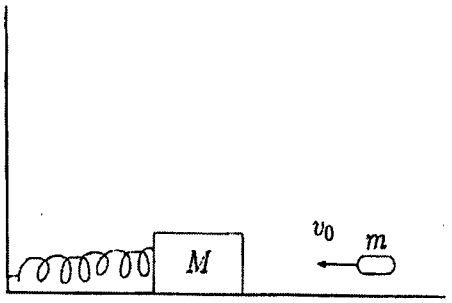
(*g*) Prove that the torque due to gravity on a rigid body about its center of mass is zero.

(*h*) Calculate the momentum of a photon of energy 1.5×10^{-18} Joules. 5×3=15

2. (*a*) Considering the flow of mass and momentum, carefully derive the equation of motion of a rocket, stating all assumptions and conventions. 5

(*b*) Solve this rocket equation for a constant gravitational field. Interpret this solution for how a rocket should burn its fuel in order to escape from Earth's gravity. Are this rocket equation and its solution applicable for a journey from Earth to Mars ? 3,1,1

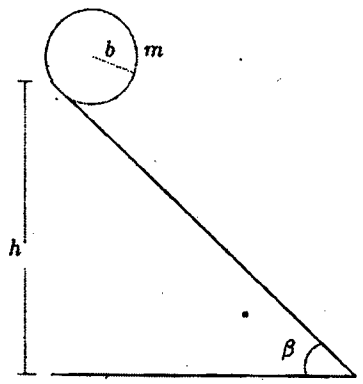
(*c*) A block of mass M is attached to a wall by a spring of spring constant *k*. A bullet of mass *m* is shot at the block with speed v_0. If the bullet gets embedded into the block, find the maximum compression in the spring. 5



3. (*a*) Derive an expression for the total angular momentum of an extended rigid body whose motion involves translation as well as rotation. Explain clearly why some terms survive and other terms vanish. For rotation about a fixed axis, obtain an expression for the component of angular momentum along the axis of rotation. Give the physical interpretation of each term in the final expression. 8

(*b*) Estimate the order of magnitude value of each term in the expression derived above for the Earth in motion around the Sun. (Assume $M_{Earth} = 6 \times 10^{24}$ kg, $R_{Earth} = 6400$ km, Sun-Earth distance = 150 million km). 2

(*c*) A uniform drum of radius *b* and mass *m* rolls without slipping on an inclined plane that makes an angle β with the horizontal. If the drum starts from rest, find the speed of its center of mass after it has descended a height *h*. 5



4. (*a*) Reduce the two-body problem for the motion of two masses interacting via a central force to a one-body problem. Obtain the one-body equation of motion in plane polar co-ordinates in terms of the reduced mass of the system. By considering the torque, prove that such motion must be confined to a plane. 7

(*b*) Give the expressions for the magnitude of angular momentum and the total energy (conserved quantities) in the above problem. By absorbing the tangential part of kinetic energy into U(*r*) potential energy, define an effective potential energy $U_{eff}(r)$. Sketch this effective potential energy in an energy diagram and qualitatively describe the different kinds of motion for different ranges of energy. 8

5. (*a*) What are elastic constants of an elastic material ? Establish the relation between the elastic constants : Y (Young's Modulus), n (modulus of rigidity) and K (Bulk Modulus). 8

(*b*) Derive an expression for the rate of flow of a liquid through a capillary tube. 7

6. (*a*) What is an inertial frame of reference ? Derive the expression for Galilean Transformation equations for space-time coordinates. Show that acceleration is invariant under Galilean Transformation. 8

(*b*) Derive an expression for the time period of oscillation of the plane of a Foucalt pendulum when the pendulum is placed at a latitude of λ on Earth and the rotation angular frequency of Earth is Ω. 7

7. Describe the motivation, setup and result of the Michelson-Morley experiment and explain the physical interpretation and significance of the null result. 8

A rod of length l_0 lies in the (x', y') plane of its rest frame making an angle θ_0 with the x'-axis. What is the length and orientation of the rod in the lab frame (x, y) in which the rod moves in the direction of the positive x-axis with velocity v ? 7