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3 (Sem-6/CBCS) PHY HE 5

2025

**PHYSICS**

(Honours Elective)

Paper : PHY-HE-6056

**(Classical Dynamics)**

Full Marks : 80

Time : Three hours

***The figures in the margin indicate full marks for the questions.***

1. Answer the following questions :  $1 \times 10 = 10$ 
  - (a) What is called gyroradius? Give its mathematical expression.
  - (b) What do you mean by degree of freedom? Mention a system having two degrees of freedom.
  - (c) State the principle of virtual work.
  - (d) What is called phase space? Mention its dimensions.

- (e) What do you mean by cyclic or ignorable coordinates?
- (f) State the postulates of special theory of relativity.
- (g) Write down the assumptions taken to derive the Lorentz transformation equations of space-time.
- (h) Can a particle move through a medium with a speed greater than that of light in that medium? Justify your answer.
- (i) Define coefficient of viscosity. Mention its unit.
- (j) Why do bubbles of air or gas rise up through water or any other liquid?

2. Answer the following questions:  $2 \times 5 = 10$

- (a) Does kinetic energy of a charged particle change when it enters a magnetic field? Justify your answer.
- (b) Distinguish between Lagrangian and Hamiltonian formalisms.
- (c) State time dilation in special theory of relativity.
- (d) Show that  $d\tau = \frac{i}{c} ds$ , where  $d\tau$  is the element of proper time and  $ds$  is the length element in four space.

- (e) Why does Poiseuille's formula fail in the cases of tubes of wider bore and gases?

3. Answer **any four** from the following questions:  $5 \times 4 = 20$

- (a) Show that an electron moving with uniform velocity follows a parabolic path in a transverse uniform electric field.
- (b) Derive Lagrange's equations of motion for a conservative system using D'Alembert's principle.
- (c) What do you mean by Minkowski's space? Four momentum  $p_\mu$  is given

$$\text{by } p_\mu = m_0 \frac{dx}{d\tau} \mu = m_0 v_\mu.$$

Use this expression to obtain the following relation:

$$E^2 = p^2 c^2 + m_0^2 c^4,$$

where symbols have their usual meanings.  $2+3=5$

- (d) What is called twin paradox in special theory of relativity? Discuss the paradox using space-time diagram.

$2+3=5$

(e) Use Hamilton's canonical equations to derive the equation of motion of a simple pendulum. Find an expression for time period of oscillation of the pendulum. 4+1=5

(f) (i) Obtain the expression for Reynold's number in terms of inertial force and force due to viscosity. 3

(ii) Write the law of dynamical similarity of flows of two different liquids through two geometrically similar tubes. 2

4. Answer the following questions : 10×4=40

(a) (i) Write down Lagrange's equations of motion for non-conservative system. 1

(ii) Derive Hamilton's canonical equations. 4

(iii) Using equation of motion of a particle in transverse direction in a central force field, show that angular momentum is conserved. And hence deduce Kepler's second law of planetary motion. 3+2=5

Or

(b) (i) What do you understand by stable and unstable equilibria of a system? 2+2=4

(ii) Obtain Lagrange's equation of motion for small oscillations of a system in the neighbourhood of stable equilibrium. 4

(iii) What do you mean by normal modes of oscillation? 2

(c) (i) Write the equation of motion (in radial direction) of a particle in central force field. Prove the conservation of total energy  $E$  of the particle directly from the equation of motion. 1+3=4

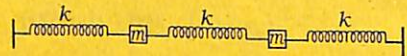
(ii) If  $r = e^{-\theta}$  describes the orbit of a particle under central force  $F(r)$ , show that  $F(r) \propto \frac{1}{r^3}$ . 3

- (iii) State Hamilton's principle. Using this principle show that two Lagrangians  $L$  and  $L + \frac{dF(t)}{dt}$  give the same equation of motion.

1+2=3

**Or**

- (d) (i) Two identical particles, each of mass  $m$  are attached to three identical springs, each of stiffness constant  $k$  as shown in the figure. Show that the system undergoes simple harmonic oscillations when one of the particles is slightly displaced from equilibrium position. 5



- (ii) Show that Lorentz transformations of space and time can be regarded as transformations due to rotation of axes in the four dimensional Minkowski's space. 5
- (e) (i) Write brief notes on space-like and time-like intervals. 2+2=4
- (ii) Show that in four-space, the Lorentz transformation equations involve transforming from orthogonal to non-orthogonal system. 3

- (iii) Give a geometrical interpretation of the length contraction in four-space.

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**Or**

- (f) (i) If the Lagrangian of a conservative system does not contain time explicitly, show that

$$H = \sum_k p_k \dot{q}_k - L \quad 3$$

- (ii) A Lagrangian is given by

$$L = \frac{1}{2} \alpha \dot{q}^2 - \frac{1}{2} \beta q^2$$

where  $\alpha$  and  $\beta$  are constants. Deduce the Hamiltonian of the system. 3

- (iii) Prove that pressure and kinetic energy of a liquid are convertible from one into the other. 4

- (g) (i) Show that the quantity  $ds^2 = dx^2 + dy^2 + dz^2 - c^2 dt^2$  is invariant under Lorentz transformation. 3

- (ii) A muon formed high up in the atmosphere travels with a speed  $0.99c$  for a distance of  $5.4\text{ km}$  before it decays. What is the life of the muon as measured by us and as measured by the muon?  $1+2=3$
- (iii) Define acceleration using four-velocity vector and hence obtain relativistic form of Newton's 2nd law of motion.  $2+2=4$

**Or**

- (h) (i) Obtain the velocity profile for streamline flow of a liquid through a capillary tube. Deduce the fraction of liquid which flows through the section upto distance  $\frac{r}{2}$  from the axis, where  $r$  is the radius of the capillary tube.  $4+3=7$
- (ii) Three capillary tubes of lengths  $8l$ ,  $0.2l$  and  $2l$  and radii  $r$ ,  $0.2r$  and  $0.5r$  respectively are connected in series. If the total pressure across the system in an experiment is  $P$ , deduce the pressure across the shortest (middle) capillary tube.

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