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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_μ 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

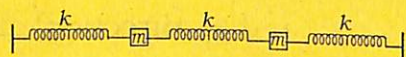
(ii) If $r = e^{-\theta}$ describes the orbit of a particle under central force $F(r)$, show that $F(r) \propto \frac{1}{r^3}$. 3

- (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. 3

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 α and β 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 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. 3