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 : 1×10=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 : 2×5=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 : 5×4=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 by $p_\mu = m_0 \frac{dx}{d\tau} \mu = m_0 v_\mu$.

Use this expression to obtain the following relation :

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

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

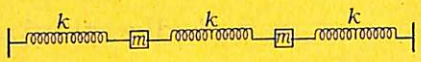
(c) (i) Write the equation of motion (in radial direction) of a particle in central force field. Prove the conservation of total energy E of the particle directly from the equation of motion. 1+3=4

(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

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

$ds^2=dx^2+dy^2+dz^2-c^2dt^2$

is invariant under Lorentz transformation. 3

(ii) A muon formed high up in the atmosphere travels with a speed $0{\cdot}99c$ for a distance of $5{\cdot}4\,km$ 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 $8l$, $0{\cdot}2l$ and $2l$ and radii r, $0{\cdot}2r$ and $0{\cdot}5r$ 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
