

2023

1st Semester Examination (CCFUP : NEP)

PHYSICS

Paper : MJ A1-T (Multidisciplinary Major)
(Mathematical Methods and Mechanics)

Full Marks : 40

Time : Two Hours

*The figures in the margin indicate full marks.
Candidates are required to give their answers
in their own words as far as practicable.*

Group - A

Answer any *five* of the following questions : $2 \times 5 = 10$

1. Define the term 'reduced mass' in the context of the two-body problem.
2. A spaceship travels at a speed of $0.8c$ relative to an observer on Earth. The spaceship measures 100 meters in its rest frame. Calculate the length of the spaceship as observed from Earth.
3. A particle of mass m moves in a plane under the influence of a central force $F(r) = \frac{k}{r^2}$, where k is a constant. Show that the angular momentum L of the particle is conserved.

P.T.O.

4. A comet moves under the gravitational influence of the Sun. If the comet's orbit is highly eccentric, describe its motion at perihelion and aphelion.
5. A uniform rod of length L and mass M is rotating about an axis perpendicular to its length. Determine the radius of gyration k of the rod about this axis.
6. Write the order and power of the given differential equation : $\frac{d^3y}{dx^3} + \left(\frac{dy}{dx}\right)^3 = 5y^5$.
7. What will happen to the surface tension of water if detergent is added to the water? Explain your comment.
8. What is a pseudo force in a non-inertial frame of reference?

Group - B

Answer any **four** of the following questions :

$$5 \times 4 = 20$$

9. Derive Poiseuille's equation for flow of a liquid through a capillary tube.
10. A cylindrical body of radius $R = 0.3$ m, mass $M = 2$ kg, and moment of inertia $I = 0.03$ kg m² about its symmetry axis is rolling without slipping down an inclined plane with an angle of inclination $\theta = 30^\circ$. Calculate the acceleration of the body's center of mass as it rolls down the plane. Assume there is no air resistance.

(3)

11. Find the angle in between face diagonals of a cube with unit length using vector method.

12. Show that $\vec{V} = (2xy + z^3)\hat{i} + x^2\hat{j} + 3xz^2\hat{k}$ is a conservative field. Find its scalar potential ϕ such that $\vec{V} = \bar{\nabla}\phi$. Find the work done by the force \vec{V} in moving a particle from $(1, -2, 1)$ to $(3, 1, 4)$.

13. (a) Show that for homogeneous isotropic medium $Y = 2n(1 + \sigma)$. Symbols have their usual meaning.

(b) Calculate the difference between the pressures inside and outside a spherical soap bubble of diameter 1 inch blown with a solution of surface tension 25 dynes per cm. 3+2

14. (a) Find the unit tangent vector to any point on the curve $x = t^2 + 1$, $y = 4t - 3$, $z = 2t^2 - 6t$.

(b) Evaluate $\frac{d}{dt} \left(\mathbf{V} \cdot \frac{d\mathbf{v}}{dt} \times \frac{d^2\mathbf{v}}{dt^2} \right)$. 3+2

Group - C

Answer any **one** of the following questions :

10×1=10

15. (a) Solve the following equation by the use of suitable integrating factor $x dy - y dx + x^2 dx = 0$.

P.T.O.

(b) If $\vec{A} = 5u^2\hat{i} + u\hat{j} - u^3\hat{k}$ and $\vec{B} = (\sin u)\hat{i} - (\cos u)\hat{j}$,

find $\frac{d}{du}(\vec{A} \cdot \vec{B})$ and $\frac{d}{du}(\vec{A} \times \vec{B})$.

(c) Derive the Galilean transformations for the coordinates (x', y', z') as observed from a moving reference frame S' relative to an inertial frame S . 3+5+2

16. (a) Find the gravitational potential and gravitational field due to a uniform solid sphere (i) at an external point and (ii) at an internal point.

(b) What is capillary action? Deduce an expression for the capillary rise h of a liquid of density ρ (θ = angle of contact). 5+5