

December, 2 0 2 5
(Mathematical Physics-I)

Full Marks : 100

Time : 3 hours

The figures in the right-hand margin indicate marks

Answer **all** questions

Part—I

1. All the questions are compulsory. Answer in 1 word each or choose the correct answer from the choice given : 10×1
- (a) A function continuous at a point
- (i) not differentiable at that point
 - (ii) differentiable at that point
 - (iii) may or may not be differentiable at that point
 - (iv) None of these
- (b) The equation $ax^2 + bx + c = 0$ represents the equation of
- (i) circle
 - (ii) parabola
 - (iii) hyperbola
 - (iv) straight line
- (c) The order and degree of the differential equation
- $$\left(\frac{d^2y}{dx^2}\right) + 5\left(\frac{dy}{dx}\right)^2 + 2 = 0$$
- (i) 2 and 1
 - (ii) 1 and 3
 - (iii) 1 and 2
 - (iv) 2 and 3
- (d) \vec{P} , \vec{Q} and \vec{R} are three coplanar vectors. The value of their scalar triple product is
- (i) 1
 - (ii) -1
 - (iii) 0
 - (iv) None of these
- (e) The divergence of a vector function is zero. The vector function is called _____ vector.
- (i) rotational
 - (ii) irrotational
 - (iii) solenoidal
 - (iv) None of these

(f) The value of $\vec{\nabla} \cdot (\vec{\nabla} \phi + \vec{\nabla} \psi) = \text{-----}$.

(g) If $x = Pq$, $y = \frac{P}{q}$, then $\frac{\partial(x, y)}{\partial(P, q)} = \text{-----}$.

(i) $\frac{-2q}{P}$

(ii) $\frac{-2P}{q}$

(iii) 1

(iv) 0

(h) In orthogonal curvilinear coordinates, the quantities h_1, h_2 and h_3 are known as -----.

(i) The value of $\vec{\nabla} \times \vec{r} = \text{-----}$.

(j) The volume element in curvilinear coordinate is

(i) $h_1 h_2 h_3$

(ii) $dx dy dz$

(iii) $h_1 h_2 h_3 du dv dw$

(iv) $h_1 h_2 h_3 + du dv dw$

Part—II

2. Answer *all* questions within 50 words each :

9×2

(a) Write the difference between continuity and differentiability.

(b) Draw the graph of $y = 2^x$.

(c) Find the approximate value of $\sqrt{16 \cdot 4}$.

(d) Show that

$$\vec{a} \times (\vec{b} \times \vec{c}) + \vec{b} \times (\vec{c} \times \vec{a}) + \vec{c} \times (\vec{a} \times \vec{b}) = 0$$

(e) Find the unit vector normal to the surface $x^2 + y^2 - z = 0$ at a point (2, 1, 5).

(f) Explain the physical meaning of curl.

(g) State Gauss's divergence theorem.

(h) Write two properties of Dirac delta function.

(i) Determine the spherical polar coordinates of the point A(5, 2, 1).

Part—III

3. Answer *any eight* questions within 250 words each :

8×5

(a) Test the differentiability of the function $f(x) = |x - 1|$ at $x = 1$.

(b) Solve the differential equation

$$\frac{dy}{dx} = \frac{x \cos x + \sin x}{y(2 \log y + 1)}$$

(c) What is an exact differential equation? Prove that the necessary and sufficient condition for the differential equation $Mdx + Ndy = 0$ is $\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$.

(d) Show that the scalar product of two vectors under rotation is invariant.

(e) Find the value of n for which the vector $r^n \vec{r}$ is solenoidal, where $\vec{r} = x \hat{i} + y \hat{j} + z \hat{k}$.

(f) Derive the expression for gradient in terms of orthogonal curvilinear coordinates.

(g) Evaluate

$$\int_0^3 (t^2 + 1) \delta(t-2) \delta(t-1) dt$$

(h) Prove that cylindrical coordinate system is orthogonal.

(i) Show that

$$\vec{\nabla} \times (u \vec{v}) = u(\vec{\nabla} \times \vec{v}) + (\vec{\nabla} u) \times \vec{v}$$

(j) Find the Binomial series for $\frac{1}{(1+x)^{3/2}}$.

Part—IV

4. Answer *any four* questions within 800 words each :

4×8

(a) Define integrating factor. Solve the differential equation $(y^3 - 2x^2y)dx + (2xy^2 - x^3)dy = 0$ by finding the integrating factor.

(b) Find the maximum volume of the largest rectangular parallelepiped that can be inscribed in an ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$$

(c) Define vector triple product. Prove that

$$\vec{a} \times (\vec{b} \times \vec{c}) = (\vec{a} \cdot \vec{c}) \vec{b} - (\vec{a} \cdot \vec{b}) \vec{c}$$

(d) Explain what do you mean by a Jacobian. Find the Jacobian of an implicit function.

(e) Define orthogonal curvilinear coordinates. What are scale factors? Express curl in terms of orthogonal curvilinear coordinates.

DECEMBER, 2025
MECHANICS

Time- 3 hrs

Full Marks-100

Answer as per instructions.

Figures in the right hand margin indicates marks

Part-1: Fill in the Blanks

(10 × 1 = 10)

1. The moment of inertia for a system can be calculated using the _____ axis theorem for shifting to parallel axes.
2. In a rotating frame, the fictitious force acting on a particle moving radially is the _____ force.
3. For damped oscillations, when damping is equal to $\frac{km}{m}$, the system is _____ damped.
4. The relation between Young's modulus Y and bulk modulus K involves the Poisson's ratio σ as $Y = \frac{3K(1 - 2\sigma)}{2(1 + \sigma)}$.
5. Poiseuille's equation describes the _____ of a viscous fluid through a capillary tube.
6. The gravitational potential inside a uniform solid sphere is proportional to _____.
7. Kepler's second law states that the radius vector sweeps out equal areas in equal _____.
8. The Michelson-Morley experiment aimed to detect the motion of Earth through the _____.
9. In special relativity, the Lorentz factor $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$.
10. The relativistic mass $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$.

Part-2: Answer each within 50 words.

(9 × 2 = 18)

1. State the parallel axis theorem for moment of inertia.
2. Define Coriolis force and give its expression in a rotating frame.
3. Differentiate between overdamped and critically damped oscillations.
4. Derive the relation between shear modulus η and Young's modulus Y .
5. Explain Poiseuille's equation briefly.
6. State Kepler's three laws of planetary motion.
7. What is the equivalence principle in gravitation?
8. Describe time dilation in special relativity.
9. Define relativistic Doppler effect.

Part-3: Answer any 8 out of 10 in 250 words

(8 x 5 = 40)

1. Derive the expression for moment of inertia of a flywheel.
2. Discuss Eulers' equations for rigid body motion.

3. Explain forced oscillations and resonance with quality factor.
4. Describe the bar pendulum and its use in determining Gravity 'g'.
5. Derive the bending moment equation for a cantilever beam.
6. Discuss kinematics of fluid motion and surface tension effects.
7. Solve the two-body central force problem and derive Kepler's laws.
8. Explain geosynchronous orbits and GPS basics.
9. What is understood by length contraction and time dilation.
10. What is Doppler effect when the object is moving towards and away from source.

Part-4: Answers any 4 questions in 500 words

(4 × 8 = 32)

1. Discuss non-inertial frames with centrifugal and Coriolis forces, including examples of motion in rotating systems.
2. Discuss elasticity constants relations and Poiseuille's flow with viscosity corrections.
3. Discuss gravitational field and potential for spherical shells and solids.
4. Describe the Michelson-Morley experiment and outline its results.
5. Explain the concept of simultaneity, time dilation, velocity addition, and length contraction.

DECEMBER, 2025
BIO PHYSICS

Time: 3 Hrs

Full Marks: 100

Answer as per instructions
Figures in the righthand margin indicates marks

PART-I

1. Answer **all** questions **[10x1]**
- (i) Chloride (Cl^-) is the most abundant ion in humans after sodium (True / False).
 - (ii) The combination of biology and physics is known as -----.
 - (iii) The process of heat transfer in biological tissues is known as -----.
 - (iv) Entropy is a measure of -----.
 - (v) The conduction, convection and ----- are three methods of heating.
 - (vi) The ----- folding must be a thermodynamically favorable within a cell.
 - (vii) The grand canonical ensemble is a statistical mechanics model for open systems that can exchange both ----- and ----- with a large heat and particle reservoir, maintaining constant temperature (T), volume (V), and chemical potential (μ).
 - (viii) The ----- diffusion is the rapid, horizontal movement of lipids and proteins within one leaflet of the cell membrane, essential for membrane fluidity and function.
 - (ix) The ----- no of ATPs are formed outside the mitochondria.
 - (x) The Brownian motion was discovered by -----.

PART-II

2. Answer **all** questions **[9x2]**
- (i) Write the key aspects of thermal interaction.
 - (ii) Write the difference between bonding and intermolecular forces.
 - (iii) Write heat equation, when heat diffuses through a given region over time.
 - (iv) Write any two daily life examples of entropy.
 - (v) What is the difference between ATP synthase and ATP hydrolysis?
 - (vi) What is composite system in biophysics?
 - (vii) What is lateral diffusion in the membrane?
 - (viii) Write the concept of absorption by biomolecules.
 - (ix) Write equation of continuity for an incompressible flow of fluid.

PART-III

3. Answer any **eight** questions

[8x5]

- (i) What is Casimir effect? How does this effect works?
- (ii) What is an electric dipole? Name the force between two electric dipoles. Write its SI units.
- (iii) Explain first law of thermodynamics with suitable examples.
- (iv) Explain physics of many particle system with examples.
- (v) What is ensemble? Explain grand canonical ensemble with one example.
- (vi) Derive an expression for Navier Stokes equation.
- (vii) What is biomolecule? Describe vibrational spectra of biomolecules.
- (viii) Write short notes on sedimentation of cell culture.
- (ix) What is diffusion? Derive an expression on Fick's law of diffusion.
- (x) Write the difference between kinesin and dynein.

PART-IV

[4x8]

Answer the following questions (Any Four)

- 4. Describe the domain of physics in biology with daily life applications.
- 5. Write short notes on photosynthesis in chloroplast.
- 6. Write short notes on Maxwell-Boltzmann distribution law.
- 7. Explain second law of thermodynamics with examples.
- 8. What is enthalpy? Derive an expression for Gibb's free energy.

DECEMBER, 2025
MECHANICS

Time- 3 hrs

Full Marks-100

Answer as per instructions.
Figures in the right hand margin indicates marks

PART-1: fill in the blanks

(10 x 1)

1. The point in a system of particles that moves as if the entire mass of the system were concentrated there is called the _____.
2. The _____ theorem states that the moment of inertia of a planar body about an axis perpendicular to its plane is the sum of the moments of inertia about two perpendicular axes in its plane.
3. A force that appears to act on a mass whose motion is described using a non-inertial frame of reference is known as a _____ force.
4. In a _____ oscillation, the amplitude of motion decreases over time due to energy dissipation.
5. The reciprocal of the fraction of energy lost per radian in an oscillatory system is defined as the _____.
6. The property of a beam to resist bending is known as _____.
7. According to _____ Law, the square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.
8. The _____ experiment provided the experimental basis for the null result regarding the "aether wind".
9. In Special Relativity, the phenomenon where a moving clock is observed to run slower than a clock at rest is called _____.
10. The principle that mass and energy are interconvertible is expressed by the _____ equivalence formula.

PART-2: Answer the following questions in 50 words

(9 x 2)

1. Define the Radius of Gyration in the context of rigid body dynamics.
2. State the Principle of Conservation of Angular Momentum.
3. What is the Coriolis force, and when does it act on a particle?
4. Distinguish between transient and steady states in forced oscillations.
5. Define Flexural Rigidity for a bending beam.
6. What is a Geosynchronous orbit?.
7. Explain the basic concept of the Global Positioning System (GPS) as mentioned in the syllabus.
8. State the two fundamental postulates of the Special Theory of Relativity.
9. Briefly explain the concept of Simultaneity in relativity.

PART-3: Answer any 8 out of 10 in 250 words

(8 x 5)

1. Derive the expression for the Moment of Inertia of a Flywheel.
2. Explain the Laws of Physics in rotating coordinate systems and derive the expression for centrifugal force.
3. Discuss the three cases of damped oscillations: oscillatory, critically damped, and overdamped.
4. Derive Poiseuille's Equation for the flow of a liquid through a capillary tube.
5. Describe the relation between different Elastic constants.
6. Discuss the Two-body problem and show how it can be reduced to a one-body problem.
7. Derive the Gravitational potential and field due to a uniform spherical shell at an external point.
8. Explain the Michelson-Morley Experiment and the significance of its negative result.
9. Derive the Relativistic addition of velocities formula from Lorentz transformations.
10. Explain the Variation of mass with velocity and define the concept of a massless particle.

PART-4: Answer any 4 Long Answer Questions Within 800 Words.

(4 x 8)

1. State and prove the Perpendicular and Parallel Axis Theorems and calculate the moment of inertia for a uniform solid cylinder about its longitudinal axis.
2. Formulate the differential equation for Forced Oscillations. Find the steady-state solution and obtain expressions for Resonance.
3. State Kepler's Laws of Planetary Motion. Derive Kepler's Second and Third laws starting from the differential equation of motion under a central force field.
4. Derive the Lorentz Transformation equations in space time relativity.
5. (a) Derive the expression for the Twisting torque on a cylinder or wire.
(b) Discuss Mass-Energy Equivalence in relativity.
