[CO4]

11. *(a)* In classical mechanics Newton's law can be written in more familiar form $F = m_0 a$. The relativistic equation $F = dp/dt$, cannot be so simply expressed. Show rather, that

$$F = \frac{m_0}{\sqrt{1-u^2/c^2}}\left[a + \frac{u(u.a)}{c^2 - u^2}\right]$$

where $a = du/dt$, is the ordinary acceleration and m_0 is rest mass.

(b) Establish the Einstein's mass-energy relation $E = mc^2$. The symbols have their usual meanings. 2+3

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B. Sc. Physics Examination, 2025

(1st Year, 1st Semester)

PHYSICS

Paper : MAJOR/101

(Mechanics, Waves and Oscillations)

Time : 2 Hours *Full Marks* : 40

Use a separate answer script for both Groups A and B.

GROUP—A

Answer **Question 1** (compulsory), *any* **one** from **Question 2** and **Question 3** and *any* **one** from **Question 4** and **Question 5**

Total three questions need to be answered from Group A

[CO-1]

1. *(a)* A particle of unit mass is traveling along the horizontal x-axis in a resistive medium such that at $t = 0$, it is at $x = 0$ and has speed v_0. The resistive force of the medium has magnitude proportional to the square of the instantaneous speed. Describe its motion by finding its position, speed and acceleration at any time $t > 0$.

(b) A particle of unit mass is subjected to a force

$$F(x) = -kx + \lambda x^2$$

where k and λ are positive constants. Find the equilibrium points and nature of the equilibrium points. Find also the frequency of oscillation about the point of stable equilibrium, if any. (2+1+1+1)+(2+2+1)

[CO-3]

2. Derive expression for the force acting on a particle in an uniformly rotating frame of reference. 5

(OR)

[CO3]

3. Find the inertia tensor of a momogeneous rectangular block with sides a, b and c about its principal axes through its centre of mass; axes being parallel to the sides. Take density and mass of the block as ρ and M respectively. 5

[CO3]

4. Justify the statement — there are 21 independent elastic constants at the most.

A beam of negligible weight is fixed rigidly at one end and loaded at the free end. Assuming bending is small, define neutral layer and discuss the deformation of different layers in relation to neutral layer. Find also an expression for the internal bending moment about the neutral layer. 2+3

(OR)

[CO3]

5. Derive an expression for the velocity profile for a steady flow of an incompressible viscous liquid through a horizontal tube of length l and radius a. Calculate the amount of liquid that flows per sec through an imaginary coaxial tube of same length and radius $\frac{a}{2}$. 3+2

[CO1]

9. *(a)* A particle of mass m is subjected to a central force $F(r)$ only. Its angular momentum is L. Let r and θ be the polar coordinates in the plane of the motion of the particle. Derive the following differential equation for orbit of the system (the path of the particle in space)

$$\frac{d^2u}{d\theta^2} = -u - \frac{m}{L^2u^2} F\left(\frac{1}{u}\right)$$

where the parameter $u = \frac{1}{r}$.

(b) The path, $r = 2a\cos\theta$ of a particle, is moving under a central force where a is constant. Find the corresponding law of force. 2+3

(OR)

[CO1]

10. A particle of mass m is in the inverse-square force field $F(r) = \frac{k}{r^2}$, where k is a negative constant. Its angular momentum is L. Calculate its $V(r)$, centrifugal potential (V_{cent}) and effective potential (V_{eff}). Draw the energy-diagram of $V(r)$, $V_{cent}(r)$ and $V_{eff}(r)$ as function of r. Suppose the motion is bound and periodic (i.e. total energy < 0), then find the distance from the center of force where the effective potential (V_{eff}) is minimum (condition for circular orbit). Evaluate the value of minimum effective potential (V_{eff}). 1+1+2+1

GROUP—B

Answer *any* **two** from **Questions 6**, **7** and **8**, *any* **one** from **Question 9** and **10** and **Question 11** (compuslory)
(Total 4 questions need to be answered)

[CO2]

6. *(a)* Define the logarithmic decrement in weakly damped harmonic oscillations. How does the damping coefficient can be found from an experimental measurement of consecutive amplitudes of the damped oscillatory motion?

(b) A spring supports a mass of 5 g which executes damped harmonic oscillations. It is found to have successive maxima of 2·1 cm and 1·3 cm. If the resistive force constant b is 10 g/s, then find the damping coefficient γ, angular frequency ω, natural frequency ω_0 and the stiffness constant k of the spring. (2+1)+2

[CO2]

7. *(a)* A bottle is floating upright in a large bucket of water. In equilibrium it is submerged to a depth d_0 below the surface of the water. Show that if it is pushed down to a depth d and released, it will execute harmonic motion and find the frequency of its oscillations. If $d_0 = 20$ cm what is the period of the oscillations?

(b) A particle is subjected to two SHMs represented by the equations $x = a_1 \sin \omega t$ and $y = a_2 \sin(2\omega t + \delta)$ in a plane acting at perpendicular to each other simultaneously. Find the resultant motion of the particle for $\delta = \pi/2$. What is the nature of the resultant curve? 2½+2½

[CO2]

8. *(a)* Consider an oscillator of mass m immersed in a viscous fluid (damped harmonic oscillator). Suppose the oscillator is subject to a restoring force proportional to the distance from a fixed point on the x-axis and a damping force proportional to the velocity v (v is not too large). The damped harmonic oscillator is also acted by an external force $F(t) = F_0 \cos \omega t$. It acts along the x-axis. Set up the differential equation for the lightly damped forced harmonic oscillator. Write down the steady state solution (derivation is not required).

(b) Define the amplitude resonance in force vibrations. The force harmonic oscillations have equal displacement amplitudes at $\omega_1 = 400/\text{s}$ and $\omega_2 = 600/\text{s}$. Find the resonance frequency at which displacement amplitude is maximum. (1+1)+3