3 Yr. Degree/4 Yr. Honours 2nd Semester Examination, 2024 (CCFUP)

Subject : Physics

Course : PHYS2011 (MAJOR)

Time: 2 Hours **Full Marks: 40**

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

1. Answer *any five* questions: 2×5=10

(a) A frame S' is moving with velocity $5\hat{\imath} + 7\hat{\jmath}$ m/s relative to an inertial frame S. A particle is moving with velocity $(t+5)\hat{\imath} + 9\hat{\jmath}$ m/s with respect to S'. Find the acceleration of the particle in the frame S'.

(b) Find the angle with the ground for which an athlete can make the longest jump in the horizontal direction.

(c) What is meant by elastic and inelastic collisions?

(d) A wheel of mass 10 kg and radius of gyration 1m is rotating with an angular velocity 90 rpm. Calculate the torque required to bring it at rest in 4 minutes.

(e) "An object becomes weightless in an artificial satellite."—Explain.

(f) A particle moves in a force field derivable from a potential $V(x) = \frac{x^4}{4} - 2x^2 + \frac{11}{2}x^2 - 6x$. Find the position and the nature of equilibrium points.

(g) Discuss the differences between periodic motion and oscillatory motion with example.

(h) What are fictitious forces? Why are they called 'fictitious'?

2. Answer *any two* questions from the following: 5×2=10

(a) Show that $\vec{F} = (2xy + z^3)\hat{\imath} + x^2\hat{\jmath} + 3xz^2\hat{k}$ is a conservative force field. Find the associated potential. 2+3

(b) (i) A uniform sphere of radius r and radius of gyration k rolls down without slipping in an inclined plane of length l. Show that the speed v of the sphere at the bottom of the plane, starting from the top, is given by $v^2 = \frac{2gl\sin\theta}{1+k^2/r^2}$. Here, g and θ are the acceleration due to gravity and the angle of inclination, respectively.

(ii) Two spheres have the same mass and external radius. Outwardly, they look exactly similar. But one of them is solid and the other hollow. If these spheres are allowed to fall on the same inclined plane simultaneously, then which will take less time to reach the bottom? 3+2

(c) (i) Discuss the differences between the inertial mass and the gravitational mass of an object.

(ii) If the radius of the earth is $6{\cdot}637 \times 10^6$ m, its mean density is $5{\cdot}57 \times 10^3$ kgm^{-3} and gravitational constant is $6{\cdot}66 \times 10^{-11}$ $Nm^2\,kg^{-2}$, calculate the earth's surface potential. 2+3

(d) What is a compound pendulum? Determine the time period of oscillation of a compound pendulum having radius of gyration k and length l (here l is the distance of point of suspension from its centre of gravity). 2+3

3. Answer *any two* questions from the following: 10×2=20

(a) (i) Define Moment of inertia. Moment of inertia plays the same role in rotation as mass does in translation. —Explain.

(ii) Calculate the moment of inertia of a circular disc of mass M and radius r about an axis through its centre and perpendicular to its plane.

(iii) Show that, if the above disk rolls (without slipping) on a horizontal plane with angular velocity ω, then its total energy is given by $\frac{3}{4}\,Mr^2\omega^2$. (2+2)+3+3

(b) (i) Define the terms Young's modulus (Y), Rigidity modulus (n) and Poisson's ratio (σ).

(ii) Show that for a homogeneous isotropic medium $Y = 2n(1+\sigma)$ where the symbols have their usual significance.

(iii) A flexible wire of length 2m and cross-section $1\,mm^2$ is stretched tight between two points A and B in the same horizontal plane. When a mass of 10g is hung from the midpoint of the wire, it is found that this point is depressed to a distance of 1 cm below the line AB. Calculate the Young's modulus for the material of the wire. (1+1+1)+4+3

(c) (i) A particle of mass m moves under the action of a central force. Show that the orbit lies in a plane and the areal velocity is constant.

(ii) A particle of mass m moves in the x-y plane so that its position vector is given by $\vec{r} = a\cos\omega t\hat{\imath} + b\sin\omega t\hat{\jmath}$ where a, b and ω are positive constants and $a > b$. Show that (1) the particle moves on an ellipse, (2) the force is always directed towards the origin and proportional to the distance. (2+2)+(3+3)

(d) (i) A particle of mass 2 unit moves along the x-axis attracted towards the origin by a force whose magnitude is numerically equal to $8x$. If it is initially at rest $x = 20$, find the position and the velocity of the particle at any time.

(ii) What is the logarithmic decrement of a damped oscillatory system?

(iii) A particle is displaced from the equilibrium position by a distance $l = 1$ cm and then left alone. The particle starts oscillating under weakly damped condition with logarithmic decrement, $\lambda = 0\cdot02$. Prove that the particle covers nearly 2 m distance before its oscillations die down. (2+2)+2+4