'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Major 1st Semester Examination, 2024

PHYSMAJ102-PHYSICS

MECHANICS

Time Allotted: 2 Hours 30 Minutes | Full Marks: 60

The figures in the margin indicate full marks.

GROUP-A

1. Answer any ***four*** questions from the following: $3\times4=12$

(a) What are Galilean transformations? Use Galilean transformations to show that the distance between two points (x_1, y_1, z_1) and (x_2, y_2, z_2) is invariant in two inertial frames. 1+2

(b) Find the work done in stretching a wire of 1 mm^2 cross-section and 2 m length, through 0.1 mm. Given $Y=2\times10^{11}$ N/m^2. 3

(c) What do you understand by stable and unstable equilibrium? Find the position of the stable equilibrium for the potential $U(x)=\frac{1}{4}x^4-\frac{1}{2}x^2$. 2+1

(d) A satellite is in a geosynchronous orbit around the Earth. Calculate its altitude above the Earth's surface assuming the radius of the Earth to be 6400 km and the mass of the Earth to be 6×10^{24} kg. 3

(e) In a conservative force field, show that the total energy of a particle is conserved. 3

(f) Sketch the stress-strain diagram and briefly explain the graph. 3

GROUP-B

Answer any *four* questions from the following $6\times4=24$

2. What is Coriolis force? Show that the Coriolis force acting on a body of mass m in rotating frame is $-2m\vec{\omega}\times\vec{v}_r$, where $\vec{\omega}$ is the angular velocity of the rotating frame and $\vec{v}_r$ is the velocity of the body in the rotating frame. 2+4

3. (a) Why is the gravitational potential always negative? 1+5
(b) Find the gravitational potential due to a solid homogeneous sphere at a point inside it, and hence derive the corresponding field.

4. (a) Define moment of inertia of a rigid body. 2+4
(b) Calculate the moment of inertia of a solid cylinder about an axis passing through its centre of mass and perpendicular to its length.

5. (a) Define rigidity modulus of a material. 2+4
(b) Show that the couple per unit twist of a rod of length l, modulus of rigidity η, radius of cross section r, is given by $\tau=\frac{\pi\eta r^4}{2l}$.

6. (a) Prove that the velocity of escape of a body from the surface of the Earth is given by $v_e = \sqrt{\dfrac{2GM}{R}}$, where G is the gravitational constant, M is the mass of the Earth and R is the radius of the Earth. 3+3

(b) A rocket ejects gas at a constant rate. The mass of the rocket at a given moment is 500 kg and it is losing mass at a rate of 5 kg/s. If the velocity of the exhaust gases relative to the rocket is 300 m/s, calculate the acceleration of the rocket at that instant. Assume the rocket is in free space and no external forces are acting on it.

7. What is centre of mass? Show that the angular momentum of a system of particles about a point is the sum of the angular momentum of the centre of mass about the point and the angular momentum of the particles with respect to the centre of mass. 1+5

GROUP-C

Answer any *two* questions from the following $12\times2=24$

8. (a) What do you mean by the terms (i) Gravitational field and (ii) Gravitational potential? 2

(b) Derive expressions for gravitational potential and intensity (i) outside (ii) inside and (iii) on the surface of a thin spherical shell. Plot graphs to show the nature of variations with distance from the centre of the spherical shell. 8+2

9. (a) For a rigid body show that the motion of the body is governed by the external forces only. 2

(b) A solid sphere is rotating about its diameter with an angular velocity ω, if its radius reduces to $1/n$ times of its original value calculate its angular velocity. 2

(c) What is radius of gyration? Calculate the radius of gyration of a uniform rod of length L about an axis passing through its centre of mass perpendicular to its length. 1+3

(d) A circular hoop of radius R starts rolling down a smooth inclined plane without slipping. Show that its acceleration down the plane is $\frac{1}{2}g\sin\theta$, where θ is the angle of the inclined plane with respect to the horizontal. 4

10. (a) State Hooke's law. 1

(b) Prove that Poisson's ratio lies between -1 and $1/2$. 3

(c) Prove that the axial modulus of elasticity is related to other elastic constants by $\chi=\kappa+\frac{4}{3}\eta$ where the symbols have their usual meanings. 5

(d) Calculate the Poisson's ratio for a material given $Y = 12.25\times10^{10}\ \mathrm{N/m^2}$ and $\eta=4.55\times10^{10}\ \mathrm{N/m^2}$. 3

11. (a) State Kepler's laws of planetary motion. 3

(b) Show that the areal velocity of a particle moving in a central force field is always constant. 3

(c) A particle of mass m is acted on by a central force. If (r, θ) be the polar co-ordinates of the particle, show that the total energy of the particle is given by $E=\dfrac{L^2}{2m}\left[\left(\dfrac{du}{d\theta}\right)^2+u^2\right]+v(r)$, where $v(r)$ is the potential energy, L is the angular momentum of the particle and $u=\dfrac{1}{r}$. 6

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