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End Semester Examination, December 2024

B.Sc. (Hons.) Physics – Vth Semester

CLASSICAL DYNAMICS (BSPH307A)

Time: 2.5 hrs.

Max Marks: **50**

Note: *All Questions are compulsory. Marks are indicated against each question.*

PART-A

Q.1 *Attempt any five questions:*

(a) A cube of mass $m = 2$ kg slides on a slope without friction. The slope makes an angle of 30 degrees with the horizontal. If the cube is released at $t = 0$ from a height of 1 m from the ground, calculate the time taken for it to reach the end of the slope if $g = 6 \text{ m/s}^2$ (i.e. height = 0 m) [CO-1] [L-2] **2**

(b) A force of 20 N acts on a 5 kg object. Calculate the object's acceleration. [CO-1] [L-3] **2**

(c) A 1.5 kg ball is dropped from a height of 20 m. Calculate the ball's velocity just before it hits the ground. (Assume $g = 9.8 \text{ m/s}^2$ and neglect air resistance.) [CO-1] [L-3] **2**

(d) What does it mean for a quantity to be conserved in the context of the Euler-Lagrange equations? [CO-1] [L-2] **2**

(e) Why can the Euler-Lagrange equations be applied to any coordinate system? How does this flexibility benefit problem-solving in classical mechanics? [CO-1] [L-2] **2**

(f) Derive the Lagrangian for a particle falling freely under the gravitational acceleration (g) of the earth, near the surface of the earth. Assume its distance from the surface of the earth is given by $h(t)$. [CO-1] [L-1] **2**

(g) Consider a simple pendulum of length l and mass M under gravitational acceleration g . The pendulum moves in a plane, and the angle it makes with the vertical is $\theta(t)$. Solve for the Lagrangian $L = T - V$, where T is the kinetic energy and V is the potential energy. [CO-1] [L-1, L-3] **2**
2x5

PART-B

Q.2 Explain how the Hamiltonian formulation of the simple pendulum provides a more general approach to solving the system's dynamics compared to the Lagrangian formulation. Specifically, how does the Hamiltonian formalism help in understanding conserved quantities like energy and momentum in the system? [CO-2] [L-2] **10**

OR

Consider a particle of mass m falling straight towards a planet of mass M . Consider the center of the planet to be the origin of our Cartesian coordinate system (x, y, z) and let the distance between the centers of the particle and planet be $r = \sqrt{x^2 + y^2 + z^2}$.

a) Write the expression for the kinetic energy of the particle in terms of r .

b) Write the expression for the potential energy of the particle in terms of r (remember that conventionally we assign potential energy at infinite distance to be zero).

c) Write the expression for the Lagrangian of the particle. [CO-2] [L-2] **10**

- Q.3 A particle has a rest mass of 1 kg and is moving at a speed of $0.9c$. Calculate its relativistic momentum and total energy. [CO-3] [L-3] **10**

OR

Derive the relativistic Doppler effect formula for light emitted from a source moving towards an observer at a velocity of $0.5c$. [CO-3] [L-2] **10**

- Q.4 Blood, with a viscosity of $0.003 \text{ Pa}\cdot\text{s}$, flows through a blood vessel with an inner radius of 1 mm and a length of 10 cm. If the pressure difference between the two ends of the vessel is 500 Pa, calculate the flow rate using Poiseuille's equation. [CO-4] [L-3] **10**

OR

Explain Reynolds number and its significance in fluid dynamics. Discuss the conditions under which flow transitions from laminar to turbulent. Calculate the Reynolds number for water flowing at a velocity of 1 m/s in a pipe of diameter 0.05 m, and comment on whether the flow would be laminar or turbulent (use $\eta_{\text{water}}=0.001 \text{ Pa}\cdot\text{s}$ and $\rho_{\text{water}}=1000 \text{ kg/m}^3$). [CO- 4] [L-3, L-4] **10**

- Q.5 Discuss how can the geodesic equation be derived using a variational principle, specifically by extremizing the path length or action of a particle along its trajectory? [CO-1] [L-4] **10**

OR

Consider a particle of mass m moving in a central force field where the potential energy $V(r)$ depends only on the radial distance r from the origin. If the Lagrangian in polar coordinates is;

$$L = \frac{1}{2}m(\dot{r}^2 + r^2\dot{\theta}^2) - V(r)$$

use the Euler-Lagrange equations to find the equations of motion for r and θ .

[CO- 1] [L-3] **10**