Assignment Booklet

**M.Sc. (Physics) Programme
(MSCPH)**

CLASSICAL MECHANICS II

Valid from 1ˢᵗ January, 2026 to 31ˢᵗ December, 2026

**ignou
THE PEOPLE'S
UNIVERSITY**

**School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi-110068
(2026)**

Dear Student,

Please read the section on assignments in the Programme Guide for M.Sc. (Physics). A weightage of 30 per cent, as you are aware, has been earmarked for continuous evaluation, **which would consist of one tutor-marked assignment** for this course. The assignment is in this booklet. The total marks for this assignment is 100, of which 40 marks are needed to pass it.

Instructions for Formatting Your Assignments

Before attempting the assignment please read the following instructions carefully:

1) On top of the first page of your answer sheet, please write the details exactly in the following format:

<div align="center">

ENROLMENT NO.: …..………………………………………

NAME: ……………………………………………………

ADDRESS: …………………………………………

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COURSE CODE:………………………….

COURSE TITLE: …………………………

ASSIGNMENT CODE: …………………..

STUDY CENTRE: ………………………..   **DATE:** ………………………………………

PLEASE FOLLOW THE ABOVE FORMAT STRICTLY TO FACILITATE EVALUATION AND TO AVOID DELAY.

2) Use only foolscap size writing paper (but not of very thin variety) for writing your answers.

3) Leave 4 cm margin on the left, top and bottom of your answer sheet.

4) Your answers should be precise.

5) **Submit the assignment answer sheets within the due date.**

6) The assignment answer sheets are to be submitted to your Study Centre as per the schedule. **Answer sheets received after the due date shall not be accepted. We strongly suggest that you retain a copy of your answer sheets.**

7) This assignment is **valid from 1st January, 2026 to 31st December, 2026**. If you have failed in this assignment or fail to submit it by December 31, 2026, then you need to get the assignment for the year 2027, and submit it as per the instructions given in the Programme Guide.

8) **You cannot fill the examination form for this course** until you have submitted this assignment. For any queries, please contact: slamba@ignou.ac.in; mbnewmai@ignou.ac.in

We wish you good luck.

Tutor Marked Assignment
CLASSICAL MECHANICS II

Note: Attempt all questions. The marks for each question are indicated against it.

PART A

1. a) The Lagrangian for a harmonic oscillator if given as:

    $$L = \frac{1}{2}m(\dot{x}^2 + \dot{y}^2) + \frac{1}{2}m\omega^2(x^2 + y^2)$$

    The transformed coordinate under rotation about the Z-axis is given as:

    $x' = x\sin\theta + y\cos\theta$.

    Determine the corresponding y' so that the transformation leaves the Lagrangian invariant. (5)

    b) Determine the Hamiltonian and the Hamilton's equation of motion:

    i) The Lagrangian of a bead of m moving without friction along a wire bent in the shape of a parabola in the X-Y pane with $y = x^2$ is given by:

    $$L = \frac{1}{2}m(1 + 4x^2)\dot{x}^2 - mgx^2$$

    ii) The Lagrangian of a relativistic particle with charge e is given as:

    $$L = -mc^2\sqrt{1 - \left(\frac{v}{c}\right)^2} - e\phi + e\vec{A}\cdot\vec{v}\,.$$ (10)

    c) Write down the expression for the Routhian for a bead of mass m sliding due to gravity on an elliptical wire for which the Lagrangian is given as:

    $$L = \frac{1}{2}m(a^2\sin^2\theta + b^2\cos^2\theta)\dot{\theta}^2 - mgb\sin\theta$$

    Hence derive the equation of motion. (5)

    d) If $G = J_y = zp_x - xp_z$, using Poisson bracket show that G generates a roation in X-Z plane. (5)

2. a) The transformation of a 1D harmonic oscillator is given as:

    $$Q = \frac{\alpha}{q} \text{ and } P = \alpha pq^2$$

    i) Determine the Hamitonian and the value of α so that the transformation is canonical.

    ii) Obtain the generating function $F_1(q, Q)$. Using $F_1(q, Q)$, obtain $F_2(q, P)$. (20)

b) The Hamiltonian of a system with two degrees of freedom is given as:

$$H(q_1, q_2, p_1, p_2) = \frac{p_1^2}{2} + \frac{p_2^2}{2} + \sin(q_1 + 2q_2).$$

Determine the new Hamiltonian K. (5)

PART B

3. a) A simple pendulum with a bob of mass m and a string of length l_0 with Hamiltonian

$$H = \frac{p_\theta^2}{2ml_0} - mgl_0 \cos\theta .$$

Construct Hamilton-Jacobi equation and obtain the characteristic function in integral form. Write the new coordinates P,Q. (10)

b) A particle of mass m moves under a potential $V(r) = -k/r, k > 0$. The total energy of the system is

$$E = \frac{1}{2}m\dot{r}^2 + \frac{l^2}{2mr^2} - \frac{k}{r}$$

where l is the angular momentum.

i) Obtain the radial action and the angular action variables. Hence, express the total action.

ii) Determine the radial and the angular frequencies and explain their significance. (15)

4. a) Derive the expression for total energy for a heavy symmetric top. (10)

b) Obtain the expression for the rotational kinetic energy of a rigid body when the rotation is referred to its principal axes of inertia, for a spherical top (a uniform solid sphere). (5)

c) A rigid body consisting of a uniform plate with $x = y = a$ and mass M, obtain the moments of inertia (I_{xx}, I_{yy}, I_{zz}) and hence the principal moments of inertia. (10)

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