MPH-006

ASSIGNMENT BOOKLET

M.Sc. (Physics) Programme
(MSCPH)

CLASSICAL MECHANICS II

Valid from 1st January, 2025 to 31st December, 2025

School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi-110068
(2025)

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:

ENROLMENT NO.: ……

NAME: ……

ADDRESS: ……

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, 2025 to 31st December, 2025**. If you have failed in this assignment or fail to submit it by December 31, 2025, then you need to get the assignment for the year 2026, 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 and mbnewmai@ignou.ac.in

We wish you good luck.

Tutor Marked Assignment
CLASSICAL MECHANICS II

Course Code: MPH-006
Assignment Code: MPH-006/TMA/2025
Max. Marks: 100

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

PART A

1. a) (i) What is Legendre transformation of a function? Express the Legendre transformation of a Lagrangian to obtain the Hamilton's function *H*.

   (ii) The Hamiltonian of a simple harmonic oscillator is given as:

   $$H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 q^2 .$$

   Show that the velocity vector is tangential to the curve defined by the Hamiltonian. Draw a labeled diagram of the velocity vector for the phase trajectory for energy E_1. (10)

   b) Consider a particle of mass *m* moving in a plane attracted to the origin due to the potential k/r :

   (i) Choose an appropriate coordinate

   (ii) Write down the Lagrangian, the momenta conjugate to your choice of coordinates, the Hamiltonian and the action for the system.

   (iii) Show that the action is invariant under translation of time. What conservation law does this yield? (2+5+3)

   c) Consider a Lagrangian *L* where q is cyclic. Show that the momentum conjugate to q is conserved under the translation $q \to q + a$. (5)

2. a) (i) What is a canonical transformation? Why do we use canonical transformation? Give an example where a canonical transformation becomes useful.

   (ii) The Hamiltonian of a harmonic oscillator if given by

   $$H = \frac{1}{2}(p^2 + \omega^2 q^2)$$

   Solve the problem of the harmonic oscillator using canonical transformation with the generator $F = \frac{1}{2}\omega q^2 \cot(2\pi Q)$. (10)

   b) Using symplectic condition for canonical transformation, show that the transformation is canonical

   $$Q = \log(1 + \sqrt{q}\cos p),\ P = 2(1 + \sqrt{q}\cos p)\sqrt{q}\sin p$$

   Obtain the generating function $F = F_3(p, Q)$ for the transformation. (10)

   c) State Liouville's theorem and write the mathematical expression. Show that if ρ depends on q, p through the Hamiltonian $H(q, p)$, then $[\rho, H] = 0$. (5)

PART B

3. a) Consider a damped harmonic oscillator whose Lagrangian is given by:

$$L = e^{bt}\left(\frac{m\dot{q}^2}{2} - \frac{m\omega^2}{2}q^2\right) \qquad (5+10)$$

(i) Write the equation of motion and hence obtain the corresponding Hamiltonian.

(ii) Using Hamilton-Jacobi equation associated with the Hamiltonian, solve the equations of motion.

b) For a particle moving in central force field, the Hamiltonian of the system is given by

$$H = \frac{1}{2m}\left(p_r^2 + \frac{p_\theta^2}{r^2}\right)$$

Assuming the motion to be elliptical, obtain action variables J_r and J_θ. (10)

c) Use the Hamilton-Jacobi method to find Hamilton's principal function W for a particle in the three dimensional isotropic oscillator well with a potential

$$V = \frac{1}{2}k(x^2 + y^2 + z^2) = \frac{1}{2}kr^2$$

Hence obtain the corresponding momentum (p_x, p_y, and p_z) and the corresponding action variables (J_x, J_y, and J_z). (10)

4. a) Using appropriate labelled diagram, obtain the kinetic energy of a free symmetrical top of mass *M*. (10)

b) Consider a uniform square plate of length $x = y = a$ and mass *m.* Obtain the moment of inertia I_{zz} along z-axis. (5)

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