PHE-11

ASSIGNMENT BOOKLET
Bachelor's Degree Programme (B.Sc.)

MODERN PHYSICS

Valid from January 1, 2025 to December 31, 2025

It is compulsory to submit the Assignment before filling in the Term-End Examination Form.

Please Note

- You can take electives (56 or 64 credits) from a minimum of TWO and a maximum of FOUR science disciplines, viz. Physics, Chemistry, Life Sciences and Mathematics.
- You can opt for elective courses worth a MINIMUM OF 8 CREDITS and a MAXIMUM OF 48 CREDITS from any of these four disciplines.
- At least 25% of the total credits that you register for in the elective courses from Life Sciences, Chemistry and Physics disciplines must be from the laboratory courses. For example, if you opt for a total of 64 credits of electives in these 3 disciplines, at least 16 credits out of those 64 credits should be from lab courses.
- You cannot appear in the Term-End Examination of any course without registering for the course. Otherwise, your result will not be declared and the responsibility will be yours.

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

2025

Dear Student,

We hope you are familiar with the system of evaluation to be followed for the Bachelor's Degree Programme. At this stage you may probably like to re-read the section on assignments in the Programme Guide for Elective Courses that we sent you after your enrolment. 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.

Instructions for Formatting Your Assignments

Before attempting the assignment please read the following instructions carefully:

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

ENROLMENT NO. : ……

NAME : ……

ADDRESS : ……

……

……

COURSE CODE : ……..

COURSE TITLE : ……..…….

ASSIGNMENT NO. : ……..…

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) While solving problems, clearly indicate the question number along with the part being solved. Be precise. Write units at each step of your calculations as done in the text because marks will be deducted for such mistakes. Take care of significant digits in your work. Recheck your work before submitting it.

6) **This assignment will remain valid from January 1, 2025 to December 31, 2025**. However, you are advised to submit it within **12 weeks** of receiving this booklet to accomplish its purpose as a teaching-tool.

We strongly feel that you should retain a copy of your assignment response to avoid any unforeseen situation and append, if possible, a photocopy of this booklet with your response.

We wish you good luck.

Tutor Marked Assignment
MODERN PHYSICS

Course Code: PHE-11
Assignment Code: PHE-11/TMA/2025
Max. Marks: 100

Note: Attempt all questions. Symbols have their usual meanings. The marks for each question are indicated against it.

---

1. a) A spacecraft travels past Earth and Mars in a straight line at a speed $v = 0.8c$ at an instant when Earth and Mars are 2.4×10^{11} m apart; the distance being measured in the fixed frame of reference in which Earth and Mars are at rest. How far apart are Earth and Mars in the frame of the spacecraft? In the frame of the spacecraft, how much time elapses between the spacecraft crossing Earth and the spacecraft reaching Mars? (10)

   b) Neutral hydrogen atoms are moving along the axis of an evacuated tube with a speed of 2.0×10^6 ms^{-1}. A spectrometer is arranged to receive light emitted by these atoms in the direction of their forward motion. This light, if emitted from resting hydrogen atoms, would have a measured wavelength of 486.13 nm. Calculate the expected wavelength for light emitted from the approaching atoms, using the relativistic formula. (5)

   c) Show that when the kinetic energy of a relativistic particle is equal to its rest energy, the speed of the particle is ~ $0.866c$. (5)

   d) Two spacecrafts A and B moving in opposite directions are each approaching the moon with speeds of 2.2×10^8 ms^{-1} and 2.5×10^8 ms^{-1}, respectively, as observed by an observer on the moon. Calculate the speed of A with which it is (i) approaching the moon, and (ii) approaching B, as observed by an observer in A. (5)

2. a) Using Heisenberg's Uncertainty Principle explain whether a particle trapped inside a one dimensional box of finite length can be at rest. (5)

   b) An electron microscope uses an electron beam of energy 1.0 keV. Can this microscope be used to obtain the image of an individual atom? (The size of an atom $\approx 10^{-10}$ m.) (5)

   c) The quantum mechanical wave function for a particle is given by
   $\psi(x) = \begin{cases} A x^{\frac{3}{2}} e^{-\alpha x}, & x > 0 \\ 0, & x < 0 \end{cases}$. Determine (i) The normalization constant A and (ii) the most probable position of the particle. (10)

   d) The eigenvalues and eigenfunctions of a quantum mechanical operator A are denoted by a_n and ψ_n respectively. If $f(x)$ denotes a function that can be expanded in the powers of x, show that:
   $$f(A)\psi_n = f(a_n)\psi_n$$ (5)

3. a) Calculate the expectation value of the kinetic energy of a simple harmonic oscillator in its ground state. (10)

   b) Write down the wave functions (i) ψ_{210} and (ii) ψ_{300} for the hydrogen atom. Obtain the expectation value of r for the ground state hydrogen atom. (10)

   c) An *X*-ray tube operates at 40 kV. Calculate the minimum wavelength of the emitted rays. (5)

4. a) The half-life of radon $^{222}_{86}\mathrm{Rn}$ is 3.82 days. How long will it take for 60 percent of a sample of radon to decay? (5)

   b) I) State giving reasons, which of the following reactions are possible?

   i) $n^{\circ} \rightarrow p^{+} + e^{-} + \bar{\nu}_e$ (2×3)

   ii) $\pi^{-} + p \rightarrow n + \pi^{o}$

   v) $\bar{\Lambda}^{\circ} \rightarrow p + \pi^{-}$

   II) Classify the following particles as Baryons, Mesons and Leptons:

   $\mu, \quad \nu_e, \quad \Sigma^{+}, \quad \Lambda, \quad p, \quad K^{+}, \quad \eta^{0}, \quad \pi^{+}$ (4)

   c) Calculate the mass defect and binding energy per nucleon for a lithium nucleus $\left(^{7}_{3}\mathrm{L_i}\right)$:

   Mass of lithium nucleus (M) = 7.000000 u
   Mass of proton (m_p) = 1.007825 u
   Mass of neutron (m_n) = 1.008665 u
   1 u = 931 MeV (5)

   d) Draw a curve of binding energy per nucleon as a function of mass number. With the help of this curve, explain the process of fission and fusion. (5)

******