PHE-11

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

MODERN PHYSICS

Valid from January 1, 2026 to December 31, 2026

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

Please Note

- You can take electives (56 to 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 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 onus will be on you.

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

2026

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 : ……

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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, 2026 to December 31, 2026**. 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
PHE-11: Modern Physics

Course Code: PHE-11
Assignment Code: PHE-11/TMA/2026
Max. Marks: 100

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

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1. a) A muon decays spontaneously into an electron and two neutrinos. If the number of muons at $t = 0$ is N_0 and the number at time t is N where N is given by the expression $N = N_0 e^{-t/\tau}$. The mean lifetime of the muon is $\tau = 2.20\,\mu s$. If the muons are travelling with a speed of 0.95c, calculate the observed lifetime of the muons and the number of muons which remain after travelling a distance of 3.0 km. (5)

   b) Two rockets of rest length L_0 are approaching the earth from opposite directions with velocities of $\pm c/3$. How long would one of them appear to the other? (5)

   c) How fast and in what direction must a galaxy **S** be moving, if an absorbtion line observed at a wavelength of 550 nm for a stationary galaxy is shifted to 430 nm for **S**. (5)

   d) Electrons in a television set are accelerated through a potential difference of 40 kV. Assuming that the electrons start from rest, calculate their velocity using the relativistic equation for the kinetic energy. (5)

   e) A particle of mass M, initially at rest, decays into two particles with rest masses m_1 and m_2 respectively. Show that the total energy of the mass m_1 is:

$$E_1 = \frac{c^2[M^2 + m_1^2 - m_2^2]}{2M} \qquad (5)$$

2. a) Calculate the de Broglie wavelength of an electron in the first Bohr orbit of the hydrogen atom. (5)

   b) A photon and an electron each have an energy of 6.0×10^3 eV. What are their wavelengths? Which of these would you use to probe atomic structures? (5)

   c) Determine the normalization constant N for the following wavefunction:

$$\psi(r, t) = Ne^{-\frac{iEt}{\hbar}} r\, e^{-\frac{mZq^2}{\hbar^2}r}$$

   where $\psi(r, t)$ is defined over $0 \le r \le \infty$, E is the energy, Z is a constant, q is the charge of the electron, and m is the mass of the particle. (5)

   d) Estimate the minimum kinetic energy a proton confined to a nucleus of diameter 10^{-15} m may have. (5)

e) Show that

i) $\left[x, e^{-\frac{iap}{\hbar}} \right] = ae^{-\frac{iap}{\hbar}}$

ii) $[L_y, L_z] = i\hbar L_x$ (5)

3. a) The normalised eigenfunctions of a simple harmonic oscillator are given by

$$\psi_n(x) = \left(\frac{a}{\sqrt{\pi}\, 2^n\, n!} \right)^{1/2} H_n(ax)\, \exp\left(-\frac{a^2 x^2}{2} \right) \qquad n = 0, 1, 2, ...$$

Calculate $< x >$ and $< p_x >$ for the ground state harmonic oscillator eigenfunction. (10)

b) *X*-rays from a cobalt $(Z = 27)$ tube have a strong *K* line of wavelength 1.785 Å and a weak line due to chromium impurity $(Z = 24)$. Using Moseley's law, calculate the wavelength of the weak line. (5)

c) (i) Determine the average kinetic energy of the hydrogen atom in its ground state.
(ii) Using the uncertainty relation, show that the dimension of the most stable ground state of the hydrogen atom is of the order of the first Bohr radius. (10)

4. a) A radioactive sample emits *n* β-particles in 2s. In next 2s it emits 0.75 *n* β-particles. Calculate the mean life of the sample? (8)

b) In a nuclear reactor ^{235}U undergoes fission liberating 200 MeV of energy. The reactor has a 10% efficiency and produces 1000 MW power. If the reactor is to function for 10 years, find the total mass of uranium required. (6)

c) Describe the principle and working of a cyclotron. Derive an expression of the maximum kinetic energy of the particle when it reaches the outermost radius of the cyclotron. (8)

d) Write the charge, baryon number and spin of a photon and a proton. (3)

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