BPHET-141

ASSIGNMENT BOOKLET

BACHELOR'S DEGREE PROGRAMME
(BSCG)

ELEMENTS OF MODERN PHYSICS

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 B.Sc. 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. The assignment is in this booklet, and it consists of two parts, Part A and B. The total marks of all the parts are 100, of which 35% 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: ……

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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) Solve Part A and Part B of this assignment, and **submit the complete assignment answer sheets containing Parts A and B 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, mbnewmai@ignou.ac.in

We wish you good luck.

Tutor Marked Assignment
ELEMENTS OF MODERN PHYSICS

Course Code: BPHET-141
Assignment Code: BPHET-141//TMA/2025
Max. Marks: 100

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

PART A

1. a) A spacecraft *A* has a speed 0.80c with respect to the Earth. If the speed of another spacecraft *B* with respect to spacecraft *A* is 0.50c, what is the speed of *B* with respect to the Earth (5)

   b) A particle is travelling through the Earth's atmosphere at a speed of 0.6c. To an Earth-bound observer, the distance it travels is 4.0 km. How far does the particle travel in its own frame of reference? (5)

   c) A particle of rest mass 2.0 kg has an initial speed of $2\times10^{8}\,\text{ms}^{-1}$. A constant relativistic force of magnitude 1.5×10^{6} N is exerted on the particle in the same direction as the initial relativistic momentum for 1000 s. Calculate the magnitudes of the initial and final relativistic linear momentum and its final speed. (10)

   d) A star emits light with wavelength 420 nm. An observer on earth measures the wavelength of the light received from the star to be 600 nm. Calculate the speed with which the star is moving. (5)

2. a) Determine the wavelengths of the photons scattered at (i) 60° and (ii) 90° when *X*-rays of wavelength 4.5 pm are scattered from a target. (5)

   b) Calculate the de Broglie wavelength of a ^{87}Rb atom that has been laser cooled to 200 μK. (Assume that the kinetic energy is $\frac{3}{2}k_BT$). (5)

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

   d) The quantum mechanical wave function for a particle is given by

$$\psi(x)=\begin{cases} N x^{\frac{3}{2}} e^{-2x}, & x>0 \\ 0 \quad\quad , & x<0 \end{cases}$$

   Determine (i) the normalization constant *N* and(ii) the most probable position of the particle. (10)

PART B

3. a) The eigenfunction of a particle confined in a box of length L ($0 \le x \le L$) is

$$\psi(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{3\pi x}{L}\right)$$

Calculate $\left\langle \hat{p}_x{}^2 \right\rangle$ and the probability of finding the particle between $x = 0$ and $x = L/4$. (5+5)

b) A particle encounters a step potential of height V_0. What is the reflection and transmission coefficient if $E = 1.5V_0$? Show that $R + T = 1$. (5)

c) Show that, for a symmetric potential function $(V(x) = V(-x))$, the parity operator commutes with the Hamiltonian. What is the parity of the of the following eigenfunctions of a symmetric potential well of width 2a: (i) $\psi(x) = A\cos\left(\frac{3\pi x}{2a}\right)$ and (ii) $\psi(x) = A\sin\left(\frac{\pi x}{a}\right)$. (10)

4. a) The half life of ^{51}Cr is 27.70 days. After how many days will only 10% of the element be left over? (5)

b) Establish the relation for binding energy per nucleon for $^{A}_{Z}X$ nuclei. Calculate the value of binding energy per nucleon for $^{68}_{28}$Ni. Given:

Mass of Ni : 63.9280 u

Mass of proton : 1.007825 u

Mass of neutron : 1.008665 u

Is this nucleus stable? (10)

c) A piece of wood from the ruins of an ancient dwelling was found to have a ^{14}C activity of 14 disintegrations per minute per gram of its carbon content. The ^{14}C activity of living wood is 16 disintegrations per minute per gram. How long ago did the tree die from which the wood sample came? Take half-life of radiocarbon as 5760 years. (5)

d) Calculate Q-Value of the reaction:

$$^{27}_{13}\text{Al} + ^{4}_{2}\text{He} \rightarrow ^{30}_{14}\text{Si} + ^{1}_{1}\text{H}$$

Take $m\left(^{27}_{13}\text{Al}\right) = 26.9815\,\text{u}$, $m\left(^{1}_{1}\text{H}\right) = 1.0078\,\text{u}$, $m\left(^{4}_{2}\text{He}\right) = 4.0026$ u and $^{30}_{14}\text{Si} = 29.9738\,\text{u}$. (5)

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