PHE-11

BACHELOR OF SCIENCE (B.Sc.)

Term-End Examination

December, 2005

PHE-11 : MODERN PHYSICS

Time : 2 hours *Maximum Marks : 50*

Note : *Attempt **all** questions. The marks for each question are indicated against it. The symbols have their usual meanings. The values of the physical constants are given at the end. You may use log tables.*

1. Answer any ***five*** parts : 5×2

(a) Explain how the twin paradox is resolved.

(b) A rocket is moving with a speed of 0·8c with respect to the Earth in a certain direction. It is given an additional velocity 0·5c. What is its final velocity ?

(c) Explain why we do not observe the manifestations of wave particle duality in the macroscopic world.

(d) Show that for a particle moving in a circle, the uncertainty principle can be expressed as $\Delta L \Delta \theta \geq \hbar$, where L is the angular momentum and θ, the angular position of the particle.

(e) Draw the energy level diagram (upto $n = 4$) of a quantum oscillator executing simple harmonic motion.

(f) Obtain the spectral terms for the $n = 2$ state of a hydrogenic atom.

(g) State giving reasons if the following reactions are possible :

(i) $p + p \rightarrow p + \Lambda^0 + \Sigma^+$

(ii) $\pi^- + p \rightarrow n + \pi^0$

2. The Milky Way galaxy is about 10^5 light years across. For protons having relativistic energy of the order of 10^{20} eV, calculate

(a) the energy of the protons in joules,

(b) the increase in their mass, and

(c) the time taken by a proton to cross the galaxy in its own frame.

Rest mass of the proton = $1{\cdot}67 \times 10^{-27}$ kg. *1+3+6*

OR

(a) An event occurs at $x = 10$ km, $y = 1$ km, $z = 2$ km and $t = 5$ s in the frame of reference S. What are the coordinates of this event in S', moving relative to S along the xx'-axes at a speed $0{\cdot}9c$? 5

(b) A galaxy emits light of frequency $1{\cdot}2 \times 10^{15}$ Hz. It is measured to be 6×10^{14} Hz on the Earth. Calculate the speed of the galaxy with respect to the Earth. 5

3. Attempt any ***two*** parts : 2×5

(a) Show that the eigenvalues of a hermitian operator are real.

(b) The average kinetic energy of a free electron in a metal is $\left(\frac{3kT}{2}\right)$ at high temperatures. At what temperature would the electron's average de-Broglie wavelength be 0·5 nm ?

(c) Normalise the wave function $\psi(x) = A e^{-x^2}$.

4. Attempt any ***two*** parts : 2×5

(a) Determine $< r >$ for the ground state of the hydrogen atom.

(b) Explain the concept of spin angular momentum. Determine $[\sigma_x, \sigma_y]$ and $[\sigma_y, \sigma_z]$, given

$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \sigma_y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \text{ and}$$

$$\sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}.$$

(c) X-rays of wavelength 1·5 Å are incident on a sodium chloride crystal with d-spacing 2·8 Å. What is the highest order maximum that can be observed in the diffraction pattern ?

5. Attempt any ***two*** parts : 2×5

(a) Calculate the fission rate for ^{235}U required to produce 500 MW of energy and the energy released in complete fission of 500 g of ^{235}U. Energy released per fission of ^{235}U is 200 MeV.

(b) Show that the radius of curvature of the path of a particle inside a cyclotron is proportional to $\sqrt{N}$, where N is the number of times the particle is accelerated across the space between its dees.

(c) Explain the working of a nuclear reactor with the help of a schematic diagram.

Physical constants :

$h = 6{\cdot}626 \times 10^{-34}$ Js

$m_e = 9{\cdot}1 \times 10^{-31}$ kg

$k = 1{\cdot}38 \times 10^{-23}$ J K^{-1}

$N_A = 6{\cdot}02 \times 10^{23}$ mol^{-1}