

# PHYSICS

## Paper – II

Time allowed : *Three Hours*

Maximum Marks : **200**

### Question Paper Specific Instructions

*Please read each of the following instructions carefully before attempting questions :*

*There are **EIGHT** questions in all out of which **FIVE** are to be attempted.*

*Questions no. 1 and 5 are compulsory. Out of the remaining **SIX** questions, **THREE** are to be attempted selecting at least **ONE** question from each of the two Sections **A** and **B**.*

*Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.*

*All questions carry equal marks. The number of marks carried by a question/part is indicated against it.*

*Answers must be written in **ENGLISH** only.*

*Unless otherwise mentioned, symbols and notations have their usual standard meanings.*

*Assume suitable data, if necessary and indicate the same clearly.*

*Neat sketches may be drawn, wherever required.*

#### List of Useful Constants :

Mass of proton	$= 1.673 \times 10^{-27} \text{ kg}$	
Mass of neutron	$= 1.675 \times 10^{-27} \text{ kg}$	
Mass of electron	$= 9.11 \times 10^{-31} \text{ kg}$	
Planck constant	$= 6.626 \times 10^{-34} \text{ Js}$	
Boltzmann constant	$= 1.380 \times 10^{-23} \text{ JK}^{-1}$	
Bohr magneton	$= 9.273 \times 10^{-24} \text{ A m}^2$	
Nuclear magneton ( $\mu_N$ )	$= 5.051 \times 10^{-27} \text{ JT}^{-1} (\text{A m}^2)$	
Electronic charge	$= 1.602 \times 10^{-19} \text{ C}$	
Atomic mass unit (u)	$= 1.660 \times 10^{-27} \text{ kg}$	
	$= 931 \text{ MeV}$	
$g_s^p = 5.5855 \mu_N$		$m(p) = 1.00727 \text{ u}$
$m(n) = 1.00866 \text{ u}$		$m({}_2^4\text{He}) = 4.002603 \text{ u}$
$m({}_6^{12}\text{C}) = 12.00000 \text{ u}$		$m({}_{38}^{87}\text{Sr}) = 86.908893 \text{ u}$
$m({}_1^2\text{H}) = 2.014022 \text{ u}$		$m({}_1^3\text{H}) = 3.0160500 \text{ u}$

## SECTION A

- Q1. Answer all of the following :** **8×5=40**
- (a) What is the de Broglie wavelength of an electron whose kinetic energy is 100 eV? 8
- (b) Normalize the ground state wave function  
$$\psi_0(x) = A e^{(-\alpha x^2/2)}$$
for the simple harmonic oscillator and find expectation values  $\langle x \rangle$  and  $\langle x^2 \rangle$ . 8
- (c) An atom in an excited state of 4.7 eV emits a photon and ends up in the ground state. The lifetime of the excited state is  $10^{-13}$  s. Calculate the energy uncertainty and obtain the spectral line width in wavelength of photon. 8
- (d) What is Lamb shift? How is it measured? 8
- (e) Given that the rotational inertia of HCl molecule has the value  $I = 2.66 \times 10^{-47}$  kg-m<sup>2</sup>, estimate the energy difference between the lowest and first excited state of HCl. 8
- Q2.** (a) Derive an expression for transmission coefficient for a particle through a rectangular potential barrier. 20
- (b) Using WKB approximation find out the lifetime of  $\alpha$ -emitter. 20
- Q3.** (a) Show that
- (i) no two of the three components of angular momentum operator commute and 10
- (ii) the third component of the angular momentum operator commutes with the square of angular momentum operator. 10
- (b) Discuss the different coupling schemes in atomic spectroscopy with suitable diagrams. 10
- (c) Explain the origin of the anomalous Zeeman effect. 10
- Q4.** (a) Explain spin-spin and spin-lattice relaxation times in NMR spectroscopy. How do they influence the line width of the NMR line? 10
- (b) How is proton magnetic resonance applied to determine the chemical shifts in molecules containing hydrogen atom? Illustrate your answer with a suitable example. 10
- (c) What are the characteristics of a Raman spectrum? How do you study Raman spectra in the laboratory? Give two applications of Raman effect. 20

## SECTION B

**Q5. Answer all of the following :**

**8×5=40**

- (a)  ${}_{14}^{27}\text{Si}$  and  ${}_{13}^{27}\text{Al}$  are mirror nuclei. Their ground states are identical except the charge. If their mass difference is 6 MeV, estimate their radius neglecting the proton-neutron mass difference. 8
- (b) Calculate the energy released per gram of fuel for the nuclear reaction 8
- $${}_{1}^{2}\text{H} + {}_{1}^{2}\text{H} \rightarrow {}_{1}^{3}\text{H} + {}_{1}^{1}\text{H}$$
- (c) Explain why each of the following reactions is forbidden : 8
- (i)  $p + p \rightarrow p + p + n$
- (ii)  $p + p \rightarrow p + \pi^{+} + \gamma$
- (iii)  $\Xi^{0} \rightarrow n + \pi^{0}$
- (iv)  $\Lambda \rightarrow p + \pi^{0}$
- (v)  $\nu_{e} + p \rightarrow n + e^{+}$
- (d) X-ray of wavelength  $1.4 \text{ \AA}$  is found to be Bragg reflected from (111) plane of an fcc structure. If the lattice parameter of the crystal is  $5 \text{ \AA}$ , find the angle at which the X-ray beam is incident on the (111) plane of the crystal. 8
- (e) A silicon diode operates at a forward bias voltage of  $0.4 \text{ V}$ . Calculate the factor by which the current will be multiplied when the temperature is increased from  $25^{\circ}\text{C}$  to  $150^{\circ}\text{C}$  ( $\eta$  for Si = 2). 8

- Q6.** (a) How does the semi-empirical mass formula explain the stability of a nucleus against beta decay? 20
- (b) Briefly explain the meson theory of nuclear force. 10
- (c) What are the major components of a fission reactor? With a schematic diagram explain its working. 10
- Q7.** (a) Explain in detail the classification of elementary particles. 20
- (b) What is a Josephson effect? Derive an expression for the current flowing through the junction formed by two superconducting films separated by an insulator. 20

- Q8.** (a) Explain with the help of a neat diagram the structure of a n-channel FET and its IV characteristics. In what way is an FET different from a BJT? 20
- (b) Show that the NAND gate is a universal gate. 10
- (c) For the logical equation given below, form the truth table and draw the corresponding logic circuit using different gates : 10

$$Y = A \cdot B + \overline{A \cdot B}$$