CSM – 59/19

Physics

Paper – II

Time : 3 hours

Full Marks : 300

The figures in the right-hand margin indicate marks.

*Candidates should attempt Q. No. 1 from Section – A and Q. No. 5 from Section – B which are compulsory and any **three** of the remaining questions, selecting at least **one** from each Section.*

SECTION – A

1. Answer any **three** of the following : $20 \times 3 = 60$

   (a) Give any four experiments which showed the inadequacy of classical mechanics.

   (b) (i) A particle has the wave function $\Psi(r) = N e^{-\alpha r}$, where N is a normalization factor and α is a known real parameter.

Calculate the factor N and the expectation value $< r >$.

(ii) Calculate the de Broglie Wavelength for an electron with kinetic energy of 1 MeV. (Rev energy of an electron = 0.5 11 MeV).

(c) A beam of X-rays with wavelength 0.24 nm is directed towards a sample. The X-rays scatter from the electrons within the sample, imparting momentum to the electrons, which are initially at rest in the lab frame. After scattering the X-rays are detected at various angles relative to the direction of the incoming beam using a detector that can resolve their wavelength.

(i) What is the longest wavelength measured by the detector?

(ii) At what scattering angle does this occur?

(iii) For this scattering angle, what is the kinetic energy of the recoiling electron ?

(d) When the Raman Spectrum of nitrogen (^{14}N ^{14}N) was measured for the first time (before the discovery of neutron in 1932), scientists were very puzzled to find that the nitrogen nucleus has a spin of I = 1. Explain.

(i) How they could find the nuclear spin I = 1 from the Raman Spectrum ?

(ii) Why they were surprised to find I = 1 for the nitrogen nucleus ?

Before 1932, one thought the nucleus contained protons and electrons.

2. Obtain the Schrodinger equation for a free particle in one dimension and represent the wave function as a linear combination of superposition of harmonic wave. Explain how this can be generalized to three dimensions. Explain in detail.

60

3. (a) What is Raman Effect ? Explain theoretically the observed characteristics of the Raman spectrum of a diatomic molecule. How is it used to explain the structure of a molecule ? 45

(b) Explain L – S and J – J coupling schemes. Discuss the selection rules applicable in each case and the classification of electronic states. 15

4. (a) Explain how the Nuclear Magnetic Resonance (NMR) is achieved in practice. To what characteristic energy is the NMR technique sensitive ?

Outline the features of a NMR spectrometer. Write about the structural studies using NMR. 50

(b) Discuss any one of the applications of Mossbauer spectroscopy. 10

SECTION – B

5. Answer any **three** questions of the following :

(a) Explain the basic assumptions of the liquid drop model. Derive the Weizsacker's semi-empirical mass formula for a nucleus. Discuss the contribution of each term. 20

(b) What are 'magic numbers' ? Write about the shell model of the nucleus. Discuss the successes and limitations of shell model. 20

(c) (i) Explain parity violation in betadecay.

(ii) Explain the process of 'internal conversion'. 10+10 = 20

(d) (i) Explain nuclear fission process. What is the energy liberated during fission process ?

(ii) Discuss the source of energy in the Sun and the Stars. 10+10 = 20

6. (a) (i) Based on their fundamental interactions, write a detailed note on the classification of elementary particles.

(ii) Discuss, in detail, the Quark model. Also explain the importance of color quantum number in quark interactions. 15+15 = 30

(b) (i) Explain, in detail, the field quanta of electroweak and strong interactions.

(ii) Explain briefly the elementary ideas about unification of forces. 15+15 = 30

7. (a) (i) Explain how does the band theory lead to the classification of conductors, semi-conductors and insulators.

(ii) What is Meissner effect in super-conductors ? 20+10 = 30

(b) (i) Outline the applications of Josephson's Junction.

(ii) Write a note on Cubic Crystal Structure.

(iii) Enumerate the properties of high temperature superconductivity.

10+10+10 = 30

8. (a) Describe, in detail, the characteristics of Class A, B and C amplifiers. 20

(b) Explain the characteristics of an ideal operational amplifier. 20

(c) Discuss, in detail, the Ionospheric propagation of radio frequency waves. 20