2021

PHYSICS

PAPER-II

Time Allowed — 3 Hours *Full Marks — 200*

If the questions attempted are in excess of the prescribed number, only the questions attempted first up to the prescribed number shall be valued and the remaining ones ignored.

*Answers may be given either in **English** or in **Bengali** but all answers must be in one and same language.*

Group-A

Answer *any six* questions.

1. (a) Explain the concept of wave particle dualism. If matter has a wave nature, why is this wavelike character not observable in our daily experiences?

   (b) Calculate wavelength of the de Broglie wave associated with an electron having a kinetic energy of 100 eV. (3+2)+5=10

2. (a) State and explain Heisenberg's uncertainty principle. Using the concept of wave packet obtain approximately the uncertainty relation regarding position and momentum.

   (b) Applying uncertainty principle, prove that a free electron cannot exist in an atomic nucleus. (3+2)+5=10

3. Explain with the help of a block diagram the working principle of a feedback amplifier and hence find out an expression for voltage gain with feedback. What are the advantages of negative feedback? 7+3=10

4. (a) State and explain Pauli's exclusion principle. Apply it to determine the maximum number of electrons that can exist in K, L, M and N shells.

   (b) For the electronic transition ${}^1D_2 \rightarrow {}^1P_1$, draw the energy level diagram to show Zeeman splitting of energy levels ${}^1D_2$ and ${}^1P_1$ in presence of magnetic field. Also show all allowed transitions. (2+4)+4=10

5. (a) Derive an expression for the canonical partition function.

   (b) Consider a system whose three energy levels are given by 0, ϵ, and 2ϵ. The energy level ϵ is two-fold degenerate while the other two are non-degenerate. Find the partition function of the system. 5+5=10

6. (a) State and derive Bragg's law for X-ray diffraction by crystal planes.

   (b) X-rays with 1·54Å are used for the calculation of the d_{100} plane of a cubic crystal. The Bragg's angle of the first order diffraction is 10°. What is the size of the unit cell? 5+5=10

7. (a) Draw a graph of binding energy per nucleon versus mass number and explain the important features of the graph. Explain nuclear fusion from the binding energy graph with an example.

   (b) For each of the following decays state a conservation law that forbids it: (3+3)+4=10

   (i) $n \rightarrow p + e^-$

   (ii) $n \rightarrow \pi^+ + e^-$

   (iii) $n \rightarrow p + \pi^-$

   (iv) $n \rightarrow p + \gamma$

8. (a) What is Q-value of nuclear reaction? How can it be determined?

   (b) Find the mass of ${}_6C^{14}$ (in amu) from the following nuclear reaction:

$$ {}_7N^{14} + {}_0n^1 = {}_6C^{14} + {}_1H^1 + 0{\cdot}55\text{MeV} $$

   Given that the mass of proton = 1·00758 amu, mass of neutron = 1·00898 amu, mass of ${}_7N^{14}$ =14·00752 amu and 1 amu = 931 MeV. (2+3)+5=10

9. Distinguish between dia–, para– and ferromagnetic materials. Derive the Curie–Weiss law of ferromagnetism. 5+5=10

Group-B

Answer *any seven* questions.

10. (a) Starting from the time-dependent Schrödinger equation, deduce the time-independent Schrödinger equation for three dimensional motion.

    (b) What are stationary states? Why are they so called?

    (c) Find the expectation values $< x >$ and $< x^2 >$ for a Gaussian packet given by

$$ \psi(x) = \left(\frac{1}{\sigma\sqrt{\pi}}\right)^{\frac{1}{2}} \exp\left(\frac{-x^2}{2\sigma^2}\right) \exp\left(ik_0x\right) $$

5+(2+3)+(5+5)=20

11. (a) Obtain the energy eigenfunctions of a particle trapped in a one dimensional box of length L. Sketch the ground state and first excited state eigenfunctions with their probability densities.

    (b) Show that the eigenfunctions are orthogonal to one another.

    (c) Find the probability that the particle can be found between $0{\cdot}45L$ and $0{\cdot}55L$ for the ground state. (6+4)+5+5=20

12. (a) Find the minimum magnetic field needed for the Zeeman effect to be observed in a spectral line of 400 nm wavelength when a spectrometer of resolution 0·010 nm is used. Derive the necessary formula used in the calculation.

    (b) Find out whether the transitions ${}^2D_{\frac{3}{2}} \rightarrow {}^2P_{\frac{3}{2}}$ and ${}^2D_{\frac{3}{2}} \rightarrow {}^2S_{\frac{1}{2}}$ are forbidden or allowed by the selection rules.

    (c) What are Stokes' and anti-Stokes' lines? (4+6)+(3+3)+4=20

13. (a) Explain MB, FD and BE statistics, especially about their differences. How do the FD and BE distributions tend to MB distribution?

(b) Three identical particles are to be distributed in three states. What are the number of possible ways of distributing them according to MB, FD and BE statistics?

(c) Calculate the Fermi energy in electron volts for sodium assuming that it has one free electron per atom. Given that the density of sodium = $0{\cdot}97\ \text{g cm}^{-3}$ and atomic weight of sodium = 23.

(5+4)+5+6=20

14. (a) Obtain an expression for Planck's formula in terms of frequency for black-body radiation, using BE statistics.

(b) A system of two energy levels E_0 and E_1 is populated by N particles at temperature T, following classical distribution law.

(i) Derive an expression for the average energy per particle.

(ii) Derive an expression for the specific heat of the system. 10+(5+5)=20

15. (a) What are Miller indices? Show that the spacing between consecutive planes defined by Miller indices $(h\,k\,l)$ is given by $d_{hkl} = \left[\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}\right]^{-\frac{1}{2}}$.

(b) Find the possible values of the total angular-momentum quantum number J under LS coupling of two atomic electrons whose orbital quantum numbers are $l_1 = 1$ and $l_2 = 2$.

(c) A particle of energy E is incident of a rectangular potential barrier of width a and height V_0 when $E < V_0$. Find out the transmission coefficient. (3+4)+3+10=20

16. (a) Explain the classification of solids into conductors, semiconductors and insulators on the basis of band theory.

(b) The energy gap in silicon is 1·1 eV and in diamond it is 6 eV. State the transparency of these substances to visible light.

(c) Define superconductivity. Explain the effect of an external magnetic field on the superconducting state of a material. 6+6+(2+6)=20

17. (a) What are the essential features of the liquid-drop model of the nucleus? Indicate what properties of the nucleus are well predicted by this model.

(b) The nuclear binding energy may be approximated by the empirical expression

$$B.E. = a_1 A - a_2 A^{\frac{2}{3}} - a_3 \frac{Z(Z-1)}{A^{\frac{1}{3}}} - a_4 \frac{(A-2Z)^2}{A}$$

where the symbols have their usual meanings. Explain the various terms in the expression.

(c) Considering a set of isobaric nuclei, derive a relationship between A and Z for the most stable isobar.

(6+4)+6+4=20

18. (a) Simplify the following Boolean expressions:

(i) $(A+B)(\bar{A}+C)(B+C)$

(ii) $(\bar{A}+B)(A+\bar{B})+\overline{(\bar{A}\bar{B})(A\bar{B})}$

(b) Design a logic circuit to implement the following Boolean expression:

$$Y = A.B.C + A.(\bar{B}+\bar{C})$$

(c) Realize the following function using only (i) NAND gates and (ii) NOR gates: $Y=(A+C)(\bar{A}+B)$ (3+3)+4+(5+5)=20

19. (a) What ate the differences between a JFET and a BJT?

(b) An n-channel JFET has $I_{DSS}=12mA$ and pinch-off voltage $V_p=-4V$. Find the drain current for $V_{GS}=-2V$, If the transconductance g_{mo} of a JFET with the same I_{DSS} at $V_{GS}=0$ is 4 millimho, find the pinch-off voltage.

(c) Draw a circuit diagram of a differentiator using an OP AMP. Derive an expression for the output voltage. 5+(3+4)+(4+4)=20