2015

PHYSICS

[Honours]

PAPER – VI

Full Marks : 90

Time : 4 hours

The figures in the right hand margin indicate marks

GROUP – A

Answer any *two* questions : 15 × 2

1. (*a*) Draw the static characteristics of an *n*-channel JFET and explain it. What is pinch -off-voltage ? 3 + 1

(*b*) How can one use *n*-channel MOSFET in either the enhancement or the depletion region ? Give corresponding volt-ampere curve and explain. 2 + 3

(*c*) Draw a circuit diagram of a two stage RC coupled transistor amplifier. Derive an expression for the low frequency voltage gain of its. 4

(*d*) The output voltage of an amplifier is 10V at 5kHz and 7·07 V at 25 kHz. What is the decibel change in output power level ? 2

2. (*a*) What is compton effect ? Show that compton shift is independent of wavelength of incident X-rays. 1 + 4

(*b*) Show that

$$h\nu' = \frac{h\nu}{1+\in(1-\cos\theta)},$$

where $h\nu'$ and $h\nu$ are the energies of the scattered and the incident photons respectively, and $\in = \frac{h\nu}{mc^2}$, m being the rest mass of the electron, θ is the scattering angle of the photon. 3

(*c*) Explain the presence of unmodified component of X-rays in the study of compton effect. 3

(*d*) State Ehrenfest's theorem and show that

$$\frac{d}{dt}\langle x\rangle = \frac{\langle p_x\rangle}{m},$$

where the symbols have their usual meanings. 4

3. (*a*) Draw the structure of f.c.c. and b.c.c. crystals and hence calculate their packing fractions. 4

(*b*) X-rays of wavelength 0·71Å are reflected from(110) plane of a rock-salt crystal of lattice constant $a = 2{\cdot}82$Å. Calculate the corresponding glancing angle for second order reflection. 3

(*c*) In a cubic unit cell, find the angle between the normal to the planes $(h_1k_1l_1)$ and $(h_2k_2l_2)$. 3

(*d*) What do you mean by the local field ? For cubic symmetry write the expression of

local field. Derive the clausius-Mossotti relation expressing the relationship between dielectric constant and atomic polarisability. 1 + 1 + 3

4. (*a*) What is a multivibrator ? Draw the circuit diagram of an astable multivibrator using transistors and explain its operation. 1 + 1 + 4

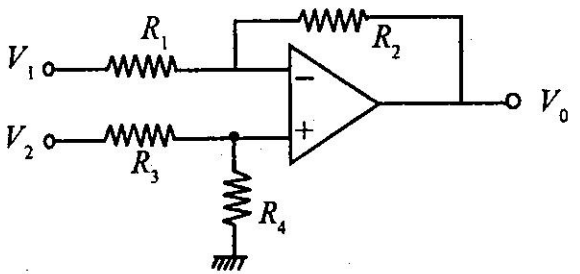
(*b*) What is Hall effect in metal ? Find an expression for the Hall coefficient of a metal. 1 + 4

(*c*) Draw a block diagram of a analog to digital converter and explain its operation. 4

GROUP – B

Answer any *five* questions : 8 × 5

5. (*a*) Find the expression for the output voltage of the following circuit : 4



(*b*) Design a circuit diagram using OPAMPs to solve the following two simultaneous equations :

$$a_1x + b_1y = c_1$$
$$\text{and } a_2x + b_2y = c_2$$

and explain the operation of the circuit. 4

6. (*a*) In connection with a CRO explain the following terms : 3

(*i*) Sweep voltage

(*ii*) Synchronization

(*iii*) Blanking circuit.

(*b*) A Lissajous pattern is obtained on a CRO screen when sinusoidal voltages are applied to the two sets of deflecting plates. The figure makes 3 tangencies with the horizontal and 5 tangencies with the vertical. If the frequency of the horizontal signal is 2kHz, find the frequency of the vertical signal. 2

(*c*) Describe different types of buses in connection with 8085 Processor. 3

7. (*a*) Show that the momentum operator $\frac{\hbar}{i}\frac{\partial}{\partial x}$ is Hermitian. 2

(*b*) Show that

$$\left[\hat{L}^2, \hat{L}_x\right] = 0$$ 3

(*c*) Show that

$$\left[\hat{L}_z, \hat{L}_\pm\right] = \pm\hbar L_\pm$$

where $\hat{L}_\pm = \hat{L}_x \pm i\hat{L}_y$. 3

8. (*a*) Define the creation (a^+) and annihilation (a) operators for a harmonic oscillator and Show that

(*i*) $\hat{H} = \hbar w\left(a^+ a + \frac{1}{2}\right)$

(*ii*) $\hat{H}a\psi_n = \left(E_n - \hbar w\right)a\psi_n$. 5

(*b*) Define number operator. In the harmonic oscillator problem, $a^+ = \frac{\hat{x} - i\hat{p}}{\sqrt{2}}$ and $a = \frac{\hat{x} + i\hat{p}}{\sqrt{2}}$

in dimensionless unit $(\hbar = m = w = 1)$. An unnormalised energy eigen function is $\psi_n = (2x^2 - 1)\exp(-x^2/2)$. What is its state ? 1 + 2

9. A potential barrier of height V_0 extended from $x = 0$ to $x = a$. Prove that for a particle of energy $E < V_0$, the transmission through the barrier is given by

$$|T|^2 = \left[1 + \frac{V_0^2}{4E(V_0 - E)} \sin h^2 \alpha a\right]^{-1}$$

where $\alpha^2 = \frac{2m(V_0 - E)}{\hbar^2}$. 8

10. (*a*) What is superconductivity ? Explain the phenomena of superconductivity. 1 + 3

(*b*) Write the general properties of superconductors. Define and discuss type I and type II superconductor. 4

11. Describe quantum theory of paramagnetism and obtain an expression for paramagnetic susceptibility for normal field strength and ordinary temperature. Explain why the theoretical results do not agree with the experimental results for the ions of the iron group. Write the modified expression for susceptibility for the ions of iron group. 5 + 2 + 1

12. (*a*) Write the schrödinger equation of a particle of mass m moving in a central potential $V(r)$. By applying the method of separation of variables, write the radial part of this equation. Identify each term of the effective potential for nonzero angular momentum. 1 + 2 + 2

(*b*) Write Pauli's spin matrices. For these spin matrices, prove the following relations : 3

(*i*) $\sigma_x\sigma_y = i\sigma_z$

(*ii*) $\sigma_x\sigma_y + \sigma_y\sigma_x = 0$

GROUP – C

Answer any *five* questions : 4 × 5

13. (*a*) Including electron spin degeneracy, prove that the hydrogen atom energy levels are $2n^2$ fold degenerate. 2

(*b*) Verify that $\psi = A \sin\theta \exp(i\phi)$ is an eigen function of L^2, where A is a constant. Identify its eigenvalue. 2

14. (*a*) Examine whether the following operators are linear or not : 2

(*i*) $\hat{A}f(x) = f(x) + x$

(*ii*) $\hat{B}f(x) = f(-x)$

(*b*) The normalised wave function of a particle is $\psi(x) = Ae^{i(ax - bt)}$, where A, a and b are constant. Evaluate the uncertainty in its momentum. 2

15. (*a*) What do you mean by CMRR of a differential amplifier ? 2

(*b*) The open-loop voltage gain of IC 741 op-amp is 10^5, and CMRR is 90 dB. Find the output voltage for 1 μV common-mode input. 2

16. An assembly language perform the following operations :

(*i*) It loads 1A H in the accumulator

(*ii*) Increments this by one

(*iii*) Stores the result in the memory location E050H.

Write the program. Which will be the content in the accumulator after execution ? 4

17. Derive an expression for binding energy for an ionic crystal and obtain the expression for Madelung constant. 4

18. The distance d_{100} between (100)-planes in bcc structure is 0·232 nm. What is the size of the unit cell ? Determine also the effective number of atoms in the unit cell. 4

19. The interatomic distance for a nickel crystal was found to be 0·91 Å . When the electrons with a kinetic energy 54 eV were scattered, the principal maximum occured at $\theta = 65^{\circ}$. Show that this experiment Verifies the de Broglie relation (Given $\sin 65^{\circ} = 0{\cdot}91$). 4

20. Show that the de Broglie wavelength of a particle of rest mass m and kinetic energy T is given by the relativistic formula

$$\lambda = \frac{hc}{\sqrt{T^2 + 2mc^2T}}$$ 4