2017

PHYSICS

[Honours]

PAPER – VI

Full Marks : 90

Time : 4 hours

The figures in the right hand margin indicate marks

Candidates are required to give their answers in their own words as far as practicable

Illustrate the answers wherever necessary

[OLD SYLLABUS]

GROUP – A

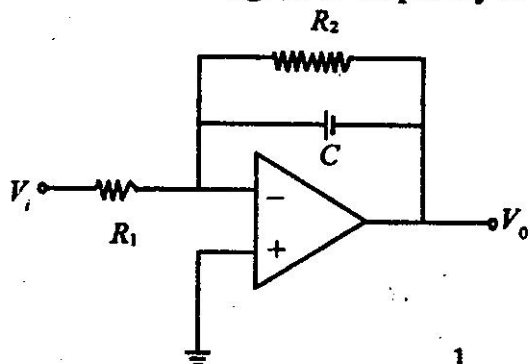
Answer any **two** questions : 15 × 2

1. (*a*) Distinguish between combinational and sequential logic circuits. Briefly discuss the operation of full-adder using half-adder with necessary diagrams and truth tables. 2 + 3

(*b*) Explain the operation of edge-triggered D flip-flop with necessary diagram and truth table. Draw the circuit of a 4-bit DAC and explain its operation. $1\frac{1}{2} + 2\frac{1}{2}$

(*c*) Briefly discuss the process of working of a microprocessor in terms of functional block diagram. 3

(*d*) Show that in the practical OP-AMP integrator circuit shown in fig. , the frequency at



which the voltage gain falls to $\frac{1}{\sqrt{2}}$ of its low frequency value ($w \approx 0$) is given by $\frac{1}{2\pi CR_2}$. 3

2. (*a*) Draw and explain the circuit diagram of a class *B* push-pull amplifier using transistor. 2 + 2

(*b*) Find an expression for the efficiency of a class *B* push-pull amplifier. 4

(*c*) Define the pinch-off voltage of a JFET. Sketch the depletion region before and after pinch-off. 1 + 3

(*d*) Find the drain-current of a *n*-channel JFET having pinch-off voltage $V_P = -6\text{V}$ and drain-source saturation current $I_{DSS} = 12\text{mA}$ at the following gate-source voltages : (*a*) $V_{GS} = \text{OV}$, (*b*) $V_{GS} = -1{\cdot}8\text{ V}$ and (*c*) $V_{GS} = -3\text{V}$. 3

3. (*a*) (*i*) For Compton scattering, show that the change in wavelength of the scattered photon is $\Delta\lambda = \frac{h}{m_0 c}(1-\cos\phi)$, where m_0 is the rest mass of electron, ϕ is the scattering angle, h is Planck constant and c is the speed of light. 5

(*ii*) If the energy of the incident photon is 1·22 MeV and that of the scattered one is 0·511 MeV, what is the scattering angle the photon ? 3

(*b*) Starting from Schrödinger equation of motion in one dimension, derive the equation of continuity. 4

(*c*) A particle wave function is given by $\psi(r) = Ae^{-Br}$, where A is the normalization constant and B is some other constant. Obtain the radial probability distribution and sketch the graph. Find the value of r at which it is maximum. 1 + 1 + 1

4. (*a*) Derive Laue's equation for X-ray diffraction by crystals. Show that these are consistent with the Bragg's law. 4 + 1

(*b*) Prove that fcc lattice is reciprocal to bcc lattice. 3

(*c*) Calculate the packing efficiency of sodium chloride.

[Given : Radius of Na^+ ion = 0·98Å, Radius of Cl^- ion = 1·81Å]. 2

(*d*) A harmonic oscillator state is described by the wave function

$$\psi(x) = \frac{1}{\sqrt{3}}\psi_0(x) + \sqrt{\frac{2}{3}}\psi_2(x),$$

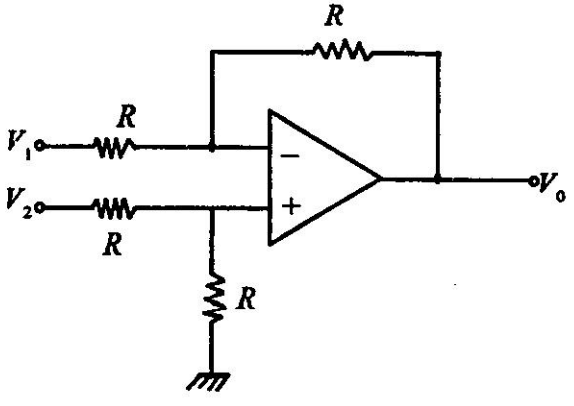
ψ_0 and ψ_2 denote the ground and the second excited eigen state of Hamiltonian respectively. Determine the expectation value of the energy of that State. 2

(*e*) Are the energy eigenfunctions for a particle in an infinite potential box of length L the momentum eigenfunctions ? If not find the correct momentum eigenfunctions. 3

GROUP – B

Answer any **five** questions : 8×5

5. (*a*) Find the output voltage in the given circuit, where the terms and symbols are of usual meaning. Find the closed loop gain with out any approximation when $V_2 = 0$. 3 + 3



(*b*) Is it possible to realize OPAMP differentiator circuit as a high-pass filter ? 2

6. (*a*) Show that

$$\langle \hat{p}_x \rangle = m\frac{d\langle \hat{x} \rangle}{dt},$$ where $\hat{x}$ and $\hat{p}_x$ denote the position and conjugate momentum operator. What does the relation imply physically. 3 + 1

(*b*) Find the constant α which makes $e^{-\beta x^2}$ an eigenfunction of the operator

$$\left(\frac{d^2}{dx^2} - \alpha x^2\right).$$ 2

(*c*) Show that the eigenstates

$$\psi_{100} = \frac{1}{\sqrt{\pi a_0^{3/2}}} e^{-r/a_0} \text{ and } \psi_{210} = \frac{1}{\sqrt{2\pi a_0^{3/2}}} \left(\frac{r}{a_0}\right) e^{-r/2a_0}$$

of the hydrogen atom are orthogonal. 2

7. (*a*) Derive an expression for deflection sensitivity of a CRT using magnetic deflection. 4

(*b*) The electron beam in a CRT enters a magnetic deflection system after being accelerated through a potential difference of 1 kV. The deflection system employs a magnetic field of 150 Gauss acting over an axial length of 1 cm. Find the deflection of the spot on the fluorescent screen placed at a distance of 20 cm from the centre of the deflection system. 2

(*c*) How can the phase difference between two ac voltages of the same frequency be measured by a CRO ? 2

8. (*a*) Determine the following operators are linear or not :

(*i*) $\hat{Q} f(x) = f(-x)$

(*ii*) $\hat{Q} f(x) = f^*(x)$. 2

(*b*) Find $\left[\hat{P}, \hat{H}\right]$ where $\hat{H}$ is the Hamiltonian operator of a linear harmonic oscillator. Hence determine whether the ground state wave function of the hamiltonian is an eigen state of momentum operator $\hat{p}$ or not. 2 + 1

(c) In the ground state of harmonic oscillator, show that the probability of finding the particle outside the classical limits is about 16%. 3

9. (a) The result form Kronig-Penney model is given by

$$p\frac{\sin \alpha a}{\alpha a} + \cos \alpha a = \cos ka$$

where $p^2 = \frac{mV_0 ba}{\hbar}$ and $\alpha^2 = \frac{2mE}{\hbar^2}$, symbols have their usual meanings. Plot the curve of the left hand side as a function of αa and draw the conclusions. 3

(b) Prove that the number of possible states in an energy band of a finite crystal is equal to the number of primitive cells in it. 2

(c) The energy near the valence band edge of a crystal is given by $E = -AK^2$, where $A = 10^{-39}$ Jm^2. An electron with wave

vector $\vec{k} = 10^{10}\,\hat{x}\,m^{-1}$ is removed from an orbital in the completely filled valence band. Determine the effective mass and momentum of the hole. 3

10. (*a*) For a one dimensional harmonic oscillator with mass m and angular frequency w, define

$$\hat{a}_{\mp} = \sqrt{\frac{mw}{2\hbar}}\left(\hat{x} \pm i\frac{\hat{P}_x}{mw}\right).$$

Using the basic commutation relation between $\hat{x}$ and $\hat{P}_x$ show that the Hamiltonian $\hat{H} = \hbar w\left(\hat{a}_+\hat{a}_- + \frac{1}{2}\right)$. Obtian the expression of ground state wavefunction. 3 + 3

(*b*) By using the principle of uncertainty, find the zero point energy of the harmonic oscillator. 2

11. Describe polarizability of atoms. Obtain Clausius Mosotti equation between polarizability and dielectric constant of a solid. 8

12. A potential barrier of height V_0 extends from $x = 0$ to $x = a$, prove that for a particle of energy $E < V_0$ the transmission probability 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 $\alpha^2 = 2m(V_0 - E)/\hbar$. 8

GROUP –C

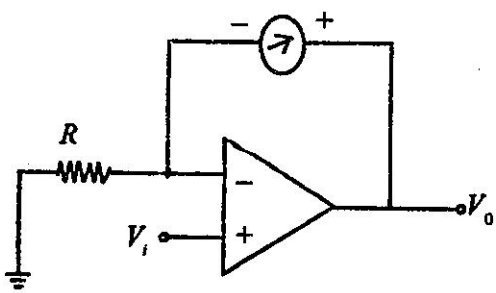
Answer any five questions : 4 × 5

13. Show that how a half-adder circuit can be constructed using only NAND gates and explain its operator. 4

14. What is *D*-type FF ? Explain its operator with logic diagram. Write its advantages over SR/FF. 4

15. (*a*) A differential amplifier has difference mode gain $A_d = 5000$ and CMRR = 1000. Find the output voltage for inputs $v_1 = 200\ \mu V$ and $v_2 = 190\ \mu V$. 2

(*b*) A moving coil meter is connected in the –ve feedback path of an OP-AMP. The meter shows a full scale deflection when a current 100 μA passes through it. Find the value of R such that the full scale deflection is obtained with $v_i = 10V$. 2



16. (*a*) What is the Hall coefficient ? What is its importance ? 1 + 1

(b) How does the critical temperature in super-conducting material relate with Debye temperature ? 2

17. A beam of silver atom moving with velocity 10^5 cm/s passes through a magnetic field of gradient 0·5 wb/m^2/cm for a distance 10 cm. What is the separation between spin up and spin down components of the beam when it comes out of the magnetic field ? Before calculation derive the expression of required separation. 4

18. An operator $\hat{A}$ does not contain time explicitly. Then show that the expectation value of this observable is constant in time if the operator representing this observable commutes with the Hamiltonian. 4

19. Determine the probability and probability current density for the Gaussion wave packet

$$\psi(x) = a\, e^{-\sigma^2 x^2/2} \cdot e^{ikx}. \qquad 2+2$$

20. Draw a full-adder circuit using basic gates. Give the truth table and Boolean expression of full-adder. 2 + 1 + 1