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1 (Sem–4) PHY 2

2025

PHYSICS

Paper : PHY0400204

(Quantum Mechanics)

Full Marks : 45

Time : 2 hours

The figures in the margin indicate full marks for the questions.

Symbols have their usual meanings.

1. Objective-type : *(Answer **all** questions)* $1\times5=5$

(a) If λ_c is the Compton shift, what is the greatest wavelength change in Compton scattering?

(b) What is the outcome of $\left[\hat{x}, e^{\hat{x}}\right]$?

(c) Plot the wavefunction $\psi(x)=\frac{1}{a^2}xe^{-x/a}$ for $x > 0$, where a is a constant and real number.

(d) What is the requirement of de Broglie wavelength of electron for the diffraction of electrons by a crystal?

(e) What is the total degeneracy in energy of H-atom with principal quantum number $n=2$?

2. Very short answer-type : *(Answer **any five** questions)* 2×5=10

(a) Write Planck's blackbody radiation formula and obtain Rayleigh-Jeans formula under limiting condition.

(b) Write the general form of the eigenvalue equations for the Hamiltonian of a one-dimensional linear harmonic oscillator and mention possible eigenvalues.

(c) What is the minimum value of the product $\Delta x \Delta p_x$? Plot Δp_x versus Δx.

1+1=2

(d) Why group velocity and not the phase velocity is considered to describe the velocity of a moving material particle?

(e) What is zero-point energy? Why it cannot be equal to zero for a particle confined in a potential box?

1+1=2

(f) If λ_p and λ_α are the de Broglie wavelengths of a proton and an alpha particle moving with same non-relativistic speeds, then find the ratio $\frac{\lambda_p}{\lambda_\alpha}$.

(g) Write the differential forms of linear momentum and energy operators. Is momentum operator Hermitian?

1+1=2

(h) An attempt is made to measure the position of an electron in an atom. The uncertainty of this measurement is 1Å. What is the minimum uncertainty in the measurement of linear momentum of the electron?

(i) Using the general expression for spherical harmonics $Y_{\ell}^{m_l}(\theta, \varphi)$, evaluate Y_1^0.

(j) Write the eigenvalue equations for the z-component of orbital angular momentum and square of the orbital angular momentum operators for a particle under the action of a spherically symmetric potential.

3. Short answer-type : *(Answer **any four** questions)* 5×4=20

(a) Obtain the normalization constant by normalizing the given wavefunction

$$\psi(x) = \frac{3}{\sqrt{10}}(a^2 - x^2) \text{ in the region}$$

$-a \le x \le a$. Hence, show the variation of the normalized wavefunction with x graphically with a mention of the peak value. 3+2=5

(b) An experiment on photoelectric effect is conducted for a metal. The stopping potentials are $4.50V$ and $0.20V$ corresponding to light wavelengths $190nm$ and $550nm$, respectively. Find the work function of the metal.

(c) Provide a brief physical interpretation of wavefunction.

(d) Consider a beam of particles of mass m, moving in the positive x direction with energy E towards a potential step at $x = 0$. The potential $V(x)$ is zero for $x \le 0$ and it is $\frac{3}{4}E$ for $x > 0$. Find the reflection coefficient.

(e) Starting with time dependent Schrödinger equation, obtain the differential form of equation of continuity involving the probability current density.

(f) Briefly describe the Davisson-Germer experiment that confirms wave nature of electrons.

(g) Write the time-independent Schrödinger equation for a one-dimensional linear harmonic oscillator and provide its ground state solution using the Hermite polynomials.

(h) Find the outcome of the commutation relation,

$$\left[\hat{x}\hat{p}_y - \hat{y}\hat{p}_x, \hat{y}\hat{p}_z - \hat{z}\hat{p}_y\right]$$

4. Essay-type : *(Answer **any one** question)* 10×1=10

(a) Starting with the concept of wave packet, obtain the intensity distribution. Introduce the Gaussian form of wave packet and briefly explain its connection with a moving material particle. 7+3=10

(b) Write the time independent Schrödinger equation in three dimensions for a particle experiencing central potential and obtain its radial and angular parts in spherical polar coordinate system. Using the idea of separation of variables, find the normalized azimuthal wavefunction. 7+3=10

(c) Consider a particle inside a one-dimensional potential box having infinite potential barriers at $x=0$ and $x=L$. The wavefunction of the particle is $\psi(x)=Nx(L-x)$, where N is the normalization constant. Find the expectation values of position and linear momentum operators.

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1 (Sem–4) PHY 3

2025

PHYSICS

Paper : PHY0400304

(Analog Electronics)

Full Marks : 45

Time : 2 hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : 1×5=5

   (a) What is the output frequency of a full wave rectifier where input frequency is 100*Hz*?

   (b) In ______ amplifier, the collector current flows for less than half cycle of the input signal.

   (c) What type of amplifier is used to reject hum and static voltage induced into its input leads?

(d) The change in the output wave shape from input wave shape in an amplifier is called ________.

(e) State the biasing method of a photodiode.

2. Answer the following questions : ***(any five)*** 2×5=10

(a) Why does the frequency response of a RC coupled amplifier decrease with increasing frequency after cutoff?

(b) How is electrostatic deflection caused in a CRO?

(c) What happens when the feedback resistance of an operational amplifier is replaced by a *(i)* capacitor *(ii)* diode? Write an expression for the output voltage in each case.

(d) Why is a diode called a non-linear device?

(e) Define CMRR. What is the significance?

(f) Explain Q point of a transistor.

(g) What is static and dynamic resistance of a diode?

(h) State the principle behind light emitting diodes.

(i) State the role of coupling capacitors and bypass capacitor in a two state stage RC coupled amplifiers.

(j) State the characteristics of an ideal Op-Amp.

3. Answer the following questions : ***(any four)*** 5×4=20

(a) 1+2+2=5

(i) Draw the circuit diagram of a full wave rectifier circuit with a filter.

(ii) Draw and explain the nature of signal at various stages.

(iii) A power supply A delivers $15V$ DC with a ripple of $0{\cdot}6V_{rms}$ while another power supply B delivers $20V$ DC with a ripple of $2m\ V_{rms}$. Which power supply is better and why?

(b) 1+1+3=5

(i) Define faithful amplification of a transistor amplifier.

(ii) How is faithful amplification obtained in CE configuration?

(iii) Draw the characteristics of a transistor amplifier and show the active, cutoff and saturation region. Why does these region's occur ?

(c) How does negative feedback effect the input and output impedance of an amplifier ? How is the change profitable in practice ? 2+3=5

(d) 2+2+1=5

(i) What is Barkhausen Criteria for continuous undamped oscillations ?

(ii) How is this criteria met in RC phase-shift oscillator ?

(iii) A phase-shift oscillator uses $10pF$ capacitor. Find the value of R to produce a frequency of $1000kHz$.

(e) 2+2+1=5

(i) Draw the characteristic of Zener diode. How does this differ from a normal diode ?

(ii) On what does the breakdown voltage depend on and how can this voltage be changed ?

(iii) How is a Zener diode biased and why ?

(f) Why is CE configuration used in 90–95% of all the transistor applications ?

(g) A sinusoidal signal whose amplitude is $1V$ is applied at the input terminals of

(i) An inverting amplifier of $R_1 = 1k\Omega$, $R_F = 2k\Omega$.

(ii) A non-inverting amplifier with $R_1 = 1k\Omega$, $R_F = 2k\Omega$.

(iii) A comparator circuit.

Draw the output in each case if R_F is the feedback resistance and the power supply is $V_{CC} = \pm 10V$. What is the function of negative feedback from the analysis ? 3+2=5

(h) 1+1+3=5

(i) What is $3dB$ frequency *or* half power frequency ?

(ii) What does half power frequency denote ?

(iii) Explain the condition of distortionless amplification based on frequency response.

4. Answer the following questions : ***(any one)*** 10

(a) 2+3+5=10

(i) What is stabilization in amplifiers ?

(ii) Why is stabilization required ? Explain.

(iii) Compare stability of Fixed Bias and Voltage Divider bias explaining the reason behind this.

(b) 5+5=10

(i) How does the energy band diagram of a *P–N* junction change in forward bias and reverse biased condition ?

(ii) How is the current across the junction caused for the two conditions ? Explain with required diagrams.

(c) 2+3+5=10

(i) What are *h* parameters ?

(ii) Draw the *h* parameter equivalent circuit for a CE configuration.

(iii) Find expressions for input and output impedance of an amplifier as a function of the *h* parameter.

(d) 2+2+6=10

(i) Define Slew Rate of an OP–AMP.

(ii) What is the use of slew rate in applications of OP–AMPs ?

(iii) It is required to design a circuit using OP–AMP to obtain the output

$V_{out} = (2V_1 + 3V_2 - 4V_3)$

draw a circuit to obtain the output if V_1, V_2 and V_3 are the inputs.