2022

PHYSICS — HONOURS

Paper : CC-7

(Syllabus : 2019-2020)

[Modern Physics]

Full Marks : 50

The figures in the margin indicate full marks.

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

Answer ***question no.*** **1** and ***any four*** questions from the rest.

1. Answer ***any five*** questions : 2×5

(a) What is the importance of the Davisson–Germer experiment?

(b) Find the eigenstate of $i\frac{d}{dx}$.

(c) Is $\Psi(x,t) = c_1\psi_1(x)e^{-iE_1t/\hbar} + c_2\psi_2(x)e^{-iE_2t/\hbar}$ a stationary state?

(d) State the Superposition Principle as understood in quantum mechanics.

(e) Calculate binding energy for ${}^{16}_{8}$O. Given that

$M\left({}^{1}_{1}H\right) = 1.007825\,\text{u}$, $M\left({}^{1}_{0}n\right) = 1.008665\,\text{u}$, $M\left({}^{16}_{8}O\right) = 15.994915\,\text{u}$ and $1\,\text{u} = 931.5\,\text{MeV}$.

(f) In stable nuclei, why are neutrons in excess of protons?

(g) What is the difference between temporal coherence and spatial coherence?

2. (a) Assume we have a two-slit experiment in which the screen is replaced by a large planar array of detectors for charged particles, and normal to this and towards this is sent electrons from an electron gun. In the path between the electron gun and the detector array are two narrow slits, the line joining them being parallel to the 'screen'. What kind of pattern is detected on the detector array ("screen") when (i) both slits are open (ii) either slit is closed? Justify your answers. Suppose the electron gun emits one electron at a time. To determine which slit it passes through, we place a small detector near one of the slits. What do we observe on the 'screen'? Explain.

(b) A photon of wavelength λ is scattered by an electron, initially at rest. Show that the change in the wavelength of photon is given by $\Delta\lambda = \lambda' - \lambda = \frac{h}{m_0 c}(1-\cos\theta)$, where θ is the angle of scattering of the photon.

(c) How do you interpret the de Broglie wave in quantum mechanics? Calculate the ratio of de Broglie wavelength of an electron and an α-particle accelerated by the same potential difference.

3+4+(2+1)

3. (a) Show that the operator $\frac{d}{dx}$ is not Hermitian.

(b) Using the equations $\left[\hat{x}_i, \hat{p}_j\right] = i\hbar\delta_{ij}$ $(i, j = 1, 2, 3)$, show that for $\hat{L}_x = \hat{y}\hat{p}_z - \hat{z}\hat{p}_y, \hat{L}_y = \hat{z}\hat{p}_x - \hat{x}\hat{p}_z,$ $\hat{L}_z = \hat{x}\hat{p}_y - \hat{y}\hat{p}_x$, we must have $\left[\hat{L}_x, \hat{L}_y\right] = i\hbar\hat{L}_z$.

(c) For the first excited state of the harmonic oscillator the wave function is $x\,exp\left[-\frac{m\omega}{2\hbar}x^2\right]$.

Show that the value of the uncertainty product $\Delta x \Delta p$ is $\frac{3}{2}\hbar$.

3+4+3

4. (a) Consider 1D linear harmonic oscillator with potential

$$V(x) = \frac{1}{2}m\omega^2 x^2 .$$

The ground state wave function is given by

$$\psi(x) = \left(\frac{\alpha}{\pi}\right)^{1/4} e^{-\alpha x^2/2}, \text{ where } \alpha = \frac{m\omega}{\hbar}.$$

Calculate average kinetic energy and average potential energy and hence show that ground state energy is given by

$$E_0 = \frac{1}{2}\hbar\omega .$$

(b) Derive an expression for the time derivative of the expectation value of the momentum operator for a particle moving in one-dimension, that is, for

$$\frac{d\langle \hat{p}_x \rangle}{dt}.$$

(c) For a finite square well of depth $V(x) = -V_0$ in one-dimension, given a plane wave $Ae^{i(p_x x - Et)/\hbar}$ incident on it, discuss qualitatively what happens afterwards for various values of E relative to $|V_0|$.

5+3+2

5. (a) Is the nuclear force between two protons different from that between a proton and a neutron? Discuss.

(b) Show that in β decay ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + \beta^{-} + \bar{\nu}_e$, the kinetic energy of recoil nucleus Y is given by

$$E_Y = \left[\frac{Q + 2m_0c^2}{2M_Yc^2}\right]T_{max}$$

where Q = β disintegration energy, T_{max} = maximum kinetic energy of β particles. Assume that the motion of the recoil nucleus is non-relativistic.

(c) Discuss briefly the phenomenon of pair production. Does electron-positron pair creation by a gamma ray photon in the vicinity of a nucleus fall within the realm of non-relativistic quantum mechanics? Justify your answer. 2+4+(3+1)

6. (a) Describe the fission of a nucleus based on the liquid drop model.

(b) ${}^{235}U$ is fissile with slow neutron but ${}^{238}U$ is not, why?

(c) Write short notes on :

(i) Primary source of energy of the sun

(ii) Carbon-nitrogen-oxygen cycle (also known as the Bethe-Weiszäcker cycle), the principal source of energy in stars exceeding 1.3 solar masses. 3+3+(2+2)

7. (a) What is 'population inversion'?

(b) List the possible sources of 'line broadening'.

(c) Establish a relation between Einstein's A, B coefficients and hence comment on the incoherency observed in ordinary light. 3+3+4

(Syllabus : 2018-2019)

[Digital Systems and Applications]

Full Marks : 50

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Answer ***question no.*** **1** and ***any four*** questions from the rest.

1. Answer ***any five*** questions : 2×5

(a) Convert $(010111011001)_2$ to its hexadecimal equivalent.

(b) Subtract $(1011)_2$ from $(11100)_2$ using 2's complement method of subtraction.

(c) 'Positive logic AND gate is equivalent to negative logic OR gate'— Justify the statement.

(d) How can you construct AND gate from NOR gates?

(e) What is meant by Race Around Condition in flip-flops?

(f) Differentiate between combinational and sequential circuits.

(g) What are the various methods of triggering flip-flops?

2. (a) Implement OR gate using Diode logic with proper circuit diagram. Explain its operation and verify the truth table.

(b) What are the advantages of polysilicon in VLSI technology? How is polysilicon deposited?

(c) What are the methods of introducing dopant impurities in a wafer? (1+2+1)+(2+2)+2

3. (a) Simplify the expression :

$$Y(A,B,C,D) = \sum_m (7,9,10,11,12,13,14,15)$$ using K-map method.

(b) Draw the circuit diagram of the above expression using NAND gate only.

(c) Evaluate the sum :

$(4)_{16} + (C)_{16} = (?)_{16}$

(d) Convert $(10.7)_2$ into its decimal equivalent. 3+3+2+2

4. (a) Explain with proper circuit diagram the function of Full Adder.

(b) Design a 2's complement Adder-Subtractor.

(c) Draw the circuit diagram of an Encoder and explain its operation. 3+4+3

5. (a) What do you mean by a buffer register?

(b) Explain with proper circuit diagram the function of shift left register.

(c) Cascade two half adders to construct a full adder. 2+4+4

6. (a) Draw a D-type flip-flop using NAND gates and write down the truth table.

(b) Draw the circuit diagram and explain the function of edge triggered J-K flip-flop.

(c) Mention the differences between Astable and Monostable Multivibrator. 3+4+3

7. (a) Design and explain the operation of a 4 bit ripple counter.

(b) Convert the above ripple counter into MOD-10 counter. Draw the circuit diagram and explain operation.

(c) Mention the differences between RAM and ROM. 4+4+2

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