U.G. 4th Semester Examination - 2021

PHYSICS

Course Code : BPHSCCHC402

Course Title : Modern Physics

Full Marks : 30 Time : 2 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.

1. Answer any **ten** questions: 1×10=10

a) Bohr radius of hydrogen atom is 0.5Å. Find the momentum of the electron in this orbit, if the orbit is the ground state.

b) If ψ_m and ψ_n be two solution of Schrödinger's equation, then show that $A\psi_m + B\psi_n$ is also a solution of the same equation. (Where A, B are constant)

c) A wave-function is given by $\psi(r, t) = Ae^{i(kx-\omega t)}$ for $0 \le x \le 1$. A is a constant. Does the probability of finding the particle between x=0.25 and x=0.5 changes with time?

d) If $\hat{x}$ and $\hat{p}_x$ are two operators corresponding to two observables x and p. If it is possible to measure these two observables simultaneously with full accuracy. What is the value of $[\hat{x}, \hat{p}]$?

e) Assuming that the lowest energy of a particle confined in an infinite potential box to be 40ev. Calculate its energy in the first excited state.

f) $\hat{H}\psi = E\psi$. What is the physical condition for which the equation follows the time independent Schrödinger equation.

g) Show that Planck's constant has the dimension of angular momentum.

h) Show that an electron moving through a potential difference of 150V has a de Broglie wavelength of 1Å.

i) What is the physical meaning of the mathematical condition, $[\hat{A}, \hat{B}] \neq 0$, where $\hat{A}$ and $\hat{B}$ are two operators corresponding to two observables?

j) Define Phase and Group velocity.

k) Planck's constant "h" is the minimum possible value of which physical quantity?

l) Write down the expression for probability current density in one dimension.

m) What is the ω and k relation for which a Gaussian wave packed doesn't broader with time?

n) A nucleus emits an α-particle followed by two β-particles. Show that the final nucleus is an isotope of the original one.

o) What is Compton effect?

2. Answer any **five** of the following questions: $2\times5=10$

a) A particle in a 2D box (L×L) has the wave function $\left(\frac{2}{L}\right)\sin\frac{n\pi}{L}x.\sin\frac{m\pi}{L}x$, n and m are positive integers. What is the minimum energy of the particle?

b) Find the eigen function of the operator $\left(x+\frac{d}{dx}\right)$.

c) A wave function is given by

$$\psi(x)=\frac{1}{2}\psi_1(x)+\frac{\sqrt{3}}{2}\psi_2(x).$$

What is the probability of existence in ψ_2 state?

d) Using the extreme single parrticle shell model, calculate the ground state, spin and parity of $_{12}Mg^{25}$.

e) A wave function is given by $\psi=Ae^{-x^2}$. Find the expectation value of x and x^2. (Domain $[-\infty,\infty]$)

f) Determine the activity of 1gm sample of Sr-90 whose half-life against β-decay is 28 years.

g) How many quantum numbers are required for representing the state of a particle under a potential for $V(\vec{r})=\frac{1}{4\pi\varepsilon}\frac{q}{|\vec{r}|}$, ε_0 and q are two constants?

h) Find the ratio of the stimulated to spontaneous emission rate at a temperature of 250°C for the salidium D-lines. $\left(\lambda=5890\,\text{Å}\right)$

3. Answer any **two** of the following questions: $5\times2=10$

a) A potential structure is given by

$$V(x)=5 \quad \text{for} \quad -1\le x\le +1$$
$$V(x)=0 \quad \text{for} \quad x>1$$
$$V(x)=0 \quad \text{for} \quad x<-1.$$

A beam of particles moving from left with energy of 4.5 unit.

i) Is there any probability of existence of particles in the region $-1\le x\le 1$?

ii) If the incident wave function is given by $\psi_{ir}=A\sin(kx-\omega t)$, find the I_{in} (I_{in}=Incident probability current density)

iii) Show that probability current density is 0 in the region $-1\le x\le 1$.

b) A particle of energy $E<V_0$ is on the following step potential from left,

$$V(x)=\begin{cases}0, & x<0, \quad \text{region}-\text{I}\\ V_0, & x\ge 0, \quad \text{region}-\text{II}\end{cases}$$

Write down the time-independent Schrodinger equation and their solution in the two regions. Calculate the reflection coefficient for $E<V_0$ case. $(1\frac{1}{2}+1\frac{1}{2})+2=5$

c) Write down the main features of liquid drop model. Within the liquid drop model briefly discuss about the following quantities contained in the binding energy of a nucleus

i) Volume energy term

ii) Surface energy term $1+2+2=5$

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