THE FINAL EXAMIATION OF PHYSICS 342, 16/11/1423

TIME: TWO HOURS

Q1

a- In the photoelectric experiment, the kinetic energy of the electron is 2.2eV for radiation of 200 μm and

1.0eV for radiation of 248 μm . Use these data to calculate the cutoff wavelength and the Planck's constant

b- A black cavity is placed in an oven of a temperature of 1650k. What is the value of the maximum

wavelength and what rate does energy escape from the cavity through a hole in its surface of a diameter of

1.0mm?

Q2

a- Two traveling waves with $\lambda_1 = 1m/s$ and $\lambda_2 = 10/9m/s$, $v_1 = 3m/s$ and $v_2 = 2.5m/s$. What are the group velocity, v_g , and the phase velocity, v_p , of their superposition (hint: $v = \frac{\omega}{k}$)?

b- Show that $V_g = v_p - \lambda \frac{dv_p}{d\lambda}$

Q3

Use the Schrodinger equation for the harmonic oscillator with the wave function $\Psi = axe^{-ax^2}$ to find the

parameter a and the energy, E, of the harmonic oscillator.

Q4

a- Given the wave function $\Psi(x) = A\sin\frac{n\pi x}{L}$, $0 \le x \le L$. Obtain the value of the constant A, what we call it ?

b- What is the probability of finding the particle in the region $0 \le x \le \frac{L}{4}$?

c- In the Thomson model, derive the deflection angle and show that $\theta_{max} = \frac{zkR^2}{mv^2}$, z is the $\alpha-$particle charge

and $k = \frac{Ze^2}{4\pi\varepsilon_0 R^3}$.

Q5

a- The angular momentum of the electron in the hydrogen atom is given by 2.15 $\times 10^{-34}\ J.s$. Find its velocity and the orbital radius.

b- What angles does $\hat{L}$ vector make with the Z-axis when l =2. Compare the angular momentum in this case with that of Bohr.

c- Define and derive the Zeeman effect.

d- Compute the change in the wavelength of the $3p \to 2s$ photon when a hydrogen atom is placed in a magnetic field of 4T.

$$h = 6.625\times10^{-34}\ J.s, e = 1.602\times10^{-19}\ C, m = 9.1\times10^{-31} kg$$

Q1

Use the Hellmann-Feynman theorem to obtain $\langle \frac{1}{r^2} \rangle$ for the hydrogen atom. Where the Hamiltonian is

$$\hat{H} = -\left(\frac{d2}{dr^2} + \frac{2}{r}\frac{d}{dr}\right) + \frac{l(l+1)}{2r} - \frac{1}{r} \quad \text{and} \quad E = -\frac{1}{2n^2}, n = k + l + 1$$

b- Which of the following potentials can be considers as solutions of the Thomas-Fermi equation and why?

$$\Phi(x)1 - \alpha x + \beta x^{3/2} + \ldots\ldots\ldots, \Phi(x) = axe^{-\alpha x}, \_\_\_\_, \Phi(x) = (ae^{-\alpha x} + be^{-\beta x})$$

Q2

Calculate the energies of the harmonic oscillator to the second order, who's Hamiltonian is $H = H_0 + ae^{-\beta x^2}$.

The wave functions are $\Psi_0 = Ae^{-\alpha x^2}, \Psi 1 = Bxe^{-\gamma x^2}$ ....

Q3

Given the matrix

$$\begin{matrix} 1 & i & 1 \\ -i & 0 & 0 \\ 1 & 0 & 0 \end{matrix}$$

a- Obtain its cofactor and its inverse.

b- What are the eigenvalue and eigenvector?

Q4

Given the scattering amplitude in the form

$$f(\Theta) = \frac{1}{k}\sum_{l=0}^{\infty}(2l+1)e^{i\delta_l} \sin \delta_l P_l(\cos\Theta)$$

What is the total scattering cross section? Show that $\sigma = \frac{4\pi}{k}\mathrm{Im}[f(0)]$

b-For a finite square well the potential is V(r) = $\begin{matrix} -V_0 & ,r\langle a \\ 0 & ,r\rangle a \end{matrix}$. Solve the Schrodinger equation inside and outside the well to obtain the total cross section ($l = 0$) .

Q5-

Use the Born approximation to find the differential cross section and the total cross section when a projectile

is scattered by a potential of the form V (r) = $-\frac{V_0}{r_0}(r + r_0), 0 \leq r \leq r_0$.

Q6-

A system is under a potential of the form V (x) = $\gamma |x|^{3/2}, \gamma\rangle 0$.

Use the WKB method to obtain the energy of the system.

Q7- Write names of four books you have used during this course.

Hint: 1- $\int_0^\infty e^{-bx^2} dx = \frac{1}{2}\sqrt{\frac{\pi}{b}}$,

$$\int_0^1 t^{y-1}(1-t)^{w-1} dt = \frac{\Gamma(y)\Gamma(w)}{\Gamma(y+w)}$$

THE FINAL EXAMIATION OF PHYSICS 353, 7/4/1424H

TIME: TWO HOURS

Q1

Show that $\int_{-\infty}^{\infty} f(y)\delta(y)dy = f(0)$ and $\int_{-\infty}^{\infty} \delta(y)dy = 1$ and $\delta(ay) = \frac{\delta(y)}{a}$, a is a constant

Q2

Use any learned method to obtain an explicit form of $\Psi_{321}(r,\theta,\varphi) = R_{32}(r)Y_2^1(\theta,\varphi)$

What is the energy of an electron in this state? What is its angular momentum?

Q3

The energy eigenvalues of a simple harmonic oscillator is given by $E_n = \hbar\omega_0(n+\frac{1}{2}), n = 1,2,3,\ldots\ldots$

Show that $n \geq -\frac{1}{2}$.

The potential of a simple harmonic oscillator is $V(x) = \frac{1}{2}kx^2$. Show that $<V> = \frac{\hbar\omega_0}{2}(n+\frac{1}{2})$.

Show that $a^+|n\rangle = \sqrt{n+1}|n+1\rangle$

Q4

Use the raising operator $L^+ = \hbar e^{i\phi}(\frac{\partial}{\partial\theta} + i\cot\theta\frac{\partial}{\partial\phi})$ to obtain the spherical harmonics $Y_2^2(\theta,\phi)$.

Q5

If $\frac{d<A>}{dt} = \frac{i}{\hbar} < \Psi\left|\hat{H},\hat{A}\right|\Psi >$, Show that $\frac{d<x>}{dt} = \bar{v}$, where $\bar{v}$ is the average velocity of a particle.

Q6

Show that for a wave function of the form $\Psi(x,t) = Ae^{if(x,t)}$, the current density takes the form

$$J = \frac{\hbar}{m} |A|^2 \frac{\partial f}{\partial x}$$

Q7

For the step potential with $V = 2E$, find the transmission and the reflection coefficients of a traveling

wave of energy E. Show that T+R=1

Q8

For the hydrogen atom, take the Hamiltonian of the form

$H = (p^2c^2 + m^2c^4)^{11/2} - mc^2 + V$, V= $-\frac{Ze^2}{r}$, and

Obtain its total energy.