MidTerm II - Modern Physics for Engineers

November 1, 1999

Test No. _____

Name: _____

S.S. No.: _____

Do all work in this exam booklet. Use the backs of the sheets if necessary. Please compute all numerical answers using your calculator if necessary. For any equations that require integrals, simplify the integrals, but leave as integrals.

Good luck.

EQUATION SHEET

$$\int f\, dV = \int f\, dx\, dy\, dz = \int f\, r^2 \sin\theta\, dr\, d\theta\, d\phi$$

$$V = \frac{1}{2} m\omega^2 x^2 \qquad\qquad V = -\frac{kq^2}{r}$$

$$\begin{aligned} E\psi &= -\frac{\hbar^2}{2m}\left(\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2}\right) + V(x)\psi \\ &= -\frac{\hbar^2}{2mr^2}\left(\frac{\partial}{\partial r} r^2 \frac{\partial\psi}{\partial r} + \frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\sin\theta\frac{\partial\psi}{\partial\theta} + \frac{1}{\sin^2\theta}\frac{\partial^2\psi}{\partial\phi^2}\right) + V(x)\psi \end{aligned}$$

$$p = \frac{h}{\lambda}$$

$$\hbar = 1.055 \times 10^{-34}\ \text{J}\cdot\text{s} = 4.136 \times 10^{-15}\ \text{eV}\cdot\text{sec}$$

Problem I Short Answers - 5 points each

1. What does "degeneracy" mean for quantum states?

2. An electron is captured in a potential of the form: $V = \infty$ for $x \leq 0$ and for $x \geq a$, $V = 0$ for $0 < x < a/2$ and $V = V_0$ for $a/2 < x < a$. Draw the potential, the wave function for the ground state where $E < V_0$, and the second excited state where $E > V_0$.

Problem I (continued)

3. Describe "Compton scattering". Tell whether it illustrates the wave or particle nature of light and why.

4. A laser can produce a light pulse that is 5 cm long. What is the minimum dispersion (error in wavelength) of such a pulse if the laser operates at 330 nm (a nitrogen laser)?

Problem II - 20 points

A particle is confined in the XY plane by the following potential:

$$V(x,y) = \begin{cases} 0 & \text{for } -a \leq x \leq a \text{ and } -a \leq y \leq a \\ \infty & \text{elsewhere.} \end{cases}$$

A solution to Schrödinger's equation for this potential is

$$\psi(x,y) = \begin{cases} A \cos \frac{\pi x}{2a} \sin \frac{\pi y}{a} & \text{where } V = 0 \text{ and} \\ 0 & \text{elsewhere.} \end{cases}$$

1. Give an equation which, when solved, will determine the value of A. **Do not solve the equation!**

2. What is the energy of this state?

Problem II Continued

3. Is this the ground state or an excited state? If an excited state, which one? Why?

4. Write out an equation that could be solved to determine the probability of finding the particle in the region $x > 0$. **Do not solve the equation!**