21002: Quantum Mechanics and Applications

2014-15 First Semester (July – November 2014)

Homework 1

Instructions

(1) Write the answers clearly and show the necessary mathematics.

(2) Doing homeworks is essential to understand the subject.

(3) For your own good, do not copy.

(4) Submission due date: 20 Aug 2014

(5) Assignment problems are not an exhaustive list of problems. You are encouraged to do more problems presented in standard books.

H1.1 The workfunction of Barium and Tungsten metal are 2.5 eV and 4.2 eV, respectively. Can these metals be used in photovoltaic cells which converts light energy to electrical energy?

H1.2 A photon of wavelength 40 nm strikes an electron at rest and is scattered at an angle of 150^{o}. Find the wavelength of the scattered photon.

H1.3 What is the maximum wavelength of light that can be absorbed by Hydrogen atom in the ground state? What will be the next smallest wavelength that will be absorbed by the same atom?

H1.4 Calculate the kinetic and potential energy of electron in the ground state of Hydrogen atom.

H1.5 What is the lowest wavelength present in Hydrogen emission spectrum?

H1.6 Evaluate the ratio of de Broglie wavelengths of electron and proton when they have the same kinetic energy.

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H1.7 An electron accelerated by 5 kV potential is located within a distance of 3 nm in an experiment. Calculate the percentage uncertainty in the momentum of the electron.

H1.8 The wavefunction of a particle of mass m moving in a potential, $V(x) = \alpha^2 x^2$ is given by $\psi(x) = e^{-\sqrt{m\alpha^2/2\hbar^2}x^2}$, where α is a constant. Find the energy of the particle.

H1.9 Consider an electron microscope which can apply a maximum of 40 kV potential to accelerate electrons. Using this microscope, what will be the smallest entity (let's call it microbe X) that can be seen? If you were to use neutrons instead of electrons in the machine, what must the energy of neutrons in order to look at microbe X?

H1.10 Consider a particle of mass m constrained to move on a circle of radius a. The time independent Schrödinger equation for this system can be written as

$$\frac{-\hbar^2}{2I}\frac{d^2(\Psi(\theta))}{d\theta^2} = E\Psi(\theta); \qquad 0 \le \theta \le 2\pi \qquad (1)$$

where $I = ma^2$ is the moment of Inertia and θ is the angle that describes the position of the particle on the ring.

(a) By substitution, show that the solutions to this equation are $\Psi(\theta) = Ae^{i\alpha\theta}$ where $\alpha = \pm\sqrt{2IE}/\hbar$.
(b) Argue that the appropriate boundary condition for this problem is $\Psi(\theta) = \Psi(\theta + 2\pi)$.
(c) Use the condition in (b) to find an expression for energy E.
(d) Find out the normalization constant A.