Ist ASSIGNMENT
Subject: Physics-II (Quantum Mechanics)
Due date: 16/01/2017

Date: **Roll No.** **Name**

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1. Consider a mass–spring system where a 4 kg mass is attached to a massless spring of constant k= 196 Nm^{-1}; the system is set to oscillate on a frictionless, horizontal table. The mass is pulled 25 cm away from the equilibrium position and then released.

   (a) Use classical mechanics to find the total energy and frequency of oscillations of the system.

   (b) Treating the oscillator with quantum theory, find the energy spacing between two consecutive energy levels and the total number of quanta involved. Are the quantum effects important in this system?

2. Use the Stefan's law to estimate the surface temperature of a star if the radiation it emits has a maximum intensity at a wavelength of 446 nm. What is the intensity radiated by the star?

3. Total energy radiated from a blackbody source is collected for one minute and is used to heat a quantity of water. The temperature of water is found to increase from 20°C to 20.5° C. If the absolute temperature of the blackbody was doubled and the experiment repeated with the same quantity of water at 20° C, find the temperature of water.

4. Estimate the wavelength of radiation emitted by human body whose body temperature is 98.6 °F.

5. A detached retina is being "welded" back in place using 20 ms pulses from a 0.50 W laser operating at wavelength of 632 nm. How many photons are in each pulse?

6. When two ultraviolet beams of wavelengths λ_1=80 nm and λ_2=110 nm fall on a lead surface, they produce photoelectrons with maximum energies 11.390 eV and 7.154 eV, respectively.

   (a) Estimate the numerical value of the Planck constant.

   (b) Calculate the work function, the cutoff frequency, and the cutoff wavelength of lead.

7. Light from the sun arrives at the earth, an average of 1.5 X 10^{-11} m away, at the rate of 1.4 X 10^{3} W/m^{2} of area perpendicular to the direction of the light. Assume that sunlight is monochromatic with a frequency of 5.0 X 10^{14} Hz. (a) how many photons fall per second on each square meter of the earth's surface directly facing the sun? (b) What is the power output of the sun, and how many photons per second does it emit? (c) How many photons per cubic meter are there near the earth?

8. A monochromatic x-ray beam whose wavelength is 55.8 pm is scattered through 46°. Find the wavelength of the scattered beam.

9. A photon of energy 3 keV collides elastically with an electron initially at rest. If the photon emerges at an angle of 60°, calculate: (a) kinetic energy of the recoiling electron (b) the angle at which the electron recoils.

10. Is Compton effect easier to observe with I.R., visible, UV or X-rays? In a Compton Effect experiment in which the incident x-rays have a wavelength of 10.0 pm, scattered x-rays at a certain angle have a wavelength of 10.5 pm. Find the momentum (magnitude and direction) of the corresponding recoil electrons.

11. Find the smallest energy that a photon can have in order to be able to transfer half of its energy to an electron at rest (rest mass of an electron is 0.5 Mev)

12. Use the uncertainty principle to estimate: (a) the Bohr radius of the hydrogen atom and (b) the ground state energy of the atom.

13. Hydrogen atoms in states of high quantum number have been created in the laboratory and observed in space. They are called Rydberg atoms. (a) Find the quantum number of the Bohr orbit in a hydrogen atom whose radius is 0.0100 mm (b) What is the energy of a hydrogen atom in this state?

14. Show that the maximum kinetic energy transferred to a proton when hit by a photon of energy hυ is

$$Kp = \frac{h\upsilon}{1 + \frac{m_p c^2}{2h\upsilon}}$$

Where m_p is the mass of proton and c is velocity.

15. Buckyballs are molecules made up of 60 carbon atoms arranged to form a geodesic sphere. Suppose that buckyballs are sent at a velocity of 100 ms^{-1} through a double slit arrangement in which the slits are separated by a distance of 150 nm. The buckyballs then strike an observation screen placed a further 1.25 m past the slits. [This is an experiment that has been done, though with a diffraction grating rather than just two slits.]

(a) Calculate the de Broglie wavelength of the buckyballs (i.e. treat them as if they were quantum objects), and estimate the distance between the maxima of the resultant interference pattern on the screen. Given that a buckyball has a diameter of approximately 1 nm and the mass of buckyball is $m = 1.1952 \times 10^{-23}$ kg,

(b) How does the size of the buckyball compare with the distance between neighbouring maxima of the interference pattern. Is the size of the C_{60} molecule likely to effect the visibility of the interference fringes? At what velocity for the molecules would the interference fringes start to become difficult to detect?

(c) The buckyballs can be set vibrating by the forces they experience as they pass through the slits. Might it be possible for this to result in the interference pattern disappearing?

16. In the two slit experiment, it is found that at a point Q directly opposite the midpoint between the two slits, the probability of an electron striking Q if slit 2 is closed is P1 = p.

(a) What is the probability P2 of an electron striking Q if slit 1 is closed?

(b) What would be the probability of an electron striking Q if both slits were open, but the slit through which each electron passed was observed? Explain your reasoning.

17. In fig. 1, There is a source (s) of particles say electrons; then there are two walls (wall 1 with **two slits** and wall 2 with **three slits**); after the wall, there is a detector located at some position x. Write down probability amplitude that a particle will be found at x?

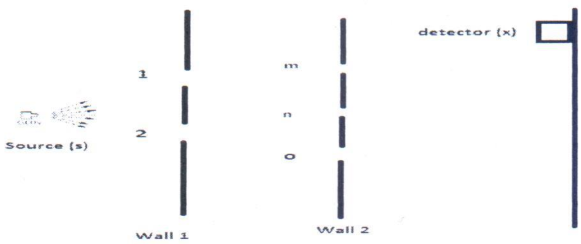

Figure 1