PYL100: Electromagnetic Waves and Quantum Mechanics (II Semester, 2016-17)

Exercise Sheet # 5

Part 2: QM History & Introduction

1) Find the energy in eV of a photon corresponding to blue light of wavelength 400 nm. Determine the maximum energy of the electron ejected by the photons corresponding to wavelength 400 nm of they fall on sodium having work function of 2.3 eV. [**Ans.**: 3.09 eV, 0.79 eV]

2) Will photoelectrons be emitted by a copper surface of work function 4.4 eV when illuminated by *visible light*? [**Ans.**: No, as λ_t = 282 nm]

3) Figure 1 below shows a graph between the stopping potential V_o and the frequency ν of the incident radiations on a photoelectric metallic surface *X*.
   (a) What is the threshold frequency?
   (b) What is the work function in *eV*?
   (c) What does the slope of the curve indicate?
   (d) Draw another curve for metal *Y* whose work function is double that of *X*.
   [**Ans.**: 2.0×10^{-15} Hz, 8.25 eV, $\frac{h}{e}$, Work function of $Y = 2 \times 8.25\ eV$, curve cuts V-axis at -16.5 V]

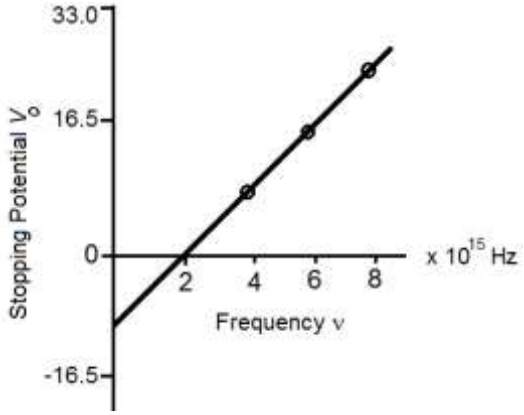

Figure 1

4) Light of wavelength 180 nm ejects photoelectrons from a metal plate whose work function is 2 eV. If a uniform magnetic field of 5×10^{-5} T is applied parallel to the plate, what would be the radius of the path followed by the electrons ejected normally from the plate with maximum energy? [**Ans.**: 0.148 m]

5) What should be the velocity of an electron if its de-Broglie wavelength is 1 μm? [**Ans.**: 720 m/s]

6) An electron and a photon each have a wavelength of 0.1 nm. What are their momenta? [**Ans.**: 6.6×10^{-24} kg ms^{-1}]

7) The light emitted by a 1 mW He-Ne laser source is attenuated by a factor of 10^{11} by passing it through an attenuator. The attenuated light is sent into an aluminium tube of length 80 cm. How many photons do you expect in the box at any given instant of time? [**Ans.**: $\approx 10^{-5}$ photons. So, not more than *one photon* is expected in the tube at any given instant of time.]

8) X-rays of wavelength 10.0 pm are scattered from a target. Find the (a) wavelength of the X-rays scattered through 45°, (b) maximum wavelength present in the scattered X-rays and (c) maximum K.E. of the recoiled electrons. [**Ans.**: 10.7 pm, 14.9 pm, 40.8 keV]

9) In a Compton collision with an electron, a photon of violet light (λ = 400 nm) is backward scattered through an angle 180°.
(a) How much energy is transferred to the electron in this collision?
(b) Compare the result with the energy the electron would acquire in a photoelectric process with the same photon. Could violet light eject electrons from a metal by Compton collision? Explain.
[**Ans.**: 37.7 μeV, 3.10 eV-W, No as energy of photons is too less.]

10) A beam of 50-keV electrons is directed from a crystal and the diffracted electrons are found at an angle of 50° relative to the original beam. What is the spacing of atomic planes of the crystal? A relativistic calculation is required for λ. [**Ans.**: 0.003 nm]

11) A two-slit electron diffraction experiment is done with slits of unequal widths. When only slit S1 is open, the number of electrons reaching the screen per second is 25 times the number of electrons reaching the screen per second when only slit S2 is open. When both slits are open, an interference pattern results in which the destructive interference is not complete. Determine the *ratio* of the probability of an electron arriving at an interference maximum to the probability of an electron arriving at an adjacent minimum. [**Ans.**: 2.25]

12) A hydrogen atom is 5.3×10^{-11} m in radius. Use the uncertainty relation to estimate the minimum KE of an electron can have in this atom. [**Ans.**: K.E. ~ 3.4 eV]

13) An excited atom gives its energy by emitting a photon of a characteristic frequency. If the average life-time of an atom in the excited state is 1×10^{-8}s, find the bandwidth of the emitted radiation.
[**Ans.**: $\Delta\nu \geq 8 \times 10^6$ Hz]

14) A flat screen is located 0.60 m away from a single slit. Light with a wavelength of 510 nm shines through the slit and produces a diffraction pattern. The width of the central bright fringe on screen is 0.050 m. What is the width of the slit? [**Ans.**: 1.2×10^{-5} m]

15) The wave function of a particle at t =0 is given by: $\psi(x) = Ce^{-\alpha^2 x^2} \quad (-\infty < x < \infty)$

where C and α are constants. Calculate the probability of finding the particle in the region $(0 < x < \infty)$. [**Ans.** 1/2]

16) The wave function of the particle at a certain instant is given as

$$\psi(x) = A\exp\left(-\frac{x^2}{a^2} + ikx\right)$$

If P_1 and P_2 denote the probability densities of finding the particle in the range a to a+da and 2a to 2a+da respectively. Find the ratio $P_1 : P_2$. [**Ans.** e^6]