PH-107 (2017)
Tutorial Sheet 2

* Problems to be done in tutorial.

A. Black Body Radiation:

P11*. According to Planck, the spectral energy density u(λ) of a blackbody maintained at temperature *T* is given by

$$u(\lambda,T)=\frac{8\pi hc}{\lambda^5}\frac{1}{e^{(hc/\lambda k_B T)}-1}$$

where λ denotes the wavelength of radiation emitted by the blackbody.

(a) Find an expression for the wavelength λ_{max} at which u(λ,T) attains its maximum value (at a fixed temperature T). λ_{max} should be in terms of temperature T and fundamental constants h, c and k_B.
(b) Expressing λ_{max} as α/T, obtain an expression for u_{max}(T) in terms of α, T and the fundamental constants.

P12. The earth rotates in a circular orbit about the sun. The radius of the orbit is 140 million km.
The radius of the earth is 6000 km and the radius of the sun is 700,000 km. The surface temperature of the sun is 6000 K. Assuming that the sun and the earth are perfect black bodies, calculate the equilibrium temperature of the earth.

B. Photoelectric Effect:

P13. Light of wavelength 2000 Å falls on a metal surface. If the work function of the metal is 4.2 eV, find the kinetic energy of the fastest and the slowest emitted photoelectrons. Also find the stopping potential and cutoff wavelength for the metal.

[**Ans.:** 2.0 eV, 0, 2V, 2960 Å]

P14. An experiment on photoelectric effect of a metal gives the result that the stopping potential for λ = 1850 Å and 5460 Å are 4.62 and 0.18 V respectively. Find the value of Planck's constant, the threshold frequency and the work function.

[**Ans.:** 6.64×10^{-34} Js, 0.5×10^{15} Hz, and 2.1 eV]

P15*. A monochromatic light of intensity 1.0 μW/cm^2 falls on a metal surface of area 1 cm^2 and work function $\phi=4.5$ eV. Assume that only 3% of the incident light is absorbed by the metal (The rest is reflected back) and that the photoemission efficiency is 100 % (i.e. each absorbed photon produces one photo-electron). The measured saturation current is 2.4×10^{-9} Amp.

(a) Calculate the number of photons/second falling on the metal surface. (b) What is the energy of the incident photon in eV ? (c) What is the stopping potential ?

A. Compton Scattering:

P16*. A photon of energy $h\nu$ is scattered through 90^o by an electron initially at rest. The scattered photon has a wavelength twice that of incident photon. Find the frequency of the incident photon and the recoil angle of the electron.

[**Ans.:** 1.23×10^{20} Hz, $\theta = 26.6^o$]

P17. Find the energy of the incident x-ray if the maximum kinetic energy of the Compton electron is $m_oc^2/2.5$.

[**Ans.:** 0.69 m_oc^2]

P18. Show that a free electron cannot absorb a photon. Hence photoelectron requires bound electron. In Compton Effect, however, the electron can be free. Why ?

P19*. Two Compton scattering experiments were performed where x-rays were scattered off free particles of mass **m**. In the first experiment, increase in wavelength, at an angle $\theta = 45^0$, is 7×10^{-14} m.

(a) Calculate the Compton wavelength and the mass of the scatterer?

E_1 and E_2 are the energies of the incident x-rays in the first and the second experiments such that $E_2=E_1/2$. In the second experiment, the wavelength of the scattered x-ray at an angle $\theta = 60^0$ is measured to be 9.9×10^{-12} m.

(b) What are the wavelengths of the incident X-rays in the two experiments?

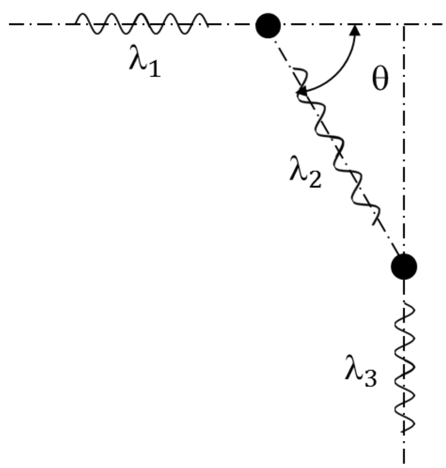
P20. Find the smallest energy that a photon may have and still transfer one half of its energy to an electron initially at rest.

[**Ans.:** 0.256MeV]

P21*: Consider Compton Scattering. Show that if the angle of scattering θ increases beyond a certain value θ_o, the scattered photon will never have energy larger than $2m_oc^2$, irrespective of the energy of the incident photon. Find the value of θ_o.

[**Ans.:** $\theta_o = 60^o$]

P22*. In a Compton scattering experiment (see figure below), X-rays scattered at an angle $\theta\left(>\frac{\pi}{4}\right)$ off a free electron initially at rest, gets re scattered by another free electron, also initially at rest.



(a) If $\delta\lambda = (\lambda_3 - \lambda_1) = 1.538\times10^{-12}\,m$, what is the value of the angle θ ?

(b) If $\lambda_2 = 68\times10^{-12}\,m$, at what angle does the first electron recoil due to collision with the X-ray photon of wavelength λ_1?