Black Body radiation:

1. At what wavelength does a cavity at 6000 K radiate most per unit wavelength?

   [Ans: 4820Å, 1.356×10^{6} J/m^{4}]

2. A cavity radiator at 6000°K has a hole 10.0mm in diameter drilled in its wall. Find the power radiated through the hole in the range 5500-5510Å. [Ans:7.51Watt]

3. A) Assuming the surface temperature of the sun to be 5700°K, use Stefan's law, to determine the rest mass lost per second to radiation by the sun. Take the sun's diameter to be 1.4×10^{9}m. b) What fraction of the sun's rest mass is lost each year from electromagnetic radiation? Take the sun's rest mass to be 2.0×10^{30}kg.

   [Ans: a) 4.094×10^{9} kg/sec, b) 6.5×10^{-14}]

4. At a given temperature, λ_{max}=6500Å for a blackbody cavity. What will λ_{max} be if the temperature of the cavity walls is increased so that the rate of emission of spectral radiation is doubled?

   [Ans: 5466Å]

5. Show that, at the wavelength λ_{max}, where $U(\lambda)$ has its maximum $U(\lambda_{max})=170\pi(kT)^5/(hc)^4$

6. Find the temperature of a cavity having a radiant energy density at 2000 A° that is 3.82 times the energy density at 4000 A°. [Ans: 17950K]

7. For heating metals, a very small hole in an electric furnace acting as a 'black body is used. If the area of the hole is 100 mm^2 and it is desired to maintain the metal at 1100°C, how much energy travels per sec through this hole? [Ans: 20.13 Watt]

8. An electric heater emits 1500W of thermal radiation. Assuming that the coils of the heater radiates like blackbody, determine its temperature. [Given: surface area of the coil=0.030m^2 and $\sigma=5.67\times10^{-8}$W/m^2/K^4.] [Ans: 969.1K]

9. Taking sun's temperature to be 5902 K, calculate the wavelength corresponding to the maximum emission of sun. [Ans: 4913Å]

10. Estimating the average human body to have a total surface area of 1.5 m^2 and skin temperature of 30°C, find the energy that one would lose in space in 30 sec (Assume the emissivity of the skin surface to be 0.9) [Ans: 1.936×10^{4} Joule]

Compton Effect & Pair-Production:

1. Prove that it is impossible for a photon to give up all its energy and momentum to a free electron, so that photoelectric effect can take place only when photons strikes bound electrons.
2. A beam of X-rays is scattered by free electrons. At 45° from the beam direction the scattered X rays have a wavelength of 0.022 Å. What is the wavelength of the X rays in the direct beam? *[0.015Å]*
3. An X rays photon whose initial frequency was 1.5 $\times 10^{19}$ sec^{-1} emerges from a collision with an electron with a frequency of 1.2 $\times 10^{19}$ sec^{-1}. How much kinetic was imparted to the electron? *[12.43KeV]*
4. An x rays photon of initial frequency 3 $\times 10^{19}$ sec^{-1} collides with an electron and is scattered through 90°. Find its new frequency. *[2.42$\times 10^{19}$ sec^{-1}]*
5. Find the energy of an X- ray photon which can impart a maximum energy of 50 KeV to an electron. *[0.141MeV]*
6. A monochromatic X-ray beam whose wavelength is 0.558Å is scattered through 46°. Find the wavelength of the scattered beam. *[0.565Å]*
7. A 1,000 Watt radio transmitter operates at a frequency of 880 KHz. How many photons per second does it emit? *[1.71$\times 10^{30}$ photons/sec]*
8. Light from the sun arrives at the earth, an average of 1.5$\times 10^{11}$ m away, at the rate of about 1,400 watts/m^2 of area perpendicular to the direction of the light. Assume that sunlight is monochromatic with a frequency of 5.0$\times 10^{14}$ 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 in watts, and how many photons per second does it emits? (c) How many photons per m^3 are there near the earth? *[4.2$\times 10^{21}$photons/m^2; 4.0$\times 10^{26}$W,1.2$\times 10^{45}$photons/s; 5.6$\times 10^{13}$ photons/m^3]*
9. Consider an X-ray beam, with λ=1.00Å, and also a γ-ray beam from a Cs^{137} sample, with λ=1.88$\times 10^{-2}$ Å. If the radiation scattered from free electrons is viewed at 90° to the incident beam (a) what is the Compton wavelength shift in each case? (b) What kinetic energy is given to a recoiling electron in each case? (c) What percentage of the incident photon energy is lost in the collision in each case? *[0.0242Å in each case, 0.295KeV & 378KeV, 2.4% & 57%]*
10. Show that maximum kinetic energy of recoiling electron is $K_{max} = \frac{2m_0C^2\lambda_C^2}{\lambda^2+2\lambda\lambda_C}$, where m_0, rest mass of electron, λ, wave length of the incident X ray beam and λ_C, the Compton wavelength.
11. Show that $\frac{\Delta E}{E}$, the fractional change in photon energy in the Compton effect, equal $(h\nu'/m_0C^2)(1-\cos\theta)$.
12. What fractional increase in wavelength leads a 75% loss of photon energy in a Compton collision?[300%]
13. Through what angle must a 0.20 MeV photon be scattered by a free electron so that it loses 10% of its energy? *[44.19°]*
14. What is the maximum possible kinetic energy of a recoiling Compton electron in terms of the incident photon energy $h\nu$ and the electron's rest mass energy m_0C^2?
15. A particular pair is produced such that the positron is at rest and the electron has a kinetic energy of 1.0 MeV moving in the direction of flight of the pair-producing photon. (a) Neglecting the energy transferred to the nucleus of the nearby atom, find the energy of the incident photon. (b) What percentage of the photon's momentum is transferred to the nucleus? [2.02 MeV, 29.7%]

de-Broglie's Waves & Uncertainty Principle:

1. An electron and a photon each have a wavelength of 2.0Å. What are their (a) momenta (b) total energies? (c) Compare the kinetic energies of the electron and the photon.
[3.31×10^{-24} kg m/s, E_e=0.51003776 MeV and E_{photon}=6200eV, $(E_K)_{electron}$=37.76 eV and $(E_K)_{photon}$=6200 eV]
2. A non relativistic particle is moving three times as fast as an electron. The ratio of their de Broglie wavelengths, particle to electron is 1.1813×10^{-4}. Identify the particle. [Neutron]
3. (a) Show that the de-Broglie wavelength of a particle, of charge 'e' rest mass m_0, moving at relativistic speeds is given as a function of the accelerating potential V as
$$\lambda = \frac{h}{\sqrt{2m_0eV}}\left(1+\frac{eV}{2m_0C^2}\right)^{-\frac{1}{2}}$$
4. Find the kinetic energy of an electron whose de-Broglie wavelength is the same as that of a 100-KeV X-ray. [9.74 KeV]
5. An electron and a proton have the same kinetic energy. Compare the wavelengths [$\lambda_e > \lambda_H$]
6. An electron and a proton have the same velocity. Compare the wavelengths. [$\lambda_e > \lambda_H$]
7. An electron and a proton have the same wavelength. Prove that the energy of the electron is greater.
8. Calculate de-Broglie wavelength of a neutron or an electron of energy 1MeV. Compare it with the wavelength of electromagnetic radiation for which the photon has the same energy.
[$\lambda_n=2.87\times10^{-14}$m, $\lambda_e=8.75\times10^{-13}$m, $\lambda_{photon}=12.43\times10^{-13}$m]
9. Show that if a particle moves with velocity 0.707C where C is the velocity of light in vacuum, then its de-Broglie wavelength and Compton wavelength become equal. [0.707C=C/√2]
10. The phase velocity of ripples on a liquid surface is $\sqrt{\frac{2\pi S}{\lambda\rho}}$, where S is the surface tension and ρ the density of the liquid. Find the group velocity of the ripples. [$v_g=(3/2)v_p$]
11. The phase velocity of ocean waves is $\sqrt{g\lambda/2\pi}$, where g is the acceleration of gravity. Find the group velocity of ocean waves. [v_g= ½ v_p]
12. Find the phase and group velocities of the de-Broglie waves of an electron whose speed is 0.900C.
13. Show that the group velocity of a wave is given by $v_g = \frac{dv}{d\left(\frac{1}{\lambda}\right)}$
14. A) show that the phase velocity of the de-Broglie waves of a particle of mass m and de-Broglie wavelength λ is given by $v_p = C\sqrt{1+(m_0C\lambda/h)^2}$
b) Compare the phase and group velocities of an electron whose de Broglie wavelength is exactly 1×10^{-13}m. [v_p = 1.01C, v_g = 0.99C]

14. An electron of mass 9.1×10^{-31} kg has a speed of 1km/sec with an accuracy of 0.05%. Calculate the uncertainty with which the position of the electron can be located. [0.232×10^{-3}m]
15. An electron is confined to a box of length 10^{-9} m. Calculate the minimum uncertainty in its velocity. [0.116×10^{6} m/s]
16. The life time of an excited state of an atom is 10^{-8} sec. Calculate the minimum uncertainty in the determination of energy of the excited state. [6.25×10^{-8} eV]
17. Show that if the uncertainty in the location of a particle is about equal to its de Broglie wavelength, than the uncertainty in its velocity is about equal to one sixth its velocity?
18. The speed of a bullet of mass 50 gm is measured to be 300 m/s with an uncertainty of 0.01%. With what accuracy can we locate the position of the bullet if it is measured simultaneously with its speed? [7.07×10^{-32}m]
19. The angular momentum of the electron in the hydrogen atom is 2ħ with an error of 5 %. Show that its angular position in a circular orbit around the nucleus cannot be specified at all.