2.7 Exercises

Photon and Blackbody Radiation

Ex 2.1. The light from a He-Ne laser has a wavelength of 632.8 nm. What is the energy in each photon of this light?

Ex 2.2. A sodium lamp emits orange-colored light of wavelength 589 nm. How many photons will be released per second by a 60 W lamp if all light is assumed to be of this wavelength?

Ex 2.3. In a green laser the light of wavelength 1064 nm produced by a Nd-doped crystal is passed through a frequency-doubler KTP which produces light of wavelength 532 nm. How many photons of 1064 nm must be produced per second if light coming out of the laser has a power of 5 mW?

Ex 2.4. Two lasers are rated at same power 10 mW. One of the lasers is the He-Ne laser which emits light at 632.8 nm and the other is a He-Cd laser which emits at 325 nm. Which laser emits photons at a higher rate?

Ex 2.5. Silicon has a bandgap of 1.1 eV. What frequency light would you need to excite an electron across this bandgap?

Ex 2.6. The power in the visible part of sun light has a maximum at wavelength of 481 nm. What should be the minimum bandgap of a semiconductor that would be needed if you are to absorb this light.

Ex 2.7. The Earth can be treated as a black body radiator at temperature 300K. What would be the maximum wavelength at which electromagnetic waves from Earth will be emitted?

Ex 2.8. The tungsten filament in an incandescent light bulb is heated to around 3000K. What would be the maximum wavelength at which electromagnetic waves from the bulb will be emitted if the surface of the filament is a perfect radiator?

Ex 2.9. The background radiation in the universe, called the cosmic microwave background radiation (CMBR), that is almost isotropic in all directions in space is a thermal radiation that follows closely the blackbody distribution with the peak at 1.06 mm. What does it say about the temperature of the universe?

Ex 2.10. The nearest star from the Solar system is Proxima Centauri which has radius $R = 1.0 \times 10^8$ m and a surface temperature of 3,000 K. Calculate the total power radiated by Proxima Centauri's surface.

Ex 2.11. A body is heated to various temperatures. The total intensity of all electromagnetic waves from the body at some temperature T_0 (in Kelvin) is found to be I_0. (a) What will be the intensity at twice the temperature, $T = 2T_0$? (b) What will be the intensity at half the temperature, $T = \frac{1}{2}T_0$?

Ex 2.12. A body is heated to various temperatures. The intensity of the electromagnetic waves from the body at some temperature T_0 (in Kelvin) is found to peak at $\lambda = \lambda_0$. (a) At what wavelength the intensity will peak if the temperature, $T = 2T_0$? (b) At what wavelength the intensity will peak if the temperature, $T = \frac{1}{2}T_0$?

Ex 2.13. Suppose your temperature is a constant 36°C. (a) If your body can be treated as a blackbody radiator, at what wavelength will the electromagnetic radiation peak? (b) If your surface area is 0.3 m^2, estimate the energy your body radiates away in one hour?

Ex 2.14. The peak intensity of Cosmic Microwave Background Radiation (CMBR) is $3.7\times10^{-18}\,\text{W m}^{-2}\text{Hz}^{-1}\text{sr}^{-1}$. The frequency at the max intensity is f_{max} 160 GHz. What will be the total intensity of the CMRB over all frequencies?

Photoelectric effect

Ex 2.15. The work function for sodium is 2.3 eV. (a) What is the maximum wavelength (or minimum frequency) of light that is capable of ejecting electrons from sodium? (b) A beam of blue light with wavelength $\lambda = 440$ nm strikes the surface of a sodium plate, decide if electrons be ejected. If yes, calculate the speed of the ejected electron that has the maximum kinetic energy. If no, explain why not.

Ex 2.16. The work function for platinum is 6.4 eV. (a) What is the maximum wavelength (or minimum frequency) of light that is capable of ejecting electrons from platinum? (b) A beam of blue light with wavelength $\lambda = 440$ nm strikes the surface of a platinum plate, decide if electrons be ejected. If yes, calculate the speed of the ejected electron that has the maximum kinetic energy. If no, explain why not. (c) What will happen if UV light of wavelength 120 nm is incident on the platinum plate? If electrons are ejected here, find the stopping potential.

Ex 2.17. An unknown metal produces a photocurrent when light of wavelength of 330 nm shines on it. A stopping potential of 0.25 V is required to stop the photocurrent. From these observations find the work function of the metal.

Ex 2.18. Light of wavelength of 125 nm and intensity 3000 W/m^2 shines on an area of 0.5 cm^2 of a gold plate. (a) What will be the stopping potential required? (b) How much photocurrent will be produced?

Ex 2.19. For this exercise do not assume that you know the value of the Planck constant h. You will use the data in this problem to find the value of h. In a photoelectric experiment it is found that stopping potential is 2.0 V when a light of wavelength 320 nm is incident on a metal surface while a stopping potential of 1.0 V is required when the wavelength of the incident light is 450 nm. (a) From the given data deduce the value of the Planck constant. (b) What is the work function of the metal?

Compton effect

Ex 2.20. X-rays of wavelength 21 pm from tungsten are incident on a graphite target, which can be considered to contain free electrons. (a) Find the Compton shift at angles (i) 30°, (ii) 60°, (iii) 90°, and (iv) 120°. (b) Find the wavelength of the X-rays at angles (i) 30°, (ii) 60°, (iii) 90°, and (iv) 120°

Ex 2.21. X-rays of wavelength 71 pm from molybdenum are incident on a graphite target and observations are made at 90° to the original direction. It is found that the detected photon has less energy than the incident X-ray due to Compton scattering. What are the (a) energy and (b) momentum of the scattered electron assuming the scattered electron to be at rest and zero binding energy.

Ex 2.22. Light of various wavelengths are incident on a free electron target and the scattered light is observed at 60° to the original direction. (a) What will be the wavelengths of the scattered light if the incident light has the following wavelengths: (i) 2 cm (Microwave), (ii) 550 nm (visible), (iii) 10 nm (uv), (iv) 21 pm (X-ray), (v) 100 fm (Gamma ray). (b) What is the percentage change in energy of the photon in each case? (c) What is the percentage change in momentum of the photon in each case?

Ex 2.23. A 100 keV X-ray scatters off a free electron target and the scattered light is observed at 90° to the original direction. (a) What will be the wavelength of the scattered light. (b) What is the percentage change in energy of the photon? (c) What is the percentage change in momentum of the photon?

Ex 2.24. A 100 GeV gamma-ray scatters off a free electron target and the scattered light is observed at 90° to the original direction. (a) What will be the wavelength of the scattered light. (b) What is the percentage change in energy of the photon? (c) What is the percentage change in momentum of the photon?