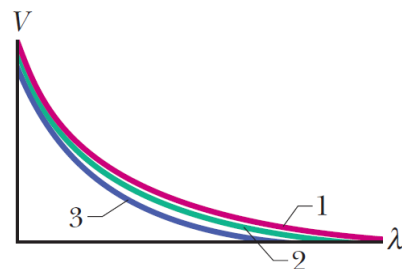


Modern Physics: MP-QZ02

2_ 1 Photon A has twice the energy of photon B. Which of the following is right about their momentum and wavelength?

(A) $p_A < p_B; \lambda_A < \lambda_B$ (B) $p_A > p_B; \lambda_A < \lambda_B$ (C) $p_A > p_B; \lambda_A > \lambda_B$ (D) $p_A < p_B; \lambda_A > \lambda_B$ (E) none of the above

1_ 2 Photoelectric effect: The figure gives the stopping voltage V versus the wavelength λ of light for three different materials. Rank the materials according to their work function, greatest first.



(A) 3, 2, 1 (B) 1, 2, 3 (C) 1, 3, 2 (D) 3, 1, 2 (E) all have the same work function

2_ 3 Which of the following is right?

(A) Both in photo-electric effect and Compton scattering photon give up all its energy to electron
 (B) in photo-electric effect photon give up all its energy to electron while in Compton scattering only part of its energy is given up
 (C) in Compton scattering photon give up all its energy to electron while in photoelectric effect only part of its energy is given up
 (D) Both in photo-electric effect and Compton scattering photon give up part of its energy to electron
 (E) it depends on the incident angle in both experiments

5_ 4 A metal plate is illuminated with light of a certain frequency. Which of the following determine whether or not electrons are ejected:

(a) the intensity of the light, (b) how long the plate is exposed to the light, (c) the thermal conductivity of the plate, (d) the area of the plate, (e) the material of which the plate is made?

2_ 5 Rank following electromagnetic radiations according to the energies of their photons, from least to greatest. 1. blue light 2. yellow light 3. x-rays 4. radio waves

(A) 1, 2, 3, 4 (B) 4, 2, 1, 3 (C) 4, 1, 2, 3 (D) 3, 2, 1, 4 (E) 3, 1, 2, 4

3_ 6 How did Planck modify the classical theory of blackbody radiation to correctly determine his radiation law?

(A) He found that the blackbody model was incorrect for purposes of theory (B) He accepted the Stefan-Boltzmann law (C) He assumed light was absorbed and emitted in quanta (D) He realized that the charge of the electron was not quantized (E) He proved the necessity of relativistic considerations

5_ 7 Which of the following are assumed when analyzing photons involved in Compton scattering?

(A) Momentum, but not energy, is conserved when the photon scatters from an electron. (B) The photon always recoils with significant energy lost to the electron. (C) The photon behaves like a wave and diffracts at an angle θ from the electron. (D) Scattering from tightly bound electrons always produces the photons with greatest wavelength change. (E) Energy and momentum are treated relativistically in the scattering.

The following 3 problems are questions about photo-electric effect:

5_ 8 Suppose the current is established with the incident light. when you increase only the intensity of the light onto the emitter, you measure

(A) A decrease in the necessary stopping voltage (B) An increase in the necessary stopping voltage (C) No change in either current or stopping voltage (D) Either a or c. You cannot determine which from the information given. (E) An increased current

3_ 9 When you increase only the frequency of the incoming light onto the emitter, you measure

(A) An increased current (B) A decrease in the necessary stopping voltage (C) An increase in the necessary stopping voltage (D) No change in either current or stopping voltage (E) Either a or c. You cannot determine which from the information given.

3_ 10 When you interchange your emitter for one with a smaller work function, you measure

(A) An increased current (B) A decrease in the necessary stopping voltage (C) An increase in the necessary stopping voltage (D) No change in either current or stopping voltage (E) Either a or c. You cannot determine which from the information given.

Problem 11

Read the paragraph of Stefan-Boltzmann law above. Now you are given 3 data of our Sun: (1)the Sun's radius $R_s = 7.0 \times 10^8 \text{ m}$; (2)the average Sun-Earth distance $R = 1.5 \times 10^{11} \text{ m}$; (3)the power per unit area (at all frequencies) from the Sun is measured at the Earth to be 1400 W/m^2 . Assume that the Sun is a blackbody. Determine the Sun's surface temperature. (02小題)

A body that absorbs *all* radiation incident on it is called an *ideal blackbody*. In 1879 Josef Stefan found an empirical relation between the power radiated by an ideal blackbody and the temperature:

$$R = \sigma T^4 \quad 3-4$$

where R is the power radiated per unit area, T is the absolute temperature, and $\sigma = 5.6703 \times 10^{-8} \text{ W/m}^2\text{K}^4$ is a constant called Stefan's constant. This result was also derived on the basis of classical thermodynamics by Ludwig Boltzmann about five years later, and Equation 3-4 is now called the Stefan-Boltzmann law. Note that the power per unit area radiated by a blackbody depends only on the temperature and not on any other characteristic of the object, such as its color or the material of which it is composed. Note, too, that R tells us the *rate* at which energy is emitted by the object. For example, doubling the absolute temperature of an object, e.g., a star, increases the energy flow out of the object by a factor of $2^4 = 16$. An object at room temperature (300°C) will double the rate at which it radiates energy as a result of a temperature increase of only 57°C . Thus, the Stefan-Boltzmann law has an enormous effect on the establishment of thermal equilibrium in physical systems.

答案空格編號:11 (a) $T = \underline{\hspace{2cm}}$ K

Ans:=5800

答案空格編號:12 (b) With the temperature you calculated in (a), determine the constant in the Wien's displacement law for λ_{max} , the wavelength at which $R(\lambda)$ is a maximum. Assume $\lambda_{max} = 500\text{nm}$ for the radiation from the Sun. The constant = $\underline{\hspace{2cm}}$ m.K

EXAMPLE 3.1 Stefan's Law Applied to the Sun

Estimate the surface temperature of the Sun from the following information. The Sun's radius is given by $R_s = 7.0 \times 10^8 \text{ m}$. The average Earth-Sun distance is $R = 1.5 \times 10^{11} \text{ m}$. The power per unit area (at all frequencies) from the Sun is measured at the Earth to be 1400 W/m^2 . Assume that the Sun is a blackbody.

Solution For a black body, we take $a = 1$, so Equation 3.4 gives

$$e_{\text{total}}(R_s) = \sigma T^4 \quad (3.5)$$

where the notation $e_{\text{total}}(R_s)$ stands for the total power per unit area at the surface of the Sun. Because the problem gives the total power per unit area at the Earth, $e_{\text{total}}(R)$, we need the connection between $e_{\text{total}}(R)$ and

$e_{\text{total}}(R_s)$. This comes from the conservation of energy:

$$e_{\text{total}}(R_s) \cdot 4\pi R_s^2 = e_{\text{total}}(R) \cdot 4\pi R^2$$

or

$$e_{\text{total}}(R_s) = e_{\text{total}}(R) \cdot \frac{R^2}{R_s^2}$$

Using Equation 3.5, we have

$$T = \left[\frac{e_{\text{total}}(R) \cdot R^2}{\sigma R_s^2} \right]^{1/4}$$

or

$$T = \left[\frac{(1400 \text{ W/m}^2)(1.5 \times 10^{11} \text{ m})^2}{(5.6 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4)(7.0 \times 10^8 \text{ m})^2} \right]^{1/4} = 5800 \text{ K}$$

Ans:=2.898E-3

Determine the size of a star

Problem 12

From previous problem. Measurement of the wavelength at which the spectral distribution $R(\lambda)$ from a certain star is maximum indicates that the star's surface temperature is 3000K. If the star is also found to radiate 100 times the power P_{Sun} radiated by the Sun, what is the radius of the star? The Sun's surface temperature is 5800 K. Hint: Use Stefann-Boltzmanns' law $R \propto T^3$, here R is the power radiated per unit area. (01小題)

答案空格編號:13 the ratio $\frac{r_{star}}{r_{Sun}} = \underline{\hspace{2cm}}$

If the Sun and the star both radiate as blackbodies (astronomers nearly always make that assumption, based on, among other things, the fact that the solar spectrum is very nearly that of an ideal blackbody), their surface temperatures from Equation 3-5 are 5800 K and 3000 K, respectively. Measurement also indicates that $P_{\text{star}} = 100 P_{\odot}$. Thus, from Equation 3-4 we have

$$R_{\text{star}} = \frac{P_{\text{star}}}{(\text{area})_{\text{star}}} = \frac{100 P_{\odot}}{4\pi r_{\text{star}}^2} = \sigma T_{\text{star}}^4$$

and

$$R_{\odot} = \frac{P_{\odot}}{(\text{area})_{\odot}} = \frac{P_{\odot}}{4\pi r_{\odot}^2} = \sigma T_{\odot}^4$$

So we have

$$\begin{aligned} r_{\text{star}}^2 &= 100 r_{\odot}^2 \left(\frac{T_{\odot}}{T_{\text{star}}} \right)^4 \\ r_{\text{star}} &= 10 r_{\odot} \left(\frac{T_{\odot}}{T_{\text{star}}} \right)^2 = 10 \left(\frac{5800}{3000} \right)^2 r_{\odot} \\ r_{\text{star}} &= 37.4 r_{\odot} \end{aligned}$$

Since $r_{\odot} = 6.96 \times 10^8$ m, this star has a radius of about 2.6×10^{10} m, or about half the radius of the orbit of Mercury. This star is a red giant (see Chapter 13).

Ans:=37.4

Photoelectric Effect of K

Problem 13

The threshold frequency of potassium is 558 nm. (a)What is the work function for potassium? (b)What is the stopping potential when light of 400 nm is incident on potassium? (02小題)

答案空格編號:14 (a) $\Phi = \underline{\hspace{2cm}}$ eV

Ans:=2.22

答案空格編號:15 (b) $V_0 = \underline{\hspace{2cm}}$ V

1. Both questions can be answered with the aid of Equation 3-21:

$$eV_0 = \left(\frac{1}{2}mv^2 \right)_{\max} = hf - \phi$$

$$V_0 = \frac{hf}{e} - \frac{\phi}{e}$$

2. At the threshold wavelength the photoelectrons have just enough energy to overcome the work function barrier, so $\left(\frac{1}{2}mv^2 \right)_{\max} = 0$, hence $V_0 = 0$, and

$$\frac{\phi}{e} = \frac{hf_{te}}{e} = \frac{hc}{e\lambda_t}$$

$$= \frac{1240 \text{ eV} \cdot \text{nm}}{558 \text{ nm}} = 2.22 \text{ eV}$$

3. When 400-nm light is used, V_0 is given by Equation 3-21:

$$V_0 = \frac{hf}{e} - \frac{\phi}{e} = \frac{hc}{e\lambda} - \frac{\phi}{e}$$

$$= \frac{1240 \text{ eV} \cdot \text{nm}}{400 \text{ nm}} - 2.22 \text{ eV}$$

$$= 3.10 \text{ eV} - 2.22 \text{ eV} = 0.88 \text{ V}$$

Ans:=0.88

Planck and Boltzmann constants

Problem 14

The Planck and Boltzmann constants are given in SI units as:

$h = 6.626 \times 10^{-34} \text{ J.s}$ and $k_B = 1.38 \times 10^{-23} \text{ J/K}$. Convert them into eV for J. (04小題)

答案空格編號:16 (a) $h = \underline{\hspace{2cm}} \text{ eV.s}$

Ans:=4.136E-15

答案空格編號:17 (b) $k_B = \underline{\hspace{2cm}} \text{ eV/K}$

Ans:=8.614E-5

答案空格編號:18 (c) the photon energy for frequency

$\nu = 6 \times 10^{14} \text{ Hz} = \underline{\hspace{2cm}} \text{ eV}$

Ans:=2.482

答案空格編號:19 (d) the thermal energy for temperature at 300K = $\underline{\hspace{2cm}} \text{ eV}$

Ans:=2.584E-2

Problem 15

Light of wavelength 400 nm and intensity 0.01 W/m^2 is incident on potassium. (a) Estimate the time lag for the emission of photoelectrons expected classically. Hint: the energy an atom absorbs from the incident light is proportional to the cross-sectional area of the atom. (b) Calculate the number of photons incident per second per square meter. (02小題)

答案空格編號:20 (a) the time lag = _____ s

Ans:=1.13E3

答案空格編號:21 (b) the photon number $N = \underline{\hspace{2cm}}$ photons/s $\cdot \text{m}^2$

According to Example 3-5, the work function for potassium is 2.22 eV. If we assume $r = 10^{-10} \text{ m}$ to be the typical radius of an atom, the total energy falling on the atom in time t is

$$\begin{aligned} E &= (10^{-2} \text{ W/m}^2)(\pi r^2)t = (10^{-2} \text{ W/m}^2)(\pi 10^{-20} \text{ m}^2)t \\ &= (3.14 \times 10^{-22} \text{ J/s})t \end{aligned}$$

Setting this energy equal to 2.22 eV gives

$$\begin{aligned} (3.14 \times 10^{-22} \text{ J/s})t &= (2.22 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV}) \\ t &= \frac{(2.22 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV})}{(3.14 \times 10^{-22} \text{ J/s})} = 1.13 \times 10^3 \text{ s} = 18.8 \text{ min} \end{aligned}$$

According to the classical prediction, no atom would be expected to emit an electron until 18.8 min after the light source was turned on. According to the photon model of light, each photon has enough energy to eject an electron immediately. Because of the low intensity, there are few photons incident per second, so the chance of any particular atom absorbing a photon and emitting an electron in any given time interval is small. However, there are so many atoms in the cathode that some emit electrons immediately.

The energy of each photon is

$$\begin{aligned} E &= hf = hc/\lambda = (1240 \text{ eV} \cdot \text{nm})/(400 \text{ nm}) = (3.10 \text{ eV})(1.60 \times 10^{-19} \text{ J/eV}) \\ &= 4.96 \times 10^{-19} \text{ J} \end{aligned}$$

Since the incident intensity is $10^{-2} \text{ W/m}^2 = 10^{-2} \text{ J/s} \cdot \text{m}^2$, the number of photons per second per square meter is

$$\begin{aligned} N &= \frac{10^{-2} \text{ J/s} \cdot \text{m}^2}{4.96 \times 10^{-19} \text{ J/photon}} \\ &= 2.02 \times 10^{16} \text{ photons/s} \cdot \text{m}^2 \end{aligned}$$

This is, of course, a lot of photons, not a few; however, the number n per atom at the surface is quite small. $n = 2.02 \times 10^{16} \text{ photons/s} \cdot \text{m}^2 \times \pi(10^{-10})^2 \text{ m}^2/\text{atom} = 6.3 \times 10^{-4} \text{ photons/s} \cdot \text{atom}$, or about 1 photon for every 1000 atoms.

Ans:=2.02E16

Problem 16

What is the Compton wavelength for an electron? (01小題)

答案空格編號:22 $\lambda_e =$ _____ nm

Ans:=0.00243

Problem 17

X-rays of wavelength $\lambda = 0.200$ nm are aimed at a block of carbon. The scattered x-rays are observed at an angle of 45.0 degree to the incident beam. Calculate the increased wavelength of the scattered x-rays at this angle. (01小題)

答案空格編號:23 $\Delta\lambda =$ _____ nm

EXAMPLE 3.7 The Compton Shift for Carbon

X-rays of wavelength $\lambda = 0.200$ nm are aimed at a block of carbon. The scattered x-rays are observed at an angle of 45.0° to the incident beam. Calculate the increased wavelength of the scattered x-rays at this angle.

Solution The shift in wavelength of the scattered x-rays is given by Equation 3.27. Taking $\theta = 45.0^\circ$, we find

$$\Delta\lambda = \frac{h}{m_e c} (1 - \cos \theta)$$

$$\begin{aligned} &= \frac{6.63 \times 10^{-34} \text{ J}\cdot\text{s}}{(9.11 \times 10^{-31} \text{ kg})(3.00 \times 10^8 \text{ m/s})} (1 - \cos 45.0^\circ) \\ &= 7.11 \times 10^{-13} \text{ m} = 0.00071 \text{ nm} \end{aligned}$$

Hence, the wavelength of the scattered x-ray at this angle is

$$\lambda = \Delta\lambda + \lambda_0 = 0.200711 \text{ nm}$$

Ans:=0.000711