68. Sunlight reaching the Earth's surface has an intensity of about $1000\,\mathrm{W/m^2}$. Estimate how many photons per square meter per second this represents. Take the average wavelength to be 550 nm.

69. A beam of red laser light $(\lambda = 633\,\mathrm{nm})$ hits a black wall and is fully absorbed. If this light exerts a total force $F = 5.5\,\mathrm{nN}$ on the wall, how many photons per second are hitting the wall?

70. If a 100-W lightbulb emits 3.0% of the input energy as visible light (average wavelength 550 nm) uniformly in all directions, estimate how many photons per second of visible light will strike the pupil (4.0 mm diameter) of the eye of an observer 1.0 km away.

71. An electron and a positron collide head on, annihilate, and create two 0.90-MeV photons traveling in opposite directions. What were the initial kinetic energies of electron and positron?

72. By what potential difference must (*a*) a proton $(m = 1.67 \times 10^{-27}\,\mathrm{kg})$, and (*b*) an electron $(m = 9.11 \times 10^{-31}\,\mathrm{kg})$, be accelerated to have a wavelength $\lambda = 5.0 \times 10^{-12}\,\mathrm{m}$?

73. In some of Rutherford's experiments (Fig. 27–18) the α particles $(\text{mass} = 6.64 \times 10^{-27}\,\mathrm{kg})$ had a kinetic energy of 4.8 MeV. How close could they get to a gold nucleus $(\text{charge} = +79e)$? Ignore the recoil motion of the nucleus.

74. By what fraction does the mass of an H atom decrease when it makes an $n = 3$ to $n = 1$ transition?

75. Calculate the ratio of the gravitational to electric force for the electron in a hydrogen atom. Can the gravitational force be safely ignored?

76. Electrons accelerated by a potential difference of 12.3 V pass through a gas of hydrogen atoms at room temperature. What wavelengths of light will be emitted?

77. In a particular photoelectric experiment, a stopping potential of 2.10 V is measured when ultraviolet light of wavelength 290 nm is incident on the metal. Using the same setup, what will the new stopping potential be if blue light of wavelength 440 nm is used, instead?

78. In an X-ray tube (see Fig. 25–35 and discussion in Section 25–11), the high voltage between filament and target is *V*. After being accelerated through this voltage, an electron strikes the target where it is decelerated (by positively charged nuclei) and in the process one or more X-ray photons are emitted. (*a*) Show that the photon of shortest wavelength will have

$$\lambda_0 = \frac{hc}{eV}.$$

(*b*) What is the shortest wavelength of X-ray emitted when accelerated electrons strike the face of a 30-kV television picture tube?

79. The intensity of the Sun's light in the vicinity of the Earth is about $1000\,\mathrm{W/m^2}$. Imagine a spacecraft with a mirrored square sail of dimension 1.0 km. Estimate how much thrust (in newtons) this craft will experience due to collisions with the Sun's photons. [*Hint*: assume the photons bounce off the sail with no change in the magnitude of their momentum.]

80. Light of wavelength 300 nm strikes a metal whose work function is 2.2 eV. What is the shortest de Broglie wavelength for the electrons that are produced as photoelectrons?

81. Photons of energy 6.0 eV are incident on a metal. It is found that current flows from the metal until a stopping potential of 4.0 V is applied. If the wavelength of the incident photons is doubled, what is the maximum kinetic energy of the ejected electrons? What would happen if the wavelength of the incident photons was tripled?

82. Visible light incident on a diffraction grating with slit spacing of 0.010 mm has the first maximum at an angle of 3.5° from the central peak. If electrons could be diffracted by the same grating, what electron velocity would produce the same diffraction pattern as the visible light?

83. (*a*) Suppose an unknown element has an absorption spectrum with lines at 2.5, 4.7, and 5.1 eV above its ground state and an ionization energy of 11.5 eV. Draw an energy level diagram for this element. (*b*) If a 5.1-eV photon is absorbed by an atom of this substance, in which state was the atom before absorbing the photon? What will be the energies of the photons that can subsequently be emitted by this atom?

84. Light of wavelength 424 nm falls on a metal which has a work function of 2.28 eV. (*a*) How much voltage should be applied to bring the current to zero? (*b*) What is the maximum speed of the emitted electrons? (*c*) What is the de Broglie wavelength of these electrons?

85. An electron accelerated from rest by a 96-V potential difference is injected into a $3.67 \times 10^{-4}\,\mathrm{T}$ magnetic field where it travels in an 18-cm-diameter circle. Calculate e/m from this information.

86. Estimate the number of photons emitted by the Sun in a year. (Take the average wavelength to be 550 nm and the intensity of sunlight reaching the Earth (outer atmosphere) as $1350\,\mathrm{W/m^2}$.)

87. Apply Bohr's assumptions to the Earth–Moon system to calculate the allowed energies and radii of motion. Given the known distance between the Earth and Moon, is the quantization of the energy and radius apparent?

Answers to Exercises

A: $\lambda_\mathrm{p} = 725\,\mathrm{nm}$, so red.
B: More 1000-nm photons (lower frequency).
C: $5.50 \times 10^{14}\,\mathrm{Hz}$, 545 nm.
D: Only λ.
E: Decrease.