CHAPTER 18 Review

REFLECTING ON CHAPTER 18

- Oscillators on the surface of a blackbody can oscillate only with specific frequencies. When they emit electromagnetic radiation, they drop from one allowed frequency to a lower allowed frequency.
- The photoelectric effect demonstrated that electromagnetic energy can be absorbed only in discrete quanta of energy. Electromagnetic energy travels like a wave, but interacts with matter like a particle.
- When a photon ejects an electron from a metal surface, the maximum kinetic energy of the electron can be calculated from the equation $E_{k(max)} = hf - W$, where W is the work function of the metal.
- The Compton effect shows that both energy and momentum are conserved when a quantum of light energy, or a photon, collides with a free electron.
- The energy of a photon is $E = hf$.
- The momentum of a photon is $p = \frac{h}{\lambda}$.
- The diffraction of electrons by crystals demonstrated that electrons have wave properties. The wavelength of a particle of matter is $\lambda = \frac{h}{mv}$.
- Physicists accept the dual properties of matter and electromagnetic energy. Electromagnetic energy behaves like particles and particles of matter have wave properties. These concepts are called the "wave-particle duality."

Knowledge/Understanding

1. Describe how a negatively charged electroscope can be used to provide evidence for the photoelectric effect.
2. (a) Describe the properties of a blackbody and explain how it is simulated in the laboratory.
   (b) How did the actual radiation spectrum emitted by a heated blackbody differ from the predictions of the classical wave theory?
3. The ultraviolet catastrophe was considered to be a flaw in the explanation of the blackbody emission spectra by the classical wave theory. In what way was it unexplained?
4. (a) The results of Lenard's photoelectric experiment partly correlated with the classical wave theory of light. Explain how it agreed.
   (b) In what way did Lenard's results differ from the predictions of the classical wave theory of light?
5. (a) Einstein saw a connection between the photoelectric effect and the Planck proposal that energy be quantized. Explain how Einstein developed an equation to describe the photoelectric effect.
   (b) Einstein's photoelectric equation is actually another example of conservation of energy. Explain how this applies.
6. A lithium surface in a photoelectric cell will emit electrons when the incident light is blue. Platinum, however, requires ultraviolet light to eject electrons from its surface.
   (a) Which of the two metals has a larger value for its work function? Explain your answer.
   (b) Which of the two metals has a higher threshold frequency? Explain your answer.
7. (a) How did a knowledge of the charge on an electron make it possible to calculate the numerical values of the kinetic energies of electrons emitted from a metal surface?
   (b) How did the data from Millikan's photoelectric experiments support Einstein's theory of the photoelectric effect?
8. (a) Explain the sequence by which Compton derived an expression for the momentum of a photon, considering that it has no mass.
   (b) In what way does a photon change "colour" after it has collided with an electron. Is "colour" always a suitable term to use?

9. **(a)** Explain the sequence that de Broglie used in taking Compton's expression for the momentum of a light photon and proposing that particles of matter have a corresponding matter wave and wavelength.
   (b) How can the matter wavelength of a particle be increased to make it more easily detectable?

Inquiry

10. Design and sketch a simple door opener that will open electrically when a person passes through a light beam.

Communication

11. Explain how Lenard was able to determine the maximum kinetic energy of the electrons coming from the emitter of his photoelectric apparatus.
12. **(a)** Explain how Einstein was able to include the properties of different types of emitter metals in his photoelectric equation.
    (b) Initially, very few physicists accepted Einstein's claim for the quantum nature of light. Why did this opposition exist?
13. "Wave-particle duality" is a term used to describe the dual properties of both light and particles in motion. Has this meant that Maxwell's equations for electromagnetic wave propagation and Newton's classical mechanics have been discarded? Discuss your opinion.

Making Connections

14. A light meter is used by a photographer to ensure correct exposure for photographs. If the photocell in the meter is to operate satisfactorily up to the red light wavelength of 650 nm, what should be the work function of the emitter material?
15. Some science fiction writers use a large sail to enable a space vehicle to move through space. It is argued that sunlight will exert a pressure on the sail, causing it to move away from the Sun. Prepare a report and/or display in which you indicate
    (a) whether the proposal has merit
    (b) what type of surface should be used for the sail

Problems for Understanding

16. The work function for a nickel surface is 5.15 eV. What is the minimum frequency of the radiation that will just eject an electron from the surface?
17. **(a)** The longest wavelength of light that will just eject electrons from a particular surface is 428.7 nm. What is the work function of this surface?
    (b) Use Table 18.1 to identify the material used in the surface.
18. When ultraviolet radiation was used to eject electrons from a lead surface, the maximum kinetic energy of the electrons emitted was 2.0 eV. What was the frequency of the radiation used?
19. The electrons emitted from a surface illuminated by light of wavelength 460 nm have a maximum speed of 4.2×10^5 m/s. Given that an electron has a mass of 9.11×10^{-31} kg, calculate the work function (in eV) of the surface material.
20. Assume that a particular 40.0 W light bulb emits only monochromatic light of wavelength 582 nm. If the light bulb is 5.0% efficient in converting electric energy into light, how many photons per second leave the light bulb?
21. **(a)** Calculate the momentum of a photon of light with a wavelength of 560 nm.
    (b) Calculate the momentum of the photons of light with a frequency of 6.0×10^{14} Hz.
    (c) A photon has an energy of 186 eV. What is its momentum?
22. An electron is moving at a speed of 4.2×10^5 m/s. What is the frequency of a photon that has an identical momentum?
23. What is the momentum of a microwave photon if the average wavelength of the microwaves is approximately 12 cm?
24. **(a)** Calculate the wavelength of a 4.0 eV photon.
    (b) What is the de Broglie wavelength of a 4.0 eV electron?
    (c) What is the momentum of an electron if its de Broglie wavelength is 1.4×10^{-10} m?