chapter 29 PARTICLES AND WAVES

Section 29.1 The Wave-Particle Duality
Section 29.2 Blackbody Radiation and Planck's Constant
Section 29.3 Photons and the Photoelectric Effect

☐ 1. Light is usually thought of as wave-like in nature and electrons as particle-like. In which one of the following activities does light behave as a particle *or* does an electron behave as a wave?
(a) A Young's double slit experiment is conducted using blue light.
(b) X-rays are used to examine the crystal structure of sodium chloride.
(c) Water is heated to its boiling point in a microwave oven.
(d) An electron enters a parallel plate capacitor and is deflected downward.
(e) A beam of electrons is diffracted as it passes through a narrow slit.

☐ 2. Upon which one of the following parameters does the energy of a photon depend?
(a) mass (c) polarization (e) phase relationships
(b) amplitude (d) frequency

☐ 3. For which one of the following problems did Max Planck make contributions that eventually led to the development of the "quantum" hypothesis?
(a) photoelectric effect (d) the motion of the earth in the ether
(b) uncertainty principle (e) the invariance of the speed of light through vacuum
(c) blackbody radiation curves

◘ 4. Determine the energy of a single photon in a beam of light of wavelength 450 nm.
(a) 2.0 eV (c) 2.8 eV (e) 4.5 eV
(b) 2.5 eV (d) 4.2 eV

◘ 7. A laser emits photons of energy 2.5 eV with a power of 10^{-3} W. How many photons are emitted in one second?
(a) 4.0×10^{14} (c) 4.0×10^{18} (e) 2.5×10^{21}
(b) 2.5×10^{15} (d) 1.0×10^{21}

◘ 8. An X-ray generator produces photons with energy 49 600 eV or less. Which one of the following phrases most accurately describes the wavelength of these photons?
(a) 0.025 nm or longer (c) 0.75 nm or longer(e) 0.75 nm or shorter
(b) 0.050 nm or longer (d) 0.25 nm or shorter

☐ 12. Which one of the following phrases best describes the term *work function*?
(a) the minimum energy required to vaporize a metal

(b) the work required to place a charged particle on a metal surface
(c) the minimum energy required to remove electrons from the metal
(d) the minimum energy required to remove an atom from a metal surface
(e) the work done by electromagnetic radiation when it hits a metal surface

☐ 13. Which one of the following quantities is the same for all photons in vacuum?
(a) speed (c) kinetic energy (e) total energy
(b) frequency (d) wavelength

☐ 14. Complete the following statement: The term *photon* applies
(a) only to X-rays. (d) to any form of particle motion.
(b) only to visible light. (e) to any form of electromagnetic radiation.
(c) to any form of wave motion.

☐ 15. Which type of wave motion *does not* involve photons?
(a) gamma rays (c) radio waves (e) sound waves
(b) microwaves (d) infrared radiation

◘ 16. Which one of the following statements concerning photons is false?
(a) Photons have zero mass.
(b) The rest energy of all photons is zero.
(c) Photons travel at the speed of light in a vacuum.
(d) Photons have been brought to rest by applying a strong magnetic field to them.
(e) The energy of a photon is proportional to its frequency.

◘ 17. Photons of what minimum frequency are required to remove electrons from gold?
Note: *The work function for gold is 4.8 eV.*
(a) 7.3×10^{14} Hz (c) 3.8×10^{17} Hz (e) 4.6×10^{14} Hz
(b) 1.2×10^{15} Hz (d) 6.5×10^{15} Hz

◘ 21. Photons of energy 5.0 eV strike a metal whose work function is 3.5 eV. Determine which one of the following best describes the kinetic energy of the emitted electrons.
(a) 1.5 eV or less (c) 2.5 eV or more (e) 3.5 eV or less
(b) 1.5 eV or more (d) 3.5 eV or more

☐ 27. Which one of the following is demonstrated by the Compton effect?
(a) time dilation (d) electrons have wave properties
(b) length contraction (e) electromagnetic radiation has particle properties
(c) the uncertainty principle

☐ 28. Complete the following statement: The photon or "particle" theory of electromagnetic radiation is necessary to explain the
(a) refraction of light by a prism.
(b) diffraction of light by a grating.
(c) reflection of light from a mirrored surface.
(d) results of Compton scattering experiments.
(e) interference of light in Young's double-slit experiment.

Section 29.5 The De Broglie Wavelength and the Wave Nature of Matter

34. What kinetic energy must each neutron in a beam of neutrons have if their wavelength is 0.10 nm? The mass of a neutron is 1.67×10^{-27} kg.
(a) 6.6×10^{-19} J (c) 2.6×10^{-20} J (e) 7.1×10^{-20} J
(b) 1.3×10^{-20} J (d) 6.3×10^{-20} J

35. Approximately, what is the de Broglie wavelength of an electron that has been accelerated through a potential difference of 150 V? The mass of an electron is 9.11×10^{-31} kg.
(a) 0.1 nm (c) 10 nm (e) 1000 nm
(b) 1 nm (d) 100 nm

39. Determine the de Broglie wavelength of a neutron ($m = 1.67 \times 10^{-27}$ kg) that has a speed of 5.0 m/s.
(a) 79 nm (c) 395 nm (e) 1975 nm
(b) 162 nm (d) 529 nm

Section 29.6 The Heisenberg Uncertainty Principle

48. If Planck's constant were changed to 660 J · s, what would be the minimum uncertainty in the position of a 120-kg football player running at a speed of 3.5 m/s?
(a) 0.032 m (c) 0.13 m (e) 0.50 m
(b) 0.065 m (d) 0.25 m

49. In an experiment to determine the speed and position of an electron ($m = 9.11 \times 10^{-31}$ kg), three researchers claim to have measured the position of the electron to within $\pm 10^{-9}$ m. They reported the following values for the speed of the electron:

***Researcher* A** $3 \times 10^{6} \pm 2 \times 10^{4}$ m/s
***Researcher* B** $4 \times 10^{8} \pm 2 \times 10^{7}$ m/s
***Researcher* C** $2 \times 10^{7} \pm 5 \times 10^{5}$ m/s

Which of these measurements violates *one or more* basic laws of modern physics?
(a) **A** only (c) **A** and **B** (e) **A**, **B**, and **C**
(b) **B** only (d) **B** and **C**

50. The x component of the velocity of an electron ($m = 9.11 \times 10^{-31}$ kg) is known to be between 100 m/s and 300 m/s. Which one of the following is a true statement concerning the uncertainty in the x coordinate of the electron?
(a) The maximum uncertainty is about 10^{6} m.
(b) The minimum uncertainty is about 6×10^{-7} m.
(c) The maximum uncertainty is about 6×10^{-7} m.
(d) The minimum uncertainty is about 3×10^{-36} m.
(e) The maximum uncertainty is about 3×10^{-36} m.