7.6 The Dual Nature of Light and Matter

ight exhibits both a particle and a wave nature. De Bro-lie proposed that *all* matter has both a particle and a wave ature. The **de Broglie wavelength** of any particle of mass ı and speed v is

$$\lambda = \frac{h}{p} = \frac{h}{mv} \qquad [27.14]$$

)e Broglie also proposed that the frequencies of the 'aves associated with particles obey the Einstein relationship ; = hf.

:7.7 The Wave Function

n the theory of **quantum mechanics**, each particle is lescribed by a quantity Ψ called the **wave function**. The robability per unit volume of finding the particle at a par-icular point at some instant is proportional to Ψ^2. Quan-um mechanics has been highly successful in describing he behavior of atomic and molecular systems.

27.8 The Uncertainty Principle

According to Heisenberg's **uncertainty principle**, it is impossible to measure simultaneously the exact position and exact momentum of a particle. If Δx is the uncertainty in the measured position and Δp_x the uncertainty in the momentum, the product $\Delta x\, \Delta p_x$ is given by

$$\Delta x\, \Delta p_x \geq \frac{h}{4\pi} \qquad [27.16]$$

Also,

$$\Delta E\, \Delta t \geq \frac{h}{4\pi} \qquad [27.17]$$

where ΔE is the uncertainty in the energy of the particle and Δt is the uncertainty in the time it takes to measure the energy.

FOR ADDITIONAL STUDENT RESOURCES, GO TO WWW.SERWAYPHYSICS.COM

MULTIPLE-CHOICE QUESTIONS

1. What is the surface temperature of a distant star having a peak wavelength of 475 nm? (a) 6 100 K (b) 5 630 K (c) 5 510 K (d) 6 350 K (e) 6 560 K

2. In a photoelectric experiment, a metal is irradiated with light of energy 3.56 eV. If a stopping potential of 1.10 V is required, what is the work function of the metal? (a) 1.83 eV (b) 2.46 eV (c) 3.20 eV (d) 4.66 eV (e) 0.644 eV

3. An electron is accelerated through a potential differ-ence of 3.00 V before colliding with a metal target. What minimum wavelength light can such an electron emit? (a) 204 nm (b) 352 nm (c) 414 nm (d) 536 nm (e) 612 nm

4. What is the de Broglie wavelength of an electron acceler-ated from rest through a potential difference of 50.0 V? (a) 0.100 nm (b) 0.174 nm (c) 0.139 nm (d) 0.834 nm (e) 0.435 nm

5. A photon scatters off an electron at an angle of 1.30 × 10^2 ° with respect to its initial motion. What is the change in the photon's wavelength? (a) 0.002 43 nm (b) 0.243 nm (c) 0.001 72 nm (d) 0.004 85 nm (e) 0.121 nm

6. Which of the following statements are true according to the uncertainty principle? (a) It is impossible to simul-taneously determine both the position and the momen-tum of a particle with arbitrary accuracy. (b) It is impos-sible to simultaneously determine both the energy and the momentum of a particle with arbitrary accuracy. (c) It is impossible to determine a particle's energy with arbitrary accuracy in a finite amount of time. (d) It is impossible to measure the position of a particle with arbitrary accuracy in a finite amount of time. (e) It is impossible to simultaneously measure both the energy and position of a particle with arbitrary accuracy.

7. The first order x-ray scattering angle of crystal A is greater than the corresponding scattering angle of crystal B for x-rays of a given energy. What can be said of the separation distance d_A of crystalline planes in crystal A as compared with the separation distance d_B in B? (a) $d_A = d_B$ (b) $d_A > d_B$ (c) $d_A < d_B$ (d) The answer depends on the energy of the x-rays. (e) The answer depends on the intensity of the x-rays.

8. A proton, electron, and a helium nucleus all move at speed v. Rank their de Broglie wavelengths from lon-gest to shortest. (a) proton, helium nucleus, electron (b) helium nucleus, proton, electron (c) proton, elec-tron, helium nucleus (d) helium nucleus, electron, pro-ton (e) electron, proton, helium nucleus

9. Which one of the following phenomena most clearly demonstrates the particle nature of light? (a) dif-fraction (b) the photoelectric effect (c) polarization (d) interference (e) refraction

10. Which one of the following phenomena most clearly demonstrates the wave nature of electrons? (a) the pho-toelectric effect (b) Wien's law (c) blackbody radiation (d) the Compton effect (e) diffraction of electrons by crystals