Ch 24 (5th ed)

CONCEPTUAL QUESTIONS

1. Make a list summarizing the successes and failures of the Bohr theory.

2. The theory of special relativity requires that time, distance, and energy be treated in a new way as a particle approaches the speed of light. Because these corrections were understood at the time that Bohr developed his model of the hydrogen atom, could he have included them and achieved better agreement with experimental results? Why or why not?

3. You find that the lowest frequency at which you can set up a standing wave in a wire loop, as shown in Figure 24-1, is 10 hertz. When you increase the driving frequency slightly above 10 hertz, the resonance goes away. What is the next frequency at which resonance will again appear? Explain.

4. A 48-centimeter-long wire loop is used to demonstrate standing waves, as shown in Figure 24-1. What are the three longest wavelengths that will produce standing waves?

5. One might be tempted to interpret the de Broglie wave of an electron as a modified orbital path around the nucleus in which the electron deviates up and down from a circular path as it orbits. Does this model overcome the difficulties of Bohr's model? Explain.

6. For standing waves on a guitar string, adjacent antinodes are always moving in opposite directions. Use this principle to explain why a standing-wave pattern with three antinodes cannot exist on a wire loop.

7. Your friend claims that light is a wave. What experimental evidence could you cite to demonstrate that light behaves like a particle?

8. Your friend claims that electrons are particles. What experimental evidence could you cite to demonstrate that electrons behave like waves?

9. In Chapter 10 we found that an infinite amount of energy is required to accelerate a massive particle to the speed of light. What does this imply about the mass of a photon?

10. De Broglie argued that his relationship between wavelength and momentum should apply to photons as well as to electrons. For massless particles, the relationship takes the form $p = h/\lambda$. Which has more momentum, a red photon or a blue photon? Explain.

11. When applied to photons, the de Broglie relationship $p = h/\lambda$ shows that mass is not required for a particle to have momentum, which disagrees with our classical definition for particles. What other quantity that classically depends on mass can also be attributed to a photon?

12. Which of the following technical terms can be used to describe both an electron and a photon: wavelength, velocity, mass, energy, or momentum? Explain.

13. Why is it not correct to say that an electron is a particle that sometimes behaves like a wave and light is a wave that sometimes acts like a particle?

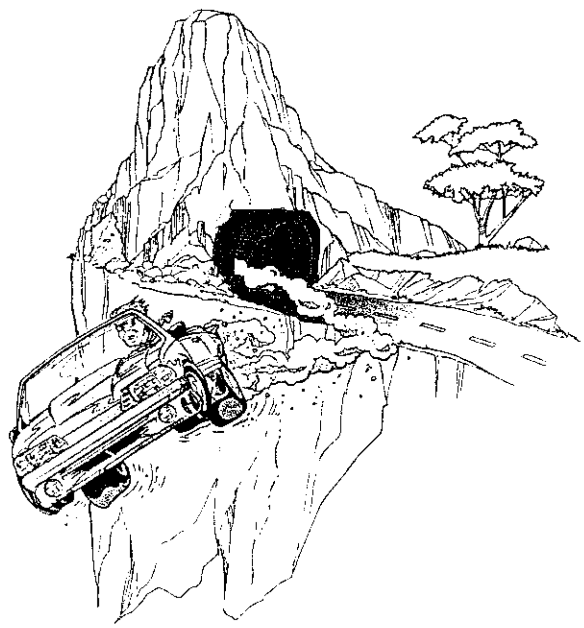
14. Why do you think that the particle nature of the electron was discovered before its wave nature?

15. The wavelength of red light is 600 nanometers. An electron with a speed of 1.2 kilometers per second has the same wavelength. Will the electron look red? Explain.

16. Bohr could never really explain why an electron was limited to certain orbits. How did de Broglie explain this?

17. An electron and a proton have the same speeds. Which has the longer wavelength? Why?

18. Why doesn't a sports car diffract off the road when it is driven through a tunnel?



19. When we perform the two-slit experiment with electrons, do the electrons behave like particles, waves, or both? What if we perform the experiment with photons?

20. Two students are discussing what happens when you turn down the rate at which electrons are fired at two slits. Student 1 claims, "Since you still get an interference pattern even with only one electron at a time, each electron must interfere with itself. As weird as it sounds, each electron must be going through both slits." Student 2 counters, "That's crazy. I can't be at class and on the ski slope at the same time. Each electron must pass through only one slit." Which student is correct? Explain.

21. If the two-slit experiment is performed with a beam of electrons so weak that only one electron passes through the apparatus at a time, what kind of pattern would you expect to obtain on the detecting screen?

22. In the two-slit experiment with photons, what type of pattern do you expect to obtain if you turn the light source down so low that only one photon is in the apparatus at a time?

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53. Phosphorescent materials continue to glow after the lights are turned off. How can you use the model of the atom to explain this?

54. Can infrared rays cause fluorescence? Why or why not?

55. What is stimulated emission?

56. How does light from a laser differ from light emitted by an ordinary light bulb?

EXERCISES

1. What is the de Broglie wavelength of a Volkswagen (mass = 1000 kg) traveling at 30 m/s (67 mph)?

2. A bullet for a 30-06 rifle has a mass of 10 g and a muzzle velocity of 900 m/s. What is its wavelength?

3. Nitrogen molecules (mass = 4.6×10^{-26} kg) in room-temperature air have an average speed of about 500 m/s. What is a typical wavelength for these nitrogen molecules?

4. What is the de Broglie wavelength for an electron traveling at 50 m/s?

5. What is the wavelength for a photon with energy 2 eV?

6. What is the wavelength for an electron with energy 2 eV?

7. What speed would an electron need to have a wavelength equal to the diameter of a hydrogen atom (10^{-10} m)?

8. What is the speed of a proton with a wavelength of 2 nm?

9. What is the size of the momentum for an electron that is in the lowest energy state for a one-dimensional box whose length is 2 nm?

10. What is the size of the momentum for an electron that is in the first excited energy state for a one-dimensional box whose length is 2 nm?

11. A child runs straight through a door with a width of 0.75 m. What is the uncertainty in the momentum of the child perpendicular to the child's path?

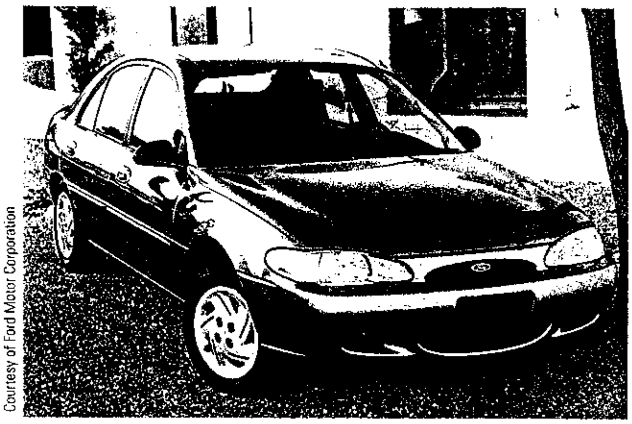
12. A Ford Escort passes through a tunnel with a width of 10 m. What uncertainty is introduced in the Escort's momentum perpendicular to the highway?

13. A proton passes through a slit that has a width of 10^{-10} m. What uncertainty does this introduce in the momentum of the proton at right angles to the slit?

14. An electron passes through a slit that has a width of 10^{-10} m. What uncertainty does this introduce in the momentum of the electron at right angles to the slit?

15. What is the minimum uncertainty in the position along the highway of a Ford Escort (mass = 1000 kg) traveling at 20m/s (45 mph)? Assume that the uncertainty in the momentum is equal to 1% of the momentum.

16. What is the uncertainty in the momentum of a Ford Escort with a mass of 1000 kg parked by the curb? Assume that you know the location of the car with an uncertainty of 0.1 mm.



Courtesy of Ford Motor Corporation

17. What is the uncertainty in the location of a proton along its path when it has a speed equal to 0.1% the speed of light? Assume that the uncertainty in the momentum is 1% of the momentum.

18. What is the uncertainty in each component of the momentum of an electron confined to a box approximately the size of a hydrogen atom, say, 0.1 nm on a side?

19. Consider an electron confined to a diameter of 0.1 nm. If the electron's speed is on the order of the uncertainty in its speed, how fast is it traveling? Assuming that the electron can still be treated without making relativistic corrections, find its kinetic energy (in electron volts).

20. Repeat the previous problem for a proton confined to a diameter of 10^{-14} m.

21. Electrons in an excited state decay to the ground state with the release of a photon. The uncertainty in the time that an electron will spend in the excited state can be estimated by the average lifetime for electrons in that state. What will be the spread in energy, in electron volts, of the photons from a state with a lifetime of 2×10^{-8} s?

22. The lifetime of an excited nuclear state is 5×10^{-12} s. What will be the spread in energy, in electron volts, of the photons from this state?

23. If the photons from an excited atomic state show a spread in energy of 2×10^{-4} eV, what is the lifetime of the state?

24. The uncertainty principle allows for "violation" of conservation of energy for times less than the associated uncertainty. For how long could an electron increase its energy by 10 eV without violating conservation of energy?