UNIT 7 Review

Knowledge/Understanding

Multiple Choice

In your notebook, choose the most correct answer for each of the following questions. Outline your reasons for your choice.

1. The kinetic energy of a particle travelling near the speed of light is
   (a) always less than the rest energy
   (b) equal to mc^2
   (c) equal to $\frac{1}{2}mv^2$
   (d) equal to $(m - m_0)c^2$
   (e) equal to $(m_0 - m)c^2$
2. When an object with a rest mass of 2.0 kg approaches the speed of light, its mass approaches
   (a) 0 **(c)** 1.0 kg **(e)** ∞
   (b) 0.5 kg **(d)** c^2
3. If you direct light at a metal surface, the energies of the emitted electrons
   (a) are random
   (b) vary with the speed of light
   (c) vary with the intensity of light
   (d) vary with the frequency of light
   (e) are constant
4. In the Bohr model of the atom, an electron emits energy when it
   (a) accelerates in its orbit
   (b) decelerates in its orbit
   (c) jumps from a higher energy level to a lower energy level
   (d) jumps from a lower energy level to a higher energy level
   (e) is in the ground state

Short Answer

5. If you were travelling in a spaceship at 0.9 c, would you notice any time dilation effects for clocks in the spaceship? Explain your reasoning.
6. A clock on a flying carpet streaks past an Earthling who is looking at her watch. What does the Earthling notice about the passage of time on the moving clock, compared with her watch? What would a wizard on the flying carpet notice about the passage of time on the Earthling's watch, compared to the clock on the carpet? Does it matter which timepiece is considered to be in motion and which is considered to be at rest?
7. Explain the following statement: The speed of light is a constant.
8. Max Planck introduced an hypothesis regarding the energy of vibration of the molecules in order to satisfy the observed spectrum emitted from a hot body. What was this hypothesis and on whose work did he reportedly base his idea?
9. **(a)** Describe the relationship Phillip Lenard found between the energy of photoelectrons and the frequency of the incident light.
   (b) Describe how increasing the light intensity affects the electron flow.
10. **(a)** Use the photon theory of light to explain why a photographer might use a red safety light in a darkroom for black and white photography.
    (b) Sunburn is caused by the ultraviolet component of sunlight, not by the infrared component. How does the photon theory account for this?
11. Does it take more or less energy to remove a photoelectron from lead than from aluminum? (See Table 18.1 on page 853) Explain your reasons.
12. Describe the technique that was used successfully to demonstrate the existence of de Broglie matter waves.
13. **(a)** Some features of the emission spectrum could still not properly be explained by the Bohr model. Name two such features.
    (b) Paul Dirac modified Erwin Schrödinger's equation. What was he seeking to include and how successful was he?

Inquiry

14. Suppose you had a rod of length L aligned parallel to the y-axis of an x-y reference frame labelled S and an identical rod of length L' aligned parallel to the y'-axis of an x'-y' reference frame labelled S' When the two frames are aligned, it is seen that the rods are the same

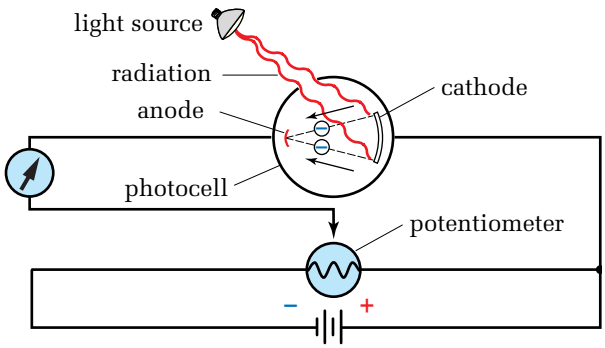
length. Allow the frames to be offset in the *x*-direction and then set one of them in motion so that the rods move past each other. Argue that the length of either rod will not be seen to change. What would be the physical implications if one of the rods was observed to change?

15. Some people thought that they had disproved Einstein's special theory of relativity by describing the twin paradox. According to this thought experiment, identical twins Al and Bert grow up on Earth. Al rides a rocket, which travels close the speed of light, to Alpha Centauri and then returns. Consider the following points.

- From Bert's point of view of Earth, Al has been travelling at a high rate of speed, so his clock would have slowed down. When Al returns, he should be younger than Bert.
- However, from Al's point of view, it was Bert who was travelling at a high rate of speed. It was Bert's clock that slowed down, so Bert would be younger than Al. Since these two results are contradictory, the special theory of relativity must be wrong.

Explain why the special theory of relativity does not fully describe what is happening in this example. (Hint: Are both frames of reference equivalent?)

16. The phototube shown in the diagram was used to determine the stopping potential (also called "cut-off voltage") for electrons emitted from the cathode (emitter) when different wavelengths of light were incident on its surface. The table that follows the diagram records the values of the wavelengths used and the corresponding stopping potential.



Colour	Wavelength (nm)	Stopping potential (V)	Maximum E_k of photoelectrons (J)	Frequency (Hz)
green	530.0	0.045		
green	500.0	0.244		
blue	460.0	0.402		
violet	410.0	0.731		

(a) Prepare a table similar to the one above and complete the remaining two columns by calculating the maximum kinetic energy of the emitted electrons (using $E = qV$) and the frequency of the light.

(b) Draw a graph with maximum E_k on the vertical axis and frequency on the horizontal axis.

(c) From your graph, determine the work function for the particular emitter material used.

(d) Identify the metal used in the emitter (see Table 18.1 on page 853).

(e) Calculate the slope of the graph and compare it with Planck's constant.

(f) Explain how you feel that the graph would or would not be different if

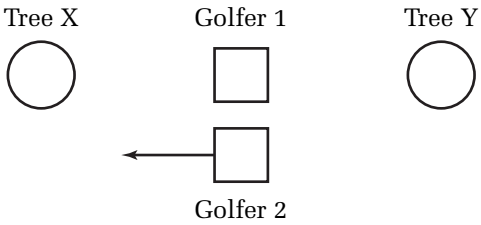
- the emitter had been made from a different material
- the intensity of the light was doubled in each case

17. When a charged particle passes through a magnetic field that is perpendicular to its motion, its path is deflected into a circular path. If the strength of the field (B) is known and you assume that the particles are singly charged, prove that the radius of the path indicates the momentum of the particle.

Communication

18. In your own words, explain the term "relativity."

19. **(a)** Several golfers are out on a golf course when two trees are struck by lightning. The arrangement is as shown in the diagram. Golfer 1 is at rest relative to the two trees and observes that both trees were struck simultaneously. Golfer 2 is driving a relativistic golf cart. In the golf cart frame of reference, which tree was struck first? Give reasons for your answer.



(b) During a storm, a passenger in a stretch limousine, travelling close to the speed of light (the ultimate speed limit), noticed that two large hailstones struck the limousine simultaneously, one on the hood of the car and one on the trunk. According to a pedestrian who was standing on the sidewalk as the car sped past, which hailstone struck first? Give reasons for your answer.

20. Explain what it means to say that a certain quantity is quantized.

21. Describe the evidence that matter behaves as a wave.

Making Connections

22. Find examples in this textbook where the study of a particular area of physics was advanced by new experimental results that led to a new theory, and vice versa. Express your thoughts in writing about the manner in which science advances, using these examples.

23. Despite the complexity of some observed phenomena and some equations, the following statement is true: The basic ideas underlying all science are simple. Prove this to yourself by examining the chapters in this textbook. For each chapter, write down at least three simple but scientifically correct statements that summarize one or more of the concepts in the chapter. For example, one of the sentences for Chapter 17, Special Theory of Relativity, could be "Energy and matter are equivalent" or "Energy and matter are interchangeable." Make some of your statements general (to apply to an entire unit, for example) and relate some to specific concepts.

24. The Cavendish Laboratory for experimental physics at the University of Cambridge, England, has been responsible for many significant discoveries and inventions in the history of physics. These include the discoveries of the electron and neutron and the inventions of the mass spectrometer, cloud chamber, and the Cockcroft-Walton proton accelerator. Between 1879 and 1937, the chair of the laboratory was occupied by James Clerk Maxwell, Lord Rayleigh, J.J. Thomson, and Ernest Rutherford. Write an essay that examines the research done in this famous laboratory. Identify and discuss some of the factors that have enabled members of the Cavendish Laboratory to be so productive.

25. Although physics has come a long way in its understanding of matter and energy, much work remains and it is uncertain that a full understanding is even possible. Write an essay to discuss the status of quantum mechanics. What are its present weaknesses? Express your own views on whether a full understanding of the interactions between matter and energy is possible. Popular books that explore this topic have been written by Stephen Weinberg, Murray Gell-Mann, and Leon Lederman, and will help you to frame your argument.

Problems for Understanding

26. Relativistic speeds are speeds at which relativistic effects become noticeable. Just how fast is this? To answer the question, determine the following.
- **(a)** At what speed relative to your frame of reference would a particle have to travel so that you would see that its length in the direction of motion had decreased by 1.0%?
- **(b)** At what speed relative to your frame of reference would a particle have to travel for you to detect that its mass had increased by 0.10%?

27. **(a)** How much energy would be released if a 1.0 kg brick was converted directly into energy?
- **(b)** For how long could this amount of energy power a 100 W light bulb?

28. The star Alpha Centauri is 4.2 light-years away (a light-year is the distance light travels in one year: 365.25 days).
- **(a)** If you travelled in a spaceship at a speed of 2.0×10^8 m/s, how long would this distance appear to be?
- **(b)** How long would a one-way trip take you?
- **(c)** How much time would pass for someone back on Earth?

29. **(a)** Calculate the energy required to give an electron a speed of $0.90c$, starting from rest.
- **(b)** Compare this to its rest mass energy.
- **(c)** In terms of its rest mass, what is the mass of an electron travelling at this speed?

30. Suppose you allowed a 100 W light bulb to burn continuously for one year.
- **(a)** How much energy would it radiate in this time?
- **(b)** To what change in mass does this correspond?

31. Radiation of wavelength 362 nm is incident on a potassium surface. What will be the maximum kinetic energy of the electrons emitted from this surface? (Refer to Table 18.1 on page 853.)

32. Calculate the maximum kinetic energy of the electrons emitted from the cathode emitter of a photocell if the stopping potential is 4.7 V.

33. **(a)** A zinc surface is used on the emitter of a photocell. What will be the threshold frequency necessary for a photocurrent to flow? (See Table 18.1 on page 853)
- **(b)** What is the threshold wavelength for zinc?

34. **(a)** Calculate the de Broglie wavelength of an electron moving with a speed of 5.82×10^5 m/s.
- **(b)** An electron is accelerated across an electric potential difference of 64.0 V. Calculate the de Broglie wavelength of this electron.

35. An electron drops from the second energy level of the hydrogen atom to the first energy level.
- **(a)** Calculate the frequency of the photon emitted.
- **(b)** Calculate the wavelength of the photon.
- **(c)** In which series does the spectral line belong?

36. Calculate the wavelength of the second line in the Balmer series.

37. A typical classroom helium-neon laser has a power of 0.80 mW and emits a monochromatic beam of red light of wavelength 670 nm.
- **(a)** Calculate the energy (in J) of each photon in the beam.
- **(b)** If the laser is left on for 5.0 min, how many photons will be emitted?

38. A photon of light is absorbed by a hydrogen atom in which the electron is already in the second energy level. The electron is lifted to the fifth energy level.
- **(a)** What was the frequency of the absorbed photon?
- **(b)** What was its wavelength?
- **(c)** What is the total energy of the electron in the fifth energy level?
- **(d)** Calculate the radius of the orbit representing the fifth energy orbit.
- **(e)** If the electron subsequently returns to the first energy level in one "jump," calculate the wavelength of the corresponding photon to be emitted.
- **(f)** In which region of the electromagnetic spectrum would the radiation be found?