1. Two slits are separated by $2.00 \times 10^{-5}$ m. They are illuminated by light of wavelength $5.60 \times 10^{-7}$ m. If the distance from the slits to the screen is 6.00 m, what is the separation between the central bright fringe and the third dark fringe?
   A) 0.421 m  
   B) 0.224 m  
   C) 0.168 m  
   D) 0.084 m  
   E) 0.070 m

2. Light of wavelength $\lambda$ in vacuum strikes a lens that is made of glass with index of refraction 1.6. The lens has been coated with a film of thickness $t$ and index of refraction 1.3. For which one of the following conditions will there be no reflection?
   A) $2t = \frac{\lambda}{2}$  
   B) $2t = \frac{\lambda}{1.33}$  
   C) $2t = \frac{\lambda}{1.6}$  
   D) $2t = \frac{1}{2} \left( \frac{\lambda}{1.6} \right)$  
   E) $2t = \frac{1}{2} \left( \frac{\lambda}{1.3} \right)$

3. A lens that has an index of refraction of 1.61 is coated with a non-reflective coating that has an index of refraction of 1.45. Determine the minimum thickness for the film if it is to be non-reflecting for light of wavelength $5.60 \times 10^2$ nm.
   A) $1.93 \times 10^{-7}$ m  
   B) $3.86 \times 10^{-7}$ m  
   C) $4.83 \times 10^{-8}$ m  
   D) $9.66 \times 10^{-8}$ m  
   E) $8.69 \times 10^{-8}$ m
4. In a science fiction novel, a starship takes three days to travel between two distant space stations according to its own clocks. Instruments on one of the space stations indicate that the trip took four days. How fast did the starship travel, relative to the space station?
   A) $1.98 \times 10^8$ m/s
   B) $2.24 \times 10^8$ m/s
   C) $2.51 \times 10^8$ m/s
   D) $2.83 \times 10^8$ m/s
   E) $2.99 \times 10^8$ m/s

5. During a baseball game, a batter hits a ball directly back to the pitcher who catches it. An observer flying over the stadium at a speed of $0.75c$, measures 0.658 s as the time between the two events (hitting and catching the ball). What is the proper time interval between the two events?
   A) 0.288 s
   B) 0.435 s
   C) 0.658 s
   D) 0.715 s
   E) 0.994 s

6. A meter stick is observed to be only 0.850 meters long to an inertial observer. At what speed, relative to the observer, must the meter stick be moving?
   A) $2.04 \times 10^8$ m/s
   B) $1.58 \times 10^8$ m/s
   C) $2.50 \times 10^8$ m/s
   D) $1.31 \times 10^8$ m/s
   E) $2.22 \times 10^8$ m/s

7. A spaceship leaves our solar system at a constant speed of $0.920c$ and travels to a point in the Andromeda galaxy. According to astronomers in an inertial reference frame on Earth, the distance to the galaxy is $2.081 \times 10^{22}$ m. What distance does the crew on the ship measure on its journey?
   A) $9.07 \times 10^{21}$ m
   B) $9.85 \times 10^{21}$ m
   C) $1.91 \times 10^{22}$ m
   D) $8.16 \times 10^{21}$ m
   E) $4.77 \times 10^{22}$ m
8. The temperature of a 5.00-kg lead brick is increased by 525 °C. If the specific heat capacity of lead is 128 J/(kg · °C), what is the increase in the mass of the lead brick when it has reached its final temperature?
   A) $5.80 \times 10^{-11}$ kg
   B) $9.12 \times 10^{-11}$ kg
   C) $1.60 \times 10^{-12}$ kg
   D) $3.73 \times 10^{-12}$ kg
   E) $2.80 \times 10^{-12}$ kg

9. The power capacity of all nuclear power plants in the United States is $1.01 \times 10^{5}$ MW. In one hour, what is the total change in the mass of the nuclear fuel at these power plants due to the energy being taken from the reactors? Assume 100% efficiency.
   A) $1.12 \times 10^{-6}$ kg
   B) $7.59 \times 10^{-5}$ kg
   C) $5.11 \times 10^{-4}$ kg
   D) $4.04 \times 10^{-3}$ kg
   E) 3.62 kg

10. Determine the energy of a single photon in a monochromatic beam of light of wavelength 625 nm.
    A) 1.99 eV
    B) 2.08 eV
    C) 2.32 eV
    D) 3.49 eV
    E) 4.77 eV

11. Photons of energy 5.0 eV strike a metal surface that has a work function of 3.5 eV. Determine which one of the following best describes the kinetic energy of the emitted electrons.
    A) 1.5 eV or less
    B) 1.5 eV or more, but less than 2.5 eV
    C) 2.5 eV or more, but less than 3.5 eV
    D) 3.5 eV or more
    E) 3.5 eV or less, but more than 1.5 eV
12. Approximately, what is the de Broglie wavelength of an electron that has been accelerated through a potential difference of 225 V? The mass of an electron is $9.11 \times 10^{-31}$ kg.
   A) 0.14 nm  
   B) 0.082 nm  
   C) 0.043 nm  
   D) 0.0092 nm  
   E) 0.22 nm

13. Determine the approximate wavelength (in nm) of light emitted from the $n = 4$ level to the $n = 2$ level electron transition in a hydrogen gas.
   A) 490  
   B) 512  
   C) 645  
   D) 756  
   E) 804

14. According to the Bohr model, what is the radius of a hydrogen atom when its electron is excited to the $n = 9$ state?
   A) $5.87 \times 10^{-12}$ m  
   B) $5.29 \times 10^{-11}$ m  
   C) $4.76 \times 10^{-10}$ m  
   D) $4.28 \times 10^{-9}$ m  
   E) $1.51 \times 10^{-8}$ m

15. The position of a hydrogen atom ($m = 1.7 \times 10^{-27}$ kg) is known to within $2.0 \times 10^{-6}$ m. What is the minimum uncertainty in the atom's velocity?
   A) zero m/s  
   B) 0.0085 m/s  
   C) 0.011 m/s  
   D) 0.016 m/s  
   E) 0.031 m/s

16. Light propagates from soda lime glass ($n = 1.518$) into Pyrex glass ($n = 1.473$). Determine the critical angle for this situation.
   A) $13.99^\circ$  
   B) $45.86^\circ$  
   C) $52.48^\circ$  
   D) $65.22^\circ$  
   E) $76.01^\circ$
Use the following to answer questions 17-18:

A ray of light is normally incident on face ab of a plastic prism with an index of refraction \( n = 1.20 \) as shown.

17. Determine the largest value of the angle \( \alpha \) so that the ray is totally reflected at the face ac if the prism is immersed in air.
   A) 28°
   B) 34°
   C) 45°
   D) 56°
   E) Total internal reflection will not occur for any value of \( \alpha \).

18. Determine the largest value of the angle \( \alpha \) so that the ray is totally reflected at the face ac if the prism is immersed in a liquid with refractive index 1.12.
   A) 21°
   B) 34°
   C) 69°
   D) 78°
   E) Total internal reflection will not occur for any value of \( \alpha \).

19. An object is placed at the focal point of a thin diverging lens of focal length \( f \). What is the image distance?
   A) \( f \)
   B) \( 2f \)
   C) \( 1/f \)
   D) \( f/2 \)
   E) at an infinite distance
20. A converging lens is used to focus light from a small bulb onto a book. The lens has a focal length of 10.0 cm and is located 40.0 cm from the book. Determine the distance from the lens to the light bulb.
   A) 8.6 cm  
   B) 13 cm  
   C) 20 cm  
   D) 30 cm  
   E) 50 cm

21. An object with a height of 4.0 cm is placed 30.0 cm from a lens. The resulting inverted image has a height of 1.5 cm. What is the focal length of the lens?
   A) 7.5 cm  
   B) 8.2 cm  
   C) 15 cm  
   D) 17 cm  
   E) 21 cm

22. A camera with a focal length of 0.0500 m (a 50-mm lens) is focused for an object at infinity. To focus the camera on a subject which is 4.00 m away, how should the lens be moved?
   A) 1.0 cm closer to the film  
   B) 0.06 cm closer to the film  
   C) 4.94 cm closer to the film  
   D) 0.06 cm farther from the film  
   E) 4.94 cm farther from the film

23. A 2.00-cm tall object is placed 40.0 cm from a lens. The resulting image is 8.00-cm tall and upright relative to the object. Determine the focal length of the lens.
   A) 26.6 cm  
   B) 32.0 cm  
   C) 53.3 cm  
   D) 64.0 cm  
   E) 80.0 cm
Use the following to answer question 24:

The figure is a scaled diagram of an object and a converging lens surrounded by air. Only one focal point, \( F \), of the lens is shown.

![Diagram of a converging lens and object points](image)

24. At which of the labeled points will the image be formed?
   A) A  
   B) B  
   C) C  
   D) D  
   E) E

Use the following to answer question 25:

A diverging lens has a focal length of \(-15\) cm. A 5-cm object is placed 35 cm from the lens.

25. What is the magnification of the image?
   A) +0.3  
   B) \(-0.3\)  
   C) +0.7  
   D) \(-0.7\)  
   E) +0.8
Answer Key

1. A
2. E
3. D
4. A
5. B
6. B
7. D
8. D
9. D
10. A
11. A
12. B
13. A
14. D
15. D
16. E
17. B
18. A
19. D
20. B
21. B
22. D
23. C
24. C
25. A