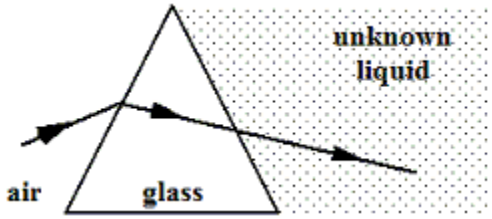
1. Light propagates from soda lime glass ($n$ = 1.518) into Pyrex glass ($n$ = 1.473). Determine the smallest angle of incidence onto the Pyrex glass that will cause all of the light to be reflected back into the soda lime glass.
   A) 13.99°
   B) 76.01°
   C) 52.48°
   D) 65.22°
   E) None of these

2. A ray of blue light travels through air and is refracted as it enters a glass prism shown in the figure. An unknown liquid is in contact with the right side of the prism. The light then follows the path shown. Which one of the following statements concerning this situation is true?




   A) The frequency of the light changes inside the prism.
   B) The index of refraction of the glass is smaller than that of air.
   C) The index of refraction of the unknown liquid is the same as that of the glass.
   D) The speed of light is larger in the liquid than in the glass.
   E) The refractive index of the liquid is the same as that of air.

3. An object is placed 6.5 cm from a converging lens with a focal length of 14 cm. Which one of the following statements is true concerning the image?
   A) The image is virtual and 6.0 cm from the lens.
   B) The image is virtual and 12 cm from the lens.
   C) The image is real and 3.0 cm from the lens.
   D) The image is real and 6.0 cm from the lens.
   E) None of these statements is true.

4. An object with a height of 6.0 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) 6.0 cm
   C) 15 cm
   D) 17 cm
   E) None of these

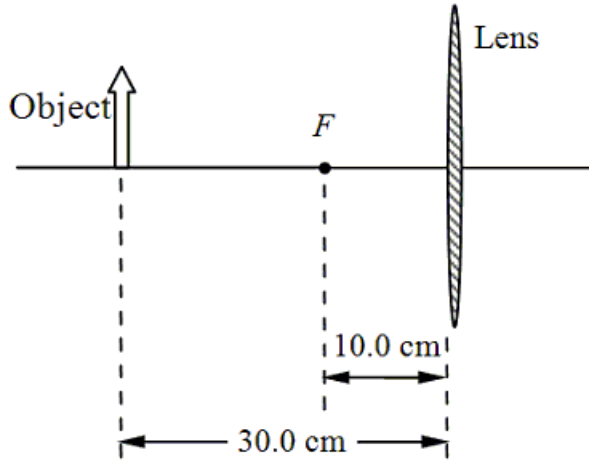
Use the following to answer question 5:

A diverging lens has a focal length of –15 cm. A 12-cm object is placed 35 cm from the lens.

5. What is the height of the image?
   A) 2.4 cm
   B) 3.6 cm
   C) 4.8 cm
   D) 6.0 cm
   E) None of these

Use the following to answer question 6:

An object is placed 30.0 cm from a converging lens that has a focal length of 10.0 cm as shown in the diagram.
**Note**: *The diagram is not drawn to scale.*




6. Where are the properties of the image?
   A) smaller, virtual, inverted
   B) smaller, real, inverted
   C) smaller, real, upright
   D) larger, virtual, inverted
   E) None of these

7. A double slit is illuminated with monochromatic light. The $m = 0$ and $m = 2$ bright fringes (i.e., the central fringe and the second-nearest-neighbor fringe) are separated by 3.8 cm on a screen which is located 3.5 m from the slits. The separation between the slits is 0.12 mm. What is the approximate wave length of the light, in nano-meters?
   A) 565
   B) 651
   C) 632
   D) 704
   E) None of these

8. 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) 0.42 m
   B) 0.22 m
   C) 0.19 m
   D) 0.08 m
   E) None of these

9. A plate that has an index of refraction of 1.31 is coated with a film 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) $1.93 \times\times 10^{-7}$ m
   B) $3.86 \times 10^{-7}$ m
   C) $4.83 \times\times 10^{-8}$ m
   D) $9.66 \times 10^{-8}$ m
   E) None of these

10. A bomb is designed to explode 2.00 s after it is armed. The bomb is launched from earth and accelerated to an unknown final speed. After reaching its final speed, however, the bomb is observed by people on earth to explode 2.90 s after it is armed. What is the final speed of the bomb just before it explodes?
    A) 0.492*c*
    B) 0.524*c*
    C) 0.611*c*
    D) 0.882*c*
    E) None of these

11. A spaceship leaves our solar system at a constant speed of 0.920*c* and travels to a point in the Andromeda galaxy. According to astronomers 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) None of these

12. Determine the total energy (in MeV) of an electron traveling at 0.98*c*. (The rest mass of an electron is about $9.11 \times 10^{-31}$ kg. (1 eV = $1.6 \times 10^{-19}$ J and 1 MeV = one million eV.)
    A) 0.25 MeV
    B) 0.51 MeV
    C) 0.73 MeV
    D) 2.58 MeV
    E) None of these

13. 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 (in grams) of the nuclear fuel at these power plants due to the energy being taken from the reactors? Assume 100% efficiency. Note: 1 MW = $1 \times 10^6$ W
    A) 1.7
    B) 20.5
    C) 9.8
    D) 4.0
    E) None of these

14. A laser emits a $5.0 \times 10^3$-J pulse of light that has a wavelength of 480 nm. Determine the number of photons in the pulse. Note: h = $6.63 \times 10^{-34}$ J-s.
    A) $5.2 \times 10^{16}$
    B) $2.5 \times 10^{19}$
    C) $1.2 \times 10^{22}$
    D) $3.1 \times 10^{22}$
    E) None of these

15. When ultraviolet photons with a wavelength of $3.45 \times 10^{-7}$ m are directed at the surface of an unknown metal in vacuum, electrons with a maximum kinetic energy of 1.52 eV are emitted from the surface. What is the work function of the metal?
    A) 3.60 eV
    B) 3.11 eV
    C) 2.59 eV
    D) 2.08 eV
    E) None of these

16. 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. Planck's constant: $h = 6.63 \times 10^{-34}$ J-s. $1 \text{ eV} = 1.6 \times 10^{-19}$ J.
    A) 0.14 nm
    B) 0.082 nm
    C) 0.043 nm
    D) 0.0092 nm
    E) None of these

17. 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. What is the approximate minimum uncertainty in the $x$ coordinate of the electron?
    A) $1 \times 10^{6}$ m.
    B) $3 \times 10^{-7}$ m.
    C) $6 \times 10^{-7}$ m.
    D) $3 \times 10^{-9}$ m.
    E) None of these.

18. Which one of the following will result in an electron transition from the $n = 4$ level to the $n = 7$ level in a hydrogen atom?
    A) emission of a 0.28 eV photon
    B) emission of a 0.57 eV photon
    C) absorption of a 0.85 eV photon
    D) absorption of a 0.57 eV photon
    E) None of these

19. Determine the wavelength (in nm) of the photon emitted when the electron in a hydrogen atom undergoes a transition from the $n = 3$ level to the $n = 1$ level.
    A) 435
    B) 234
    C) 103
    D) 90
    E) None of these

20. Photons of what minimum frequency are required to remove electrons from gold? Note: The work function for gold is 4.8 eV.
    A) $7.3 \times 10^{14}$ Hz
    B) $1.2 \times 10^{15}$ Hz
    C) $3.8 \times 10^{17}$ Hz
    D) $6.5 \times 10^{15}$ Hz
    E) None of these

## Answer Key

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