

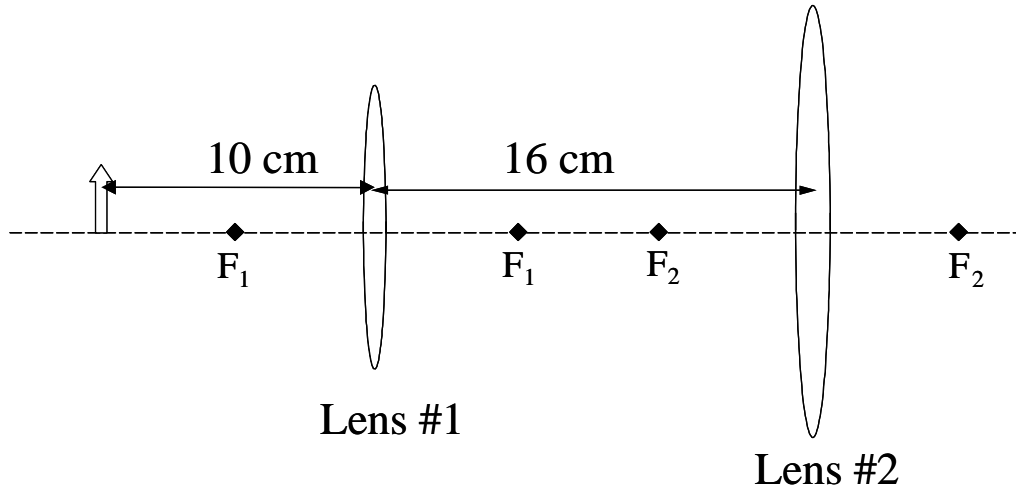
*The next two questions pertain to the following situation.*

A nearsighted person has a far point of 40 cm unaided. She wears corrective glasses and the lenses are 2 cm in front of her eyes.

1. What kind of lenses must she wear so that she can see objects very far away (at  $\infty$ ) clearly?
  - a. diverging lens
  - b. converging lens
  
2. What must be the magnitude of the refractive power  $|P|$  of the corrective glasses in diopters (1 diopter  $\equiv 1/\text{m}$ )?
  - a. 2.63 diopters
  - b. 1.91 diopters
  - c. 3.27 diopters

*The next three questions pertain to the following situation.*

Two lenses are separated by 16 cm. Both Lens #1 and Lens #2 are converging lenses and have a focal length of 5 cm. An object (arrow) is located 10 cm to the left of Lens #1.



3. **If lens #2 were not present**, the image formed by lens #1 would be

- 5 cm to the right of lens #1.
- 10 cm to the right of lens #1.
- 15 cm to the right of lens #1.
- 20 cm to the right of lens #1.
- 25 cm to the right of lens #1.

4. Where is the final image of the **pair of lenses**?

- 25 cm to the left of lens #2
- 15 cm to the left of lens #2
- 10 cm to the left of lens #2
- 20 cm to the right of lens #2
- 30 cm to the right of lens #2

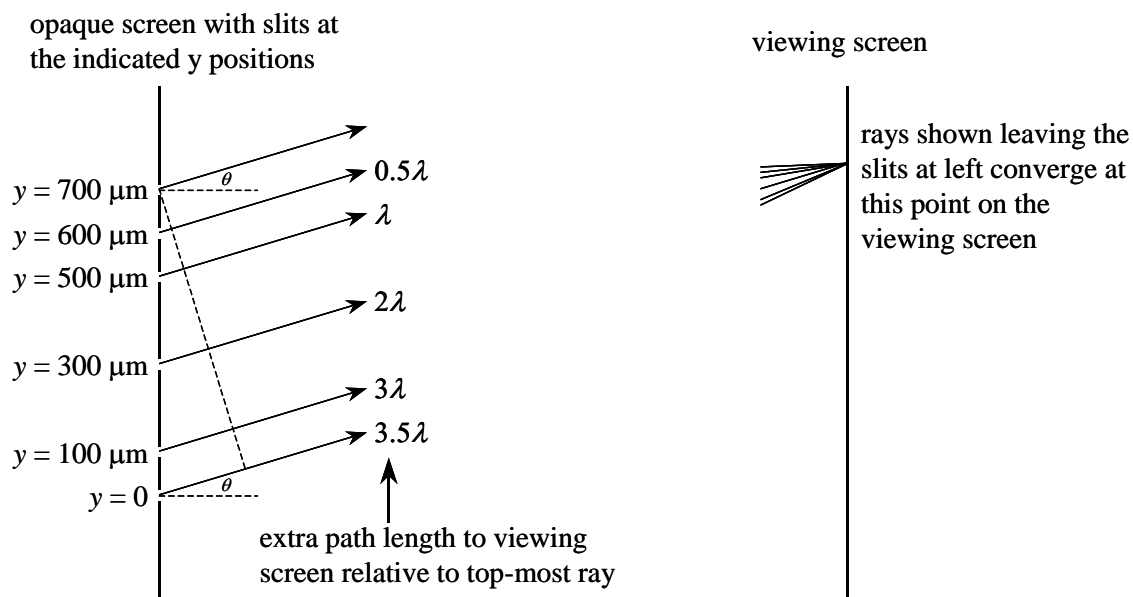
5. The final image formed by the **pair of lenses** is

- inverted relative to the object.
- upright relative to the object.

The next two questions pertain to the following situation.

Six slits are cut into an opaque screen as shown in the following figure. The spacing between the slits is *not uniform*; the y positions of the slits are indicated on the diagram. A viewing screen is positioned several meters to the right of the slits.

The screen is illuminated from the left by a light source of wavelength  $\lambda$ . The particular light rays leaving the slits and converging at one point on the viewing screen are drawn in the diagram. The path lengths from the slits to that point on the screen differ for each of the rays. (The path length differences relative to the top-most ray are shown in the figure.)



6. The *intensity* of the light measured at the point of convergence of the rays is  $I_6$ . If the intensity of light out of one slit is  $I_1$ , what is the ratio of the intensities  $I_6 / I_1$ ?

- $I_6 / I_1 = 0$ .
- $I_6 / I_1 = 2$ .
- $I_6 / I_1 = 4$ .
- $I_6 / I_1 = 9$ .
- $I_6 / I_1 = 36$ .

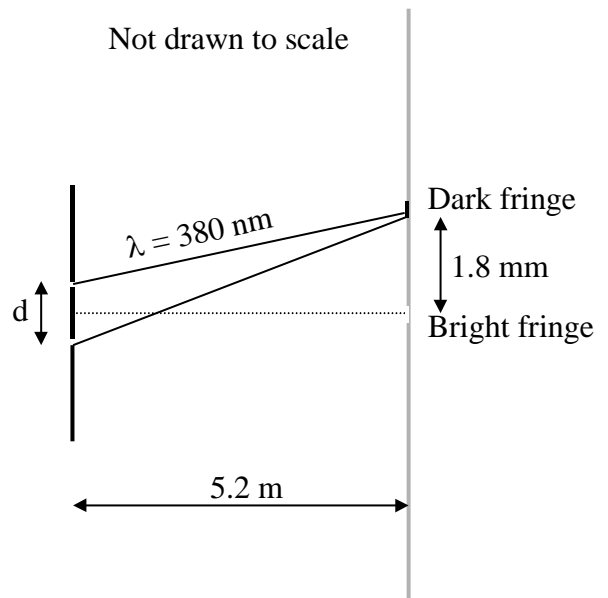
7. Given that the wavelength of light is  $\lambda = 650 \text{ nm}$ , determine the angle  $\theta$  in the figure.

- 3.25 mrad
- 6.50 mrad
- 1.75 mrad

*The next three questions pertain to the following situation:*

8. Blue light with wavelength  $\lambda = 380$  nm is incident upon two narrow slits separated by a distance  $d$  before striking a screen 5.2 meters away. The distance between the central bright fringe and first dark fringe is  $1.8 \times 10^{-3}$  m. Calculate  $d$  the spacing between the slits. (You may approximate  $\sin(\theta) \approx \tan(\theta) \approx \theta$ )

- $d = 0.15$  mm
- $d = 0.21$  mm
- $d = 0.36$  mm
- $d = 0.41$  mm
- $d = 0.55$  mm

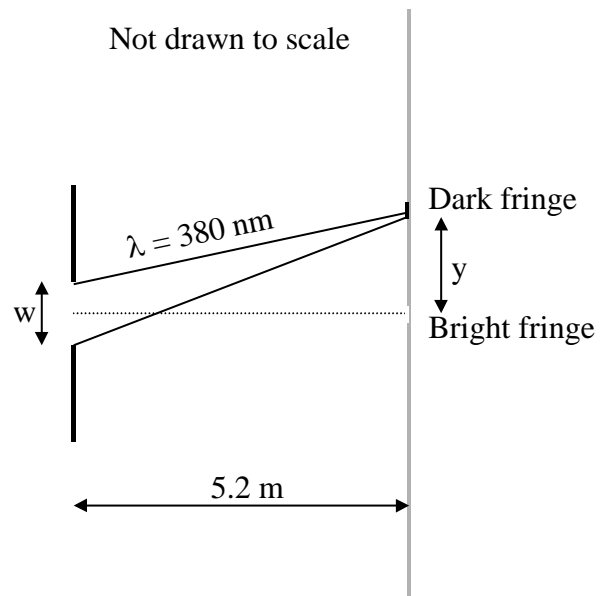


9. Now red light ( $\lambda = 650$  nm) is incident on the same two slits, the distance  $y$  between the central bright fringe and the first dark fringe is

- $y < 1.8$  mm
- $y = 1.8$  mm
- $y > 1.8$  mm

10. Now the two slits are replaced by a **single slit** with width  $w = d$ , and illuminated with the original blue light. What is the distance  $y$  to the first dark fringe?

- $y < 1.8$  mm
- $y = 1.8$  mm
- $y > 1.8$  mm



***The next three questions pertain to the following situation:***

If you go to the Art Institute of Chicago, you can admire paintings by the French painter Georges Seurat. For his work, Seurat uses small dots of color to produce an image. At a distance of a few meters, the eye cannot resolve these dots. You thus see a “smooth” picture.

11. If each dot is the same size, which color dots are the easiest to resolve?

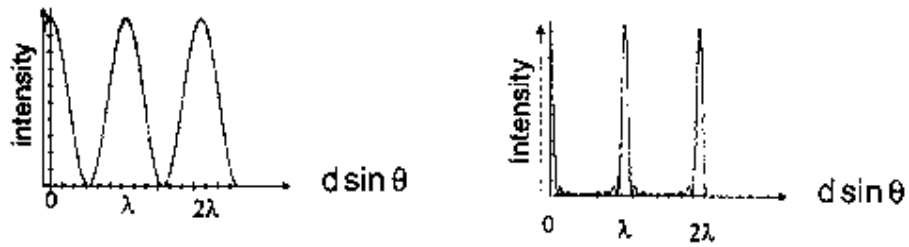
- a. Red ( $\lambda = 660 \text{ nm}$ )
- b. Green ( $\lambda = 550 \text{ nm}$ )
- c. Blue ( $\lambda = 470 \text{ nm}$ )

12. Assume the green ( $\lambda = 550 \text{ nm}$ ) dots in the painting are separated by a distance  $d = 2.0 \text{ mm}$ . What is the maximum distance,  $L$ , a person with normal, unaided vision (near point  $25 \text{ cm}$ , far point infinity, pupil diameter  $2.0 \text{ mm}$ ) can stand from the painting to resolve the individual green dots?

- a.  $L = 1.44 \text{ m}$
- b.  $L = 2.31 \text{ m}$
- c.  $L = 3.27 \text{ m}$
- d.  $L = 4.89 \text{ m}$
- e.  $L = 5.96 \text{ m}$

13. Let  $L$  be the answer to the previous question. If the distance between the green dots were  $1.0 \text{ mm}$  instead of  $2.0 \text{ mm}$ , the maximum distance a person with normal, unaided vision (near point  $25 \text{ cm}$ , far point infinity, pupil diameter  $2.0 \text{ mm}$ ) can stand from the painting to resolve the individual green dots would be

- a. smaller than  $L$ .
- b. equal to  $L$ .
- c. larger than  $L$ .

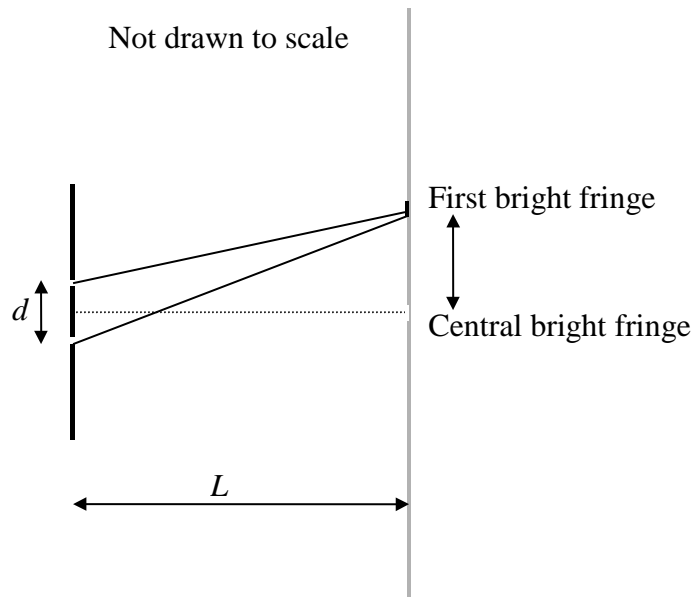


14. Consider a diffraction pattern produced by passing light of wavelength  $\lambda$  through a screen containing a series of equally spaced slits.

True or false: The total number of slits is greater in the pattern on the right than in the pattern on the left.

- a. true
- b. false

*The next two questions pertain to the following situation:*



15. An electron beam of energy 2 eV is incident on two slits separated by a distance  $d = 100$  nm. A screen is placed  $L = 2$  m away from the slits. What is the separation between the first interference maximum and the center line? (The mass of the electron is  $511$  keV/ $c^2$ .)

- a. 6.5 mm
- b. 17.3 mm
- c. 36.2 mm

16. The electron beam is replaced by a beam of light. What energy of photons will recreate the exact same pattern on the screen?

- a. 2 eV
- b. 350 eV
- c. 1.4 keV

17. A 2.5 mW laser pointer emits green light of wavelength  $\lambda = 530$  nm. How many photons does it emit per second?

- a.  $6.7 \times 10^{15}$  photons/s
- b.  $3.1 \times 10^{10}$  photons/s
- c.  $4.6 \times 10^{14}$  photons/s

18. In the photoelectric effect, a metal with work function  $W_0 = 2.8$  eV is illuminated by monochromatic light of wavelength  $\lambda = 671$  nm. If the intensity of the light is increased, which of the following occurs?

- a. no photoelectrons are emitted
- b. the maximum kinetic energy of the photoelectrons increases
- c. the work function of the metal decreases

19. Consider a singly ionized He atom. What is the wavelength of a photon that is emitted as the atom makes a transition between the  $n = 5$  and  $n = 3$  states?

- a. 151 nm
- b. 321 nm
- c. 570 nm
- d. 821 nm
- e. 1282 nm

20. What is the maximum number of electrons that can be found in the  $n = 3$  shell of an atom?

- a. 14
- b. 18
- c. 24



*The next two questions pertain to the following situation:*

Imagine a universe where the electron has a spin of  $3/2$ . Its spin quantum number  $m_s$  could then have the following four values:  $m_s = +3/2, +1/2, -1/2,$  and  $-3/2$ .

21. If this were true, the first element with a filled shell would be the first of the noble gases and it would be:

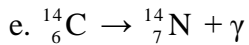
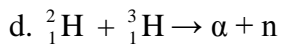
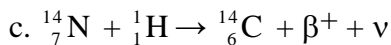
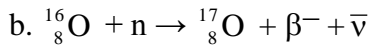
- a. He with 2 electrons
- b. Li with 3 electrons
- c. Be with 4 electrons
- d. C with 6 electrons
- e. O with 8 electrons

22. Consider a beam of hydrogen atoms in the ground state ( $n = 1$ ) in this universe where the electron has spin  $3/2$ . The atoms are placed in a uniform  $B$  field. How many possible energy levels can the atoms be in?

- a. 1
- b. 2
- c. 4
- d. 6
- e. 8

23. Of the hypothetical nuclear reactions below, which is possible?  $\beta^+$  and  $\beta^-$  represent the positron (the antiparticle of the electron) and electron, with charges  $+1e$ , and  $-1e$ , respectively and  $\nu$  and  $\bar{\nu}$  represent (neutral) neutrinos.

a. none are possible



24. The nucleus of nitrogen  ${}^{14}_7\text{N}$  has a mass of  $13,040 \text{ MeV}/c^2$ . What is the binding energy of this nucleus? (The mass of the proton is  $938.3 \text{ MeV}/c^2$ , and that of the neutron is  $939.5 \text{ MeV}/c^2$ )

a. 2.2 MeV

b. 15.4 MeV

c. 47.9 MeV

d. 80.7 MeV

e. 104.6 MeV

25. A radioactive isotope has a half-life of 8 months. What fraction of a sample of the isotope will still remain after 2 years?

a. 1/32

b. 1/16

c. 1/8

d. 1/4

e. 1/2

***The next two questions refer to the following situation:***

The H- $\alpha$  line is a spectral line observed from the transition between  $n = 3$  and  $n = 2$  energy levels in hydrogen. It is often seen in the spectrum of light from celestial objects.

26. Determine the wavelength of light emitted from this transition for a source at rest.

- a. 656 nm
- b. 1240 nm
- c. 374 nm

27. The absorption spectrum of a distant galaxy exhibits an H- $\alpha$  line that is red-shifted by 1%. Given Hubble's law  $v = H_0 d$  with  $H_0 = 70$  km/s/Mpc, determine the distance to the galaxy in Megaparsecs (Mpc).

- a. 90 Mpc
- b. 43 Mpc
- c. 17 Mpc

## ANSWER KEY

- |       |       |
|-------|-------|
| 1. A  | 15. B |
| 2. A  | 16. C |
| 3. B  | 17. A |
| 4. E  | 18. A |
| 5. B  | 19. B |
| 6. C  | 20. B |
| 7. A  | 21. C |
| 8. E  | 22. C |
| 9. C  | 23. D |
| 10. C | 24. E |
| 11. C | 25. C |
| 12. E | 26. A |
| 13. A | 27. B |
| 14. A |       |