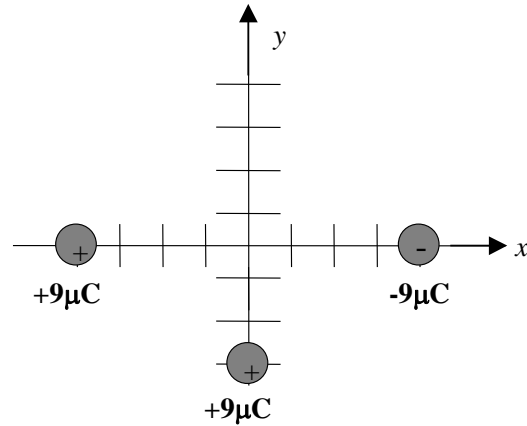


*The next two questions pertain to the following situation:*

Three charges are placed located as shown in the figure to the right. The grid spacing is in meters..

1. Calculate the **x-component of the net force** on the bottom charge at (0,-3) due to the two charges on the x-axis.

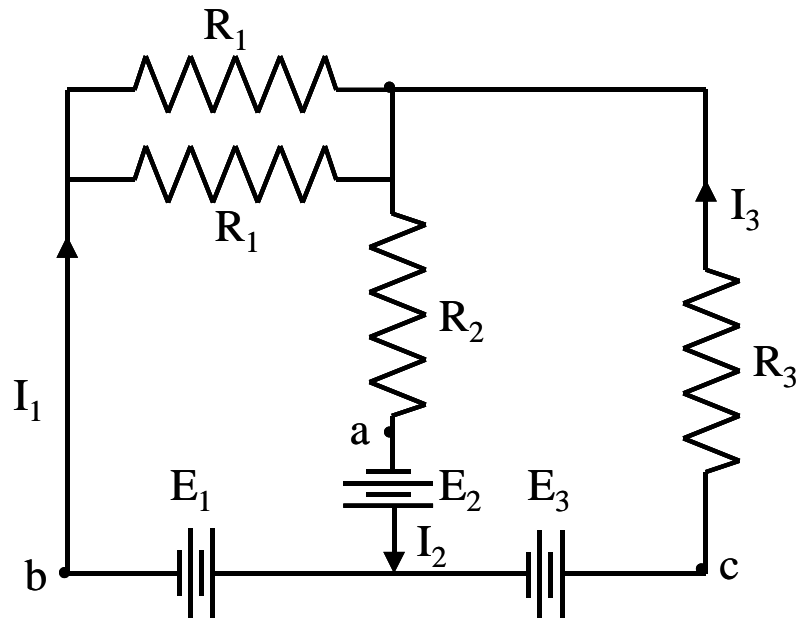
- (A)  $F_x = -4.66 \times 10^{-2} \text{ N}$
- (B)  $F_x = -3.50 \times 10^{-2} \text{ N}$
- (C)  $F_x = 0$
- (D)  $F_x = +3.50 \times 10^{-2} \text{ N}$
- (E)  $F_x = +4.66 \times 10^{-2} \text{ N}$



2. Calculate the **y-component of the net force** on the bottom charge due to the two other charges.

- (A)  $F_y = -4.66 \times 10^{-2} \text{ N}$
- (B)  $F_y = -3.50 \times 10^{-2} \text{ N}$
- (C)  $F_y = 0$
- (D)  $F_y = +3.50 \times 10^{-2} \text{ N}$
- (E)  $F_y = +4.66 \times 10^{-2} \text{ N}$

The next three questions pertain to the following situation.



3. Which of the following equations is **not** valid?

- a.  $+E_1 + R_1 I_1 + I_2 R_2 - E_2 = 0$
- b.  $+E_1 + (R_1/2) I_1 - R_3 I_3 + E_3 = 0$
- c.  $+E_2 - R_2 I_2 - R_3 I_3 + E_3 = 0$

4. Which of the following is a valid Kirchhoff current equation for the above circuit?

- a.  $I_1 + I_2 + I_3 = 0$
- b.  $I_1 - I_2 + I_3 = 0$
- c.  $I_1 + I_2 - I_3 = 0$

5. Let  $E_1 = 9$  volts,  $E_2 = 3$  volts and  $E_3 = 5$  volts. Which of the three points (a, b or c) has the lowest electric potential?

- a. point a
- b. point b
- c. point c

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

The resistors  $R_1$  and  $R_2$  each have resistance  $10\ \Omega$ , the capacitors  $C_1$ ,  $C_2$ , and  $C_3$  all have capacitance  $1\ \mu\text{F}$ . The battery supplies a potential difference of  $10\ \text{V}$ . A perfect ammeter (without resistance) is connected in the lower left of the circuit, as shown in the figure. The switch on the top right is initially in the open position, and the capacitors are fully charged.

6. What is the current  $I$  through the ammeter with the switch open?

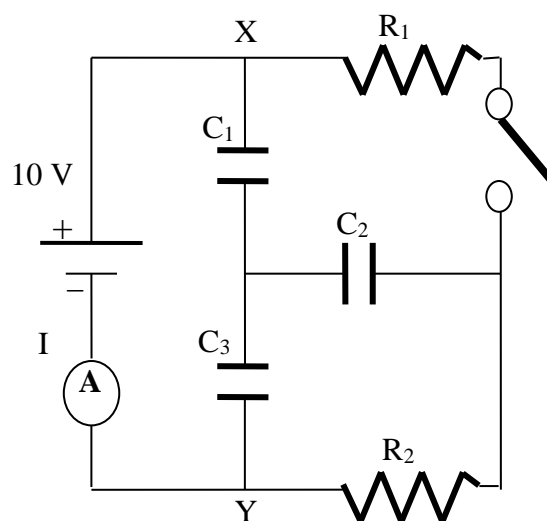
- a.  $0.0\ \text{A}$
- b.  $1.0\ \text{A}$

7. What is the effective capacitance between points X and Y with the switch open?

- a.  $0.33\ \mu\text{F}$
- b.  $0.5\ \mu\text{F}$
- c.  $0.67\ \mu\text{F}$
- d.  $2\ \mu\text{F}$
- e.  $3\ \mu\text{F}$

8. What is the charge on capacitor  $C_2$  with the switch open?

- a.  $1.11\ \mu\text{C}$
- b.  $2.22\ \mu\text{C}$
- c.  $3.33\ \mu\text{C}$
- d.  $4.44\ \mu\text{C}$
- e.  $6.67\ \mu\text{C}$



9. You close the switch and wait until the ammeter settles down. What current  $I$  is shown on the ammeter?

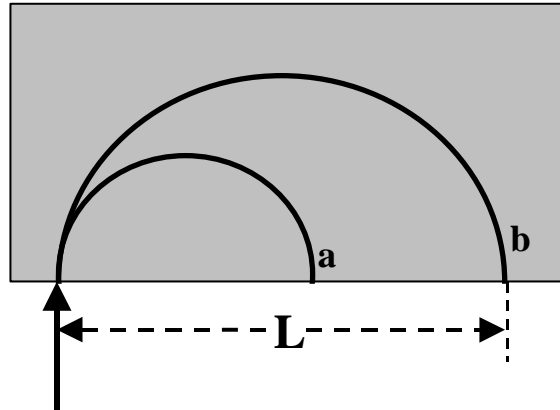
- a.  $0.5\ \text{A}$
- b.  $1.0\ \text{A}$
- c.  $2.0\ \text{A}$

10. What is the charge on capacitor  $C_2$  now that the switch is closed?

- a.  $0\ \mu\text{C}$ .
- b.  $2.5\ \mu\text{C}$
- c.  $5.0\ \mu\text{C}$

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

Two **positively** charged particles enter a region of uniform magnetic field  $B$ . The  $B$  field is oriented perpendicular to the page. The paths of the two charged particles are shown.



11. Which direction is the  $B$  field pointing?

- a. Into the page
- b. Out of the page

12. If the two particles have the same mass and initial velocity which one has the greater charge?

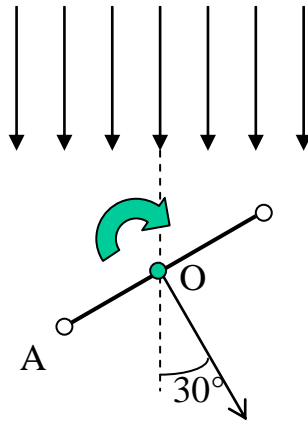
- a. Particle **a**
- b. Particle **b**

13. Let  $B = 1.5 \text{ T}$ ,  $m_b = 3.0 \times 10^{-27} \text{ kg}$ ,  $v_b = 2 \times 10^7 \text{ m/s}$  and  $q_b = 1.6 \times 10^{-19} \text{ C}$ . What is the length  $L$ ?

- a.  $L = 0.33 \text{ m}$
- b.  $L = 0.50 \text{ m}$
- c.  $L = 1.50 \text{ m}$
- d.  $L = 2.67 \text{ m}$
- e.  $L = 7.50 \text{ m}$

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

In the figure is shown a square loop ( $L = 2\text{ cm}$ ) of wire in edge view, which is free to rotate around an axis  $O$  (perpendicular to the page). The loop consists of 8 loops of wire and the normal to the loops forms an angle of  $30^\circ$  degrees. An external battery (not shown) causes a current  $I = 3.0\text{ amps}$  to flow around the loop. The external magnetic field directed down ( $B = 0.7\text{ T}$ ) creates a clockwise torque on the current loop.



14. What is the direction of the current in wire  $A$ ?

- a. into the page
- b. out of the page

15. What is the magnitude of the torque?

- a.  $3.4 \times 10^{-3}\text{ N m}$
- b.  $8.4 \times 10^{-3}\text{ N m}$
- c.  $12.6 \times 10^{-3}\text{ N m}$

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

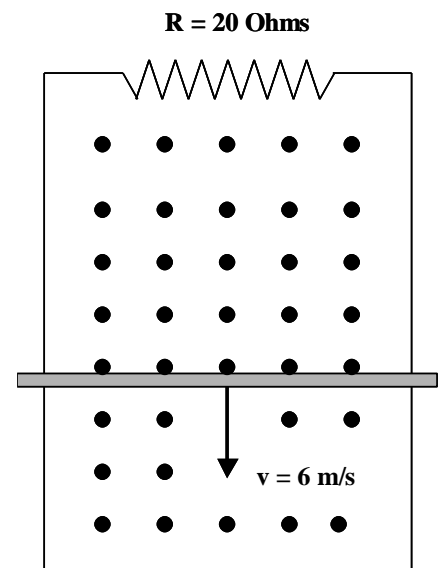
Two fixed conductors are connected by a resistor  $R = 20 \Omega$ . The two fixed conductors are separated by  $L = 1.5 \text{ m}$ . A moving conductor is pushed along them (without friction) **at a constant speed**  $v = 6 \text{ m/s}$ . A  $3 \text{ T}$  magnetic field (shown by the black dots in the figure) points out of the page.

16. In which direction does the current flow through the resistor?

- a. to the right
- b. to the left

17. What force must be applied to the bar to keep it moving at  $6 \text{ m/s}$ ?

- a.  $4 \text{ N}$
- b.  $6 \text{ N}$
- c.  $7.5 \text{ N}$

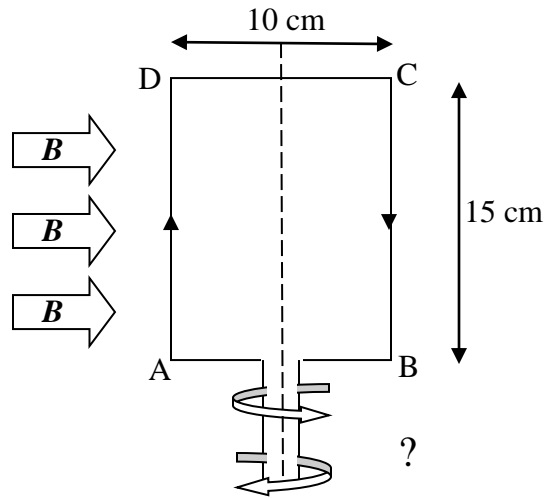


18. If the  $20 \text{ ohm}$  resistor was replaced by a  $100 \text{ ohm}$  resistor, the net force needed to keep the bar moving at  $6 \text{ m/s}$  would

- a. Increase
- b. Remain the same
- c. Decrease

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

This loop has 200 turns of wire with resistance  $0.3 \Omega/\text{m}$ . It is turned at a steady rate and dissipates energy with a peak power of  $100 \text{ W}$ . The external magnetic field is constant and the current flows around the loop in the direction indicated in the figure at the instant shown.



19. What is the peak emf generated in the loop?

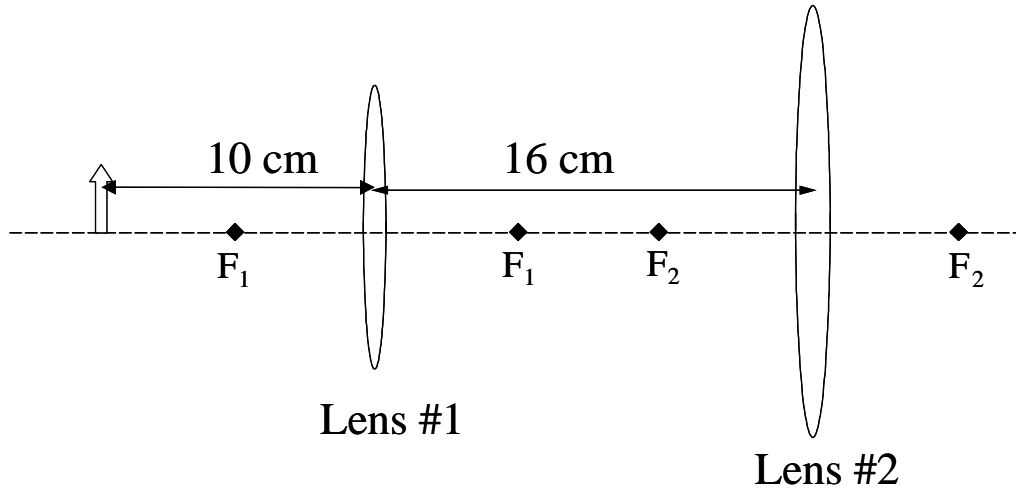
- 23 V
- 55 V
- 100 V
- 173 V
- 284 V

20. As viewed from below, the direction of rotation of the loop is

- clockwise (that is, AD comes out of the page at the instant shown)
- counter-clockwise (that is, AD goes into the page at the instant shown)

*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.



21. **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.

22. 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

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

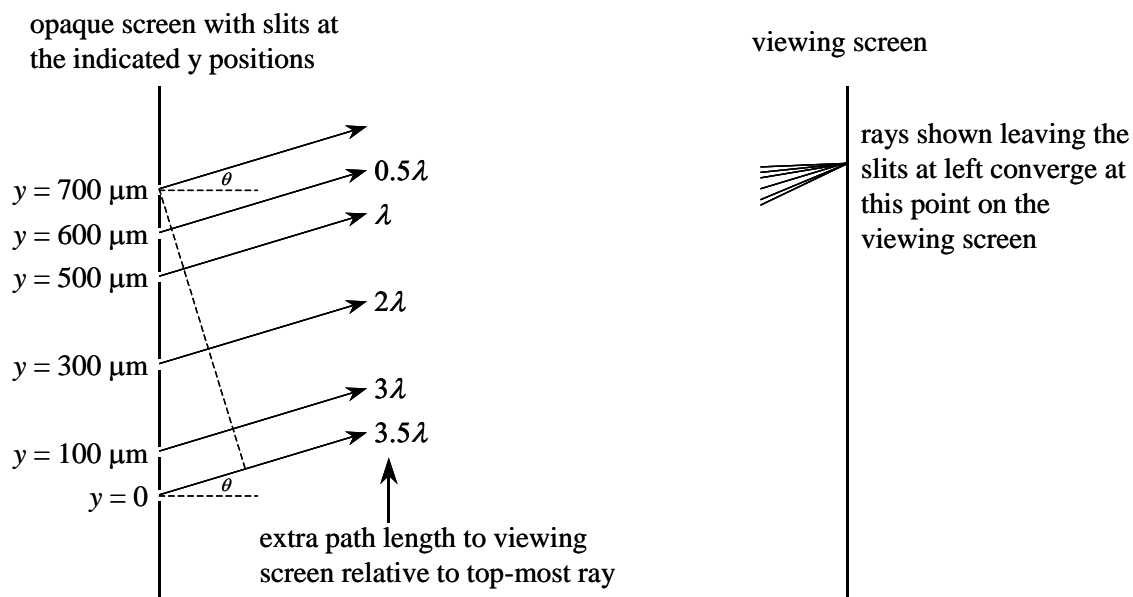
- inverted relative to the object.
- upright relative to the object.



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.)

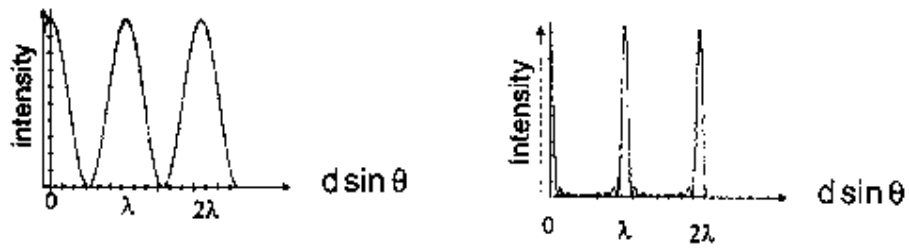


24. The *intensity* of the light measured at the point of convergence of the rays is  $I_6$ . If the intensity of light out of one slit is  $I_1$ , what is the ratio of the intensities  $I_6 / I_1$ ?

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

25. 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



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

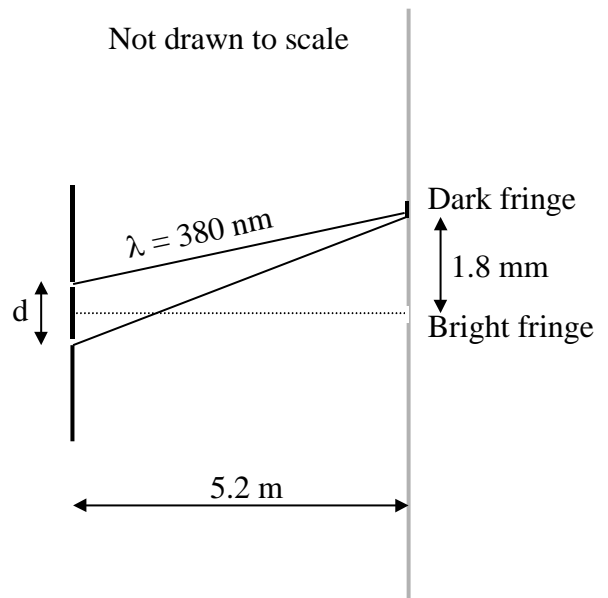
True or false: The total number of slits is greater in the pattern on the right than in the pattern on the left.

- a. true
- b. false

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

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

- $d = 0.15 \text{ mm}$
- $d = 0.21 \text{ mm}$
- $d = 0.36 \text{ mm}$
- $d = 0.41 \text{ mm}$
- $d = 0.55 \text{ mm}$

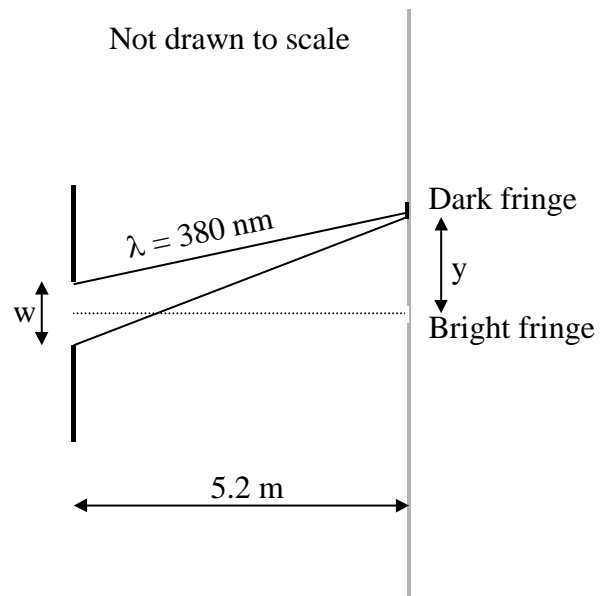


28. Now red light ( $\lambda = 650 \text{ nm}$ ) is incident on the same two slits, the distance  $y$  between the central bright fringe and the first dark fringe is

- $y < 1.8 \text{ mm}$
- $y = 1.8 \text{ mm}$
- $y > 1.8 \text{ mm}$

29. 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?

- $y < 1.8 \text{ mm}$
- $y = 1.8 \text{ mm}$
- $y > 1.8 \text{ mm}$



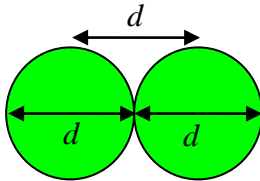
**The next three questions refer to the following situation:**

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.

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

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

31. The diameter of the green ( $\lambda=550$  nm) dots in the painting is  $d = 2.0$  mm and the dots are touching each other, as shown in the figure below. What is the maximum distance,  $L$ , a person with normal, unaided vision (near point 25 cm, far point infinity, pupil diameter 2.0 mm) can stand from the painting to resolve the individual green dots?

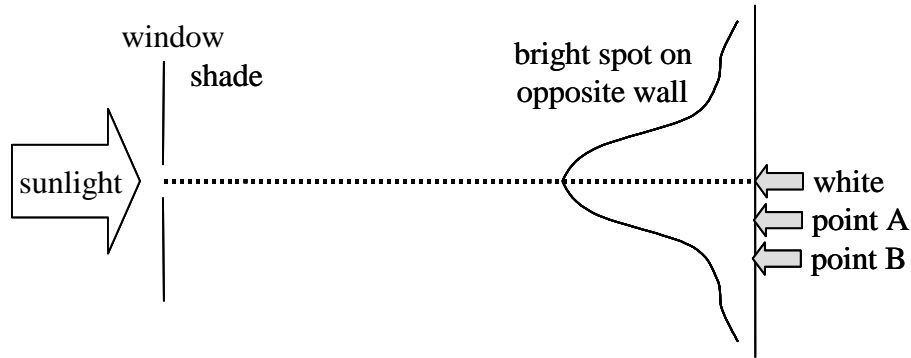


- a.  $L = 1.44$  m
- b.  $L = 2.31$  m
- c.  $L = 3.27$  m
- d.  $L = 4.89$  m
- e.  $L = 5.96$  m

32. Let  $L$  be the answer to the previous question. If the diameter of the green dots were 1.0 mm instead of 2.0 mm, the maximum distance a person with normal, unaided vision (near point 25 cm, far point infinity, pupil diameter 2.0 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  $L$ .

33. Sunlight shines through a pinhole in an otherwise opaque window shade, creating a bright spot on a wall on the opposite side of the room. Because of diffraction effects, the *color* of the bright spot (as well as its intensity) varies with distance from the center of the spot. Assume that the range of wavelengths in sunlight extends from 400 nm (blue) to 700 nm (red).



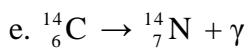
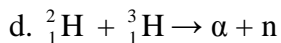
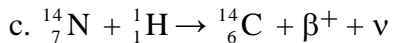
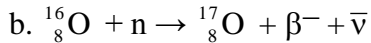
Which one of the following statements can be correct?

Relative to the center of the bright spot, which is white,

- point A contains equal intensities of all colors of light while point B consists only of red light.
- point A contains only blue light while point B contains only red light.
- points A and B only contain green light.
- point A is deficient in blue light while point B is deficient in red light.
- point A is deficient in red light while point B is deficient in blue light.

34. 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



35. 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  $-3/2$ . 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

36. Consider a hydrogen atom in the  $n = 1$  state. The atom is placed in a uniform B field of magnitude 2.5 T. Calculate the energy difference between the highest and lowest electronic energy levels in the presence of the B field.

a.  $9.3 \times 10^{-5}$  eV

b.  $29 \times 10^{-5}$  eV

c.  $11.6 \times 10^{-5}$  eV

37. 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

38. 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

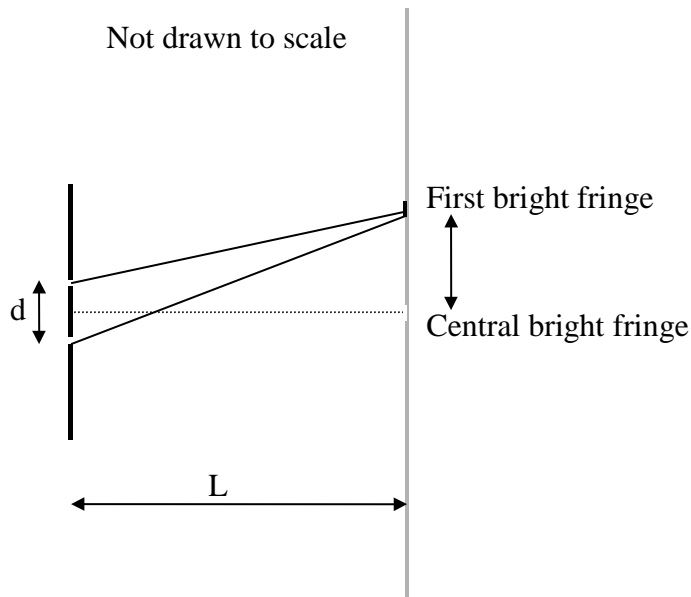
39. The nucleus of nitrogen  ${}^{14}_7\text{N}$  has a mass of  $13,040 \text{ MeV}/c^2$ . What is the binding energy of this nucleus? (The mass of the proton is  $938.3 \text{ MeV}/c^2$ , and that of the neutron is  $939.5 \text{ MeV}/c^2$ )

- a. 2.2 MeV
- b. 15.4 MeV
- c. 47.9 MeV
- d. 80.7 MeV
- e. 104.6 MeV

40. 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:*



41. 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

42. 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



43. You decide to build your own burglar alarm system using your knowledge of the photoelectric effect from Phys. 102. Your idea is to shine a laser onto a metal, generating a current from the release of photoelectrons. If the beam is blocked (by a burglar), the current stops, and the alarm goes off.

To ensure that the burglar does not see the beam of light, you use an infrared laser (with wavelength 1064 nm). Now you need to select a metal with the right work function  $W_0$  to complete your alarm; you have the following choices:

Metal A –  $W_0 = 1 \text{ eV}$

Metal B –  $W_0 = 1.5 \text{ eV}$

Metal C –  $W_0 = 2 \text{ eV}$

Which metal(s) will work for this application?

- a. All of them
- b. A and B
- c. B and C
- d. A only
- e. C only

***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. It is often seen in the spectrum of light from celestial objects.

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

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

45. 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. E  | 26. A |
| 2. C  | 27. E |
| 3. A  | 28. C |
| 4. B  | 29. C |
| 5. B  | 30. C |
| 6. A  | 31. E |
| 7. C  | 32. A |
| 8. C  | 33. D |
| 9. A  | 34. D |
| 10. A | 35. C |
| 11. B | 36. B |
| 12. A | 37. B |
| 13. B | 38. B |
| 14. A | 39. E |
| 15. A | 40. C |
| 16. A | 41. B |
| 17. B | 42. C |
| 18. C | 43. D |
| 19. B | 44. A |
| 20. A | 45. B |
| 21. B |       |
| 22. E |       |
| 23. B |       |
| 24. C |       |
| 25. A |       |