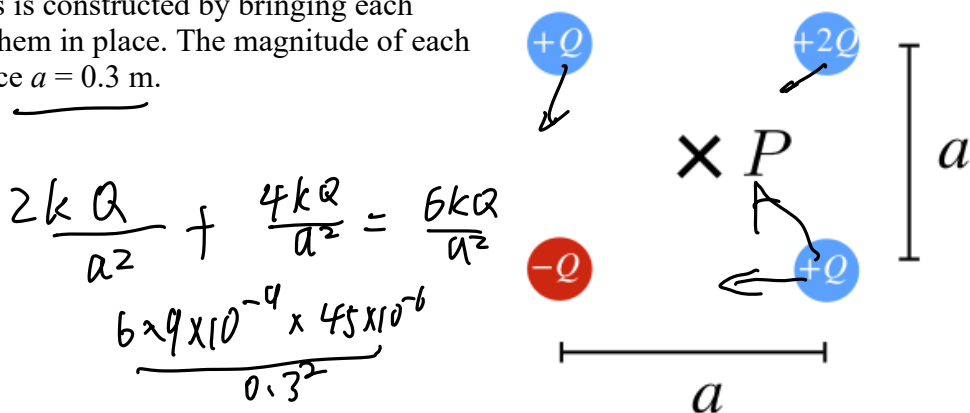


The next four questions pertain to the situation described below.

The above configuration of charges is constructed by bringing each charge in from infinity and fixing them in place. The magnitude of each charge is $Q = 45 \mu\text{C}$ and the distance $a = 0.3 \text{ m}$.



3) What is the magnitude of the electric field at the origin of the square, point P?

- a. $|E_P| = 1.91 \times 10^7 \text{ N/C}$
 ✓ b. $|E_P| = 2.7 \times 10^7 \text{ N/C}$ ✓
 c. $|E_P| = 1.35 \times 10^7 \text{ N/C}$
 d. $|E_P| = 8.1 \times 10^6 \text{ N/C}$
 e. $|E_P| = 5.73 \times 10^6 \text{ N/C}$

$$\begin{aligned}
 & - \int_{\infty}^a - \frac{kQ^2}{x^2} dx \\
 & = - \left. \frac{kQ^2}{x} \right|_{\infty}^a = - \frac{kQ^2}{a} \\
 & - \int_{\infty}^{\sqrt{2}a} \frac{kQ^2}{x^2} dx = \left. \frac{kQ^2}{x} \right|_{\infty}^{\sqrt{2}a} = \frac{kQ^2}{\sqrt{2}a} \\
 & - \frac{kQ^2}{a} - \frac{kQ^2}{a} + \frac{kQ^2}{\sqrt{2}a} + \frac{4kQ^2}{a} \\
 & = - \frac{2kQ^2}{\sqrt{2}a}
 \end{aligned}$$

4) Find the amount of work you must do to construct this configuration.

- ✓ a. $W = 78.5 \text{ J}$
 b. $W = 122 \text{ J}$
 c. $W = 0 \text{ J}$
 d. $W = -85.9 \text{ J}$
 e. $W = 262 \text{ J}$

5) The top left charge is released and accelerates off to infinity. Calculate the final velocity of the charged particle which has a mass $m = 0.009 \text{ kg}$.

- a. $1.73 \times 10^7 \text{ m/s}$
 b. 97.7 m/s
 ✓ c. 152 m/s

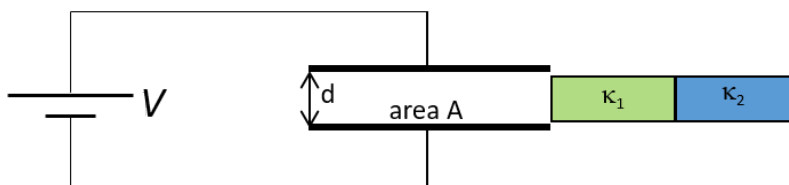
$$\begin{aligned}
 & - \frac{kQ^2}{a} - \frac{kQ^2}{\sqrt{2}a} \\
 & = \frac{2kQ^2}{\sqrt{2}am} \\
 & \frac{2kQ^2}{x} \Big|_a^{\infty} = - \frac{2kQ^2}{a} \\
 & \frac{kQ^2}{x} \Big|_{\sqrt{2}a}^{\infty} = - \frac{kQ^2}{\sqrt{2}a} \\
 & - \frac{kQ^2}{x} \Big|_a^{\infty} = \frac{kQ^2}{a}
 \end{aligned}$$

6) After the top left charge is removed, how does the magnitude of the electric field at the origin change? The magnitude:

- ✓ a. Increases
 b. Decreases
 c. Stays the same

The next three questions pertain to the situation described below.

A parallel plate capacitor is constructed from two plates each with area $A = 0.065 \text{ m}^2$, separated by a distance $d = 0.0052 \text{ m}$. The capacitor is connected to a battery with voltage $V = 12 \text{ Volts}$.



7) What is energy stored in the capacitor when the space ~~between the plates is empty?~~

b.

a. $U_0 = 6.51 \times 10^{11} \text{ J}$

✓ b. $U_0 = 7.96 \times 10^{-9} \text{ J}$

c. $U_0 = 1.33 \times 10^{-9} \text{ J}$

$$E = \frac{1}{2} C U^2$$

$$C = \frac{\epsilon_0 \epsilon A}{d}$$

8) A dielectric is now placed between the plates. The left half has a dielectric constant κ_1 , and the right half has dielectric constant κ_2 . Let C_0 represent the capacitance of the plates before the dielectric is inserted. What is the capacitance of the system with the dielectric completely filling the region between the plates?

C

a. $C = C_0 (2\kappa_1\kappa_2)/(\kappa_1 + \kappa_2)$

b. $C = C_0 (\kappa_1\kappa_2)/(\kappa_1 + \kappa_2)$

✓ c. $C = C_0 (\kappa_1 + \kappa_2)/2$

$$C_0 = \frac{\epsilon_0 \epsilon A}{d}$$

$$C_1 = \frac{\epsilon_0 \kappa_1 \cdot \frac{A}{2}}{d}$$

$$C_2 = \frac{\epsilon_0 \kappa_2 \cdot \frac{A}{2}}{d}$$

$$\frac{\epsilon_0 \cdot A}{d} \cdot \frac{\kappa_1 + \kappa_2}{2}$$

$$C = C_1 + C_2 = C \cdot \frac{(\kappa_1 + \kappa_2)}{2}$$

9) As the dielectric is inserted, the charge on the top plate of the capacitor

b.

a. decreases.

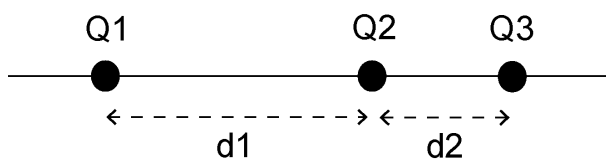
✓ b. increases.

c. remains the same.

$$C \uparrow$$

$$Q = C U$$

The next two questions pertain to the situation described below.



Three charges are placed along a line (x axis): from left $Q1 = -8\mu\text{C}$, $Q2 = -4\mu\text{C}$, and $Q3 = 16\mu\text{C}$. The distance between $Q1$ and $Q2$ is 2.1 cm. The distance between $Q2$ and $Q3$ is 1.05 cm.

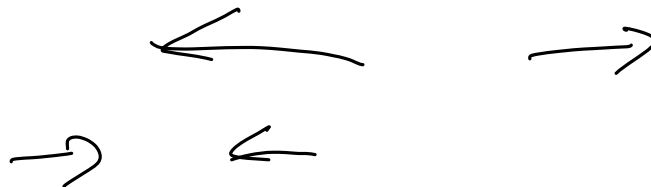
10) What is the x component of the net force on $Q2$? *e.*

- a. $F_{2x} = 0 \text{ N}$
- b. $F_{2x} = -5880 \text{ N}$
- c. $F_{2x} = -4570 \text{ N}$
- d. $F_{2x} = 4570 \text{ N}$
- ✓ *e. $F_{2x} = 5880 \text{ N}$*

$$\frac{9 \times 10^9 \times (32) \times 10^{-6}}{0.021^2} + \frac{9 \times 10^9 \times (64) \times 10^{-6}}{0.0105^2}$$

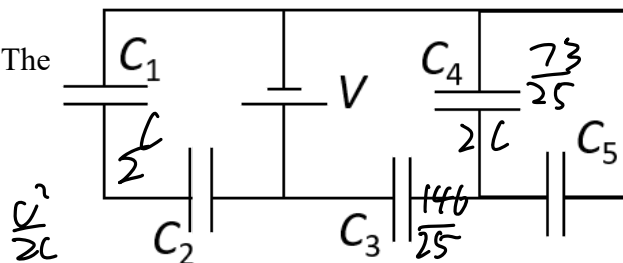
11) If $Q2$ is removed, where is it possible for the electric field to be zero? *a.*

- ✓ *a. Left of $Q1$*
- b. Between $Q1$ and $Q3$
- c. Right of $Q3$
- d. Between $Q1$ and $Q3$ and right of $Q3$
- e. Left of $Q1$ and right of $Q3$



The next three questions pertain to the situation described below.

Five identical capacitors with capacitance $C = 25 \mu\text{F}$ are connected to a battery with voltage V as shown in the figure. The charge on capacitor C_4 is observed to be $Q_4 = 73 \mu\text{C}$.



12) Capacitors C_4 and C_5 are in: C .

- a. series.
- b. neither series nor parallel.
- ✓ c. parallel.

$$\frac{2C^2}{3C} = \frac{2}{3}C$$

$$\frac{C}{2} + \frac{2}{3}C = \frac{7}{6}C$$

13) What is the equivalent capacitance of the five capacitors in this configuration?

- a. $C_{eq} = 50 \mu\text{F}$
- b. $C_{eq} = 125 \mu\text{F}$
- ✓ c. $C_{eq} = 29.2 \mu\text{F}$
- d. $C_{eq} = 62.5 \mu\text{F}$
- e. $C_{eq} = 5 \mu\text{F}$

C .

$$\frac{219}{25}$$

$$Q = CV$$

$$V_1 = \frac{73 \times 10^{-6}}{25 \times 10^{-6}}$$

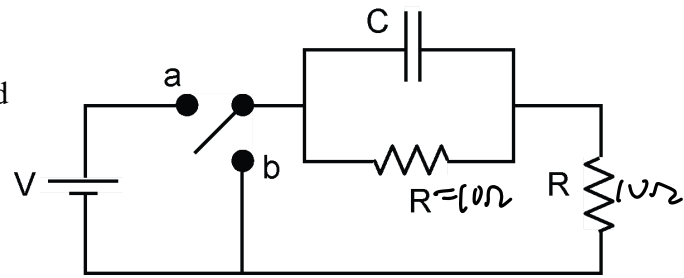
14) What is the voltage V of the battery?

d .

- a. $V = 2.92 \text{ V}$
- b. $V = 4.38 \text{ V}$
- c. $V = 5.84 \text{ V}$
- ✓ d. $V = 8.76 \text{ V}$
- e. $V = 0.973 \text{ V}$

The next three questions pertain to the situation described below.

Two resistors of equal resistance $R = 10\ \Omega$ are connected to a capacitor of $C = 40\ \mu\text{F}$ and a battery $V = 5\ \text{V}$ as in the figure. In the beginning the switch is open from both positions, a and b and the capacitor is uncharged.



15) What is the current through the capacitor immediately after the switch is moved to position a? $a,$

- ✓ ☒ a. 0.5 A
☐ b. 0 A
☐ c. 0.25 A

$$\frac{5}{10} = 0.5$$

16) Calculate the charge on the capacitor after the switch has been in position a for a long time. $a,$

- ✓ ☒ a. 100 μC
☐ b. 400 μC
☐ c. 200 μC

$$\frac{2.5 \times 40 \times 10^{-6}}{10^{-4}}$$

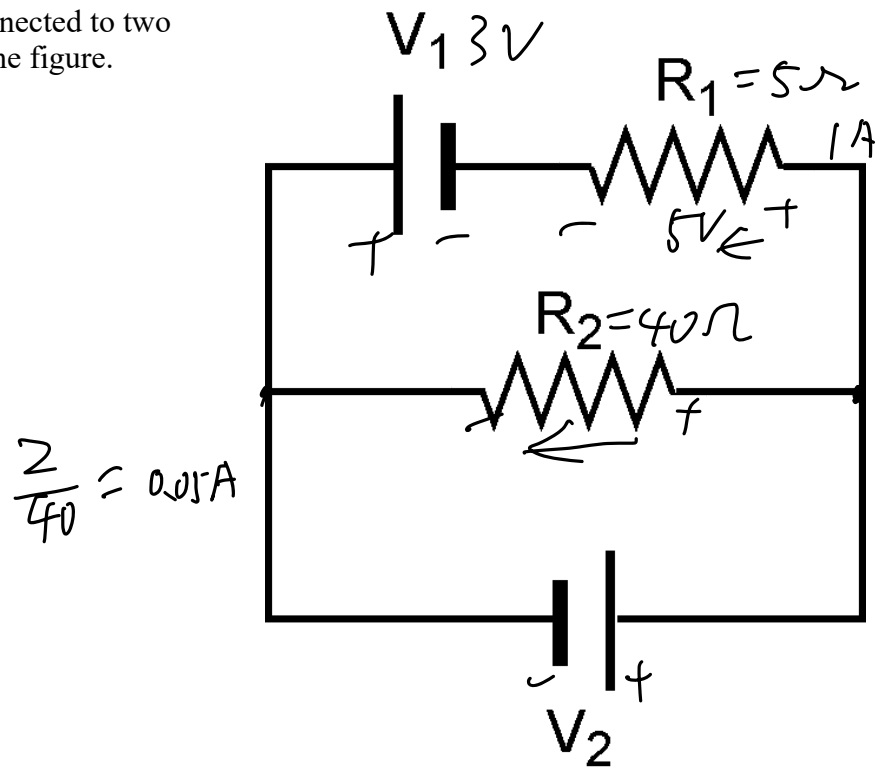
17) After the capacitor was fully charged, the switch is moved to position b discharge the capacitor. What is the time constant of discharging the capacitor? $b-$

- ✓ ☒ b. 200 μs
☐ a. 400 μs
☐ c. 800 μs

$$5 \times 40 \times 10^{-6} = 2 \times 10^{-4}$$

The next two questions pertain to the situation described below.

Two resistors ($R_1 = 5\ \Omega$, $R_2 = 40\ \Omega$) are connected to two batteries ($V_1 = 3\ \text{V}$, $V_2 = 2\ \text{V}$) as shown in the figure.



18) What is the current through R_2 ?

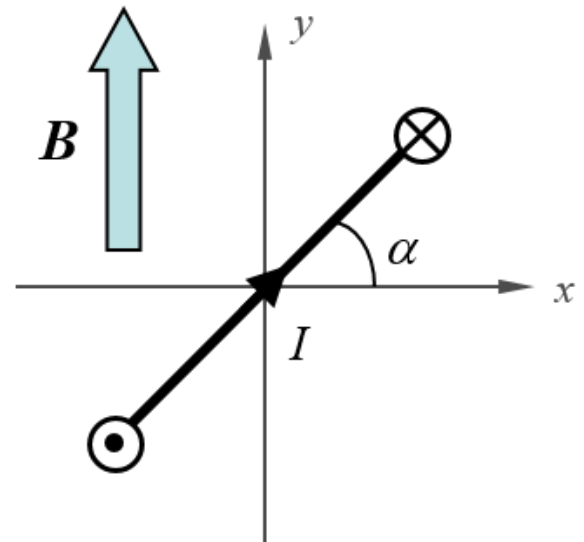
a. 0.025 A

b. 0.125 A

✓ c. 0.05 A

The next three questions pertain to the situation described below.

A generator consists of a square loop of wire with length $L = 1.8$ m spinning with constant angular velocity ω uniform magnetic field $B = 0.7$ T directed in the positive y direction as shown in the figure.



20) As the loop spins, at which orientation is the peak voltage generated?

- ✓ ☒ a. $\alpha = 90^\circ$
☐ b. $\alpha = 0^\circ$
☐ c. $\alpha = 45^\circ$

a.

21) If the peak voltage generated is 230 Volts, what is the angular velocity of the loop?

- ✓ ☒ a. $\omega = 261$ radians/second
☐ b. $\omega = 145$ radians/second
☒ c. $\omega = 101$ radians/second

$$\mathcal{E} = \frac{Bos}{\Delta t} = B \frac{d(L \cdot L \cos \omega t)}{dt} \\ = -B\omega L^2 \sin \omega t$$

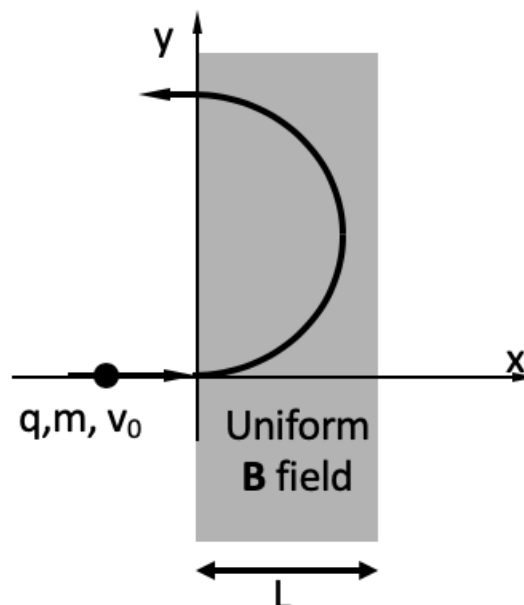
22) If the induced current is traveling in the direction shown on the image, in what direction is the loop being rotated?

- ✓ ☒ a. counterclockwise
☐ b. clockwise

a,

The next three questions pertain to the situation described below.

A positive charge enters a region of uniform magnetic field and then starts to move in a circle, as shown. The initial speed of the particle is 0.23 m/s, its mass is 23 g, and the charge is 0.7 C.



23) What is the direction of the magnetic field?

b.

- a. Out of the page (+z)
- ✓ b. Into the page (-z)
- c. Left (-x)
- d. Down (-y)
- e. Up (+y)

24) If the exit point is 0.2 m above the entry point from the entry point, what is the acceleration of the particle when it first enters the field? The magnitude of the magnetic field in this situation would be 0.0756 T

b.

$$a = \frac{v^2}{R}$$

- a. 0.0028 m/s² up (+y)
- ✓ b. 0.529 m/s² up (+y)
- c. 0.529 m/s² down (-y)

25) The region of uniform field extends only a finite distance (L) in the x-direction. For a magnetic field strength of 0.34T, what is the minimum value of the extent in the x-direction that allows the particle to complete a semi-circle as shown?

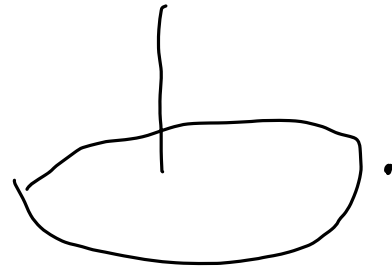
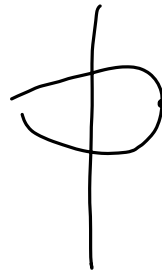
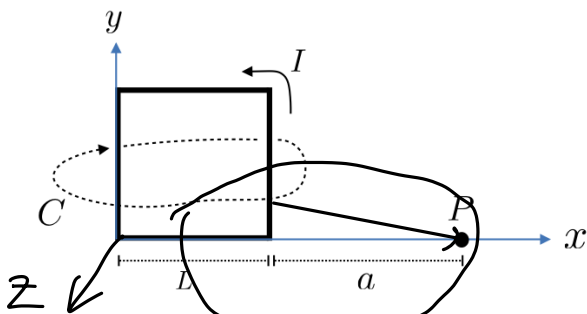
a.

$$qvB = m \frac{v^2}{r}$$

$$r = \frac{mv}{qB}$$

- ✓ a. 0.0222 m
- b. 0.0111 m
- c. 0.0444 m

The next two questions pertain to the situation described below.



Consider the above square loop of wire with current I flowing through it in the direction shown. The z direction is out of the page.

26) Which of the following expressions computes the magnetic field at point P due only to the right segment of the wire?

a. $\hat{x} \frac{\mu_0 I}{4\pi} \int_0^L dy \frac{a}{(a^2 + y^2)}$

b. $\hat{x} \frac{\mu_0 I}{4\pi} \int_0^L dy \frac{a}{(a^2 + y^2)}$

c. $\hat{x} \frac{\mu_0 I}{4\pi} \int_0^L dy \frac{a}{(a^2 + y^2)^{3/2}}$

$$2\pi r \cdot B = \mu_0 I$$

✓ d. $-\hat{z} \frac{\mu_0 I}{4\pi} \int_0^L dy \frac{a}{(a^2 + y^2)^{3/2}}$

e. $-\hat{z} \frac{\mu_0 I}{4\pi} \int_0^L dy \frac{a}{(a^2 + y^2)}$

27) What is the line integral of the B field around the loop C that goes around the square shown in the above figure? $\oint_C B \cdot dl =$

$\mu_0 I$

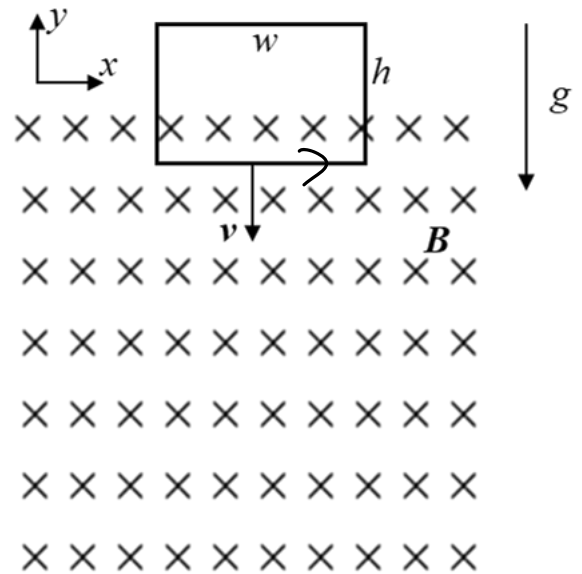
✓ a. 0

b. $-2\mu_0 I$

c. $2\mu_0 I$

The next three questions pertain to the situation described below.

A wire loop with mass $m = 0.4$ kg, width $w = 1.5$ m and height $h = 0.8$ m is released from rest just above a region of uniform magnetic field $B = 2.5$ T directed into the page. There is no magnetic field outside this region. The gravitational force causes the loop to fall and its motion is constrained to the xy plane (e.g. it falls straight down without rotating). At the moment shown in the diagram, the loop is partially in the magnetic field and is observed to be moving downward with speed $|v| = 1.2$ m/s, and the magnitude of the current induced in the loop is measured to be $I = 0.74$ Amps.



$$E = B L v$$

$$I = \frac{E}{R} \quad R = \frac{E}{I}$$

28) What is the resistance of the loop?

b.

- a. $R = 3.242 \, \Omega$
- ✓ b. $R = 6.08 \, \Omega$
- c. $R = 4.864 \, \Omega$
- d. $R = 4.5 \, \Omega$
- e. $R = 4.66 \, \Omega$

29) At the position shown in the figure the induced current in the loop is flowing a.

- ✓ a. counterclockwise
- b. clockwise

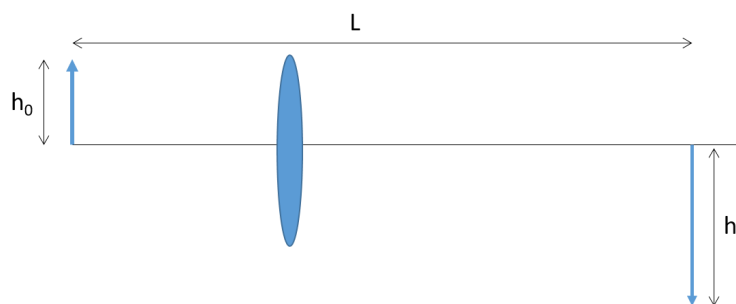
30) At the moment shown in the figure and described in the text, the magnitude of the acceleration of the loop is

d.

- a. $|a| = 6.938 \, \text{m/s}^2$
- b. $|a| = 9.81 \, \text{m/s}^2$
- c. $|a| = 3.7 \, \text{m/s}^2$
- ✓ d. $|a| = 2.861 \, \text{m/s}^2$
- e. $|a| = 16.738 \, \text{m/s}^2$

The next four questions pertain to the situation described below.

An object of height $h_o = 0.22$ m is placed to the left of a converging lens producing an image a distance of height $h_i = 0.48$ m a distance $L = 2.8$ m to the right of the object.



31) The image is *a*,

- ✓ ☒ a. real
☐ b. virtual

32) The focal length of the lens is *b*.

- ✓ ☒ a. $f = 3.54$ m
☒ b. $f = 0.603$ m
☐ c. $f = 1.62$ m
☐ d. $f = 1.32$ m
☐ e. $f = 0.151$ m


$$-\frac{s'}{s} = \frac{-0.48}{0.22}$$

$$s' = \frac{24}{11} s$$

$$\frac{35}{11} s = 2.8$$

$$\frac{s' \cdot s}{s^2 + s} = f$$

$$\frac{\frac{24}{11} s^2}{L}$$

33) A block of glass with width $w = 3.4$ m, is placed just  to the right of the lens. A ray of light is incident on the block at an angle $\theta_i = 40^\circ$, and refracted such that it makes an angle $\theta_f = 28^\circ$ inside the glass. How does inserting the block of glass effect the location of the image?

a

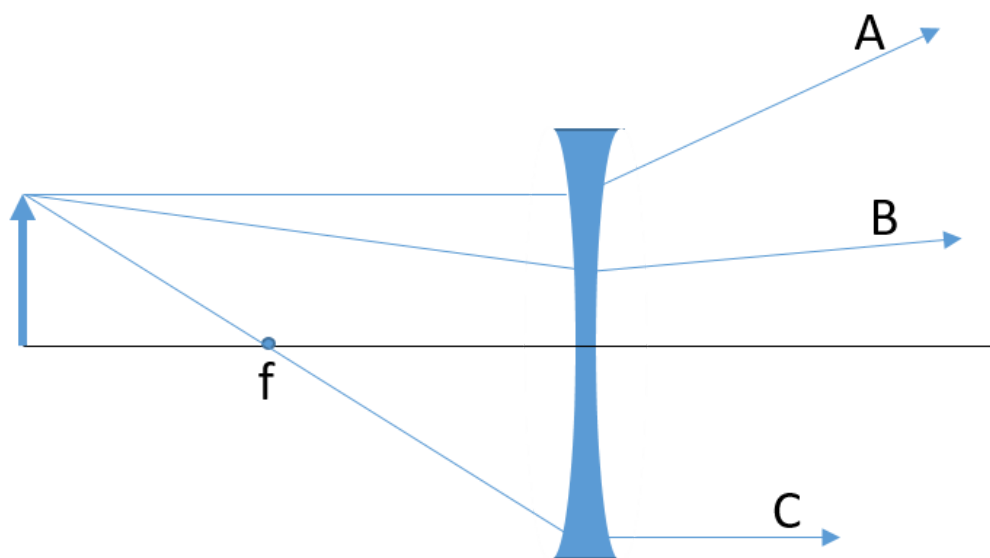
- ✓ ☒ a. The image is **further** from the object when the glass block is inserted.
☐ b. Inserting the glass block **does not change** the position of the image.
☐ c. The image is **closer** to the object when the glass block is inserted.

34) What is the n_{glass} , the index of refraction of the glass?

c

- ✓ ☒ a. $n_{\text{glass}} = 1.73$
☐ b. $n_{\text{glass}} = 1.87$
☒ c. $n_{\text{glass}} = 1.37$

The next two questions pertain to the situation described below.



An object is placed to the left of a diverging lens as shown in the figure. The point labeled f is the focal point for the lens.

35) Which of the three rays shown is **NOT** correct? *b*

- a. ~~A~~
- ☒ b. B
- c. C

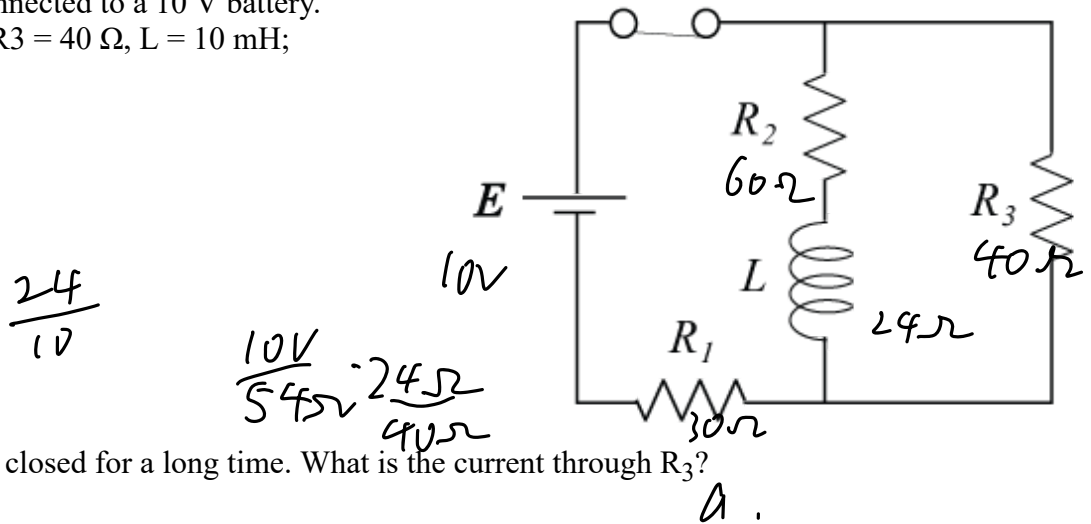
36) The image is *b.*

- a. inverted
- ☒ b. upright

The next three questions pertain to the situation described below.

Here is an RL circuit connected to a 10 V battery.

$R_1 = 30 \Omega$, $R_2 = 60 \Omega$, $R_3 = 40 \Omega$, $L = 10 \text{ mH}$;



37) The switch has been closed for a long time. What is the current through R_3 ?

- ✓ ☒ a. 0.111 A
 b. 0 A
 c. 0.143 A

38) After the switch was closed for a long time, it is open. How long does it take for current through the inductor to be halved?

- ✓ ☒ a. 417 μs
 b. 69.3 μs
 c. 100 μs
 d. 144 μs
 e. 289 μs

b.

$$e^{-\frac{Rt}{L}} = \frac{1}{2}$$

$$\frac{Rt}{L} = \ln 2$$

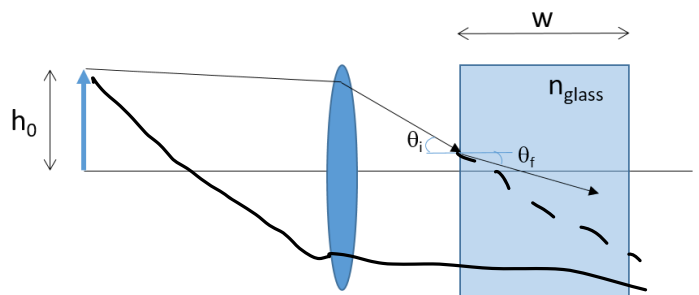
$$t = \frac{L \ln 2}{R}$$

39) After the switch was left open for a long time, it is closed again. What are the currents through R_2 and R_3 immediately after the closure?

$$R_2 \approx 0$$

$$\frac{10}{70}$$

- ✓ ☒ a. 0 A, 0.333 A
 b. 0.0741 A, 0.111 A
 c. 0 A, 0.143 A
 d. 0 A, 0 A
 e. 0.111 A, 0 A

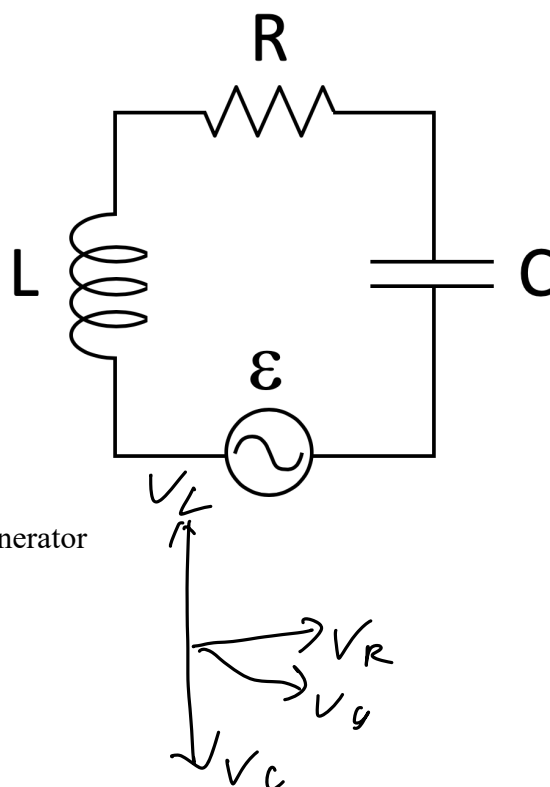


The next four questions pertain to the situation described below.

An LRC circuit has $L=34 \text{ mH}$, $C=16 \text{ uF}$, $R=11 \text{ ohms}$. The AC voltage generator is supplying a maximum voltage of 60 V at a frequency of 433 rad/s .

$$X_L = 433 \times 0.034 = 14.722$$

$$X_C = \frac{1}{433 \times 16 \times 10^{-6}} = 144.341$$



b. 40) The current through the resistor _____ the voltage across generator

- a. Is exactly in phase with
- ✓ b. leads
- c. lags

c. 41) The current through the inductor _____ the current through the resistor

- a. lags
- b. leads
- ✓ c. Is exactly in phase with

b. 42) What is the maximum current through the resistor?

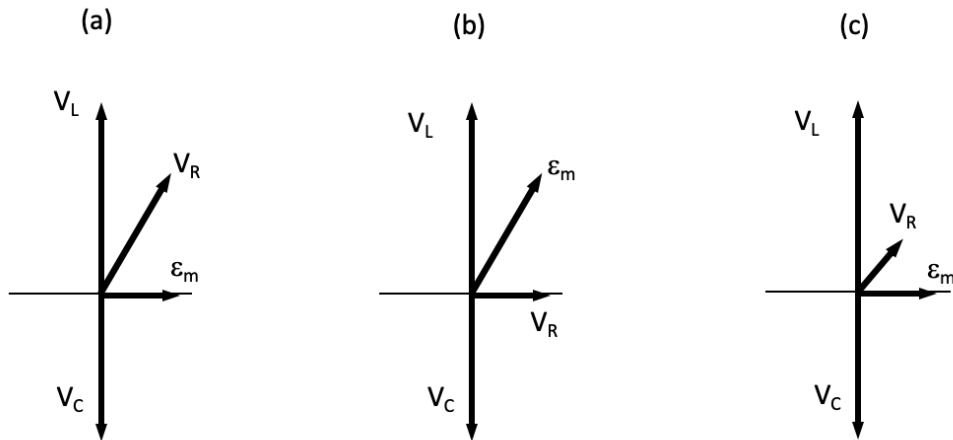
- a. 0.0035 A
- ✓ b. 0.46 A
- c. 0.38 A
- d. 0.42 A
- e. 5.5 A

a. 43) In order to increase the maximum current in the circuit, the frequency of the generator should be

- ✓ a. increased
- b. decreased
- c. changing the frequency of the generator does not effect the maximum current.

The next two questions pertain to the situation described below.

An RLC circuit has maximum voltages across each component $V_L=440\text{V}$, $V_C=373\text{V}$, $V_R=173\text{V}$. The resistor has a resistance of 6Ω .



44) Which of the above best represents the phasor diagram for this circuit?

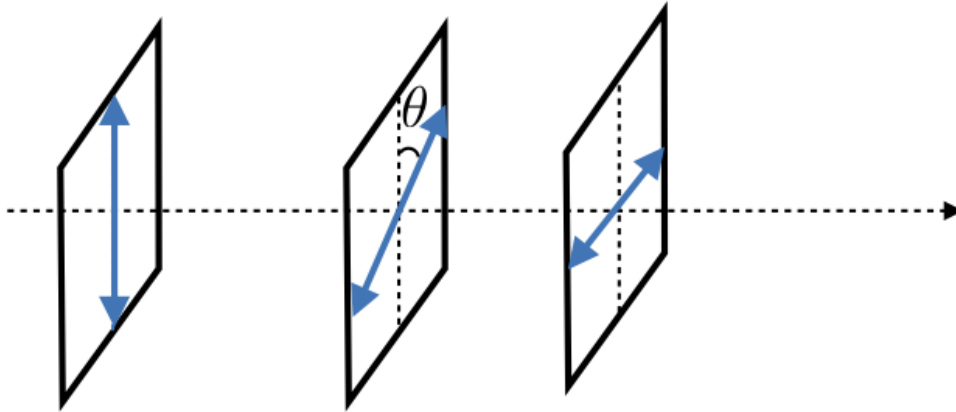
- a. A
- ☒ b. B
- c. C

45) What is the average power dissipated by the resistor?

- ☒ a. 2490 W
- b. 122 W
- c. 2670 W

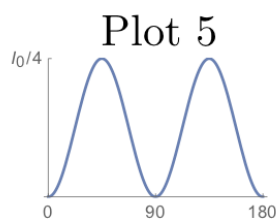
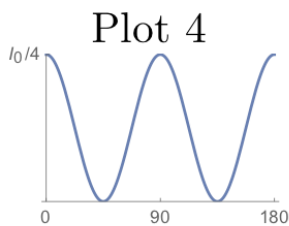
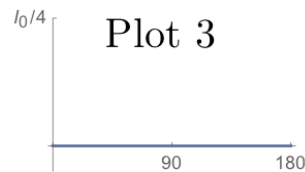
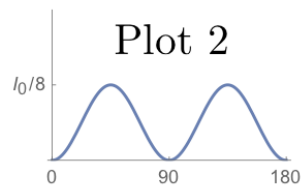
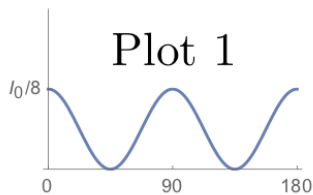
The next two questions pertain to the situation described below.

Three linear polarizers are arranged as follows:



Where θ is the angle between the vertical axis and the transmission axis of the second polarizer. The first polarizer has a vertical transmission axis and the second is horizontal. Unpolarized light is incident from the left with intensity I_0 .

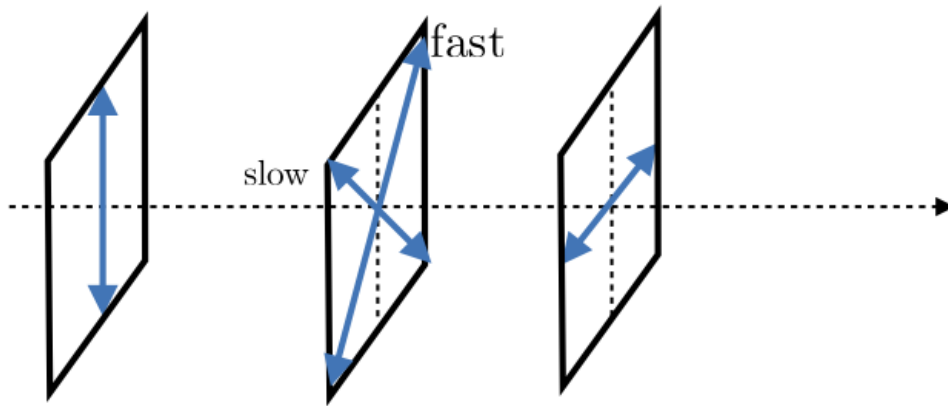
46) Which plot below best describes the final intensity as a function of θ ?



$$\frac{1}{2} I_0 \cdot \frac{1}{2}$$

- a. Plot One
- b. Plot Two
- c. Plot Three
- d. Plot Four
- ☒ e. Plot Five

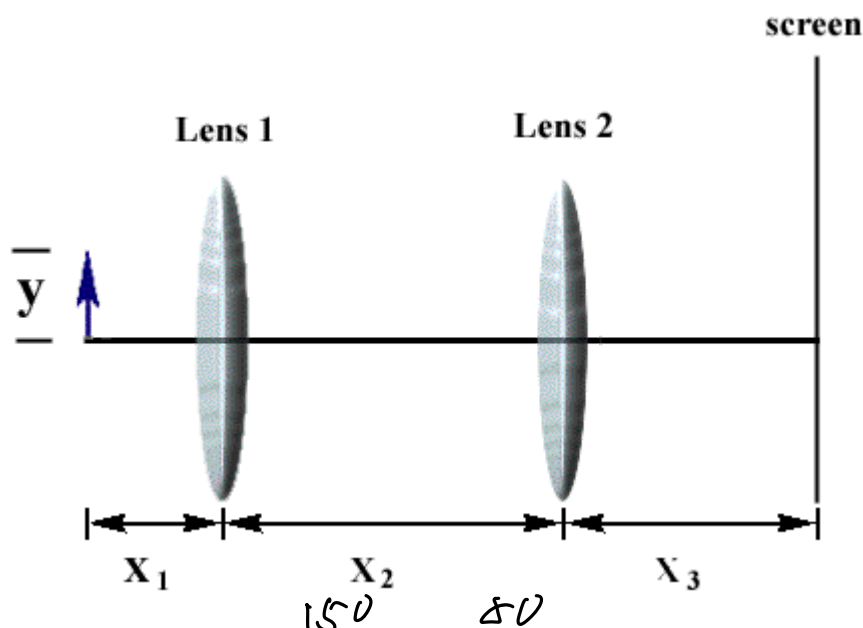
47) The middle polarizer is replaced with with a quarter wave plate such that the fast and slow axis are at 45 degrees to the horizon/vertical as shown below. What is the polarization of the final wave?



- a. Right circularly polarized
- b. Left circularly polarized

✓ c. Linearly Polarized

The next two questions pertain to the situation described below.



An object 5 cm high is located $X_1 = 75$ cm from a converging lens of focal length $f_1 = 50$ cm. A second converging lens of focal length f_2 is located $X_2 = 200$ cm from the first lens. An image of the object is to be formed on a screen $X_3 = 175$ cm from the second lens.

48) What must the focal length f_2 of the second lens be so that the final image appears on the screen?

- a. 93.33 cm
- b. 150 cm
- c. 52.5 cm
- d. 80.77 cm

✓ e. 38.89 cm

$$\frac{1}{75} + \frac{1}{s'} = \frac{1}{50}$$

$$\frac{1}{s'} = \frac{1}{50} - \frac{1}{75}$$

$$\frac{1}{50} + \frac{1}{175}$$

49) The final image formed on the screen (compared to the original object) is:

a. real and inverted

✓ b. real and upright

c. virtual and upright

d. no image forms on the screen

e. virtual and inverted