Semester II lab quiz Study Guide (E&M, Optics)
Physics 136/164 **DISTANCE LEARNING EDITION**

In this guide, lab titles/topics are listed alphabetically, with a page break in between each one. **You only need to study those labs that will be covered on your quiz.**

Spring 2020 Lab quiz 2 covers four labs: Kirchhoff's Laws, EM Induction, Interference, and Thin Lenses.

You are allowed to refer to the electronic labs themselves, your own lab notes, pre- and post-lab exercises, and handouts that your instructor may have provided.

Students work alone on lab quizzes.

Questions and tasks on the lab quizzes are based directly on what you have learned and done in lab activities. Therefore you should expect to turn in a perfect quiz if your lab notebook is complete, detailed, well-written and explains completely how you carried out activities and interpreted them.

Patience and extreme care will be rewarded, but as in real life, careless mistakes will be costly.

TIPS:

Read the descriptions and sample questions and contact your lab instructor with any questions.

Be familiar with the experiments, calculations and concepts.

Check your work and pay attention to details; verify and include units, label graph axes, read and use your calculator carefully.

Keep a neat set of lab notes with diagrams and details, and **answer all questions with full sentences** in your notes.

<u>**DC Circuits I and II**</u>

Given a table of current and voltage data for an arbitrary resistor, plot V vs. I and determine the resistance from analyzing the graph.

Be able to physically set up a circuit with specified resistor(s) in series or parallel with other resistor(s), or with combinations of resistors. Be able to place voltmeters and ammeters to measure the voltage or current across/through any circuit element or combination of elements.

Be able to measure the resistance of resistors using a multimeter.

SAMPLE 1

The current vs. voltage characteristics for an unknown resistor are indicated in the table below.

V (volts)	I (mA)
1	0.35
2	0.68
3	1.02
4	1.35
5	1.60

a. On graph paper, make a large graph of voltage vs. current.

b. What is the resistance of the resistor? Include units. <u>Use the graph</u> to determine your answer, and explain your reasoning.

SAMPLE 2

a. Draw a circuit diagram, involving a power supply, a voltmeter, an ammeter, and two 500 ohm resistors connected in parallel. Set it up so that the ammeter measures the current through only <u>one</u> of the resistors and the voltmeter measures the voltage across it.

b. If the power supply is set at 8.0 V, what will be the reading of the voltmeter? What will be the reading of the ammeter?

(more samples on next page)

SAMPLE 3

Please go to a test bench where you will find two multimeters, a power supply, and a resistor board.

Set everything up so that:

a. The power supply is outputting **seven** (7.0) volts through the load. Remember, don't trust the needle pointer display. Use one of the meters just to check the initial value; it won't drift much after that.

b. The load has resistors 1 and 3 in series with each other, and the combination is in parallel with resistor 2.

c. One of the meters measures the voltage across resistor 1.

d. The other meter measures <u>only</u> the current that is passing through resistor 2.

Variation of SAMPLE 3:

b. The load has resistors 2 and 3 in parallel with each other, and the combination is in series with resistor 1.

c. One of the meters measures the voltage across the parallel combination.

d. The other meter measures <u>only</u> the current that is passing through resistor 2.

Variation of SAMPLE 3:

b. The load has all 3 resistors in parallel with each other.

c. One of the meters measures the voltage across the parallel combination.

d. The other meter measures <u>only</u> the current that is passing through resistor 1.

Variation of SAMPLE 3:

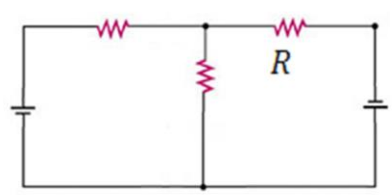
b. The load has all 3 resistors in series with each other.

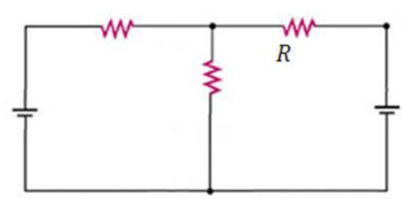
c. One of the meters measures the voltage across the entire series combination.

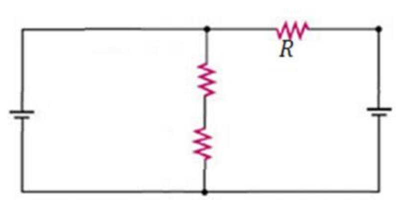
d. The other meter measures the current that is passing through resistor 3.

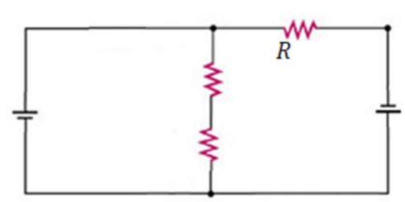
SAMPLE 4: There are several stations set up around the lab that contain two power sources and three resistors.

Which of the following circuit diagrams is an accurate representation of the actual circuit? Identify which station you were at, and circle the correct circuit diagram. **(Do not disconnect any of the wires. If any of the wires are disconnected, please let the instructor know.)**









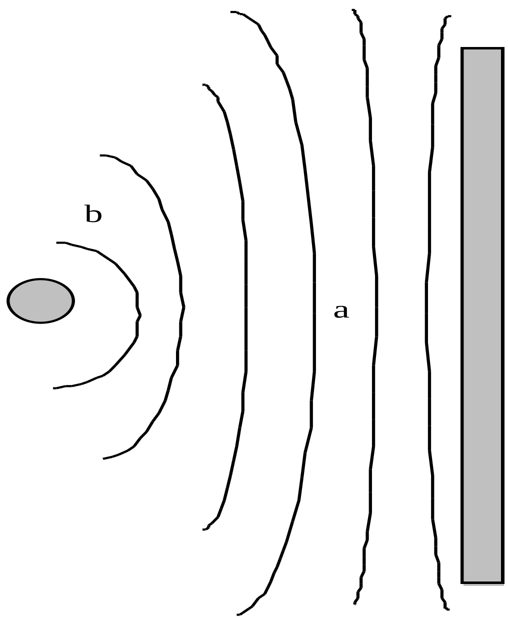
Electric Field and Electric Potential

Given a map of equipotential lines, draw E field lines (or vice versa).
Estimate (quantitatively) the E field strength and direction at any point.

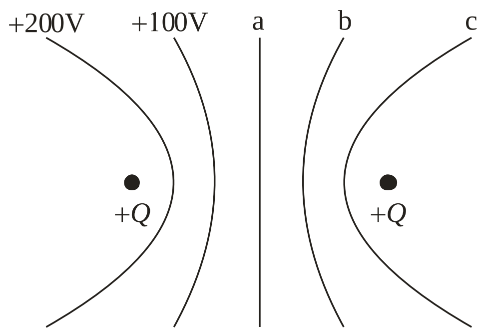
SAMPLE

A seven volt battery is connected across two electrodes, positive terminal to the oval electrode and negative terminal to the flat electrode. The figure shows portions of the equipotential lines between two electrodes, with each line indicating an electric potential that differs by one volt from that of adjacent lines.

Draw the electric field lines for this electrode configuration. Indicate the direction of the electric field by using arrowheads.
What is the magnitude of the electric field at point a? Point b? Include units.



Two equal positive charges are placed one meter apart (see figure below). The equipotential lines are at 100 V intervals. What is the potential for line c? Include units.

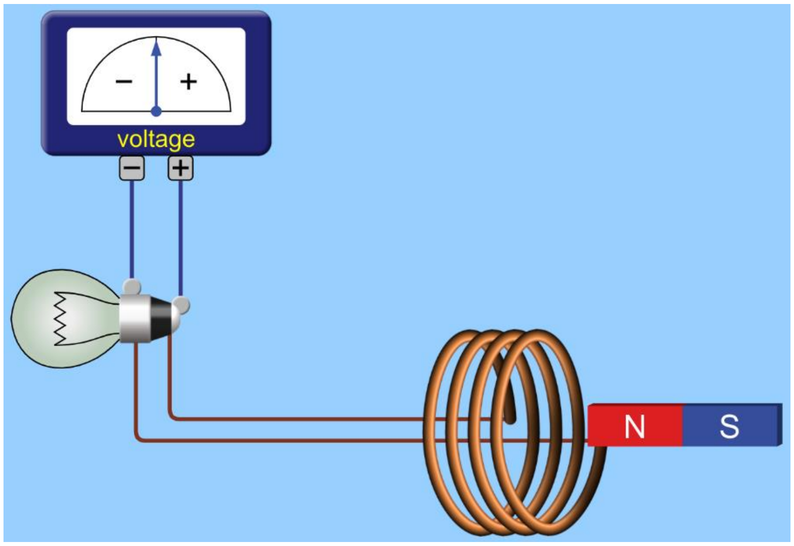

+200V
+100V
a
b
c
+Q
+Q

Electromagnetic Induction (Distance learning labs)

Given a circuit similar to the one below, determine which way the voltmeter needle deflects when a magnet is moved in a specified manner. Alternately, determine which way the magnet must be moved to produce a specified voltmeter needle deflection.

To receive full credit, you must be prepared to show all reasoning, such as information on the direction and magnitude of the primary and secondary fields (e.g., "it points left") and the direction of current flows (e.g, "clockwise as seen from the right").

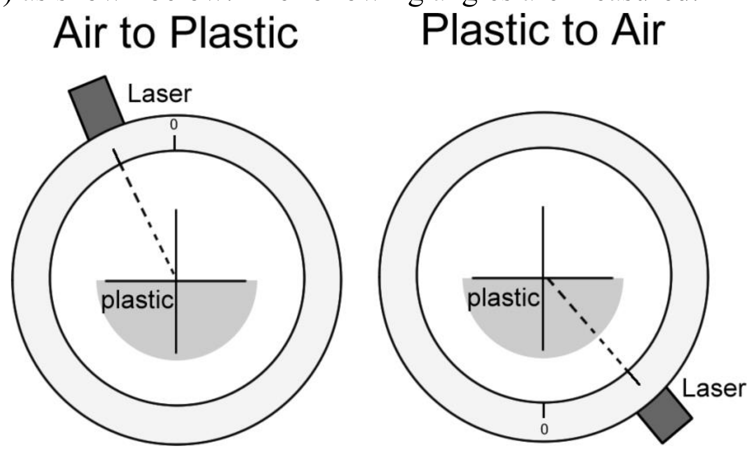
Question: When the magnet shown below moves to the right, in which direction does the voltmeter needle deflect? Justify your answer by specifying the directions of both the primary and secondary fields and the direction of induced current flow within the secondary coil.



Answer: The primary field associated with the bar magnet points to the left, at a location within the coil. When the magnet is moved to the right, the primary field intersecting the coil decreases in magnitude. According to Lenz's Law, this results in an induced field that also points to the left, to replace the decreasing primary field, hence trying to keep the flux the same. Using the right-hand rule, a leftward-pointing secondary field must be associated with a current moving clockwise (as seen from the right) through the coil. Following the coil and wires, this current runs from right (higher voltage) to left (lower voltage) through the bulb. The voltmeter needle always points to the side with higher voltage, so it **deflects to the right**.

Geometrical Optics

Light from a laser travels from air through plastic semi-circle (and through the plastic semi-circle to air) as shown below. The following angles are measured:



Complete the calculations for the index of refraction of the plastic $n_{plastic}$, **including a range of uncertainty**.

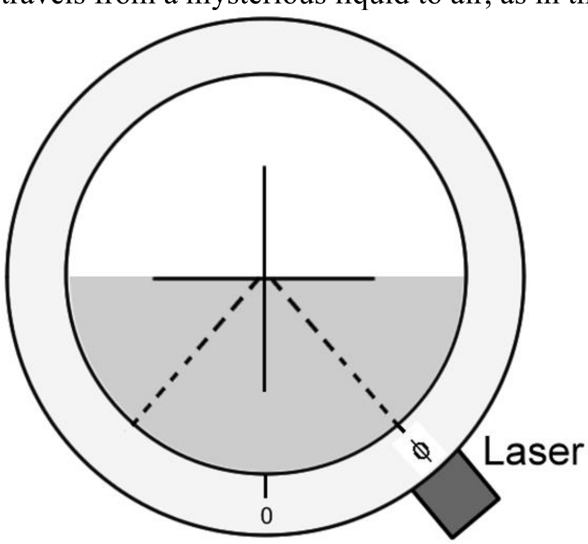
Air to Plastic

θ_i	θ_f	$n_{plastic}$
$24.5° - 25.5°$	$15.5° - 16.5°$	
$32.5° - 33.5°$	$20.5° - 21.5°$	

Plastic to Air

θ_i	θ_f	$n_{plastic}$
$29.5° - 30.5°$	$49.5° - 50.5°$	
$39.5° - 40.5°$	$79.5° - 80.5°$	

b) A light ray experiences ***total internal reflection*** at a ***critical angle*** of $\phi = 40°$ as it travels from a mysterious liquid to air, as in the diagram below.



What is the index of refraction of the liquid?

Interference of Light (Distance learning labs)

Given information about a pattern observed on a screen when there are 2 identical light sources separated by a distance d

- Calculate one of the following quantities, given the others: wavelength of the laser, path length difference, distance between fringes on the screen, or distance between the centers of the 2 narrow slits.

Question 1. You have set up a two source interference experiment with two red lasers. What happens to the location of the middle bright spot on a screen some distance away from the two sources when you increase the separation between the two sources?

Answer 1: The location of the middle bright spot doesn't change – the path length difference to this spot is still zero, even as the two sources are separated more.

Question 2: In practice, we typically don't use two lasers for two source interference, because you can't get the two lasers close enough together to see interference. Instead, you shine light from a single laser onto two slits. These two slits then act just like two sources: we can use the same reasoning and equations to predict the pattern of bright spots.

Suppose you shine green laser light through two slits separated by some distance d. You want to see what happens when you bring the screen closer to the light sources. What happens to the separation between the bright spots on the screen when the distance L to the screen is halved?

Answer 2: The locations of the bright spots on a screen are given by:

$$y_m = m\lambda\frac{L}{d}$$

Bringing the screen closer **decreases** the distance between the bright spots; in particular, halving the distance L to the screen halves the separation between the bright spots.

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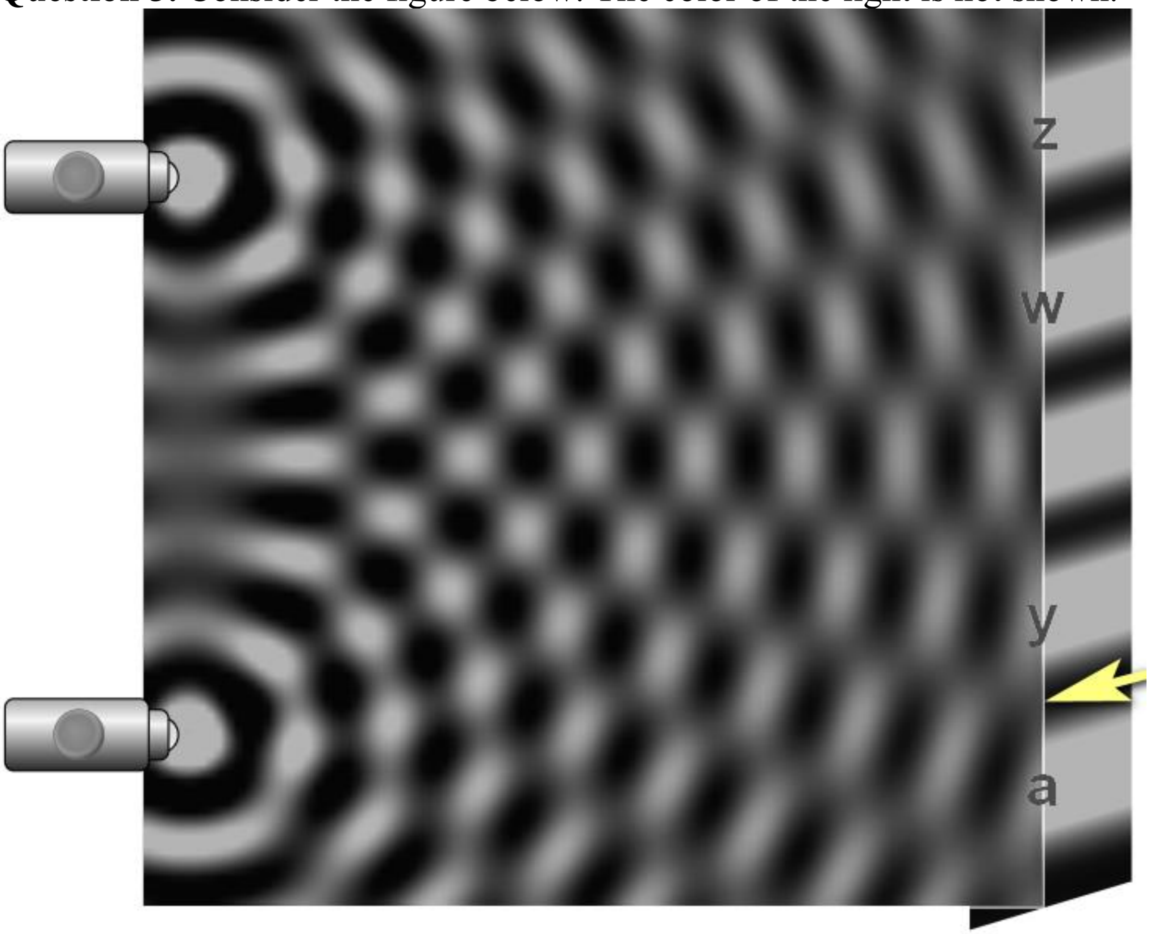
Question 3. Consider the figure below. The color of the light is not shown.



Using a "tape measure" as in lab, it is found that the path length difference between the two light sources, to the point on the screen marked by the yellow arrow, is 915 nm.
What is the wavelength of the light that is being used?

Answer 3. As we found in lab, the path length difference to point w or point y is 1.0 λ, and they are places of constructive interference. The path length difference to point a or point z is 2.0 λ, and they are also places of constructive interference. The location marked by the yellow arrow is a place of destructive interference. The path length difference to that point is 1.5 λ. Setting that equal to 915nm, we find that the wavelength λ is 610 nm.

Kirchhoff's Laws (Distance learning labs)

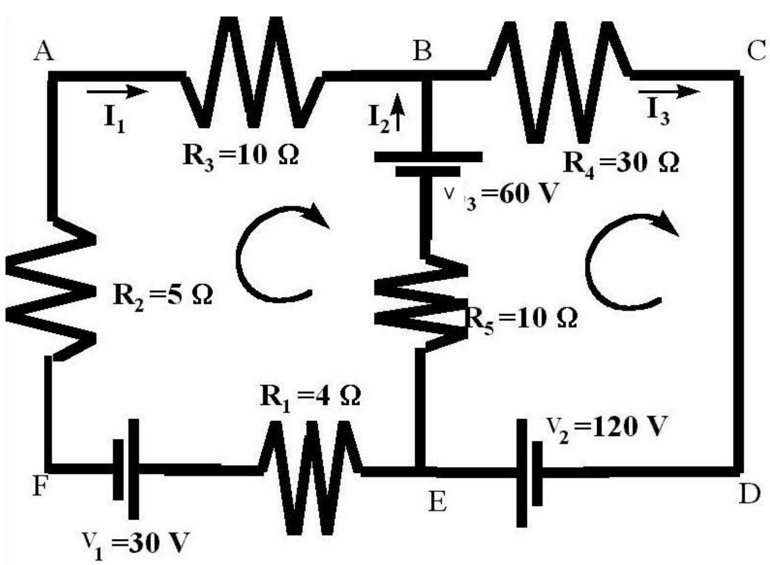
Given a multiloop circuit with any number of batteries and any number of resistors (such as the example shown), apply Kirchhoff's 2 laws and write down equations that could be solved to find all of the unknown currents. Note that the circuit and/or its labels will **not** be the same ones you analyzed in lab.

Given the solutions to a set of simultaneous equations for up to 3 unknown currents, be able to evaluate the solutions for the 3 unknowns. Be able to interpret the sign of the unknown current to determine which way the current flows "in real life."

Given some resistors with an unknown current flowing through each one, and a multimeter, determine the amount (and flow direction) of each of the unknown currents.

Question 1

We are looking for 3 equations that could be used to find the 3 currents.
i. Write an equation using Kirchhoff's voltage/loop rule, walking clockwise around the left loop, starting in the lower left-hand corner, at F.
ii. Write an equation using Kirchhoff's voltage/loop rule, walking clockwise around the right loop, starting in the upper right-hand corner, at C.
iii. Write an equation using Kirchhoff's current/junction rule, using either node B or node E (your choice).



Answers 1 (very verbose)

i. First term is $\Delta V = -(I_1)(5.0\ \Omega)$. The way that the current is assumed to flow, we are walking across resistor 2 in the same direction as current #1. Current, assumed to be comprised of positive charge, flows from high electric potential to low electric potential. The bottom side of R2 is "+" and the top side is "-". As we walk across the resistor, the final potential is lower, so we have dropped in electric potential. The change in V is negative, and Ohm's Law tells us the size of the change.

Second term is $\Delta V = -(I_1)(10.0\ \Omega)$. We are walking across resistor 3 in the same direction as current #1. Current, assumed to be comprised of positive charge, flows from high electric potential to low electric potential. The left side of R3 is "+" and the right side is "-". As we walk across the resistor, the final potential is lower, so we have dropped in electric potential. The change in V is negative, and Ohm's Law tells us the size of the change.

Third term is $\Delta V = -60$ volts.
We are walking across the battery from the positive terminal to the negative terminal. The final potential is lower, so we have dropped in electric potential. The change in V is negative, and the battery's voltage tells us the size of the change.

Fourth term is $\Delta V = (I_2)(10.0\ \Omega)$. We are walking across resistor 5 in the opposite direction as current #2. Current, assumed to be comprised of positive charge, flows from high electric potential to low electric potential. The bottom side of R5 is "+" and the top side is "-". As we walk across the resistor, the final potential is higher, so we have risen in electric potential. The change in V is positive, and Ohm's Law tells us the size of the change.

Fifth term is $\Delta V = -(I_1)(4.0\ \Omega)$. We are walking across resistor 1 in the same direction as current #1. Current, assumed to be comprised of positive charge, flows from high electric potential to low electric potential. The right side of R1 is "+" and the left side is "-". As we walk across the resistor, the final potential is lower, so we have dropped in electric potential. The change in V is negative, and Ohm's Law tells us the size of the change.

Sixth term is $\Delta V = -30$ volts.
We are walking across the battery from the positive terminal to the negative terminal. The final potential is lower, so we have dropped in electric potential. The change in V is negative, and the battery's voltage tells us the size of the change.

We have now completed a loop. Kirchhoff's voltage/loop rule says that the sum of the changes in voltage equals zero. Putting it all together, our first equation is

$$-(I_1)(5.0\ \Omega) -(I_1)(10.0\ \Omega) - 60 \text{ volts} + (I_2)(10.0\ \Omega) -(I_1)(4.0\ \Omega) - 30 \text{ volts} = 0$$

All of the terms have the same units, of voltage. You don't have to simplify, but if you do, you get:

$$-(I_1)(19.0\ \Omega) - 90 \text{ volts} + (I_2)(10.0\ \Omega) = 0$$

ii. The right hand loop yields the equation

$$+120 \text{ volts} -(I_2)(10.0\ \Omega) + 60 \text{ volts} -(I_3)(30.0\ \Omega) = 0$$

iii. Let's choose node B. Currents 1 and 2 are entering, current 3 is leaving.

$$I_1 + I_2 = I_3$$

If you want to check your equations, the solutions, in amperes, are:

$$I_1 = -1\frac{37}{53}\text{ A} \approx -1.698\text{ A}$$

$$I_2 = 5\frac{41}{53}\text{ A} \approx 5.774\text{ A}$$

$$I_3 = 4\frac{4}{53}\text{ A} \approx 4.075\text{ A}$$

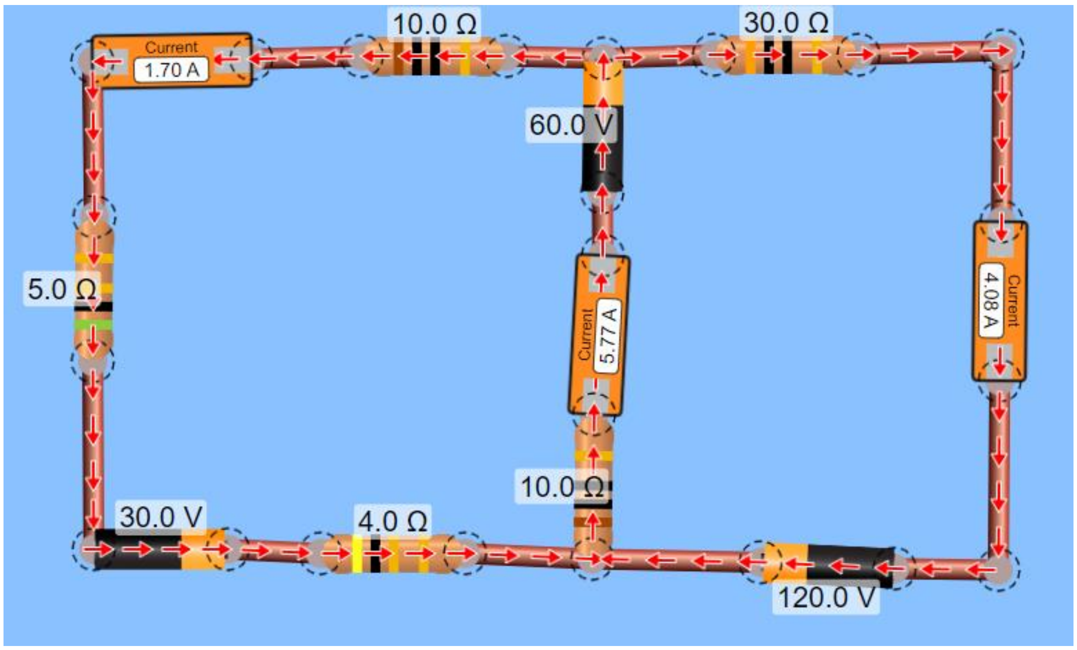
The negative sign on the first current means that the real-life current actually flows opposite to direction of the initial guess.

That is, you initially guessed that I_1 flowed upward, from location F toward location A. The negative sign for that variable in the solution simply means that when you set up the circuit, in real life a current of 1.698 amperes flows from location A to location F, *downward* through resistor R_2.

Question 2:

Use the PhET simulation to construct the circuit shown in the diagram, making certain to set the correct values of voltage and resistance.
Use the simulation and report the current through each resistor, both magnitude and direction.

Answer 2:



Notice that by measuring the 3 currents, you can check the validity of your equations because the measured values of I1, I2, and I3, with the appropriate signs, will satisfy your equations. (In Spring 2020, we will not ask you to "solve" the 3 equations algebraically.)

Thin Lenses (Distance learning labs)

Question 1:

An object is placed 42.1 cm to the left of a diverging lens that has a focal length of -25.6 cm. The object is 2.45 mm high. Find the size and orientation of the image.

Answer 1:

We know p = 42.1 cm and f = -25.6 cm. Use the thin lens equation

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

and solve for q =-15.9 cm. This is a virtual image (because q < 0).
Now use p and q in the magnification equation.

$$m = \frac{h_i}{h_o} = -\frac{q}{p}$$

We find that m = +0.377. The positive value of m means that the image is upright.
Using that m, and object height h_o = 2.45mm, solve for image height h_i = 0.925mm.

Question 2: You have a converging lens, and you want to create an upright image of a candle that is much larger than the original candle. How far away, compared to the focal length of the lens, should the lens be from the candle?

Answer 2: Because the image is upright and larger than the original, we need to create a **virtual image**. This means that the distance between the lens and the screen must be **less than the focal length**.

Question 3: You are designing another media projector, as in lab. You place a 15 cm focal length converging lens a distance of 17 cm away from your 9.5 cm tall phone. What is the height of the projected image?

Answer 3: We are told the focal length $f = 0.15$ m and the object distance $p = 0.17$ m. From this we can calculate the image distance using the thin lens equation:

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \Rightarrow \quad q = 1.28 \text{ m}$$

The positive sign here tells us that the image is on the opposite side of the lens from the object, our phone screen, and is a real image, so it will show up on a screen. From this we can calculate the magnification:

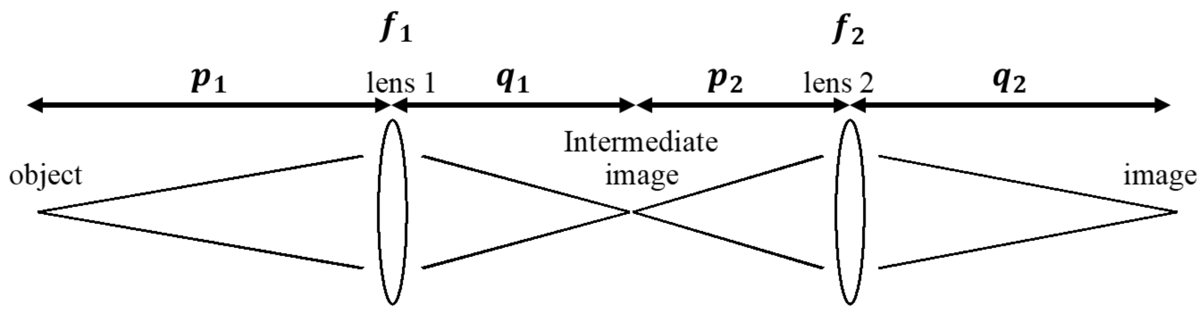
$$m = -\frac{q}{p} = -\frac{1.28\ m}{0.17\ m} = -7.5$$

The negative sign tells us that the image will be inverted. Finally, we can use the relationship between the magnification and the heights of the object and image:

$$m = -7.5 = \frac{h_i}{h_o} \quad \Rightarrow \quad h_i = -7.5 * h_o = -7.5 * (0.095\ m) = -0.71\ m = -71\ cm$$

So the size of the image is 71 cm (and it is inverted).

Question 4:



For the diagram above, what are the signs (positive or negative) of the following quantities:

Object distance p_1:
Focal Length of Lens 1 f_1:
Intermediate Image distance q_1:
Intermediate object distance p_2:
Focal Length of Lens 2 f_2:
Final Image distance q_2:

Answer 4:

Object distance p_1: This is on the same side the light propagates from, so it is **positive**
Focal Length of Lens 1 f_1:The lens is converging, so it is **positive**
Intermediate Image distance q_1: The image is a real image, so q_1 is **positive**
Intermediate object distance p_2:The intermediate image is on the same as light propagates from, so p_2 is **positive**
Focal Length of Lens 2 f_2: The lens is again converging, so it is **positive**
Final Image distance q_2: The image is a real image, so q_2 is **positive**