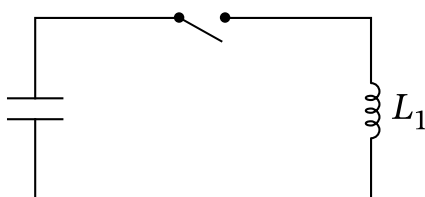


Question 3

The following information applies to parts A and B.

3. In Experiment 1, students are asked to collect data that can be graphed to determine the inductance L_1 of an inductor. The students have access to multiple charged capacitors, each of a different known capacitance, and a voltmeter that measures potential difference as a function of time. In each trial, the inductor is connected to a charged capacitor and an initially open switch, as shown in Figure 1.

Figure 1

**Part A**

- i. **Indicate** quantities that could be measured by the students that would allow them to determine L_1 using a linear graph.
- ii. Briefly **describe** a method to reduce experimental uncertainty.

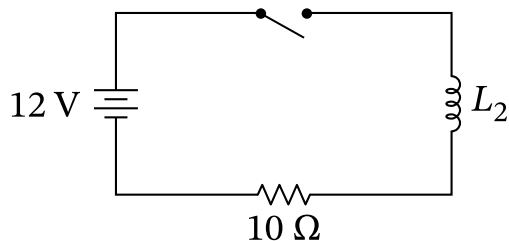
Part B

- i. **Indicate** what quantities the students could graph on the horizontal and vertical axes to create a linear graph that can be used to determine L_1 .
- ii. Briefly **describe** the relationship between L_1 and a feature of the graph from part B (i). Your answer may include an equation that relates L_1 and the chosen feature of the graph.

The following information applies to parts C and D.

In Experiment 2, the students are asked to use a graph to determine the inductance L_2 of a new inductor. The inductor is connected to a 12 V battery, a $10\ \Omega$ resistor, and an initially open switch, as shown in Figure 2.

Figure 2



After the switch is closed, the current I in the circuit is measured at different times and the corresponding rate of change of the current, $\frac{dI}{dt}$, is determined. The collected data are shown in Table 1.

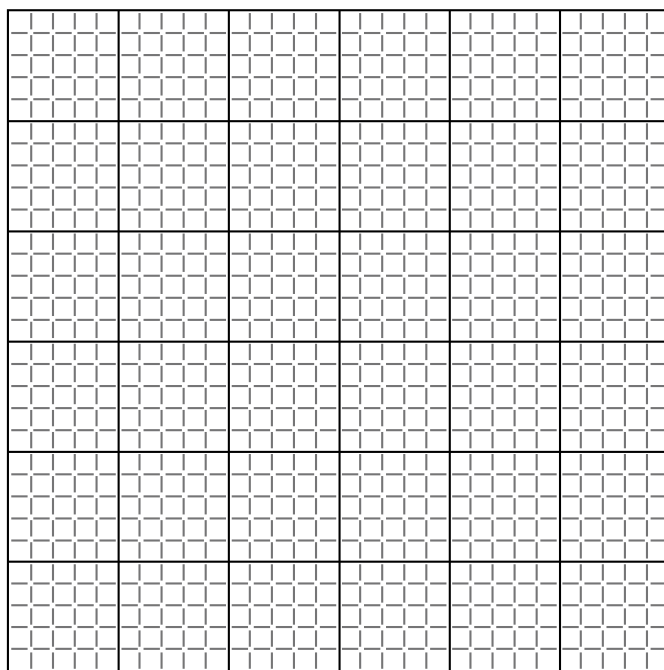
Table 1

I (A)	$\frac{dI}{dt}$ (A/s)
0.40	280
0.50	230
0.75	150
0.90	100
1.00	68

Part C

- i. **Label** the axes of the grid provided with measured or calculated quantities. Include units, as appropriate. The graphed quantities should yield a linear graph that can be used to determine L_2 .
- ii. On the grid provided, create a graph of the quantities indicated in part C (i).
- Clearly **label** each axis with a numerical scale.
 - Plot** the corresponding data points on the grid.
 - Table 2 is provided in your booklet for scratch work and will not be scored.

Quantity (units, if appropriate)



Quantity (units, if appropriate)

- iii. **Draw** a best-fit line for the data plotted in part C (ii).

Part D

Using the best-fit line that you drew in part C (iii), **calculate** an experimental value for L_2 .

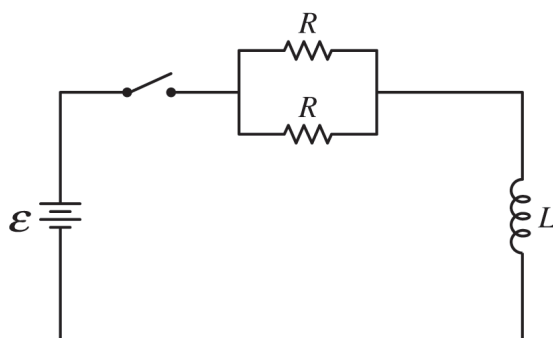
Begin your response to **QUESTION 2** on this page.

Figure 1

2. Students are asked to determine the resistance R of two identical resistors. The resistors are in parallel with each other and are connected in series to a battery of known emf $\mathcal{E}$, an inductor of known inductance L , and a switch, as shown in Figure 1. The students have access to a voltmeter that can measure potential difference as a function of time. The students are required to measure a quantity that decreases with time to determine R .

(a)

- i. On the circuit diagram shown in Figure 1, **draw** the voltmeter, using the following symbol, with connections that would allow the students to correctly measure a potential difference that decreases with time.



Voltmeter Symbol

- ii. **Describe** a procedure for collecting data that would allow the students to graphically determine the experimental value for R using the measured quantity that decreases with time. Provide enough detail so that another student could replicate the experiment.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 2** on this page.

(b)

i. On the axes shown in Figure 2, produce a graph that represents the expected trend of the data by completing the following tasks.

- **Label** the quantities graphed on the vertical and horizontal axes.
- **Sketch** a line or curve that represents the expected trend of the collected data.
- **Label** any appropriate intercepts and/or asymptotes in terms of the quantities provided.



Figure 2

ii. **Describe** how the information from the graph in part (b)(i) would be used to determine the experimental value for R .

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 2** on this page.

- (c) Starting with an appropriate application of Kirchhoff's loop rule, **derive**, but do NOT solve, a differential equation that can be used to determine the current I in the inductor at time t after the switch is closed. Express your answer in terms of R , $\mathcal{E}$, L , t , and physical constants, as appropriate.

After reaching steady state, the absolute value of the potential difference across the inductor is $|\Delta V_1|$. The students replace the original inductor with a new inductor that has nonnegligible resistance. The experiment is repeated. After a long time, the absolute value of the potential difference across the new inductor is $|\Delta V_2|$.

- (d) **Indicate** whether $|\Delta V_2|$ is greater than, less than, or equal to $|\Delta V_1|$.

_____ $|\Delta V_2| > |\Delta V_1|$ _____ $|\Delta V_2| < |\Delta V_1|$ _____ $|\Delta V_2| = |\Delta V_1|$

Justify your answer.

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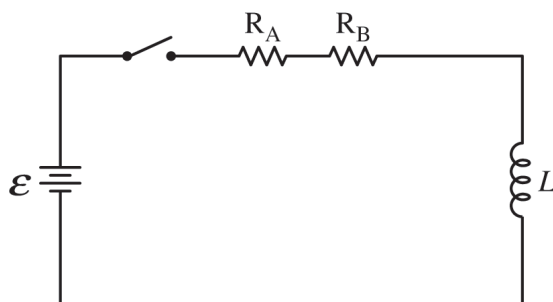
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Figure 1

2. Students are asked to determine the resistance R of identical resistors R_A and R_B . The resistors are connected in series with each other, a battery of known emf $\mathcal{E}$, an inductor of known inductance L , and a switch, as shown in Figure 1. The students have access to a voltmeter that can measure potential difference as a function of time. The students are required to measure a quantity that increases with time to determine R .

(a)

- i. On the circuit diagram shown in Figure 1, **draw** the voltmeter, using the following symbol, with connections that would allow the students to correctly measure a potential difference that increases with time.



Voltmeter Symbol

- ii. **Describe** a procedure for collecting data that would allow the students to graphically determine the experimental value for R using a measured quantity that increases with time. Provide enough detail so that another student could replicate the experiment.

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 2** on this page.

- (b)
- i. On the axes shown in Figure 2, produce a graph that represents the expected trend of the data by completing the following tasks.
- **Label** the quantities graphed on the vertical and horizontal axes.
 - **Sketch** a line or curve that represents the expected trend of the collected data.
 - **Label** any appropriate intercepts and/or asymptotes in terms of the quantities provided.



Figure 2

- ii. **Describe** how the information from the graph in part (b)(i) would be used to determine the experimental value for R .

GO ON TO THE NEXT PAGE.

Continue your response to **QUESTION 2** on this page.

- (c) Starting with an appropriate application of Kirchhoff's loop rule, **derive**, but do NOT solve, a differential equation that can be used to determine the current I in the inductor at time t after the switch is closed. Express your answer in terms of R , $\mathcal{E}$, L , t , and physical constants, as appropriate.

After reaching steady state, the absolute value of the potential difference across R_A is $|\Delta V_1|$. The students replace the original inductor with a new inductor that has nonnegligible resistance. The experiment is repeated. After a long time, the absolute value of the potential difference across R_A is $|\Delta V_2|$.

- (d) **Indicate** whether $|\Delta V_2|$ is greater than, less than, or equal to $|\Delta V_1|$.

_____ $|\Delta V_2| > |\Delta V_1|$ _____ $|\Delta V_2| < |\Delta V_1|$ _____ $|\Delta V_2| = |\Delta V_1|$

Justify your answer.

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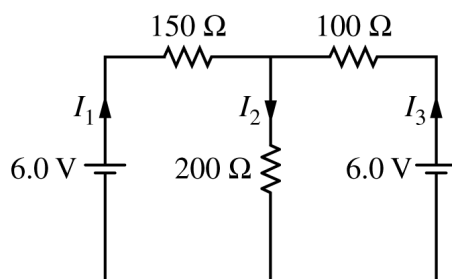


Figure 1

2. The circuit shown above is constructed with two 6.0 V batteries and three resistors with the values shown. The currents I_1 , I_2 , and I_3 in each branch of the circuit are indicated.

- (a)
- Using Kirchhoff's rules, write, but DO NOT SOLVE, equations that can be used to solve for the current in each resistor.
 - Calculate the current in the $200\ \Omega$ resistor.
 - Calculate the power dissipated by the $200\ \Omega$ resistor.

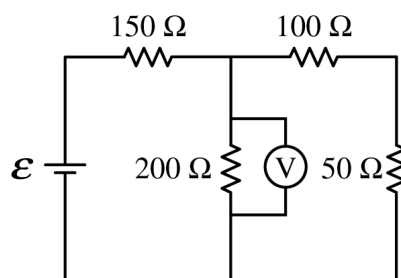


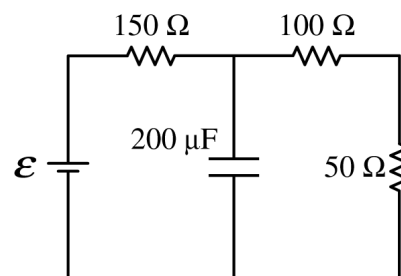
Figure 2

The two 6.0 V batteries are replaced with a battery with voltage $\mathcal{E}$ and a resistor of resistance $50\ \Omega$, as shown above. The voltmeter V shows that the voltage across the $200\ \Omega$ resistor is 4.4 V.

- (b) Calculate the current through the $50\ \Omega$ resistor.
- (c) Calculate the voltage $\mathcal{E}$ of the battery.

(d)

- i. The $200\ \Omega$ resistor in the circuit in Figure 2 is replaced with a $200\ \mu\text{F}$ capacitor, as shown on the right, and the circuit is allowed to reach steady state. Calculate the current through the $50\ \Omega$ resistor.



- ii. The $200\ \Omega$ resistor in the circuit in Figure 2 is replaced with an ideal $50\ \text{mH}$ inductor, as shown on the right, and the circuit is allowed to reach steady state. Is the current in the $50\ \Omega$ resistor greater than, less than, or equal to the current calculated in part (b) ?

_____ Greater than _____ Less than _____ Equal to

Justify your answer.

