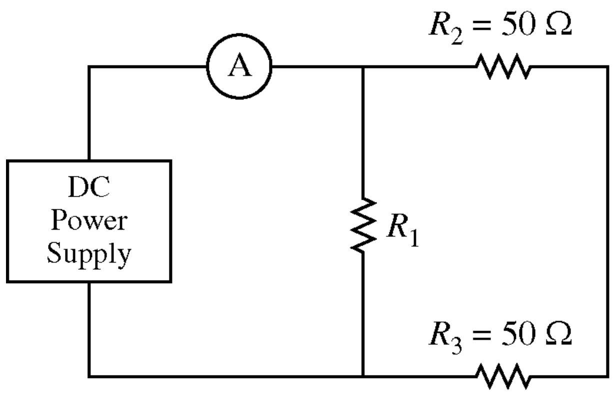
PHYSICS C: ELECTRICITY AND MAGNETISM

SECTION II

Time—45 minutes

3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.

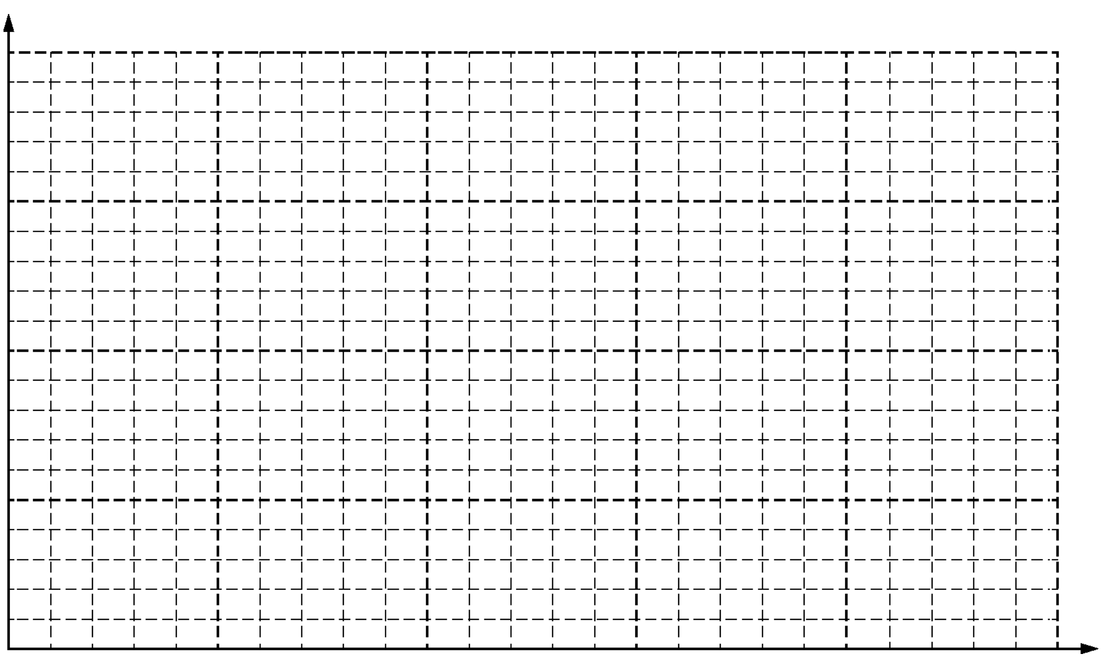


E&M. 1.

Physics students are analyzing the circuit above. A variable DC power supply is connected to an ammeter and three resistors. The resistances of two of the resistors are known to be $R_2 = R_3 = 50\ \Omega$, but the resistance of the third resistor is unknown. The students collect data on the potential difference across the power supply and the current measured by the ammeter, as follows.

Potential Difference (V)	2	4	6	8	10
Current (mA)	40	55	97	138	155

(a) On the grid below, plot the data points for the current as a function of the potential difference. Clearly scale and label all axes, including units if appropriate. Draw a straight line that best represents the data.



GO ON TO THE NEXT PAGE.

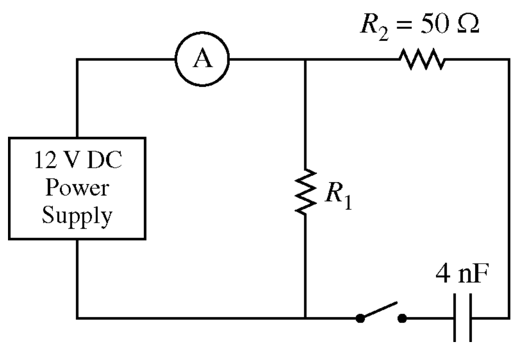
(b) Using the straight line from part (a), calculate the total resistance of the three-resistor combination.

(c) Calculate the value of R_1.

The power supply is now fixed at 12 V.

(d) Calculate the current through R_2.

(e) Resistor 3 is now removed and replaced by an open switch in series with an uncharged 4 nF capacitor, as shown below. The power supply is still fixed at 12 V.



i. Calculate the current in R_2 immediately after the switch is closed.

ii. A long time after the switch is closed, will the magnitude of the current in R_2 be greater than, less than, or equal to the current through R_2 found in part (d) ?

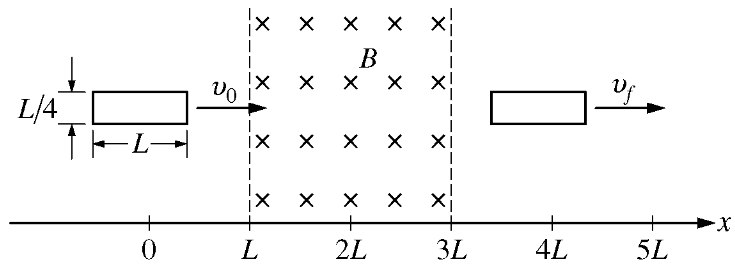
__ Greater than   __ Less than   __ Equal to

Justify your answer.

(f) The 4 nF capacitor is replaced with an uncharged 10 nF capacitor. Will the magnitude of the current in R_2 immediately after the switch is closed be greater than, less than, or equal to the current in part (e)i?

__ Greater than   __ Less than   __ Equal to

Justify your answer.



E&M. 2.

The rectangular loop of wire shown on the left in the figure above has mass M, length L, width $L/4$, and resistance R. It is initially moving to the right at constant speed v_0 , with no net force acting on it. At time $t = 0$ the loop enters a region of length $2L$ that contains a uniform magnetic field of magnitude B directed into the page. The loop emerges from the field at time t_f with final speed v_f . Express all algebraic answers to the following in terms of M, L, R, B, v_0 , and fundamental constants, as appropriate.

(a) Let x represent the position of the right end of the loop. Place a check mark in the appropriate box in each column in the table below to indicate whether the speed of the loop increases, decreases, or stays the same as the loop moves to the right.

	Position of Right End of Loop			
Speed of Loop	$L < x < 2L$	$2L < x < 3L$	$3L < x < 4L$	$4L < x < 5L$
Increases				
Decreases				
Stays the same				

(b) Derive an expression for the magnitude of the current induced in the loop as its right edge enters the field.

(c) What is the direction of the induced current determined in part (b) ?

____ Clockwise ____ Counterclockwise

Justify your answer.

(d) Write, but do not solve, a differential equation for the speed v as a function of time as the loop enters the field.

(e) What is the direction of the acceleration of the loop just before its left edge leaves the field?

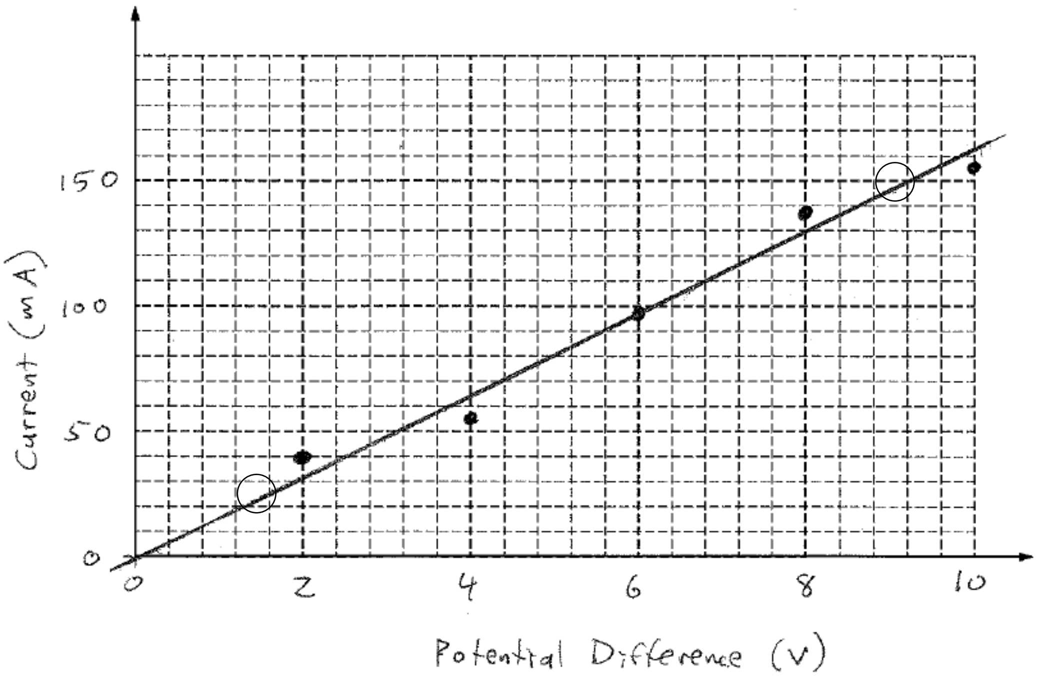
____ Left ___ Right ____ Up ____ Down

Justify your answer.

Question 1

15 points total — **Distribution of points**

(a) 3 points



For labeling both axes with proper variables and units, and using appropriate linear scales for both axes	1 point
For properly plotting the data points	1 point
For drawing a reasonable best-fit straight line	1 point

(b) 3 points

For calculating a slope using points on the line drawn in part (a), not data points unless they are on that line — 1 point

$$m = \frac{\Delta I}{\Delta V} = \frac{(150 - 25\ ) \times 10^{-3}\ \text{A}}{(9.2 - 1.6)\ \text{V}} = 0.0164\ \text{A/V}$$

For correctly relating the slope to the resistance — 1 point

$$V = IR$$

$$I = \frac{V}{R} = \frac{1}{R}V$$

$$\text{slope} = \frac{1}{R}$$

$$R = \frac{1}{\text{slope}} = \frac{1}{(0.0164\ \text{A/V})}$$

For an answer with correct units consistent with the calculated slope — 1 point

$$R = 61\ \Omega$$

Note: linear regression yields a slope of $0.01565\ \text{A/V}$ and an answer of

$$R = 63.9\ \Omega$$