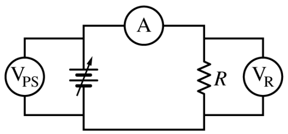
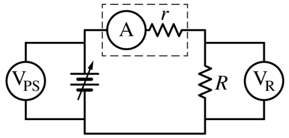


Circuit 1



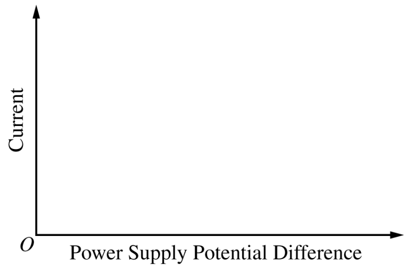
Circuit 2

2. (12 points, suggested time 25 minutes)

The two circuits shown above contain an ideal variable power supply, an ohmic resistor of resistance R, an ammeter A, and two voltmeters V_{PS} and V_R. In circuit 1 the ammeter has negligible resistance, and in circuit 2 the ammeter has significant internal ohmic resistance r. The potential difference of the power supply is varied, and measurements of current and potential difference are recorded.

(a) The axes below can be used to graph the current measured by the ammeter as a function of the potential difference measured across the power supply. On the axes, do the following.

- Sketch a possible graph for circuit 1 and label it 1.
- Sketch a possible graph for circuit 2 and label it 2.



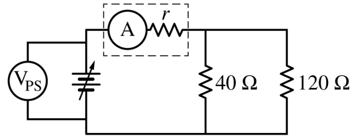
(b) Let ΔV_{PS} be the potential difference measured by voltmeter V_{PS} across the power supply, and let I be the current measured by the ammeter A. For each circuit, write an equation that satisfies conservation of energy, in terms of ΔV_{PS}, I, R, and r, as appropriate.

Circuit 1 | Circuit 2

(c) Explain how your equations in part (b) account for any differences between graphs 1 and 2 in part (a).

(d) In circuit 2, $R = 40\ \Omega$. When voltmeter V_{PS} reads 3.0 V, voltmeter V_R reads 2.5 V. Calculate the internal resistance r of the ammeter.

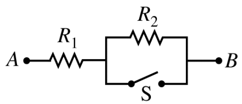
(e) Voltmeter V_R in circuit 2 is replaced by a resistor with resistance $120\ \Omega$ to create circuit 3 shown below. Voltmeter V_{PS} still reads 3.0 V.



Circuit 3

i. Calculate the equivalent resistance R_{eq} of the circuit.

ii. Calculate the current in each of the resistors that are in parallel.



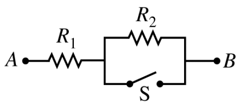
2. (12 points, suggested time 25 minutes)

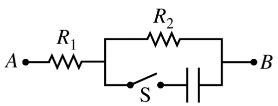
Students are given resistor 1 with resistance R_1 connected in series with the parallel combination of a switch S and resistor 2 with resistance R_2, as shown above. The circuit elements cannot be disconnected from each other, and other circuit components can only be connected at points A and B. The students also are given an ammeter and one 9 V battery. The teacher instructs the students to take measurements that can be used to determine R_1 and R_2.

(a) Complete the diagram below to show how the ammeter and the battery should be connected to experimentally determine the resistance of each resistor. Describe the experiment by listing the measurements to be taken and explaining how the measurements would be used to calculate resistances R_1 and R_2.

<u>Complete the Diagram</u>

<u>Describe the Experiment</u>





A second group of students is given a combination of circuit elements that is similar to the previous one but has an initially uncharged capacitor in series with the open switch, as shown above. The combination is placed in a circuit with a power supply so that the potential difference between A and B is maintained at 9 V. The students close the switch and immediately begin to record the current through point B. The initial current is 0.9 A, and after a long time the current is 0.3 A.

(b)

i. Compare the currents through resistor 1, resistor 2, and the switch immediately after the switch is closed to the currents a long time after the switch is closed. Specifically state if any current is zero.

ii. Calculate the values of R_1 and R_2.

iii. Determine the potential difference across the capacitor a long time after the switch is closed.

A third group of students now uses the combination of circuit elements with the capacitor. They connect it to a 9 V battery that they treat as ideal but which is actually not ideal and has internal resistance.

(c) How does the third group's value of R_1 calculated from the data they collected compare to the second group's value? Explain your reasoning with reference to physics principles and/or mathematical models.

2. (12 points, suggested time 25 minutes)

A group of students is given several long, thick, cylindrical conducting rods of the same unknown material with various lengths and diameters and asked to experimentally determine the resistivity of the material using a graph. The available equipment includes a voltmeter, an ammeter, connecting wires, a variable-output DC power supply, and a metric ruler.

(a)

i. Describe a procedure the students could use to collect the data needed to create the graph, including the measurements to be taken and a labeled diagram of the circuit to be used. Include enough detail that another student could follow the procedure and obtain similar data.

Draw a labeled diagram here.

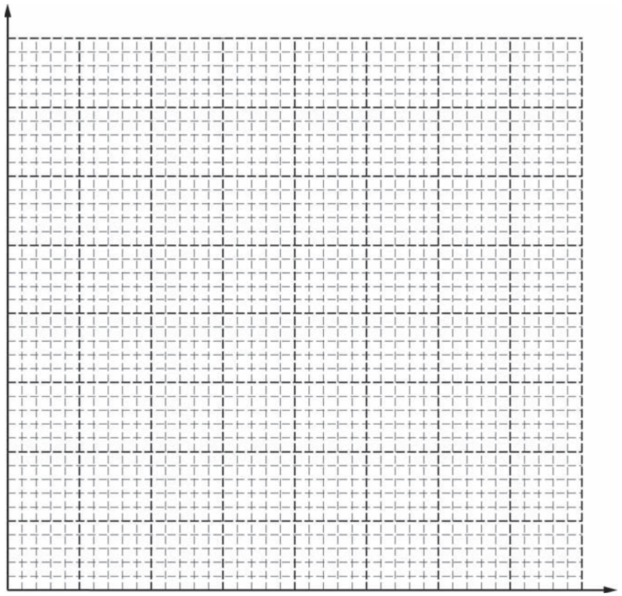
Write your procedure here.

ii. Describe how the data could be graphed in a way that is useful for determining the resistivity of the material. Describe how the graph could be analyzed to calculate the resistivity.

The students are now given a rectangular rod of the material, as shown below, whose dimensions are not known. The students are asked to experimentally determine the resistance of the rod. They obtain the data in the table below for the potential difference ΔV across the rod and the current I in it.

ΔV (V)	6.0	5.0	3.5	2.5	2.0	1.5
I (A)	0.078	0.070	0.044	0.036	0.027	0.018

(b) On the axes below, plot the data so that the resistance of the rectangular rod can be determined from a best-fit line. Label and scale the axes. Use the best-fit line to determine the resistance of the rod, clearly showing your calculations.



(c) After completing their calculations, the students begin to consider the factors that might have produced uncertainties in their results.

i. The students realize that they did not take into account the internal resistance of the power supply. Briefly describe how this would affect their value of the resistance of the rectangular rod. Explain your reasoning.

ii. The students realize that they did not take into account a possible change in the temperature of the cylindrical rods. Should the students be concerned about this? Explain why or why not.