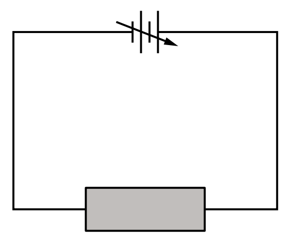
Question 3

3. In Experiment 1, students are asked to use a graph to determine the resistivity ρ_1 of a circuit element that is connected to a variable power supply, as shown in Figure 1. The circuit element is cylindrical and has uniform resistivity. The students have access to a voltmeter, an ammeter, and a ruler.

Figure 1



A. **Describe** a procedure for collecting data that would allow the students to use a graph to determine ρ_1, including any steps necessary to reduce experimental uncertainty.

B. **Describe** how the collected data could be graphed and how that graph would be analyzed to determine ρ_1.

In Experiment 2, the students are asked to use a graph to determine the resistivity ρ_2 of solid, cylindrical resistors made of the same material but of different lengths L. The cross-sectional area of each resistor is 5.0×10^{-6} m^2. The students directly measure the resistance R between the ends of each resistor. Table 1 provides L and R for each resistor.

Table 1

L (m)	R (Ω)
0.010	0.90
0.020	1.6
0.030	2.5
0.040	3.2
0.050	4.0

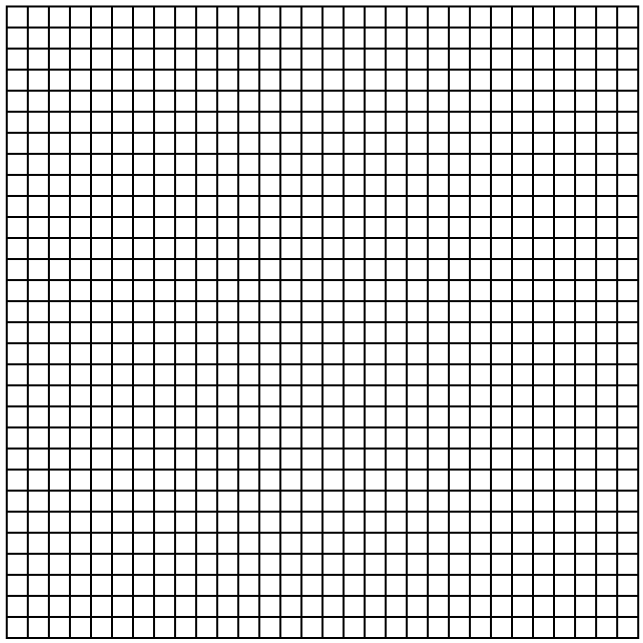
C.

i. **Indicate** two quantities, either measured quantities from Table 1 or additional calculated quantities, that could be graphed to produce a straight line that could be used to determine ρ_2.

Vertical axis: ______ Horizontal axis: ______

ii. On the grid provided, create a graph of the quantities indicated in part C (i).

- Use Table 2 to record the measured or calculated quantities that you will plot.
- Clearly **label** the axes, including units as appropriate.
- **Plot** the points you recorded in Table 2.



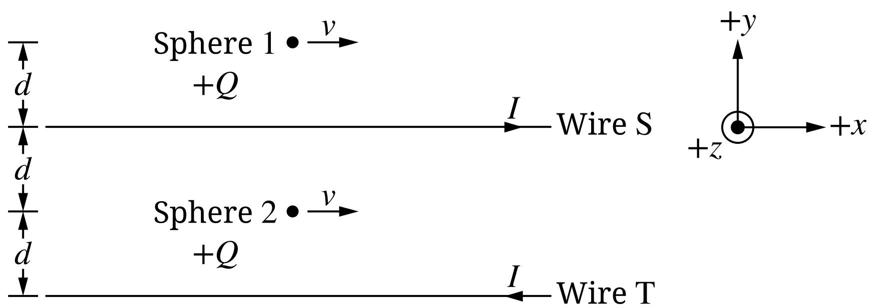
iii. **Draw** a best-fit line for the data graphed in part C (ii).

D. Using the best-fit line that you drew in part C (iii), **calculate** an experimental value for ρ_2.

Question 4

4. Long, parallel wires S and T are a distance $2d$ apart. Both wires carry equal currents I, but the currents are in opposite directions. Both wires are parallel to the x-axis. At the instant shown in Figure 1, Sphere 1 is a distance d above Wire S, Sphere 2 is a distance d below Wire S, and both spheres are moving with speed v in the $+x$-direction. Each sphere has positive charge $+Q$. Gravitational effects are negligible.

Figure 1



A. F_1 is the magnitude of the magnetic force exerted on Sphere 1 due to the currents in wires S and T. F_2 is the magnitude of the magnetic force exerted on Sphere 2 due to the currents in wires S and T.

Indicate whether F_2 is greater than, less than, or equal to F_1 by writing one of the following.

- $F_2 > F_1$
- $F_2 < F_1$
- $F_2 = F_1$

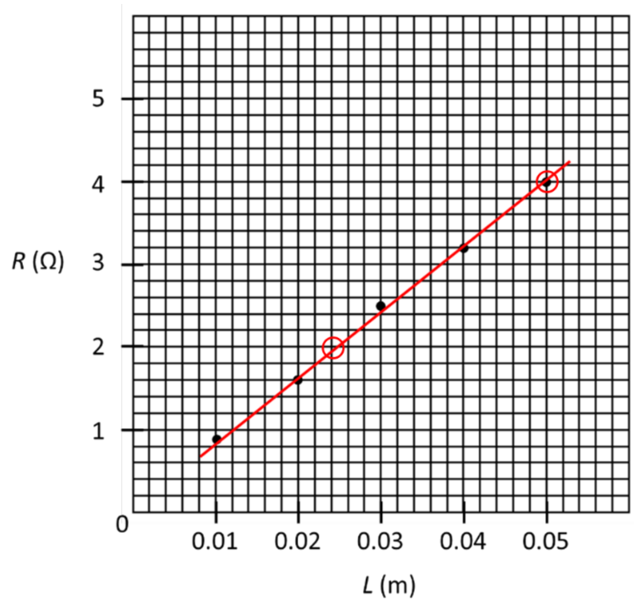
Justify your answer.

B. **Derive** an expression for the magnitude B_{tot} of the magnetic field at the location of Sphere 2 due to the currents in wires S and T in terms of d, I, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

Question 3: Experimental Design and Analysis (LAB) — 10 points

A		For a procedure in which the length of and the current in the circuit element are measured, and the cross-sectional area of the circuit element is determined	**Point A1**
		For a procedure that indicates a reasonable method of reducing experimental uncertainty Examples of acceptable responses may include the following: • Making different measurements of the current in the circuit element • Varying the potential difference of the power supply	**Point A2**
		Example Response *Measure the length and diameter of the circuit element. Use the diameter to calculate the area of the circuit element. Measure the current in the circuit element. Repeat the procedure multiple times for different potential difference settings on the variable power supply.*	
B		For indicating quantities that can be graphed appropriately to determine ρ_1, consistent with the procedure from part A, such as potential difference as a function of current **Scoring Notes:** • Responses that include the reciprocals of the preceding example, in addition to other equivalent graphs, also earn this point. • This point may be earned independently of the response in part A.	**Point B1**
		For a correct analysis of the graph, consistent with the first point of part B	**Point B2**
		Example Response *Graph the potential difference across the circuit element as a function of the current in the circuit element. Use the slope of the graph, which is* $\frac{\rho_1 \ell}{\pi r^2}$*, where* ℓ *is the length of the circuit element and r is equal to the radius of the circuit element, to determine* ρ_1.	
C	**(i)**	For indicating appropriate quantities that could be plotted on the graph to determine ρ_2, for example R as a function of L **Scoring Note:** This point may be earned: • if the vertical and horizontal variables are reversed. • for other equivalent graphs.	**Point C1**
	(ii)	For labeling the axes (including units) with a linear scale	**Point C2**
		For correctly plotting data points consistent with **one** of the following: • The quantities indicated in part C (i) • The quantities provided in the table • The axes indicated in the first point of part C (ii)	**Point C3**
	(iii)	For drawing a line or curve that approximates the trend of the plotted data	**Point C4**

Example Response



D	For correctly relating the slope of the best-fit line to ρ_2 (e.g., $\frac{\Delta R}{\Delta L} = \text{slope} = \frac{\rho_2}{A}$)	**Point D1**
	For a value for ρ_2 that is between $3.5\times10^{-4}\ \Omega\cdot\text{m}$ and $4.5\times10^{-4}\ \Omega\cdot\text{m}$	**Point D2**

Example Response

$$\text{slope} = \frac{\Delta R}{\Delta L}$$

$$\frac{\Delta R}{\Delta L} = \frac{4.0\ \Omega - 2.0\ \Omega}{0.050\ \text{m} - 0.024\ \text{m}}$$

$$\frac{\Delta R}{\Delta L} = 77\ \frac{\Omega}{\text{m}}$$

$$R = \frac{\rho L}{A}$$

$$R = \left(\frac{\rho_2}{A}\right)L$$

$$\text{slope} = \frac{\rho_2}{A}$$

$$\rho_2 = A(\text{slope})$$

$$\rho_2 = \left(5.0\times10^{-6}\ \text{m}^2\right)\left(77\ \frac{\Omega}{\text{m}}\right)$$

$$\rho_2 \approx 3.9\times10^{-4}\ \Omega\cdot\text{m}$$