

Biot-Savart, ampère and magnetic sources

AP Physics C (Mechanics and E&M, calculus-based) · Lab

Name: _____ Date: _____ Class: _____

Does the field inside a solenoid grow in proportion to the current, and does the gradient match the number of turns per metre? You will wind a simple coil, measure its axial field with a phone magnetometer, and use the straight-line graph to test $B = \mu_0 n I$.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:E&M Unit 12

Aim

Measure the magnetic field inside a long solenoid for several currents and use the gradient of the B against I graph to test $B = \mu_0 n I$.

Equipment

- Cardboard tube about 20 cm long and 4 cm across
- Enamelled copper wire, 0.5 mm, 200 turns wound evenly
- Smartphone with a magnetometer app (reads in μT)
- Ammeter, rheostat of about $10\ \Omega$ and a 3 V supply (two 1.5 V cells)
- Ruler and tape

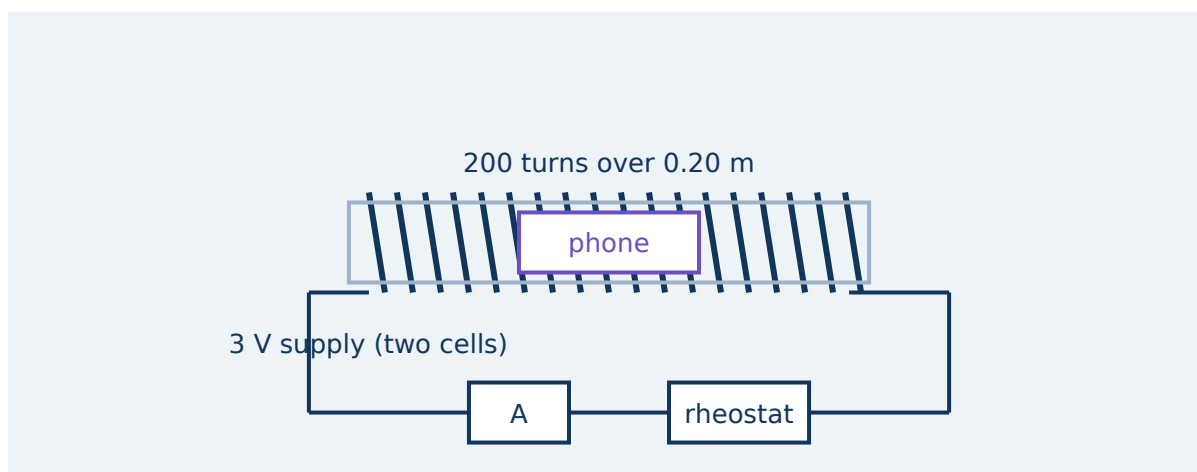
Safety

Safety

The coil warms up: switch on only for a few seconds per reading and keep I below 1.5 A. Do not short the cells. Keep the phone away from any water and remove cards with magnetic strips.

Method

1. Wind 200 turns in one layer along 20 cm and count $n = \text{turns/length}$.
2. Place the phone's sensor at the centre of the tube with its axis along the coil's axis.
3. With the current off, record the background field B_0 (about $48\ \mu\text{T}$ here).
4. Set $I = 0.20\ \text{A}$ with the rheostat, switch on, read B , then switch off.
5. Repeat for 0.40, 0.60, 0.80, 1.00 and 1.20 A.
6. Reverse the supply once at $I = 1.0\ \text{A}$ and compare to remove the background.



Set-up: the phone magnetometer measures B at the centre of the coil as the current is varied.

Results

Sample measurements, with the background field already subtracted, and the predicted field for $n = 1000$ turns per metre:

Current I (A)	0.20	0.40	0.60	0.80	1.00	1.20
B (μT), after subtracting background	245	495	740	985	1230	1480
$\mu_0 n I$ (μT), $n = 1000 \text{ m}^{-1}$	251	503	754	1005	1257	1508

Analysis questions

Question 1 Plot B against I

Plot B against I and describe the graph.

Question 2 Gradient

Calculate the gradient of the graph in μT per ampere.

Question 3 Turns per metre

Use the gradient to calculate n and compare with the counted value.

Question 4 Background field

Explain why the background field was subtracted and how reversing the current helps.

Question 5 Uncertainty

The phone resolves $1 \mu\text{T}$ and the ammeter reads to $\pm 0.02 \text{ A}$. Estimate the percentage

uncertainty in the gradient.

Question 6 Finite coil

Explain why the measured field is slightly lower than $\mu_0 n I$ and estimate the correction for a coil of length 20 cm and diameter 4 cm.

Question 7 Reducing error

Propose two ways to make the field measurement more reliable.