

Biot-Savart, ampère and magnetic sources

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

Name: _____ Date: _____ Class: _____

These twenty problems build skill with the two ways of finding the magnetic field of a current: integrating the Biot-Savart law for wires and loops, and using Ampère's law when symmetry allows. They move from direction and recall to multi-step derivations in the style of AP Physics C: Electricity and Magnetism.

The set suits AP students, first-year university physics and A Level learners ready for calculus. Use $\mu_0 = 4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$.

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

Problem 1 Direction of B (easy)

A long wire carries current out of the page.

1. State the shape of the field lines.
2. State the direction of B at a point to the right of the wire.

Problem 2 Long wire field (easy)

Kofi carries 10 A along a long straight wire.

1. Calculate B at 5.0 cm from the wire.
2. State what happens to B at 10 cm.

Problem 3 Solenoid field (easy)

A solenoid has 500 turns wound uniformly over 0.25 m and carries 2.0 A.

1. Calculate n.
2. Calculate B inside.

Problem 4 Loop at its centre (easy)

A coil has 20 turns of radius 4.0 cm and carries 0.50 A.

1. Calculate B at its centre.

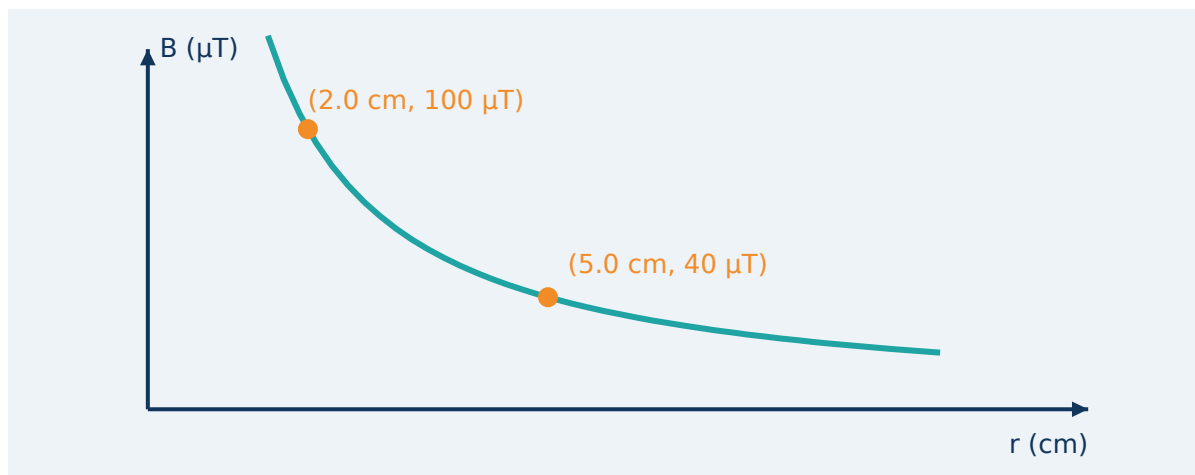
Problem 5 Force between wires (easy)

Two long wires 2.0 cm apart each carry 5.0 A.

1. Calculate the force per metre.
2. State whether they attract or repel if the currents are opposite.

Problem 6 Reading a B-r graph (easy)

The graph shows the field of a long straight wire.



Field against distance.

1. Calculate the current.
2. Calculate B at 10 cm.

Problem 7 Ampère's law statement (easy)

An Amperian loop is crossed by a 3.0 A current into the page and 1.0 A out of the page.

1. State Ampère's law.
2. Calculate $\oint \mathbf{B} \cdot d\mathbf{l}$ around the loop.

Problem 8 Inside a thick wire (medium)

A wire of radius 2.0 mm carries 5.0 A uniformly across its section.

1. Calculate B at $r = 1.0 \text{ mm}$.
2. Calculate B at $r = 2.0 \text{ mm}$.
3. Calculate B at $r = 4.0 \text{ mm}$.

Problem 9 Finite wire segment (medium)

Diego has a straight wire 0.60 m long carrying 4.0 A. A point P lies 0.10 m from its midpoint, on the perpendicular bisector.

1. Use $B = (\mu_0 I / 4\pi d)(2 \sin \theta)$ and calculate $\sin \theta$.
2. Calculate B at P.
3. Compare with an infinite wire.

Problem 10 Loop on its axis (medium)

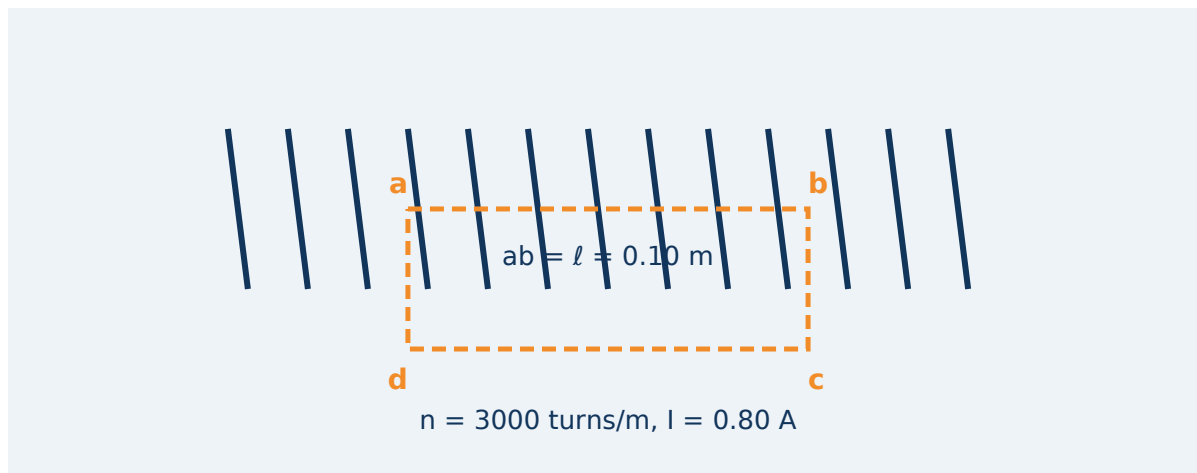
A single loop of radius 5.0 cm carries 3.0 A.

1. Calculate B at its centre.
2. Calculate B on the axis 12 cm from the centre.

3. Calculate the ratio of the two.

Problem 11 Solenoid by Ampère (medium)

The loop abcd in the diagram is used to find B inside the solenoid.



Rectangular Amperian loop.

1. Calculate the current enclosed by the loop.
2. Use Ampère's law to find B inside.
3. State why the sides bc and da contribute nothing.

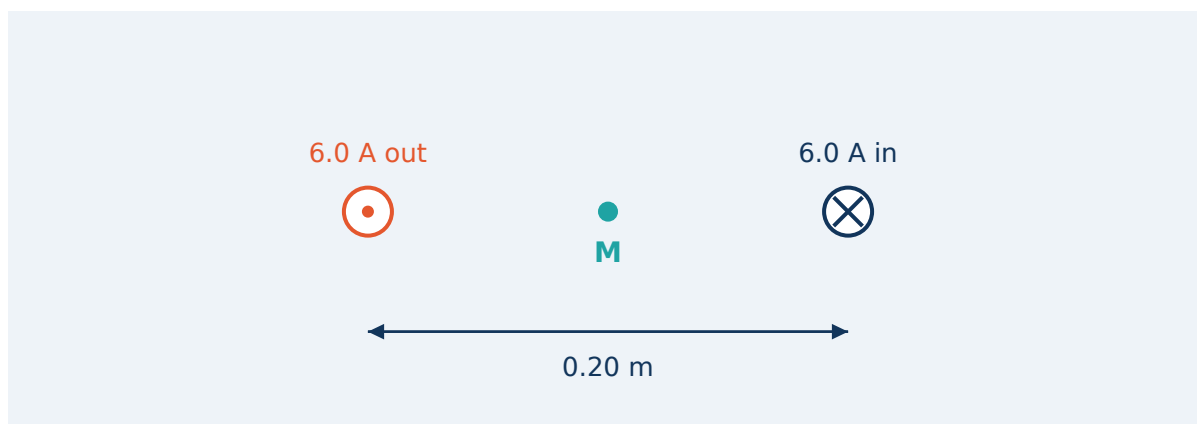
Problem 12 Toroid (medium)

A toroid has 400 turns and carries 1.2 A. The core's mean radius is 0.10 m.

1. Calculate B at the mean radius.
2. Calculate B at the inner radius 0.080 m and at the outer radius 0.12 m.

Problem 13 Opposite currents (medium)

Two long wires carry equal currents in opposite directions, as in the diagram.



Two opposite currents.

1. State the direction of each wire's field at M.
2. Calculate the total B at M.

3. State B at M if both currents pointed the same way.

Problem 14 Force over a length (medium)

Wires 0.10 m apart carry 20 A and 30 A in the same direction, over a length of 2.5 m.

1. Calculate the force on the 2.5 m of wire.
2. State its direction.

Problem 15 A moving proton (medium)

Wanjiru's proton passes with speed 2.0×10^6 m/s. At a point 1.0 cm to its side, perpendicular to its path, $B = (\mu_0/4\pi) qv \sin\theta/r^2$.

1. Calculate B at that point.
2. State why this field is much smaller than the field of a 1 A wire at the same distance.

Problem 16 Semicircular wire (hard)

A wire has two long straight sections that point toward the centre O of a semicircle of radius 0.080 m between them. The current is 6.0 A.

1. Explain why the straight sections contribute no field at O.
2. Integrate Biot-Savart to find B from the semicircle.

Problem 17 Coaxial cable (hard)

A coaxial cable has a central wire carrying 2.0 A up and a thin outer cylinder of radius 5.0 mm carrying 2.0 A down.

1. Calculate B at 3.0 mm from the axis.
2. Calculate B at 8.0 mm.
3. Explain why the cable is shielded.

Problem 18 Non-uniform current (hard)

A cylindrical wire of radius 3.0 mm carries a current density $J = J_0 r/R$ with $J_0 = 4.0 \times 10^5$ A/m².

1. Integrate to find the total current.
2. Show that B inside is $\mu_0 J_0 r^2/(3R)$.
3. Calculate B at $r = R$ and at $r = R/2$.

Problem 19 Loop near a wire (hard)

A rectangular loop 0.10 m (parallel to the wire) by 0.20 m carries 5.0 A. A long wire carries 20 A parallel to the long sides. The near side is 0.050 m from the wire and the current in it is in the same direction as the wire's.

1. Calculate the force on the near side.
2. Calculate the force on the far side.

3. Calculate the net force and say whether the loop is pulled toward or pushed from the wire.

Problem 20 Spot the error (hard)

Emma says that inside a wire of radius 4.0 mm carrying 8.0 A, B at $r = 2.0$ mm is $\mu_0 I / (2\pi r)$, the same formula used outside.

1. Identify the error.
2. Calculate Emma's value.
3. Calculate the correct B.