

Forces on currents and moving charges in magnetic fields

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These problems train you to apply $F = BIL$ and $F = Bqv$, to find the direction of magnetic forces, and to analyse circular motion of charged particles. They move from one-step substitutions to velocity selectors, cyclotrons and mass spectrometers.

They suit A Level, IB Physics, CBSE Class 12 and WAEC senior students. Use $e = 1.60 \times 10^{-19} \text{ C}$, electron mass $9.11 \times 10^{-31} \text{ kg}$ and proton mass $1.67 \times 10^{-27} \text{ kg}$.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB D.3

Problem 1 Force on a lab wire (easy)

Aarav in Pune hangs a 0.50 m wire between the poles of a magnet. The field is 0.40 T and the wire carries 3.0 A at right angles to it.

1. Calculate the force on the wire.

Problem 2 Direction of the force (easy)

A wire carries current due north through a field that points vertically downwards. Take east, north and up as a right-handed set.

1. State the direction of the force on the wire.
2. State the direction if the current is reversed.

Problem 3 Electron in a field (easy)

Chiamaka in Lagos fires electrons at $5.0 \times 10^6 \text{ m/s}$ at right angles into a 0.20 T field.

1. Calculate the force on each electron.

Problem 4 Finding the field (easy)

A 0.15 m wire carrying 6.0 A at right angles to a uniform field feels a force of 0.054 N.

1. Calculate the flux density.

Problem 5 Wire at an angle (easy)

A 0.40 m wire carrying 2.0 A lies at 30° to a field of 0.25 T.

1. Calculate the force on the wire.

2. State the force when the wire is turned parallel to the field.

Problem 6 Power cable and Earth's field (easy)

Kofi in Accra studies a horizontal cable 80 m long carrying 250 A. Earth's field there is 45 μT and is perpendicular to the cable.

1. Convert 45 μT to tesla.
2. Calculate the force on the cable.

Problem 7 Speed unchanged (easy)

A proton moves in a circle in a uniform magnetic field.

1. Explain why its speed stays constant.
2. State what happens to its kinetic energy.

Problem 8 Proton orbit radius (medium)

A proton enters a 0.80 T field at 4.0×10^6 m/s, perpendicular to the field.

1. Calculate the radius of its circular path in cm.

Problem 9 Cyclotron frequency of an electron (medium)

Mei in Singapore models an electron in a 1.5 mT field.

1. Calculate the time for one complete circle.
2. Calculate the frequency of the motion.
3. State how the answers change if the speed is doubled.

Problem 10 Selecting a speed (medium)

A velocity selector has an electric field of 2.4×10^4 V/m and a magnetic field of 0.080 T.

1. Calculate the speed of particles that pass straight through.
2. Explain what happens to a faster particle of the same charge.

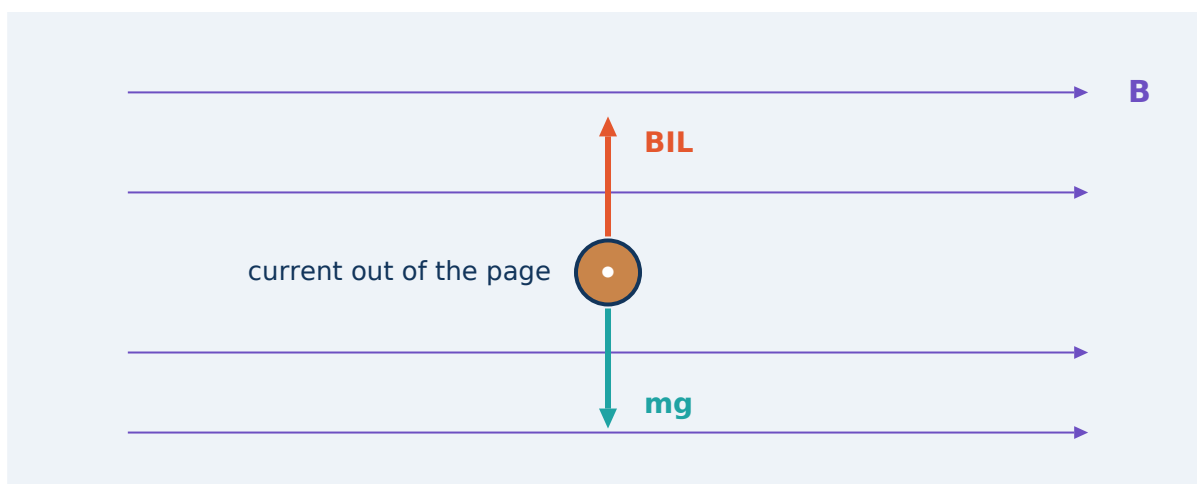
Problem 11 Electron gun then field (medium)

An electron is accelerated from rest through 150 V and then enters a 1.0 mT field at right angles.

1. Calculate its speed after acceleration.
2. Calculate the radius of its path in the field.

Problem 12 Floating wire (medium)

Diego in Texas balances a horizontal wire of mass per unit length 4.0×10^{-3} kg/m in a horizontal field of 0.050 T, perpendicular to the wire, using $g = 9.81$ N/kg.



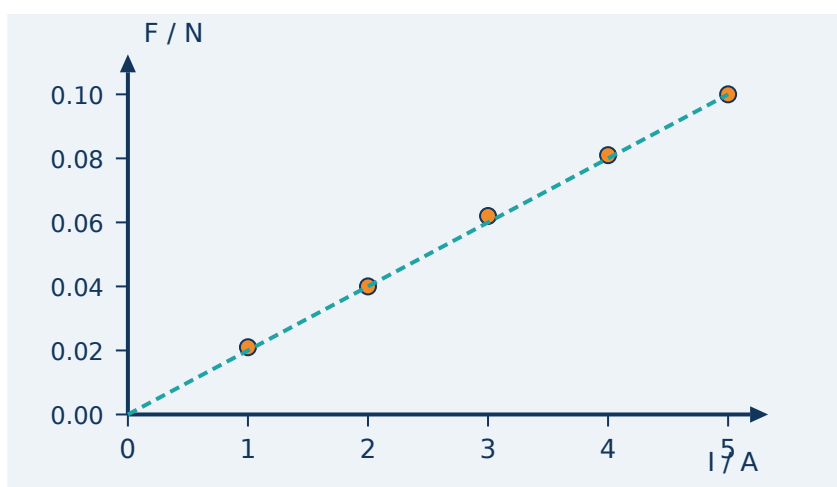
The wire floats when the upward magnetic force equals the weight.

1. Write the condition for the wire to float.
2. Calculate the current needed.

Problem 13 Reading a force graph (medium)

The graph shows the force on a 0.25 m wire for different currents in a uniform field.

1. Find the gradient of the line of best fit.
2. Use it to calculate the flux density.
3. Explain why the line passes through the origin.



Force on a 0.25 m wire against current.

Problem 14 Proton against alpha particle (medium)

A proton and an alpha particle (mass $6.64 \times 10^{-27} \text{ kg}$, charge $+2e$) enter the same field at the same speed, at right angles to it.

1. Calculate the ratio of the radius of the alpha path to that of the proton.
2. Explain the result in terms of mass and charge.

Problem 15 Tracks in a bubble chamber (hard)

Two particles with charges of equal size enter a field pointing into the page at the same point, travelling to the right. The tracks are shown.



Two particles enter the field together from the left with equal charge magnitude.

1. State the sign of the charge on each particle, giving your reasoning.
2. State which particle has the greater momentum.
3. Explain why both tracks are arcs of circles.

Problem 16 Proton cyclotron (hard)

The largest circle in a cyclotron has a radius of 0.45 m in a 1.2 T field. Protons leave on this circle.

1. Calculate their speed.
2. Calculate their kinetic energy in joules.
3. Convert the energy to MeV ($1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$).

Problem 17 Spiral path (hard)

An electron enters a 2.0 mT field with speed $4.0 \times 10^6 \text{ m/s}$ at 60° to the field lines.

1. Resolve its velocity into components perpendicular and parallel to B.
2. Calculate the radius of the circular part of the motion.
3. Calculate the distance advanced along the field in one turn (the pitch).

Problem 18 Coil in a field (hard)

A rectangular coil of 40 turns has two vertical sides 5.0 cm long, 3.0 cm apart, in a horizontal field of 0.15 T parallel to the plane of the coil. The current is 0.80 A.

1. Calculate the force on one vertical side.
2. State the direction of the force on the other vertical side.
3. Calculate the turning moment (couple) on the coil.

Problem 19 Separating chlorine ions (hard)

Singly charged chlorine ions of mass 35 u and 37 u are accelerated through 2.0 kV and then travel in a semicircle in a 0.50 T field ($1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$).

1. Show that $r = (1/B)\sqrt{2mV/q}$.
2. Calculate the two radii.
3. Calculate the distance between the landing points.

Problem 20 Checking a student's solution (hard)

A student writes: "A proton at $2.0 \times 10^6 \text{ m/s}$ in a 0.40 T field has $r = mv/(qB) = 0.52 \text{ m}$ and a period of $1.6 \times 10^{-6} \text{ s}$."

1. Show that the radius is wrong and give the correct value.
2. Calculate the correct period.
3. Suggest a quick estimate that would have exposed the error.