B10 · Fields around currents

Student notes - follow the slides, fill the blanks, work the questions

Use the right-hand rules for a straight wire, a loop and a solenoid.

Name: _____ Date: _____

Slide 1 of 6 · Currents make magnetic fields

In 1820 Oersted found that a compass near a wire turns only while the wire carries a _____. The cause is _____: every moving charge has its own magnetic field, and in a wire the fields of billions of electrons add up. Current has symbol _____ and is measured in _____. One ampere is one _____ of charge passing a point each _____.

_____ current is the way positive charge would move: out of the _____ terminal (the positive plate of the battery), through the wire and back to the negative terminal. _____ flow is the real motion in a metal and points the _____ way.

This course uses _____ current for every hand rule, unless the question says otherwise.

Into the page is drawn as a circle with a _____. Out of the page is drawn as a circle with a _____. On the diploma: if a question says “electrons”, convert to conventional current _____ you apply a hand rule.

Example. A battery is in the middle of the bottom wire of a rectangular circuit, with its positive plate on the left and its negative plate on the right. Along the top wire, which way does conventional current flow, and which way do the electrons flow?

Work:

Answer: _____

Try it. In a straight wire on the page, electrons flow down the page. Which way does conventional current flow? A compass beside the wire turns when the battery is connected and settles back when it is disconnected. What does that show?

Work:

Answer: _____

Slide 2 of 6 · The right-hand rule for a straight wire

The field of a straight wire is a set of _____ around it (look at the dot or cross picture for end-on views). Grip the wire loosely with your _____ hand, with your _____ along the conventional current. Your curled _____ show the direction of the field.

If the thumb points up the page, the fingers move across to the _____ in front of the wire and to the _____ behind it. So a point to the right of the wire has the field _____ the page and a point to the left has it _____ the page. Thumb down reverses both. Thumb right gives _____ the page above the wire and _____ the page below; thumb left reverses those.

The circles are closer together near the wire, so the field is _____ there. End-on means you look straight along the wire, so it looks like a dot or cross. With the current out of the page, the thumb points at you and the circles go _____.

At any point the field is _____ to the circle through that point. On the diploma: a wrong choice uses the _____ hand or the _____ direction.

Example. A long wire lies in the plane of the page. Conventional current flows through it from left to right. P is a point above the wire and Q is a point below it, both in the plane of the page. At P and at Q, is the magnetic field into the page or out of the page?

Work:

Answer: _____

Try it. A wire is seen end-on and its electrons flow into the page. R is a point to the right of the wire and S is a point directly above it, both in the plane of the page. Which way does the magnetic field point at R and at S: up, down, left, right, into the page or out of the page?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 6 · Loops add their fields

Bend a straight wire into a loop and every piece of wire adds a field through the middle that points the _____ way. Fields are vectors, so adding them gives a _____ field inside the loop. Outside the loop the field is weaker and points the other way. If the current in the loop is counterclockwise, the field in the middle is _____ the page (check: on top of the loop the current goes left, so thumb left puts the field below that wire, inside the loop, out of the page).

The field B of a solenoid depends on the current I (amperes, A) and on the number of turns N. Both are direct proportions: B ∝ _____ and B ∝ _____. The sign ∝ means “is directly proportional to”: if one doubles, the other doubles. B is in _____.

A _____ radius makes the field at the middle stronger, because the wire is _____ to the middle. A coil of many turns is called a _____.

When two quantities change at once and both are direct proportions, the factors _____. On the diploma: “in terms of B” answers look like _____ or B/2, so write each factor out.

Example. A solenoid with a given current and number of turns makes a magnetic field of strength B at its centre. The current is doubled and the number of turns is multiplied by three. What is the new field, in terms of B?

Work:

Answer: _____

Try it. Two flat circular coils carry the same current and have the same number of turns. Coil X has radius 4.0 cm and coil Y has radius 2.0 cm. Which coil has the stronger field at its centre, and why?

Work:

Answer: _____

Slide 4 of 6 · Poles of a solenoid and an electromagnet

To find the north pole of a solenoid, grip a wire on the _____ of the coil with your _____ hand, with your thumb along the _____ current. Look at where your fingers go on the _____ of the coil.

The field inside points toward the _____ end, because field lines leave a north pole. If the thumb points up on the front wires, that is the “behind the wire” case of the straight-wire rule: the fingers move _____, and inside the coil is behind the front wire. So the field inside runs left and the _____ end is the north pole.

An air-core solenoid has just air inside. An _____ has an _____ core: the coil’s field lines up the _____ in the iron, so the magnet is much stronger. Turn off the current and the domains go back to random.

More current, more turns or a smaller radius also make it stronger. On the diploma: the _____ and the current direction set the pole, not the terminal label. Trace the current from the _____ plate first.

Example. A solenoid is wound the opposite way to the one in the slide. The positive plate of the battery is on the left and the leads go to the top of the coil. In which direction does the conventional current flow in the wires on the front of the coil, and which end of the solenoid is the north pole?

Work:

Answer: _____

Try it. A solenoid with an iron core is wound with its front wires slanting up. This time the positive plate of the battery is on the right. (In the first example the positive plate was on the left and the front current went up.) Which end of the electromagnet is the north pole, and what two changes would make it stronger?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 5 of 6 · Method: which right-hand rule do I use?

Step 1: convert to _____ current. If the question gives electron flow, _____ it. A moving negative charge counts as current the other way.

Step 2: name the shape: a straight _____, one moving _____, or a _____.

Step 3: make the grip with your _____ hand. Wire or charge: _____ along the current. Coil: grip one _____ wire, thumb along its current.

Step 4: read the _____. Wire or charge: they curl the way the field goes around it. Coil: inside the coil they show the field, and the end the field leaves is _____.

Check: right hand, conventional current in the thumb. Electron flow in the thumb reverses your answer. On the diploma: a wrong choice uses the _____ hand or the _____ direction.

Example. A wire is seen end-on and its electrons flow into the page. R is a point to the right of the wire and S is a point directly above it, both in the plane of the page. Which way does the magnetic field point at R and at S?

Work:

Answer: _____

Try it. NEW, for teacher review. In a long vertical wire on the page, electrons flow down the page. Point U is to the left of the wire, in the plane of the page. Which way does the magnetic field point at U: into the page or out of the page?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 6 of 6 · How much charge flows? Current is charge per time

Current is charge per time: I = _____, so q = _____. I is in _____, q is in _____ and t must be in _____.

To count electrons, divide the charge by the charge of one electron: n = _____, with e = _____.

To go the other way, from a count to a charge, _____: q = _____. Then divide by the time to get the _____.

On the diploma: the number of electrons is a _____, so it is a whole number or a power of ten, never a fraction of an electron.

Example. A wire carries a current of 2.5 A for 4.0 s. Find the charge that passes a point in the wire and the number of electrons. ($e = 1.60 \times 10^{-19}$ C)

Work:

Answer: _____

Try it. NEW, for teacher review. A wire carries 3.20×10^{19} electrons past a point in 2.0 s. Find the current. ($e = 1.60 \times 10^{-19}$ C)

Work:

Answer: _____

B10 · practice

Fields around currents | Questions 1-2 of 8

Constants from the Alberta Physics 30 data sheets: $k = 8.99 \times 10^{9}$ N·m²/C², $e = 1.60 \times 10^{-19}$ C, electron mass $m_e = 9.11 \times 10^{-31}$ kg, proton mass $m_p = 1.67 \times 10^{-27}$ kg, $g = 9.81$ m/s².

Easy · B10-N01. Electrons flow through a wire from left to right. Which statement is correct?

A. Conventional current flows left to right, the same as the electrons.

B. Conventional current flows right to left, and we use the right-hand rule for conventional current.

C. Conventional current flows right to left, and we use the left-hand rule for electrons.

D. There is no current because electrons are very small.

Work:

Final answer (with unit and sign): _____

Easy · B10-N02. Conventional current flows up the page in a long vertical wire. Is the magnetic field into the page or out of the page (a) to the right of the wire, and (b) to the left of the wire?

Work:

Final answer (with unit and sign): _____

B10 · practice

Fields around currents | Questions 3-4 of 8

Easy · B10-N03. Conventional current goes to the right in a horizontal wire in the plane of the page. At a point above the wire, the field points

A. into the page
B. up the page
C. to the right
D. out of the page

Work:

Final answer (with unit and sign): _____

Medium · B10-N04. Electrons flow from right to left along a long horizontal wire in the plane of the page. What is the direction of the field at a point below the wire?

Work:

Final answer (with unit and sign): _____

B10 · practice

Fields around currents | Questions 5-6 of 8

Medium · B10-N05. A solenoid’s current is doubled while the number of turns is cut in half (the solenoid keeps the same length). What happens to the field at the centre?

A. It doubles.
B. It stays about the same.
C. It is cut to one quarter.
D. It becomes four times larger.

Work:

Final answer (with unit and sign): _____

Medium · B10-N06. A coil with an iron core has conventional current going down in the wires on the front of the coil. Which end is the north pole? Why does the iron help?

Work:

Final answer (with unit and sign): _____

B10 · practice

Fields around currents | Questions 7-8 of 8

Challenging · B10-N07. A proton moves to the right across the page. At a point above its path, its magnetic field points

A. into the page
B. up the page
C. to the left
D. out of the page

Work:

Final answer (with unit and sign): _____

Challenging · B10-N08. Using the same moving charge, say what changes if an electron moves to the right instead, and why.

Work:

Final answer (with unit and sign): _____