B14 · The motor effect

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

Find the direction and size of the magnetic force on a current-carrying wire, F = ILB.

Name: _____ Date: _____

Slide 1 of 7 · Why a wire in a field is pushed

A wire carries a huge number of moving charges, all moving the _____ way, so each feels the force in the same direction and the whole wire is pushed. This is the motor effect: _____.

Conventional current is the way _____ charge would move, so it points _____ to the electron flow. Every hand rule in this course uses conventional current.

Right-hand rule for a wire (the same rule as for one charge in B11): fingers along the _____, thumb along the _____, _____ shows the force. For electron flow, point the thumb along the _____ and the force comes out of the _____.

Example: fingers into the page, thumb right, palm faces _____, so the force on the wire is up the page. Reversing the field or the current flips the force; reversing both flips it _____.

Example. A wire carries conventional current from left to right through a magnetic field that points out of the page. In which direction is the magnetic force on the wire?

Work:

Answer: _____

Try it. A vertical wire in the plane of the page carries electrons moving down the page. The magnetic field points to the right across the page. Which way is the force on the wire: into the page, out of the page, left or right?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 7 · The size of the force: F = I L B

More current, more length in the field and a stronger field each give more force. They multiply: F = _____, where L⊥ is the length _____. Only the length _____ counts.

Current is charge per time: I = _____, in amperes, where one ampere is _____. Units: 1 T = _____, so A × m × T gives _____.

θ is the angle between the _____ and the _____, and L⊥ = _____. As for velocity in B11, only the part across the field counts. At 90°, L⊥ = _____.

Numerical questions often hide a step, such as finding I from _____. Check that the angle is measured from the _____, then decide sine or cosine. A picture settles it.

Example. 18 C of charge pass a point in a wire in 4.0 s. A 0.120 m length of the wire lies at right angles to a uniform magnetic field of 0.450 T. What is the current, and what is the size of the magnetic force on the wire?

Work:

Answer: _____

Try it. A straight wire of length 0.20 m carries 6.0 A through a magnetic field of 0.500 T, at 30° to the field direction. What is the size of the magnetic force on the wire?

Work:

Answer: _____

Slide 3 of 7 · Magnetic force against gravity

A wire in a field can feel the magnetic force and gravity at once. Gravity is _____ downward; convert the mass from _____ to kilograms. g = 9.81 _____, the same as 9.81 m/s².

If the two forces point opposite ways, _____ the sizes; the net force points the way of the larger force.

A wire that hangs still has net force _____, so ILB = _____ and I = _____. “Suspended” and “hangs motionless” both mean net force zero. Size check: a weaker field needs a _____ current.

Equal in size and opposite in direction is not the same as equal as _____. A stationary wire can still have forces on it; they just _____.

Example. A horizontal wire of mass 1.40 g has 0.0900 m of its length in a horizontal magnetic field of 0.0500 T. The north pole is on the left, the south pole on the right, and the current is 4.00 A toward you. What are the magnetic force, the weight, and the net force on the wire?

Work:

Answer: _____

Try it. The same wire (1.40 g, 0.0900 m in a 0.0500 T field) hangs still between the magnets with the current toward you. What current is needed to suspend it? Use g = 9.81 N/kg.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 4 of 7 · Method: how to choose the tool for a wire in a field

Step 1: write what is _____ and every _____. Note if the wire is at _____.

Step 2: a current in a wire uses F = _____. One moving charge uses F = _____, from lesson B11.

Step 3: use only the length _____, and L sin θ if the wire is _____. Change grams to _____.

Step 4: right hand: fingers along the _____, thumb along _____ current, palm shows the _____. Electron flow? _____ it first.

Step 5: gravity pulls _____ with mg. A wire at rest has Fnet = _____, so ILB = _____. Otherwise subtract the smaller force from the larger.

Check: units A·m·T give _____. Do the two forces point _____ ways? On the diploma: a wire at rest is _____, not “without force”.

Example. A horizontal wire of mass 1.40 g hangs still between a north pole on the left and a south pole on the right. 0.0900 m of its length is in the field, the field is 0.0500 T and the current is toward you. What current holds the wire still, and which way is the magnetic force?

Work:

Answer: _____

Try it. NEW, for teacher review. A horizontal wire of mass 2.40 g has 0.150 m of its length in a horizontal field of 0.0800 T. The north pole is on the right, the south pole is on the left and the current is away from you. The wire hangs still. What is the current, and is the magnetic force up or down?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 5 of 7 · Reading a force graph

A wire rests on a balance and carries a current in a magnet’s field, so the magnetic force pushes _____. The balance reads F = _____. Plot F against I and match it to y = (slope)x + (intercept), as in B5.

The slope is _____ and the vertical intercept is _____, the force of gravity when the current is zero. The line does not start at zero because gravity always pulls _____.

From the line: B = _____ and m = _____. Use kilograms for mass and tesla for field.

Pick two points _____, not data points. Show the slope and intercept steps with _____. To predict a reading use the equation of the line, because ILB alone leaves out the weight.

Example. A balance reading F against current I gives a straight line through P (0.80 A, 0.530 N) and Q (4.00 A, 0.786 N). The length of wire in the field is 0.120 m. Find the field strength B and the mass of the wire and supports.

Work:

Answer: _____

Try it. Using the same line, F = (0.0800 N/A)I + 0.466 N, predict the balance reading when the current is 2.50 A.

Work:

Answer: _____

Slide 6 of 7 · Two wires, two forces

Each wire makes a field, and each sits in the other's field. Do two steps: find the _____ of one wire at the other, then the _____ on the second wire.

Rule 1 (the field of a wire): grip with your right hand, _____ along the current; the fingers curl the way the field goes. For current up, the field on the right side of the wire is _____ the page.

Rule 2 (the force on a wire): fingers along the _____, thumb along the _____, _____ shows the force.

Currents in the _____ direction attract; currents in _____ directions repel. The two forces are equal in size and opposite in _____.

Use the same-direction rule as a _____ on your answer. A slinky with current shrinks because neighbouring turns _____.

Example. Wire A carries conventional current up the page. Wire B, to its right, carries conventional current down the page. Do the wires attract or repel, and which way is the force on B?

Work:

Answer: _____

Try it. Wire A carries conventional current down the page. Wire B, to its right, also carries conventional current down the page. Which way is the force on B, and do the wires attract or repel?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 7 of 7 · How a motor’s coil turns

A motor is a _____ of wire in a magnetic field. Each side of the loop is a wire in a field, so use the same rule: fingers along the _____, thumb along the _____, palm shows the force.

The two sides carry current in _____ directions, so the forces on them are _____. One side is pushed into the page and the other out of the page, so the loop _____.

The top and bottom sides run _____ the field, so they feel _____ force.

After half a turn the sides swap places. The _____ (a split ring) reverses the _____ every half turn, so the loop keeps turning the _____ way.

More _____ or more _____ of wire gives a larger force. Reverse the current, or the field, and the motor turns the _____ way.

Example. A rectangular loop sits between a north pole on the left and a south pole on the right, so the field points to the right. Conventional current goes down the left side of the loop and up the right side. (a) Which way is the force on the left side, and on the right side? (b) Does the loop turn the same way as it does with current up the left side, or the opposite way?

Work:

Answer: _____

Try it. NEW, for teacher review: The same loop has conventional current up its left side and down its right side. The magnets are swapped, so the field now points to the left. Which way is the force on the left side, and on the right side?

Work:

Answer: _____

Sketch (draw and label the diagram):

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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 $mp = 1.67 \times 10^{-27}$ kg, $g = 9.81$ m/s².

Easy · B14-N01. A wire carries conventional current to the right through a magnetic field that points up the page. The magnetic force on the wire is

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

Work:

Final answer (with unit and sign): _____

Easy · B14-N02. A 0.250 m length of wire carries 5.0 A at right angles to a magnetic field of 0.80 T. Find the magnetic force on the wire.

Work:

Final answer (with unit and sign): _____

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Easy · B14-N03. 12 C of charge pass through a wire in 3.0 s. A 0.100 m length of the wire is at right angles to a field of 0.50 T. Find the magnetic force on that length.

Work:

Final answer (with unit and sign): _____

Medium · B14-N04. A wire of mass 2.4 g has 0.100 m of its length at right angles to a field of 0.250 T. What current makes the magnetic force exactly balance gravity? Use g = 9.81 m/s².

Work:

Final answer (with unit and sign): _____

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Medium · B14-N05. A wire of mass 1.40 g has 0.0900 m of its length in a field of 0.0500 T. A current of 4.00 A flows so that the magnetic force points down. Find the size of the net force on the wire.

Work:

Final answer (with unit and sign): _____

Medium · B14-N06. A graph of scale reading against current for a wire in a field gives the line F = 0.0800 I + 0.466 (F in newtons, I in amperes). What should the scale read at 5.5 A?

Work:

Final answer (with unit and sign): _____

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Challenging · B14-N07. Two parallel wires carry currents in the same direction. Do they attract or repel? Explain using the field of one wire and the force on the other.

Work:

Final answer (with unit and sign): _____

Challenging · B14-N08. A horizontal wire of mass 5.00 g has 0.200 m of its length in a horizontal field of 0.150 T at right angles to the wire. What current holds the wire up, and what direction must the force have? Give the current in A. Use g = 9.81 m/s².

Work:

Final answer (with unit and sign): _____