B11 · Magnetic force on a moving charge

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

Find the size and direction of the magnetic force on a moving charge.

Name: _____ Date: _____

Slide 1 of 5 · What a magnetic force needs

A moving charge carries its own small field. In an outside field the two fields interact and the charge feels a _____. The force needs a _____ charge and a _____.

Its size is F = _____. Here |q| is the _____ of the charge in coulombs, used without its minus sign; v is in _____; B is in _____, where 1 T = 1 N ÷ (C·m/s). The symbol $v_\perp$ means only the part of the velocity at _____ to the field counts.

A charge moving across the field feels the _____ force. A charge moving at an angle feels _____ force. A charge moving along the field lines feels _____ force, and so does a charge that is not moving.

The formula gives only the _____ of the force, so use |q| and decide the direction separately. A _____ field has the same size and direction at every point. On the diploma: the data sheet gives the electron's charge, and a numerical response needs _____ significant digits.

Example. An electron moves at 2.5×10^{6} m/s at right angles to a uniform magnetic field of 0.350 T (uniform: the same size and direction at every point). The charge of an electron has size 1.60×10^{-19} C. What is the size of the magnetic force on the electron, in newtons?

Work:

Answer: _____

Try it. A proton (charge 1.60×10^{-19} C) moves at 4.0×10^{6} m/s at right angles to a uniform magnetic field of 0.50 T. What is the size of the magnetic force on it? What would the force be if the proton were at rest?

Work:

Answer: _____

Slide 2 of 5 · Direction: the right-hand rule

Use a flat right hand for this rule (it is a different rule from the curled grip in B10). The magnetic force is at _____ to both the velocity and the field. It never points along the _____ or along the _____.

For a positive charge: point your _____ along the magnetic field, point your _____ along the velocity, and the force pushes out of your _____.

Example: the fingers point into the page and the thumb points right, so the palm faces _____ the page and the force on the positive charge is _____ the page.

For a negative charge, find the direction for a _____ charge first and then _____ it. On the diploma: write the positive case first so the reversal is a visible step; a common wrong choice forgets to reverse for an _____.

Example. An electron moves to the right through a magnetic field that points out of the page. In which direction is the magnetic force on the electron: up the page, down the page, into the page or out of the page?

Work:

Answer: _____

Try it. A proton moves straight up the page through a field that points to the left, all in the plane of the page. Which way is the magnetic force on the proton? Which way would it be on an electron moving the same way?

Work:

Answer: _____

Slide 3 of 5 · When the motion is at an angle

Split the velocity into a part along the field and a part _____ the field. Only the part across the field, _____, produces a force.

Draw a right triangle with the velocity as the _____ (the hypotenuse). Sine = opposite side ÷ _____; cosine = side next to the angle ÷ _____. Opposite means across from the angle. Set your calculator to _____. If θ is measured between the velocity and the _____, the part across the field is opposite θ, so $v_\perp$ = _____.

If the angle is measured from the direction _____ the field, that part is next to the angle, so use _____: $v_\perp = v \cos\theta$. Draw the picture and decide which side is across the field before choosing sine or cosine.

Then use F = _____. Check that $v_\perp$ is never _____ than v. On the diploma: bearing problems use a compass, so _____ it; sine versus cosine is a favourite wrong choice.

Example. An electron travels along the ground at 1.8×10^{6} m/s in the direction 25° east of south (face south, then turn 25° toward east). The magnetic field is 0.150 T and points east. Use $e = 1.60 \times 10^{-19}$ C. What is the size of the magnetic force on the electron?

Work:

Answer: _____

Try it. A proton enters a uniform field of 0.50 T moving at 3.0×10^{6} m/s at 30° to the field direction. Use $q = 1.60 \times 10^{-19}$ C. What is the size of the force, and what is the force if the proton enters exactly along the field?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 4 of 5 · Method: how to find the force on a moving charge

Step 1, find _____: draw the field and the velocity. Only the part of v _____ the field counts. $v_\perp = v$ _____ when θ is measured from the field, and v _____ when it is measured from across the field.

Step 2, find the _____: F = _____. Use the size of the charge, with no minus sign.

Step 3, find the direction: right hand, _____ along the field, _____ along the velocity, and the palm gives the force on a positive charge. For a negative charge, _____ it.

Step 4, look for _____ forces: if a mass is given, gravity _____ also acts. “Not deflected” means the magnetic force and gravity _____.

Check: $v_\perp$ can never be _____ than v, so the force is never more than _____. The force is zero along the _____.

Example. A proton (charge $+1.60 \times 10^{-19}$ C) moves at 4.0×10^{6} m/s at 35° to a magnetic field of 0.620 T. What is the size of the magnetic force on it? (The slide ran through this question.)

Work:

Answer: _____

Try it. NEW, for teacher review. An electron moves at 2.0×10^{6} m/s at 40° to a uniform magnetic field of 0.30 T. Use $e = 1.60 \times 10^{-19}$ C. What is the size of the magnetic force on the electron? Write the step number beside each line.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 5 of 5 · Magnetic force against gravity

If a question gives the mass of a particle and asks about forces, _____ is part of the story. Gravity on the particle is _____, down, with g = 9.81 N/kg (the same as _____).

If the particle is not deflected, the net force is _____. So the magnetic force equals gravity in size and is opposite in direction: |Fm| = _____. Bars mean _____ and an arrow means size and direction: the two forces have equal size but are not the same vector.

Then |q|vB = _____, so v = _____. Write the balance equation as the _____ line of your solution.

When there is only one force, F⃗net = F⃗m is fine. On the diploma: “not deflected” or “straight line” means net force _____. If you cannot rearrange, test options with _____: a speed must end up in m/s.

Example. A particle of mass m and charge q moves horizontally through a magnetic field B that is at right angles to its velocity. It moves in a straight line, because the magnetic force and the force of gravity balance. Which expression gives its speed? A. qB/(mg). B. mg/(qB). C. mgqB. D. qBm/g. Choose one letter.

Work:

Answer: _____

Try it. A particle has mass 6.7×10^{-27} kg and charge $+3.20 \times 10^{-19}$ C and moves horizontally through a horizontal field of 6.0×10^{-5} T at right angles to its path. What speed does it need so that it is not deflected? Use g = 9.81 N/kg.

Work:

Answer: _____

B11 · practice

Magnetic force on a moving charge | 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 · B11-N01. An electron moves at 3.6×10^{4} m/s at right angles to a magnetic field of 2.50 T. Find the size of the magnetic force on it. Use $e = 1.60 \times 10^{-19}$ C.

Work:

Final answer (with unit and sign): _____

Easy · B11-N02. A proton moves toward the top of the page through a field that points into the page. In which direction is the magnetic force?

Work:

Final answer (with unit and sign): _____

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Magnetic force on a moving charge | Questions 3-4 of 8

Easy · B11-N03. Why is the magnetic force on a charged particle zero when it moves along a magnetic field line?

A. Because the particle has no charge
B. Because the field is zero along its own line
C. Because the force is cancelled by gravity
D. Because sin 0° = 0, so no component of v is at right angles to B

Work:

Final answer (with unit and sign): _____

Medium · B11-N04. A positive charge of 2.0×10^{-6} C moves at 5.0×10^{5} m/s through a field of 0.40 T. The velocity makes an angle of 40° with the field. Find the size of the magnetic force.

Work:

Final answer (with unit and sign): _____

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Magnetic force on a moving charge | Questions 5-6 of 8

Medium · B11-N05. A dust grain with charge 4.0×10^{-9} C and mass 2.0×10^{-7} kg moves horizontally through a horizontal field of 0.50 T at right angles to its path. It is not deflected. What is its speed? Use g = 9.81 N/kg (the same as 9.81 m/s²).

Work:

Final answer (with unit and sign): _____

Medium · B11-N06. A magnetic field acts on a charged particle at right angles to its velocity. What happens to the particle’s speed?

A. It stays constant, because the force is perpendicular to the velocity.

B. It increases, because there is a force.

C. It decreases, because the field opposes motion.

D. It increases and then decreases.

Work:

Final answer (with unit and sign): _____

B11 · practice

Magnetic force on a moving charge | Questions 7-8 of 8

Challenging · B11-N07. An electron moves at 2.0×10^{6} m/s at right angles to a field of 0.0400 T. Find the size of its acceleration. Use $e = 1.60 \times 10^{-19}$ C and the electron's mass $m_e = 9.11 \times 10^{-31}$ kg.

Work:

Final answer (with unit and sign): _____

Challenging · B11-N08. A positive and a negative particle with the same speed and charge size move in the same direction through the same field at right angles. Compare the size and direction of their magnetic forces.

Work:

Final answer (with unit and sign): _____