B13 · Electric and magnetic fields together

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

Add the electric and magnetic forces, and use the velocity selector v = E/B.

Name: _____ Date: _____

Slide 1 of 4 · Adding an electric and a magnetic force

Two forces act on the electron. Electric: F = _____ (charge q, electric field E). Magnetic: F = _____ (speed v, magnetic field B).

Top plate +, so E points _____. A negative charge is pushed _____ to E, so the electron is pushed up.

Right hand: up for a positive charge. _____ it for the electron.

Opposite forces: _____. The _____ force sets the direction. Same way: add.

a = _____. This is the acceleration at the instant of _____. Give size and _____.

Example. An electron ($e = 1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) moves at 3.50×10^{5} m/s to the right between plates with E = 520 N/C. The top plate is positive. A magnetic field of 2.50×10^{-3} T points into the page. What are the size and direction of the electron's acceleration as it enters?

Work:

Answer: _____

Try it. Same plates and electron, but the magnetic field now points out of the page. What are the size and direction of the electron's acceleration as it enters?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 4 · The velocity selector: v = E/B

A straight path means Fnet = _____. The forces are equal in size and _____ in direction.

The bars | | mean _____: |qE| = _____.

q is on both sides and _____: E = vB, so v = _____. Mass and charge are not in the equation.

Unit: 1 T = _____, so N/C ÷ T is _____. An alpha particle is a helium nucleus, charge _____ (twice a proton).

Another speed changes the _____ force but not the _____ force. The larger force sets the bend.

A positive particle is pushed _____ E, a negative one _____ it. Reverse the right-hand-rule answer for negative charges.

Example. In crossed fields E = 1.20 × 10^{3} N/C (top plate positive, field down) and B = 3.00 × 10^{-3} T (into the page), the straight-through speed is 4.00 × 10^{5} m/s. An electron enters moving right at 5.00 × 10^{5} m/s. Does it bend up or down, and why?

Work:

Answer: _____

Try it. A proton enters the same fields at 4.00 × 10^{5} m/s (top plate positive, B into the page, moving right). Does it pass straight through? What happens if it is replaced by an alpha particle at the same speed?

Work:

Answer: _____

Slide 3 of 4 · Method: how to solve a balance-of-forces problem

Step 1: _____ the particle. One arrow per force: electric, magnetic or _____.

Step 2: Electric F = _____. Magnetic F = _____. Sizes first. Then directions: plate signs, and the right hand reversed for a _____ charge.

Step 3: straight path or steady speed: Fnet = _____. The forces are equal and _____.

Step 4: |qE| = _____. The q _____. Solve: v = _____, E = _____ or B = E/v.

Step 5: check. Arrows _____? Does N/C ÷ T give _____?

Example. An electron goes straight through crossed fields with E = 1.20 × 10^{3} N/C (top plate positive, field down) and B = 3.00 × 10^{-3} T (into the page). What is its speed? (e = 1.60 × 10^{-19} C)

Work:

Answer: _____

Try it. NEW, for teacher review. An electron moves right at 5.00 × 10^{5} m/s and goes straight through plates with E = 1.00 × 10^{3} N/C (top plate positive, field down). What magnetic field strength and direction are needed? (e = 1.60 × 10^{-19} C)

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 4 of 4 · Choosing the tool

Find the _____ first. Write its equation. Then use the numbers. Do not hunt for a formula that fits.

Straight path: Fnet = _____. Circle: the _____ force is the net force. Accelerated from rest through ΔV: energy gained is _____.

Cues: straight _____; accelerated from rest _____; circle _____; two forces _____.

Crossed fields: an _____ and a _____ field at right angles.

Two cues: one equation per cue, in _____. Work backward from the _____ if the end of the path gives it.

$v_\perp$ is the part of v at _____ to the field. At rest, or moving _____ the field: $v_\perp = 0$, so F = _____.

Example. Three cases: (1) an electron is accelerated from rest through 400 V, then moves in a circle in a magnetic field; (2) a proton passes straight through plates and a magnetic field; (3) a positive ion moves along a magnetic field line. For each, write the first equation or statement you would use.

Work:

Answer: _____

Try it. A proton ($m = 1.67 \times 10^{-27}$ kg) starts at rest, is accelerated through a potential difference, then enters crossed fields $E = 1.20 \times 10^{3}$ N/C and $B = 3.00 \times 10^{-3}$ T and goes straight through. What potential difference accelerated it?

Work:

Answer: _____

B13 · practice

Electric and magnetic fields together | 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 · B13-N01. An electron moves at 4.0×10^{5} m/s through a magnetic field of 3.0×10^{-3} T and an electric field of 600 N/C. The two forces are in opposite directions. Find the size of the net force on the electron.

Work:

Final answer (with unit and sign): _____

Easy · B13-N02. A proton moves at 2.0×10^{5} m/s through a magnetic field of 0.0400 T. What electric field strength makes it go straight through? (N/C)

Work:

Final answer (with unit and sign): _____

B13 · practice

Electric and magnetic fields together | Questions 3-4 of 8

Easy · B13-N03. Does the speed that passes straight through a velocity selector change if the particle is an alpha particle (twice the charge of a proton) instead of a proton?

A. Yes, it doubles because the charge doubles
B. Yes, it halves because the mass is larger
C. Yes, it depends on the sign only
D. No, because v = E/B does not depend on the charge or mass

Work:

Final answer (with unit and sign): _____

Medium · B13-N04. Fields E = 600 N/C and B = 1.50×10^{-3} T are at right angles in a velocity selector. What speed passes straight through?

Work:

Final answer (with unit and sign): _____

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Electric and magnetic fields together | Questions 5-6 of 8

Medium · B13-N05. In a velocity selector the top plate is positive and the magnetic field points into the page. A proton moves right, slightly slower than E/B. Which way does it bend?

A. Up, toward the positive plate
B. Down, toward the negative plate
C. Into the page
D. Out of the page

Work:

Final answer (with unit and sign): _____

Medium · B13-N06. Using the electron in the first question (net force 9.60×10^{-17} N), find the size of its acceleration at the instant it enters the fields. Use $m_e = 9.11 \times 10^{-31}$ kg.

Work:

Final answer (with unit and sign): _____

B13 · practice

Electric and magnetic fields together | Questions 7-8 of 8

Challenging · B13-N07. A velocity selector must pass particles at 2.5×10^5 m/s through a magnetic field of 0.0300 T. The electric field comes from plates 0.0200 m apart. What potential difference is needed?

Work:

Final answer (with unit and sign): _____

Challenging · B13-N08. Why do problems with both an electric and a magnetic field usually ask only for the acceleration at the instant of entry?

Work:

Final answer (with unit and sign): _____