B5 · Reading straight-line graphs

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

Find a slope with its unit, match a graph to y = mx + b, and straighten a curve.

Name: _____ Date: _____

Slide 1 of 8 · Two variables and a line of best fit

A fair test changes one thing and measures one thing. The _____ variable is the one you change. The _____ variable is the one you measure. Everything else is held _____.

The manipulated variable goes on the _____ axis. The responding variable goes on the _____ axis. Spring test: the stretch (m) is _____. The force (N) is _____.

Points never fall exactly on a line. Every reading has a small _____. A line of best fit follows the _____.

Read values from the _____, never from single data points. Choose two points on the line that are _____, so the error is a small share of the answer.

Example. A student changes the source charge Q and measures the electric field strength E with a probe. The probe stays 0.500 m from the source in air. Which quantity is manipulated, which is responding, which is held fixed, and which one goes on the horizontal axis?

Work:

Answer: _____

Try it. A student draws a line of best fit through six scattered points. To find the slope she reads two of the data points that are close together. Give two things she should change.

Work:

Answer: _____

Slide 2 of 8 · Find the slope from the line

Slope = _____. Rise is how far the line goes _____. Run is how far it goes _____. Take B minus A for both, in the _____. F_B is the force at B. x_A is the extension at A.

Slope = _____. It shows how much the vertical quantity changes for each _____ of the horizontal quantity.

The slope unit is the _____ ÷ the _____. Here F is in N and x is in m, so the slope is in _____. A slope without its unit is incomplete.

Convert the run to _____. Keep the power of ten. A slope of 250 or 0.25 instead of 25.0 N/m means the _____ was lost.

Example. Points A (2.0×10^{-2} m, 1.00 N) and B (10.0×10^{-2} m, 3.00 N) lie on the line of best fit of spring force F against extension x. Find the slope.

Work:

Answer: _____

Try it. A different spring's line of best fit passes through C = (3.0×10^{-2} m, 1.40 N) and D = (9.0×10^{-2} m, 3.80 N). Find the slope, including its unit. Show the rise, the run and the unit check.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 8 · Match the physics equation to y = mx + b

A straight line follows y = _____. m is the _____. b is the _____, where the line crosses the vertical axis (x = _____). Hooke’s law is F = kx. F is the force (N). x is the extension (m). k is the spring constant (N/m).

Match the symbols one at a time. The vertical-axis quantity plays _____. The horizontal-axis quantity plays _____. The number multiplying x is the _____. The term that stands alone is the _____.

In F = kx, F plays y and x plays x. So the slope is the _____. The law has _____ b term, so a 0.50 N intercept is not part of the law.

Sometimes the intercept is real physics. In $v = v_0 + at$, a is the constant acceleration (m/s^2) and v_0 is the starting speed (m/s). The term with no t is the _____. Always ask if the physics equation has a _____.

Example. A cart’s speed v is plotted against time t, and the line of best fit has the equation $v = v_0 + at$, where a is a constant acceleration. Using y = mx + b, what does the slope represent and what does the vertical intercept represent?

Work:

Answer: _____

Try it. A graph of the electric field strength E against the source charge Q, measured at a fixed distance r from a point source, matches $E = kQ/r^2$. Using y = mx + b, what does the slope equal, and what should the intercept be?

Work:

Answer: _____

Slide 4 of 8 · Predict with the whole line, intercept included

Predict with the whole line: y = _____, intercept included. The spring line is F = (25.0 N/m)x + 0.50 N.

To find x from F, write the equation with F in it. _____ first. Then _____. For F = 1.20 N: 0.70 = 25.0x, so x = _____. F = kx alone gives 0.0480 m and leaves out the 0.50 N.

The line is in SI units, so convert first: 6.0 cm = _____ m. Forgetting to convert is a classic wrong choice.

Inside the measured range is _____. It is reliable. Past the range is _____. It is less reliable, because the line may not stay straight.

Example. The spring line is F = (25.0 N/m)x + 0.50 N, from measured extensions up to 12×10^{-2} m. The extension is 6.0 cm. Find the predicted force.

Work:

Answer: _____

Try it. The same line is F = (25.0 N/m)x + 0.50 N. A force of 2.30 N is applied. Find the extension this experiment predicts, in metres.

Work:

Answer: _____

Slide 5 of 8 · Method: how to get slope and constants from a graph

Step 1: pick _____ on the line. Use grid crossings, far apart. Use line points, not _____.

Step 2: _____ = rise ÷ run. Keep the power of ten. The unit is the vertical unit ÷ the _____.

Step 3: match y = mx + b. Step 4: say what the slope and the _____ mean, with units. Does the physics equation have a b term?

Step 5: predict with the _____. Check: the unit and the size fit the picture.

Example. The spring line is F = (25.0 N/m)x + 0.50 N. A and B lie on it at (2.0 × 10^{-2} m, 1.00 N) and (10.0 × 10^{-2} m, 3.00 N). Find the spring constant, then the extension for a force of 1.20 N. Write each step number beside your work.

Work:

Answer: _____

Try it. A line of best fit for another spring passes through (2.0 × 10^{-2} m, 1.50 N) and (8.0 × 10^{-2} m, 3.30 N). Find the slope and the intercept, then the force predicted for an extension of 5.0 cm. Write each step number beside your work.

Work:

Answer: _____

Slide 6 of 8 · Find Coulomb’s constant from a field graph

Here k is _____, not a spring constant. $E = kQ/r^2$. E is the field strength (N/C). Q is the source charge (C). r is the distance (m). Q is _____ (horizontal). E is _____ (vertical). r and k are held _____.

Match $E = kQ/r^2$ to $y = mx$. The slope is _____. So k = _____. Multiply by r^2, do not divide.

Keep the powers of ten. Convert first: 1 μC = _____ C. Unit check: $(N/C^2)(m^2)$ = _____.

Compare with the data-sheet _____. A numerical response uses three digits in the form _____.

Example. At r = 0.500 m, J = (2.0 μC, 1.0×10^5 N/C) and K = (10.0 μC, 4.0×10^5 N/C) lie on the line of E against Q. Find k from the graph. The data sheet gives 8.99×10^9 $N \cdot m^2/C^2$.

Work:

Answer: _____

Try it. At r = 0.300 m, a line of best fit for E against Q passes through M = (3.0×10^{-6} C, 3.2×10^5 N/C) and N = (9.0×10^{-6} C, 9.5×10^5 N/C). Find the experimental value of Coulomb’s constant. Record it as $a.bc \times 10^n$ $N \cdot m^2/C^2$.

Work:

Answer: _____

Slide 7 of 8 · Straighten a curve: plot against $1/r^2$

Fixed charges $Q_1 = 3.00\ \mu C$ and $Q_2 = 2.00\ \mu C$. Use sizes only, no minus sign. F against r is a _____. A curve has no single slope: rise over run _____ with every pair of points.

Coulomb's law: $F =$ _____ $\times (1/r^2)$. F is proportional to _____, not to r.

So plot F against _____. Then $F = (kQ_1Q_2)(1/r^2)$ matches $y = mx$: a _____ with slope _____. For r = 0.500 m: $0.500^2 = 0.250$ and $1 \div 0.250 =$ _____.

The charges are in the slope, so _____ the slope by Q_1Q_2 to get k. The slope unit is $N \div m^{-2} =$ _____. Add the unit _____ yourself.

Example. $Q_1 = 3.00\ \mu C$ and $Q_2 = 2.00\ \mu C$. Points C = (2.0 m^{-2}, 0.108 N) and D = (10.0 m^{-2}, 0.524 N) lie on the line of F against $1/r^2$. Find k.

Work:

Answer: _____

Try it. Two equal charges, $Q_1 = Q_2 = 4.00\ \mu C$. A line of F against $1/r^2$ passes through G = (2.0 m^{-2}, 0.31 N) and H = (8.0 m^{-2}, 1.20 N). Find the experimental value of Coulomb's constant.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 8 of 8 · Method: how to straighten a curve

Step 1: name the _____. Force is proportional to $1/r^2$, not to r. Step 2: plot against the quantity the law is _____: _____.

Step 3: make the new _____: square each r, then flip it. Keep an extra digit until the column is done.

Step 4: plot the new column on the _____ axis. Draw one line of best fit.

Step 5: read the slope. It holds every constant, so _____ by the ones you know. Check: the points fall on a line near the _____, and the slope unit is the vertical unit ÷ m^{-2}.

Example. Q_1 = 3.00 µC and Q_2 = 2.00 µC, with separations 1.00, 0.707, 0.500 and 0.316 m. Points C = (2.0 m^{-2}, 0.108 N) and D = (10.0 m^{-2}, 0.524 N) lie on the line of F against $1/r^2$. Find k. Write each step number beside your work.

Work:

Answer: _____

Try it. Q_1 = 2.00 µC and Q_2 = 6.00 µC. Points P = (4.0 m^{-2}, 0.43 N) and R = (12.0 m^{-2}, 1.29 N) lie on the line of F against $1/r^2$. Find the experimental value of Coulomb's constant. Write each step number beside your work.

Work:

Answer: _____

B5 · practice

Reading straight-line graphs | 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 · B5-N01. A line of best fit passes through (0.5 s, 1.2 m) and (4.5 s, 5.2 m). Find its slope in m/s.

Work:

Final answer (with unit and sign): _____

Easy · B5-N02. Two charges are fixed. A student measures the force F at several separations r and wants a straight-line graph. Which pair of axes works?

A. F on the vertical axis, $1/r^2$ on the horizontal axis
B. F on the vertical axis, r on the horizontal axis
C. r on the vertical axis, F on the horizontal axis
D. F on the vertical axis, r^2 on the horizontal axis

Work:

Final answer (with unit and sign): _____

B5 · practice

Reading straight-line graphs | Questions 3-4 of 8

Easy · B5-N03. A line of best fit is drawn for scattered data points. Which description is correct?

A. It must pass through every data point.
B. It must start at the origin.
C. It joins the first point to the last point.
D. It follows the overall trend, with points above and below it.

Work:

Final answer (with unit and sign): _____

Medium · B5-N04. An experiment gives the line F = (40.0 N/m)x + 0.30 N, with data from x = 0.010 m to 0.080 m. Find the extension x that the line predicts for F = 2.70 N.

Work:

Final answer (with unit and sign): _____

B5 · practice

Reading straight-line graphs | Questions 5-6 of 8

Medium · B5-N05. A graph of electric field strength E against $1/r^2$ from a point charge is a straight line through the origin with slope 5390 N·m²/C. Use $k = 8.99 \times 10^9$ N·m²/C². Find the source charge in coulombs.

Work:

Final answer (with unit and sign): _____

Medium · B5-N06. A student extends the line $F = (25.0\ \text{N/m})x + 0.50\ \text{N}$ to $x = 0.30$ m, but all the measurements were made between $x = 0.02$ m and 0.12 m. Predict F and say whether you trust it.

Work:

Final answer (with unit and sign): _____

B5 · practice

Reading straight-line graphs | Questions 7-8 of 8

Challenging · B5-N07. Two charges $q_1 = 2.0 \times 10^{-6}$ C and q_2 are fixed. The force on q_2 is 5.39 N at r = 0.100 m and 0.599 N at r = 0.300 m. Plot F against $1/r^2$. Find the slope in N·m², using these two points.

Work:

Final answer (with unit and sign): _____

Challenging · B5-N08. Use your slope from the previous question (0.0539 N·m²) and k = 8.99×10^9 N·m²/C² to find q_2, given $q_1 = 2.0 \times 10^{-6}$ C. Explain what the line would show about the force if q_2 were doubled.

Work:

Final answer (with unit and sign): _____

B6 · Potential difference: energy per charge

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

Explain potential difference as energy per charge, use $\Delta E = q\Delta V$, and use the electron volt.

Name: _____ Date: _____

Slide 1 of 7 · Work that stores energy between plates

A positive particle against the _____ plate is where it wants to be, so we call its electric potential energy (written Ep) _____ there, like a ball at the bottom of a hill.

To carry it toward the other plate something outside must push, because the plates pull and push it _____. Our push does _____.

The speed stays constant, so none of the work becomes _____. _____ the work is stored as electric potential energy: $\Delta Ep = 6.0 \times 10^{-16}$ J in the example, where Δ means _____. When released, Ep decreases and the same amount becomes kinetic energy, written Ek.

The positive plate _____ a positive charge away and the negative plate _____ it in.

Example. A positive particle with $q = 4.0 \times 10^{-17}$ C is carried at constant speed from the negative top plate (A) to B, gaining 6.0×10^{-16} J of electric potential energy. It is released from rest and gravity is too small to matter. Which way does it move, and how much kinetic energy does it have when it reaches the top plate?

Work:

Answer: _____

Try it. The same positive particle is held at B, with 6.0×10^{-16} J of electric potential energy, and is carried at constant speed back to the negative top plate at A. Does its electric potential energy increase or decrease, by how much, and what is its potential energy at A?

Work:

Answer: _____

Slide 2 of 7 · Potential difference: energy per charge

A bigger charge stores more energy, so divide out the charge. Electric potential difference is $\Delta V =$ _____: ΔE is the _____ (J) and q is the _____ (C).

Its unit is _____ (joules per coulomb). ΔV belongs to the _____, not the particle: a charge three times as big stores three times the energy, and $\Delta E \div q$ gives the _____ ΔV.

Rearrange for the unknown: $\Delta E =$ _____. Put in the size of the charge, then ask which way it moves: moving toward the plate that attracts it means it _____. If the plates do not change, ΔV stays the _____ for a new charge.

On a graph of ΔE against q, $\Delta E = q\Delta V$ matches $y = mx$, so the slope is _____. The line passes through the _____, because zero charge stores zero energy. Check powers of ten, since the charges are very small.

Example. On other plates, a charge $q = 6.0 \times 10^{-18}$ C stores 1.8×10^{-16} J when moved from A to B. Find the potential difference between A and B, then find the energy stored when a charge of 1.5×10^{-17} C is moved between the same two points.

Work:

Answer: _____

Try it. The same plates move several charges from A to B, and the energy stored is graphed against the charge. The line passes through C = (2.0×10^{-18} C, 0.60×10^{-16} J) and D = (8.0×10^{-18} C, 2.40×10^{-16} J). What does the slope represent, and what is its value?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 7 · Method: how to solve an energy-per-charge problem

Step 1: name the _____. Is it ΔE, q or ΔV? Write it before any number.

Step 2: write the equation with the unknown alone: ΔV = _____, ΔE = _____ or q = _____.

Step 3: put in the _____: the size of the charge in coulombs and the energy in joules. Then ask which way it moves: toward the plate that attracts it, it gains _____.

Step 4: calculate with units. Joules per coulomb is the _____. Check: a bigger charge stores _____ energy.

Example. A charge of 6.0×10^{-18} C stores 1.8×10^{-16} J when it is moved from A to B. A charge of 1.5×10^{-17} C is then moved between the same two points. Find the potential difference, then the energy stored for the new charge.

Work:

Answer: _____

Try it. A charge of 2.5×10^{-17} C stores 1.0×10^{-15} J when it is moved between two plates. Find the potential difference between the plates, then the energy stored when a charge of 8.0×10^{-18} C is moved between the same plates.

Work:

Answer: _____

Slide 4 of 7 · The volt: one joule per coulomb

One volt is one _____: 1 V = _____. “Voltage” is just _____. A battery label such as 9.0 V means ΔV = _____ in an equation. Unlike the field E, ΔV has _____.

A 9.0 V battery gives _____ to each coulomb that passes through it. A battery does not store charge to hand out; it supplies _____ for each coulomb already in the wires.

Pick the form that matches the unknown: energy from charge, ΔE = _____; charge from energy, q = _____. The unit V can always be swapped for _____.

Example. A battery is labelled 9.0 V and is connected to a heating coil. A charge of 4.0 C flows through the coil. Find the energy delivered.

Work:

Answer: _____

Try it. A 6.0 V battery is connected to a lamp. How much energy is delivered when 2.5 C of charge passes through the lamp, and how much charge must pass to deliver 90 J?

Work:

Answer: _____

Slide 5 of 7 · A charge accelerated through a voltage

Voltage supplies energy and the particle turns it into speed. Rearrange $\Delta V = \Delta E/q$ to $\Delta E = q\Delta V$. Kinetic energy is $E_k = \frac{1}{2}mv^2$; the small i means _____ and f means _____. Only the electric force changes the energy here, so all of $q\Delta V$ becomes kinetic energy: $q\Delta V$ = _____.

The initial term drops out only when the problem says _____ (v_i = _____). Do not drop it automatically.

From rest: v = _____, where $E_k = q\Delta V$. If it is already moving, find the _____ energy $\frac{1}{2}mv_i^2$ and the _____ $q\Delta V$. Final E_k = start + gain, then solve for v.

Use the particle's own q and m (electron, proton and alpha particle differ). Check: a particle sped up by the voltage must end _____ than it started.

Example. An electron starts from rest at the negative plate of an electron gun and is accelerated through $\Delta V = 1.80 \times 10^3$ V. With $q = 1.60 \times 10^{-19}$ C and $m = 9.11 \times 10^{-31}$ kg, find its speed at the positive plate.

Work:

Answer: _____

Try it. An electron enters the gap at $v_i = 1.50 \times 10^7$ m/s and is accelerated through $\Delta V = 6.00 \times 10^2$ V. Find its final speed. Use $q = 1.60 \times 10^{-19}$ C and $m = 9.11 \times 10^{-31}$ kg.

Work:

Answer: _____

Slide 6 of 7 · Method: how to find the speed of a charge accelerated through a voltage

Step 1: write the energy rule _____. The energy gained from the voltage becomes _____.

Step 2: find the energy _____: qΔV, with the size of the charge in coulombs and the voltage in volts. The answer is in _____.

Step 3: find the _____ energy. “From rest” means ½mv_i² = _____. If it is already moving, work out ½mv_i² with the particle’s own _____.

Step 4: final Ek = start + _____. Then v = _____. Check: the unit is _____, and a particle sped up by the voltage ends _____ than it began.

Example. An electron starts from rest and crosses a gap with a voltage of 1.80×10^{3} V. With $q = 1.60 \times 10^{-19}$ C and $m = 9.11 \times 10^{-31}$ kg, find its speed at the end.

Work:

Answer: _____

Try it. A proton starts from rest and is accelerated through 2.00×10^{3} V. With $q = 1.60 \times 10^{-19}$ C and $m = 1.67 \times 10^{-27}$ kg, find its final speed.

Work:

Answer: _____

Slide 7 of 7 · The electron volt

The electron volt (eV) is a unit of _____, not of voltage. One eV is the energy an electron gains when accelerated through _____.

1 eV = qΔV = $(1.60 \times 10^{-19}\ \text{C})(1\ \text{V})$ = _____ (data sheet).

A charge of n electrons gains _____ for each volt: an electron through 24.0 V gains _____ eV, an alpha particle (charge 2e) through 15.0 V gains _____ eV.

To switch units: eV × 1.60×10^{-19} = _____, and joules ÷ (1.60×10^{-19}) = _____. The equation ΔE = qΔV still needs joules, coulombs and volts. Read the unit in the question first and finish in it.

Example. An alpha particle (charge 3.20×10^{-19} C) is accelerated from rest through 45.0 V. Find the kinetic energy it gains, first in electron volts and then in joules.

Work:

Answer: _____

Try it. An electron enters the gap at 1.0×10^{6} m/s and is accelerated through 80.0 V. Find its final kinetic energy in electron volts. Record the answer as a.bc × 10^{n} eV. Use m = 9.11×10^{-31} kg.

Work:

Answer: _____

B6 · practice

Potential difference: energy per charge | Questions 1-2 of 7

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 · B6-N01. A charge of 5.0×10^{-18} C is moved between two points, and 1.5×10^{-16} J of energy is stored. Find the potential difference.

Work:

Final answer (with unit and sign): _____

Easy · B6-N02. A 12 V battery drives 8.0 C of charge through a motor. How much energy does the battery deliver, in joules?

Work:

Final answer (with unit and sign): _____

B6 · practice

Potential difference: energy per charge | Questions 3-4 of 7

Easy · B6-N03. The potential difference between two points is 30 V. A second charge, twice as large, is moved between the same points. What is the new potential difference?

A. 60 V, because the charge doubled
B. 15 V, because q is in the denominator
C. Zero, because the energy cancels
D. 30 V, because ΔV belongs to the points and not to the charge

Work:

Final answer (with unit and sign): _____

Medium · B6-N04. An electron is accelerated from rest through 3500 V. Use $e = 1.60 \times 10^{-19}$ C and electron mass $m_e = 9.11 \times 10^{-31}$ kg. Find its final speed.

Work:

Final answer (with unit and sign): _____

B6 · practice

Potential difference: energy per charge | Questions 5-6 of 7

Medium · B6-N05. A particle with charge 4.80×10^{-19} C is accelerated from rest through 25.0 V. Find the kinetic energy it gains, in electron volts.

Work:

Final answer (with unit and sign): _____

Challenging · B6-N06. An electron enters a gap moving at 2.0×10^{7} m/s and is accelerated through 4.00×10^{2} V. Find its final speed.

Work:

Final answer (with unit and sign): _____

B6 · practice

Potential difference: energy per charge | Questions 7-7 of 7

Challenging · B6-N07. An electron and a proton are each accelerated from rest through the same 100 V. Which gains more kinetic energy, and which ends with the greater speed? Explain.

Work:

Final answer (with unit and sign): _____

B7 · Fields between plates

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

Use E = ΔV/Δd between parallel plates and find force, acceleration and speed of a charge.

Name: _____ Date: _____

Slide 1 of 5 · Radial and uniform fields

A field is a region where a _____ feels a force. The arrows show the force on a _____ test charge.

Around a point charge the field is _____: arrows point _____ a positive source and _____ a negative one. Closer in, the arrows bunch up: a _____ field. The direction changes from place to place.

Between parallel plates the field is _____ (constant): parallel, evenly spaced arrows, the same at R, at S and between. The arrows point from the _____ plate to the _____ plate.

The force on a charge is F = _____, and F = ma links it to the acceleration. If E does not change along the path, neither does the _____.

Example. A small positive object is released from rest in each of two fields, a point-charge field (positive source) and the uniform field between plates, and nothing else acts on it. In each field, does its acceleration increase, decrease or stay the same as it moves, and what happens to its kinetic energy?

Work:

Answer: _____

Try it. Describe the direction and spacing of the field arrows (a) around a negative point charge and (b) between two plates when the top plate is positive. Sketch both.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 5 · The field between plates

A uniform field is the same everywhere between plates. A bigger _____ or a smaller _____ makes a _____ field.

Formula: E = _____. E is the field strength, in _____ (size only). ΔV is the potential difference between the plates, in _____. Δd is the gap between the plates, in _____.

Direction: from the _____ plate to the _____ plate. V/m and _____ are the same unit. Multiply both sides by Δd: ΔV = _____.

Plates only. For one _____ use $E = kQ/r^2$, where Q is the source charge and r is the distance from it. Write each rearranged form out.

On a graph of E against 1/Δd, $E = \Delta V \times (1/\Delta d)$ matches y = mx: y is _____, x is _____ and the slope is _____. Rewrite the equation to match y = mx first.

Example. Plates are 0.0150 m apart and connected to a 120 V battery. Find the field strength between the plates, then find the battery voltage needed for a field three times as strong with the same gap.

Work:

Answer: _____

Try it. The battery voltage is kept the same while the plate gap is changed. The field is graphed against 1/Δd. The line passes through C = (25 m^{-1}, 4.5×10^3 V/m) and D = (100 m^{-1}, 18.0×10^3 V/m). What does the slope represent, and what is its value?

Work:

Answer: _____

Slide 3 of 5 · Force, acceleration and speed between plates

Force gives _____. Energy gives _____. Only the electric force acts, so ma = _____. From B4: F = qE, where q is the particle's charge.

Field: E = _____. Acceleration: a = _____. Speed from rest: qΔV = _____, so v = _____. The field is uniform, so a is _____.

If the question gives E and not ΔV, find ΔV = _____ first. Use the electron's charge and mass from the data sheet. Keep every digit on your calculator and round _____.

Use the particle's own q and m. A proton has the same size of charge as an electron but a much bigger _____. Two routes that agree are a good check. A speed stays well below _____.

Example. An electron ($q = 1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) starts from rest in a uniform field of 4.00×10^{3} V/m. The plates are 0.0600 m apart. Find the final speed of the electron at the other plate.

Work:

Answer: _____

Try it. A proton ($q = 1.60 \times 10^{-19}$ C, $m = 1.67 \times 10^{-27}$ kg) starts from rest against the positive plate. The plates are 0.0150 m apart and the voltage is 300 V. Find its final speed using energy, then check the speed using the acceleration and the gap.

Work:

Answer: _____

Slide 4 of 5 · Method: parallel-plate problems

Step 1: find the field. E = _____, with the gap in _____.

Step 2: find the field direction. It points from the _____ plate to the _____ plate.

Step 3: find the force. F = _____, using the size of q. A positive charge is pushed _____ the field. A negative charge is pushed _____ it.

Step 4: find the acceleration. a = _____, in the same direction as the force. Step 5: find the speed. From rest, qΔV = _____, or check with v = _____. Check: a speed stays well below _____.

Example. An alpha particle ($q = 3.20 \times 10^{-19}$ C, $m = 6.65 \times 10^{-27}$ kg) starts from rest against the positive plate. The gap is 0.0200 m and the battery is 175 V. Find its acceleration and its speed at the other plate.

Work:

Answer: _____

Try it. An electron ($q = 1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) starts from rest against the negative plate. The gap is 0.0300 m and the battery is 450 V. Find its acceleration and its speed at the other plate. Write each step number beside your work.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 5 of 5 · Not starting from rest

If a particle is already moving when it enters (look for "_____"), it has initial kinetic energy ½mv_i², and the field adds more or takes some away.

Find ΔV = _____. Find the initial kinetic energy from the entering speed. Find the energy gained or lost: _____.

An electron moving toward the + plate: unlike charges _____, so it _____. Ek final = Ek initial _____. A proton moving toward the + plate: like charges _____, so it _____. Ek final = Ek initial _____.

Then v_f = _____. Check: a charge that speeds up ends _____, and a slowed charge ends _____, than its starting speed.

Example. An electron ($q = 1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) enters the gap at 2.00×10^{6} m/s toward the positive plate. The field is 3.00×10^{3} V/m and the gap is 0.0500 m. Find its speed at the positive plate.

Work:

Answer: _____

Try it. A proton ($q = 1.60 \times 10^{-19}$ C, $m = 1.67 \times 10^{-27}$ kg) enters the gap moving at 4.0×10^{5} m/s toward the positive plate, which repels it. The potential difference is 400 V. Find its speed at the positive plate, and say how you know the answer makes sense.

Work:

Answer: _____

B7 · practice

Fields between plates | 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 · B7-N01. Two parallel plates 0.0300 m apart are connected to a 150 V battery. Find the electric field strength between them in V/m.

Work:

Final answer (with unit and sign): _____

Easy · B7-N02. The gap between two plates is halved while the battery voltage stays the same. What happens to the field strength between them?

A. It doubles.
B. It halves.
C. It stays the same.
D. It becomes four times larger.

Work:

Final answer (with unit and sign): _____

B7 · practice

Fields between plates | Questions 3-4 of 8

Easy · B7-N03. A positive charge is released from rest at different places between large parallel plates. How does its acceleration compare from place to place?

A. It is larger near the positive plate.
B. It is larger near the negative plate.
C. It increases as the charge speeds up.
D. It is the same everywhere, because the field is uniform.

Work:

Final answer (with unit and sign): _____

Medium · B7-N04. An electron starts from rest in a uniform field of 2500 V/m across plates 0.08 m apart. Find its final speed.

Work:

Final answer (with unit and sign): _____

B7 · practice

Fields between plates | Questions 5-6 of 8

Medium · B7-N05. A proton starts at rest between plates 0.0400 m apart with a potential difference of 800 V. Use $e = 1.60 \times 10^{-19}$ C and proton mass $m_p = 1.67 \times 10^{-27}$ kg. Find its acceleration in m/s².

Work:

Final answer (with unit and sign): _____

Medium · B7-N06. Using the proton in the previous question, find its final speed when it reaches the far plate.

Work:

Final answer (with unit and sign): _____

B7 · practice

Fields between plates | Questions 7-8 of 8

Challenging · B7-N07. An electron enters the gap at 1.0×10^6 m/s toward the positive plate. The plates are 0.020 m apart with 3.0×10^3 V across them. Find its speed at the positive plate.

Work:

Final answer (with unit and sign): _____

Challenging · B7-N08. A graph of E against $1/\Delta d$ for a fixed battery is a straight line through the origin with slope 150 V. What does the slope represent, and what happens to E if the gap is doubled?

Work:

Final answer (with unit and sign): _____

B8 · Energy conservation and 2-D motion of charges

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

Use energy conservation, then split a sideways-entering charge into constant-speed and accelerated motion.

Name: _____ Date: _____

Slide 1 of 7 · Energy conservation for a charge in a field

Ep means electric potential energy and Ek means kinetic energy, as in B6. “At A” and “at B” name the two points. Only the electric force does work, so total energy _____: Ep(A) + Ek(A) = _____.

If the charge starts _____, Ek(A) = 0, so Ek(B) = _____. The potential energy lost becomes _____.

Then ½mv² = Ek, so v = _____. Use the object’s own _____ (the ball’s, not an electron’s).

The charge q is not needed when the energies are given. To compare speeds at two points, compare the _____: more kinetic energy means more speed for the same mass.

Example. A charged pith ball ($m = 2.00 \times 10^{-4}$ kg, $q = 1.5 \times 10^{-8}$ C) is held at A in a uniform field with 4.0×10^{-7} J of electric potential energy, then released. At B it has 2.5×10^{-8} J of electric potential energy. Find its speed at B.

Work:

Answer: _____

Try it. The same pith ball is released from rest at A, which has 4.0×10^{-7} J of electric potential energy. It reaches a point C where its electric potential energy is 1.0×10^{-7} J. Find its kinetic energy at C and say whether its speed there is greater or less than at B (where Ek = 3.75×10^{-7} J).

Work:

Answer: _____

Slide 2 of 7 · A charge entering a uniform field sideways

A charge entering a field sideways is like a ball rolling off a table: it keeps moving forward while a _____ pulls it down. Here the force is _____, and gravity is too small to matter. The horizontal speed v_x is the speed _____.

The electric force is at _____ to the plates and points toward the plate of the opposite sign (an electron toward the _____ plate). Motion does not need a force in its own direction.

The two directions do not _____ each other. Horizontal: net force _____, acceleration zero, constant velocity v_x, _____ motion. Vertical: constant force, constant acceleration a = _____, speed grows from zero, _____ motion.

Together these make a _____. In explanations say “net force zero” or “constant force” in each direction.

Example. An electron enters the uniform field between parallel plates moving horizontally with speed v_x. Gravity is too small to matter. The top plate is negative and the bottom plate is positive. Complete the table for horizontal and vertical motion (net force, acceleration, velocity, motion type), then name the shape of the path.

Work:

Answer: _____

Try it. A proton enters the same field at the same horizontal speed as the electron, beside the top plate (negative top, positive bottom). Compare the proton’s path with the electron’s path in direction and in how sharply it bends.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 7 · From acceleration back to voltage

To go from motion back to voltage, work the chain backward from what you want, then forward with numbers. The electric force is the only force, so F = _____.

Then E = _____, where q is the charge that feels the force (use the electron's size, 1.60×10^{-19} C; the direction is found separately), and then ΔV = _____ (multiply both sides of E = ΔV/Δd by Δd). Each formula has three quantities, so each step is one _____, with units.

Write the chain of formulas _____, before any numbers: a → F → E → ΔV. Use the electron's mass and charge from the data sheet.

Never use ΔV = ΔEp/q here: the _____ is not given.

Example. An electron ($m = 9.11 \times 10^{-31}$ kg, $q = 1.60 \times 10^{-19}$ C) between parallel plates has an acceleration of 3.00×10^{15} m/s². The plates are 0.0360 m apart. Find the potential difference between the plates.

Work:

Answer: _____

Try it. An electron ($m = 9.11 \times 10^{-31}$ kg, $q = 1.60 \times 10^{-19}$ C) has an acceleration of 2.50×10^{15} m/s² between plates 0.0480 m apart. Find the potential difference between the plates.

Work:

Answer: _____

Slide 4 of 7 · The full two-direction problem

L is the _____ and Δd is the _____. Time is the _____ between the two directions. Horizontal motion is uniform: t = _____.

Vertically $\Delta d = v_i t + \frac{1}{2}at^2$, and the vertical starting speed v_i is _____, so Δd = _____, which gives a = _____. Then run the chain: F = _____, E = _____, ΔV = _____.

“Just reaches the far end of the other plate” means the particle starts beside one plate and covers the full gap Δd (the vertical distance) in the time t. This is the greatest voltage that lets the electron escape: a bigger voltage gives a bigger acceleration, and the electron would hit the plate _____. Set up two columns, horizontal and vertical, and fill in what you know in each.

For the final speed, the vertical speed is v_y = _____ (from $v^2 = v_i^2 + 2ad$ with v_i = 0, and d the vertical distance); combine it with v_x as two sides of a right triangle: v = _____, angle θ = $\tan^{-1}$(_____), measured from the _____. Name the principles in order: uniform motion, then uniform acceleration.

Example. An electron enters horizontally at $v_x = 4.00 \times 10^6$ m/s beside one plate. The plates are L = 0.100 m long and Δd = 0.0400 m apart. It just reaches the far end of the other plate. Find the potential difference between the plates. ($m = 9.11 \times 10^{-31}$ kg, $q = 1.60 \times 10^{-19}$ C)

Work:

Answer: _____

Try it. An electron enters horizontally at 3.00×10^6 m/s beside one plate. The plates are 0.0800 m long and 0.0300 m apart, and it just reaches the far end of the other plate. Find the potential difference between the plates, and name the two physics principles you used, in order.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 5 of 7 · Method: how to solve a two-direction problem

Step 1, _____: make an x column (along the plates, _____) and a y column (across the plates, _____).

Step 2, _____: write what you know in each column. A sideways entry means the across speed at the start is _____.

Step 3, _____: time is the _____ between the two columns. Get it from the column with enough numbers: t = _____.

Step 4, _____: across the plates, Δd = _____, F = _____, E = _____ and ΔV = _____. Use the chain forwards or backwards.

Step 5, _____: v_y = _____. Then v = _____ and the angle = _____ from the horizontal.

Check: v_x never changes and v_y grows with time, so the final speed must be _____.

Example. An electron enters horizontally at $v_x = 4.00 \times 10^{6}$ m/s beside one plate. The plates are L = 0.100 m long and Δd = 0.0400 m apart, and it just reaches the far end of the other plate. Use the five steps to find the potential difference between the plates, then the final speed and the angle. ($m = 9.11 \times 10^{-31}$ kg, $q = 1.60 \times 10^{-19}$ C)

Work:

Answer: _____

Try it. NEW, for teacher review. An electron enters horizontally at 2.50×10^{6} m/s beside one plate. The plates are 0.0600 m long and 0.0150 m apart, and it just reaches the far end of the other plate. Use the five steps to find the potential difference between the plates and the final speed.

Work:

Answer: _____

Slide 6 of 7 · Where does the particle land?

A long numerical response is worth doing in order, with each result _____: field, force, acceleration, time, distance.

Field from the voltage and the gap: E = _____. Acceleration with the particle's own charge and mass: a = _____.

Vertical motion starts at zero vertical speed and covers the gap: Δd = _____, so t = _____. Horizontal motion is constant speed, so the horizontal distance is x = _____.

Check the units at the end, then record the answer as _____ with its unit and three digits.

Example. An alpha particle ($q = 3.20 \times 10^{-19}$ C, $m = 6.65 \times 10^{-27}$ kg) enters horizontally at 2.00×10^{5} m/s beside the top plate of a pair of plates 0.0260 m apart with 600 V across them. The top plate is positive and the bottom plate is negative, so the alpha particle is pushed toward the bottom plate and lands on it. Find the horizontal distance it travels. Record the answer as $a.bc \times 10^{n}$ m.

Work:

Answer: _____

Try it. An electron ($q = 1.60 \times 10^{-19}$ C, $m = 9.11 \times 10^{-31}$ kg) enters horizontally at 5.00×10^{6} m/s beside the top plate of a pair of plates 0.0200 m apart with 100 V across them. The top plate is negative and the bottom plate is positive, so the electron is pulled toward the bottom plate and lands on it. Find the horizontal distance it travels.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 7 of 7 · Still charges: the oil-drop experiment

A drop that hangs still has _____. The electric force _____ equals the weight _____: qE = _____. So q = _____. Find the field first: E = _____.

Count the extra electrons with n = _____, where e = _____. Electrons are counted, so n is a _____. Use g = _____.

The field points from the positive plate to the negative plate. A drop pushed _____ the field is negative. A negative drop has _____ electrons.

Millikan found that every measured charge was a whole-number multiple of _____: q = _____. A value that gives a _____ when divided by e cannot be right. Charge comes in _____.

Example. An oil drop of mass 1.96×10^{-15} kg hangs still between plates 0.0100 m apart with 400 V across them. The top plate is positive. Find the charge on the drop and the number of extra electrons. ($g = 9.81$ m/s², $e = 1.60 \times 10^{-19}$ C)

Work:

Answer: _____

Try it. NEW, for teacher review. A drop of mass 3.26×10^{-15} kg hangs still between plates 0.0200 m apart with 500 V across them. The top plate is positive. Find the charge on the drop and the number of extra electrons. ($g = 9.81$ m/s², $e = 1.60 \times 10^{-19}$ C)

Work:

Answer: _____

B8 · practice

Energy conservation and 2-D motion of charges | Questions 1-2 of 7

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 · B8-N01. A charged ball ($m = 3.00 \times 10^{-4}$ kg) is released from rest where its electric potential energy is 5.0×10^{-6} J. At another point its electric potential energy is 8.0×10^{-7} J. Find its speed there.

Work:

Final answer (with unit and sign): _____

Easy · B8-N02. A proton enters a uniform field between horizontal plates moving parallel to the plates. Which statement describes its motion?

A. Constant velocity parallel to the plates and constant acceleration across them
B. Constant acceleration in both directions
C. Constant velocity in both directions
D. Velocity changes parallel to the plates only

Work:

Final answer (with unit and sign): _____

B8 · practice

Energy conservation and 2-D motion of charges | Questions 3-4 of 7

Easy · B8-N03. Name the shape of the path of a charged particle that enters a uniform electric field at right angles to the field. Explain with one sentence about each direction.

Work:

Final answer (with unit and sign): _____

Medium · B8-N04. An electron has an acceleration of 4.00×10^{15} m/s² between plates 0.0250 m apart. Find the potential difference between the plates.

Work:

Final answer (with unit and sign): _____

B8 · practice

Energy conservation and 2-D motion of charges | Questions 5-6 of 7

Medium · B8-N05. An electron enters horizontally at 5.00×10^6 m/s beside one plate. The plates are 0.120 m long. How long does the electron take to cross the plates?

Work:

Final answer (with unit and sign): _____

Challenging · B8-N06. Use the electron from the previous question. It just reaches the far end of the other plate, so it moves 0.0500 m across the gap during that time. Find the potential difference between the plates.

Work:

Final answer (with unit and sign): _____

B8 · practice

Energy conservation and 2-D motion of charges | Questions 7-7 of 7

Challenging · B8-N07. In the previous two questions, name the principles you used in order. Give one principle that also describes the event but you did not need.

Work:

Final answer (with unit and sign): _____

B9 · Magnets and magnetic fields

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

Describe poles, magnetic materials, the field around a magnet, the Earth as a magnet, and domains.

Name: _____ Date: _____

Slide 1 of 5 · Poles and magnetic materials

Every magnet has two poles: _____ and _____. Opposite poles _____. Like poles _____.

Cut a magnet in half: each half still has _____. A single pole, a _____, has never been found.

An iron nail is magnetic, but it is not a magnet. It has _____. It is attracted to _____ end of a magnet and is never repelled.

Strongly magnetic: _____, _____ and _____. Steel is mostly iron, so it is _____ too.

On the diploma: _____ proves a magnet. _____ does not.

Example. Bars X and Y are each brought close to both ends of a bar magnet, using the same end of each bar at both ends of the magnet. X is attracted to the north end and also attracted to the south end. Y is attracted to the north end and repelled by the south end. Which bar is a magnet, which is only magnetic, and which pole of Y is near the south end of the bar magnet?

Work:

Answer: _____

Try it. A bar magnet is cut in half. (a) Describe the poles of each half. (b) An iron nail is attracted to the north end of a bar magnet. Is it attracted, repelled or not affected at the south end, and why?

Work:

Answer: _____

Slide 2 of 5 · Magnetic fields and the test compass

Every field needs a test object. Magnetism uses a small _____, a tiny magnet on a pivot.

The magnetic field is a _____: it has a size and a direction. Its symbol is _____. Its unit is the _____.

Direction: the way the _____ pole of a compass points there. The field points the way the force acts on a north pole.

Outside a magnet, lines leave _____ and enter _____. Lines are closest near the poles, where the field is _____.

At any point the field touches the line (it is _____) and follows the _____.

Between two close opposite poles the lines are straight and parallel. The field is _____: the same size and direction everywhere.

Example. A bar magnet has its north pole on the right and its south pole on the left. Compasses A and B are above and below the middle of the magnet, C is just past the north end and D is just past the south end, both on the line through the magnet. For each of A, B, C and D, give the direction its north pole points: left, right, up or down.

Work:

Answer: _____

Try it. Two bar magnets face each other with a small gap. The right end of the left magnet is a north pole and the left end of the right magnet is a south pole. In the gap, which way does the field point, what kind of field is it, and which way does a compass's north pole point?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 5 · Method: how to draw the field lines of a bar magnet

Step 1: mark the _____. Label the north end and the south end.

Step 2: draw the lines out of _____ and into _____. Lines never _____.

Step 3: space the lines by _____. Crowd them near the poles. Parallel, evenly spaced lines mean a _____ field.

Step 4: add an _____ to every line, from N to S outside the magnet. A compass's north pole lines up that way.

Check: no line crosses another or starts in empty space.

Example. A bar magnet has its north pole on the right and its south pole on the left. Compasses A and B are above and below the middle of the magnet, C is just past the north end and D is just past the south end, both on the line through the magnet. Use the four steps to draw the field lines and say which way the north pole of each compass points.

Work:

Answer: _____

Try it. NEW, for teacher review. A bar magnet has its north pole on the left and its south pole on the right. Use the four steps to draw four field lines with arrows. Which way does the north pole of a compass point (a) just above the middle of the magnet and (b) just past the north end, on the line through the magnet?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 4 of 5 · The Earth is a magnet

A north pole is attracted only to a _____ pole. An iron nail is attracted to _____ pole.

A compass needle’s north end points _____, toward the top of a map. So the pole it is attracted to is up there, and it is a magnetic _____ pole.

The Earth acts like a huge bar magnet. Its south pole is near geographic _____. Its north pole is near geographic _____.

A compass points along the _____, and its north end points to a _____ pole. It follows the _____ of the magnet inside, not the labels on a model. On the diploma, the Earth’s “north” magnetic pole is really a _____ pole.

Example. A globe with a bar magnet inside stands for the Earth, with geographic north at the top. A compass C at the equator points toward the top of the page. Is the end of the Earth’s magnet inside the top of the globe a north pole or a south pole, and in which direction does the Earth’s magnetic field point at C?

Work:

Answer: _____

Try it. A student hides a bar magnet in a plastic ball and uses it as a model Earth. A compass T beside the ball at its equator points up toward the model’s labelled north. The compass stays where it is in the room and only the ball turns. Which pole of the hidden magnet is at the top, and what would T do if the ball were turned upside down?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 5 of 5 · Domains: why magnets and nails behave this way

A magnetic material has tiny regions called _____. Each is a tiny magnet with a _____ and a _____ end.

Magnet: the domains line up the _____ and stay lined up. Plain iron nail: the domains point in _____ directions and their effects _____.

Bring a south pole near the nail: free domains (they can turn) swing their _____ ends toward it. The near end becomes a _____ pole, so the nail is _____. It is now a _____ magnet, only while a magnet is close. Plastic has _____ a magnet can line up.

Atoms always jiggle a little: _____. When the magnet leaves, jostling turns the domains back to _____ directions. Heat and _____ make the jostling stronger and knock the domains out of line. On the diploma: use the word _____ and link cause and effect with “because”.

Example. A magnet is pulled away from an iron nail that it had attracted. After a short time the nail no longer attracts a paper clip. Use domains to explain why the nail attracted the paper clip while the magnet was close, and why it stopped when the magnet was removed.

Work:

Answer: _____

Try it. A magnet is brought near a plastic comb and near an iron nail. Explain why the nail is attracted but the comb is not, and describe two ways to weaken a permanent magnet.

Work:

Answer: _____

B9 · practice

Magnets and magnetic fields | 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 · B9-N01. A steel nail is attracted to both ends of a bar magnet. A second object is attracted to one end of the bar magnet and repelled by the other. Which statement is correct?

A. The nail is a magnet.
B. The second object is a magnet.
C. Both objects are magnets.
D. Neither object is a magnet.

Work:

Final answer (with unit and sign): _____

Easy · B9-N02. List the three pure elements that are strongly magnetic. Give one way to destroy a permanent magnet.

Work:

Final answer (with unit and sign): _____

B9 · practice

Magnets and magnetic fields | Questions 3-4 of 8

Easy · B9-N03. A bar magnet has its north pole on the left. A compass is placed above the middle of the magnet. Which way does the compass’s north pole point?

A. Toward the left
B. Straight up
C. Straight down
D. Toward the right

Work:

Final answer (with unit and sign): _____

Medium · B9-N04. In Edmonton, the north pole of a compass points toward the Arctic. What kind of magnetic pole does the Earth have near the Arctic? Explain.

Work:

Final answer (with unit and sign): _____

B9 · practice

Magnets and magnetic fields | Questions 5-6 of 8

Medium · B9-N05. Describe the domains in (a) a bar magnet, (b) an iron nail away from any magnet, and (c) a plastic comb.

Work:

Final answer (with unit and sign): _____

Medium · B9-N06. A nail is stroked many times in one direction with the north pole of a magnet. What happens inside the nail?

A. The domains line up, so the nail becomes a weak magnet.
B. New domains are created in the nail.
C. The nail loses all of its domains.
D. The atoms in the nail change into iron.

Work:

Final answer (with unit and sign): _____

B9 · practice

Magnets and magnetic fields | Questions 7-8 of 8

Challenging · B9-N07. The north pole of a bar magnet is brought near the end of a long iron nail. A second nail hangs from the first nail. What explains this?

A. The first nail becomes charged by the magnet.
B. Gravity pulls the nails together.
C. The second nail has more domains.
D. The first nail’s domains are lined up by the magnet, so it attracts the second nail.

Work:

Final answer (with unit and sign): _____

Challenging · B9-N08. A bar magnet is cut in half. A student says one half is a north pole and the other half is a south pole. Correct the statement using domains.

Work:

Final answer (with unit and sign): _____

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): _____

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): _____

B11 · practice

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): _____

B11 · practice

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): _____

B12 · Charged particles on circular paths

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

Find the radius of a circular path, r = mv/(qB), including after acceleration through a voltage.

Name: _____ Date: _____

Slide 1 of 5 · Why the path is a circle

The magnetic force is at _____ to the velocity. No part of the force points along the motion, so it cannot change the _____. It only changes the _____.

The force always points to one _____, so the path is a _____. This is uniform _____ motion. Outside the field the path is _____.

The net force toward the centre is the _____ force. Here it is the _____ force. On the diploma: the _____ stays the same in a magnetic field.

To find which way a particle curves, use the right-hand rule at the first moment (reverse it for an _____). The path bends toward the _____.

Example. An electron moves up the page. A uniform magnetic field covers the whole page and points out of the page, toward you. Does the electron start to curve toward the left side or the right side of the page?

Work:

Answer: _____

Try it. An electron enters a region with an electric field between charged plates, and an identical electron enters a magnetic field at the same speed, both moving at right angles to the field. Compare the shape of the two paths, and say what happens to the speed in each.

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 5 · The radius of the circle: r = mv/(qB)

The magnetic force is the net force on the circle. Newton's second law: qvB = _____. Divide both sides by v: qB = _____. Solve for r: r = _____.

B is the field strength, in _____ (T). Put in the _____ of q. The velocity is at _____ to B. This formula is _____ on the data sheet, so show where it comes from.

A bigger v or m makes a _____ circle. A bigger q or B makes a _____ circle.

Use SI units: _____, metres per second, _____ and tesla. On the diploma: explain a change in the radius using _____.

Example. A proton (mass 1.67×10^{-27} kg, charge 1.60×10^{-19} C) moves at 3.2×10^{5} m/s at right angles to a magnetic field of 0.150 T. What is the radius of its circular path?

Work:

Answer: _____

Try it. An electron (mass 9.11×10^{-31} kg, charge size 1.60×10^{-19} C) moves to the right at 6.0×10^{6} m/s at right angles to a field of 2.0×10^{-3} T that points out of the page. What is the radius of its path, and does it circle clockwise or counterclockwise on the page?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 3 of 5 · Accelerate first, then bend

Two stages: a voltage speeds the particle up, then a field bends it. Stage one: the charge gains energy _____ (B6), so qΔV = _____. This gives the _____. ΔV is the voltage, in volts. The particle starts from _____.

Stage two: r = _____, using the speed from stage one. Use the _____ of q.

Keep _____ digits in the speed. Use SI units and the _____ charge in both stages. On the diploma: _____ your two stages.

Example. An electron starts at rest and is accelerated through 150 V, then enters a magnetic field of 1.2×10^{-3} T at right angles to its velocity. The electron's mass is 9.11×10^{-31} kg and its charge size is 1.60×10^{-19} C. What is the radius of its path in the magnetic field?

Work:

Answer: _____

Try it. An alpha particle (mass 6.65×10^{-27} kg, charge 3.20×10^{-19} C) starts at rest and is accelerated through 800 V. It then enters a field of 0.0500 T at right angles. What is the radius of its path in the field?

Work:

Answer: _____

Slide 4 of 5 · Method: how to solve a circular-path problem

Step 1: _____ the problem. Is there an accelerator first? Mark the plates (energy) and the field (_____), and name the unknown.

Step 2: find the speed from the energy: $qΔV$ = _____, so v = _____, from rest. If the speed is given, _____ this step. Keep the full value.

Step 3: set the magnetic force equal to the _____ force: qvB = _____. Solve for the unknown (r, v, m or q) and use the _____ of q.

Step 4: calculate with units: kilograms, _____, coulombs and tesla. Put in the _____ speed from step 2.

Step 5: find which way it turns. Use the right-hand rule for the first force (reverse it for a _____ charge). The _____ is on that side. Check: a faster or heavier particle makes a _____ circle, and more charge or field makes a _____ one.

Example. An electron starts at rest and is accelerated through 150 V. It then moves to the right into a field of 1.2×10^{-3} T, into the page. Find the radius of its path and which way it turns. ($m = 9.11 \times 10^{-31}$ kg, $q = 1.60 \times 10^{-19}$ C)

Work:

Answer: _____

Try it. NEW, for teacher review. A proton starts at rest and is accelerated through 2.00×10^{3} V. It then moves to the right into a field of 0.0400 T, out of the page. Find the radius of its path and which way it turns. ($m = 1.67 \times 10^{-27}$ kg, $q = 1.60 \times 10^{-19}$ C)

Work:

Answer: _____

Slide 5 of 5 · Using the radius to find the charge

Run the formula backward. Start from qvB = _____ and solve for the unknown. For the charge, q = _____. For the field, B = _____.

Ask what multiplies the unknown. Do the _____ to both sides. Check: put the answer back into r = mv/(qB). Is the _____ the same?

Charge = n × e (B1). Here e = _____ and n is a whole number of electrons. So n = q ÷ _____. A negative charge means n _____ electrons.

The calculator will not give an exact whole number, so write n as a _____ number. On the diploma: write each rearranging step.

Example. A negatively charged particle of mass 9.6×10^{-27} kg moves at 3.0×10^{5} m/s on a circle of radius 0.0144 m in a field of 0.250 T. What is its charge, and how many extra electrons does it have? ($e = 1.60 \times 10^{-19}$ C)

Work:

Answer: _____

Try it. A proton (mass 1.67×10^{-27} kg, charge 1.60×10^{-19} C) moves at 2.4×10^{5} m/s on a circle of radius 0.025 m. What is the strength of the magnetic field?

Work:

Answer: _____

B12 · practice

Charged particles on circular paths | 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 · B12-N01. Why does a charged particle move in a circle when it enters a magnetic field at right angles to the field?

Work:

Final answer (with unit and sign): _____

Easy · B12-N02. An electron moves at 2.0×10^{6} m/s at right angles to a field of 0.0400 T. Find the radius of its path. 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): _____

B12 · practice

Charged particles on circular paths | Questions 3-4 of 8

Easy · B12-N03. A proton moves in a circle in a magnetic field. The field strength is doubled, with the same speed. What happens to the radius?

A. It doubles.
B. It is unchanged.
C. It becomes four times smaller.
D. It is halved.

Work:

Final answer (with unit and sign): _____

Medium · B12-N04. A proton moving at 1.5×10^{5} m/s enters a field of 0.0800 T at right angles. Find the radius of its circular path. Use the proton's mass $m_p = 1.67 \times 10^{-27}$ kg.

Work:

Final answer (with unit and sign): _____

B12 · practice

Charged particles on circular paths | Questions 5-6 of 8

Medium · B12-N05. A proton starts at rest and is accelerated through 250 V. It then enters a field of 0.250 T at right angles. Find the radius of its path.

Work:

Final answer (with unit and sign): _____

Medium · B12-N06. An electron and a proton enter the same field at right angles with the same speed. Which has the larger radius?

A. The proton, because it has the larger mass
B. The electron, because it is lighter
C. They have the same radius because the charges are equal in size
D. The electron, because it is negative

Work:

Final answer (with unit and sign): _____

B12 · practice

Charged particles on circular paths | Questions 7-8 of 8

Challenging · B12-N07. A particle of mass 6.68×10^{-27} kg moves at 2.0×10^{5} m/s at right angles to a field of 0.500 T. Its path has radius 8.35×10^{-3} m. Find the size of its charge.

Work:

Final answer (with unit and sign): _____

Challenging · B12-N08. Compare the path of a charged particle between two parallel charged plates with its path in a magnetic field at right angles to its velocity. Mention the force, the path and the speed.

Work:

Final answer (with unit and sign): _____

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): _____

B13 · practice

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): _____

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):

B14 · practice

The motor effect | 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 $mp = 1.67 \times 10^{-27}$ 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): _____

B14 · practice

The motor effect | Questions 3-4 of 8

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): _____

B14 · practice

The motor effect | Questions 5-6 of 8

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): _____

B14 · practice

The motor effect | Questions 7-8 of 8

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): _____

B15 · The generator effect and Lenz’s law

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

Explain how motion in a field separates charge, use ΔV = Blv, and apply Lenz’s law.

Name: _____ Date: _____

Slide 1 of 8 · A moving rod separates charge

The generator effect runs the motor effect backward: _____.
Pulling a rod through a field pulls its _____ through the field too. Each feels a force.

Right hand: fingers along the _____, thumb along the rod’s _____ (in B14 the thumb pointed along the current). The palm shows the force on a _____ charge.
_____ it for electrons.

The electrons gather at one end, so that end is _____. The other end is _____.

Reverse the velocity or the field, and the polarity _____.

Example. A horizontal metal rod is pulled straight down the page through a magnetic field that points into the page. Which end of the rod, left or right, becomes positive?

Work:

Answer: _____

Try it. A vertical rod is pulled to the right through a magnetic field that points out of the page. Which end, top or bottom, becomes positive, and how does this compare with the field into the page?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 2 of 8 · How large is the potential difference?

ΔV is the potential difference between the _____ of the rod. ΔV = _____. B is the field (T), l is the rod length (m), v is the speed (m/s).

Faster rod, longer rod or stronger field: a _____ ΔV. 1 T × 1 m × 1 m/s = _____. Example: (0.250 T)(0.40 m)(3.0 m/s) = _____.

The equation is _____ on the data sheet. Write the rearranged form, such as v = _____, before the numbers.

For ratio questions, _____ the change factors. Never add them.

Example. A rod of length 0.60 m moves at right angles to a magnetic field of 0.150 T and to its own length. The potential difference between its ends is 0.90 V. What is the speed of the rod? (ΔV = Blv)

Work:

Answer: _____

Try it. A rod moving through a field produces a potential difference ΔV. A second rod has twice the length, moves at half the speed, and is in a field three times as strong. What is its potential difference? A. ΔV/3 B. ΔV C. 3ΔV D. 6ΔV

Work:

Answer: _____

Slide 3 of 8 · Closing the circuit

The rod slides on two _____ (parallel metal bars) with a _____ (a part that uses electrical energy, like a lamp) joining the ends. The rod acts like a _____.

Conventional current leaves the _____ end, goes round the circuit and returns to the _____ end. Inside the rod it goes from negative to positive.

Find the ends first (right hand, then reverse). Then _____ the current: clockwise or counterclockwise.

Reverse the velocity or the field, and the current _____.

Example. A rod slides on two rails. A resistor joins the right-hand ends of the rails, and the magnetic field points into the page. When the rod is pulled to the right the top end is positive and the current is clockwise. Now the rod is pulled to the left. Does conventional current go clockwise or counterclockwise?

Work:

Answer: _____

Try it. Same rails and rod, but the field now points out of the page and the rod is pulled to the right. Does conventional current go clockwise or counterclockwise, and which end of the rod is positive?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 4 of 8 · A magnet and a coil

A coil can do it too. When a magnet and a coil move _____ to each other, the electrons in the coil feel a force. This is electromagnetic _____. Michael _____ discovered it in 1831.

Current flows only _____ they move. A magnet held still gives _____ current.

Reverse the motion or the pole, and the current _____.

Faster, a stronger magnet or more turns gives _____ current. Four times the turns gives about _____ the current.

Example. Pushing the south pole of a bar magnet into a coil at a steady speed deflects the meter needle to the right. Predict the needle for (a) pulling the same pole out at the same speed, (b) pushing the north pole in at the same speed, (c) pushing the south pole in twice as fast, and (d) holding the magnet still inside the coil.

Work:

Answer: _____

Try it. Pushing the south pole into a coil at a steady speed gives a deflection of 2 divisions to the right. Predict the needle if the same pole is pushed in at half the speed into a coil with four times as many turns.

Work:

Answer: _____

Slide 5 of 8 · Motors and generators

A motor and a generator are the same device used both ways. Motor: electricity in, _____ out. Generator: motion in, _____ out.

Name the energy change: motion to _____, or the reverse.

A generator joined to a lamp is _____ to turn. Its current is in a field, so it feels a force that _____ the turning.

With nothing connected there is no _____, so no force. The extra _____ you do goes into the lamp’s energy.

Example. A hand-cranked generator is easy to turn when its wires are not connected to anything, and noticeably harder when it is connected to a lamp that lights. Explain why it is harder when connected, and where the extra energy goes.

Work:

Answer: _____

Try it. A small toy motor is spun by hand with its two wires joined to a lamp, and the lamp lights. Is the device acting as a motor or a generator? Name the energy change.

Work:

Answer: _____

Slide 6 of 8 · Lenz’s law: the force opposes the motion

A moving magnet makes currents in a conductor. A current made by motion in a field, with no battery, is an _____ current. It feels a _____, and the force acts on the magnet.

Lenz’s law: the force from an induced current _____ the motion that caused it. A magnet falling feels a force _____.

Chain: motion → _____ → _____ → slower fall. No current means _____ force. A better conductor carries a _____ current.

The force always opposes the motion. It takes energy _____.

In air the magnet falls 0.30 m in _____. In the aluminium tube it takes _____.

Example. Three rods of the same size, one plastic, one aluminium and one copper, each have a ring magnet dropped over them from the same height. Copper conducts better than aluminium; plastic is an insulator. Order the rods from fastest fall to slowest and explain.

Work:

Answer: _____

Try it. A pendulum with a strong magnet at its end swings between two aluminium blocks and is moving to the right through its lowest point. What is the direction of the magnetic force on the magnet right now, what happens to the swing over time, and does this force’s direction change when it swings back to the left?

Work:

Answer: _____

Slide 7 of 8 · Lenz’s law for a coil: which way the current goes

An induced current turns a coil into a _____. By Lenz’s law, that magnet _____ the motion that caused the current.

Step 1: which way is the magnet _____? Step 2: which pole opposes that? A magnet moving closer must be _____, so the near end is the _____ pole. A magnet moving away must be _____, so the near end is the _____ pole.

Step 3: the field inside a coil points toward its _____ end. Grip a wire on the _____ of the coil with the right hand, thumb along the conventional current. The fingers inside the coil show the field.

Thumb up puts the field inside to the _____. Thumb down puts it to the _____. Reverse the motion and the pole and the current both _____.

Example. A coil is joined to a meter in a closed circuit. The north pole of a bar magnet is pushed toward the right end of the coil. (a) Which pole does the right end of the coil become? (b) Which way does the conventional current go in the wires on the front of the coil, up or down? (c) The magnet is then pulled back out. What happens to the pole and to the current?

Work:

Answer: _____

Try it. NEW, for teacher review: The south pole of a bar magnet is pushed toward the left end of a coil in a closed circuit. Which pole does the left end of the coil become, and which way does the conventional current go in the wires on the front of the coil?

Work:

Answer: _____

Sketch (draw and label the diagram):

Slide 8 of 8 · Method: how to find an induced voltage and its direction

Step 1: list v, B and l with units: _____, _____, _____. All at _____.

Step 2: ΔV = _____. Keep every digit. The unit is _____.

Step 3: right hand, then reverse for electrons. They gather at the _____ end. The other end is _____.

Step 4: current leaves the _____ end. Step 5: _____: the force on the rod _____ v. Reverse v or B, and every direction _____.

Example. A 0.40 m rod is pulled to the right at 3.0 m/s through a field of 0.250 T that points into the page. The rod is part of a closed circuit with a resistor on the right. Find the potential difference, the positive end, the direction of the current and the direction of the force on the rod.

Work:

Answer: _____

Try it. A 0.60 m rod is pulled to the left at 2.0 m/s through a field of 0.500 T that points into the page. The rod is part of a closed circuit with a resistor on the right. Find the potential difference, the positive end, the direction of the current and the direction of the force on the rod. Write each step number beside your work.

Work:

Answer: _____

B15 · practice

The generator effect and Lenz’s law | Questions 1-2 of 8

Constants from the Alberta Physics 30 data sheets: $k = 8.99 \times 10^{9}\ N \cdot m^2/C^2$, $e = 1.60 \times 10^{-19}\ C$, electron mass $m_e = 9.11 \times 10^{-31}\ kg$, proton mass $mp = 1.67 \times 10^{-27}\ kg$, $g = 9.81\ m/s^2$.

Easy · B15-N01. What is the difference between the motor effect and the generator effect?

Work:

Final answer (with unit and sign): _____

Easy · B15-N02. A vertical rod is pulled to the right through a magnetic field that points into the page. Which end of the rod becomes positive?

A. The top end
B. The bottom end
C. The left end
D. Neither end

Work:

Final answer (with unit and sign): _____

B15 · practice

The generator effect and Lenz’s law | Questions 3-4 of 8

Easy · B15-N03. A 0.80 m rod moves at 5.0 m/s at right angles to a field of 0.040 T and to its own length. Find the potential difference between its ends.

Work:

Final answer (with unit and sign): _____

Medium · B15-N04. A 0.50 m rod moves at 12 m/s at right angles to a 0.25 T field. What potential difference appears between its ends?

Work:

Final answer (with unit and sign): _____

B15 · practice

The generator effect and Lenz’s law | Questions 5-6 of 8

Medium · B15-N05. A magnet is pushed into a coil and the meter shows a current. List three changes that would make the current larger.

Work:

Final answer (with unit and sign): _____

Medium · B15-N06. Why is a generator harder to turn when it is connected to a lamp?

A. The induced current gives a magnetic force that opposes the motion.
B. The lamp makes the magnet heavier.
C. The lamp removes the magnetic field.
D. The coil stops being a conductor.

Work:

Final answer (with unit and sign): _____

B15 · practice

The generator effect and Lenz’s law | Questions 7-8 of 8

Challenging · B15-N07. A magnet is dropped from rest through 0.30 m in air. Find the free-fall time. Then compare it with 2–3 s for the same magnet inside a vertical aluminium tube. Use g = 9.81 m/s². Give the free-fall time in seconds.

Work:

Final answer (with unit and sign): _____

Challenging · B15-N08. A magnet is dropped through a plastic tube, an aluminium tube and a copper tube of the same size. Rank the fall times from shortest to longest and explain.

Work:

Final answer (with unit and sign): _____