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: _____

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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): _____

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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): _____

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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): _____

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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): _____