B9 · Magnets and magnetic fields

Completed notes

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

Slide 1 of 5 · Poles and magnetic materials

Every magnet has two poles: **north** and **south**. Opposite poles **attract**. Like poles **repel**.

Cut a magnet in half: each half still has **two poles**. A single pole, a **monopole**, has never been found.

An iron nail is magnetic, but it is not a magnet. It has **no poles**. It is attracted to **either** end of a magnet and is never repelled.

Strongly magnetic: **iron**, **nickel** and **cobalt**. Steel is mostly iron, so it is **magnetic** too.

On the diploma: **repelled** proves a magnet. **Attracted** 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?

1. X is attracted to both ends. That happens to a magnetic material without poles, such as iron, so X is magnetic but not a magnet.

2. Y is repelled by the south end. Only like poles repel, so Y is a magnet.

3. The end of Y near the south end of the bar magnet is a south pole (like poles repel).

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?

1. (a) Each half has both a north pole and a south pole. Cutting never makes a lone pole.

2. (b) The nail is attracted at the south end too. The nail has no poles, so it is attracted to either end and is never repelled.

Slide 2 of 5 · Magnetic fields and the test compass

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

The magnetic field is a **vector**: it has a size and a direction. Its symbol is **B**. Its unit is the **tesla (T)**.

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

Outside a magnet, lines leave **north** and enter **south**. Lines are closest near the poles, where the field is **strongest**.

At any point the field touches the line (it is **tangent**) and follows the **arrow**.

Between two close opposite poles the lines are straight and parallel. The field is **uniform**: 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.

1. A and B (above and below the middle): left. The compass’s north pole is pulled toward the south pole on the left and pushed away from the north pole on the right.

2. C (just past the north end): right, away from the north pole.

3. D (just past the south end): right, toward the south pole.

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?

1. Field lines leave the north pole and enter the south pole, so the field in the gap points from the left magnet to the right magnet: right.

2. The lines are straight, parallel and evenly spaced, so the field is uniform.

3. A compass lines up along the field, so its north pole points right.

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

Step 1: mark the **poles**. Label the north end and the south end.

Step 2: draw the lines out of **N** and into **S**. Lines never **cross**.

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

Step 4: add an **arrow** 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.

1. Step 1: the right end is north and the left end is south.

2. Step 2: outside the magnet, every line leaves the right end, curves over or under the magnet and enters the left end.

3. Step 3: draw the lines close together near the two ends and far apart away from the magnet.

4. Step 4: put an arrow on each line from the right end around to the left end. A and B: left. C and D: right.

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?

1. Step 1: the left end is north and the right end is south.

2. Step 2: the lines leave the left end, curve over or under the magnet and enter the right end.

3. Step 3: crowd the lines near the two ends. Step 4: arrows run from the left end around to the right end.

4. (a) Just above the middle, the line runs left to right, so the compass points right.

5. (b) Just past the north end, the lines leave the magnet going left, away from north, so the compass points left.

Slide 4 of 5 · The Earth is a magnet

A north pole is attracted only to a **south** pole. An iron nail is attracted to **either** pole.

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

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

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

1. The compass’s north pole points toward the top of the globe, and a compass’s north pole is attracted to a south pole, so the Earth’s magnet has a south pole in the top end.

2. The magnetic field at C points the same way the compass’s north end points: toward the top of the page, geographic north.

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?

1. The needle’s north end points to the top, so the top end of the hidden magnet is a south pole.

2. If the ball is flipped, the south pole is now at the bottom and the needle’s north end points down.

3. The compass follows the magnet’s poles, not the labels on the ball.

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

A magnetic material has tiny regions called **domains**. Each is a tiny magnet with a **north** and a **south** end.

Magnet: the domains line up the **same way** and stay lined up. Plain iron nail: the domains point in **random** directions and their effects **cancel**.

Bring a south pole near the nail: free domains (they can turn) swing their **north** ends toward it. The near end becomes a **north** pole, so the nail is **attracted**. It is now a **temporary** magnet, only while a magnet is close. Plastic has **no domains** a magnet can line up.

Atoms always jiggle a little: **jostling**. When the magnet leaves, jostling turns the domains back to **random** directions. Heat and **hard knocks** make the jostling stronger and knock the domains out of line. On the diploma: use the word **domains** 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.

1. While the magnet was close, its field turned the free domains in the nail so they lined up. The nail then had a north end and a south end and could attract the paper clip.

2. After the magnet was removed, the jostling of the atoms turned the domains back to random directions. The effects cancelled, so the nail had no poles and no longer attracted the clip.

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.

1. The nail’s domains are free to turn toward the magnet, so it becomes a temporary magnet and is attracted.

2. Plastic has no domains that a magnet can line up, so the comb gets no poles and is not attracted.

3. Two ways to weaken a permanent magnet: heat it, or drop or hit it. Both jostle the domains out of line.

B9 · Worked 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.

1. Givens: nail attracted to both ends; object 2 attracted at one end and repelled at the other. Question: which is a magnet.

2. Repulsion only happens between two magnetic poles of the same kind, so object 2 is a magnet. A nail is attracted to either pole because it becomes a temporary magnet.

3. Answer: B. The second object is a magnet.

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

1. Givens: none. Question: three elements; one way to destroy a magnet.

2. Iron, cobalt and nickel.

3. Heating it strongly, hitting it repeatedly or placing it in a changing opposing field scrambles the domains.

B9 · Worked 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

1. Givens: N on the left, S on the right; compass above the centre. Question: direction of the compass north.

2. Outside the magnet the field runs from north to south, so above the middle it points right. The compass north follows the field.

3. Answer: D. Toward the right

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.

1. Givens: a compass north pole points toward the Arctic. Question: the kind of pole near the Arctic.

2. Unlike poles attract, so the compass’s north pole is attracted to a south pole.

3. The Earth has a magnetic south pole near the geographic Arctic.

B9 · Worked 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.

1. Givens: three objects. Question: the domains in each.

2. (a) A bar magnet has most domains lined up in the same direction.

3. (b) A nail has domains that point in random directions, so their fields cancel.

4. (c) Plastic is not a magnetic material and has no domains that line up.

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.

1. Givens: a nail stroked with a magnet. Question: the change inside.

2. Stroking pulls many randomly pointing domains into the same direction. The nail has the same atoms, but it now has a net field.

3. Answer: A. The domains line up, so the nail becomes a weak magnet.

B9 · Worked 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.

1. Givens: a magnet near nail 1; nail 2 attracted to nail 1. Question: why nail 2 hangs.

2. The magnet’s field lines up the domains in nail 1, so nail 1 becomes a temporary magnet, lines up the domains in nail 2, and attracts it.

3. Answer: D. The first nail’s domains are lined up by the magnet, so it attracts the second nail.

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.

1. Givens: a bar magnet cut in half. Question: correct the claim.

2. Each piece has lined-up domains, so each piece becomes a smaller magnet with its own north and south poles.

3. Poles cannot be isolated, so cutting never separates north from south.