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EB Education Revision Guide

How to work with Magnetism and Electromagnetism

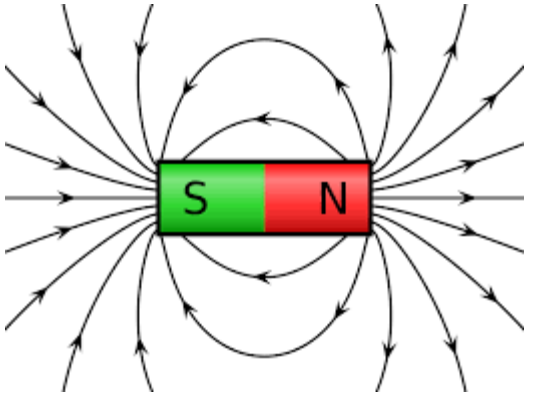
...helping everybody achieve Even Better

Magnets

Magnetic fields

- Magnets have two poles, north and south.
- They produce a **magnetic field**, this is a region where other magnets or magnetic materials will experience a force.
- Magnetic fields can be shown in diagrams by drawing magnetic field lines. These lines go from north to south. The closer together they are, the stronger the magnetic field.
- The magnetic field is strongest at the poles, the further away from a magnet you get, the weaker the field is.

Diagram



You can use plotting compasses or iron filings to see magnetic field lines. Make sure you know how!

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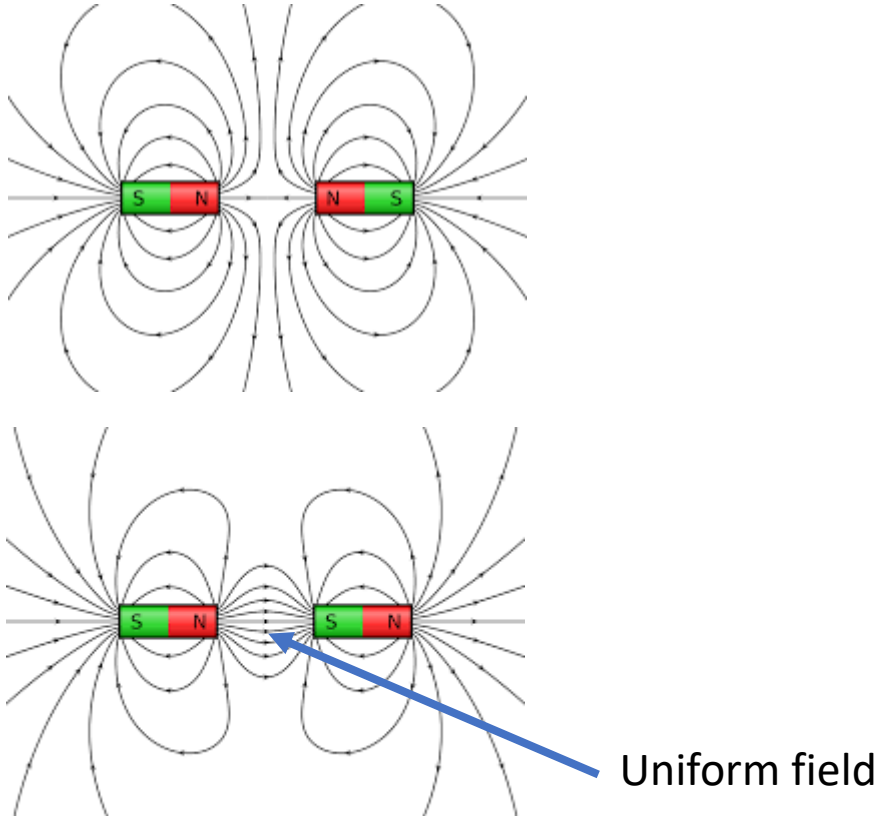
Magnetic forces

Magnetic fields

- There is a magnetic force between two magnets. Two like poles (south-south or north-north) repel each other. Two unlike poles (north-south) attract each other.
- When the north and south poles of two magnets are placed near each other, a uniform field is created between the poles – this means the magnetic field is the same strength everywhere between the poles.

Diagram



Permanent and Induced Magnets

Magnetic fields

- Iron, nickel and cobalt are magnetic elements, Steel is magnetic because it is an alloy of iron. If you place a magnetic material near a magnet it will be attracted to the magnet.
- Permanent magnets (like bar magnets) produce their own magnetic field all the time.
- Induced magnets only produce a magnetic field when they are in another magnetic field. When you place any magnetic material into a magnetic field it becomes an induced magnet, with its own poles and magnetic field.
- When you take the magnetic field away, the magnetic material will stop producing a magnetic field.
- The speed at which they lose their magnetism depends on what they are made of. Magnetically hard materials like steel lose magnetism slowly, magnetically soft materials like pure iron lose magnetism quickly.

Uses

Magnetic materials have many uses – especially since electromagnets have been invented.

a) Fridge doors (permanent magnetic strips on the door keep it closed)

b) Cranes (use induced electromagnets to move magnetic materials)

c) MRI machines (create images without using ionising radiation)

d) Speakers and microphones

e) Maglev trains (use magnetic repulsion to make trains float above the track and move them along faster, reducing friction)

f) Transformers (use induced magnetism to induce voltage)

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Electromagnetism

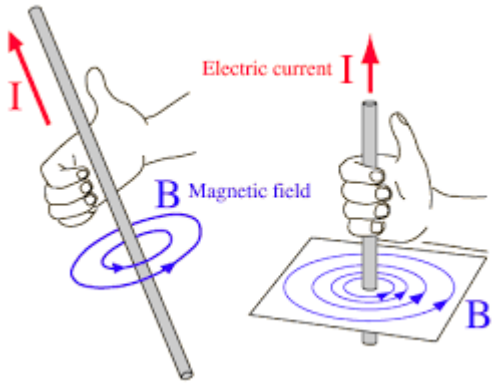
Creating a Magnetic Field

A current passing through a wire can produce a magnetic field in a non-magnetic metal.

If this wire is placed in an external magnetic field it can result in the **MOTOR EFFECT**.

- A magnetic field is created around a wire when current flows through it.
- This magnetic field is made of concentric circles which are perpendicular to the wire, with the wire in the centre.
- When the direction of the current changes, the direction of the magnetic field changes.
- The larger the current, the stronger the field.

The Right-Hand Thumb Rule



For single wires - Point your thumb in the direction of the current. The direction of your fingers shows the direction of the magnetic field.

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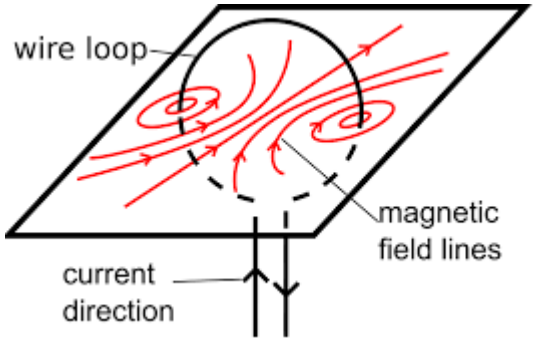
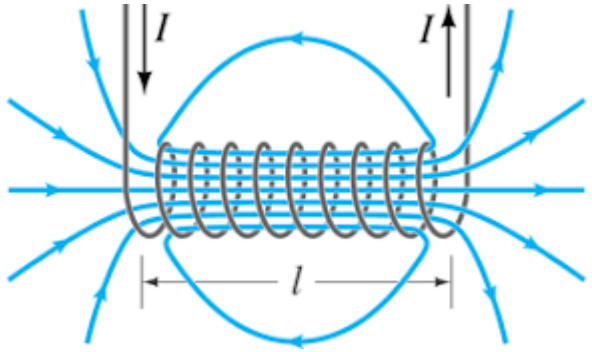
Electromagnetism

Magnetic field around a looped wire

- When a wire is bent into a loop, the concentric field lines combine to produce a magnetic field that is uniform at the centre but gets weaker the further away from the wire.



Magnetic field around a solenoid



- The right-hand grip rule can be used to find the direction for the magnetic field. For solenoids - the fingers point in the direction of the current around the loop and the thumb points to the north pole.

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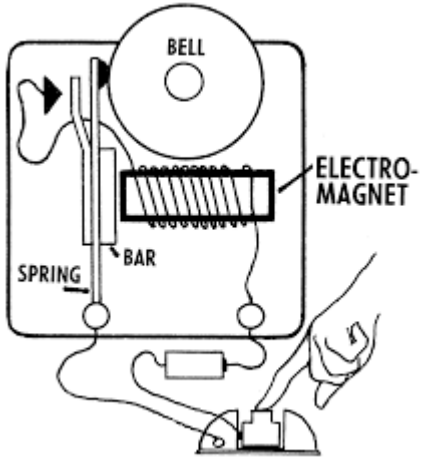
Electromagnetism

The benefits of Electromagnets

- Electromagnets induce strong magnetic fields when electric current flows through a conductor.
- Permanent magnets are always magnetic.
- Electromagnets can be turned on and off when needed whereas permanent magnets can't, this makes electromagnetism very useful.

Example of use of Electromagnets

Door bells



Scrap yards

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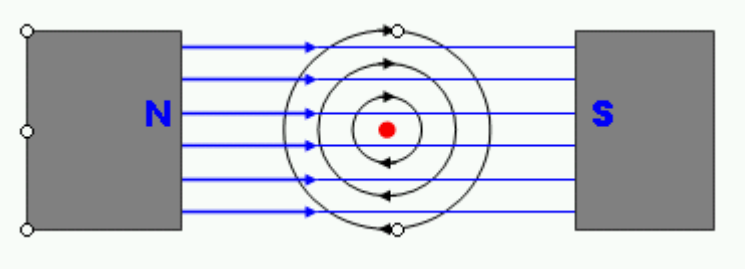
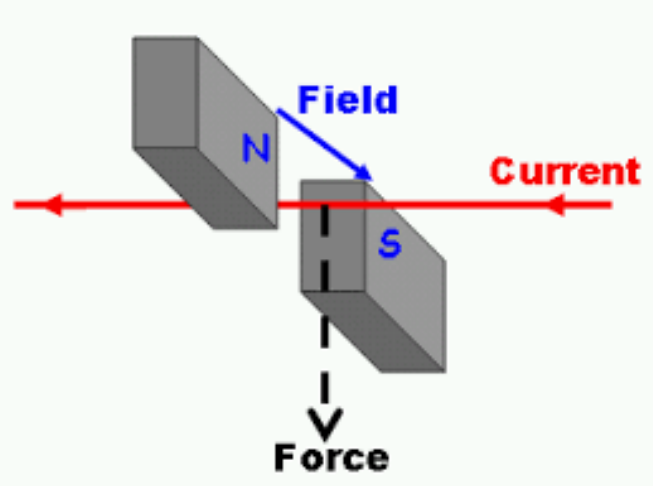
The Motor Effect

The Motor Effect

- When the current carrying wire is placed between magnetic poles, the two magnetic fields will interact. This results in a force on the wire, known as the motor effect.
- Full force is experienced when the wire is at right angles to the magnetic field (if the wire runs along the magnetic field there will be no force).
- The force always acts in the same direction relative to the magnetic field and the direction of the current. This means changing the direction of the magnetic field or current will change the direction of the force.

Diagram





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The Motor Effect

The Motor Effect

The size of the force depends on:

- The magnetic flux density (how many field lines there are – this shows the strength of the magnetic field)
- The size of the current
- The length of the conductor in the magnetic field.

$$F = B \times I \times \ell$$

- F: Force (N)
- B: Magnetic Flux Density (Tesla -- T)
- I: Current (A)
- ℓ: Length (m)

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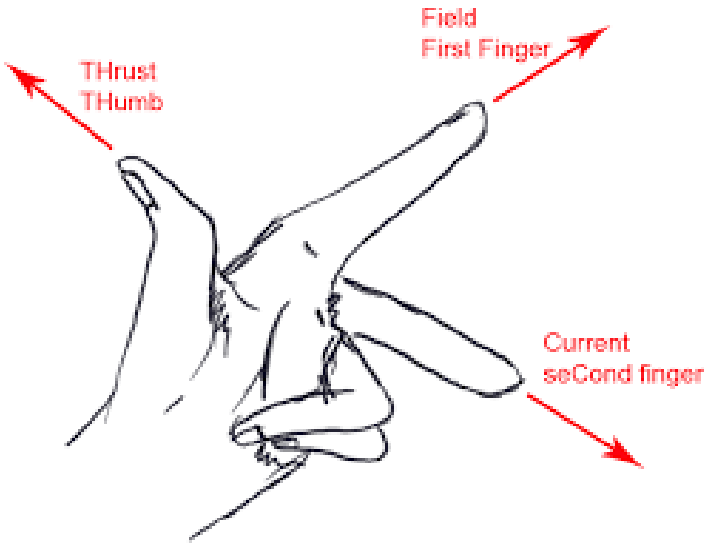
The Motor Effect

The Motor Effect

The direction of the force can be found using Fleming's left-hand rule:

- Point your **F**irst finger in the direction of the magnetic **F**ield.
- Point your se**C**ond finger in the direction of the **C**urrent (positive to negative)
- Your thu**M**b will point in the direction of the force (**M**otion)



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Your turn:

1. Ben investigate the magnetic properties of three rods.

- A soft iron rod
- A steel rod
- A wooden rod.

He places each rod in a solenoid that is connected to a direct current power supply. The power supply is switched on for a short time.

Ben tests the magnetic strength of each rod by counting how many paper clips it can pick up.

His results are shown below.

	number of paper clips picked up			
rod	Before rod place in solenoid	When there is current in solenoid	1 minute after current switched off	10 minutes after current switched off
A	0	0	0	0
B	0	6	1	0
C	0	8	7	7

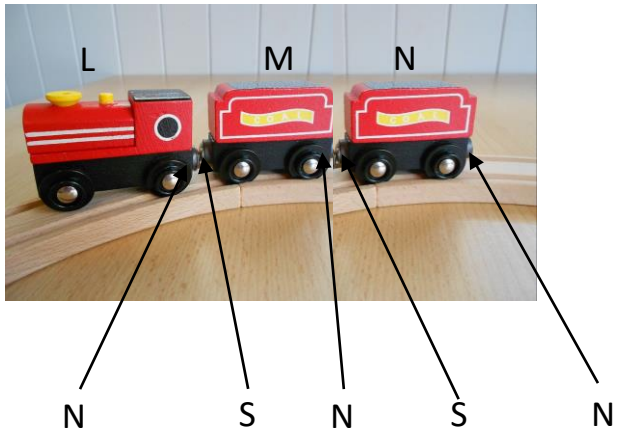
Complete the table below to show which material each rod is made from, and explain why. Use information from the results in your answer.

Rod	Material	Reason
A		It is not magnetic because it does not pick up any paper clips, whether there is a current or not.
B		
C		

Your turn:

2. The wooden trucks on a toy railway set have permanent magnets that hold the trucks together.

The magnets are arranged so that a N-pole touches a S-pole between each truck as shown below.



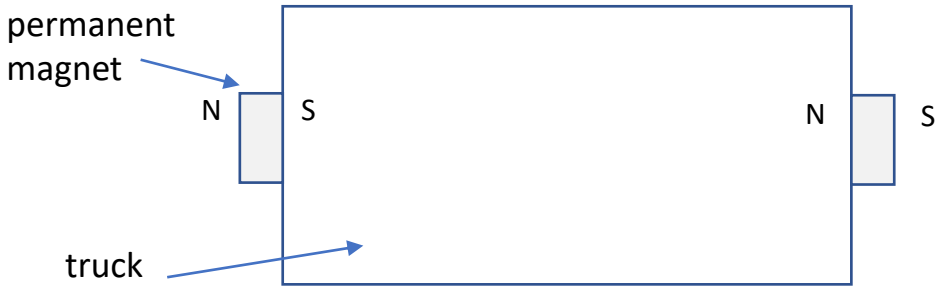
a) Truck M is removed from the train, turned through 180° and is then replaced between truck L and truck N.

How does this affect the train?

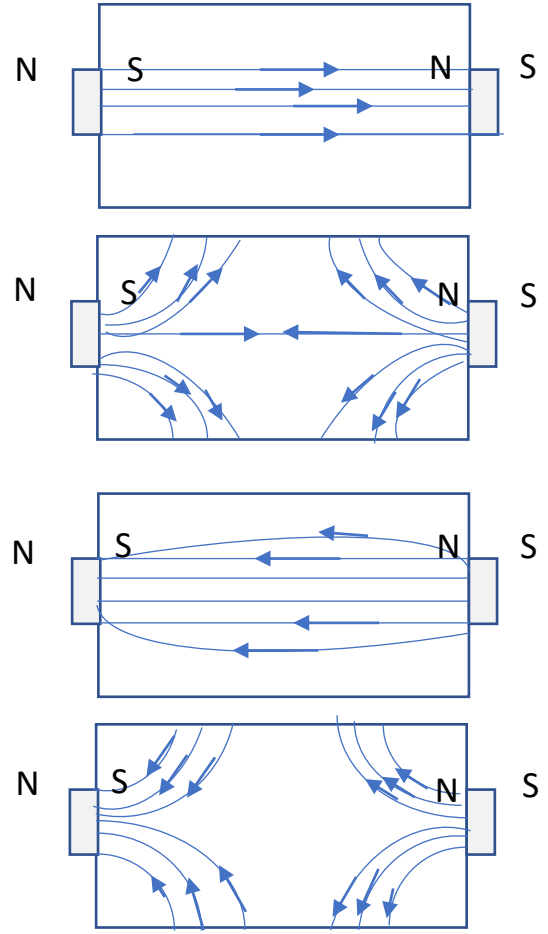
A: M still attracts L and N
B: M still attracts L but now repels N
C: L now repels both M and N
D: L still attracts N but now repels L

Your turn:

b) The diagram below shows the structure of a truck as seen from above.
Permanent magnets cause a magnetic field inside and outside the truck.



Which of the following correctly shows the field inside the truck? Put a cross next to the correct answer.



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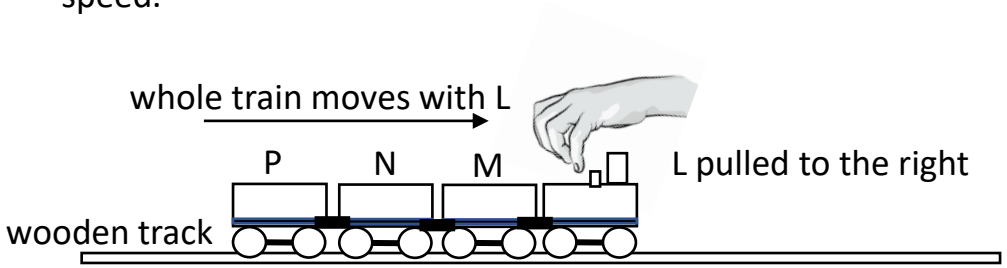
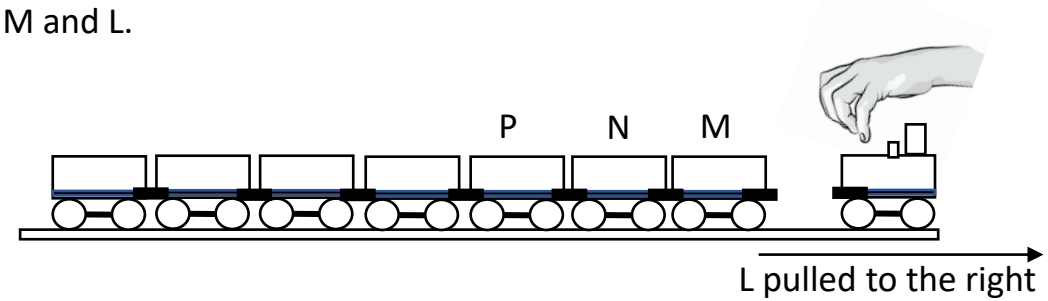
Your turn:

c) Ellie investigates the forces between the trucks in the toy railway. She places another truck, P, next to truck N. She pulls truck L in the direction shown by the arrow. The whole train travels at a constant speed.



Ellie repeats this method of adding trucks and pulling the train each time. When there are 8 trucks in total, the train comes apart between M and L.



(i) Explain why this happens, considering the forces involved.

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(ii) Devise an experiment to investigate the horizontal force needed to separate the trucks from the engine.

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(iii)Explain why a larger force is needed to separate the trucks from the engine if the force is applied at an angle to the horizontal.

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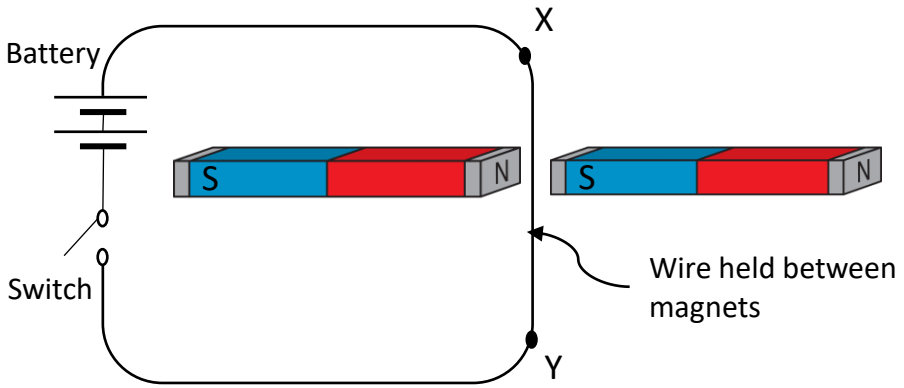
Your turn:

3. Joshua sets up the apparatus below.



Closing the switch creates a force that acts on the wire XY.

a) Explain why a force acts on the wire when the switch is closed?

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b) The force causes the wire XY to move. Draw an arrow on the diagram to show the direction in which the wire will move.

c) State the effect that this demonstrates.

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d) Joshua replaces the battery with a low frequency alternating current power supply.
He closes the switch.

Describe the movement of the wire and give a reason for your answer.

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Answers:

1. Ben investigate the magnetic properties of three rods.

- A soft iron rod
- A steel rod
- A wooden rod.

He places each rod in a solenoid that is connected to a direct current power supply. The power supply is switched on for a short time.

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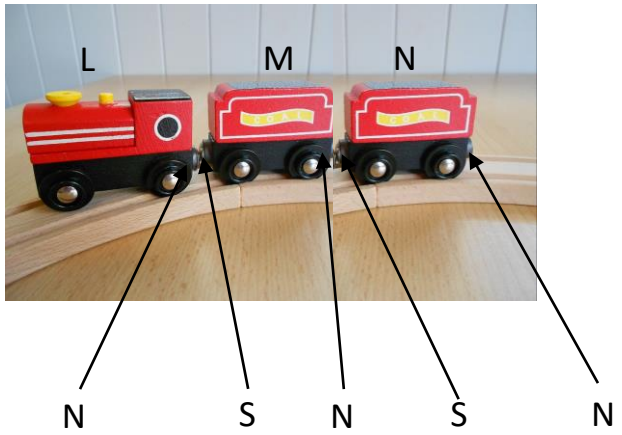
Complete the table below to show which material each rod is made from, and explain why. Use information from the results in your answer.

Rod	Material	Reason
A	Wood	It is not magnetic because it does not pick up any paper clips, whether there is a current or not.
B	Soft iron	Only attracts paper clips when there is a current in the coil
C	Steel	Attracts paper clips when there is a current in the coil and for some time after

Answers:

2. The wooden trucks on a toy railway set have permanent magnets that hold the trucks together.

The magnets are arranged so that a N-pole touches a S-pole between each truck as shown below.



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Your turn:

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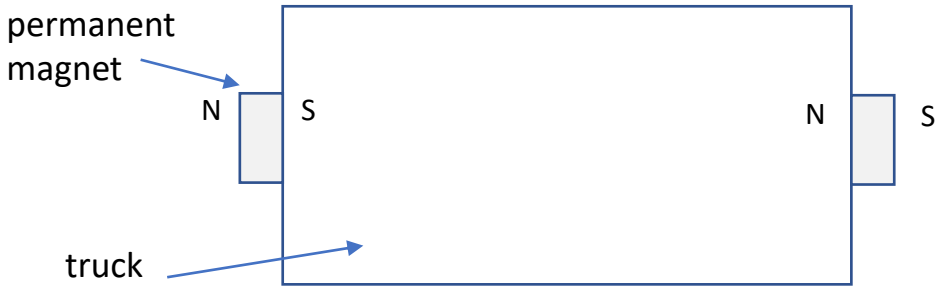

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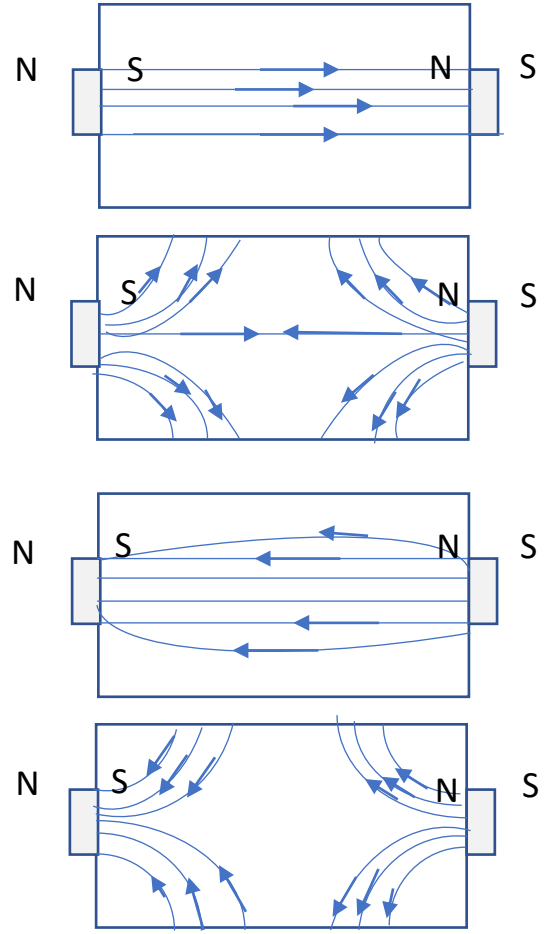

X

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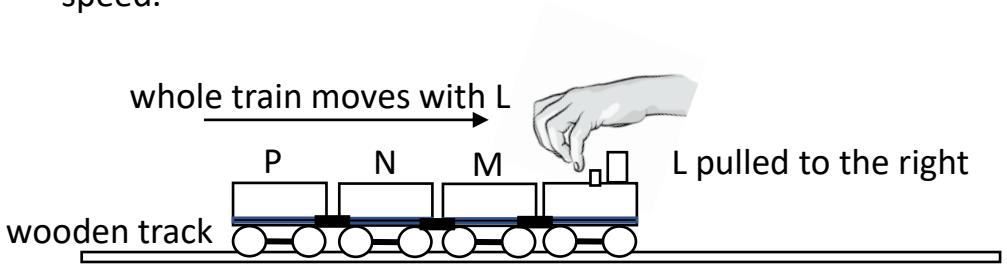
Answers:

c) Ellie investigates the forces between the trucks in the toy railway. She places another truck, P, next to truck N. She pulls truck L in the direction shown by the arrow. The whole train travels at a constant speed.



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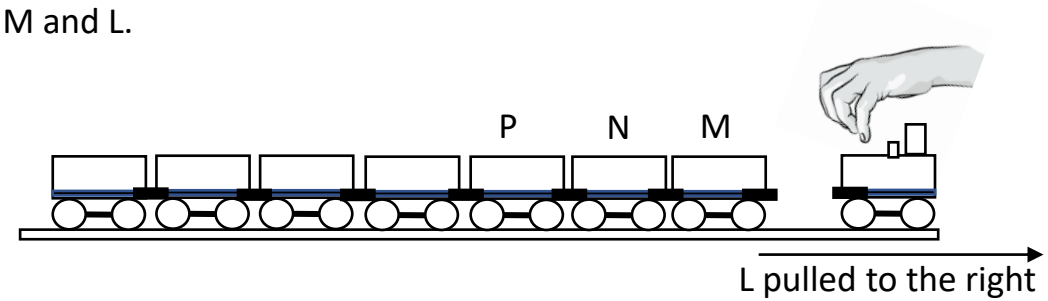

(i) Explain why this happens, considering the forces involved.

Frictional forces increase as more trucks are added, so in order to keep the constant speed, more force must be applied to Z. When they separate, the forces to the left are more than the magnetic attraction.

(ii) Devise an experiment to investigate the horizontal force needed to separate the trucks from the engine.

Use a Newton meter horizontally
Record the largest force observed
Repeat readings several times under the same conditions

(iii) Explain why a larger force is needed to separate the trucks from the engine if the force is applied at an angle to the horizontal.

The applied force must be resolved horizontally to determine the force that separates the engine from the trucks. Since the size of the resolved force is always less than the size of the actual force, than a larger force applied at an angle is needed to separate the trucks from the engine.

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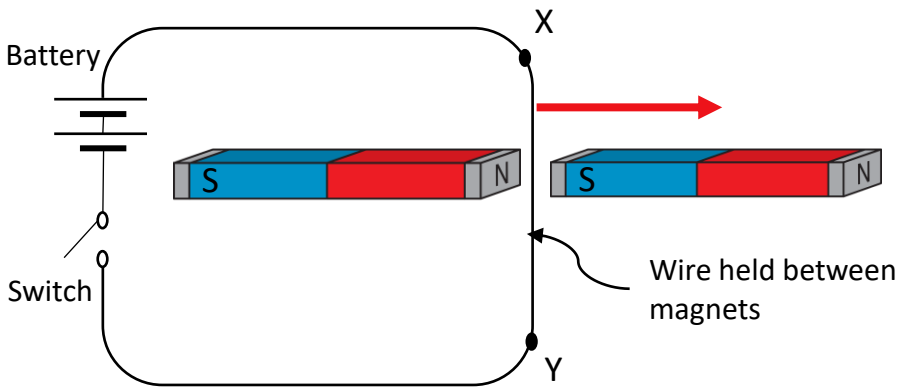
Answers:

3. Joshua set up the apparatus below.



Closing the switch creates a force that acts on the wire XY.

a) Explain why a force acts on the wire when the switch is closed?

Closing the switch makes a current through the wire. The current flowing creates a magnetic field which interacts with the permanent magnetic field.

b) The force causes the wire XY to move. Draw an arrow on the diagram to show the direction in which the wire will move.

c) State the effect that this demonstrates.

Motor Effect

d) Joshua replaces the battery with a low frequency alternating current power supply.
He closes the switch.

Describe the movement of the wire and give a reason for your answer.

Moves up and down (vibrates)
This is because the force continually changes direction.

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For more help and resources, or to work with us as a tutor, please contact us

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