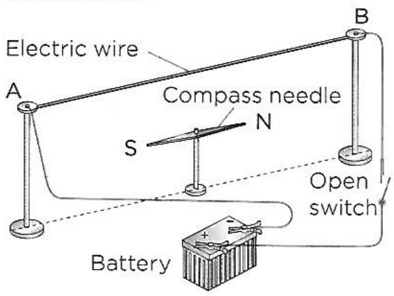
READING AND LISTENING

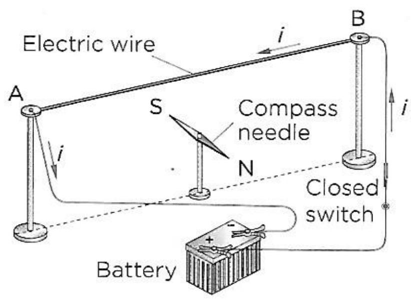
Introduction

At the beginning of the 19th century there was a great debate between scientists who believed that electricity and magnetism were completely [1] ...., and those who believed that a strong connection existed between them. This latter point of view was sustained by followers of the Philosophy of Nature (German: *Naturphilosophie*), which was widespread in the German cultural atmosphere. It involved the search for unity in nature, and revolved around the concept of [2] .... continuously attracting or repulsing each other.

This climate probably influenced the Danish scientist **Hans Christian Oersted** (1777-1851), who first observed the relationship between electricity and magnetism. In 1819, he noticed that a current flowing through a wire deflected a compass needle. Since compasses are only affected by magnetic fields, Oersted deduced that an electrical current generates a magnetic field. This is often referred to as "current-magnet interaction".

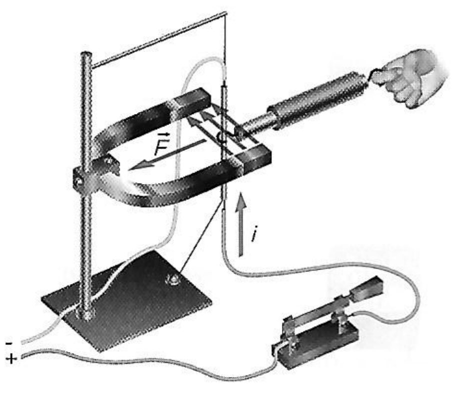


↑ Oersted's apparatus: the switch is open and a wire is placed parallel to a magnetised needle.



↑ When the switch is closed, a current flows and the needle moves.

In the same period, **Michael Faraday** (1791-1867) proved that [3] .... will experience the effect of a force exerted by a nearby magnet. The wire was attracted or repulsed by the magnet, depending on the direction of the current. This interaction is often referred to as "*magnet-current* interaction".



← Faraday's experiment: magnet-current interaction.

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LISTENING ACTIVITY

With your partner, consider the gaps in the text to the left. Try to put the right word in each gap. When you have finished, listen to the text to check your answers. Were they correct?

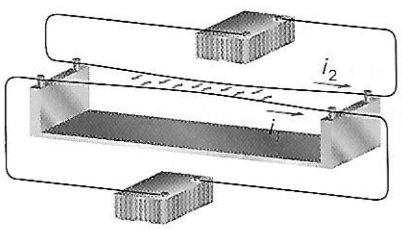
- an electric current
- magnetic fields
- two opposite poles
- current flowing in a wire
- different phenomena

Research Challenge

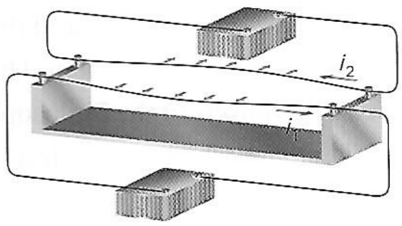
What is *"Naturphilosophie"*?
Search for Idealism, Romanticism, and Friedrich Schelling in groups of three to find out. How did you decide to share your research tasks?

André Marie Ampère, at around the same time, determined the intensity of the reciprocal force exerted by two separate, parallel wires that were being traversed by currents. He assumed that the wires produced this force through the interaction of the [4] .... generated by their currents. This phenomenon is referred to as "*current-current* interaction".

→ Ampère's experiment: current-current interaction.



↑ The currents flow in the same direction, so the wires attract each other.



↑ The currents flow in opposite directions, so the wires repel each other.

COMPREHENSION QUESTIONS 1
Answer the following questions.

1 Which phenomena did Oersted discover to be related?
2 More specifically, what caused the deflection of Oersted's compass needle?
3 What kind of connection did Faraday and Henry try to demonstrate?

All of these experiments demonstrated that current generates a magnetic field, and scientists all over the world tried to understand whether or not the converse was true: they wondered whether a magnetic field could produce an electric current as well.
Michael Faraday and **Joseph Henry** (1797-1878) in the United States each showed that there is a relationship between electricity and magnetism, demonstrating that a variable magnetic field is able to produce [5] .... in a circuit.

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Faraday's First Experiment

Using the text, label the first diagram with the words to its right.

Faraday connected a loop of wire to a sensitive ammeter (an instrument that measures the intensity of current) and a magnet, as illustrated in the following figure.

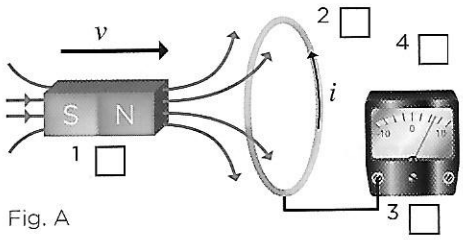

Fig. A

a Ammeter
b Loop
c Magnet
d Needle

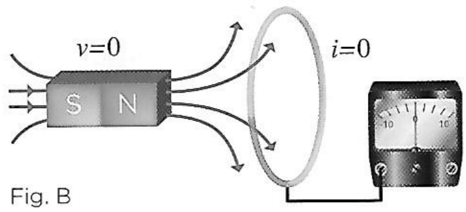

Fig. B

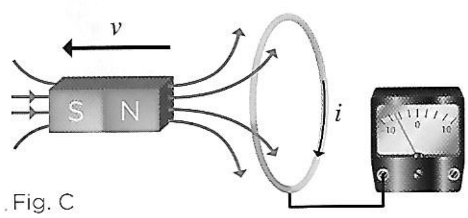

Fig. C

N North pole
S South pole
i induced loop's current

MICHAEL FARADAY
(1791–1867)

Faraday, a self-educated blacksmith's son who received little formal schooling, was one of the world's greatest experimental scientists. In 1813, he became an assistant to Humphrey Davy at the Royal Institute of London and developed his experimental research, having a preference for naturalistic studies of phenomena instead of mathematical ones. He made fundamental contributions to many branches of science, and is credited with the discovery of electromagnetic induction and the two laws of electrolysis, as well as the invention of the electric motor, electric generator, and transformer.

His experiment can be summed up in three steps:

1 If you move the magnet towards the loop, the ammeter's needle flickers in one direction (see Fig. A).
2 If you hold the magnet still, the instrument's needle reads zero (see Fig. B).
3 If you pull the magnet away, the needle flickers in the opposite direction (see Fig. C).

The movement of the needle suggests that a current is inducted in the wire when a change in the magnetic field occurs. Since no battery is connected to the circuit, the current must be generated by variations in the magnetic field. This current is usually called **induced current**, and is said to be produced by an **induced emf** (electromagnetic force, i.e. the work per unit of charge, which is equal to the electric potential difference produced across two open-circuited terminals).

COMPREHENSION QUESTIONS 2

Answer the following questions.

1 What happens if you move a magnet into and then out of a loop attached to a sensitive ammeter?
2 Is that similar to what happens when you move the loop towards and away from a static bar magnet?
3 What is the current measured by the ammeter in the previous experiment usually called?

Faraday's Second Experiment

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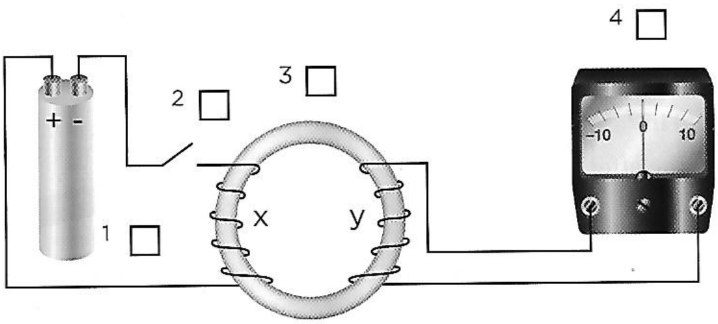
registers	shown	wrapped	generated
kept	consisting	causes	established
moves	conjectured	connected	

In his second experiment, Faraday used an apparatus [1] .... of two separate circuits, similar to that [2] .... in the following figure. The first circuit, called the primary circuit, consists of a coil [3] .... to a battery; the secondary circuit is only connected to a galvanometer, which is a type of ammeter.

LISTENING ACTIVITY

With your partner, consider the gaps in the text to the left. Try to put the right word in each gap. When you have finished, listen to the text to check your answers. Were they correct?



Using the text, label the diagram with the words below.

a Galvanometer
b Switch
c Iron ring
d Battery

The coil consists of insulated copper wire [4] .... around an iron ring. When you close the switch a current flows through the primary coil, producing a magnetic field which is intensified by the iron core. At the same time, the galvanometer needle in the secondary circuit [5] .... an impulse of current and quickly returns to zero. If the switch is [6] .... closed, a current circulates in the primary circuit and the needle continues to point to zero.
If you open the switch, the current flowing in the primary coil drops to zero and the needle suddenly [7] .... in the opposite direction, and then back to zero.

COMPREHENSION QUESTIONS 3

Answer the following questions.

1 What happens in the secondary circuit if you close the switch in the primary circuit?
2 What happens in the secondary circuit if the switch in the primary circuit remains closed?
3 What happens in the secondary circuit if you then open the switch in the primary circuit?

What [8]...................... the sudden deflection of the needle? When the switch is closed, a current flows in the primary circuit, and a magnetic field [9]...................... in the secondary circuit. However, the galvanometer's needle doesn't flicker. It is only when the intensity of the current varies, producing a change in the magnetic field, that a current impulse is [10]...................... in the secondary circuit. Faraday [11]...................... that changes in the magnetic field induce the electric current in the secondary circuit.

Research Challenge

Electricity and electromagnetic fields also have a function in living organisms: muscles, for example, are stimulated by electric currents. What is the scientific name for this branch of science?

PRACTICE

3 Fill in the gaps with the appropriate words.

Europe	**phenomena**	**alongside**	**magnetic**	**electric**
philosophical	**Ampère**	**entity**	**wires**	**electromagnetism**

Oersted was deeply influenced by *Naturphilosophie*, the [1]........................ notion that "all [2]........................ are caused by the same original [3]........................". Oersted's experiment, which demonstrated that [4]........................ current has [5]........................ effects, was the beginning of a new branch of physics: [6]........................ . This became widespread in [7]........................ . In France, [8]........................ reproduced Oersted's experiment and studied the effect of two current-carrying [9]........................ positioned [10]........................ each other.

4 Some of the following sentences are wrong. Using what you have learnt in this unit, identify them and explain why they are wrong.

1 Oersted's experiment shows that a magnetic field produces an electric current.
2 Compass needles near electric circuits always point North.
3 In Faraday's first experiment, if you move a magnet out of a loop after putting it in, the magnet will deflect in the opposite direction.
4 In Faraday's second experiment, the iron ring electrically connects the first and the second circuits.
5 When the switch is closed in Faraday's second experiment, a variation in current from zero to a definite value will produce a corresponding variation in the magnetic field, generating an induced current in the separate secondary electrical circuit.

↑ A speedometer powered by wheel rotation.

5 Now, get into a group of four. Give the other students a true sentence or a false sentence of your own, using the texts in this unit as a source. Can they tell whether it's true or false?

6 There are four ways (a-d) to complete the sentences below. Which is correct? Explain why, and use the texts in this unit to help you.

1 Oersted's experiment...
   a demonstrated the relationship between magnetic fields and electric fields.
   b found that a metal wire caused a compass needle to deflect.
   c showed that an electrical current in a wire makes a compass needle deflect.
   d demonstrated that a magnetic field attracts the current in a wire.

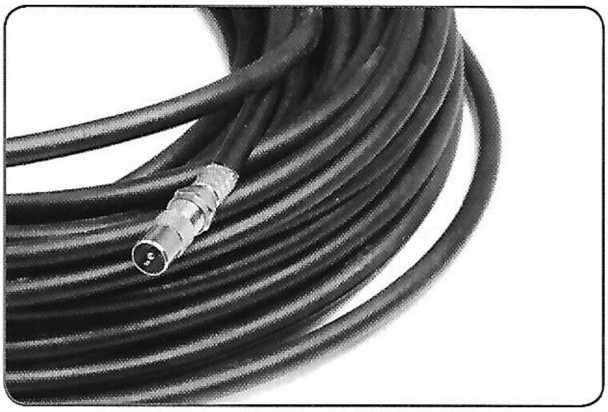
2 Faraday's experiment (magnet-current interaction)...
   a demonstrates that magnetic field produces an electric current.
   b demonstrates the relationship between current and a changing magnetic field.
   c demonstrates that a changing electric current produces a magnetic field.
   d demonstrates that a current in a wire attracts a bar magnet.

3 Faraday's second experiment...
   a shows that when the switch in the primary circuit remains closed, a current flows in the secondary circuit.
   b demonstrates that at the moment you close the switch in the primary circuit, a current flows in the secondary circuit.
   c demonstrates that if you close the switch in the primary circuit, a permanent current is induced in the secondary circuit.
   d demonstrates that opening the switch in the primary circuit stops the current in the secondary one.

PRODUCTION

7 Working in groups, discuss the following questions and then write down your answers. When you have finished, compare your answers with the other groups.

1 Having studied electromagnetic induction, can you explain why TV cables are shielded and separated from electric power lines?



2 Do you think that electromagnetic induction is often used to generate electric current?

3 Faraday's second experiment shows that when you open or close a circuit switch, an electric current is induced in any separate closed circuit nearby. What happens when you turn the light on and off many times?

4 A magnet induces a current in a circuit loop when it is moved into it and out of it. Can you use this knowledge to create a perpetual motion machine?

8 Get into groups of three, and use the school library and the Internet to find answers to the following questions.

1 In Earth's magnetosphere and ionosphere, ionized gas currents experience great variations in intensity. Do they have an effect on electrical conductors at ground level? Is any geomagnetically induced current present?

2 Most of our body is made of water, and is therefore conductive. So, is there any induced current flowing in the body of a person who experiences a magnetic field changing 50 times per second (50 Hz)? Would it be negligible or not?