How can electric current generate mechanical movement?

Task

To allow current to flow through a conductor which is in a magnetic field, and investigate if forces act on the conductor and which direction these forces have.

Equipment

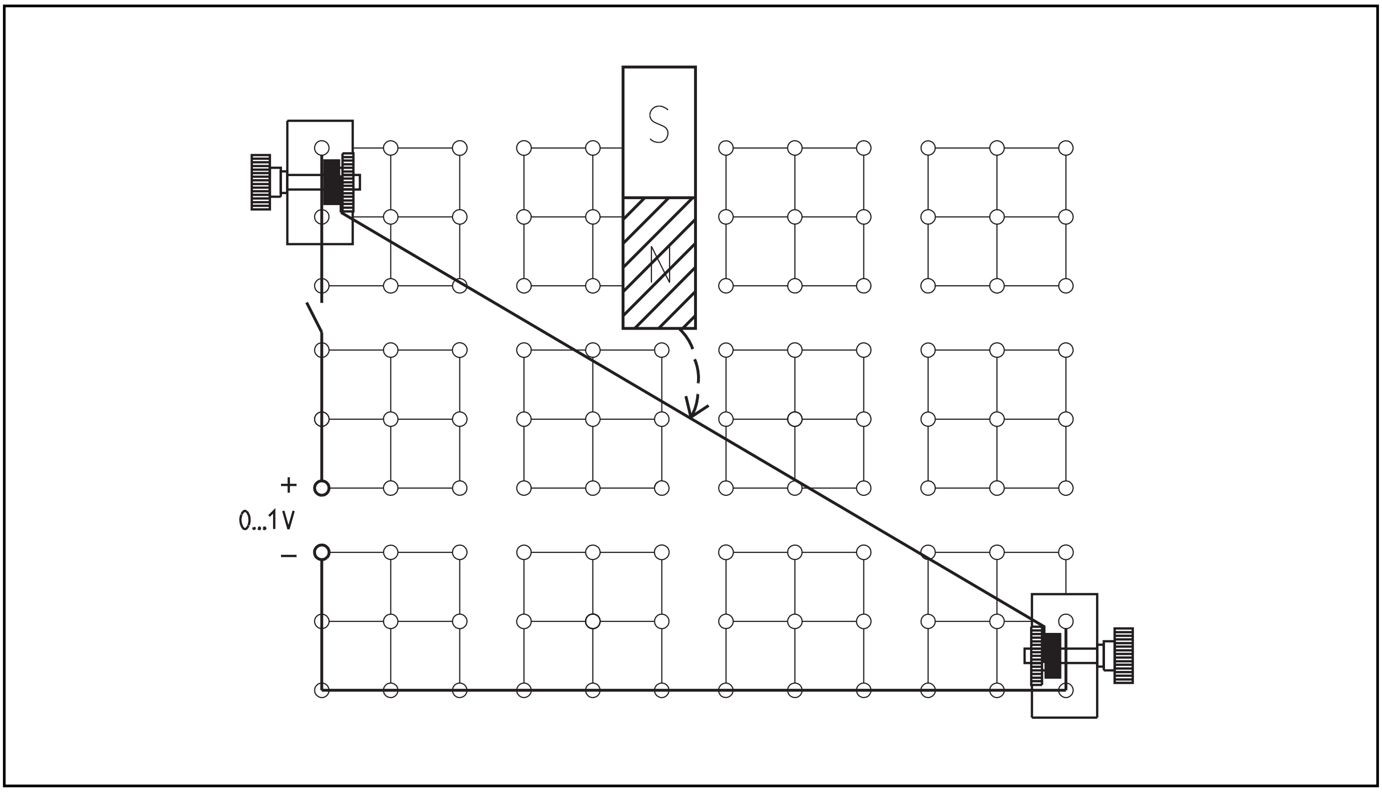
Plug-in board	06033.00	1
On/off switch	39139.00	1
Wire building block	39120.00	3
Battery holder	39115.01	1
Universal holder	39115.02	2
Bar magnet, l = 72 mm	07823.00	1
Coil, 400 turns	07829.01	1
U-core	07832.00	1
Connecting cable, 25 cm, red	07313.01	1
Connecting cable, 25 cm, blue	07313.04	1
Connecting cable, 50 cm, red	07314.01	1
Connecting cable, 50 cm, blue	07314.04	1
Power supply, 0...12 V-,6 V~, 12 V~	13505.93	1
Round-cell battery, 1.5 V, R14	07922.01	1
Copper wire, d = 0.2 mm, approx. 35 cm reqd	06106.00	(1)

Set-Up and Procedure

— Set up the circuit as shown in Fig. 1 with the switch open; clamp an approx. 30 cm long piece of copper wire between the universal holders so that it is held loosely, almost hanging down onto the plug-in board.
— Switch on the power supply, set it to 0 V and set the current limitation to 2 A.
— Close the switch and carefully increase the voltage until the control lamp on the power supply lights up; open the switch.
— Hold the magnet vertically above the lowest part of the wire, so that the gap between them is only a few millimetres, and first with the North pole down.
— Briefly open the switch, observe the behaviour of the wire and immediately open the switch again.
Note: Because we are short circuiting here, the circuit can only be briefly closed (for 1 to 2 seconds). Should it not have been possible to exactly observe the behaviour of the wire, again briefly close the circuit.
— Note your observation in Table 1 under experimental step 1.
— Now hold the magnet with the South pole down, repeat the above procedure and note what you observe (step 2).
— Reverse the polarity of the power supply and repeat the above procedure, first with the South pole down towards the wire, and then with the North pole; note what you observe (steps 3 and 4).
— Set the power supply to 0 V and switch it off.

Second experiment:
— Change the connections in the circuit to those shown in Fig. 2, with the switch again first open; position the coil with 400 turns and the U-core so on the plug-in board that the suitably hanging wire passes through the arms of the U-core without touching them, or the coil.
— Set the power supply to approx. 3.5 V and switch it on.

Fig. 1



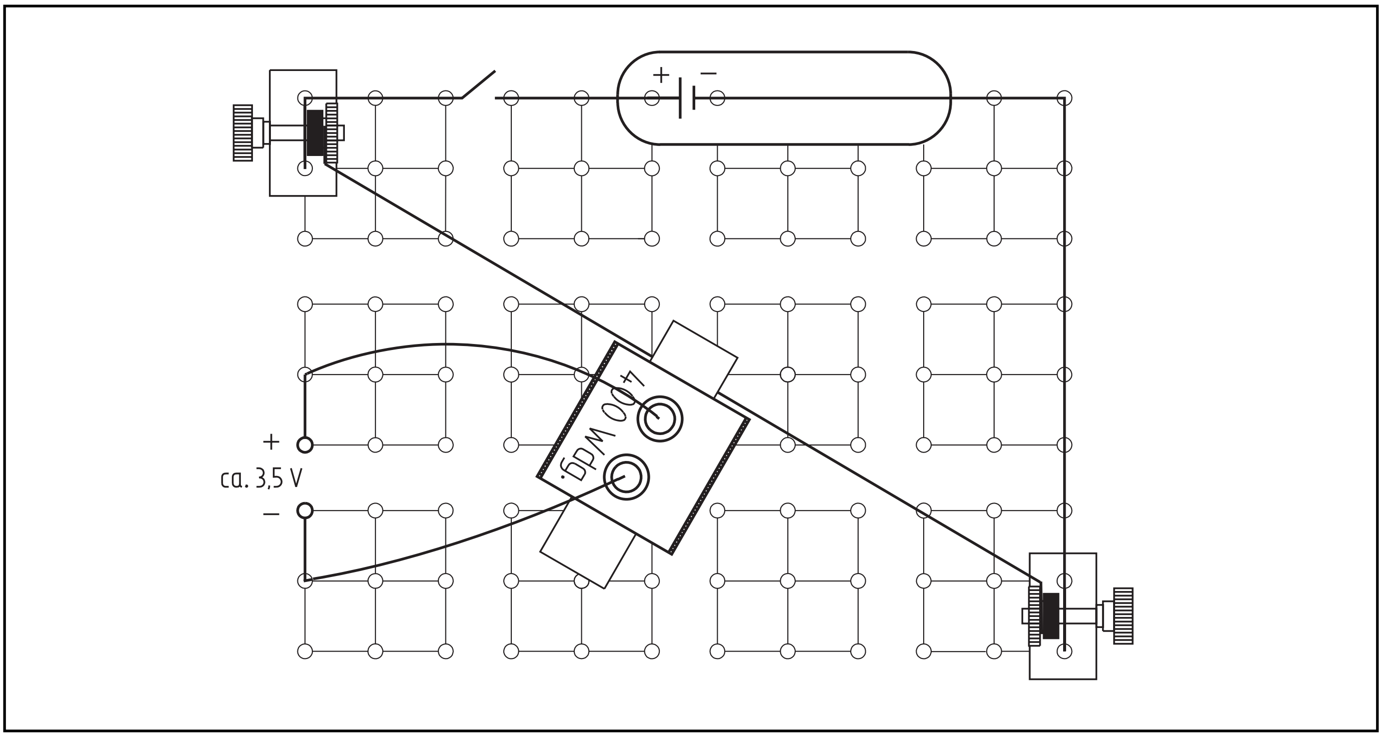
— Test with the bar magnet, if the upper pole of the electromagnet is a North pole, if not, reverse the connections to the power supply.
— Carry out the experiment in 4 steps, analagous to the first experiment:
  * North pole up, current direction from back left to front right.
  * South pole up (after reversing the connections to the power supply), current direction unchanged.
  * South pole up, current direction (after replugging the battery holder) reversed.
  * North pole up (after reversing the connections to the power supply), current direction unchanged.
— In each case, observe the deflection of the wire on briefly (!) closing the switch, and compare these deflections with those observed in the 4 steps of the first experiment (Table 1).
— Note the results of your comparison under (1).
— Set the power supply to 0 V and switch it off.

Observations
Refer to Table 1
(1)

Table 1

Experimental step	Direction of the current in the conductor	Direction of the field lines of the magnet	Direction of the force on the conductor
1	From back left to front right	Vertically down	
2			
3			
4			

Fig. 2

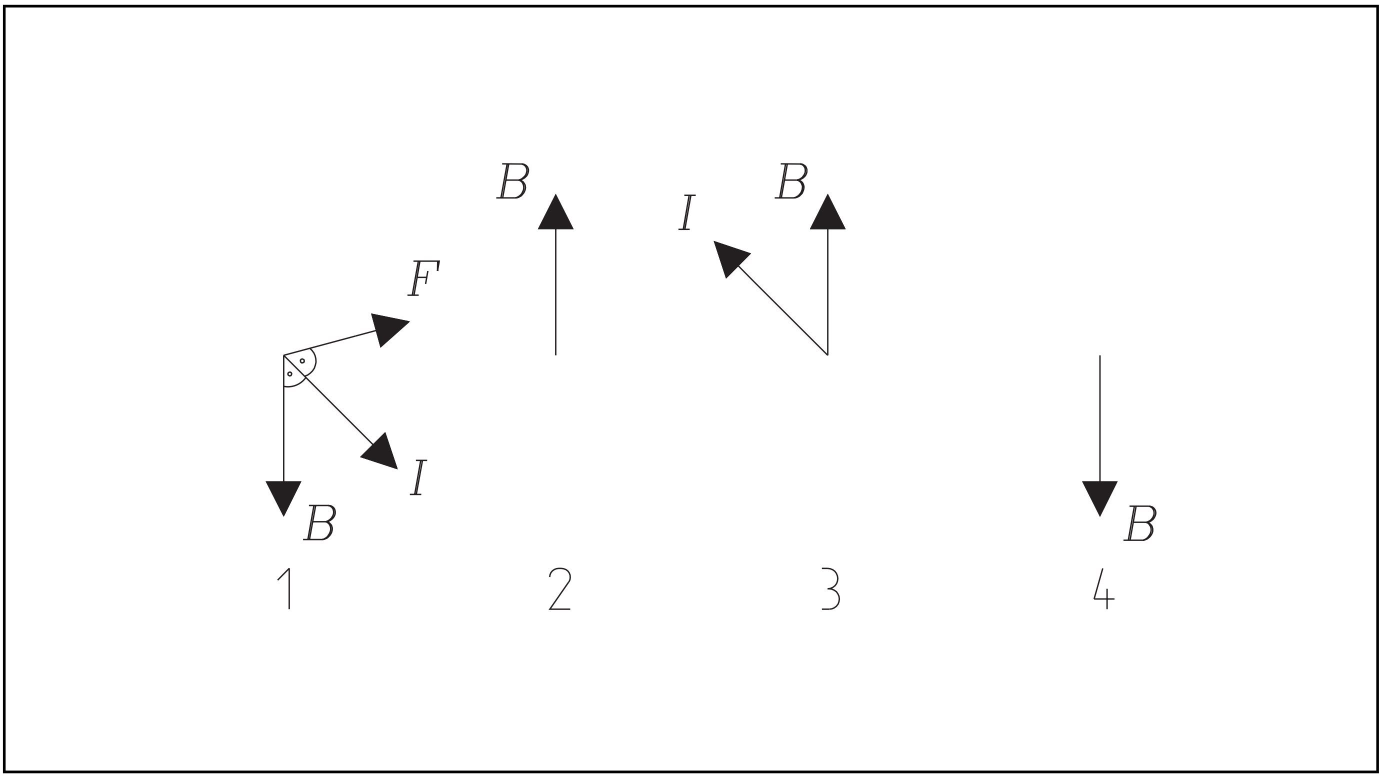


Evaluation

1. Formulate an assertion on the direction of the force in relation to the direction of the current and the field lines (refer to Table 1).

2. When we use I for the direction of the current, B for the direction of the field lines and F for the direction of the force acting on the current-carrying conductor, we can prepare a directional diagram as shown in Fig. 3 for experimental step 1. Complete the directional diagrams shown in Fig. 3 by entering the missing parts of the directional diagrams for experimental steps 2 to 4.

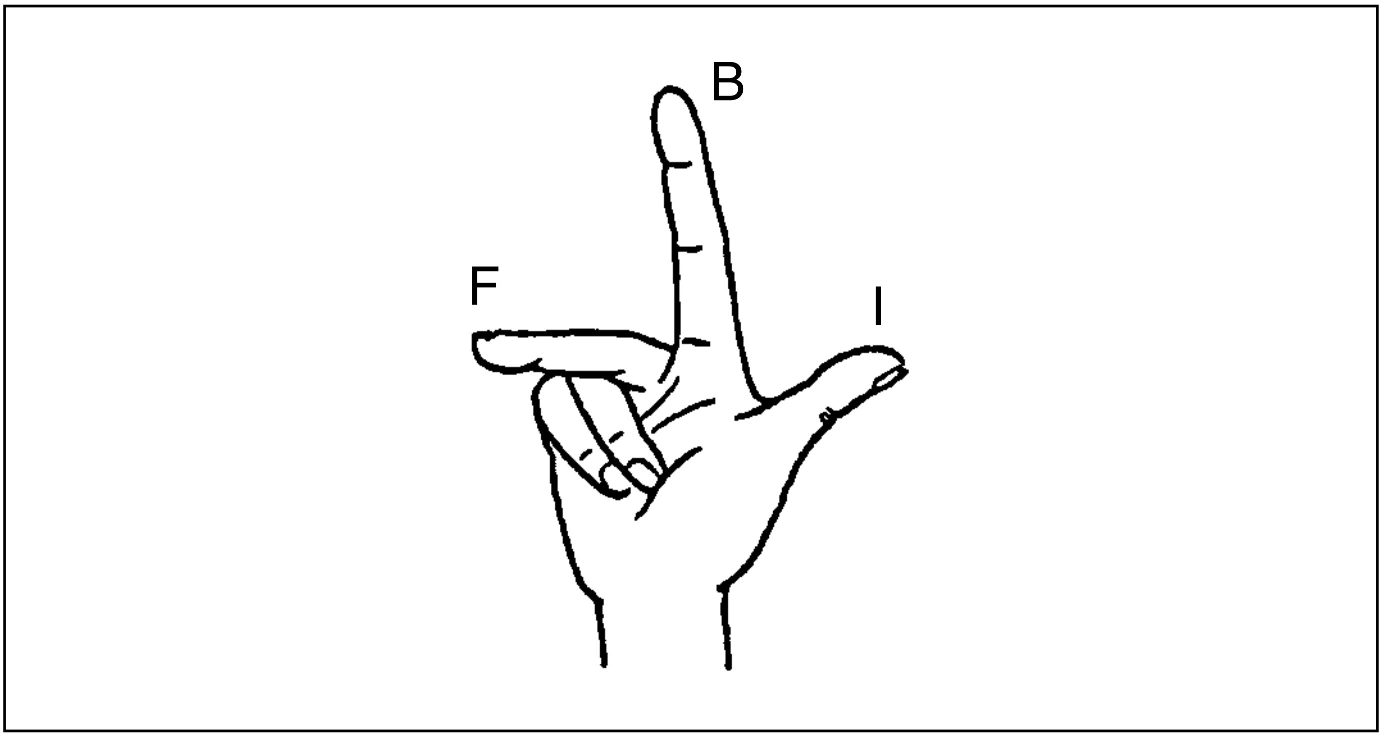
Fig. 3



3. Which conclusion can be drawn from the result of the comparison of the two experiments noted under (1)?

4. The (completed) directional diagrams in Fig. 3 have a relationship which is expressed by the “Three fingers of the right hand rule”. Look at Fig. 4 and try to formulate this rule in words.

Fig. 4



(How can electric current generate mechanical movement?)

The students should know, that a current-carrying conductor is surrounded by a magnetic field whose field lines are concentric circles, and how one can determine the direction of the field lines. They should also know the conventions, that the field lines external to a permanent magnet or an electromagnet run from the North pole to the South pole, and electric current from the positive pole to the negative pole.
The students should find out that a force acts on a current-carrying conductor in a magnetic field and how one can determine its direction.

Notes on Set-Up and Procedure

The power supply is electronically protected against overload, the maximum current strength is 2 A.
In the second experiment, a battery is required as the source of current; the duration of the short circcuit should be kept as brief as possible.
The conception of the experiment results in the findings strived for, even when only the first experiment is actuallly carried out.

Observations

Refer to Table 1

(1) The direction of the force on the conductor in each of the four steps of the second experiment is the same as that in the first experiment.

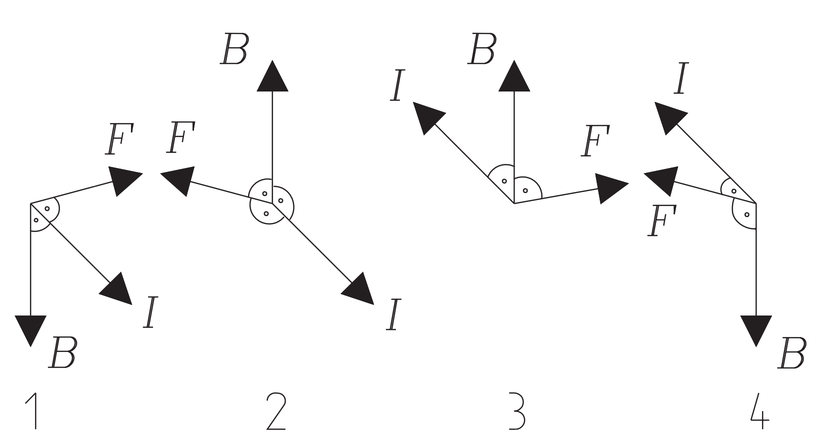
Evaluation

1. The direction of the force is vertical both to the direction of the field lines and to the direction of the current.
2. Refer to Fig. 3.
3. Regardless of whether the magnetic field is from a permanent magnet or an electromagnet, under the same conditions (direction of the magnetic field lines and of the current) the same directed force acts on a current-carrying conductor in a magnetic field.
4. When the thumb of the right hand points in the direction of the current, and the forefinger in the direction of the field lines, then the horizontally-stretched middle finger shows the direction of the force which acts on the conductor.

Table 1

Experimental step	Direction of the current in the conductor	Direction of the field lines of the magnet	Direction of the force on the conductor
1	From back left to front right	Vertically down	To back right
2	–”–	Vertically up	To front left
3	From front right to back left	–”–	To back right
4	–”–	Vertically down	To front left

Fig 3



Current-carrying conductors in magnetic fields

(How can electric current generate mechanical movement?)

Remarks

With this experiment, only a qualitative statement on the Lorentz force which acts on a current-carrying conductor is intended.

The students should – even when the Lorentz force is not taken as a theme – be aware that a force acts on the current-carrying conductor because a deflecting force acts on each electron of the current in a magnetic field. The deflected electrons take the conductor altogether with them.