What effect does a coil have in a direct current circuit when the circuit is switched on?

EEP 10.1 | S

Problem

Investigate the effect of a coil installed in one of the branches in a parallel circuit of two filament lamps

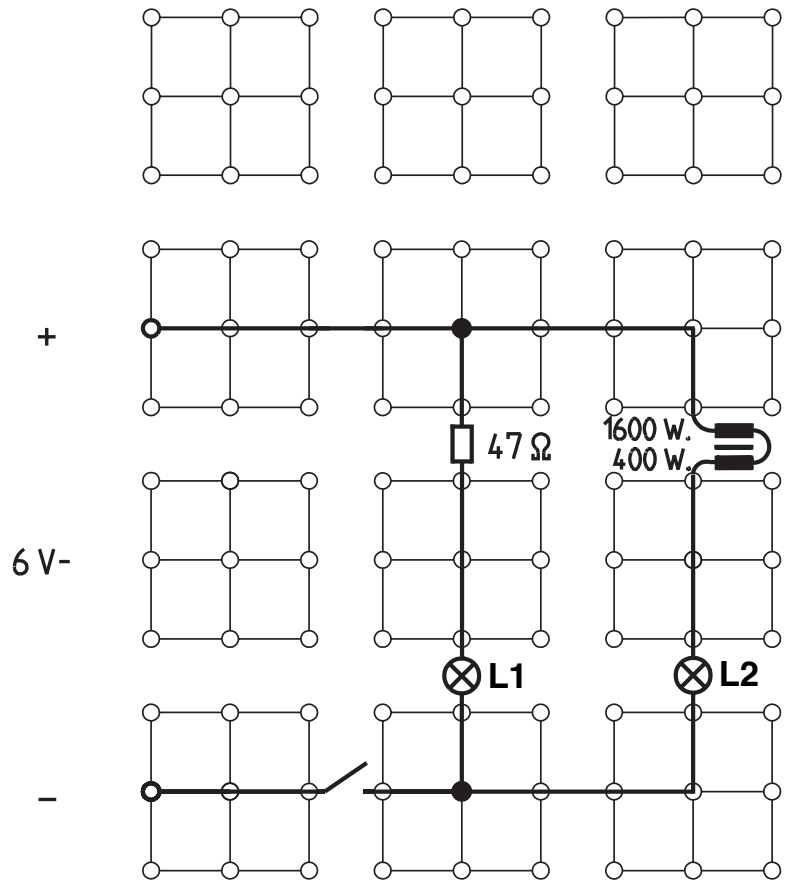
Equipment

Plug-in board	06033.00	1
On/off switch	39139.00	1
Lamp holder E10	17049.00	2
Filament lamp, 4 V/0.04 A, E10, 2 pcs.	06154.03	(1)
Resistor, 47 Ω	39104.62	1
Coil, 400 turns	07829.01	1
Coil, 1600 turns	07830.01	1
U-core	07832.00	1
Yoke	07833.00	1
Tightening screw	07834.00	1
Wire building block	39120.00	3
Connecting cables, 25 cm, red	07360.01	2
Connecting cables, 25 cm, blue	07360.04	1
Connecting cables, 50 cm, red	07361.01	1
Connecting cables, 50 cm, blue	07361.04	1
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1

Set-Up and Procedure

— Place coils on U-core.
Use the tightening screw to press U-core and yoke together firmly.
— Set up experiment as shown in Fig. 1. Switch should be in off position initially.
— Switch on power supply unit and set direct voltage to 6 V.
— Toggle on/off switch back and forth repeatedly. While doing this, observe both filament lamps L1 and L2 **simultaneously**. Note observations under (1).
— Loosen tightening screw and remove iron core from coil.
— Toggle on/off switch back and forth repeatedly. Again, observe both filament lamps simultaneously. Note observations under (2).
— Switch power supply unit off.

Fig. 1



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Observations

(1) Circuit is switched on:

Circuit is still switched on:

Circuit is switched off:

(2)

Evaluation

1. How can you explain the behavior of the coil described under (1) when switched on?
   Note: Use your knowledge of electromagnets and electromagnetic induction in your explanation.

2. What role does the 47 Ω resistor play?

3. Why do both filament lamps go off at the same time when switched off?

4. Why does the phenomenon observed when switching the circuit on not occur when the iron cores are removed from the coils?

(What effect does a coil have in a DC circuit when the circuit is switched on?)

The students know that voltage is induced in a coil as long as the magnetic field inside the coil varies. They are familiar with electromagnets and, therefore, know that a coil with a current flowing through it produces a magnetic field and they know the factors responsible for the strength of the magnetic field.
This magnetic field takes time to form when the circuit is switched on and takes time to fade away when the circuit is switched off. This causes self-induced voltage to be formed each time.
In this experiment, the student should see that the self-induced voltage formed when switching on the circuit counteracts the increase in current.

Notes on Set-Up and Procedure
Since the inductance is relatively small, it may be difficult for the students to see that there is a delay between the lighting of filament lamp L1 and filament lamp L2. Encourage them to keep trying until they perceive the delay. In the end, they may find it easier to see this by carrying out the experiment once at a low operating voltage.

Observations
(1) Circuit is switched on: Filament lamp L2 lights up after L1.
Circuit is still switched on: Both filament lamps shine with the same intensity.
Circuit is switched off: Both filament lamps go out at the same time.
(2) Both filament lamps go on and off at the same time.

Evaluation
1. After the circuit is switched on, current begins to flow and forms a variable magnetic field (one with increasing intensity). This variable magnetic field inside the coils produces an induced voltage which counteracts the connected operating voltage and delays the increase in current until it reaches its maximum value.
2. The lamps should apparently shine with the same intensity. Because the two coils have a combined resistance of 48 Ω, the 47 Ω resistor must be connected in series with filament lamp L1.
3. After the connection to the power supply unit is interrupted, both filament lamps are in a series connection. The induction current produced by the fading magnetic field must flow through both filament lamps. That is why both lamps must go out at the same time.
4. The change in the magnetic field (from zero to its maximum value) is so minimal that the induction produced when switching the circuit on can no longer be observed.

Notes
The coil functions both as a field coil and an induction coil. The voltage produced by the variation in the coil current and the resulting variation in the strength of the magnetic field in the coil is called self-induced voltage.
According to Lenz's Law, this voltage always counteracts its cause.
The following equation applies:

$$U_i = -L\ (dI\ /dt\ ).$$

L is the self-induction coefficient or inductance. It is measured in Henry (H). The coils used in this experiment without the iron core have an inductance of 50 mH and 3 mH respectively. With a closed core, the coil with 400 turns has an inductance of 100 mH, and the coil with 1600 turns has an inductance of 700 mH.

(What effect does a coil have in a DC circuit when the circuit is switched on?)

Room for notes