1 Hz resonant circuit (DEMO)

Physics | Electricity & Magnetism | Electromagnetism & Induction

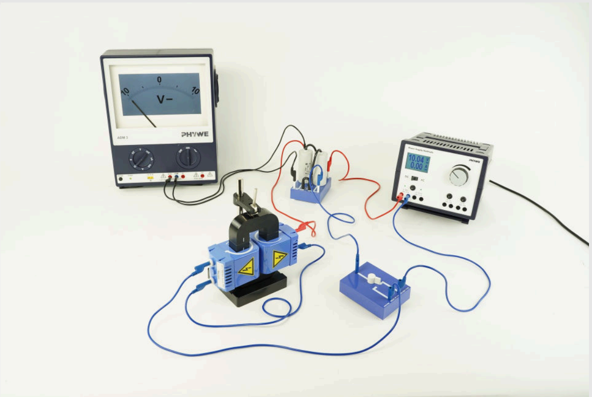
Difficulty level	Group size	Preparation time	Execution time
medium	1	10 minutes	20 minutes

This content can also be found online at:

http://localhost:1337/c/6250043169713b00034f7125

Teacher information

Application



Experimental setup

The electric oscillating circuit consisting of a capacitor connected in series with a coil can be compared or described analogously with the harmonic oscillator in mechanics.

Applications for the electric resonant circuit can be found in information technology, since a transmitting antenna is based on the principle of the electric resonant circuit.

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Other teacher information (1/2)

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Prior

Students should be familiar with the principle of the capacitor and the coil.

Principle

The energy of the electric field and that of the magnetic field alternate periodically - analogous to the kinetic and potential energy in the mechanical pendulum.

Other teacher information (2/2)

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Learning

Students should understand how an electric resonant circuit works.

Tasks

Investigate the behavior of the electric resonant circuit.

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Theory (1/3)

The energy of the electric field and that of the magnetic field alternate periodically - analogous to the kinetic and potential energy in the mechanical pendulum. When the voltage across the capacitor is at a maximum, all the energy of the circuit is in the electric field of the capacitor:

$$E_{mag} = \frac{1}{2} C \cdot U^2$$

When the capacitor discharges, the current flows through the coil. At the maximum current I, the entire energy of the oscillating circuit has been transferred to the magnetic field of the coil:

$$E_{el} = \frac{1}{2} L \cdot U^2$$

The resonant frequency of the L-C resonant circuit can be calculated with the inductance L of the coil and the capacitance C of the capacitor according to the so-called Thomson's equation of oscillation:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \quad \Leftrightarrow \quad T = \frac{1}{f_0} = 2\pi\sqrt{LC}$$

Theory (2/3)

Derivation according to the law of conservation of energy:

The total energy of the oscillating circuit E_{total} remains and is composed of the magnetic field energy of the coil and the electric field energy of the capacitor:

$$E_{total} = E_{mag} + E_{el} = \text{const.}$$

With the relations $I = \dot{Q}(t)$ and $U = Q/C$ therefore follows:

$$E_{total} = \frac{1}{2} L \dot{Q}^2 + \frac{1}{2C} Q^2 = \text{const.}$$

Derive this equation according to the time leads to:

$$I(t) \cdot \left(L\ddot{Q}(t) + \frac{1}{C} Q(t) \right) = 0$$

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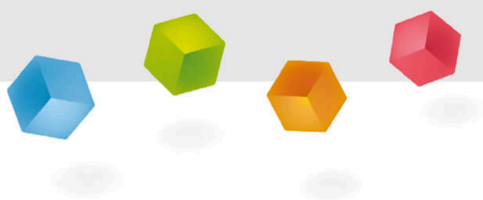
Theory (3/3)

$I(t) = 0$ is trivial. For the part in the parenthesis the following solution approach is chosen:

$Q(t) = Q_0 \cdot \sin(\omega t + \varphi)$

Here the angular frequency is $\omega = 2\pi f_0$ and the phase shift φ. For the differential equation follows

$Q(t) \cdot \left(\frac{1}{C} - \omega^2 L\right) = 0 \;\; \Rightarrow \;\; \omega^2 = \frac{1}{LC}$



Student Information

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Motivation

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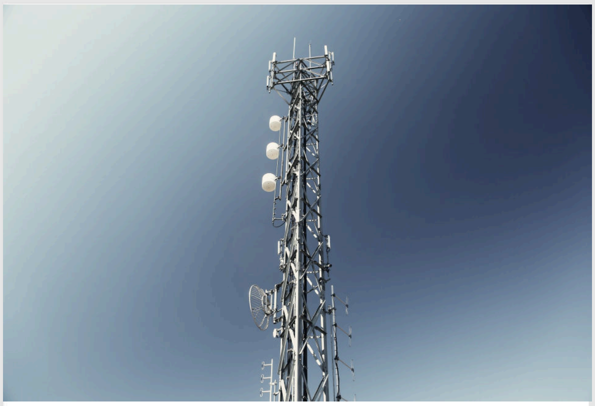
The electric oscillating circuit consisting of a capacitor connected in series with a coil can be compared or described analogously with the harmonic oscillator in mechanics.

Applications for the electric resonant circuit can be found in information technology, since a transmitting antenna is based on the principle of the electric resonant circuit.



Transmitting antenna

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Equipment

Position	Material	Item No.	Quantity
1	PHYWE Variable transformer with digital display DC: 0...20 V, 12 A / AC: 0...25 V, 12 A	13542-93	1
2	PHYWE Demo Multimeter ADM 3: current, voltage, resistance, temperature	13840-00	1
3	Capacitor, 2 x 30 µF	06007-00	1
4	Coil, 10000 turns	06519-01	2
5	Iron core, cut C type	06503-00	1
6	Clamping device for iron cores	06506-00	1
7	Two-way switch, single pole	06005-00	1
8	Connecting cord, 32 A, 750 mm, black	07362-05	3
9	Connecting cord, 32 A, 750 mm, blue	07362-04	3
10	Connecting cord, 32 A, 750 mm, red	07362-01	2

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Setup

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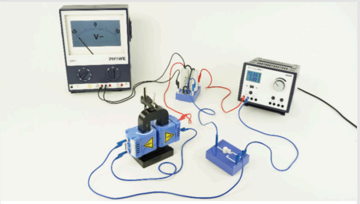

Fig. 1

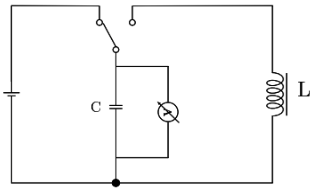

Fig. 2

- Set up the experiment according to Fig. 1 and Fig. 2.
- In the primary circuit, the power supply, the two-way switch and the capacitor are connected in series.
- In the secondary circuit, the capacitor, the coils with iron core and the two-way switch are connected in series.
- To measure the voltage, a demonstration multimeter is connected in parallel with the capacitor.

Procedure

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- Close the two-way switch so that the primary circuit is closed.
- Switch on the power supply and set a DC voltage of 10 V.
- After a short time, the capacitor is fully charged. As a check, the demonstration multimeter should also display a DC voltage of 10 V.
- (It is recommended to set a measuring range of -10 V to 10 V DC for the demonstration multimeter).
- Now flip the switch so that the secondary circuit is closed.
- Observe the pointer deflection on the demonstration multimeter.

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Report

Task (1/2)

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Drag the words into the correct boxes!

The voltage at the ______ oscillates with about 1 Hz or slower. During one ______ the sign of the ______ at the capacitor changes twice. The deflections become increasingly ______ until the voltage is at zero.

- smaller
- oscillation
- capacitor
- voltage

Check

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Task (2/2)

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Drag the words into the correct boxes!

The L-C resonant circuit is ______. This means that the resonant circuit has ______ in the form of heat. However, the ______ used in the experiment actually increases the ______ by about 2 orders of magnitude, which increases the ______ by about an order of magnitude. If the actual period duration is measured in the experiment, the inductance of the oscillating circuit can be calculated from this: $L = \frac{T^2}{4\pi^2 C}$

- damped
- period duration
- inductance
- energy losses
- C-type iron core

Check

Slide	Score / Total
Slide 14: Voltage observation	**0/4**
Slide 15: The L-C resonant circuit	**0/5**

Total score 0 / 9

Show solutions   Repeat

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