1 Hz resonant circuit (Item No.: P1434805)

Curricular Relevance

Area of Expertise: Physics → **Education Level:** Age 16-19 → **Topic:** Electricity → **Subtopic:** Electromagnetism → **Experiment:** 1 Hz resonant circuit (Demo)

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Easy	10 Minutes	10 Minutes	1 Student

Additional Requirements:

- Demonstration multimeter
- Power Supply

Experiment Variations:

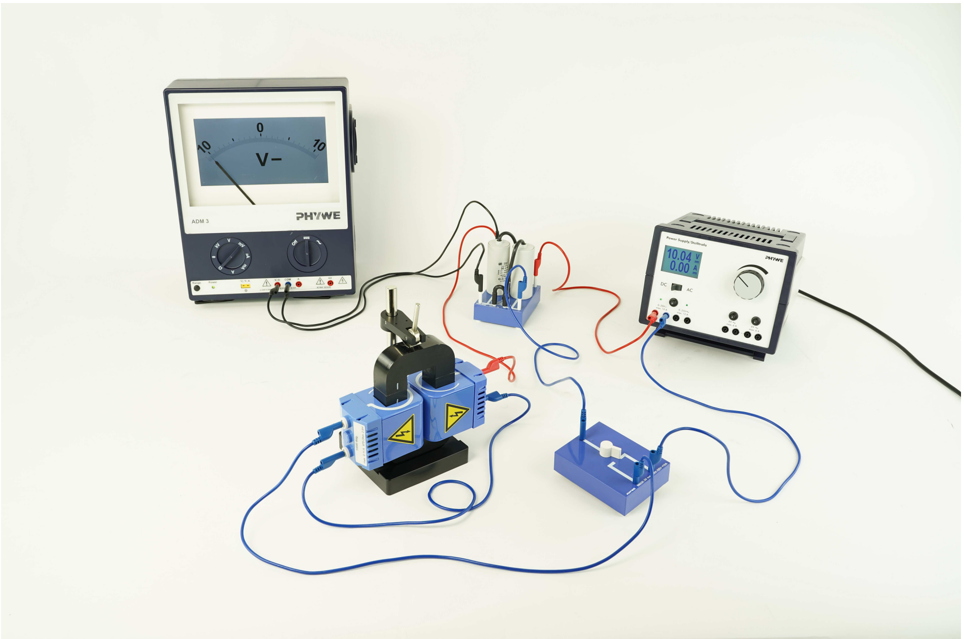
Keywords:

Induction, LC circuit, tank circuit, tuned circuit

Informations for teachers

Introduction

In this experiment, an electrical resonance circuit is built with a coil and a capacitor connected in series. The resulting resonance frequency is approximately 1 Hz.



Equipment

Position No.	Material	Order No.	Quantity
1	PHYWE Demo Multimeter ADM 3: current, voltage, resistance, temperature	13840-00	1
2	PHYWE variable transformer with digital display DC: 0...20 V, 12 A / AC: 0...25 V, 12 A	13542-93	1
3	Capacitor, 2 x 30 µF	06219-32	1
4	Clamping device for iron cores	06506-00	1
5	Iron core, cut C type	06503-00	1
6	Coil, 10000 turns	06519-01	2
7	Two-way switch, single pole	06030-00	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

Safety information

For this experiment, the general instructions for safe experimentation in scientific teaching apply.

Introduction

Application and task

The electrically oscillating circuit with the coil and the capacitor connected in series can be compared with and described analogously to the harmonic oscillator in the mechanics.

Theory

The energy of the electric field and that of the magnetic field alternate periodically, analogously to the kinetic and potential energy of the mechanical pendulum. If the voltage at the capacitor is maximum, the whole energy is stored in the electrical field of the capacitor:

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

When the capacitor discharges, a current flows through the coil. At the maximum current strength I the total energy of the resonance circuit is converted into the magnetic field of the coil:

$$E_{mag} = \frac{1}{2}L \cdot I^2$$

The resonance frequency of the L-C resonance circuit can be calculated using the inductance L of the coil and the capacitance C of the capacitor according to Thomson's equation of oscillation.

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

Derivation according to the law of conservation of energy:

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

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

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

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

Differentiation of this equation with respect to the time leads to:

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

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

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

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

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

Setup and procedure

Setup

Set up the experiment according to Fig. 1 and Fig. 2.

In the primary circuit, the power supply, the switch and the capacitor are connected in series.

In the secondary circuit, the capacitor, the coils with iron core and the switch are connected in series.

A demonstration multimeter is connected in parallel to the capacitor to measure the voltage.

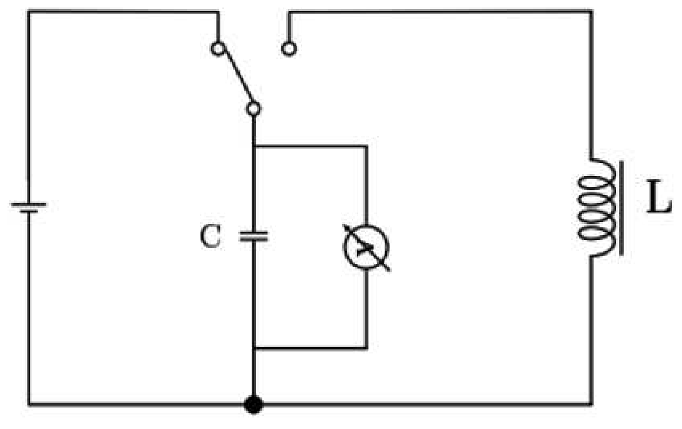


Fig. 1

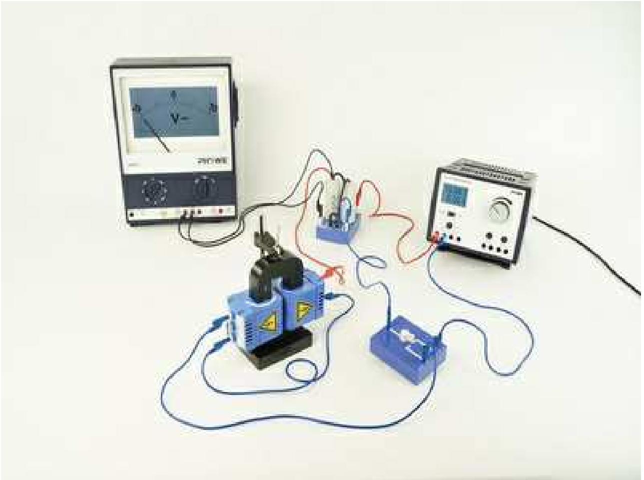


Fig. 2

Procedure

- Close the 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 charged. As a check, the demonstration multimeter should also display a DC voltage of 10 volts
- (It is recommended to set a measuring range of -10 V to 10 V DC voltage at the demonstration multimeter).
- Change the switch so that the secondary circuit is closed.
- Observe the demonstration multimeter.

Evaluation

Observation

The voltage at the capacitor oscillates at approx. 1 Hz or rather slower.

During one period the sign of the voltage measured at the capacitor changes twice.

The deflections become smaller and smaller until the voltage is at zero.

Result

The L-C resonant circuit is damped. This means that the resonant circuit has energy losses in the form of heat. The coil as well as the connection cords have a resistance at which energy is lost.

The inductance of the two coils connected in series is nominal:

$$L = 2 \cdot 2.6\, H \quad [1\, H = 1\, \Omega s]$$

The capacitance of the two capacitors connected in parallel is

$$C = 2 \cdot 30\, \mu F \quad [1\, F = 1\, s/\Omega]$$

The product is accordingly:

$$LC \approx 3 \cdot 10^{-4}\, s^2$$

and therefore

$$T \approx 0.11\, s \;\; \Rightarrow \;\; f_0 \approx 9\, Hz$$

However, due to the cut C-type iron core used in the experiment, the inductance is actually amplified by about 2 orders of magnitude, which increases the period duration by about one order of magnitude:

$$T \approx 1.1\, s \;\; \Rightarrow \;\; f_0 \approx 0.9\, Hz$$

If the actual period duration is measured in the experiment, the inductance of the resonant circuit can also be calculated:

$$L = \frac{T^2}{4\pi^2 C}$$