1.1.1. MAGNETIC RESONANCE

MAIN PRINCIPLE

Investigation of electromagnetic resonance between two Thomson electrical vibration circuits.

EQUIPMENT

Electromagnetic transmitter and receiver circuit

Figure 2.1: Electromagnetic Resonance Experimental setup

THEORY

1. VIBRATION MOTION:

A physical system is said to be in equilibrium if it is not subject to any change over time. The system, which leaves the equilibrium state as a result of an excitation, performs a continuous vibrational motion around the equilibrium state under certain conditions. The duration of a single vibration (the time between two transitions in the same direction from the equilibrium position) is called a **period**, and the number of vibrations per unit time is called **frequency**. The relationship between τ period and frequency is as shown below.

$$f.\tau = 1 \tag{2.1}$$

The largest value that the physical quantity indicating vibration will take at the moment of movement is called amplitude. If the amplitudes of successive vibrations decrease over time, we speak of **damped vibration**; if the amplitude remains constant, we speak of **undamped vibration**.

2. RESONANCE:

If the excitation that causes a system to vibrate is of short duration, the system vibrates at a frequency determined by its structure, which is called the self-vibration frequency of that system. If the system is subjected to a periodic excitation, then the system vibrates coercively with the frequency of the excitation. When the frequency of the exciter is equal to the self-vibration frequency of the system, in other words, when the system is forcibly vibrated with its self-vibration frequency, the amplitude reaches a maximum value, in which case the system is said to be in a state of resonance. **Error! Reference source not found.** shows a typical resonance curve. Here f_r is the resonance frequency at which the amplitude reaches its maximum. At this frequency value, the self-vibration frequency of the system takes the same value as the frequency of the stimulus. From the relation (**2.1**), the units of the period τ and the frequency f;

$$[\tau] = s \, , \, [f] = s^{-1} = Hertz(Hz) \tag{2.2}$$

is obtained.

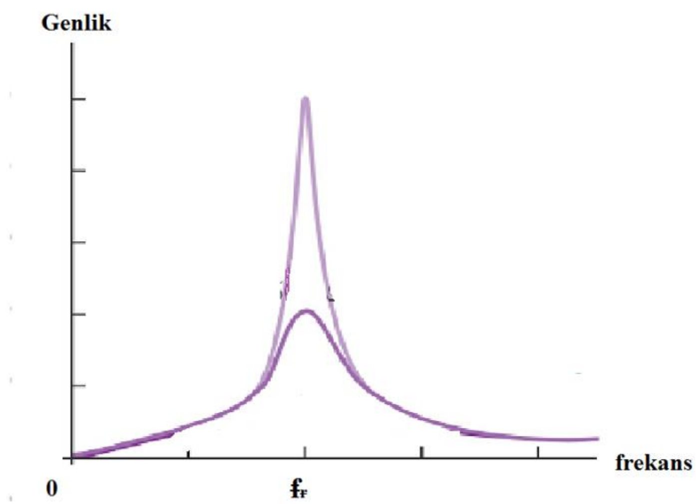

Figure 2.2

C) Thomson Vibration Circuit:

The circuit is obtained by connecting a capacitor with a capacity C and a coil with a self-induction coefficient L as shown in Figure 2.3 is called a **Thomson vibration circuit**.

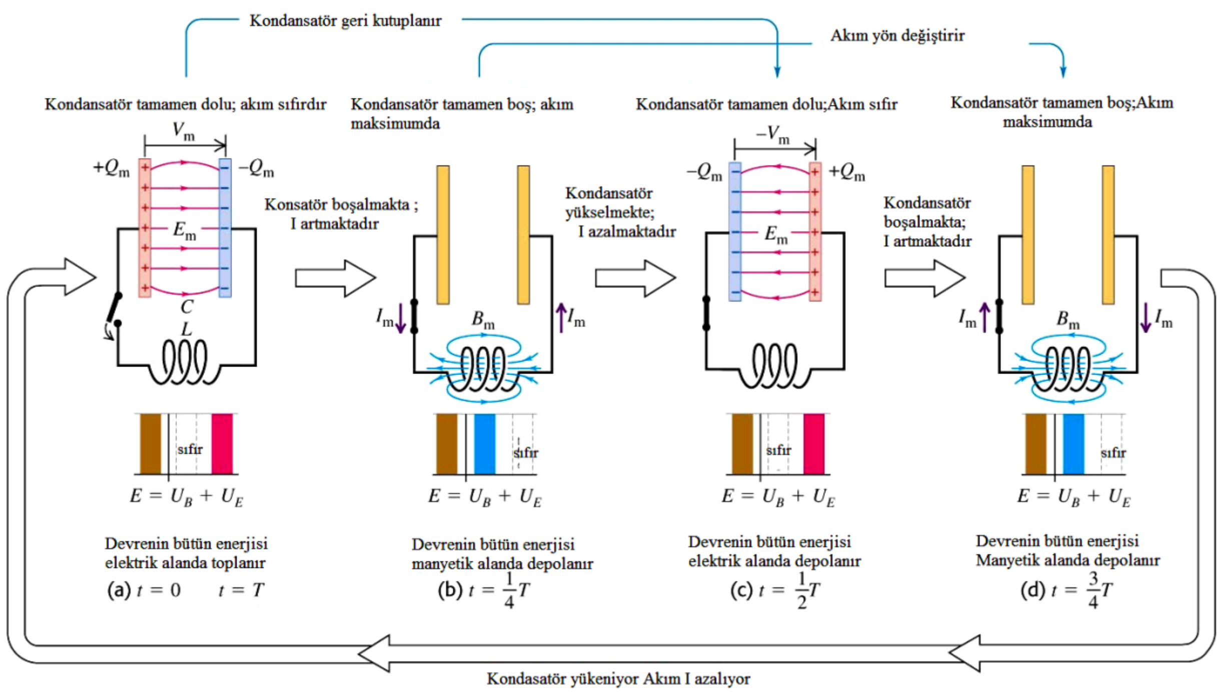

Figure 2.3

When the capacitor is charged with an electric charge q, the charge is discharged through the coil at an accelerating rate. When the charge on the capacitor is completely discharged, the current intensity reaches its maximum value (Figure 2.3b). After that, as the capacitor starts to charge again in the opposite direction, the current intensity starts to decrease and when the value of the current intensity is zero, the capacitor is again charged with q charge in the opposite direction (Figure 2.3). The capacitor starts to discharge again, this time in the opposite direction and the previous change is repeated in the opposite direction (Figure 2.3d). In this circuit, the smaller the internal resistance of the coil, the slower the damping. The period of this vibration;

$$\tau = 2\pi\sqrt{LC} \tag{2.3}$$

is obtained by the relation.

The units of the self-induction coefficient L and the capacity C of the capacitor are as follows.

$$[L] = Henry\ (H) = \frac{Vs}{A}, [C] = Farad\ (F) = \frac{Coulomb}{V} \tag{2.4}$$

D) Magnetic Coupling:

The magnetic field around a coil through which current flows changes in proportion to its intensity. On the other hand, an induction electromotive force ($iemf$) is generated at the ends of a coil in a variable magnetic field according to Faraday's law. This $iemf$ is proportional to the timedependent variation of the intensity of the magnetic field. In this case, if another coil is placed in the magnetic field of a coil, the two coils are in a state of **magnetic coupling**.

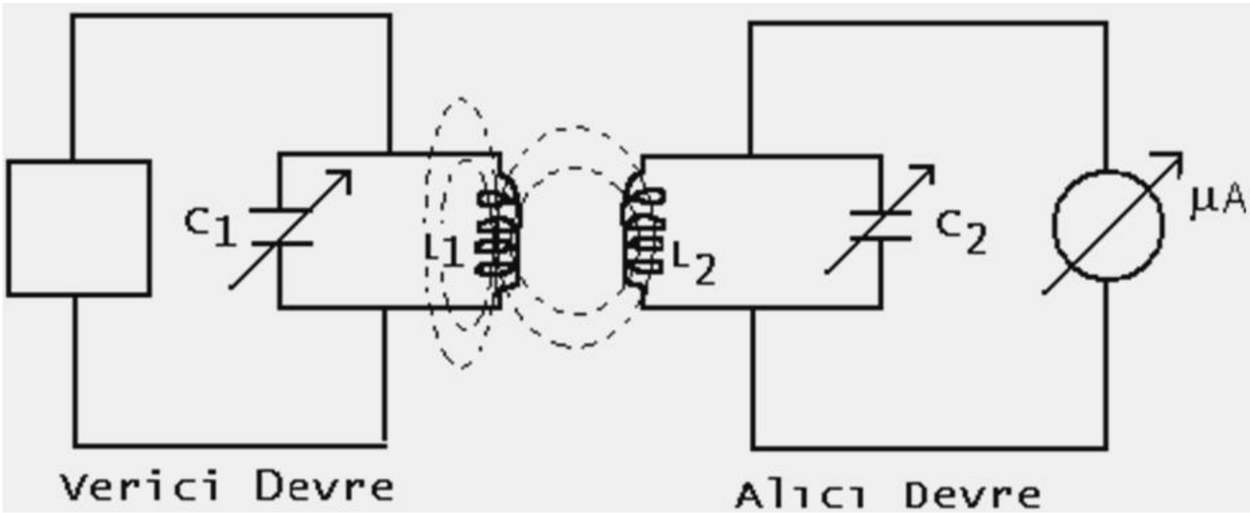

Figure 2.4

As shown in Figure 2.4, let us place a second Thomson oscillator circuit L_2C_2 near the oscillator circuit on the left side, which is electronically connected to the Thomson oscillator circuit L_1C_1 and vibrates undamped with the frequency in the Equation (**2.5**).

$$f_1 = \frac{1}{2\pi}\frac{1}{\sqrt{L_1C_1}} \tag{2.5}$$

At the end of the L_2 coil, which is magnetically coupled with the L_1 coil, an impulse of frequency f1 is generated, and the L_2C_2 circuit is forced to vibrate at the frequency f_1. However, the self-vibration frequency of the second circuit is given below.

$$f_2 = \frac{1}{2\pi}\frac{1}{\sqrt{L_2C_2}} \tag{2.6}$$

If the frequencies f_1 and f_2 are brought closer and closer to each other by changing the capacitance of the variable capacitors C_1 or C_2, the value of the current flow in the meter connected to the second circuit starts to increase. If exactly $f_1 = f_2$, the current flowing through the circuit will be maximum and the deviation on the meter will be maximum. In this case, the two circuits are resonant with each other. Hence, Equation (**2.7**) is written from relations (**2.5**) and (**2.6**).

$$L_1C_1 = L_2C_2 \tag{2.7}$$

In practice, the circuit on the left is called the transmitter, and the one on the right is the receiver.

SETUP AND PROCEDURE

Hartley oscillator circuit made with TIP 15A transistor is used as a transmitter. The resonance state is controlled by a micro ammeter connected to the receiving circuit.

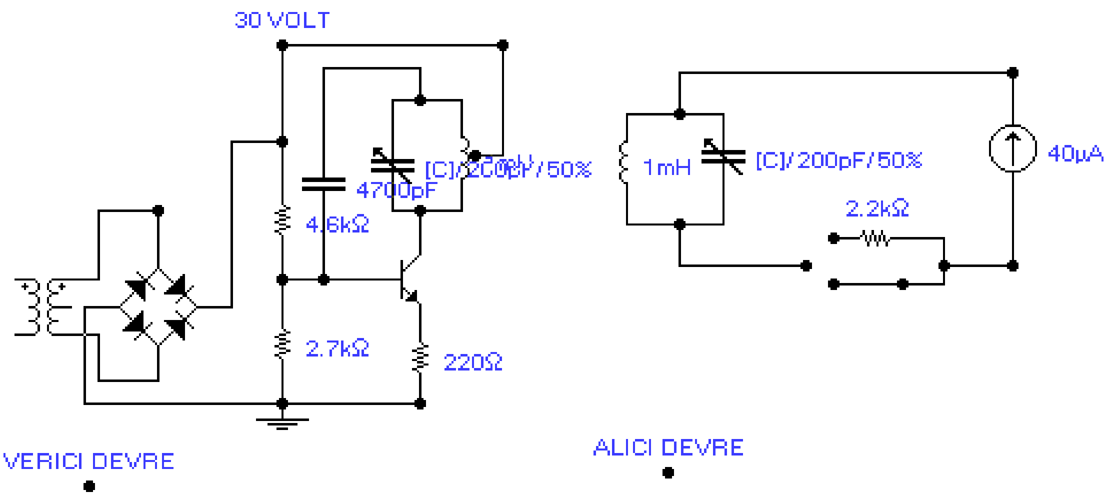

Figure 2.5: Experimental setup

1) The transmitter is switched on, and the switch in the receiver is set to the I position ($R = 0$) and placed near the transmitter in such a way as to ensure magnetic coupling (that is, the coils are perpendicular to each other and the distance between the coils is approximately 10 to 13 cm).
2) 2- The capacity C_2 is placed somewhere in the middle of the variation range (90).
3) 3- Starting from the smallest value of capacity C_1, the capacity C_1 is increased by observing the measuring instrument in the receiver. Meanwhile, the deviation of the meter starts to increase and after a maximum, it starts to decrease again. The maximum value of this deviation indicates resonance.
4) 4- If the coils are very close to each other, while approaching resonance, the needle of the meter tends to move out of the measurement area. In this case, the receiver is moved away from the transmitter. Conversely, when resonance is achieved, if the value measured from the measuring instrument is small compared to the maximum value that the instrument can measure, the receiver is brought closer to the transmitter.
5) 5- After the proper condition is achieved, the transmitter-receiver distance and C_1 capacity is kept constant. While the capacity C_2 is started and increased at appropriate intervals, both the

values of the divisions of the capacity C_2 and the currents flowing out of the circuit against them are read from the measuring instrument and recorded in Table 2.1.

Table 2.1: $R = 0$

C_2 (F)	I (μA)

6) Without changing the transmitter-receiver distance and the capacity C_1, the switch on the transmitter is turned to position 2 ($R = 2.2k\Omega$) to see the effect of the resistance on the

resonance. C_2 2 is turned back to the initial position, the measurements are repeated, and the results are recorded in Table 2.2.

Table 2.2: $R = 2.2\ k\Omega$

$C_2\ (F)$	$I\ (\mu A)$

7) $I = F(C_2)$ curves in Figure 2.6 are drawn from Table 2.1 and Table 2.2. Although these curves are drawn according to the capacity, they are resonance curves since f_2 is proportional

to C_2 capacity according to Equation (**2.6**). You will see that the peaks of the resonance curves you find here are different. Why is there such a difference?

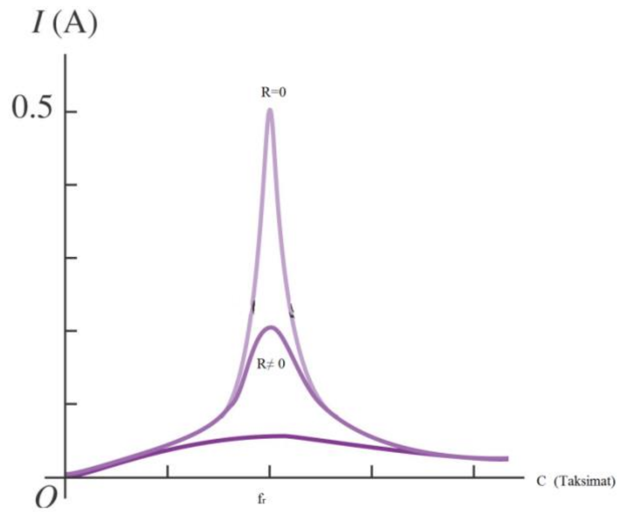

Figure 2.6