New Mansoura University
جامعة المنصورة الجديدة

PHYSICS LAB

Determination of high resistance by leakage method

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LEARNING OBJECTIVES

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- ✓ Capacitor charging action.
- ✓ Capacitor discharging action.
- ✓ Time constant calculation.
- ✓ Series and parallel capacitance.

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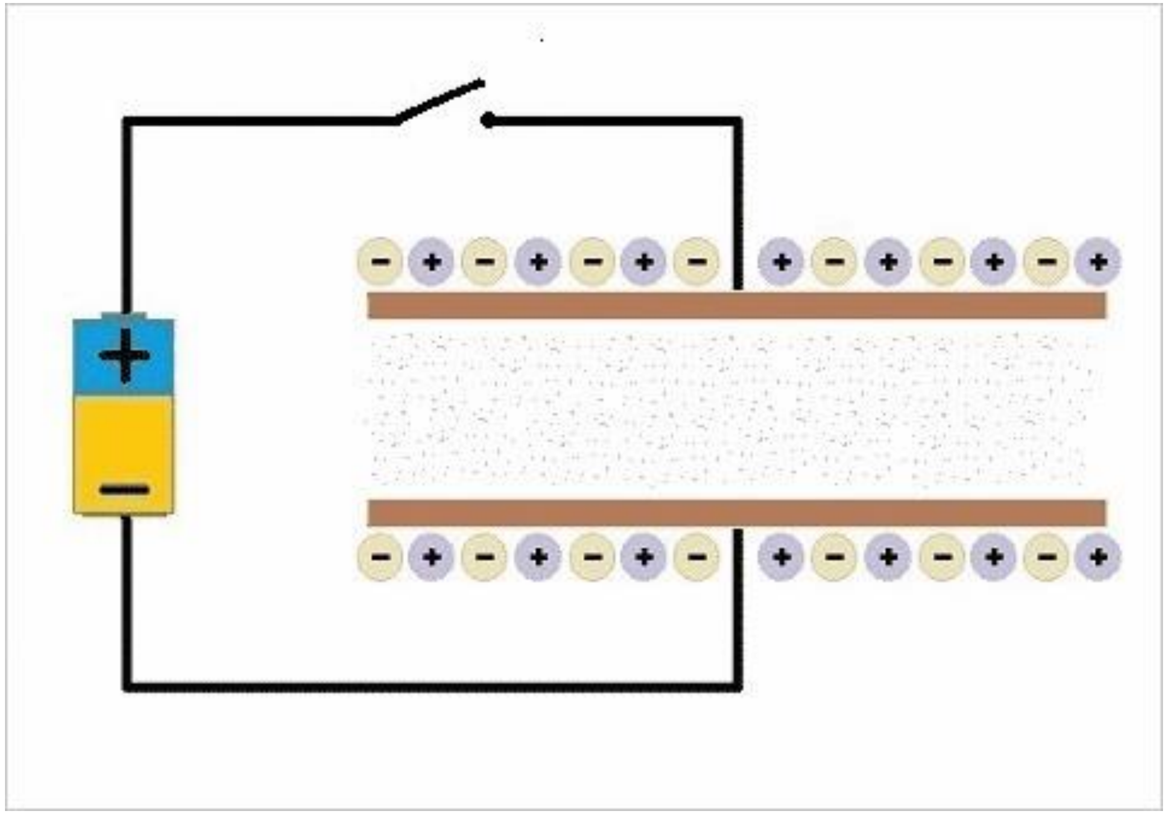

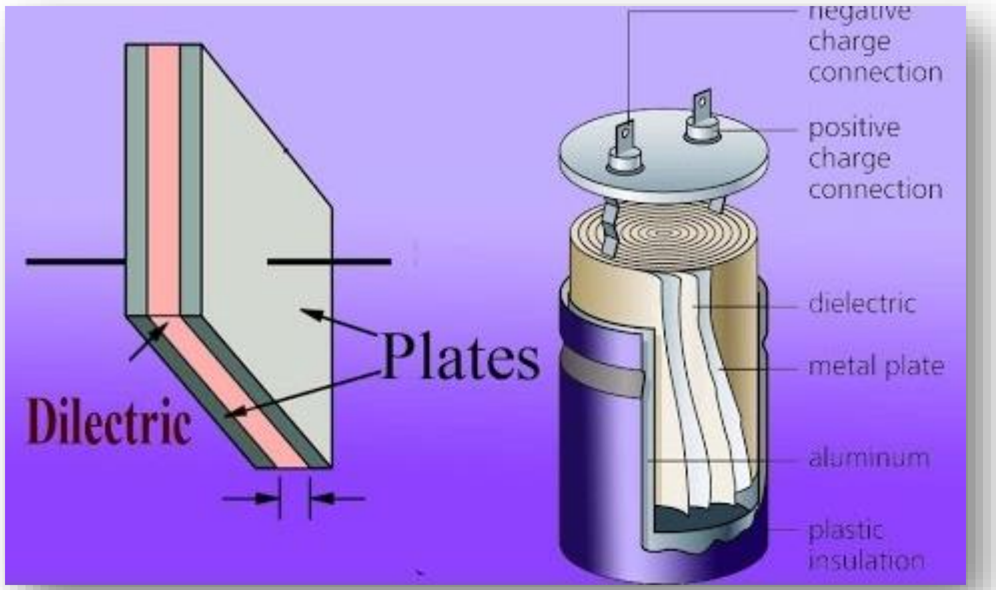

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Charging and discharging of a Capacitor

The capacitor is a device used to store energy in the form of electrical charge which can be later utilised to supply charge or energy once the power source is disconnected from it. It is used in the electric circuits of radios, computers, etc. along with these capacitors. It also provides temporary storage of energy in circuits which can be supplied when required. The property of the capacitor to store energy is known as capacitance.

Charging and Discharging of Capacitor DerivationCharging and discharging of capacitors holds importance because it is the ability to control as well as predict the rate at which a capacitor charges and discharges that makes capacitors useful in electronic timing circuits. It happens when the voltage is placed across the capacitor and the potential cannot rise to the applied value instantaneously. As the charge on the terminals gets accumulated to its final value, it tends to repel the addition of further charge accumulation.

Q = CV — (1)

In this equation, C is a constant called capacitance. It's like a measure of how much charge a conductor can hold for a given increase in potential

We can express capacitance as:

$c = \frac{Q}{V}$ (2)

This tells us that capacitance is the ratio of the charge on a conductor to its potential. The value of C depends on factors like the size and shape of the conductor, the type of material around it, and the arrangement of nearby charges. Interestingly, it doesn't depend on the material of the conductor itself.

If we set the potential (V) to 1, then from Eqn. (1):

Q = C or C = Q

Charging of a Capacitor

When you press the key, the capacitor starts to store electric charge. If we use "I" to represent the current flowing through the circuit and "Q" for the charge on the capacitor during charging, we can express the potential difference across the resistor as IR and the potential difference between the capacitor plates as Q/C. These potentials add up to the total electromotive force (ε) in the circuit. $\frac{Q}{C} + \mathrm{RI} = \varepsilon$ (1)

When the capacitor is fully charged and no more current flows (I = 0), the equation becomes $\frac{Q_0}{C} = \varepsilon$ (2)

where Q0 is the maximum charge the capacitor can hold.

From equations (1) and (2),

$$\frac{Q}{C} + \mathrm{RI} = \frac{Q_0}{C}$$

$$\frac{Q_0}{C} - \frac{Q}{C} = \mathrm{RI}$$

$$\frac{Q^0 - Q}{CR} = \mathrm{I} \quad (3)$$

Since $\mathrm{I} = \frac{dQ}{dT}$

$$\frac{Q^0 - Q}{CR} = \frac{dQ}{dT}$$

When T=0,Q=0 and T=T and Q=Q

By integrating both sides, we get

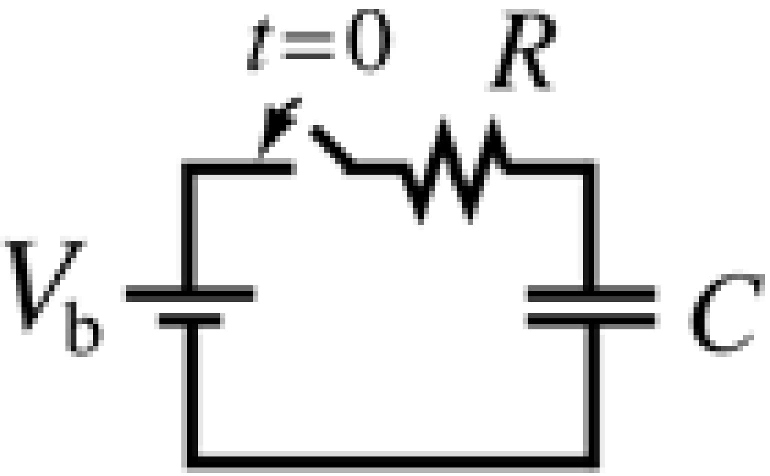
$$\int_0^Q \frac{dQ}{(Q_0 - Q)} = \int_0^t \frac{dt}{CR} = \frac{1}{CR}\int_0^t dt$$

$$Q = Q_0\left(1 - e^{-t/\tau}\right)$$

Here, $\tau = CR$

Charging a Capacitor

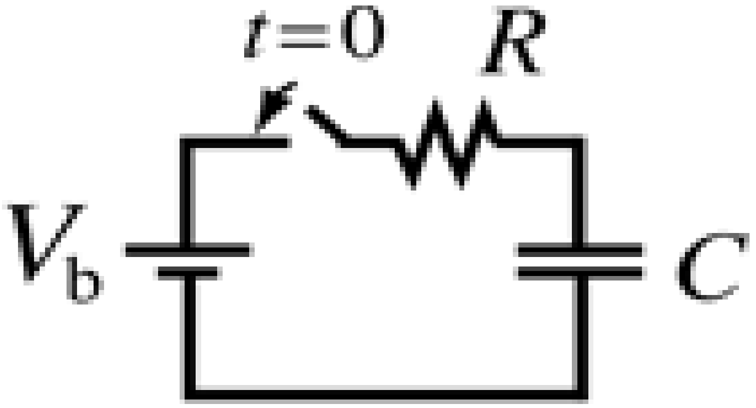
When a battery is connected to a series resistor and capacitor, the initial current is high as the battery transports charge from one plate of the capacitor to the other. The charging current asymptotically approaches zero as the capacitor becomes charged up to the battery voltage. Charging the capacitor stores energy in the electric field between the capacitor plates. The rate of charging is typically described in terms of a time constant RC.



$$V_b = V_R + V_C$$

$$V_b = IR + \frac{Q}{C}$$

Charging a Capacitor



$$V_b = V_R + V_C$$

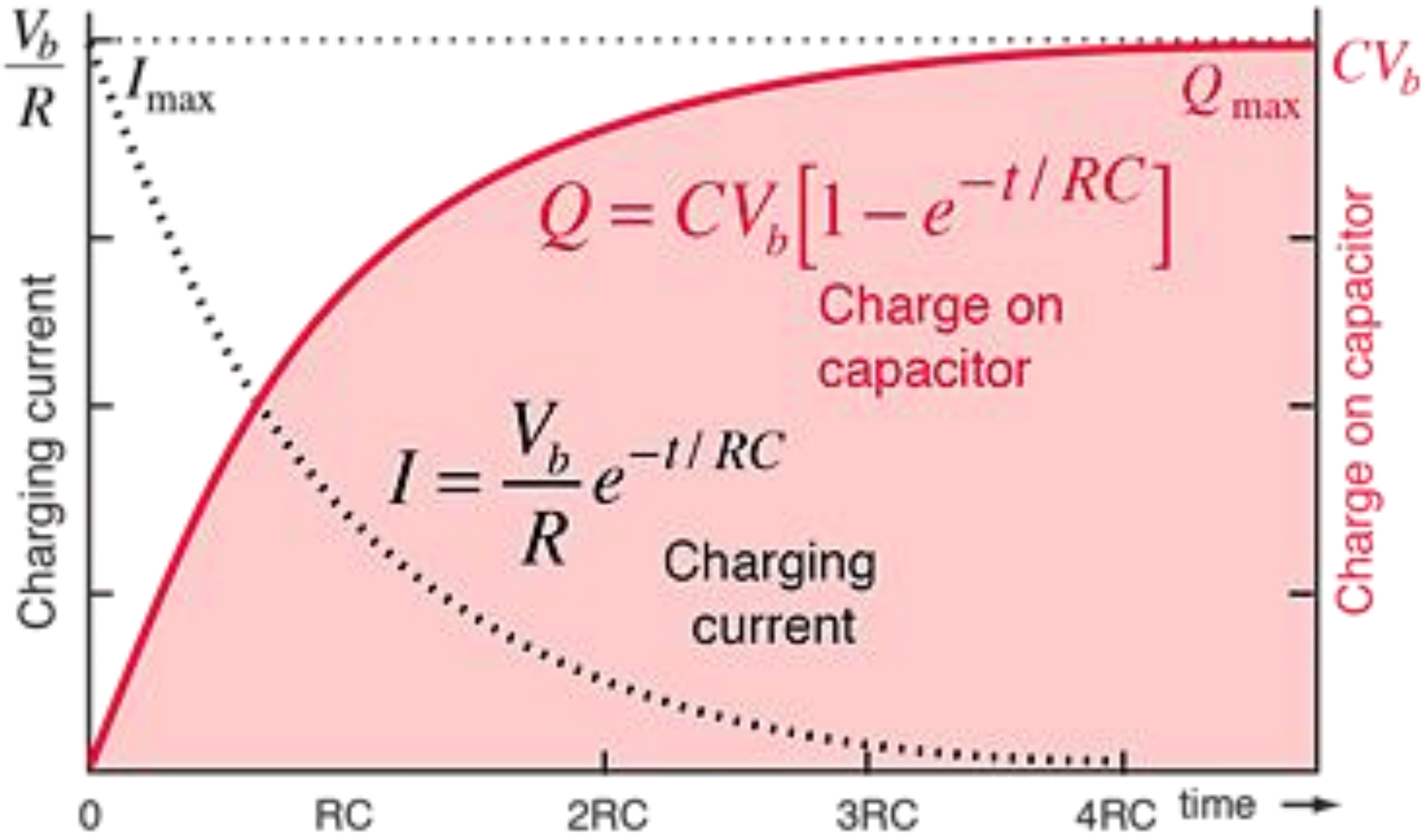
$$V_b = IR + \frac{Q}{C}$$

As charging progresses,

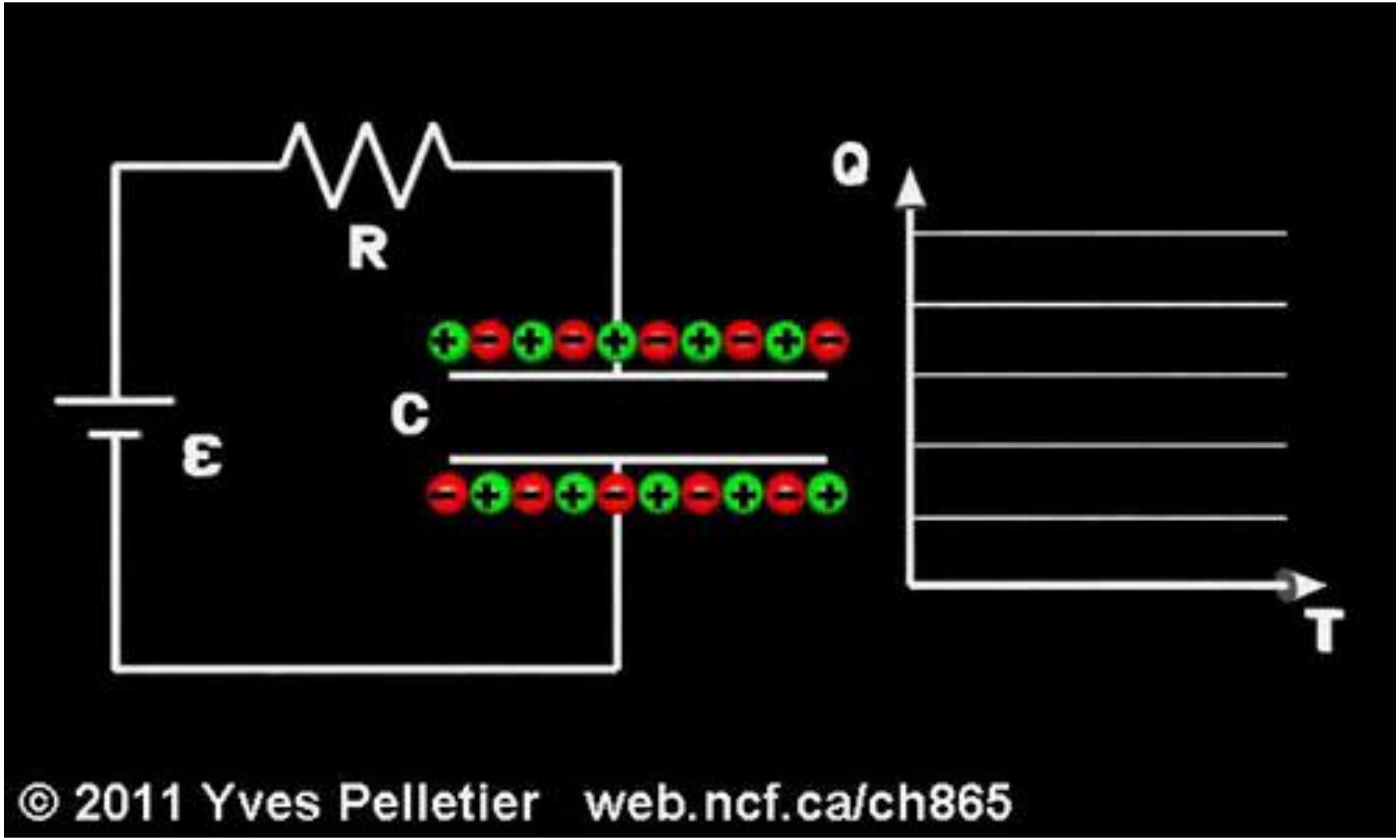
$$V_b = \underset{\Downarrow}{IR} + \frac{Q}{C}\Uparrow$$

current decreases and charge increases.

Charging a Capacitor



Charging a Capacitor



Discharging a Capacitor

Consider a capacitor has initial charge Q_o discharge through a resistance R, then after a time t the charge will be

$$Q = Q_o\, e^{-t/RC} \qquad (1)$$

this equation can be written as

$$I = I_o \qquad (2)$$

where I is the current after time t and I_o is the initial current.

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Charging a Capacitor

Time constant (T.C.)

The time constant of the circuit is given by

$$T.C. = RC \qquad (3)$$

Which is defined as the time required for the capacitor to discharge 36.8% from its initial charge.

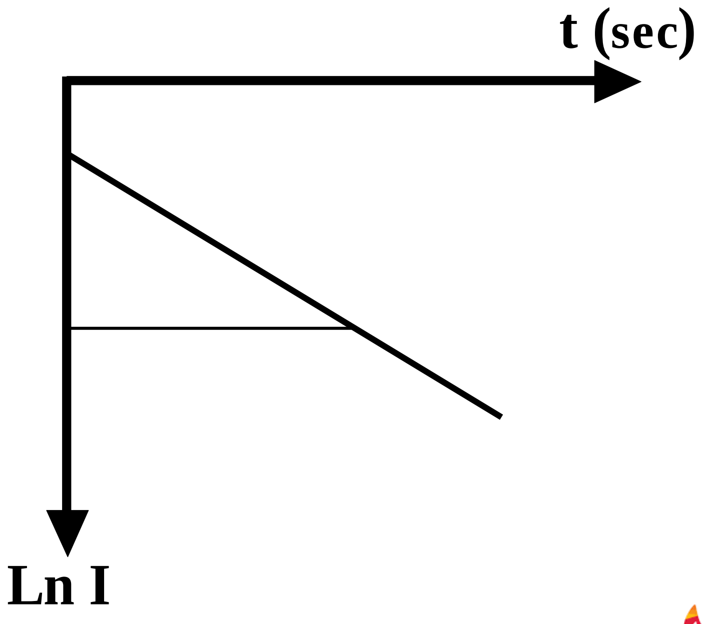
Where R is the resistance and C is the capacitance.

From eqn. (2)

$$\text{Ln } I = \text{Ln } I_o - \frac{1}{RT}t \qquad (4)$$

which is equation of a straight line between Ln I and t of

$$\text{Slope} = -\frac{1}{RC}$$



Apparatus

D.C. power supply.

capacitor.

Resistor.

Ammeter.

Two ways key.

Stopwatch.

Method

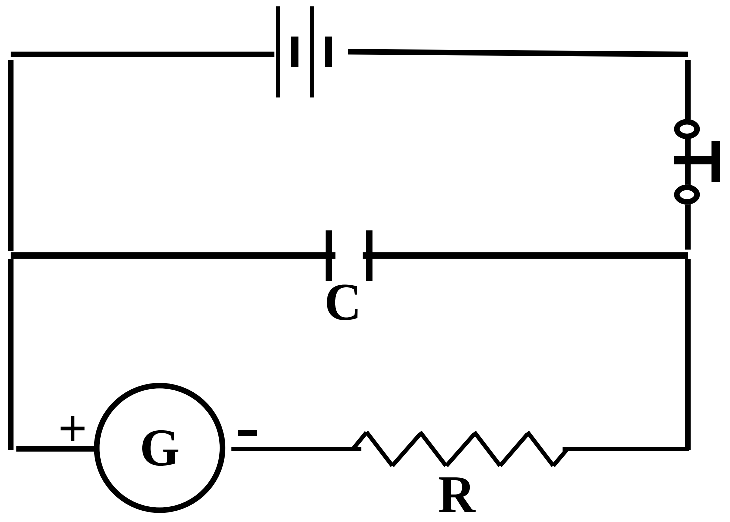
1. Connect the circuit as shown in Fig.

2. Switch on the key until the capacitor is charged.

3. Switch off the key and record the variation of the current I with time t.

4. Plot a graph between Ln I and t as shown in Fig.

5. Determine the slope of the obtained straight line and calculate R.



How to measure

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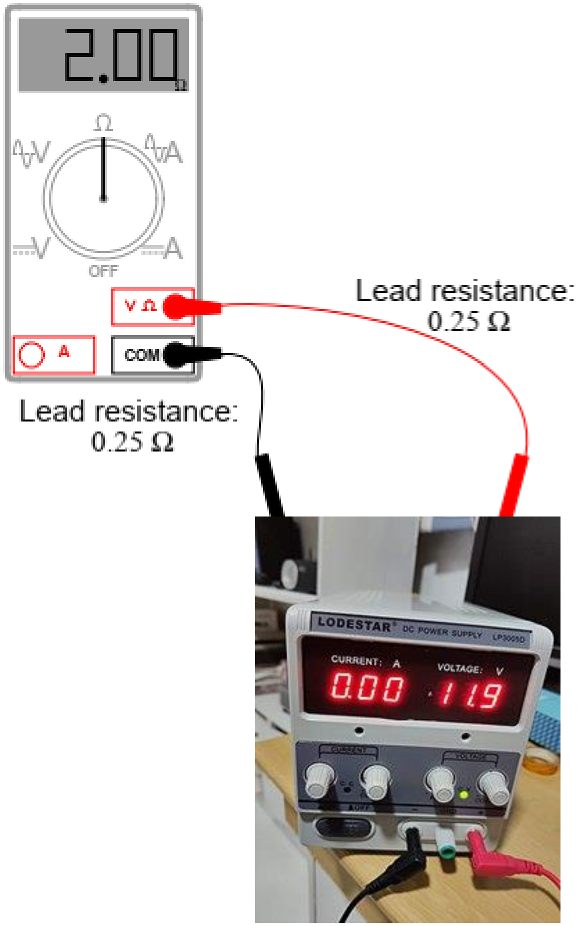
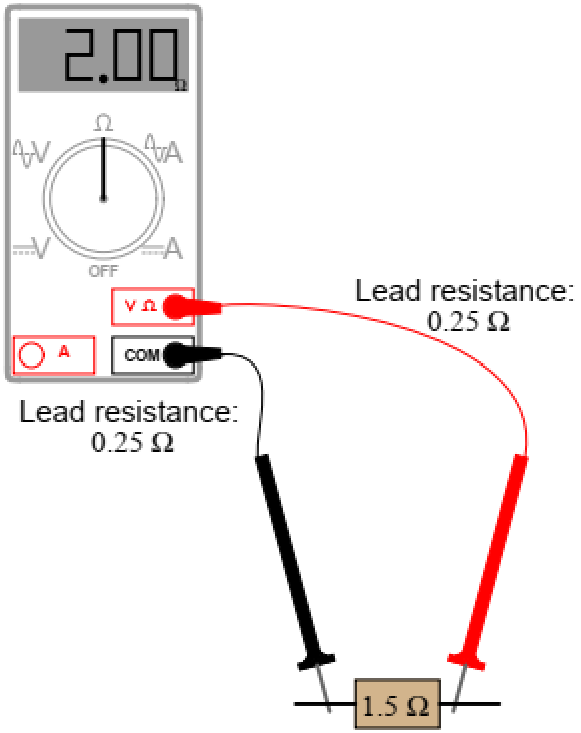
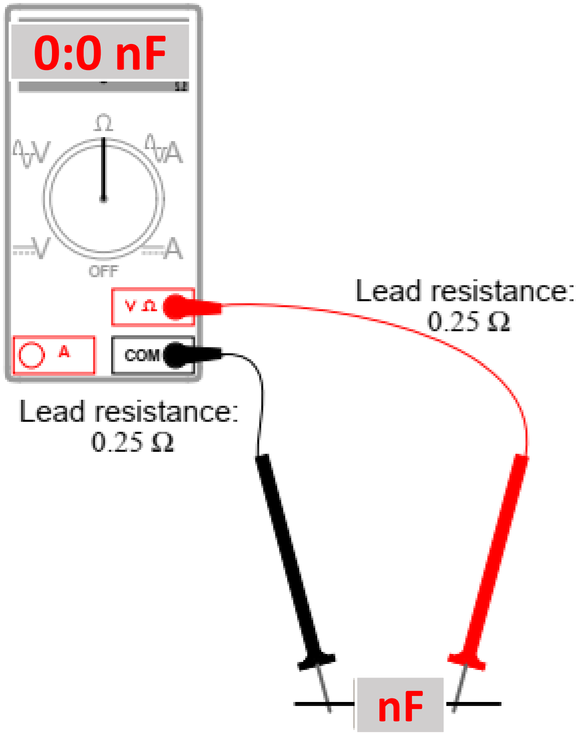
voltage



Resistance



Capacitance



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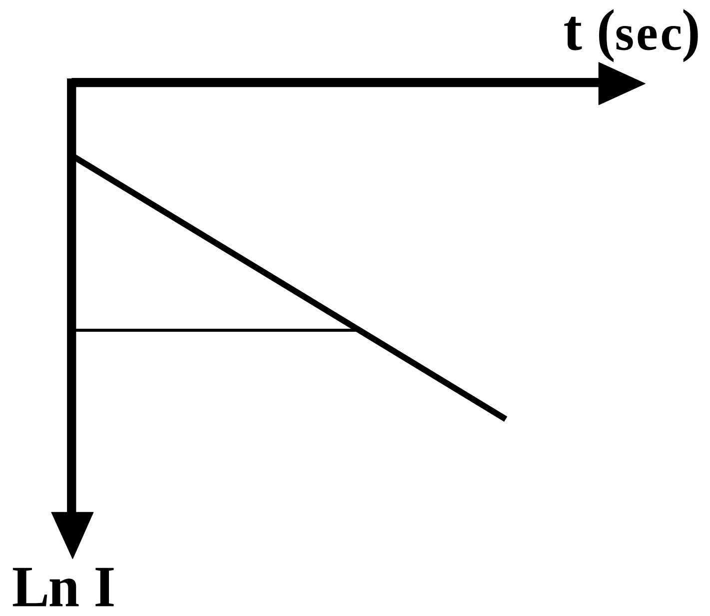
Results

Time (sec.)					
I (µA)					
Ln I (µA)					

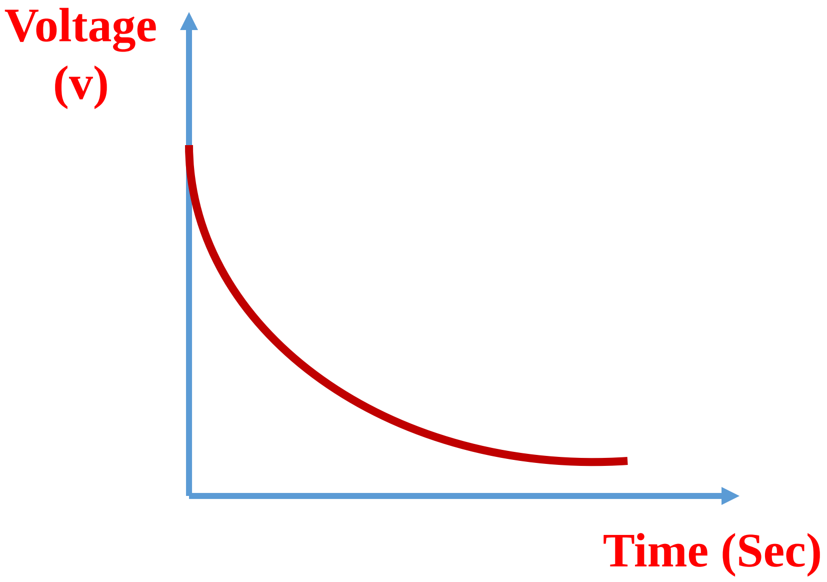
Slope = - $\frac{1}{RC}$

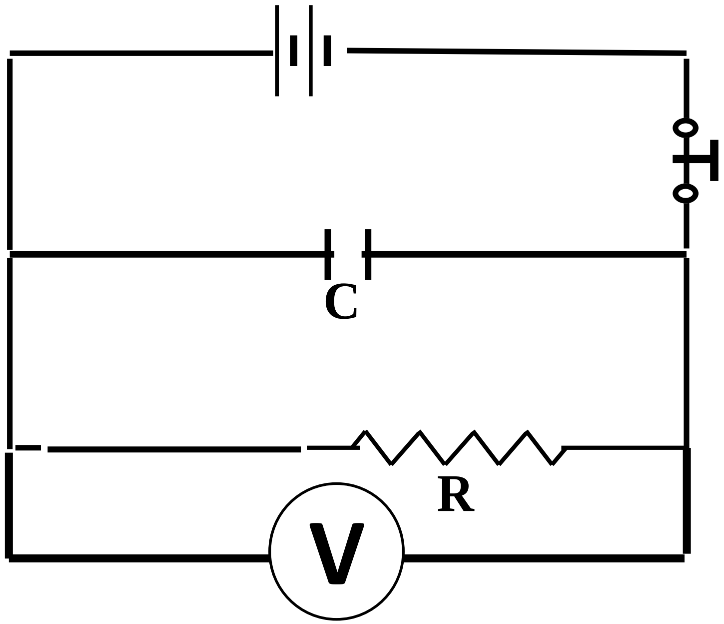
T.c. = $\frac{1}{Slope}$ (Sec)



Exercises

Time (sec.)	0	20	40	60	…………….
Voltage (V)					





What happens if another capacitor is added to the first capacitor.

1- in parallel.

2- in series.

thank you!