Charging and Discharging a Capacitor Experiment

I. INTRODUCTION

1.1. Capacitor

Consider two conductors carrying charges of equal magnitude but of opposite sign, as shown in Figure1. Such a combination of two conductors is called a **capacitor.** The conductors are called *plates.* A potential difference *V* exists between the conductors due to the presence of the charges. Because the unit of potential difference is the volt, a potential difference is often called a **voltage.** We shall use this term to describe the potential difference across a circuit element or between two points in space.

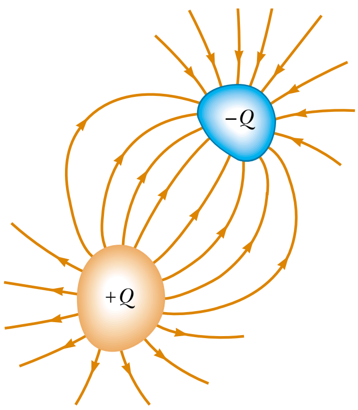


Figure 1. A capacitor consists of two conductors carrying charges

Experiments show that the quantity of charge *Q* on a capacitor is linearly proportional to the potential difference between the conductors. The proportionality constant depends on the shape and separation of the conductors. We can write this relationship as $Q = C\,\Delta V$ if we define capacitance as follows:

The **capacitance** *C* of a capacitor is the ratio of the magnitude of the charge on either conductor to the magnitude of the potential difference between them:

$$C \equiv \frac{Q}{\Delta V} \qquad \textbf{(26.1)}$$

Note that by definition *capacitance is always a positive quantity.* Furthermore, the potential difference *V* is always expressed in Equation 26.1 as a positive quantity. Because the potential difference increases linearly with the stored charge, the ratio *Q* / *V* is constant for a given capacitor. Therefore, capacitance is a measure of a capacitor's ability to store charge and electric potential energy.

From Equation 26.1, we see that capacitance has SI units of coulombs per volt. The SI unit of capacitance is the **farad** (F), which was named in honor of Michael Faraday:

$$1\ \mathrm{F} = 1\ \mathrm{C/V}$$

Any two conductors separated by an insulator (or vacuum) form a capacitor. A capacitor is a circuit element that accumulates charge when connected to a circuit. This accumulating charge gives rise to a voltage difference V across its terminals (plates). In most practical applications, each conductor initially has zero net charge and electrons are transferred from one conductor to the other. This is called charging the capacitor. Then, the two conductors have charges with equal magnitude and opposite sign, and the net charge on the capacitor as a whole remains zero.

When we say that a capacitor has charge Q (or, a charge Q is stored on the capacitor), we mean that the conductor at higher potential has charge +Qand the conductor at lower potential has charge -Q.

The electric field at any point in the region between the conductors is proportional to the magnitude Qof charge on each conductor. It follows that the potential difference V_{ab} between the conductors is also proportional to Q .

In the simple act of charging or discharging a capacitor, we find a situation in which the currents, voltages and powers do change with time.

1.2 Charging a Capacitor

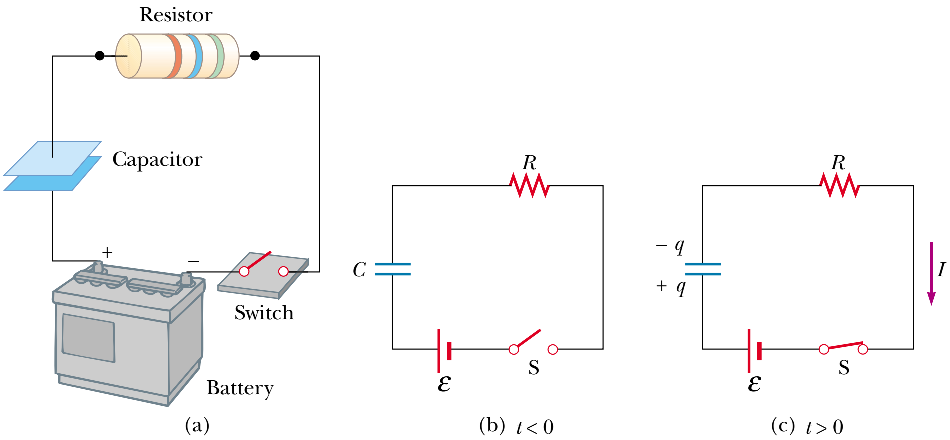


Figure 2. Charging a capacitor

Let us assume that the capacitor in Figure 2 is initially uncharged. There is no current while switch S is open If the switch is closed at t =0, however, charge begins to flow, setting up a current in the circuit, and the capacitor begins to charge.Note that during charging, charges do not jump across the ca- pacitor plates because the gap between the plates represents an open circuit. Instead, charge is transferred between each plate and its connecting wire due to the electric field established in the wires by the battery, until the capacitor is fully charged. As the plates become charged, the potential difference across the capacitor increases. The value of the maximum charge depends on the voltage of the battery. Once the maximum charge is reached, the current in the circuit is zero because the potential difference across the capacitor matches that supplied by the battery.

To analyze this circuit quantitatively, let us apply Kirchhoff's loop rule to the circuit after the switch is closed. Traversing the loop clockwise gives

$$\boldsymbol{\varepsilon} - \frac{q}{C} - IR = 0$$

1.3 Discharging a Capacitor

Now let us consider the circuit shown in Figure 3, which consists of a capacitor carrying an initial charge Q , a resistor, and a switch. The *initial* charge Q is not the same as the *maximum* charge Q in the previous discussion, unless the dis- charge occurs after the capacitor is fully charged (as described earlier). When the switch is open, a potential difference Q/C exists across the capacitor and there is zero potential difference across the resistor because *I* = 0. If the switch is closed at *t* = 0, the capacitor begins to discharge through the resistor.

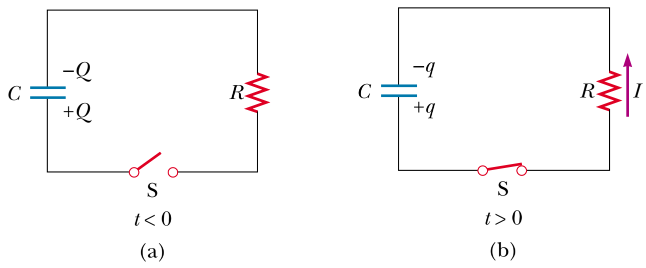


Figure 3. Discharging a capacitor

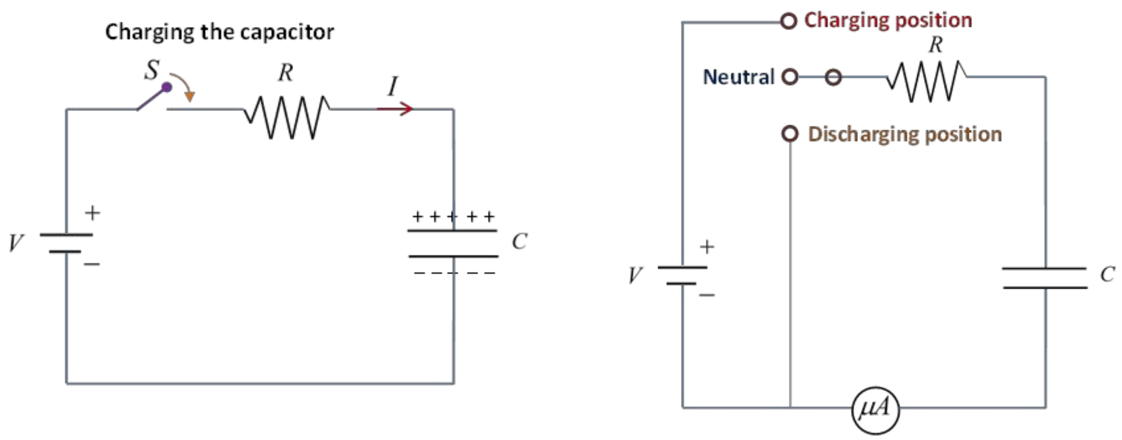
At some time *t* during the discharge, the current in the circuit is *I* and the charge on the capacitor is *q* . To obtain the appropriate loop equation for the circuit in Figure 3:

$$-\frac{q}{C} - IR = 0$$

II.APPARATUS

Resistance, cables, multimeter, basic electrical set, capacitors

III. EXPERIMENTAL PROCEDURE



1) Set up the circuit provided on the up side.

2) If you have one multimeter, prepare it for 2 situations. You can use your multimeter for measuring current and voltage.

3) Please make the connection of power supply.

4) Do not forget that Ammeters are connected in series so that the current flows through them. The ideal ammeter has a resistance of zero. Real ammeters have some internal resistance. Voltmeters are connected in parallel to resistive elements in the circuit so that they measure the potential dfference across (on each side of) the element.

5) In this experiment, the current flowing through a resis- tor will be measured as the voltage across the resistor is varied. So please fill the Tabe 1 for this circuit.

6) At time t=0 when we first close the switch S in the circuit, the capacitor has no charge, and so the current I will be determined by the resistor alone. The capacitor here acts as a short circuit. At any later time, the charge will start to increase while the current decrease. Then, q (t) will reach the constant value of q = VC . At this instant the capacitor will be fully charged. The current, on the other hand, will be zero at this instant. At this step try to fill the Table 1.

Resistance	Capacitor
$R(k\Omega)$	$C(\mu F)$
.....	.....

7) Find the experimental time constant τ of the circuit from the I vs t graphs. Find it from

Table1 Charging a capacitor

t(second)	Measured current(A)
0	
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Table2 Discharging a capacitor

t(second)	Measured current(A)
0	
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.	

both the charging and discharging graphs. Then, compare experimental time constant τ with its theoretical value obtained by

$$\tau = RC$$

Ref.

1) Serway, R, Beichner,R. Physics for Scientists ans engineers with modern physics, Fifth edition. 2000.
2) Rentech.Experiments in electricity, student guide. 2013.