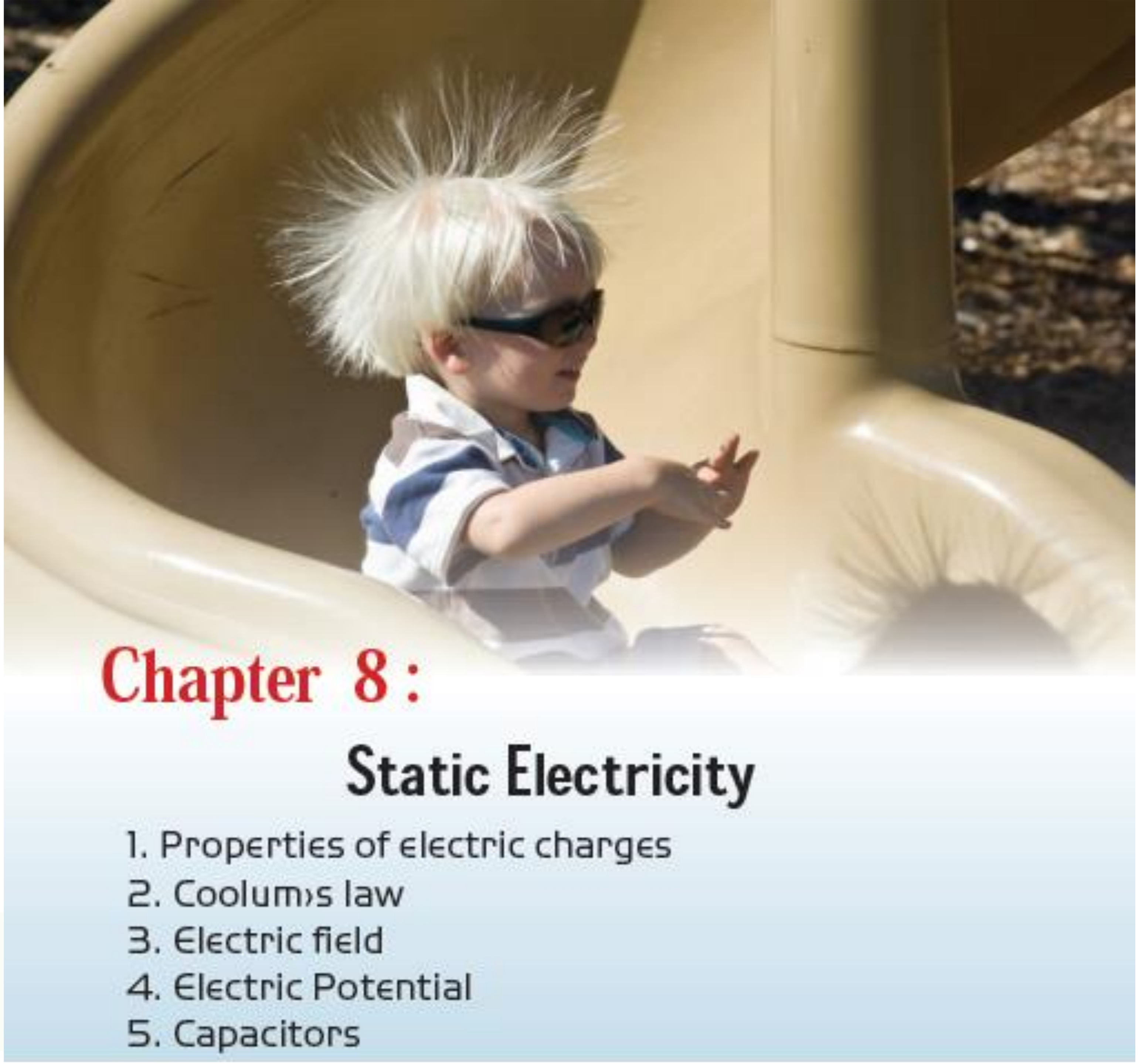
Static Electricity



Prepared by

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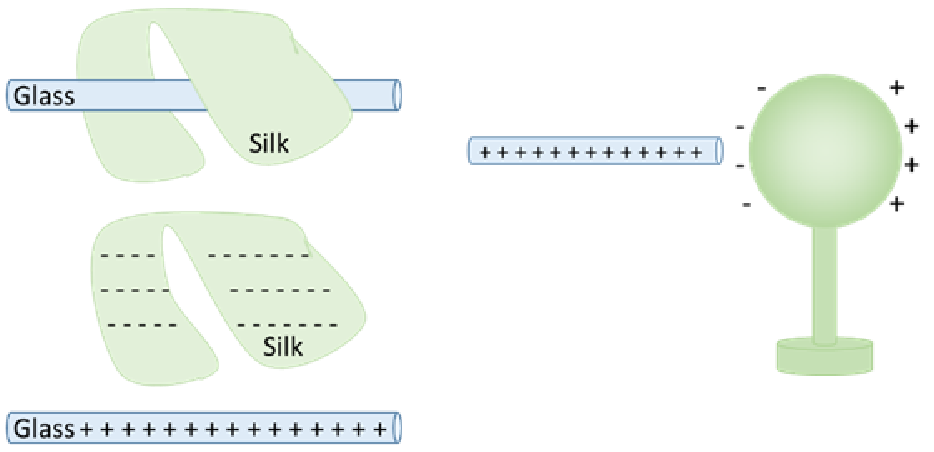
1. Properties of Electric Charges

In Nature there are two types of electrical charges, the first being negative charges such as those carried by the electron and others positive charges such as proton charges.

The magnitude of electrical charge of electron $e = 1.6 \times 10^{-19}$ C (coulomb)

Ways to get a charged body:

1. Electrification of an uncharged object with friction with another object.
2. Electrification of an uncharged object by contact with another charged object.
3. Electrifying an uncharged object without contact with another charged object.

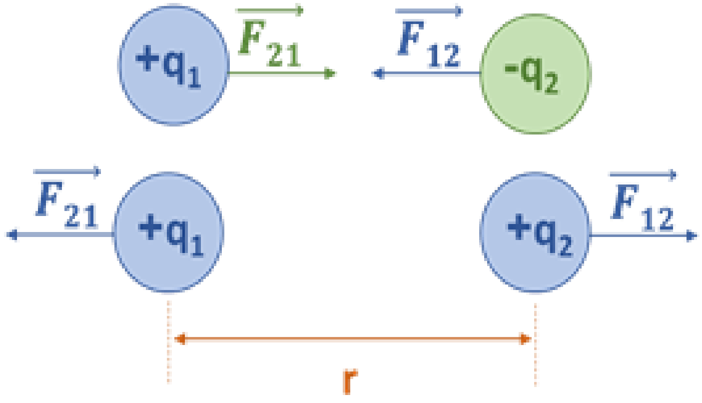


2. Coulomb's Law

Coulomb's Law: States that the magnitude of electrical force between two charged particles is directly proportional to the product of multiplying the amount of two charges ($q_1.q_2$) and inversely with the square of the distance between them (r^2)

$$F = k_e \frac{q_1 \cdot q_2}{r^2}$$

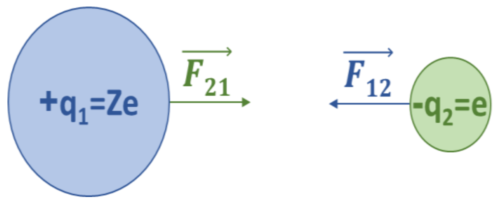
$$k_e = \frac{1}{4\pi\varepsilon_o} \cong 9 \times 10^9 \, N \cdot m^2/C^2$$



2. Coulomb's Law

Example: 8.1

Find the amount of electrical force between the charge of the nucleus of the sodium atom and the electron in one of the orbits of the atom away from the nucleus $1.2 \times 10^{-11}\ m$. Atomic number of sodium Z=11.



Solution

The forces between the nucleus of the sodium atom and the electron are attractive force.

$$F = k_e \frac{q_1 \cdot q_2}{r^2}$$

$$= (9 \times 10^9)\frac{(11 \times 1.6 \times 10^{-19}) \times 1.6 \times 10^{-19}}{(1.2 \times 10^{-11})^2} = 1.76 \times 10^{-5} N$$

2. Coulomb's Law

Example: 8.2

Find the amount of electrical charge affecting another positive charge of 5μC and 25 cm away from both are putting in the vacuum, with the electrical force between them equal to 2.4 N for the outside, and determine the type of unknown charge.

Solution

$$F_{12} = k_e \frac{q_1 \cdot q_2}{r^2}$$

$$q_1 = \frac{F_{12} \cdot r^2}{k_e \cdot q_2}$$

$$= \left(\frac{2.4 \times (0.25)^2}{(9 \times 10^9)(5 \times 10^{-6})}\right)$$

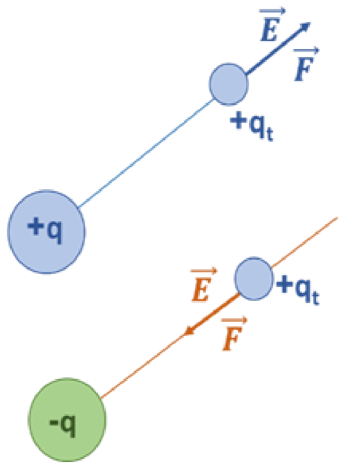
$$= 3.33 \times 10^{-6} C$$

Since the force is out (repulsive) the two charges are similar, and from there we find that the required charge is positive.

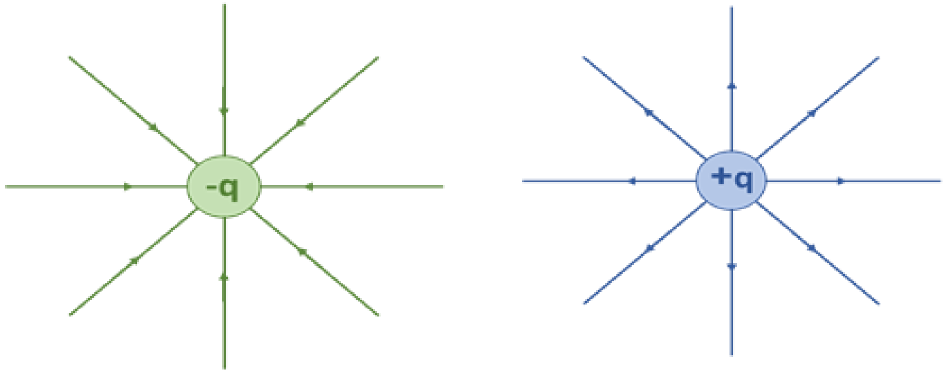
3. Electric field

The electrical field at a point: is defined as the electrical force affecting a positive point-test charge of the unit placed at that point.

$$E = \frac{F}{q_t} = k_e \frac{q}{r^2}$$



Electric Field Lines



3. Electric field

Example: 8.3

Find the magnitude of the electric field at a point 5 m away from a positive point charge of 10 μc.

Solution

$$E = k_e \frac{q}{r^2}$$

$$= 9 \times 10^9 \frac{10 \times 10^{-6}}{5^2} = 3600 \ \frac{N}{C}$$

4. Electric Potential

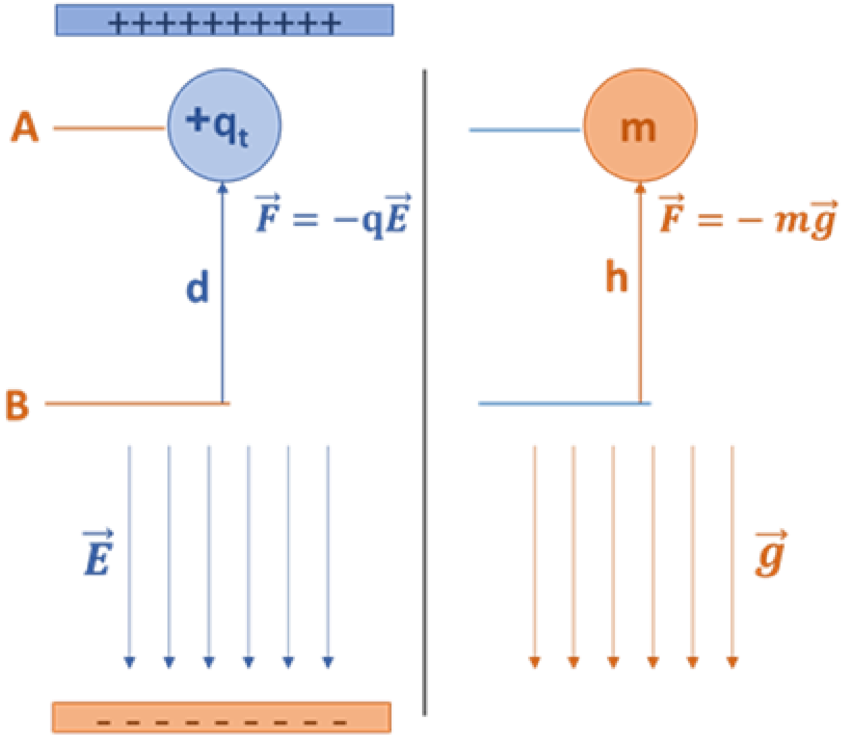
The voltage difference ΔV between two points is defined by the amount of work exerted to moving the small positive charge equal to unity, between these two points in reverse direction of the electrical field.

$$\Delta V = V_A - V_B = \frac{W}{q_t}$$

$$\Delta V = Ed$$

The IS unit of The voltage difference is volt v.

$$1\,V = \frac{1\,\mathrm{J}}{1\,C}$$



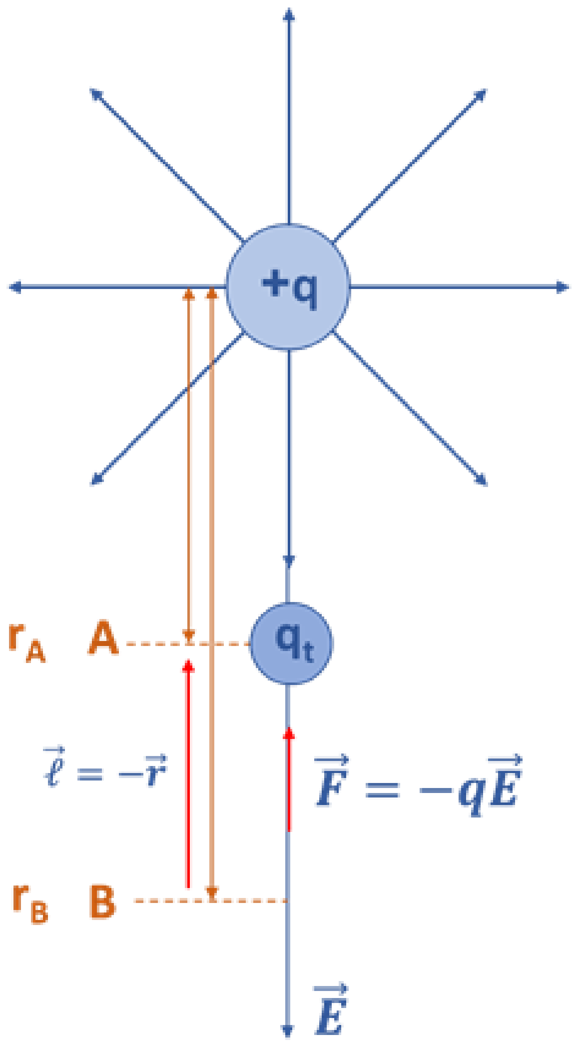
4. Electric Potential

Example: 8.5
Calculate the voltage difference between capacitive plates where the distance between the plates is 0.2 cm, if the electric field strength inside the capacitor is equal to 1000 $\frac{N}{C}$.
Solution
$\Delta V = Ed$ $= 1000 \times 0.002 = 2\ V$

4. Electric Potential

Electrical voltage for point charge

$$V = k_e \frac{q}{r}$$



Example

Find the voltage generated by the charge q = - 2 μC at point P, which is located on the 6 cm away from this charge.

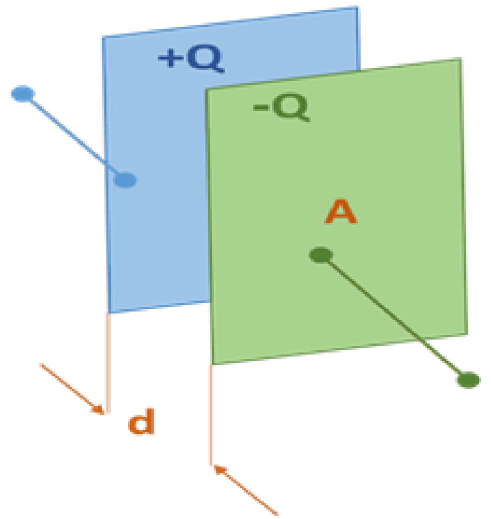
Solution

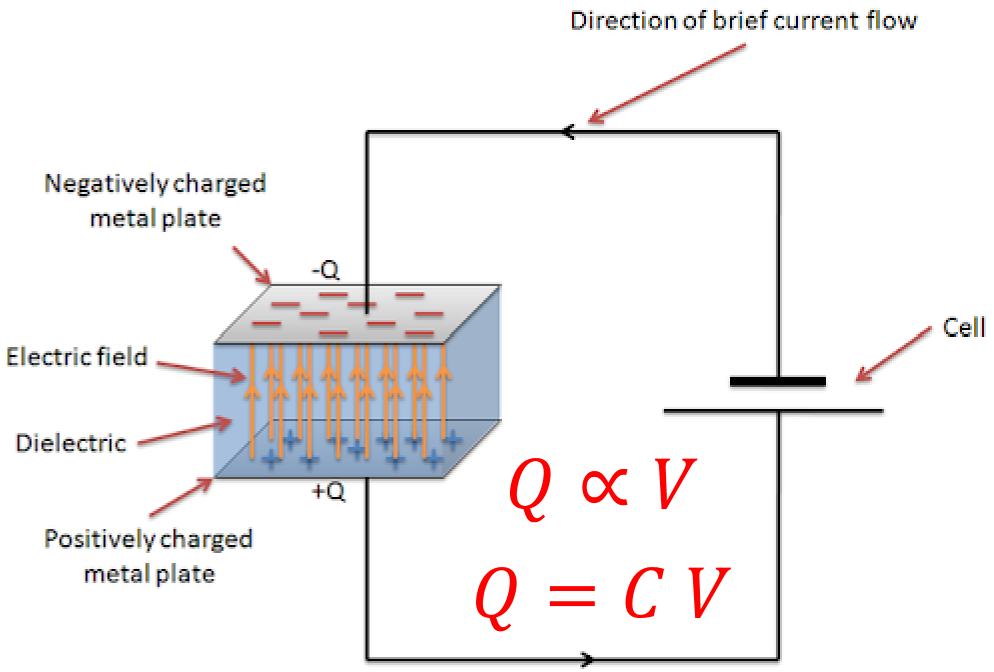
$$V = k_e \frac{q}{r}$$

$$= (9 \times 10^9) \frac{(-2 \times 10^{-6})}{0.06} = -3 \times 10^5 \ V$$

5. Capacitors

Capacitance C: defined as the amount of electrical charge accumulated on the capacitor plate when a unit difference of voltage is applied to it, measured in units of Farad F.





$$Q \propto V$$

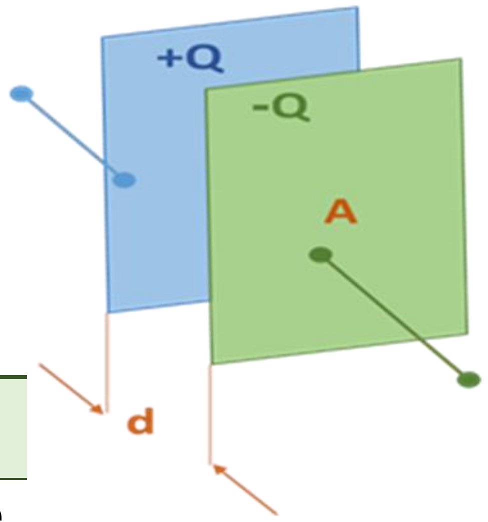
$$Q = C\,V$$

5. Capacitors

Parallel-Plate Capacitors

$$C = \frac{\varepsilon_o A}{d}$$

$$\varepsilon_o = 8.85 \times 10^{-12} \frac{C^2}{N.m^2}$$



Example: 8.7

Parllel plates capacitor has a surface dimension of 10 cm x 10 cm, and the distance between plates is 0.2 cm. Calculate the capacitance of the capacitor if you know that the isolation medium between the capacitor plates is the vacuum.

Solution

$$C = \frac{\varepsilon_o A}{d}$$

$$= \frac{(8.85 \times 10^{-12}) \times (0.1 \times 0.1)}{0.002} = 4.42 \times 10^{-11}\ F$$

5. Capacitors

The electrical energy stored in the capacitor

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

Example: 8.8

capacitor has a capacitance of 20 μF, and the difference in voltage between the two terminals is 1000 V. Calculate the electrical energy stored in it.

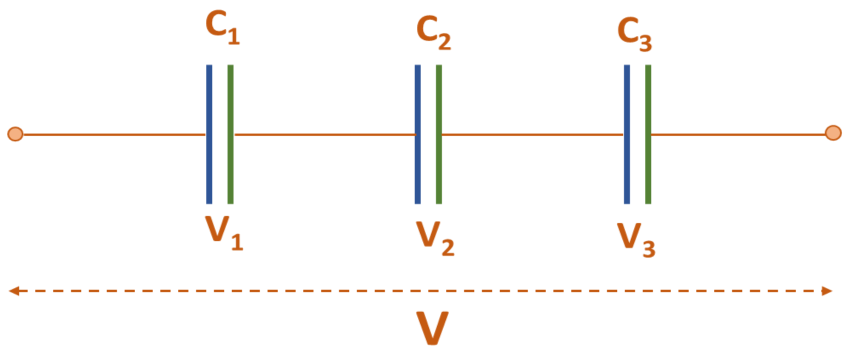
Solution

$$U = \frac{1}{2} V^2 . C$$

$$= \frac{1}{2} (1000)^2 . (20 \times 10^{-6}) = 10\ J$$

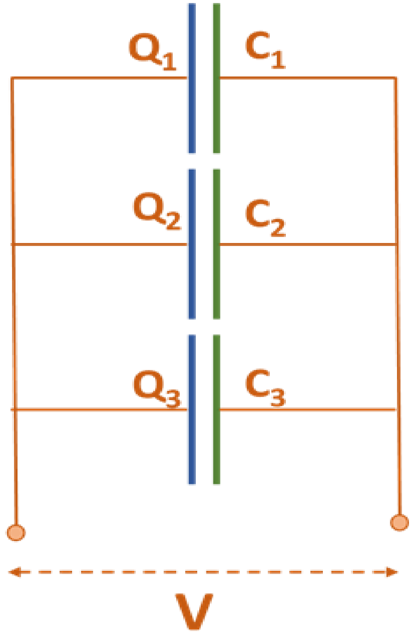
5. Capacitors

Connecting the capacitors



$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Connecting capacitors in parallel:



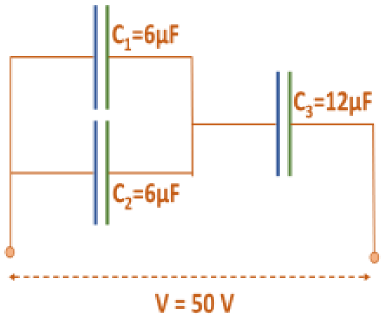
$$C_{eq} = C_1 + C_2 + C_3$$

5. Capacitors

Example: 8.9

Three capacitors connected, as shown in the Figur

a. Calculate the total capacitance in the circle.
b. Calculate the total electrical charge.
c. Calculate the electrical charge generated on each capacitor.



Solution

a. First find the capacitance of the capacitors group C1 and C2 connected in parallel:

$$C_{12} = C_1 + C_2 = 6 + 6 = 12\ \mu F$$

Total capacitance ($C_{12} = C_1 + C_2$) connected with capacitor C_3 in series

$$\frac{1}{C_t} = \frac{1}{C_{12}} + \frac{1}{C_3} = \frac{1}{12} + \frac{1}{12} = \frac{2}{12}$$

$$C_t = \frac{12}{2} = 6\ \mu F$$

b. The total electrical charge is calculated from:

$$Q_t = C_t \,.\, V_t = (6 \times 10^{-6}).(50) = 3 \times 10^{-4}\ C$$

c. To calculate the electrical charge on each capacitor, we find the voltage difference first on each capacitor.

The total voltage difference will be distributed evenly over the capacitor obtained C_{12} and the capacitor C_3 because they are connected in series and equal in capacitance $C_{12} = C_3 = 12\mu F$. If the voltage difference on them is $V_3 = V_{12} = 25$ volt The first and second capacitors are connected in parallel, that is, the voltage difference is equal in both capacitors:

$$V_1 = V_2 = 25 \text{ volt}$$