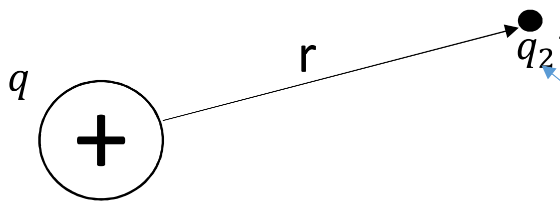
Electric field and electric potential of a point charge

Electric field $\boldsymbol{E} = \frac{\boldsymbol{F}}{q}$

Electric potential $V = \frac{W}{q}$

$$F = k\frac{q \quad q_2}{r^2}$$

$$\boldsymbol{E} = \frac{\boldsymbol{F}}{q_2} = \frac{k\frac{q \quad q_2}{r^2}}{q_2} = k\frac{q \quad q_2}{r^2} \times \frac{1}{q_2}$$



E, V ??

Imagine putting a test charge q_2

$$\boldsymbol{E} = k\frac{q}{r^2}$$

The electric potential at any point has meaning only with reference to a potential at zero. Often infinity is chosen, although for practical purposes the surface of the earth may be regarded as at zero potential. The potential of any point is then the work done in transferring a small positive test charge from the reference point to the point in question.

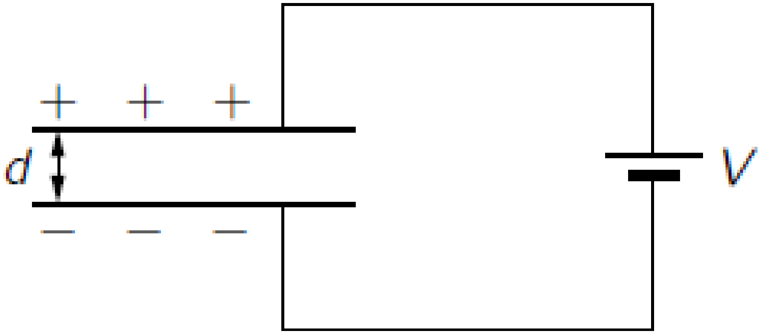
$$\mathrm{V} = \mathrm{k}\frac{q}{r}$$

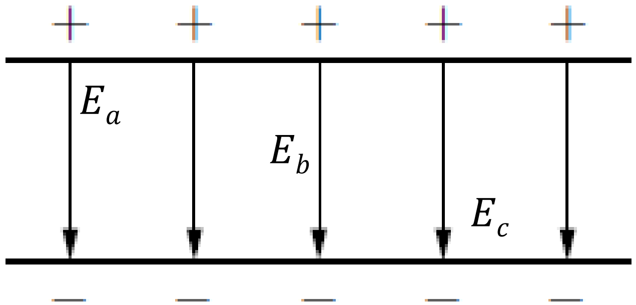
Electric field and electric potential of a point charge

Example 1.4: Electric field and electric potential due to a point charge

Calculate (a) the electric field, and (b) the electric potential at a distance of 15 cm from an isolated point charge of 5 μC.

Electric field between parallel plates





This is an important arrangement because it produces a **uniform electric field in the space between the plates**. That is, an electric field whose value is the same (in both magnitude and direction) at any point in the space.

$$\boldsymbol{E_a = E_b = E_c}$$

The electric field between the plates always points from the positive plate to the negative plate and its magnitude is given by

$$E = \frac{V}{d}$$

The above equation gives units for electric field as Vm^{-1}. (1 Vm^{-1} is the same as $1NC^{-1}$.)

Electric field between parallel plates

Example 1.5: Charged particle in the field of parallel plates

A 1 kV p.d. is connected across two parallel metal plates which are 10 cm apart. Calculate

(a) the magnitude of the electric field between them;

(b) the energy gained in eV by

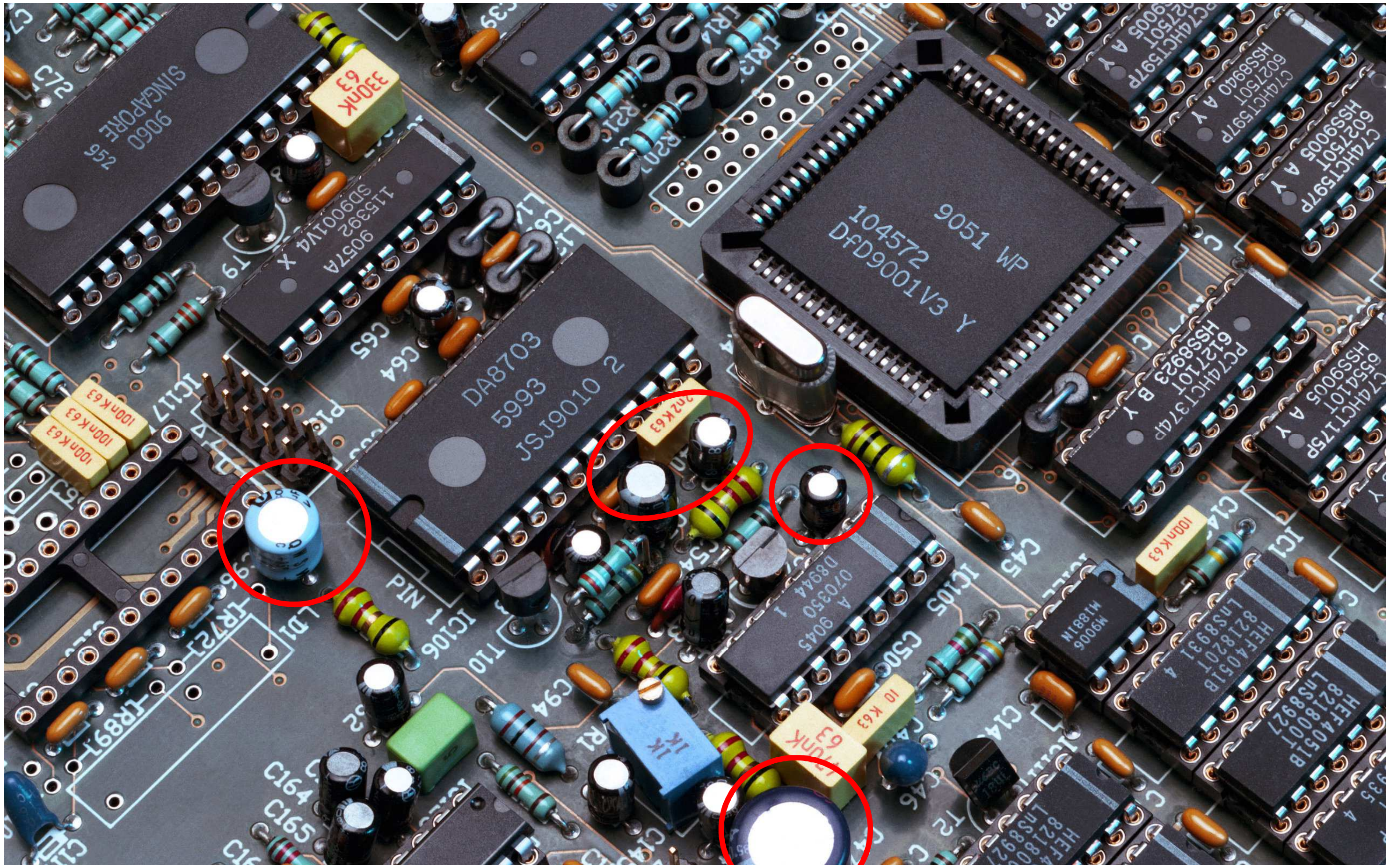
i. an electron, and

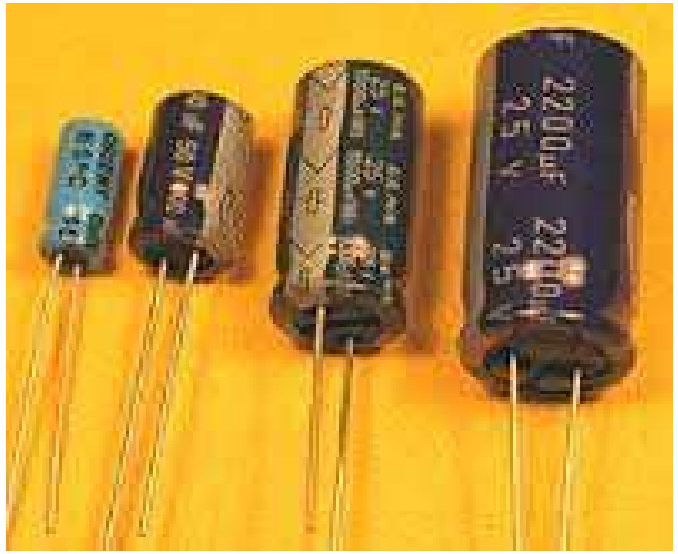
ii. an O^{2-} ion when travelling freely from one plate to the other;

(c) the speed reached by the electron in (b) i. above, if it starts from rest. (The mass of an electron $m_e = 9.1 \times 10^{-31}$ kg.)

Capacitance

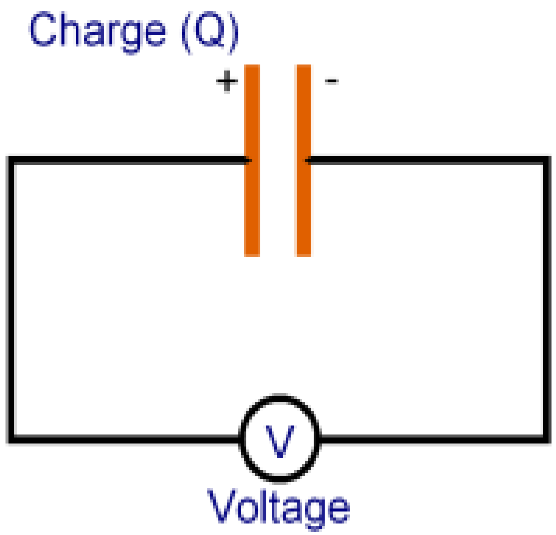
Capacitors are devices that store electric **charge**. The charge is released at a later time when it is needed.





Capacitors when not mounted on an electronic board

Capacitance

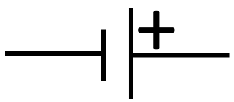


A capacitor consist of two conductors of any shape, placed near, but not touching one another. Often the space between the conductors is filled with an electrically insulating material. Each plate carries a charge of the same magnitude, one being positive, while the other is negative. The charge that is stored on the plates of a capacitor is proportional to the potential difference across the plates. Thus

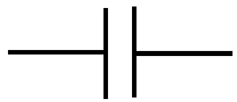
$$q = CV$$

where C is proportionality constant called **capacitance**. The unit of capacitance is the farad: 1 F = 1C V^{-1}. One farad is a very large unit and in practice, capacitances are normally much less than this. Some common capacitances are:

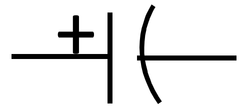
$$1\ \mu F = 1 \times 10^{-6}\ F$$
$$1\ nF = 1 \times 10^{-9}\ F$$
$$1\ pF = 1 \times 10^{-12}\ F$$



Battery

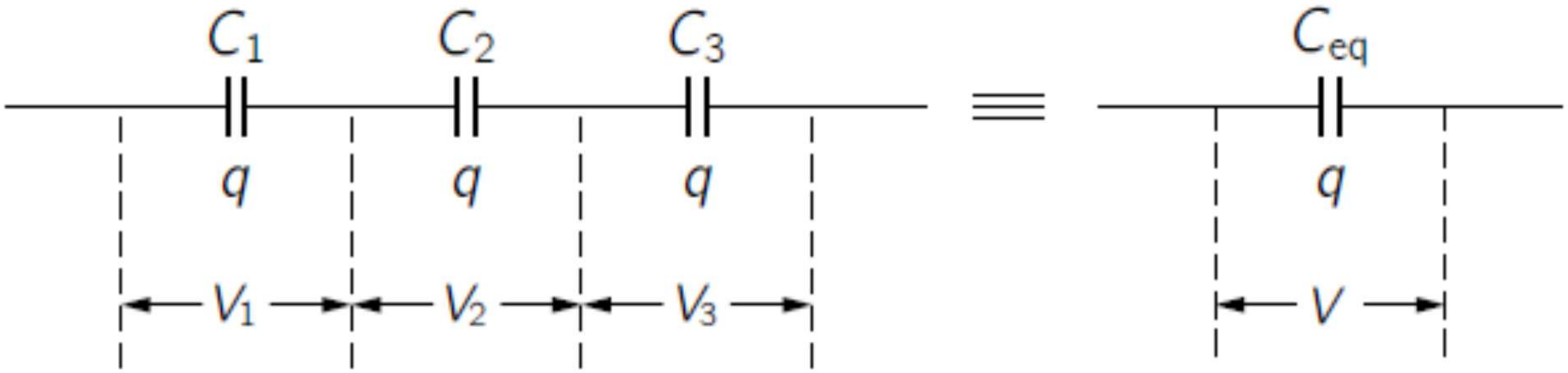


Capacitor



Electrolytic Capacitor

Capacitors in series



- Capacitors in **series all carry the same charge** which is equal to the charge on Ceq.
- **The sum of the potential difference across each capacitor is equal to the potential difference across Ceq.**

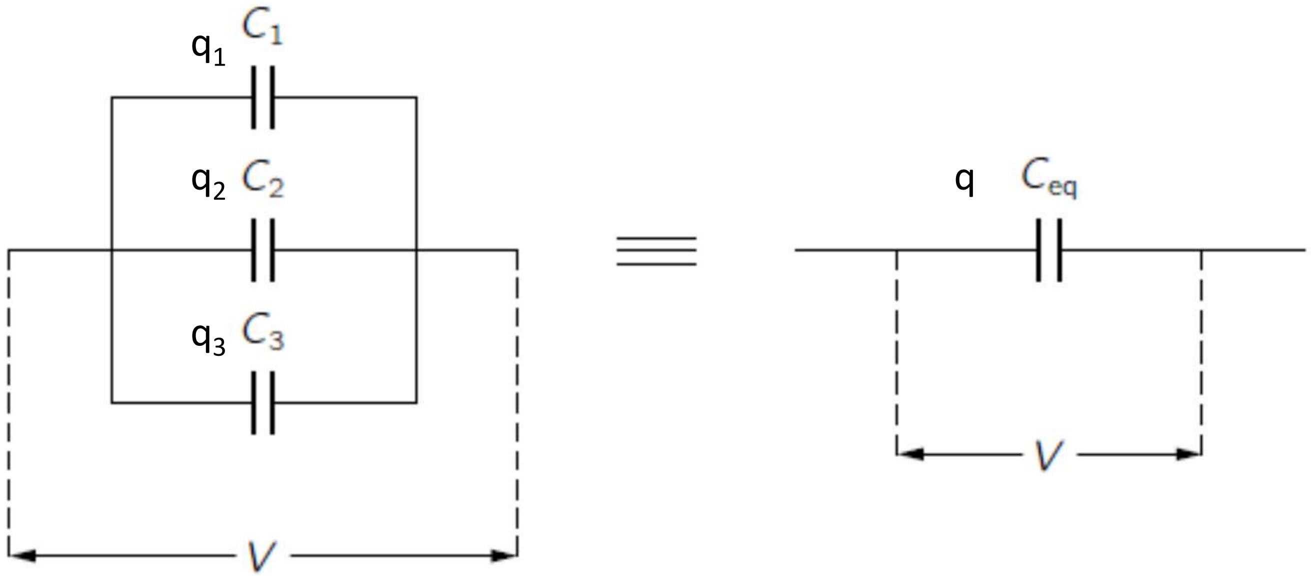
$$V_1 + V_2 + V_3 = V$$

From $q = CV$ $\qquad V = \frac{q}{C}$

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

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

Capacitors in parallel



- The voltage across each capacitor is the **same**, which is **also equal to the voltage across the equivalent capacitance**.
- The charge in each capacitor is not the same i.e. $q_1 \neq q_2 \neq q_3$
- However, **the total charge on all the individual capacitors is the same as the charge that would be stored on a single equivalent capacitor** i.e.

$$q = q_1 + q_2 + q_3$$

but $q = CV$ then

$$C_{EQ}V = C_1V + C_2V + C_3V$$

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

Energy stored in a Capacitor

Charging a capacitor requires energy. The work done in completely charging a capacitor C is given by

$$W = q\bar{V}$$

where $\bar{V}$ is the average voltage across the plates during charging. If the final voltage is V then

$$\bar{V} = \frac{1}{2}V$$

and the work done is

$$W = q\bar{V} = \frac{1}{2}qV$$

which is stored as electric potential energy in the capacitor. Since q = CV the energy stored Becomes

$$Energy = \frac{1}{2}qV = \frac{1}{2}CV^2 = \frac{q^2}{2C}$$

Energy stored in a Capacitor

Example 1.6: The equivalent capacitance of a combination of capacitors

For the arrangement shown alongside, calculate
(a) the single equivalent capacitance,
(b) the p.d. across the 10 μF capacitor,
(c) the energy stored in the 2 μF capacitor.