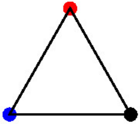
Revision

Dr Miguel Cavero

August 8, 2014

Electrostatic Force

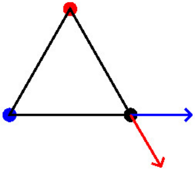
Consider three point charges in a vacuum arranged at the corners of an equilateral triangle:



Is it possible to choose the sign and magnitude of each charge so that one of them experiences a resultant electrostatic force of zero?

Electrostatic Force

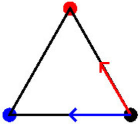
Consider the force on the black charge, due to the other two. If all three charges have the same sign, the force is repulsive due to both



Is it possible for these forces to cancel?

Electrostatic Force

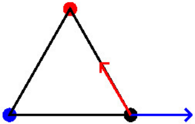
If the black charge has a different sign to the other two, the force is attractive due to both (the red and the blue)



Is it possible for these forces to cancel?

Electrostatic Force

Any combination of sign results in forces on the black charge that do not lie parallel with respect to one another.



Since forces are vectors, which have direction, a point of symmetry would be required for the forces to balance.

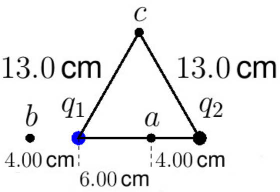
Electrostatic Force

The magnitude of the electro static force between two point charges a distance r from one another is

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

What happens to the magnitude of the force as $r \to 0$?
Remember: like charges repel and unlike charges attract.

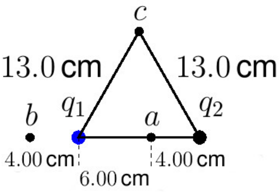
Let two charges ($q_1 = +12.0$ nC and $q_2 = -12.0$ nC) lie in a line, a distance of 10.0 cm apart.



Calculate the electric potential at points a, b and c.

Electric Potential

Let two charges ($q_1 = +12.0\,$nC and $q_2 = -12.0\,$nC) lie in a line, a distance of 10.0 cm apart.

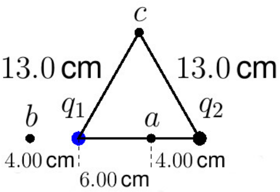


Calculate the electric potential at point a:

$$
\begin{aligned}
V_a &= k_e \frac{q_1}{(0.06)} + k_e \frac{q_2}{(0.04)} \\
&= (9.00 \times 10^9) \left[\frac{12.0 \times 10^{-9}}{(0.06)} + \frac{-12.0 \times 10^{-9}}{(0.04)} \right] \\
&= -900\,\text{V}
\end{aligned}
$$

Electric Potential

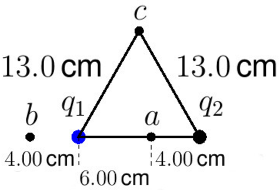
Let two charges ($q_1 = +12.0$ nC and $q_2 = -12.0$ nC) lie in a line, a distance of 10.0 cm apart.



Calculate the electric potential at point b:

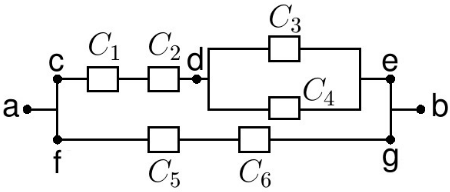
$$V_b = 1930\,\text{V}$$

Let two charges ($q_1 = +12.0$ nC and $q_2 = -12.0$ nC) lie in a line, a distance of 10.0 cm apart.



Calculate the electric potential at point c:
Can you see that the electric potential V_c is 0?
What is the electric field at c?

Capacitors

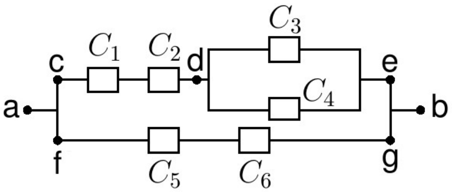


For the portion of a circuit shown above, the values of the capacitors are as follows:

$$C_1 = 7\,\mu\text{F}, C_2 = 3\,\mu\text{F}, C_3 = 3\,\mu\text{F}, C_4 = 1\,\mu\text{F}, C_5 = 4\,\mu\text{F}, C_6 = 12\,\mu\text{F}$$

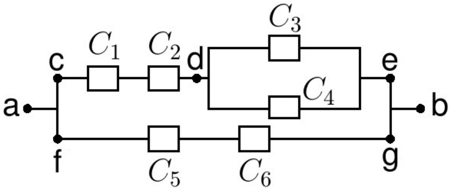
Find the equivalent capacitance $C_{\text{eq}}^{(\text{ab})}$.

Capacitors



$$C_1 = 7\,\mu\text{F}, C_2 = 3\,\mu\text{F}, C_3 = 3\,\mu\text{F}, C_4 = 1\,\mu\text{F}, C_5 = 4\,\mu\text{F}, C_6 = 12\,\mu\text{F}$$

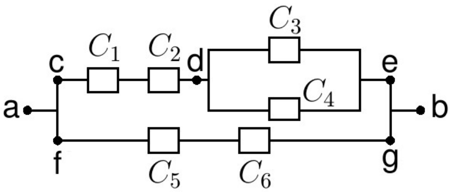
The equivalent capacitance $C_{\text{eq}}^{(\text{cd})}$ is 2.1 μF.
The equivalent capacitance $C_{\text{eq}}^{(\text{de})}$ is 4 μF.



$$C_1 = 7\,\mu\text{F}, C_2 = 3\,\mu\text{F}, C_3 = 3\,\mu\text{F}, C_4 = 1\,\mu\text{F}, C_5 = 4\,\mu\text{F}, C_6 = 12\,\mu\text{F}$$

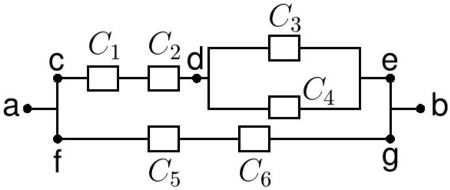
The equivalent capacitance $C_{\text{eq}}^{(\text{fg})}$ is 3 µF.

Capacitors



$$C_1 = 7\,\mu\text{F}, C_2 = 3\,\mu\text{F}, C_3 = 3\,\mu\text{F}, C_4 = 1\,\mu\text{F}, C_5 = 4\,\mu\text{F}, C_6 = 12\,\mu\text{F}$$

If the potential difference $\Delta V_{(\text{ab})}$ is 30 V, what is the potential difference $\Delta V_{(\text{ce})}$?
The potential difference $\Delta V_{(\text{ce})}$ is the same as $\Delta V_{(\text{fg})}$



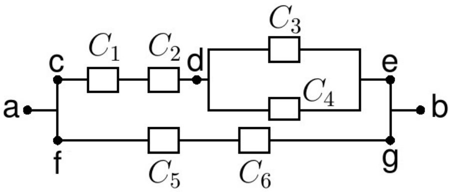
$$C_1 = 7\,\mu\text{F}, C_2 = 3\,\mu\text{F}, C_3 = 3\,\mu\text{F}, C_4 = 1\,\mu\text{F}, C_5 = 4\,\mu\text{F}, C_6 = 12\,\mu\text{F}$$

What is the charge on C_5?

The equivalent capacitance $C_{\text{eq}}^{(\text{fg})}$ is 3 μF.

The potential difference $\Delta V_{(\text{fg})}$ is 30 V. Find the charge on $C_{\text{eq}}^{(\text{fg})}$ and hence the charge on C_5.

Capacitors

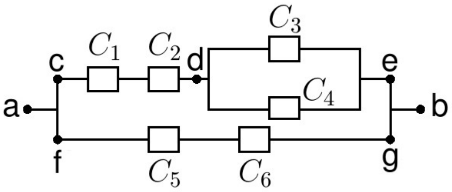


$$C_1 = 7\,\mu\text{F}, C_2 = 3\,\mu\text{F}, C_3 = 3\,\mu\text{F}, C_4 = 1\,\mu\text{F}, C_5 = 4\,\mu\text{F}, C_6 = 12\,\mu\text{F}$$

The equivalent capacitance $C_{\text{eq}}^{(\text{fg})}$ is 3 μF.
The charge q on $C_{\text{eq}}^{(\text{fg})}$ is given by

$$q = (C_{\text{eq}}^{(\text{fg})}) \times (\Delta V_{(\text{fg})})$$

and is the magnitude of the charge on C_5 and C_6, since they are in series.

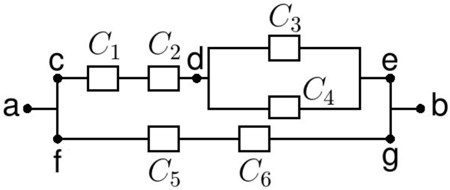


$$C_1 = 7\,\mu\text{F}, C_2 = 3\,\mu\text{F}, C_3 = 3\,\mu\text{F}, C_4 = 1\,\mu\text{F}, C_5 = 4\,\mu\text{F}, C_6 = 12\,\mu\text{F}$$

What is the potential difference across C_5?
Given the charge q on C_5, the potential difference ΔV_5 across C_5 is

$$\Delta V_5 = \frac{q}{C_5}$$

Capacitors

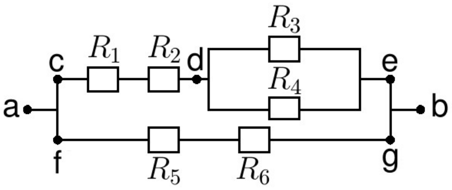


$$C_1 = 7\,\mu\text{F}, C_2 = 3\,\mu\text{F}, C_3 = 3\,\mu\text{F}, C_4 = 1\,\mu\text{F}, C_5 = 4\,\mu\text{F}, C_6 = 12\,\mu\text{F}$$

What is the potential difference across C_6?
The sum of the potential difference ΔV_6 across C_6 and ΔV_5 should equal to $\Delta V_{(\text{fg})}$:

$$\Delta V_6 + \Delta V_5 = \frac{q}{C_6} + \Delta V_5 = \Delta V_{(\text{fg})}$$

Resistors

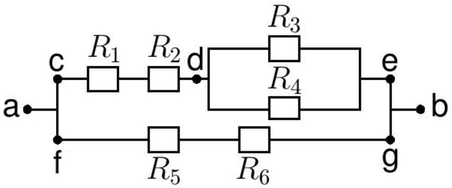


For the portion of a circuit shown above, the values of the resistors are as follows:

$$R_1 = 7\,\Omega, R_2 = 3\,\Omega, R_3 = 3\,\Omega, R_4 = 1\,\Omega, R_5 = 4\,\Omega, R_6 = 12\,\Omega$$

Find the equivalent resistance $R_{\text{eq}}^{\text{(ab)}}$.

Resistors

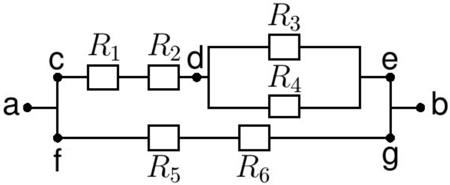


$$R_1 = 7\,\Omega, R_2 = 3\,\Omega, R_3 = 3\,\Omega, R_4 = 1\,\Omega, R_5 = 4\,\Omega, R_6 = 12\,\Omega$$

The equivalent resistances are

$$\begin{aligned} R_{\text{eq}}^{(\text{cd})} &= R_1 + R_2 \\ R_{\text{eq}}^{(\text{de})} &= \frac{R_3 R_4}{R_3 + R_4} \\ R_{\text{eq}}^{(\text{fg})} &= R_5 + R_6 \end{aligned}$$

Resistors

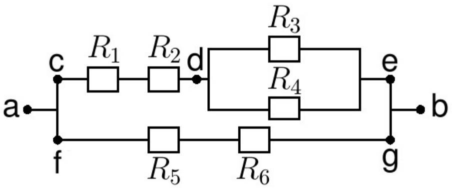


$$R_1 = 7\,\Omega, R_2 = 3\,\Omega, R_3 = 3\,\Omega, R_4 = 1\,\Omega, R_5 = 4\,\Omega, R_6 = 12\,\Omega$$

The equivalent resistance $R_{\text{eq}}^{(\text{ab})}$ is

$$R_{\text{eq}}^{(\text{ab})} = \frac{\left(R_{\text{eq}}^{(\text{fg})}\right)\left(R_{\text{eq}}^{(\text{cd})} + R_{\text{eq}}^{(\text{de})}\right)}{\left(R_{\text{eq}}^{(\text{fg})}\right) + \left(R_{\text{eq}}^{(\text{cd})} + R_{\text{eq}}^{(\text{de})}\right)}$$

Resistors

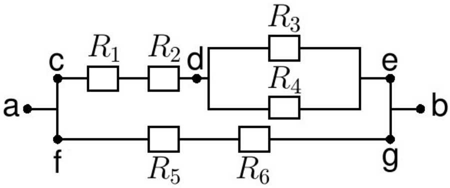


$$R_1 = 7\,\Omega, R_2 = 3\,\Omega, R_3 = 3\,\Omega, R_4 = 1\,\Omega, R_5 = 4\,\Omega, R_6 = 12\,\Omega$$

Let the potential difference $\Delta V_{\text{(ab)}}$ be 30 V. The total current is

$$I = \frac{\left(\Delta V_{\text{(ab)}}\right)}{\left(R_{\text{eq}}^{\text{(ab)}}\right)}$$

Resistors

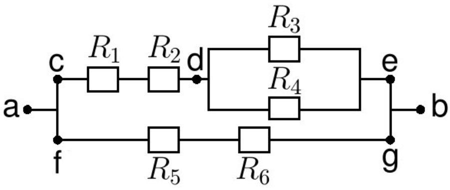


$$R_1 = 7\,\Omega, R_2 = 3\,\Omega, R_3 = 3\,\Omega, R_4 = 1\,\Omega, R_5 = 4\,\Omega, R_6 = 12\,\Omega$$

The current I_1 through branch ce is

$$I_1 = \frac{\left(\Delta V_{\text{(ab)}}\right)}{\left(R_{\text{eq}}^{\text{(ce)}}\right)}$$

Resistors



$$R_1 = 7\,\Omega, R_2 = 3\,\Omega, R_3 = 3\,\Omega, R_4 = 1\,\Omega, R_5 = 4\,\Omega, R_6 = 12\,\Omega$$

The current I_2 through branch fg is

$$I_2 = \frac{\left(\Delta V_{\text{(ab)}}\right)}{\left(R_{\text{eq}}^{\text{(fg)}}\right)}$$

The potential difference ΔV_5 across R_5 is therefore

$$\Delta V_5 = I_2 \times R_5$$