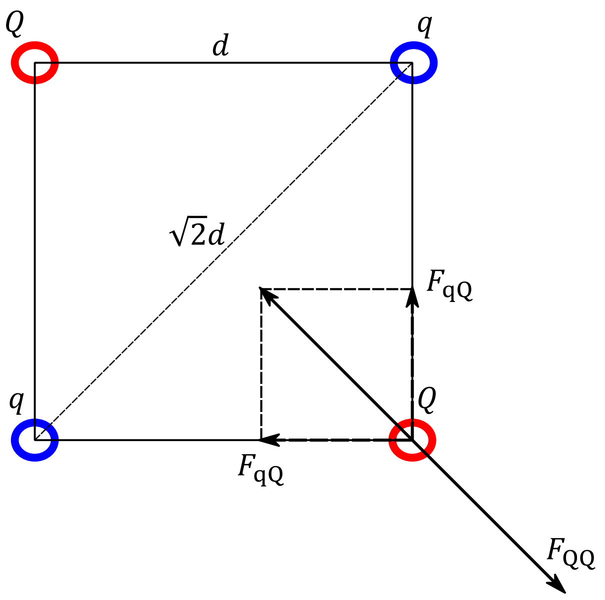
Task 1

Point-like charges in the (diagonally) opposite corners of a square	Q	[C]
Point-like charges in the (diagonally) opposite corners of a square	q	[C]
Force between the charges q and Q	F_{qQ}	[N]
Force between the charges Q and Q	F_{QQ}	[N]
Coulomb constant	k	$[\mathrm{Nm}^2/\mathrm{C}^2]$
Length of the square's edge	d	[m]



Constants:

$$k = 8.98755 \cdot 10^{-9}\mathrm{Nm}^2/\mathrm{C}^2$$

Formulas:

$$F_{\mathrm{qQ}} = \frac{kqQ}{d^2}$$

$$F_{\mathrm{QQ}} = \frac{kQ^2}{2d^2}$$

$$\frac{F_{\mathrm{QQ}}}{\sqrt{2}} = -F_{\mathrm{qQ}}$$

Solution:

$$\frac{F_{\mathrm{QQ}}}{\sqrt{2}} = -F_{\mathrm{qQ}}$$

Substitute expressions

$$\frac{kQ^2}{2\sqrt{2}d^2} = -\frac{kqQ}{d^2}$$

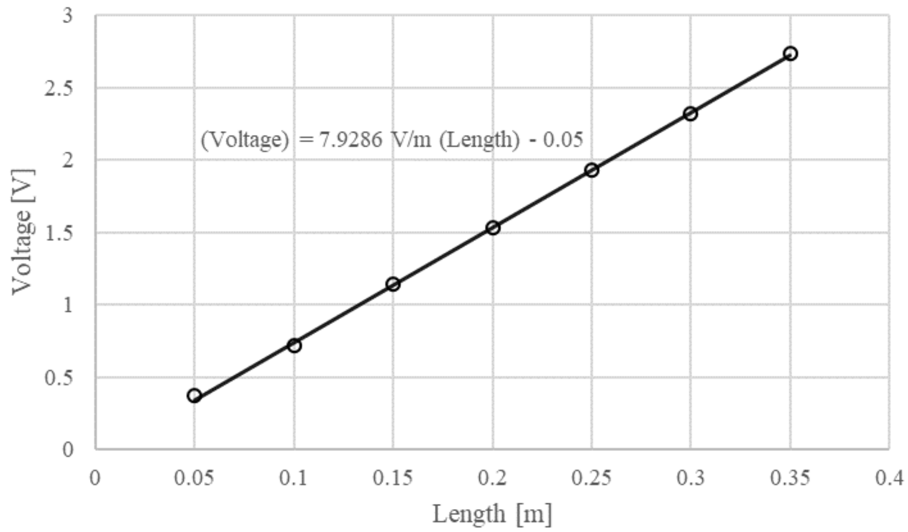
Use algebra

$$\boldsymbol{q = -\frac{Q}{2\sqrt{2}}}$$

Substitute initial values

Task 2

Diameter of the log of play dough	D	[m]
Cross-sectional area of the log of play dough	A	$[\mathrm{m}^2]$
Current in the electric circuit	I	[A]
Resistance of the electric circuit	R	$[\Omega]$
Voltage over the electric circuit	U	[V]
Resistivity of the play dough	ρ	$[\Omega \mathrm{m}]$



Formulas:

$$\rho = \frac{RA}{l}$$

$$U = RI$$

$$A = \frac{\pi D^2}{2}$$

Solution:

$$U = RI$$

solve for R

$$R = \frac{U}{I}$$

$$\rho = \frac{RA}{l}$$

substitute expressions

$$\boldsymbol{\rho = \frac{U\pi D^2}{2Il}}$$

substitute initial values and U/l = 7.9286 V/m

Task 3

Source voltage (electromotive force)	ε	[V]
Terminal voltage	U	[V]
Resistance of the conductor	R_{C}	[Ω]
Resistance internal resistance of the voltage source	R_{I}	[Ω]
Total resistance of the circuit	R	[Ω]
Current through the circuit	I	[A]

Formulas:

$$R = R_{\mathrm{C}} + R_{\mathrm{I}}$$

$$\varepsilon = RI$$

$$U = R_{\mathrm{I}}I$$

Solution:

Current through the circuit:

$$\varepsilon = RI$$

solve for I

$$I = \frac{\varepsilon}{R}$$

substitute expressions

$$\boldsymbol{I = \frac{\varepsilon}{R_{\mathrm{C}}+R_{\mathrm{I}}}}$$

substitute initial values

Terminal voltage:

$$U = R_{\mathrm{I}}I$$

substitute expressions

$$\boldsymbol{\Delta d = \frac{m_{\mathrm{ice}}}{wl\rho_{\mathrm{ice}}}}$$

Substitute initial values

Task 4

Source voltage (electromotive force)	ε	[V]
Voltage over the resistor	U_{R}	[V]
Voltage over the internal resistance of the voltage source	U_{S}	[V]
Resistance of the resistor	R_{R}	[Ω]
Resistance internal resistance of the voltage source	R_{S}	[Ω]
Total resistance of the circuit	R	[Ω]
Current through the circuit	I	[A]
Power at which electrical energy is converted into heat in the resistor	P_R	[W]
Power at which electrical energy is converted into heat in the voltage source	P_{S}	[W]
Time for which electrical energy is converted into heat	t	[s]
Chemical energy converted into heat in the voltage source	E_{S}	[J]

Formulas:

$$\varepsilon = U_{\mathrm{R}} + U_{\mathrm{S}}$$

$$\varepsilon = RI$$

$$U_{\mathrm{R}} = R_{\mathrm{R}} I$$

$$U_{\mathrm{S}} = R_{\mathrm{S}} I$$

$$P_{\mathrm{R}} = U_{\mathrm{R}} I = R_{\mathrm{R}} I^2$$

$$P_{\mathrm{S}} = U_{\mathrm{S}} I = R_{\mathrm{S}} I^2$$

$$R = R_{\mathrm{R}} + R_{\mathrm{S}}$$

$$E_{\mathrm{S}} = P_{\mathrm{S}} t$$

Solution:

Electrical power of the resistor

$$\varepsilon = RI$$

solve for I

$$I = \frac{\varepsilon}{R}$$

substitute expressions

$$I = \frac{\varepsilon}{R_{\mathrm{R}} + R_{\mathrm{S}}}$$

$$P_{\mathrm{R}} = U_{\mathrm{R}} I = R_{\mathrm{R}} I^2$$

substitute expressions

$$\boldsymbol{P_{\mathrm{R}} = R_{\mathrm{R}} \left(\frac{\varepsilon}{R_{\mathrm{R}} + R_{\mathrm{S}}}\right)^2}$$

Substitute initial values

Chemical energy converted into heat inside the voltage source:

$P_{\mathrm{S}} = U_{\mathrm{S}} I = R_{\mathrm{S}} I^2$

substitute expression

$P_{\mathrm{S}} = R_{\mathrm{S}} \left(\frac{\varepsilon}{R_{\mathrm{R}} + R_{\mathrm{S}}} \right)^2$

$E_{\mathrm{S}} = P_{\mathrm{S}} t$

substitute expression

$\boldsymbol{E_{\mathrm{S}} = R_{\mathrm{S}} \left(\frac{\varepsilon}{R_{\mathrm{R}} + R_{\mathrm{S}}} \right)^2 t}$

substitute initial values

Task 5

Source voltage (electromotive force)	ε	[V]
Terminal voltage (also the voltage over the external conductor)	U_{R}	[V]
Voltage over the internal resistance of the voltage source	U_{I}	[V]
Resistance of the external conductor	R_{R}	[Ω]
Resistance internal resistance of the voltage source	R_{I}	[Ω]
Total resistance of the circuit	R	[Ω]
Current through the circuit	I	[A]
Power at which electrical energy is converted into heat in the external conductor	P_R	[W]
Power at which electrical energy is converted into heat in the voltage source	P_{I}	[W]
Power that the battery produces	P	[W]

Formulas:

$$\varepsilon = U_{\mathrm{R}} + U_{\mathrm{I}}$$

$$\varepsilon = RI$$

$$U_{\mathrm{R}} = R_{\mathrm{R}} I$$

$$U_{\mathrm{I}} = R_{\mathrm{I}} I$$

$$P_{\mathrm{R}} = U_{\mathrm{R}} I = R_{\mathrm{R}} I^2$$

$$P_{\mathrm{I}} = U_{\mathrm{I}} I = R_{\mathrm{I}} I^2$$

$$P = \varepsilon I = RI^2$$

$$R = R_{\mathrm{R}} + R_{\mathrm{I}}$$

$$E_{\mathrm{S}} = P_{\mathrm{S}} t$$

Solution:

Power produced by the battery:

$$\boldsymbol{P = \varepsilon I}$$

substitute initial values

Power drained by the external conductor:

$$\boldsymbol{P_{\mathrm{R}} = U_{\mathrm{R}} I}$$

substitute initial values

The power that the voltage source uses:

$$\varepsilon = U_{\mathrm{R}} + U_{\mathrm{I}}$$

solve for U_{I}

$$U_{\mathrm{I}} = \varepsilon - U_{\mathrm{R}}$$

$P_{\mathrm{I}} = U_{\mathrm{I}} I$

substitute expression

$\boldsymbol{P_{\mathrm{I}} = (\varepsilon - U_{\mathrm{R}}) I}$

substitute initial values

The voltage drop in the source:

use the expression obtained earlier

$\boldsymbol{U_{\mathrm{I}} = \varepsilon - U_{\mathrm{R}}}$

substitute initial values