Brian Wilson

Requests:

Electric Fields and Electric Forces

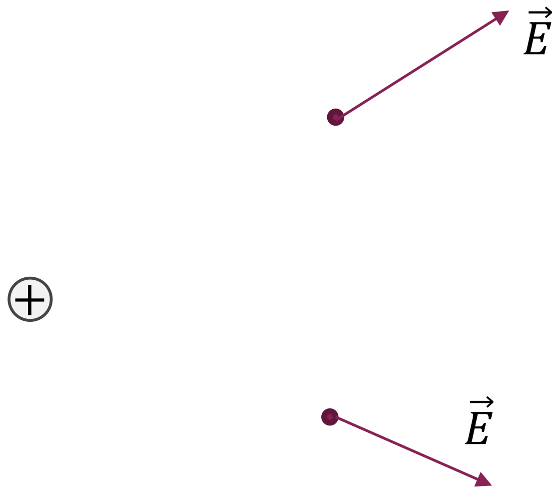
Electric Field and Electric potential

Electric potential energy and energy conservation

Uniform electric field

Kirchhoff's Loop Law

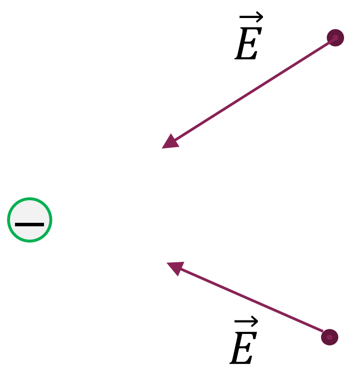
Electric Forces and Electric Fields



Magnitude of the electric field from a point charge Q at distance r away:

$$E = \frac{k_e|Q|}{r^2}$$

Direction of the electric field: points away from the positive charge and towards the negative charge. (Direction is the same as the direction of the electric force acting on a positive charge placed at the point where electric field is calculated.)



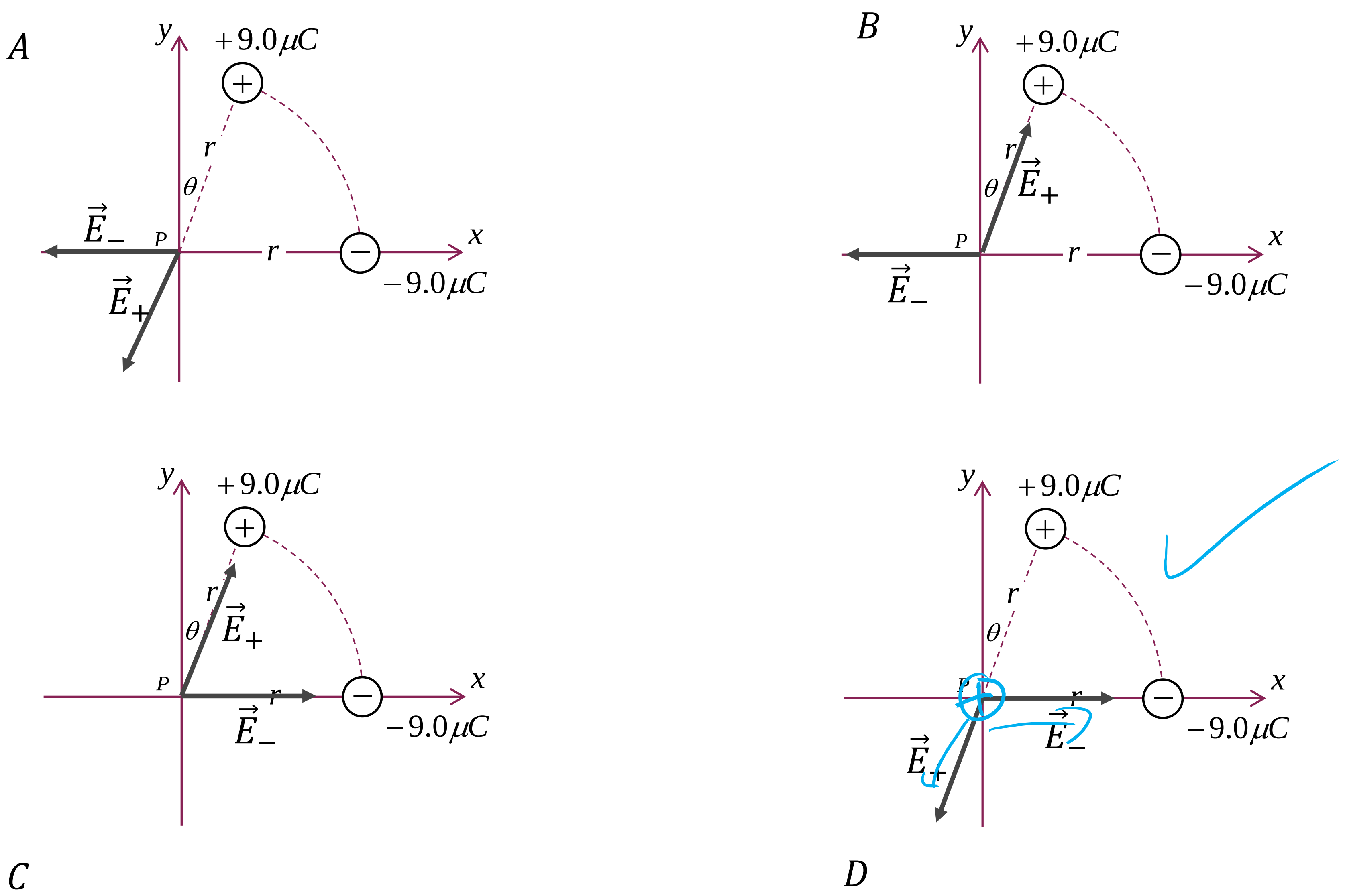
The magnitude of the electric force on a charge q placed in the electric field created by charge Q:

$$F = qE = \frac{k_e|Q||q|}{r^2}$$

Direction of the force: along the direction of the electric field for positive charge q and against the direction of the electric field for a negative charge q.

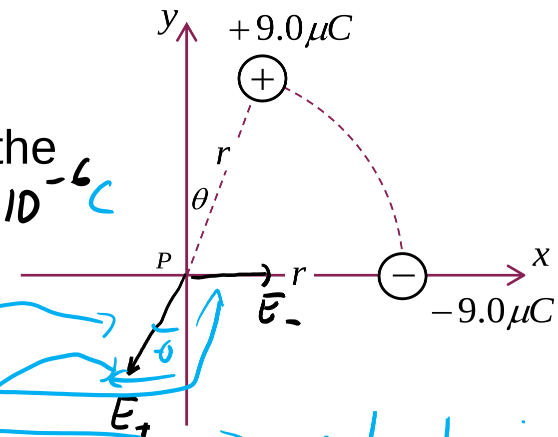
QUESTION 1A

Which figure shows correct directions of $\vec{E}_-$ and $\vec{E}_+$?



QUESTION 1B

If $r = 1.64\ cm$ and $\theta = 15^o$, what is the x component of the net electric field $\vec{E}_{NET_x}$?



$$E = \frac{kq}{r^2} = \frac{8.99\times10^9 \cdot 9.0\times10^{-6}\,C}{(0.0164\,m)^2}$$

$E = 3.0\times10^8\ N/C$

- a) $+3.01\cdot10^8\,\frac{N}{C}\ \hat{\imath}$
- b) $+2.23\cdot10^8\,\frac{N}{C}\ \hat{\imath}$
- c) $+3.79\cdot10^8\,\frac{N}{C}\ \hat{\imath}$
- d) $+1.0\cdot10^8\,\frac{N}{C}\ \hat{\imath}$

$E_{-x} = +3.0\times10^8\ \frac{N}{C}$

$E_{+x} = -3.0\times10^8\cdot\boxed{\sin 15}$

$E_{+x} = -\cancel{1.16\times10^8}$ 0.776×10^8

$\boxed{E_{-y} = 0}$ purely horizontal

$E_{+y} = -3.0\times10^8\cos 15$

$E_{+y} = 2.9\times10^8$

QUESTION 1C

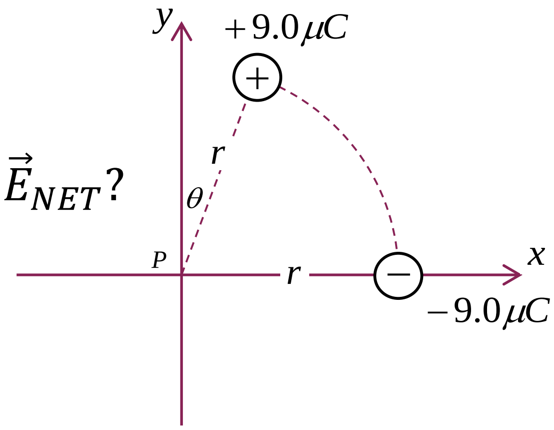
If $r = 1.64\ cm$ and $\theta = 15^o$, what is the y component of the net electric field $\vec{E}_{NET_y}$?

- a) $-7.79\cdot10^7\,\frac{N}{C}$
- b) $+7.79\cdot10^7\,\frac{N}{C}$
- c) $-2.91\cdot10^8\,\frac{N}{C}$
- d) $+2.91\cdot10^8\,\frac{N}{C}$

DIY!!

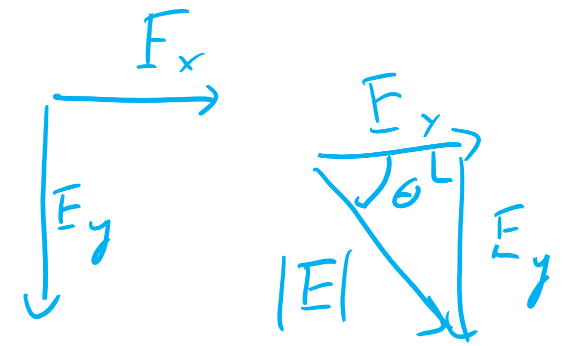
QUESTION 1D

Determine the magnitude and direction of the net electric field $\vec{E}_{NET}$?



$E_x = +2.23 \times 10^8 \ N/C$

$E_y = -2.91 \times 10^8 \ N/C$

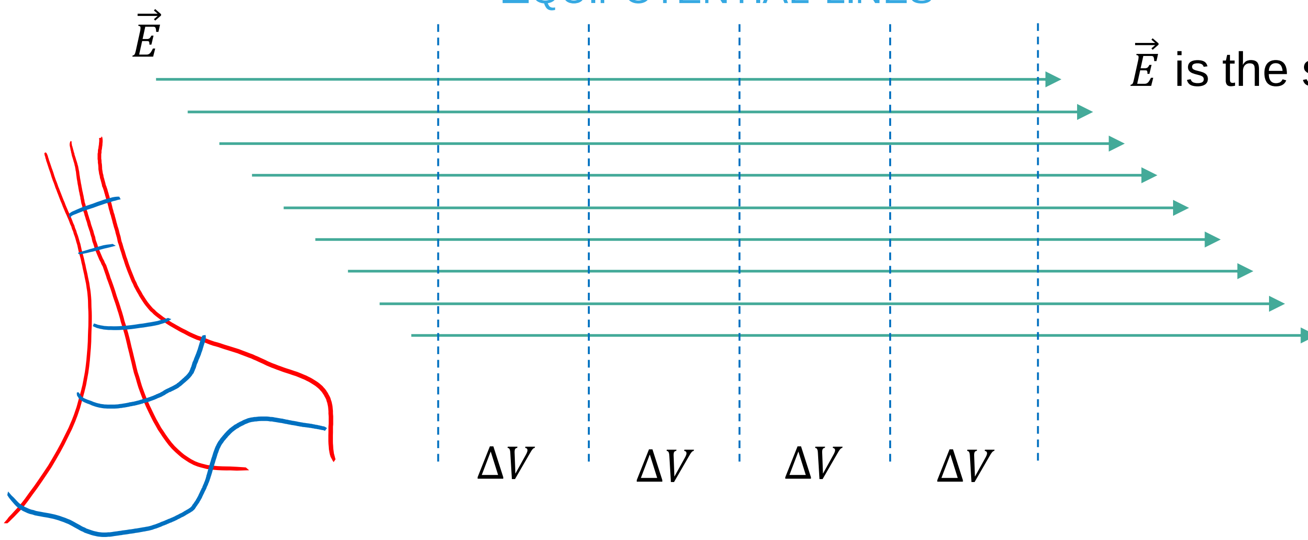


$|E|^2 = (E_x)^2 + (E_y)^2$

$\tan\theta = \dfrac{E_y}{E_x}$

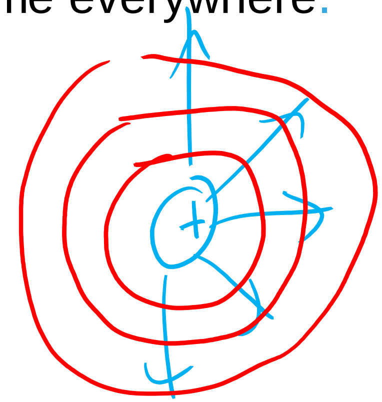
Uniform Electric Field

Equipotential lines

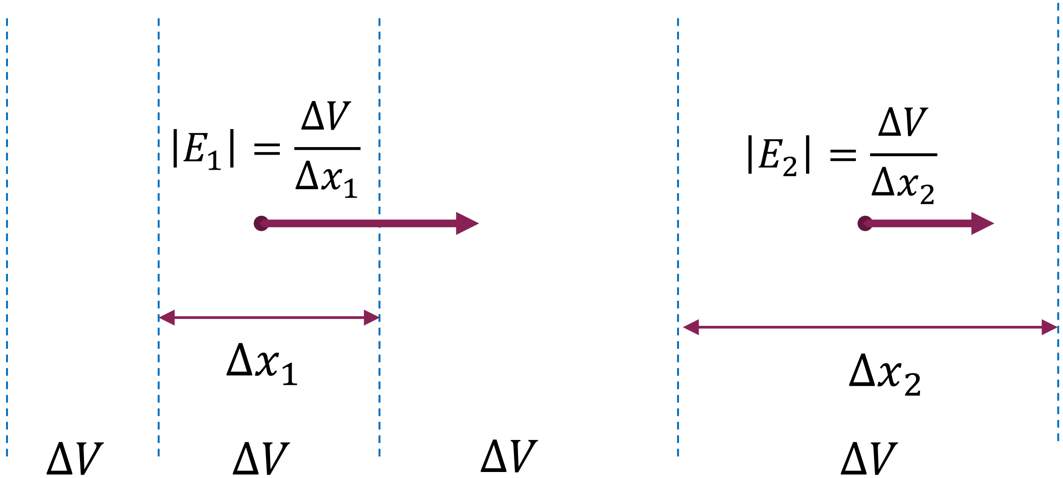


Equipotential lines have are equidistant.

$\vec{E}$ is the same everywhere.



Equipotential lines in non-uniform field:



Equipotential lines are different distances apart.

As

$$|E| = \frac{|\Delta V|}{|\Delta x|}$$

The farther apart the lines are, the weaker the fields ($|\Delta V|$ is constant)

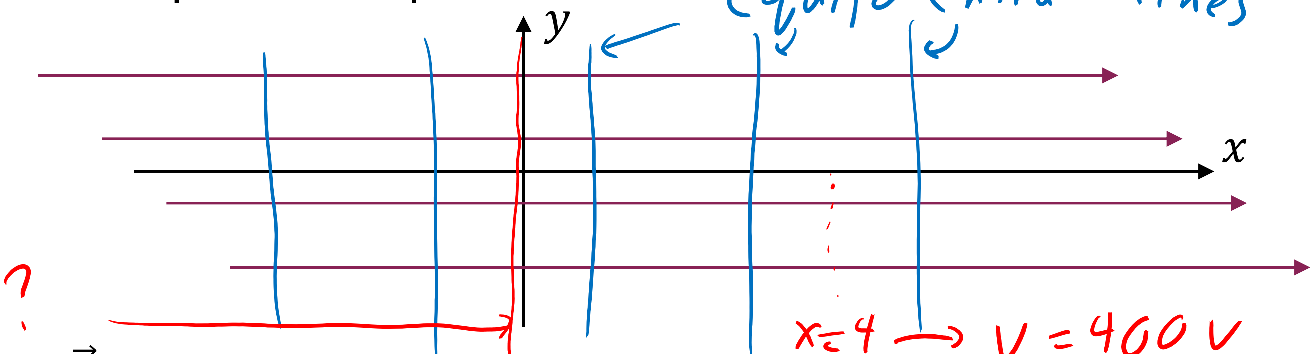
EXAMPLE

In certain region in space electric field $E_x = +200\,\frac{\mathrm{N}}{\mathrm{C}}$. Electric potential at point $x = 4.0\ \mathrm{m}$ is 400 V.

$E_y = 0$ $\quad E_z = 0$

a. What is the electric potential at $x = 0$ m?
b. Where is the electric potential equal to zero?

equipotential lines



$a)$ Think about it: $\vec{E}$ points in the +x direction, so the potential has to **increase** when going from $+4.0\ \mathrm{m}$ to zero.
Moving 4.0m, ~~losing~~ 200 V per meter = total ~~loss~~ of 800 volts. +800 V
Starting from 400 V, ~~losing~~ 800 V: -400 V

400V + 800V = 1200V

Math people: $E_x = -\frac{\Delta V}{\Delta x} \rightarrow \Delta V = -E_x \Delta x$

$x_i - x_f \neq \Delta x$

$$V_f - V_i = V(0) - V(4) = -200(4.0 - 0) = \cancel{-}{+}800\ V$$

$$V(0) - 400\ V = \cancel{-}{+}800\ V \rightarrow V(0) = \cancel{-400\ V}$$

+1200 V

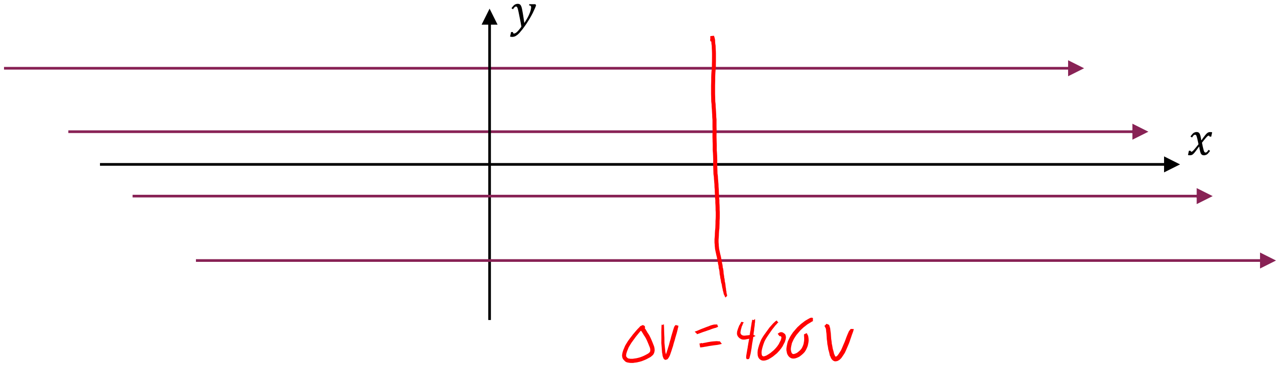
you

EXAMPLE

In certain region in space electric field $E_x = +200\,\frac{\mathrm{N}}{\mathrm{C}}$. Electric potential at point $x = 4.0\ \mathrm{m}$ is 400 V.

a. What is the electric potential at $x = 0$ m?

b. Where is the electric potential equal to zero?



$b)$

Math:

$$\Delta V = -E_x \Delta x$$
$$V_f - V_i = -E_x\left(x_f - x_i\right)$$
$$0 - 400 = -200(x_f - 4.0)$$
$$-400 = -200x_f + 800$$
$$-1200 = -200x_f$$
$$x_f = +6.0\ \mathrm{m}$$

down the field from 4.0 m checks out!

Learning Catalytics

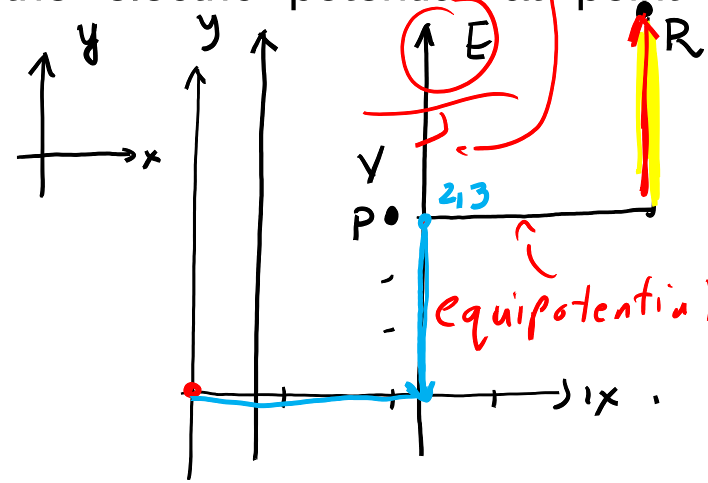
In a certain region electric field is equal to $\vec{E}_y = +3000\frac{V}{m}\hat{j}$. The electric potential at point $P = (2.0m, 3.0\ m)$ is $V(2,3) = 4000V$. What is the electric potential at point $R = (5.0m, 7.0m)$?

a) $V(5,7) = -8000\ V$
b) $V(5,7) = -11000\ V$
c) $V(5,7) = -2000\ V$
d) $V(5,7) = -17000\ V$

Learning Catalytics

$\vec{E} \perp$ equipotential → perpendicular

In a certain region electric field is equal to $\vec{E}_y = +3000\frac{V}{m}\hat{j}$. The electric potential at point $P = (2.0m, 3.0\,m)$ is $V(2,3) = 4000V$. What is the electric potential at point $R = (5.0m, 7.0m)$?



a) $V(5,7) = -8000\,V$
b) $V(5,7) = -11000\,V$
c) $V(5,7) = -2000\,V$
d) $V(5,7) = -17000\,V$

$V(2,3) = 4000\,V$

$V(5,7) = ?$

$\Delta V = -E_y \Delta y$

$\Delta V = -(3000)(4.0) = -12000\,V$

$\Delta V = V(5,7) - V(2,3)$

$-12000 = V(5,7) - 4000 \rightarrow V(5,7) = -8000$

$\Delta V = -(3000)(-3.0) = 9000\,V$

$\Delta V = V(0,0) - V(2,3)$

$9000 = V(0,0) - 4000 \rightarrow V(0,0) = 13000\,V$

Electric Potential Energy and Energy Conservation

When a charge travels across any non-zero electric potential, its kinetic and potential energies change.

The following is true in absence of external forces:

$$K_i + U_i = K_f + U_f$$

We often don't know initial and final potential energies, but we can figure out

$$\Delta U = q\Delta V.$$

If you rearrange the equation

$$K_i - K_f = U_f - U_i = \Delta U = q\Delta V$$
$$-\Delta K_i = \Delta U = q\Delta V$$

All values ($\Delta \mathrm{K}, \Delta U, q, \Delta V$) can be positive or negative so be careful!

Example

Negative charge $q = -2.0\ \mathrm{mC}$ moved across the potential difference $\Delta V = -400\ V$

a) What is the change in its potential energy?
b) What is the change in its kinetic energy?
c) Did it speed up or slow down?

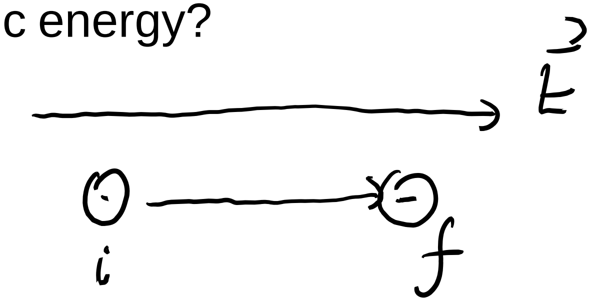
a) $\Delta U = q\Delta V = (-2.0\,\mathrm{mC}) \cdot (-400\,V) = 0.8\,J$

does in make sense? $\Delta V < 0$; charge is moving with the electric field.
Neg. charge accelerates against electric field, so it should gain ΔU when going with it (as it slows down that way)

b. $\Delta K = -\Delta U = -0.8\,J$ (slows down!)

Negative charge $q = -2.0\ \mathrm{mC}$ moved across the potential difference $\Delta V = -400\ V$. The charge has a mass $m = 2.0 \times 10^{-3}$kg and has initial velocity $v_i = 50\ \mathrm{m}/s$.
What is its final kinetic energy?

Sketch:



$$K_i + U_i = K_f + U_f \Rightarrow K_i - K_f = U_f - U_i = \Delta U = q\Delta V$$

$$K_i - K_f = \Delta U$$

$$\frac{1}{2} m v_i^2 - \frac{1}{2} m v_f^2 = \Delta U \rightarrow m v_i^2 - m v_f^2 = 2\Delta U$$

$$v_i^2 - v_f^2 = \frac{2\Delta U}{m}$$

$$v_f^2 = v_i^2 - \frac{2\Delta U}{m} \rightarrow v_f = \sqrt{v_i^2 - \frac{2\Delta U}{m}} = 41.2\ \frac{m}{s}$$

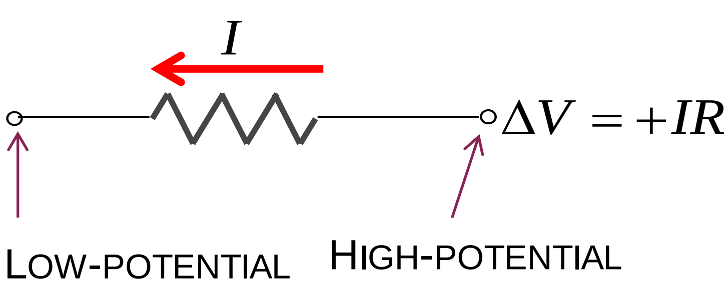
Kirchhoff's Loop Law

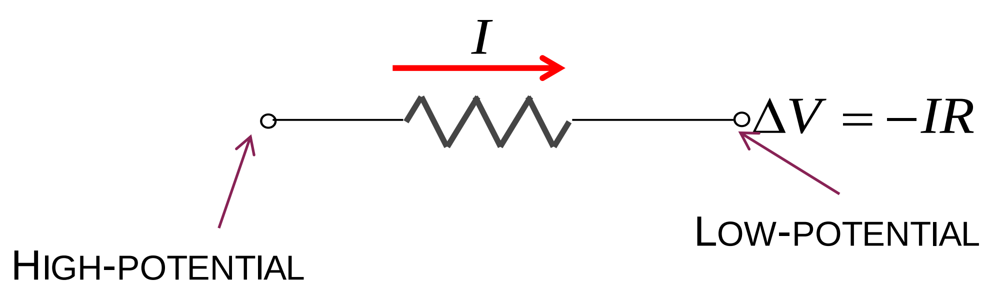
Sum of the potential differences measured across a circuit is equal to zero.

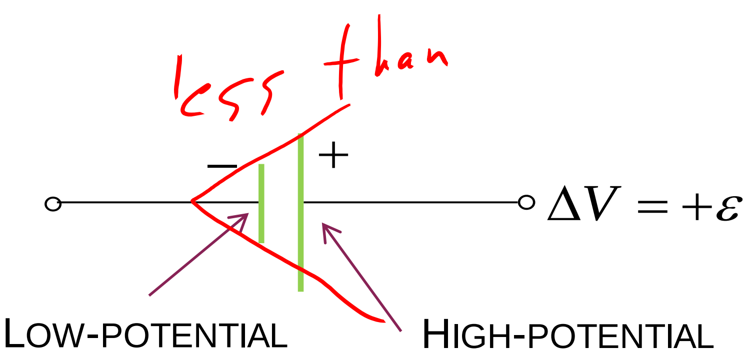
$$\sum_{i=1}^{N} \Delta V_i = 0$$

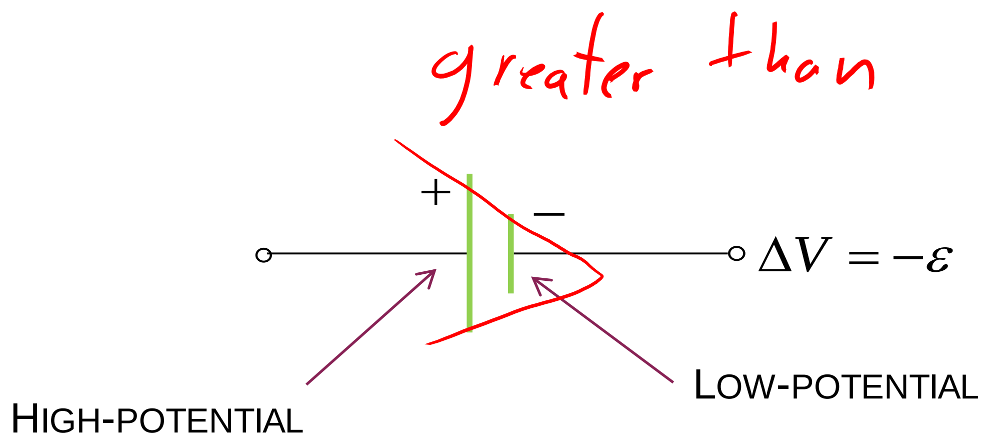
As you move along the circuit, you may pass various elements.

Consider passing through these elements, moving from left to right:

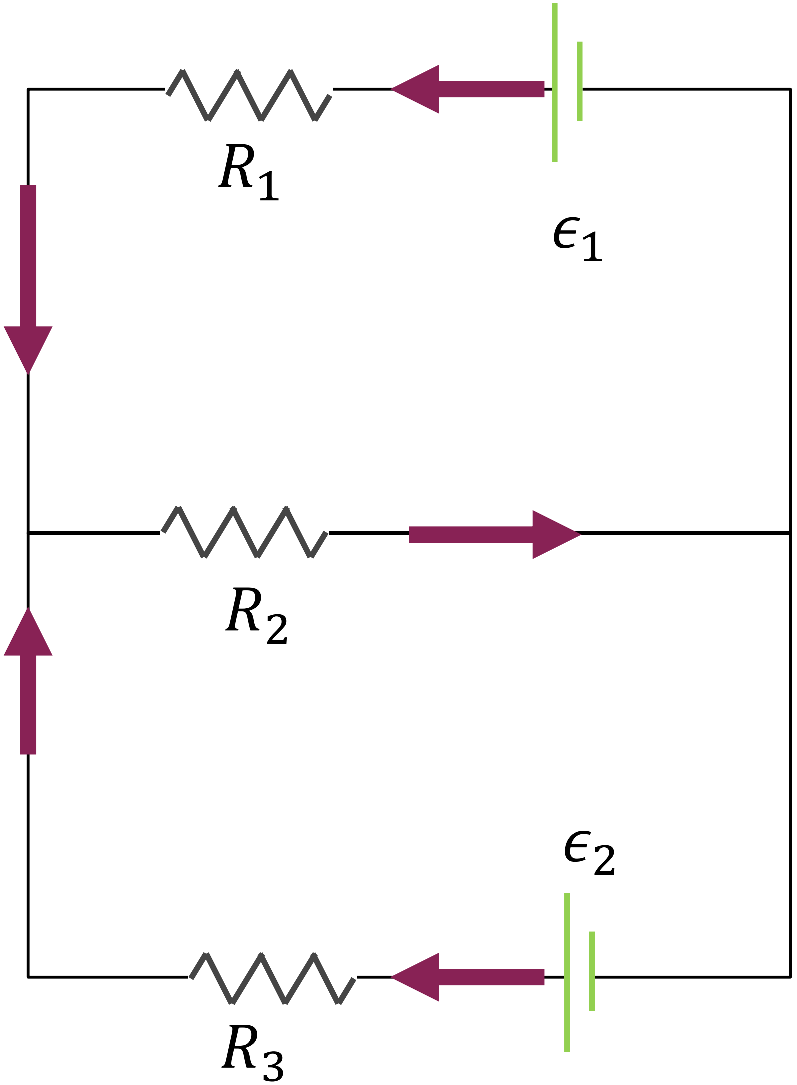








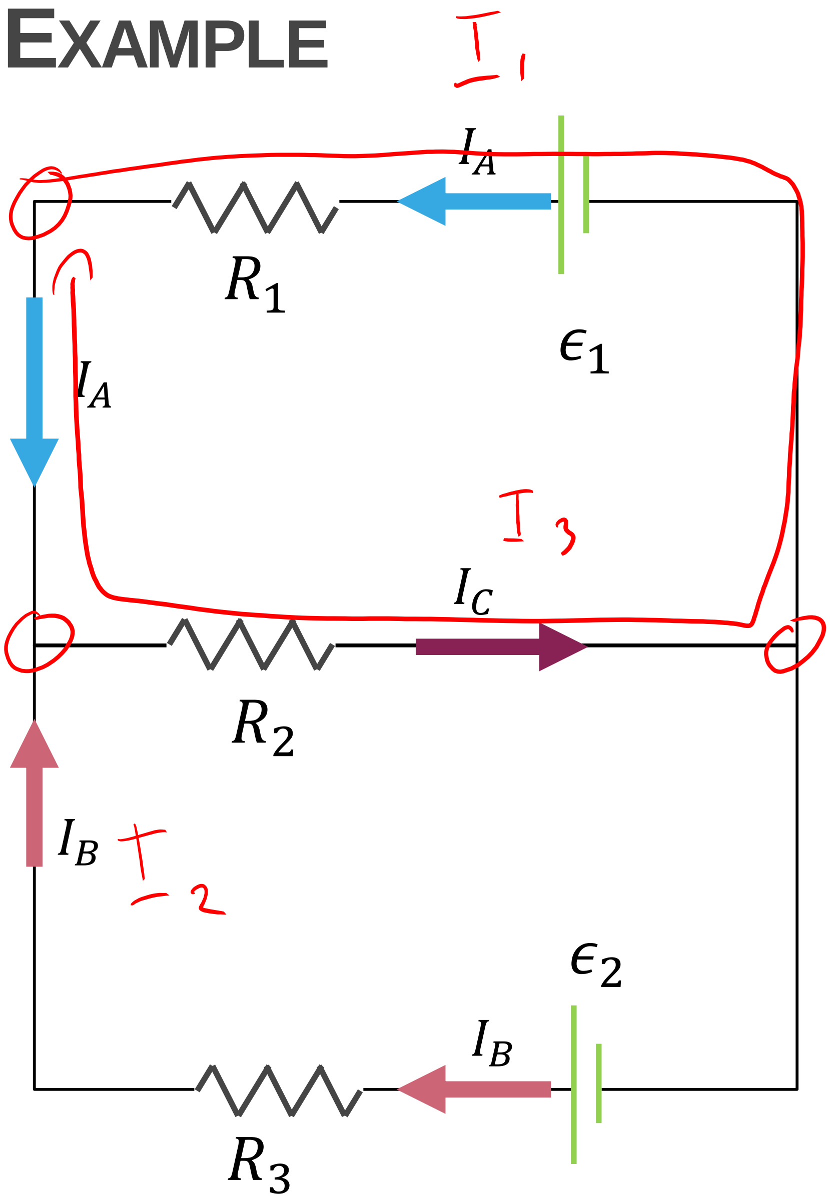
EXAMPLE



1. If the current is not show, consider a direction. It is not a problem if you guess incorrectly, as long as you are consistent a solution will sort it out for you (current will come out negative, it means you guess the direction of conventional current incorrectly)

Note: this is a two battery example, these tend to be trickier, but I thought it is a nice review.

EXAMPLE



$Junction$:

$$\boxed{I_3 = I_1 + I_2}$$

$Loop$ #1 (clockwise, $from\ the\ top-left\ corner$):

$$\Delta V_1 - \epsilon_1 + \Delta V_2 = 0$$

Against the current

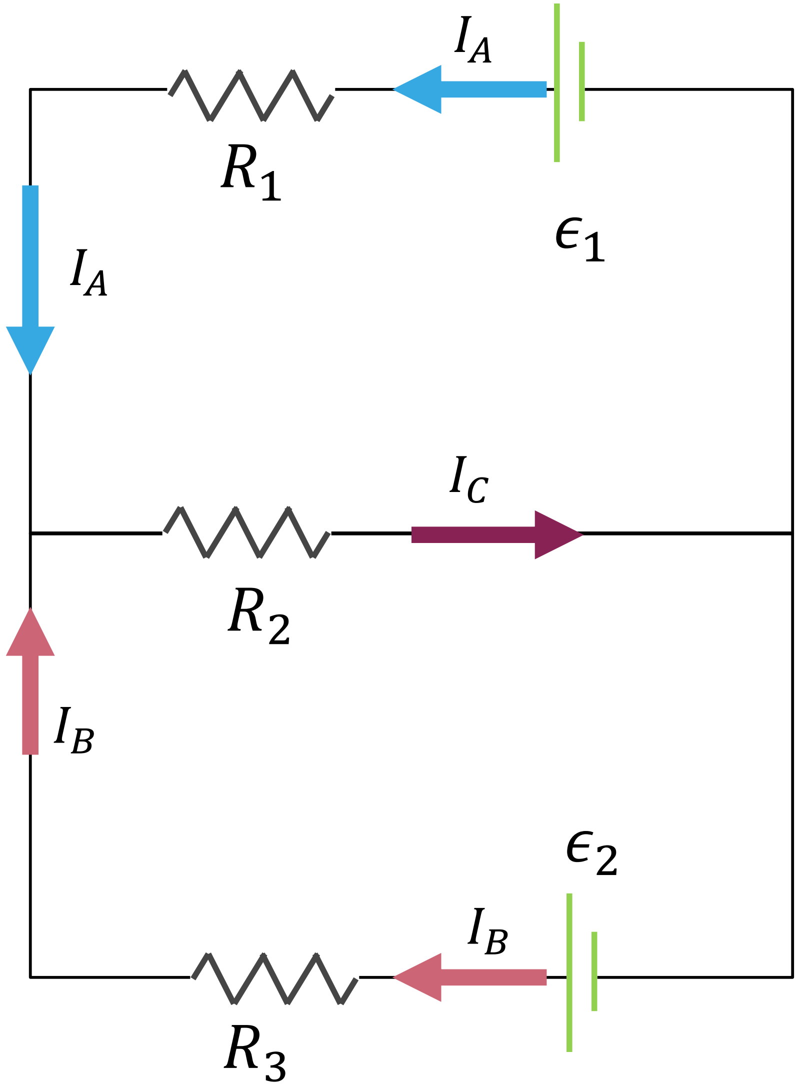
From + to −

Against the current

$$+I_A R_1 - \epsilon_1 + I_C R_2 = 0 \quad \times(-1)$$

$$-I_A R_1 + \mathcal{E}_1 - I_c R_2 = 0$$

EXAMPLE



$Junction$:

$$I_3 = I_1 + I_2$$

$Loop$ #2 (clockwise, $from\ the\ top - left\ corner$):

$$\Delta V_2 + \epsilon_2 + \Delta V_3 = 0$$

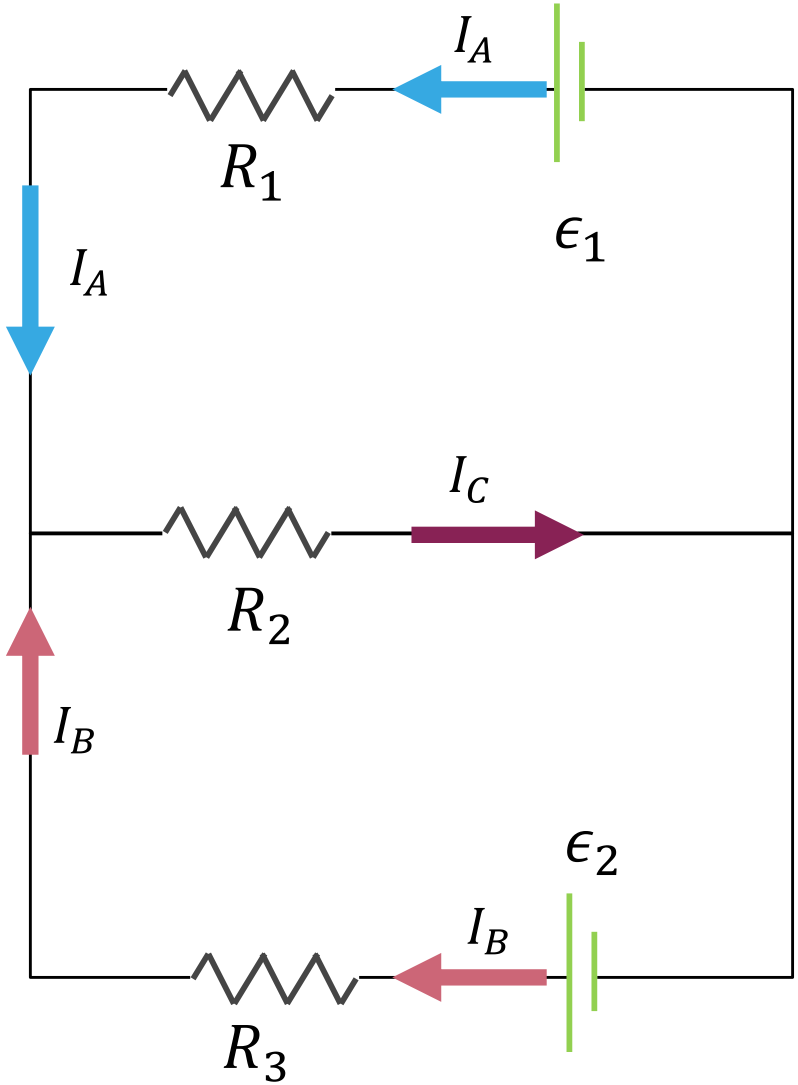
With (along) the current

From − to +

With (along) the current

$$-I_C R_2 + \epsilon_2 - I_B R_3 = 0$$

Example



$Junction$:

$$I_3 = I_1 + I_2$$

$Entire\ circuit\ (Loop\#1 + Loop\#2)$

$$\Delta V_1 - \epsilon_1 + \epsilon_2 - \Delta V_3 = 0$$

Against the current

From + to −

From − to +

With (along) the current

$$+I_A R_1 - \epsilon_1 + \epsilon_2 - I_B R_3 = 0$$