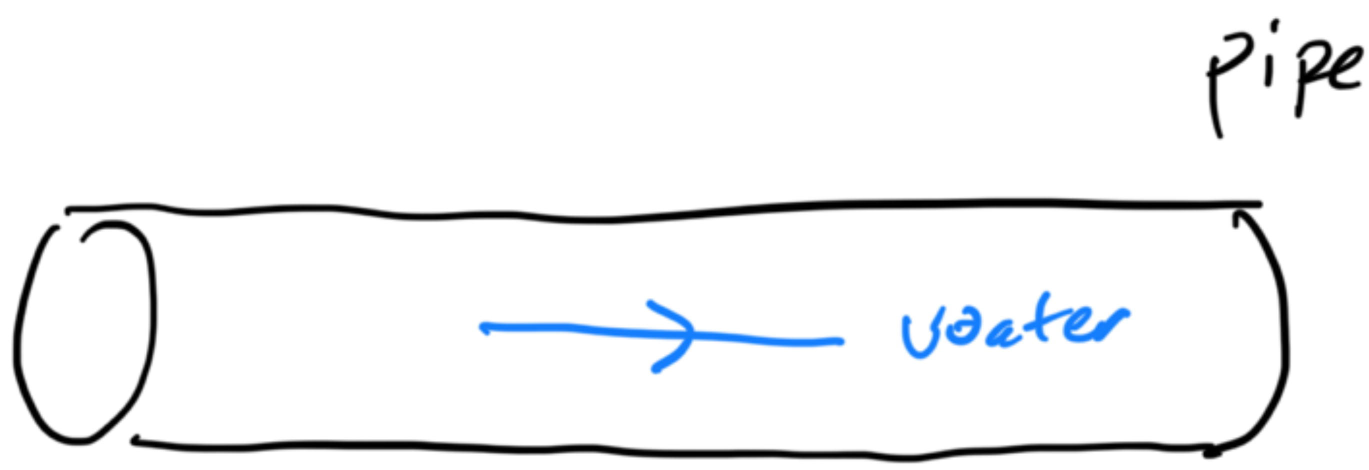
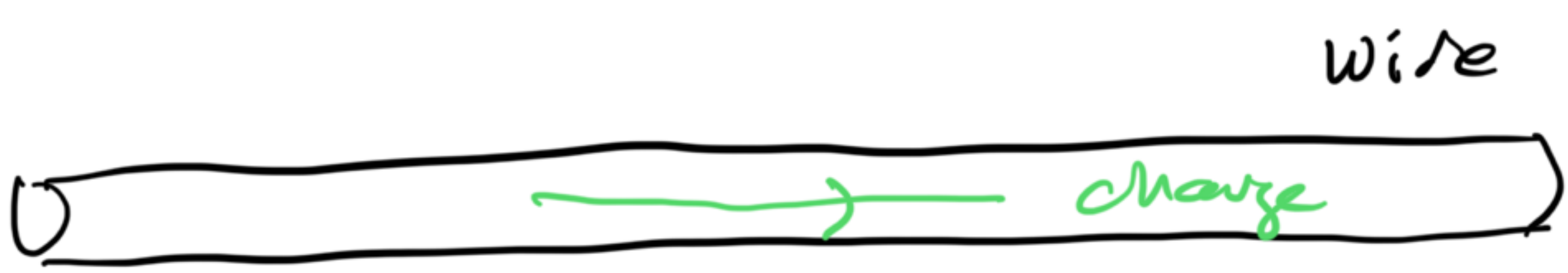
Phys 202 - Electric Current, Resistance, Electric Circuits

All of this is based on a model of electricity as a liquid. So, we think of it flowing like water in a pipe!!



Question: How much water is flowing?

Answer: measure the volume of water per second. (m^3/s)



Question: How much charge is

flowing?

Answer: measure the amount of charge (ΔQ) per second.

$$\text{electric current} \equiv \frac{\Delta Q}{\Delta t} = i \text{ (or } I\text{)}$$

$$[i] = \frac{\text{Coulombs}}{\text{second}} = \frac{C}{s} \equiv 1 \text{ Ampère}$$

$$= 1\ A$$

"amps" ← again, say the whole name!

ASQ1: Cathode Ray Tube

$i = 30\ \mu A$

How many electrons strike the screen in 25.0 s?

$i = 30\ \mu A = 30 \times 10^{-6}\ \frac{C}{s}$

$$\boxed{i = \frac{\Delta Q}{\Delta t}}$$

$$\therefore \quad \Delta Q = i\,\Delta t$$

$$= \left(30 \times 10^{-6}\ \frac{C}{s}\right)(25\,s)$$

$$= 0.00075\ C$$

How many electrons?

$$\boxed{\#\ \text{of things} = \frac{\text{Total Amount of Thing}}{\text{Amount of 1 thing}}}$$

e.g. How many apples in a basket?

Total Mass = 100 kg

mass of 1 apple = 0.25 kg.

$$\#\ \text{of apples} = \frac{100\ \text{kg}}{0.25\ \text{kg}} = 400$$

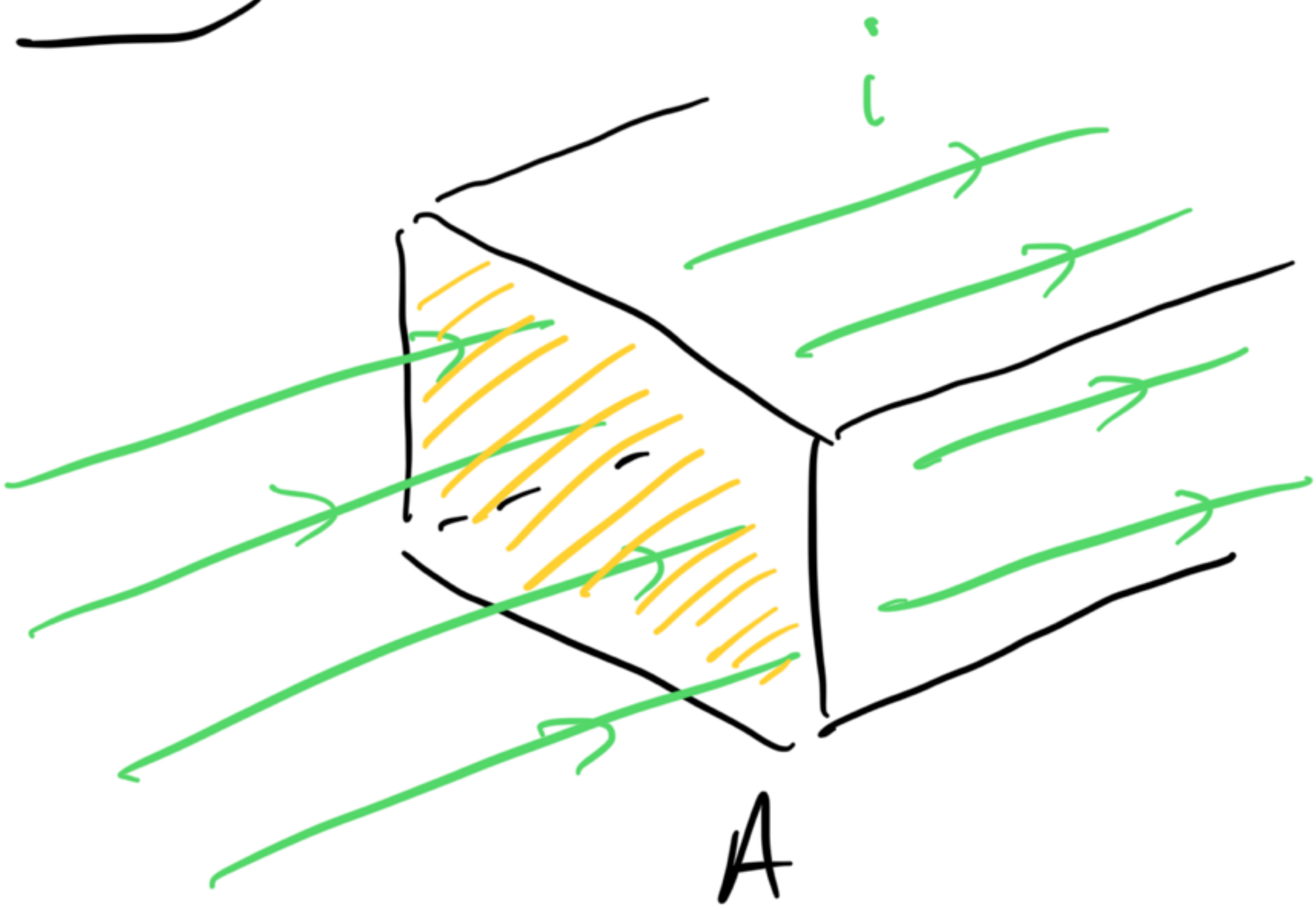
$$\#\ \text{of electrons} = \frac{\text{Total Charge}}{\text{charge on 1 electron}}$$

$$= \frac{0.00075\ C}{}$$ ← ΔQ

$$\overline{\quad 1.602 \times 10^{-19}\ C \quad}$$

$$= 4.69 \times 10^{15} \text{ electrons.}$$

ASQ2 :



$$q(t) = 4t^3 + 5t + 6$$

$$\boxed{i = \frac{\Delta Q}{\Delta t}} \Rightarrow \frac{dq}{dt} \text{ in the limit } dt \to 0$$

$$\frac{dq}{dt} = 12t^2 + 5 = i$$

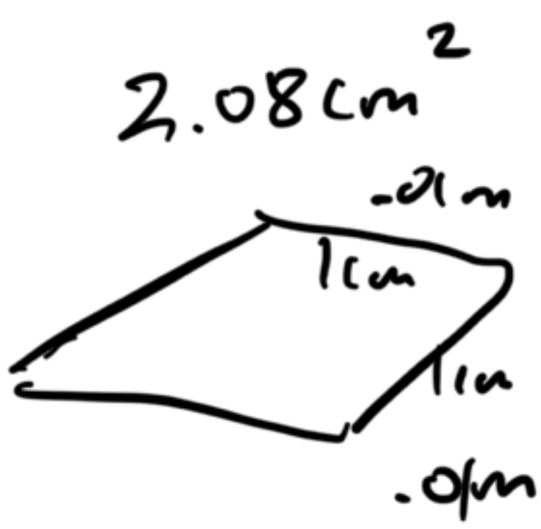
a) at $t = 1.06\,s$,

$$i = 12(1.06)^2 + 5 = \underline{\underline{18.5\,A}}$$

b) What is the <u>current density</u>?

Huh?

Define current density →



$$j \equiv \frac{i}{A} \quad \left(A/m^2\right)$$

$$= \frac{18.5\,A}{1.96 \times 10^{-4}\,m^2}$$

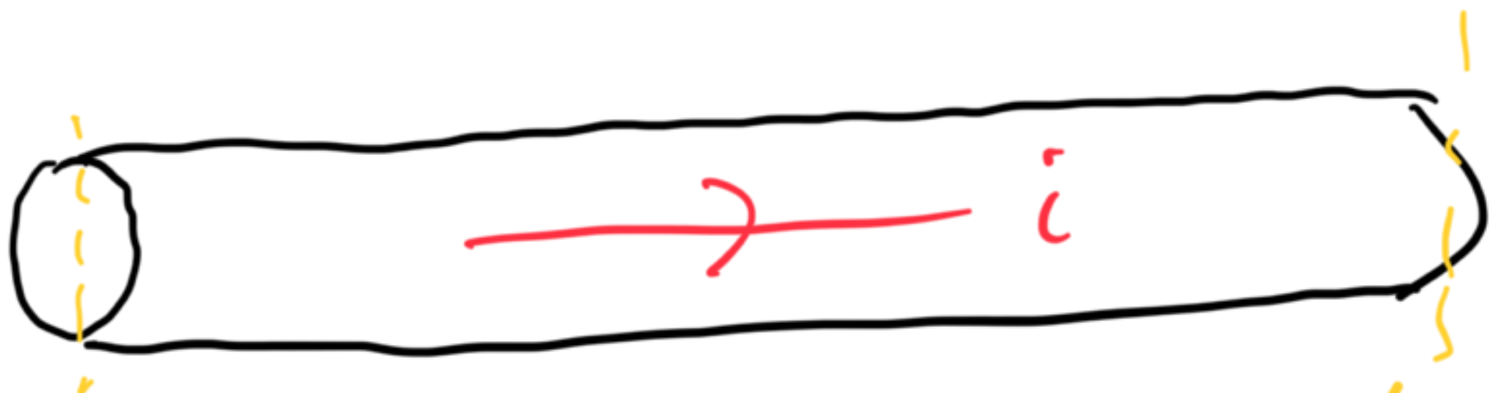
$$= 9.43 \times 10^4\ A/m^2$$

$$= 94.3\ kA/m^2$$

So, how do we get current ???

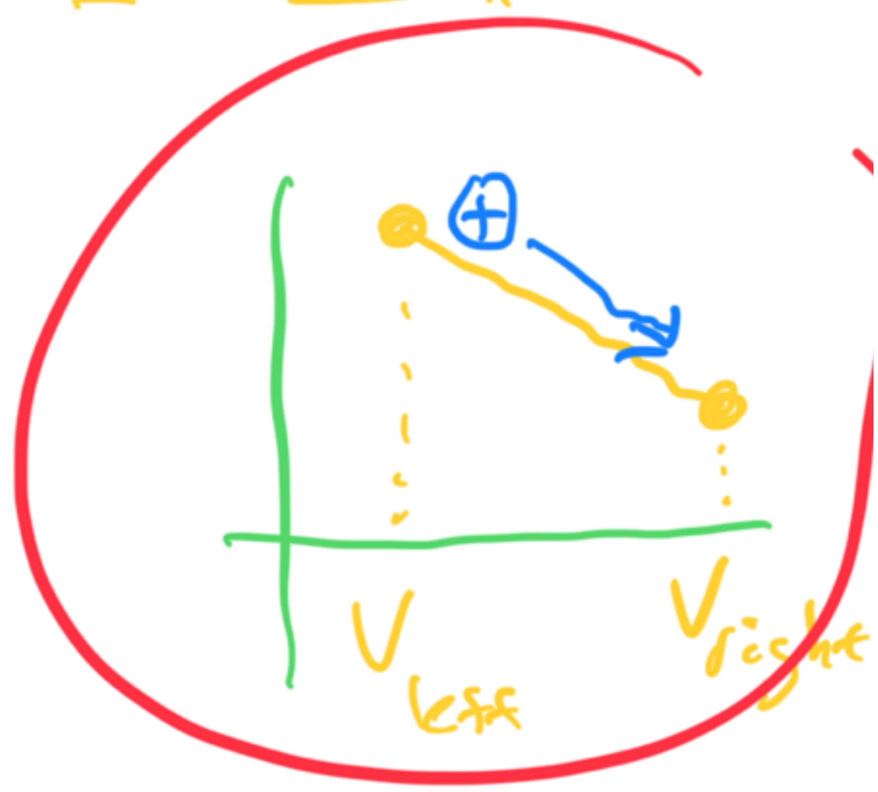
to flow in a wire !!!

Answer: Apply a voltage $\boxed{\text{difference}}$ between the two ends !!

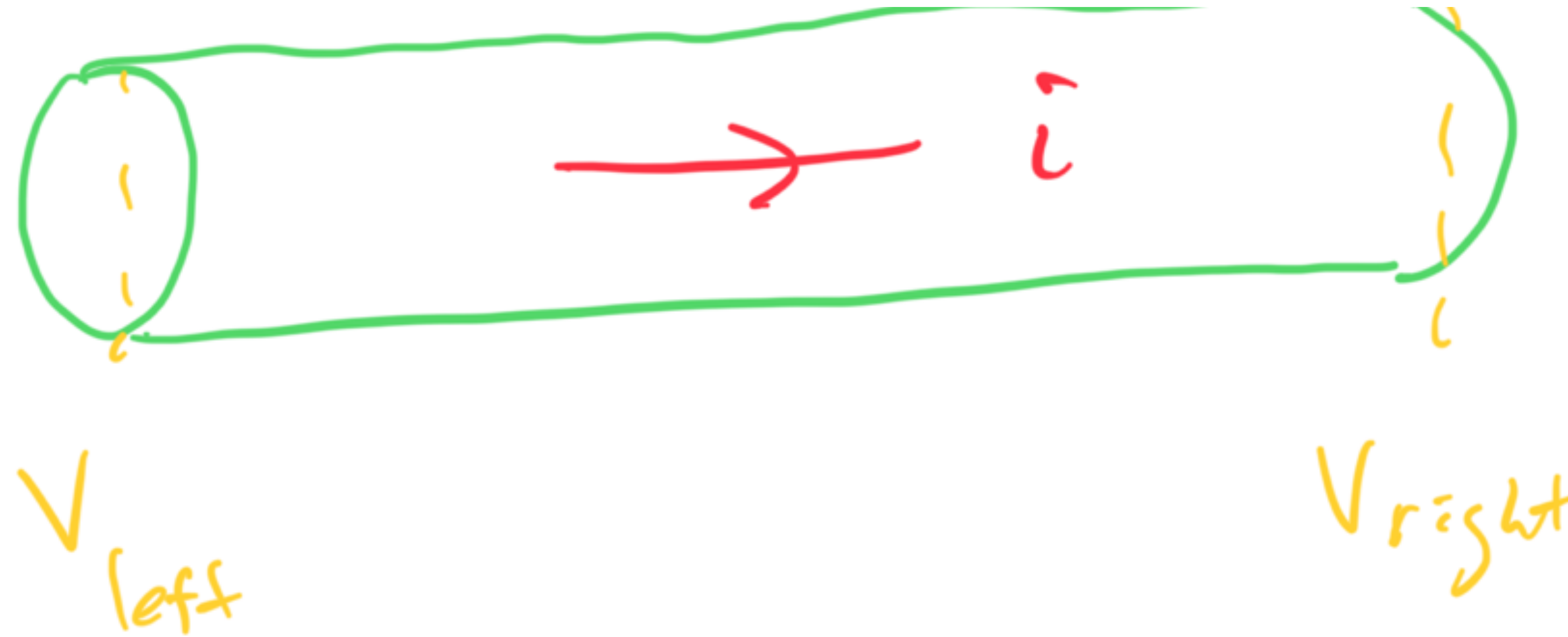


V_{left} V_{right}

$$\underbrace{V_{left}}_{\uparrow\ \text{bigger}} - \underbrace{V_{right}}_{\uparrow\ \text{smaller}} = \Delta V$$



In our model, electric current is the flow of <u>positive</u> charge.



$\Delta V = 0.5V$

How much current will flow??

Answer: It's complicated.

Depends on:

a) What the wire is made of

b) How long the wire is.

c) What the cross-section area is.

Georg Ohm (1820's)

... this.

He did experiments on

He found that for metal wires, that:

proportional to

$$\boxed{\text{current} \propto \Delta V}$$

Ohm's Law

e.g.

$\Delta V = 50V$, measure $i = 1.0A$

$\Delta V = 130V$,

predict: $i = \left(\frac{130}{50}\right)(1.0A)$

$= 2.6\ A$

In physics, when we find a situation where one thing is proportional to another, we define a constant of proportionality.

e.g.

$$|\vec{F}| \propto |\vec{\Delta x}|$$

$$\therefore |\vec{F}| = k\,|\vec{\Delta x}|$$

spring constant

device property !!!!

i.e. different for different springs

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we have that:

$$i \propto \Delta V$$

or

$$\Delta V \propto i$$

Define: $\Delta V = i \boxed{R}$

constant of proportionality.

Resistance → constant of proportionality.

$$[R] = V/A \equiv 1\ \text{Ohm}$$

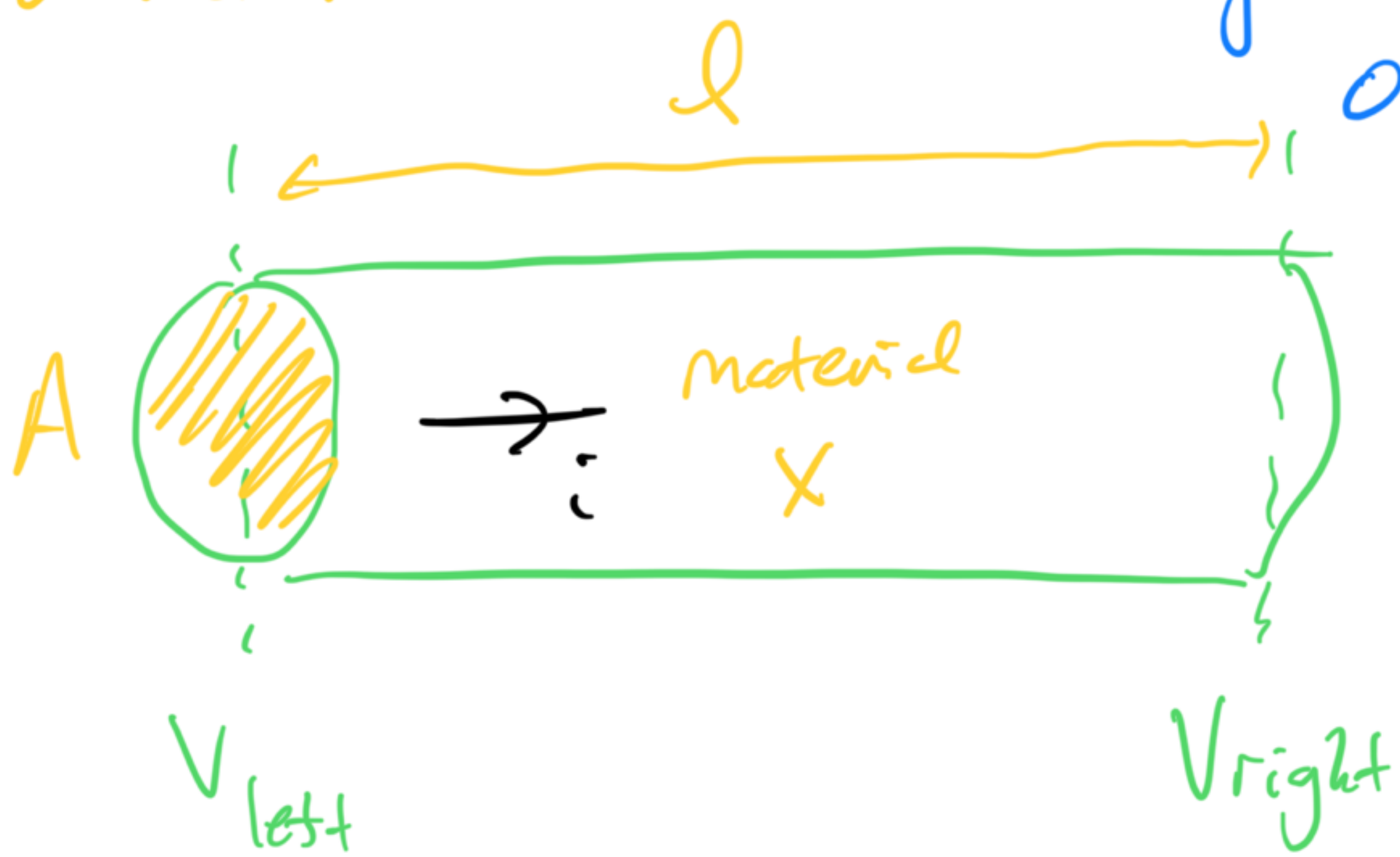
$$= 1\ \Omega$$

greek capital Omega.

$\cancel{R = 1\,O}$

Omega

Omicron



$$R = \rho\, l$$

$$\frac{\rho_x \ell}{A}$$

$\rho_x \equiv$ resisitivity of material X

(in $\Omega \cdot m$)

e.g. (A5Q3) Tungsten: $\rho_w = 5.6 \times 10^{-8}\ \Omega \cdot m$

$\ell = 1.5\,m$

$A = 0.4\ mm^2$

$= 0.4 \times 10^{-6}\ m^2$

$$R = \frac{\rho_w \cdot \ell}{A} = \frac{(5.6 \times 10^{-8})(1.5)}{0.4 \times 10^{-6}}$$

$$= 0.21\ \Omega$$

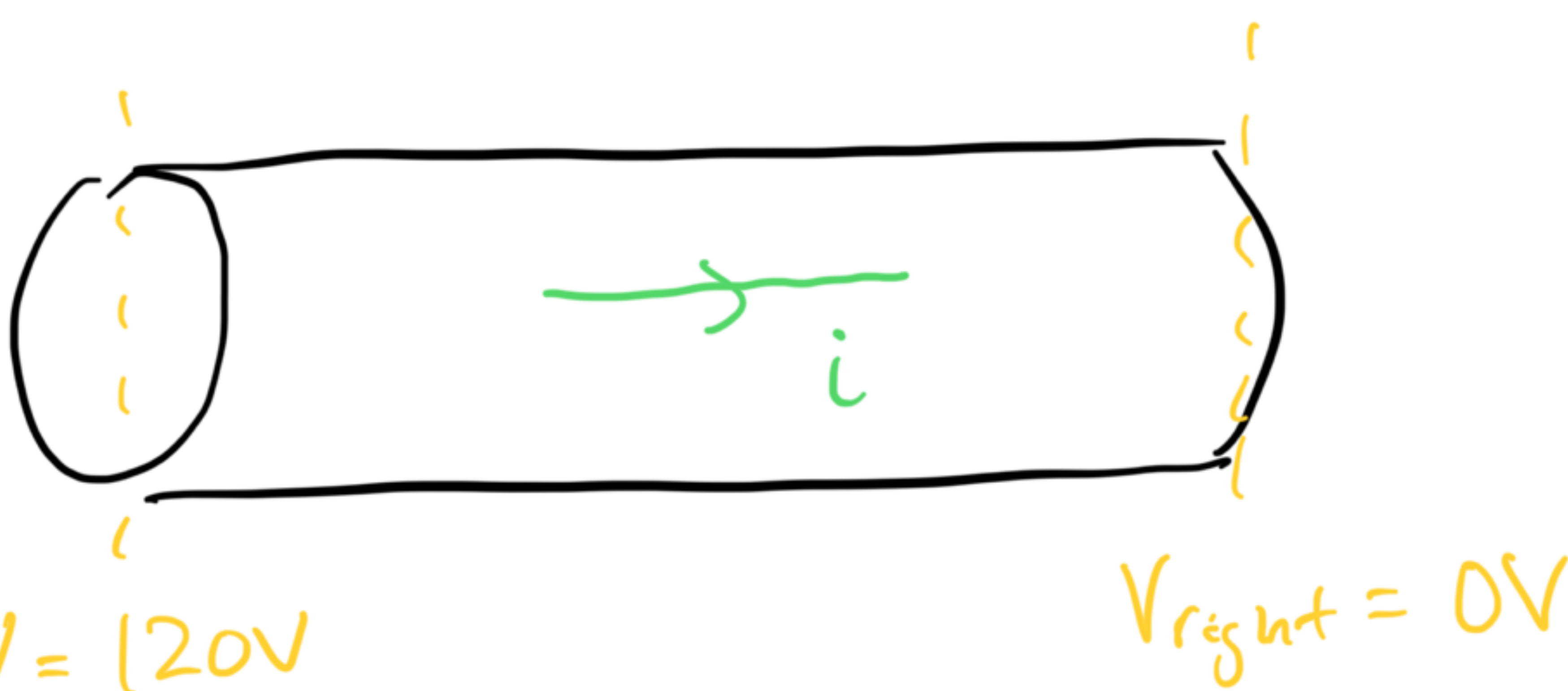
Now: $\underset{0.5\,V}{\Delta V} = iR$

$$\therefore\ i = \frac{\Delta V}{R} = \frac{0.50\,V}{0.21\,\Omega}$$

$= 2.38\ A.$

When we use electrical devices, we pay for it? What are we paying for? $\Rightarrow$ Energy!

So, how much energy is being used?



$\Delta V = 120V$ (wall outlet)

For most electrical devices, we ... Power Rating.

are provided a Power rating

Example: Toaster $\rightarrow$ 480 W

Watts = J/s

amount of energy per second. $\longrightarrow$

$$P_{electrical} \equiv i \cdot \Delta V$$

$\frac{C}{s}$

$V = J/C$

$$480\,W = i \cdot 120\,V$$

$$\therefore \; i = \underline{\underline{4.0\,A}}$$

$$\Delta V = i \cdot R$$

$$R = \frac{\Delta V}{i} = \frac{120\,V}{4.0\,A}$$

(A4Q4)

$$= \underline{\underline{30\,\Omega}}$$

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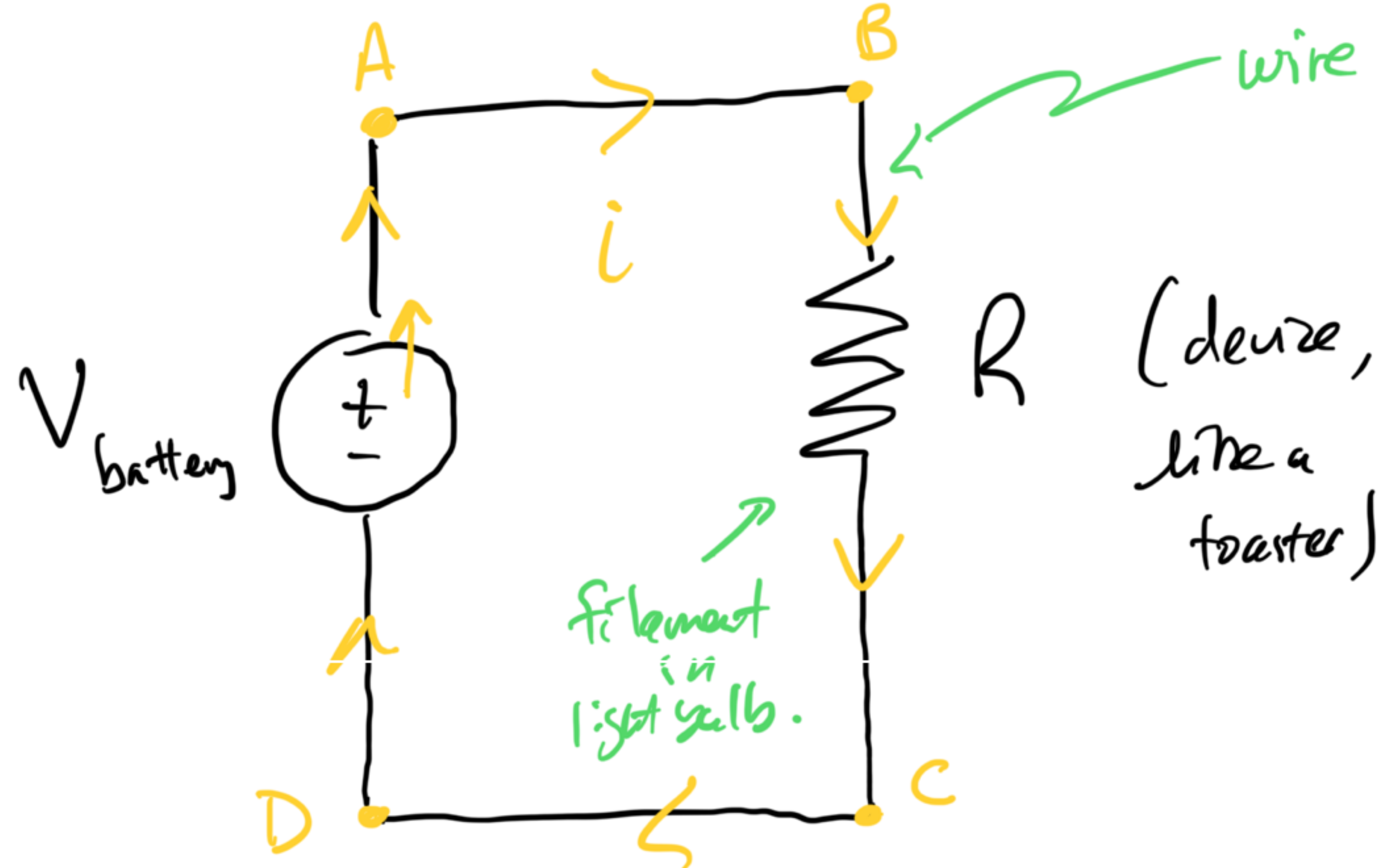
i, R | $i = \frac{dq}{dt} = \frac{\Delta q}{\Delta t}$ $R = \rho l / A$

Electric Circuits

$$\Delta V = iR$$
$$P = iV$$

Electric Circuits

How can we come up with a symbolic method for drawing electrical device situations.



Toaster

Assumptions:

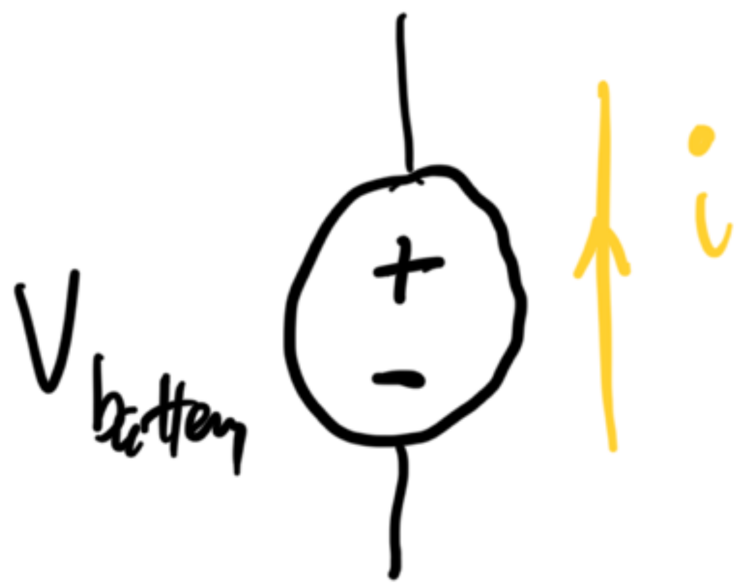
(1) Wires are perfect conductors.

$$R_{wire} \approx 0$$

$$R_{toaster} = 30\ \Omega$$

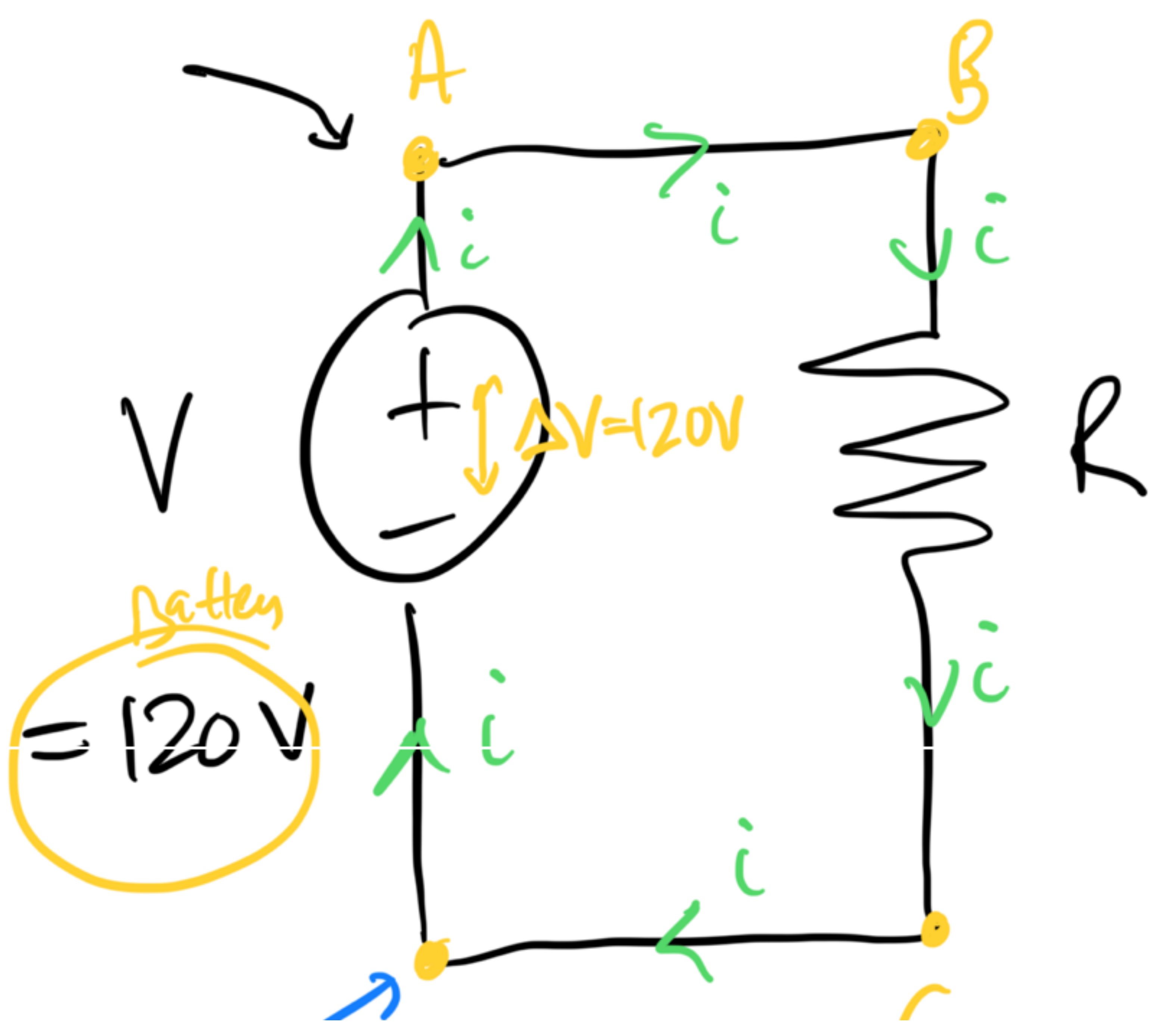
$R_{wire} \approx \cancel{0.2}\,\Omega$ $0.03\,\Omega$

2



Voltage at a Point vs.

ΔV across an Element



$V_D = 0$ D

V_A, V_B, V_C, V_D

→ voltages at specific points!!

What is V_A?

All I know

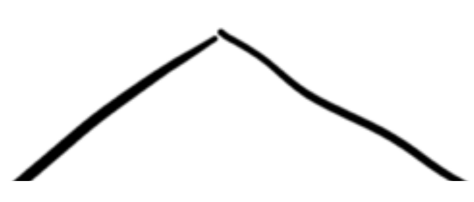
$\Delta V_{A \to D} = 120V$

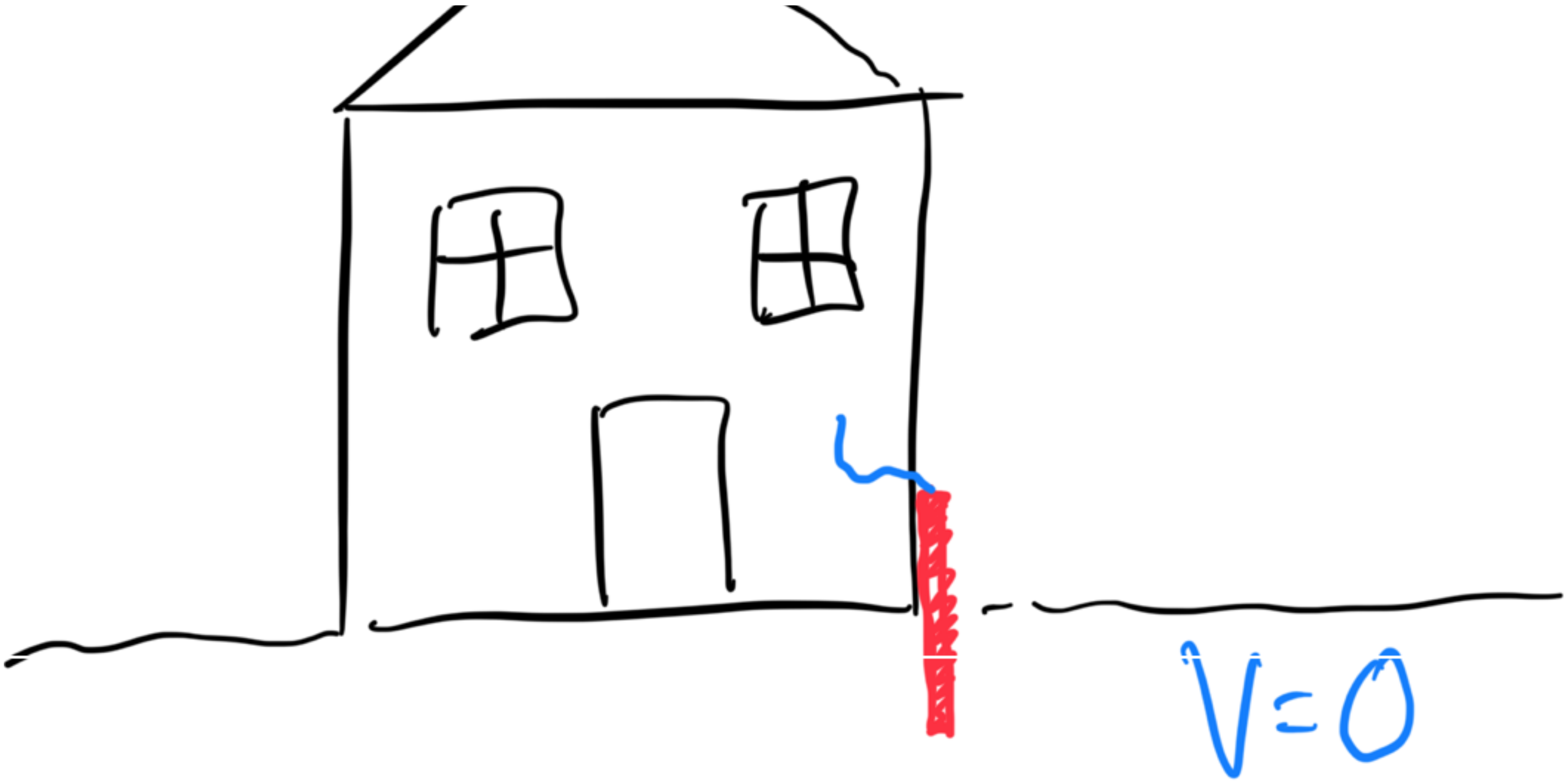
$V_A - V_D = 120V$

Choose $V_D = 0$!!

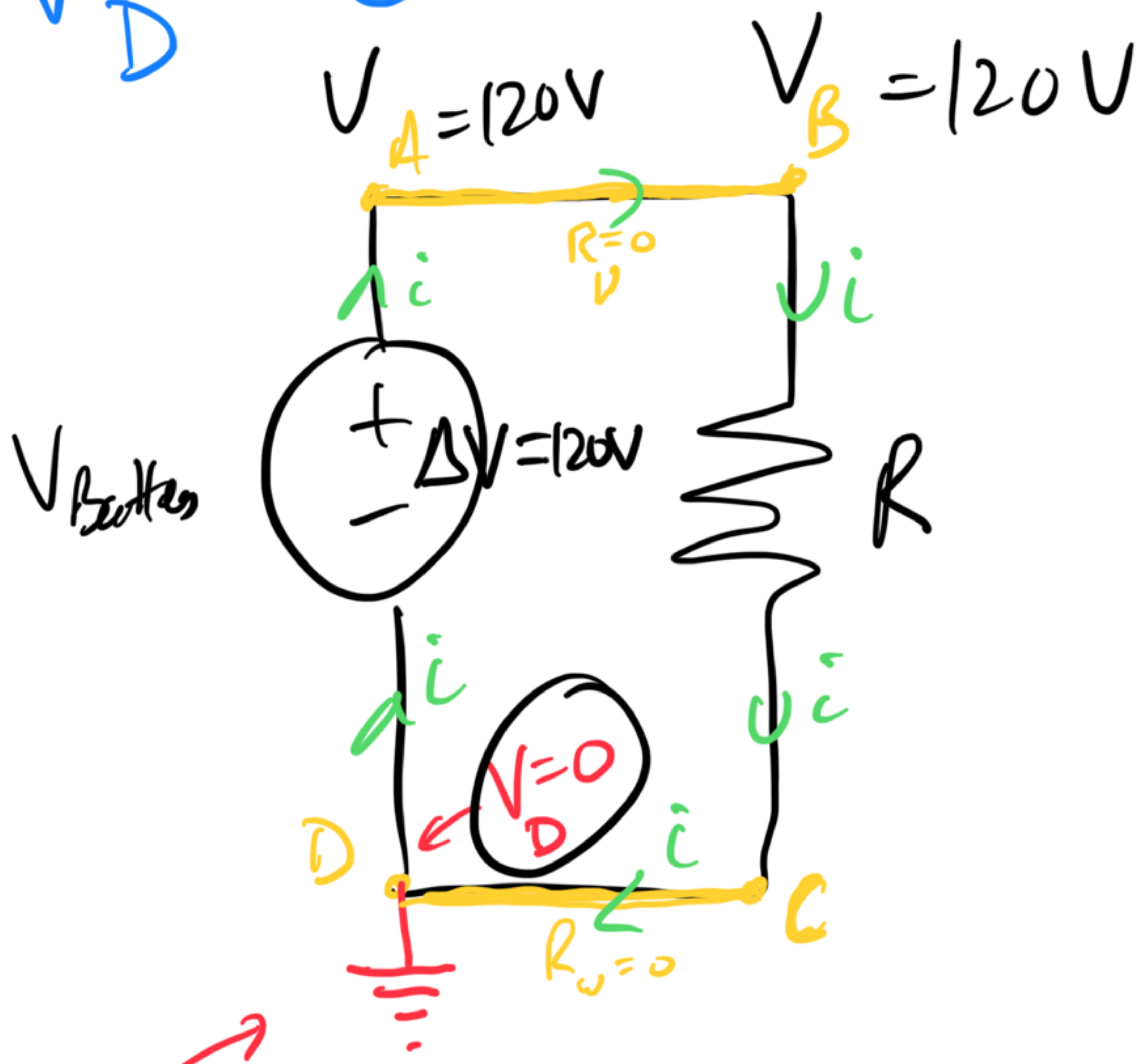
Grounding the circuit.

V=0





$V_D = 0$



Grand.

What is V_A?

$$V_A = 120\text{ V}$$

What is V_B?

$$V_B = 120\text{ V}$$

What is V_C?

$$V_C = 0\text{ V}$$

What is $\Delta V_R = V_B - V_C$

$$= 120\text{ V} - 0\text{ V}$$

$$= 120\text{ V}$$

$R = 30\,\Omega$

$$\Delta V_R = i_R R$$

$$120\,V = i_R \cdot (30\,\Omega)$$

$$i_R = 4.0\,A$$