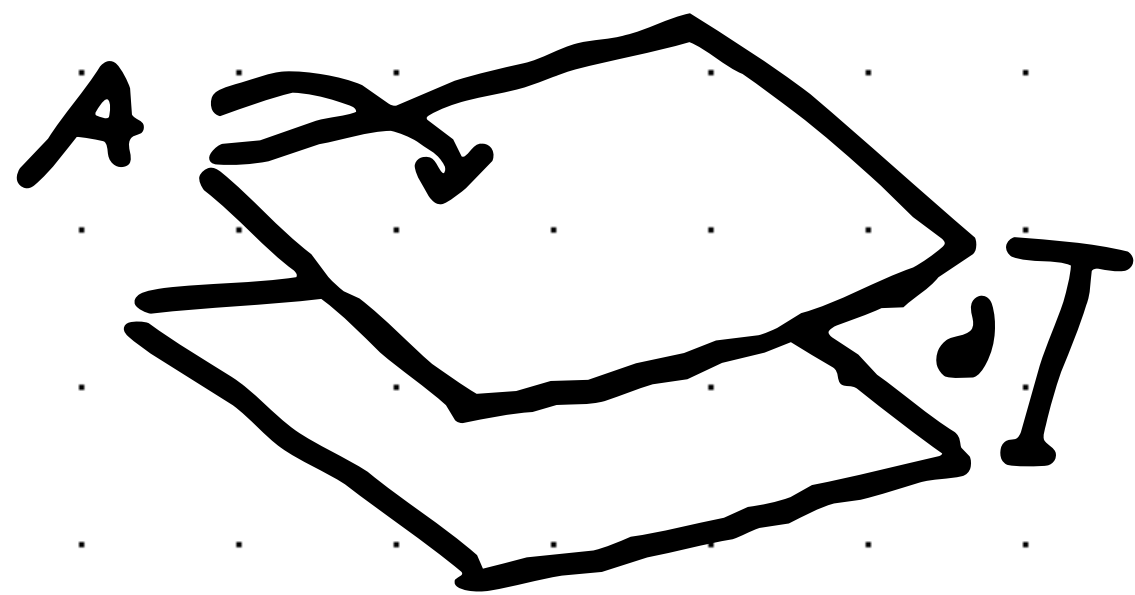


Capacitors



$$\text{Capacitance} = C = \frac{q}{V} \quad \left(\frac{\text{C}}{\text{V}} \right) \text{ or } \left(\frac{\text{Farad}}{\text{F}} \right)$$

$\xrightarrow{\text{Charge}}$ q $\xrightarrow{\text{Voltage}}$ V

$$C = \frac{\epsilon A}{d} = \frac{q}{V}$$

$\xrightarrow{\text{Permittivity of free space}} \epsilon = 8.84 \times 10^{-12} \text{ F/m}$

A = plate Area

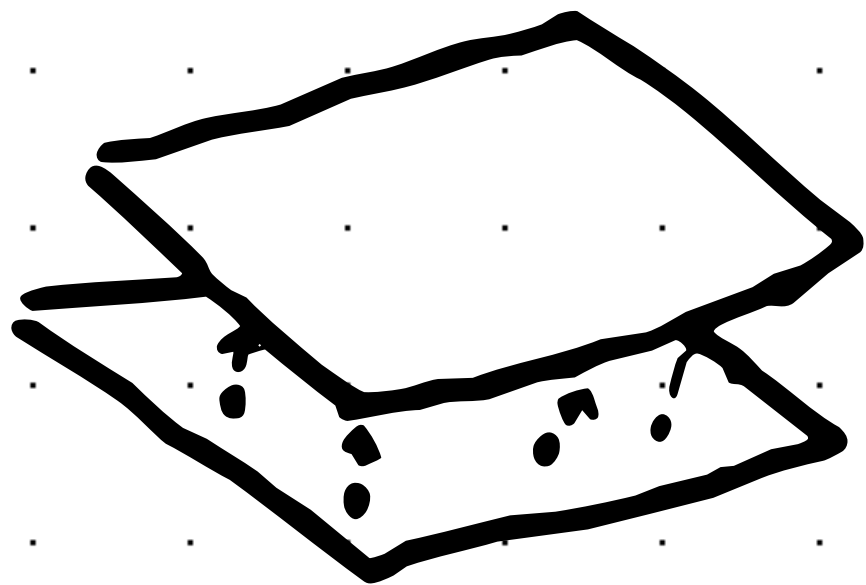
d = distance between two plates

$$i = \frac{dq}{dt} = \frac{d(CV)}{dt} = C \frac{dV}{dt}$$

Now, we are assuming that the capacitance (C) is constant. This is not true in reality, because the plate distance can change, or the plate media can change. However, for now, we will assume C is constant.

With Capacitors, Current Leads Voltage

- This is because, in a capacitor, you have two plates that are separated. by 90°!



- To create a potential difference in between the two plates, you require a bit of current!
- In other words, in order to create voltage, you NEED current first!

EQUATIONS USED BY CAPACITORS

$$V_{(t)} = \frac{1}{C} \int_{t_0}^t i_{(t)} dt + V_{(t_0)}$$

Voltage

$$i = \frac{dq}{dt} = \frac{d(CV)}{dt} = C \frac{dV}{dt}$$

Current

$$P = V_{(t)} i_{(t)} = C V_{(t)} \frac{dV_{(t)}}{dt}$$

Power

$$W \approx \frac{1}{2} C V^2$$

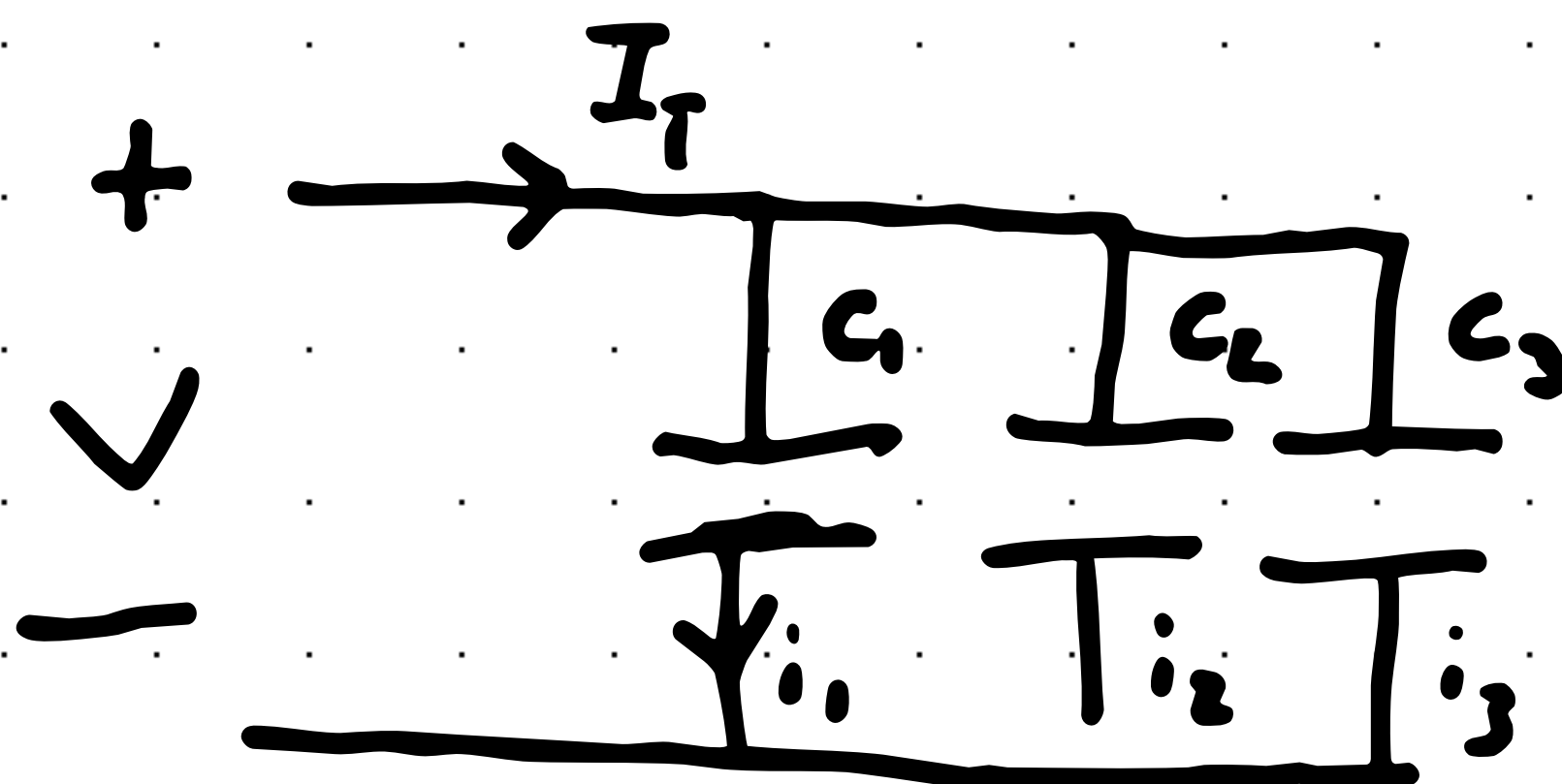
Energy "stored" in capacitor,
or Energy discharged by
capacitor

Capacitors In Series



$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Capacitors In Parallel



$$C_T = C_1 + C_2 + C_3$$

For DC Circuits

$$\text{Since } i = C \frac{dv}{dt}$$

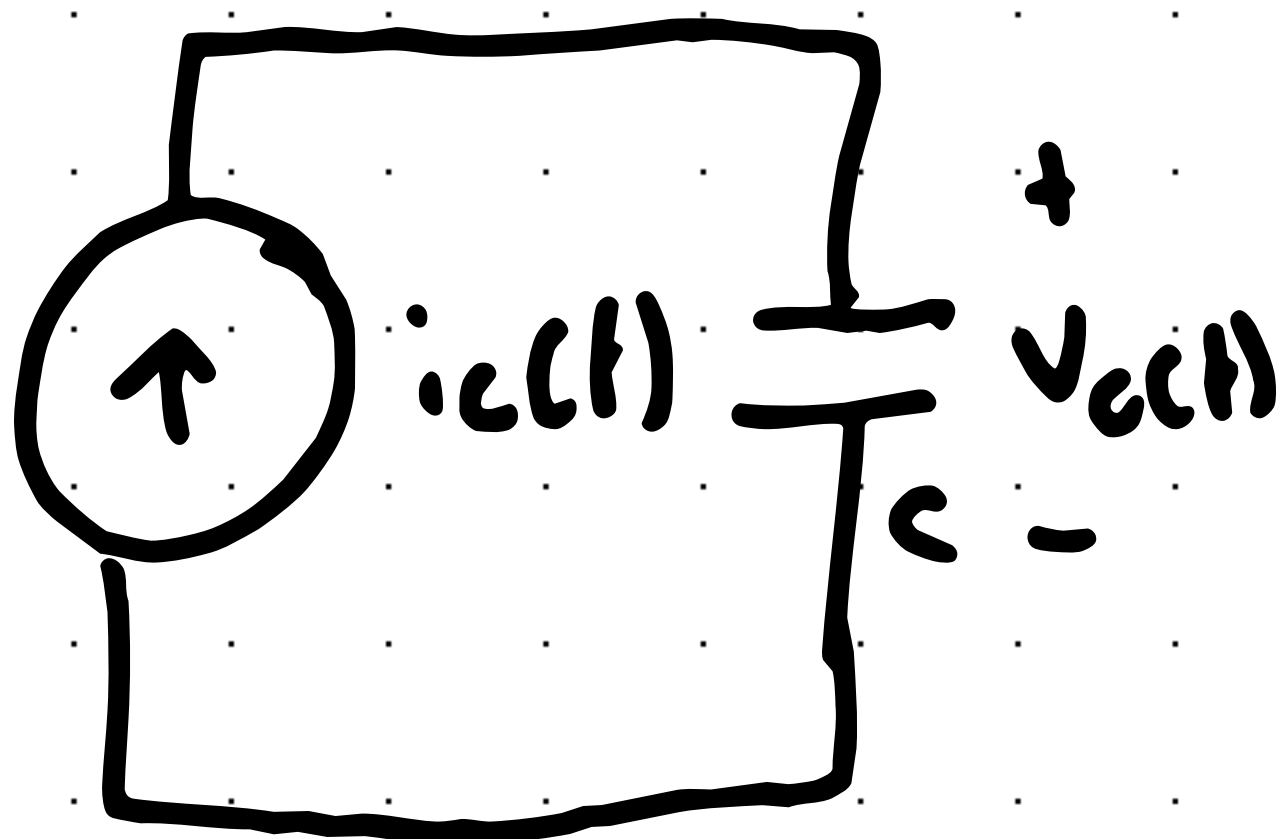
In DC, the capacitor appears to be an open circuit.

This occurs while the capacitor is charging. This is called the Transient State, or the Transient period. It is not a steady state.

While it "spools" up, there is a period where things are unknown, or unpredictable. It's like when you first get up in the morning. Or, like an old elevator first moving up, right?

Ex

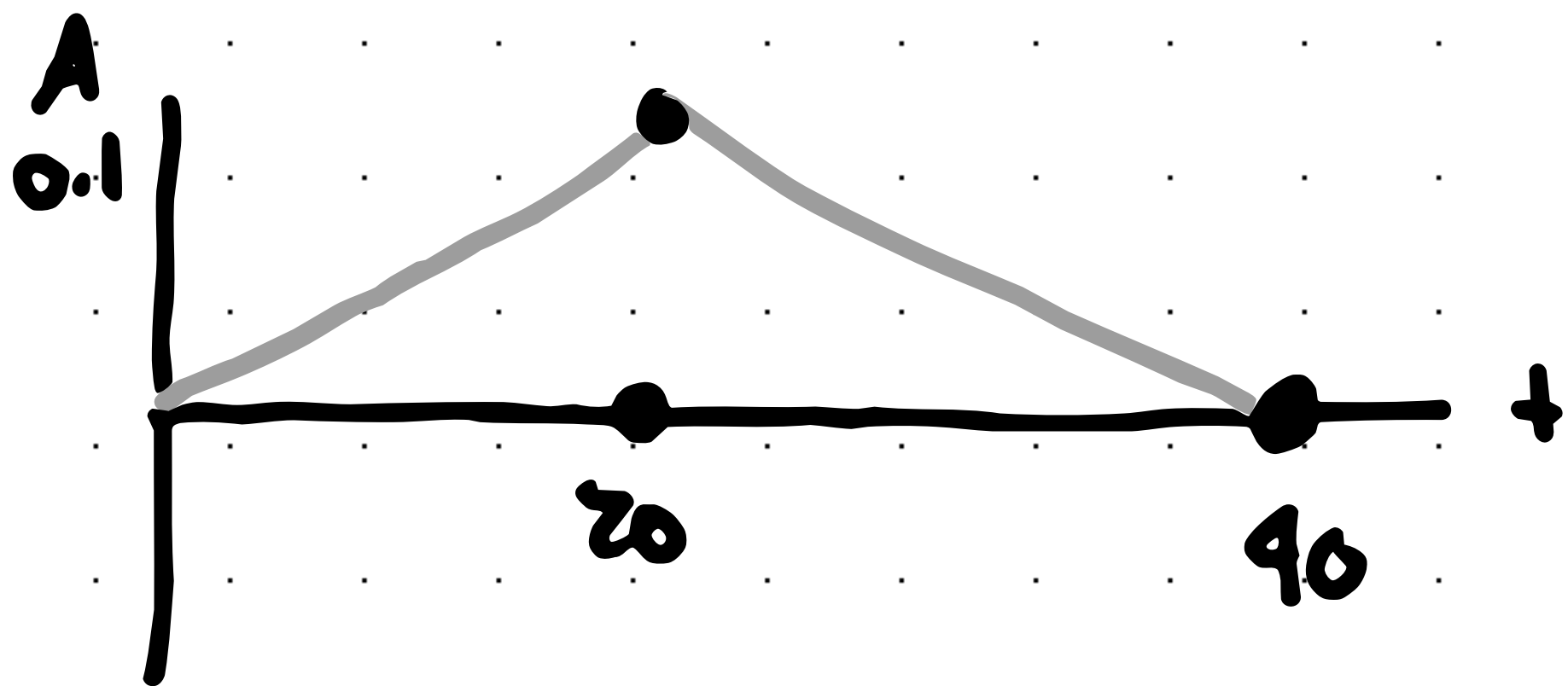
$$i_c(t) = \begin{cases} 0 & t < 0 \\ 5000t & 0 < t < 20 \mu s \\ 0.2 - 5000t & 20 \mu s < t < 40 \mu s \\ 0 & t > 0 \end{cases}$$



$$C = 0.2 \mu F$$
$$v_c(0) = 0$$

Calculate $v_c(t)$, $P(t)$, $W(t)$ and sketch

Sol



$$v_c(t) = \frac{1}{C} \int i_c(t) dt + v_0, \quad 0 < t < 20 \mu s$$

$$v_c(t) = \frac{10^6}{0.2} \int_0^t 5000t dt + v_c(0)$$

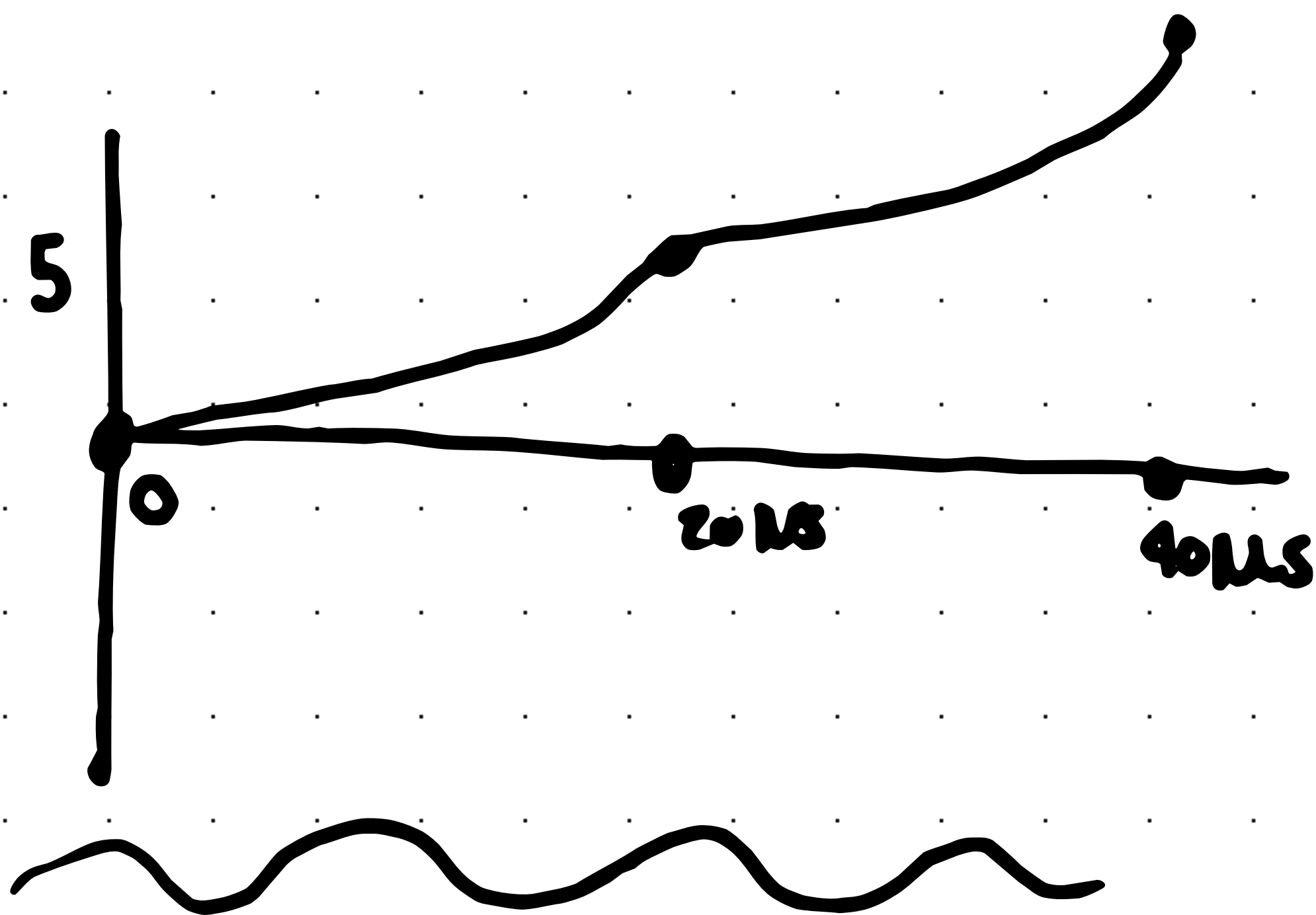
$$v(t) = \frac{10^6}{0.2} \left[5000 \frac{t^2}{2} \right]_0^t = 12.5 \times 10^9 t^2$$

$$\text{at } t = 20 \mu s \rightarrow v_c(t) = 5v$$

$$20 < t < 40 \mu s$$

$$V(t) = \frac{10^6}{0.2} \int_{20}^t (0.2 - 5000t) dt + V(t=20 \mu s)$$

$$V(t) = 10^6 t - 12.5 \times 10^9 t^2 - 10$$



$$P = V_{ch} i_{ch}$$

$$W = \int P dt = \frac{1}{2} C v^2$$

$$0 < t < 20 \mu s$$

$$P_{ch} = (5000t)(12.5 \times 10^9 t^2) = 62.5 \times 10^{12} t^3$$

$$W = \int (62.5 \times 10^{12} t^3) dt$$

$$= 15.625 \times 10^{12} t$$

$20 \mu s < 40 \mu s$

$$P(t) = (0.2 - 5000t)(10^6 + -12.5 \times 10^9 t^2 - 10) =$$

$$= 62.5 \times 10^{12} t^3 - 7.5 \times 10^9 t^2 + 2.5 \times 10^5 t - 2$$

$$W(t) = 15.625 \times 10^{12} t^4 - 2.5 \times 10^9 t^3$$

$$+ 0.125 \times 10^6 t^2 - 2 \times 10^{-11} t$$

