RC Circuits

PHY 114-01

Fall 2026

Announcements

- Keep studying for the midterm! Come to office hours with questions.
- Two parts:
  - Conceptual part: T/F with justification. If you do not justify your answer, you can only receive half credit.
  - Quantitative part: similar to the last exam.

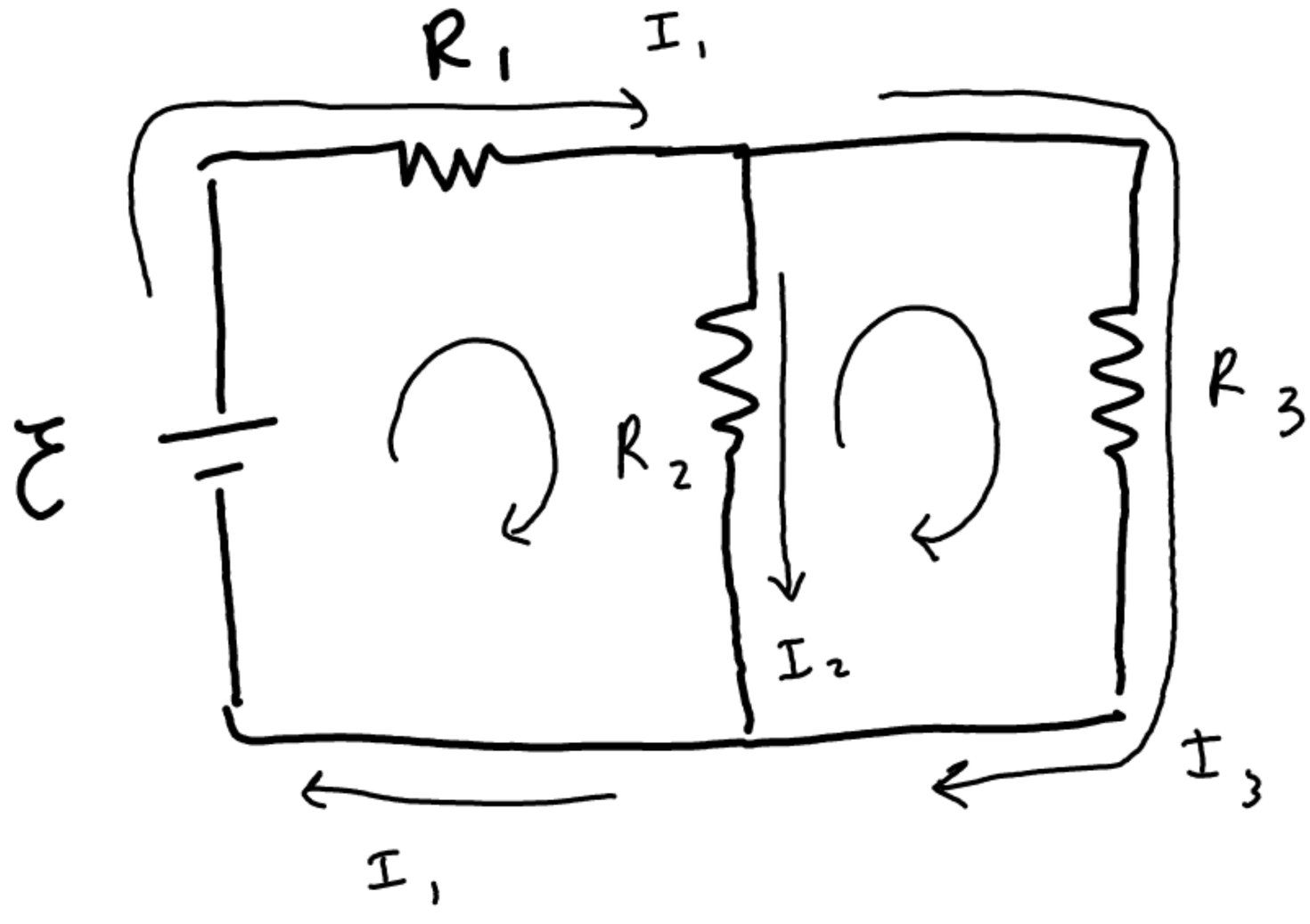
Agenda

- Last time:
  - Applying Kirchoff's laws
- This time:
  - Continue Kirchoff's law problem
  - Introduce RC circuits

Process:

1. define loops
2. label currents in each branch
3. write Loop rule for voltages $\sum_{loop} V = 0$
4. write junction rule for currents $I_{in} = I_{out}$
5. solve!

Find the current through each resistor:



1. draw loops

2. draw currents

3. loop rule

1) $\mathcal{E} - I_1 R_1 - I_2 R_2 = 0$

2) $-I_3 R_3 + I_2 R_2 = 0 \longrightarrow I_3 = \dfrac{I_2 R_2}{R_3}$

4. junction rule $I_1 = I_2 + I_3$

rewrite eqn 1: $\mathcal{E} - (I_2 + I_3) R_1 - I_2 R_2 = 0$

$$\mathcal{E} - I_2 (R_1 + R_2) - I_3 R_1 = 0$$

$$\mathcal{E} - I_2 (R_1 + R_2) - \frac{I_2 R_2}{R_3} R_1 = 0$$

$$I_2 = \mathcal{E} \cdot \left(\frac{R_1 R_2}{R_3} + R_1 + R_2 \right)^{-1}$$

$$I_2 = \varepsilon \cdot \left(\frac{R_1 R_2}{R_3} + R_1 + R_2 \right)^{-1}$$

$$= \varepsilon \cdot \left(\frac{R_1 R_2}{R_3} + \frac{R_1 R_3}{R_3} + \frac{R_2 R_3}{R_3} \right)^{-1}$$

$$I_2 = \frac{\varepsilon R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3}$$

$$I_3 = \frac{I_2 R_2}{R_3} = \frac{\varepsilon R_2}{R_1 R_3 + R_2 R_3 + R_1 R_2}$$

$$I_1 = I_2 + I_3 = \frac{\varepsilon (R_2 + R_3)}{R_1 R_3 + R_2 R_3 + R_1 R_2}$$

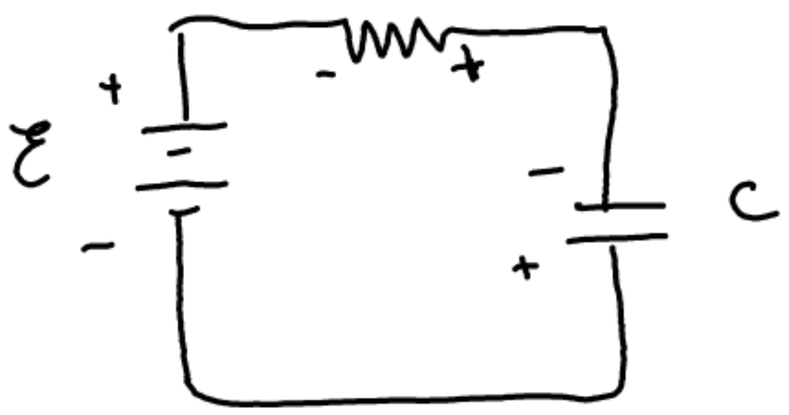
RC - circuits

So far we have only looked at the equilibrium behavior of capacitors, when they are fully charged.

Capacitors change up or discharge over time.

→ $\frac{dQ}{dt} = I$

Now that we can study current, we can study capacitors charging / discharging.



At $t = 0$, let $Q_c = 0$

What are Q_c, V_c at any time t?

start with KVL: $\mathcal{E} - iR - \frac{Q}{C} = 0$

$$\mathcal{E} - \frac{dQ}{dt} R - \frac{Q}{C} = 0$$

$$R \frac{dQ}{dt} + \frac{Q}{C} = \mathcal{E}$$

A differential equation with solution

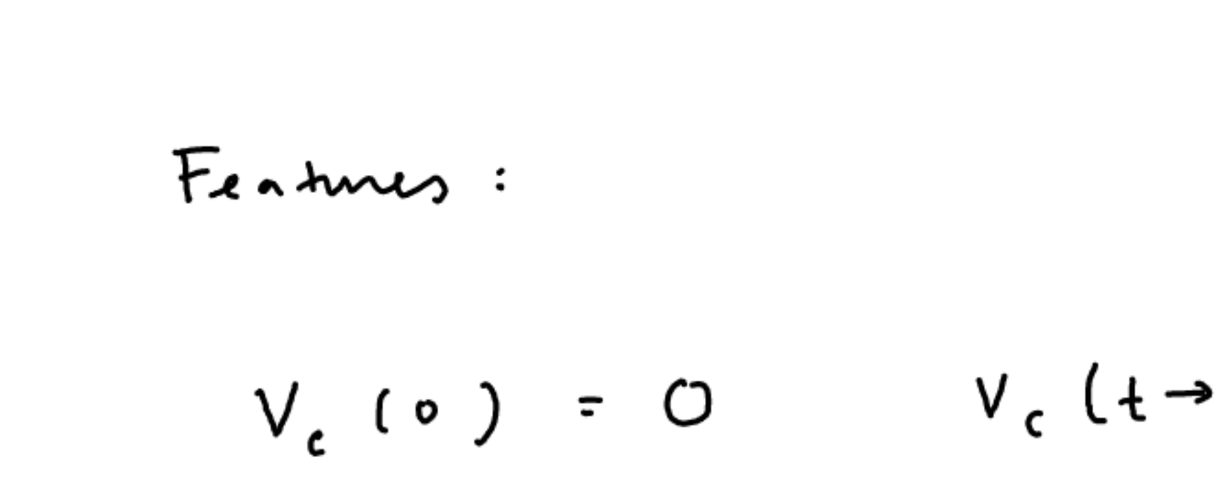
$$Q(t) = C\mathcal{E}\left(1 - e^{-t/RC}\right)$$

Thm, $V_C = \frac{Q}{C} = \mathcal{E}\left(1 - e^{-t/RC}\right)$

Features:

$V_C(0) = 0$ $\qquad$ $V_C(t \to \infty) = \mathcal{E}$ ← fully charged

$Q(0) = 0$ $\qquad$ $Q(t \to \infty) = C\mathcal{E}$ ← usual cap. eqn.



RC time constant

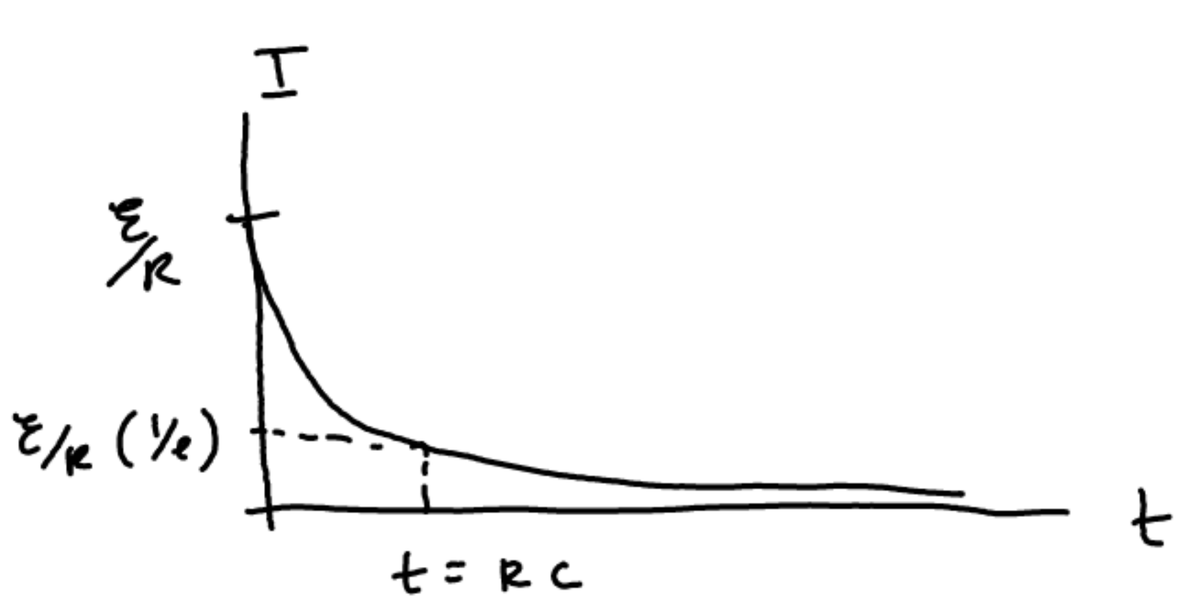
sets changing rate

$[RC] = [\Omega \cdot F]$

$= \left[\frac{V}{C/s} \cdot \frac{C}{V}\right] = [s]$

If $Q(t) = C\mathcal{E}\left(1 - e^{-t/RC}\right)$

then $I(t) = \frac{dQ}{dt} = \frac{\mathcal{E}}{R} e^{-t/RC}$



current will stop flowing when the capacitor is fully charged.