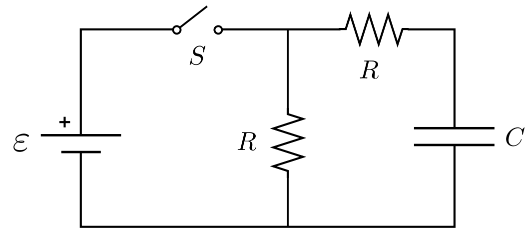
Problem C3.1 (☆☆): the diagram to the right depicts a circuit where both resistors have the same value. The switch is initially open for a long time.



(a) The switch is now closed. Find all the current(s) immediately after the switch is closed. Leave currents in simplest algebraic form.

(b) Draw the current through the capacitor and determine the time constant of the charging.

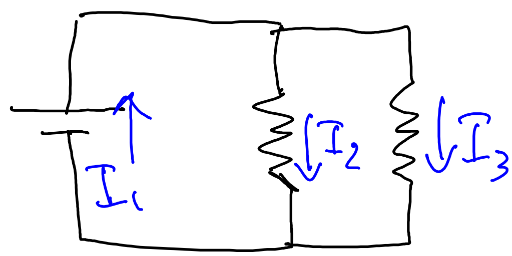
(c) What is the potential difference across the capacitor immediately and a long time after the switch is closed?

Now the switch is opened again.

(d) Find all the current(s) immediately after the switch is opened.

(e) Draw the current through the capacitor and determine the time constant of the discharging.

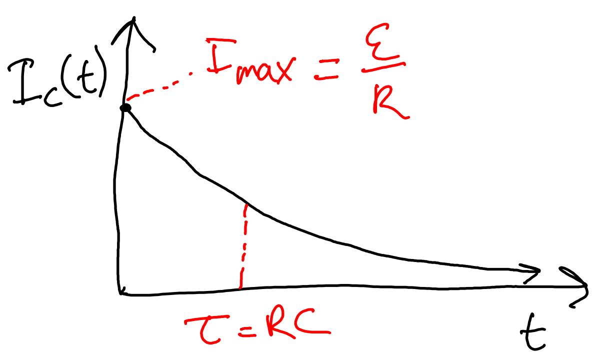
(a) After switch is closed, cap acts like wire.
∴ circuit looks like →



$$I_2 = I_3 = \frac{\mathcal{E}}{R} \qquad \therefore I_1 = I_2 + I_3 = \frac{2\mathcal{E}}{R}$$

(b) Current through uncharged capacitor peaks then decays

Kirchoff law through cap:



$$\mathcal{E} - I_3 R - \frac{Q}{C} = 0$$

$$I_3 = I_{max} e^{-t/\tau} \qquad \tau = RC$$

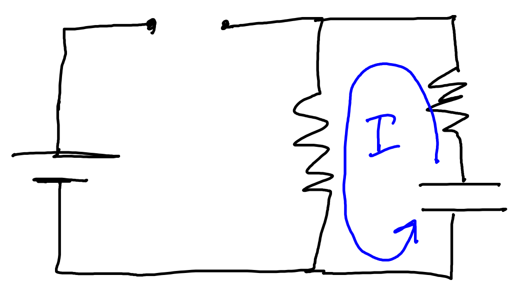
(c) Uncharged cap acts like wire:

$\therefore$ $V_c = 0$ immediately after.

Fully charged cap acts like open circuit:

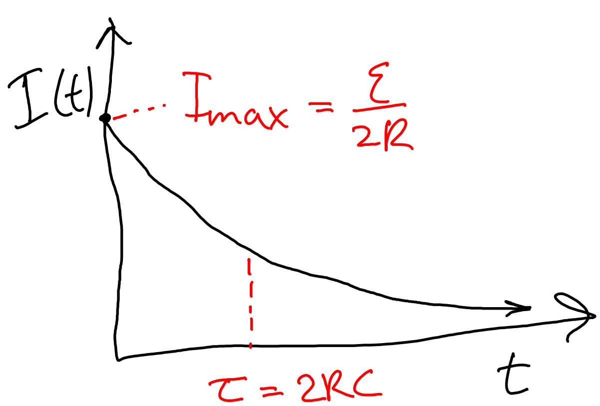
$\therefore$ $V_c = \mathcal{E}$ after long time.

(d) After switch is open, battery is disconnected and cap discharges.



$V_c = \mathcal{E}$. $\therefore I_{max} = \dfrac{\mathcal{E}}{2R}$

(e) Capacitor discharges, so current is max then decays exponentially.



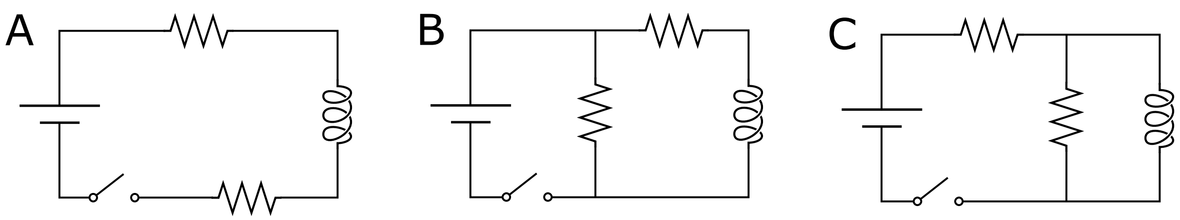
Kirchoff's loop law:

$$-\frac{Q}{C} - IR - IR = 0$$

$$I = I_{max} e^{-t/\tau}$$

$$\tau = 2RC$$

Problem C3.2 (☆☆): the diagrams below feature identical batteries, resistors, and inductors.



(a) Rank the circuits according to the current through the battery just after the switch is closed, from least to greatest.

Consider **now circuit B**.

(b) What is the potential difference across the inductor immediately after the switch is closed?

(c) What is the time constant of the current growth?

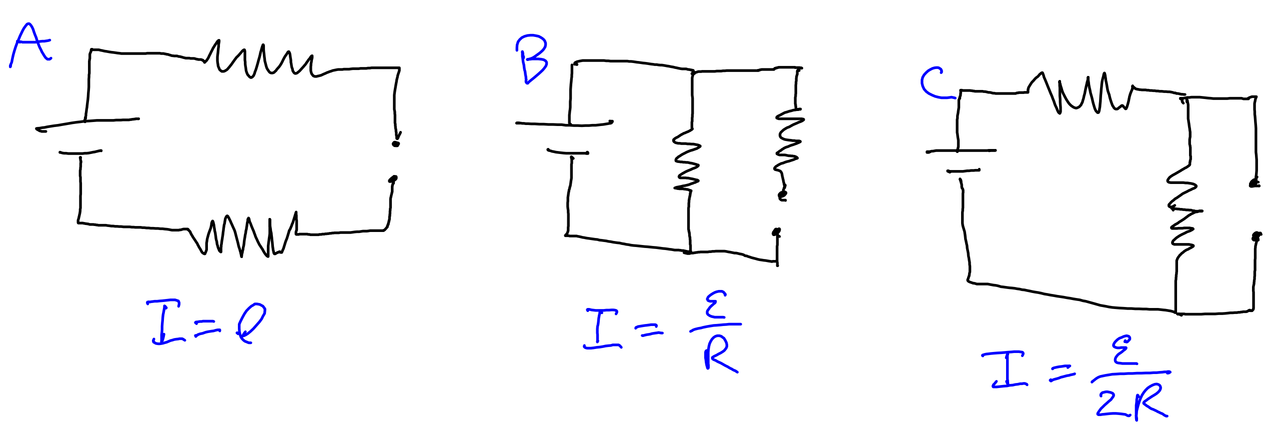
Still considering circuit B, the switch is now opened after being closed for a long time.

(d) Find all the currents immediately after the switch is opened.

(e) What is the potential difference across the inductor immediately after the switch is opened?

(f) What is the time constant of the current decay in the inductor?

(a) Inductor acts like open circuit immediately after switch is closed. ∴ circuits look like



Hence ranking is $A < C < B$

Thus we consider B from now on.

(b) Immediately, zero current runs through inductor arm, so $V_R = IR = 0$ across resistor.

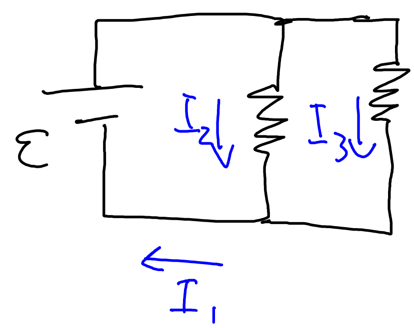
$\therefore$ all potential is across inductor: $V_L = \mathcal{E}$

Or from Kirchoff's loop law

$$\mathcal{E} - \cancel{IR}^{\,0} - V_L = 0 \quad \Rightarrow \quad \underline{V_L = \mathcal{E}}$$

(c) From loop law above $\underline{\tau = L/R}$

(d) After switch has been closed for a long time, inductor acts like a wire:

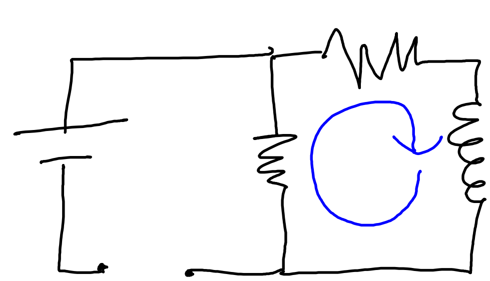


KJR: $I_1 = I_2 + I_3$ $\qquad I_2 = \dfrac{\mathcal{E}}{R} = I_3$

$$\therefore I_1 = \frac{2\mathcal{E}}{R}$$

Immediately after we open the switch, $I_3' = I_3$ (inductor current cannot change quickly).

Hence $\underline{|I_2'| = |I_3'|}$ but now I_2 flows upward



(e) Using a Kirchoff loop low that follows the current in (d)

$$-I_2'R - I_3'R - V_L = 0$$

$$\therefore V_L = -2I_2'R = -2\varepsilon$$

Note that to maintain the current and power both resistors, the max voltage in the decay of the inductor is twice what it was exposed to when the switch was closed.

(f) Kirchoff loop law for current decay:

$$-IR - IR - L\frac{dI}{dt} = 0$$

$$\therefore \tau = \frac{L}{2R}$$