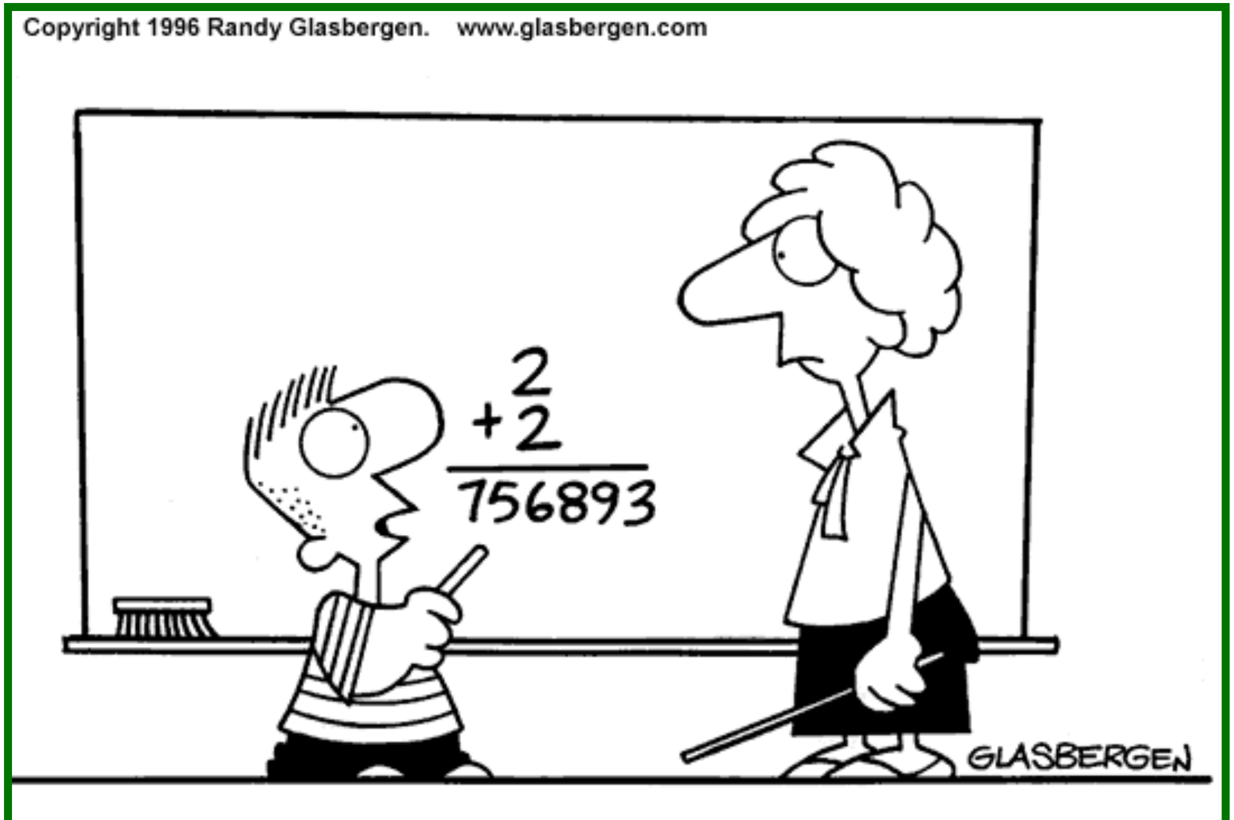
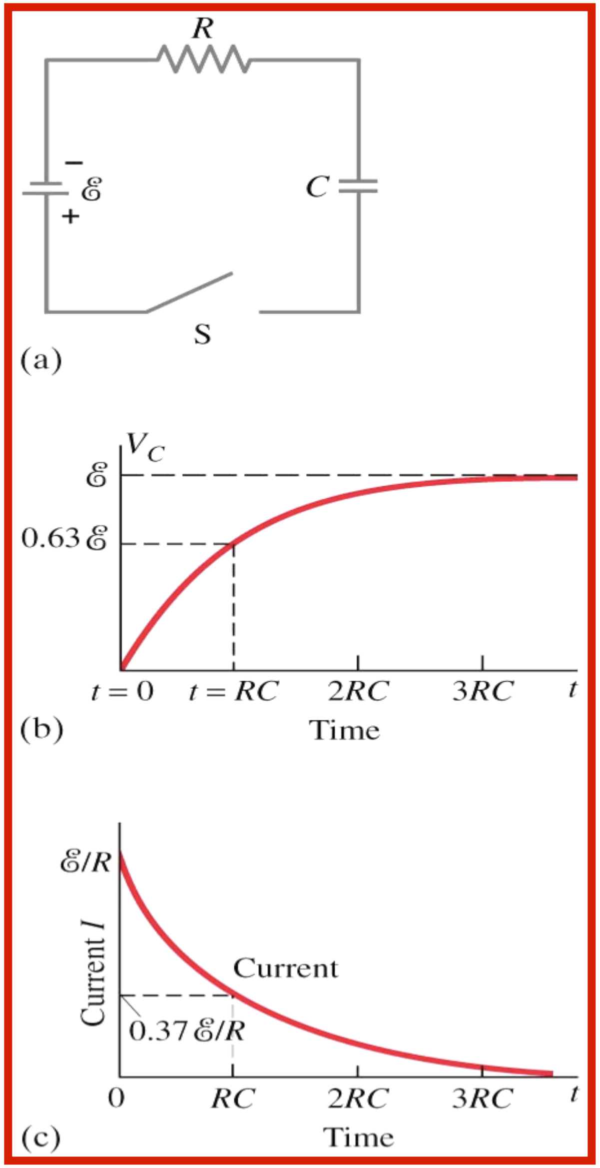
Circuits Containing Resistors & Capacitors (RC Circuits)



"In an increasingly complex world, sometimes old questions require new answers."

RC Circuits

When the switch is closed, the capacitor will begin to charge. As it does, the voltage across it increases, and the current through the resistor decreases.



- To find the voltage as a function of time, use the **Loop Rule** to write the equation for the ***voltage changes*** around the loop:

$$\mathcal{E} = IR + \frac{Q}{C}.$$

- **I = dQ/dt**, so integrate to find the charge as a function of time:

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

- The voltage across the capacitor is $\mathbf{V_C = Q/C}$. The current **I** at time **t** is found by differentiating the charge:

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

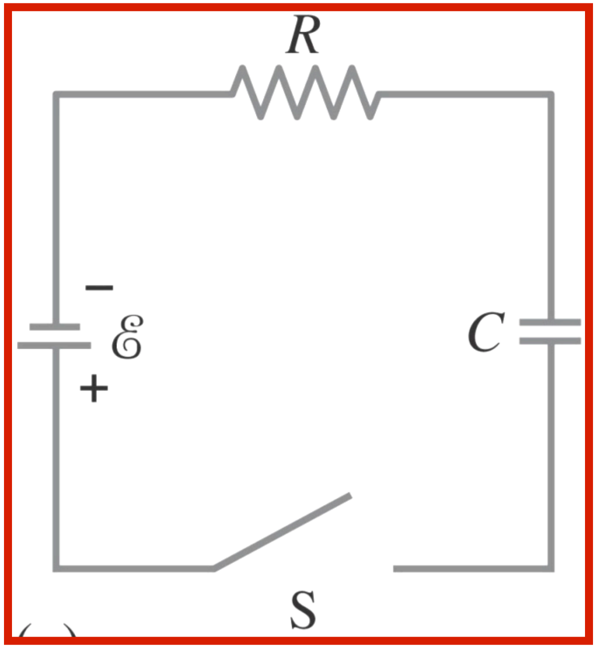
- The quantity **RC** that appears in the exponent is called ***the time constant*** of the circuit:

$$\tau = RC.$$

Example

RC Circuit, with EMF.

•The capacitance in the circuit shown is **C = 0.30 μF**, the total resistance is **R = 20 kΩ,** the battery emf is **E = 12 V**. **Calculate:**



(a) the time constant,

(b) the maximum charge the capacitor could acquire,

(c) the time it takes for the charge to reach **99%** of this value,

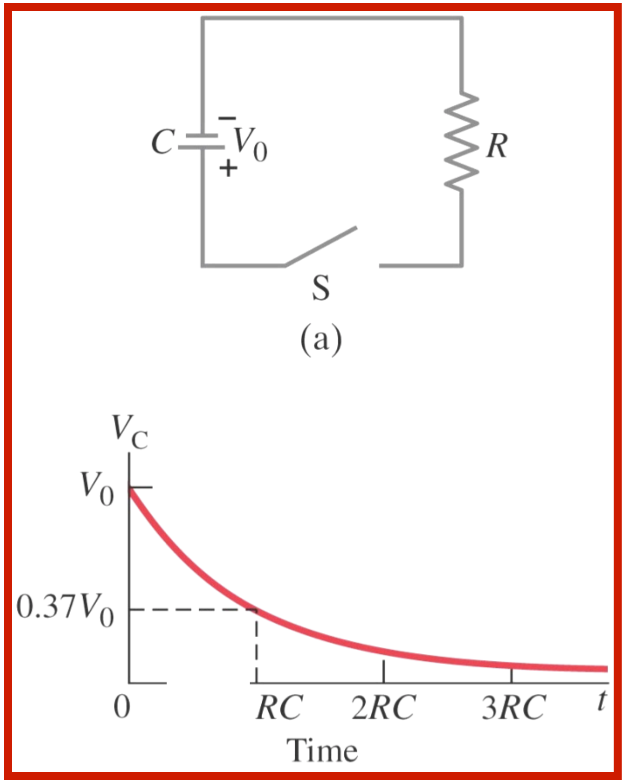
(d) the current **I** when the charge **Q** is half its maximum value,

(e) the maximum current,

(f) the charge **Q** when the current **I** is **0.20** of its maximum value.

- If an isolated charged capacitor is connected across a resistor, ***it discharges:***

$$Q = Q_0 e^{-t/RC}.$$



- The voltage & current as functions of time can be found from the charge:

$$V_C = V_0 e^{-t/RC}$$

and

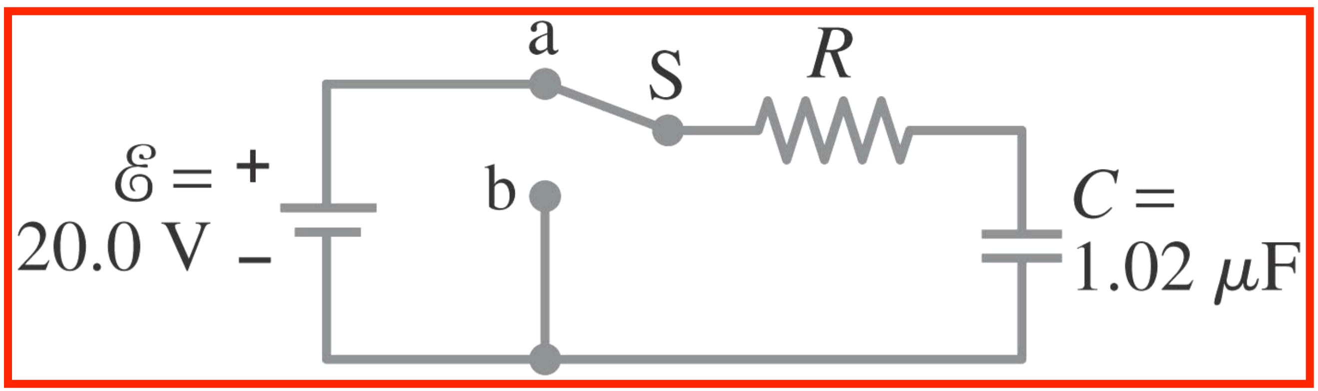
$$I = -\frac{dQ}{dt} = \frac{Q_0}{RC} e^{-t/RC} = I_0 e^{-t/RC}.$$

Example: Discharging *RC* circuit.

•In the **RC circuit** shown, the battery has fully charged the capacitor, so **$Q_0 = C\,\mathcal{E}$.** Then at **$t = 0$** the switch is thrown from position a to b. The battery **emf is 20.0 V**, and the capacitance **$C = 1.02\ \mu F$.** The current **I** is observed to decrease to **0.50** of its initial value in **40 µs.**

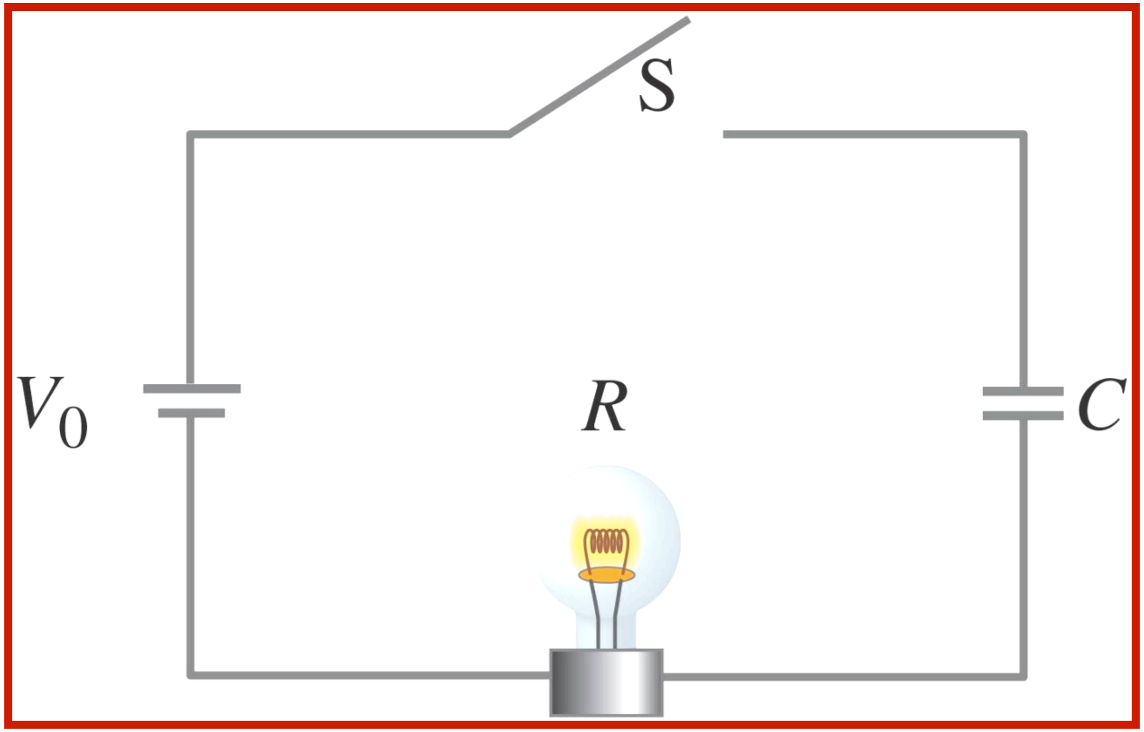
(a) What is the value of **Q**, the charge on the capacitor, at **$t = 0$**?

(b) What is the value of **R**? **(c)** What is **Q** at **$t = 60\ \mu s$**?



Conceptual Example: Bulb in RC circuit.

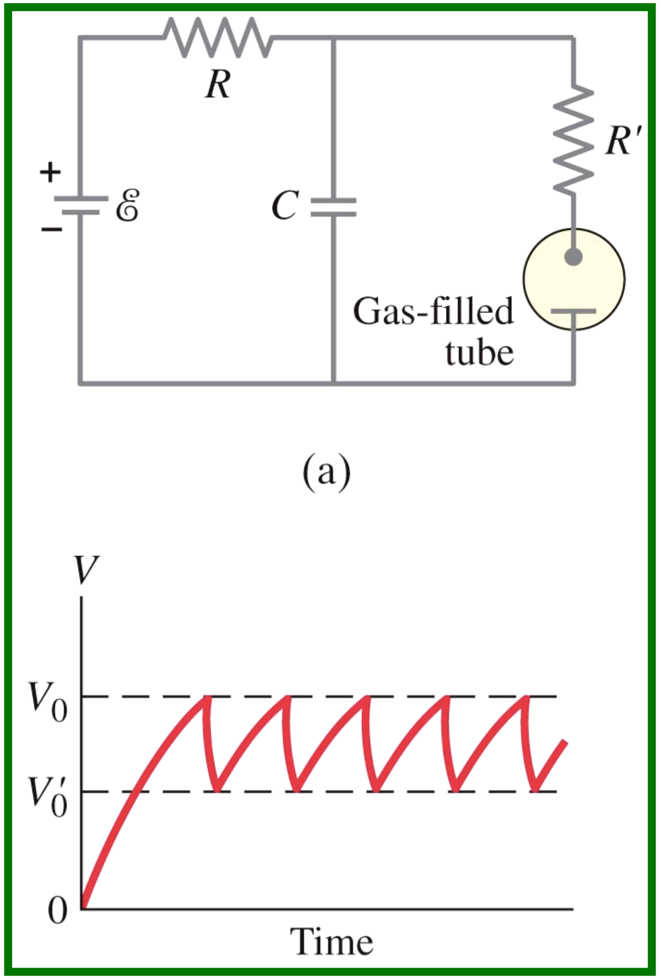
- In the circuit shown, the capacitor is originally uncharged.
- Describe the behavior of the lightbulb from the instant switch S is closed until a long time later.



Example

Resistor in a turn signal.

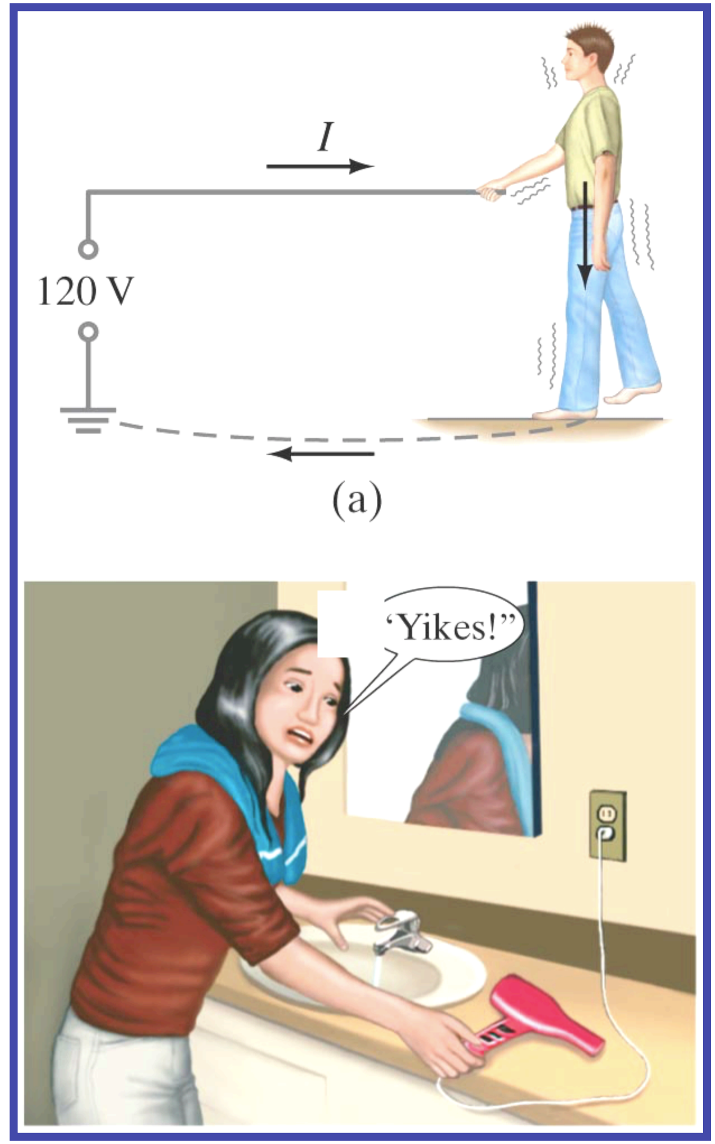
Estimate the order of magnitude of the resistor in a turn-signal circuit.



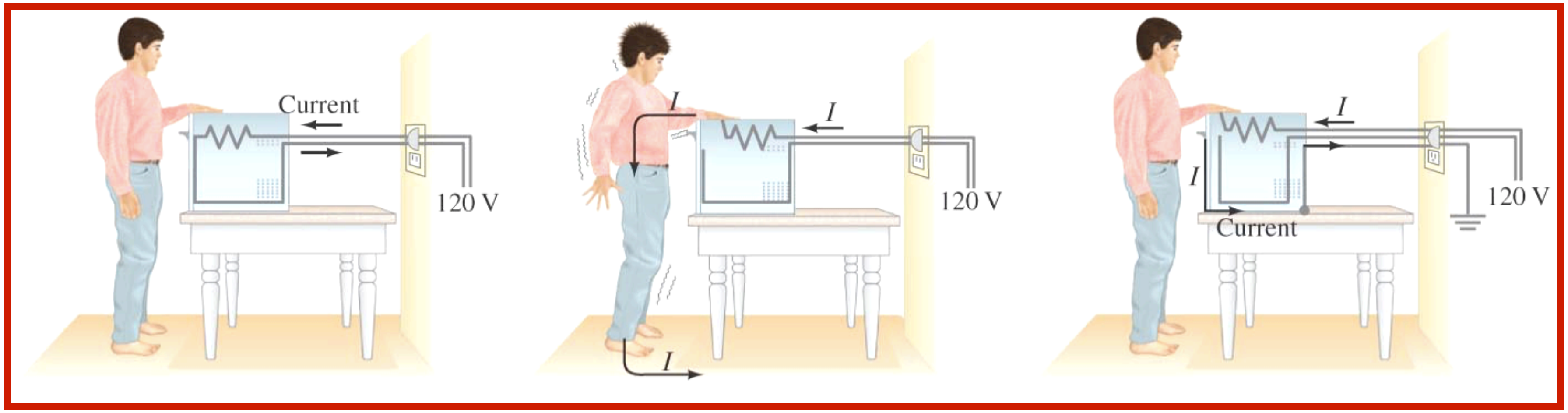
Electric Hazards

- Most people can “feel” a current of **1 mA**; a few **mA** of current begins to be painful. Currents above **10 mA** may cause uncontrollable muscle contractions, making rescue difficult.
- Currents around **100 mA** passing through the torso can cause death by ventricular fibrillation.
- Higher currents may not cause fibrillation, but can cause severe burns.
- Household voltage can be lethal if you are wet and in good contact with the ground. Be careful!

A person receiving a shock has become part of a complete circuit.



Faulty wiring and improper grounding can be hazardous. Make sure electrical work is done by a professional.



- The safest plugs are those with three prongs; they have a separate ground line.
- Here is an example of household wiring – colors can vary, though! Be sure you know which is the hot wire before you do anything.