RC Circuits

Kirchhoff's loop rule:

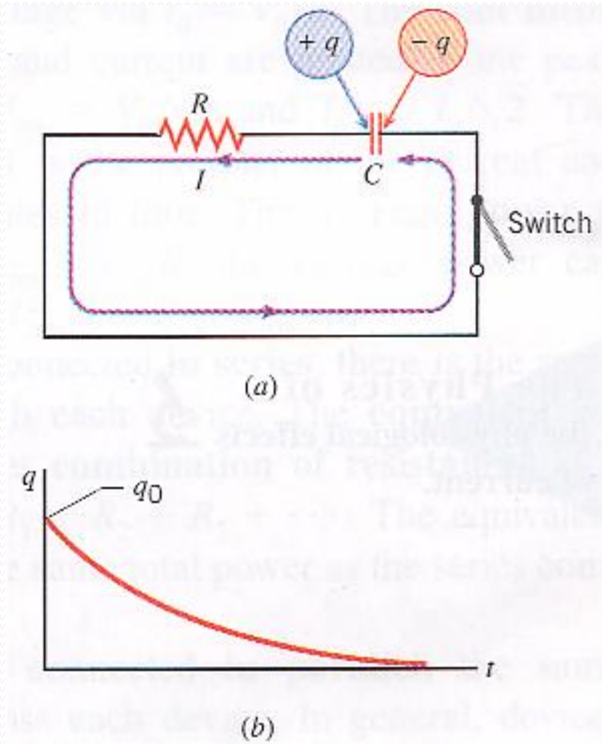
$-IR+q/C=0$

How behaves a capacitor?

(a) Discharging a capacitor.

(b) show the circuit and the charge a versus time, respectively.

The charge is not removed instantaneously out of to the capacitor.



Considering that $I=-dq/dt\approx-\Delta q/\Delta t$, we write

$q/C+R(\mathrm{d}q/\mathrm{d}t)=0$

or

$\mathrm{d}q/\mathrm{d}t=-q/(RC)$.

Now we separate the variables:

$dq/q=-dt/(RC)$

Integrating from Q at $t=0$ to q at time t gives

$\ln(q/Q)=-t/(RC)$

and therefore:

$q=Q\,e^{-t/(RC)}$

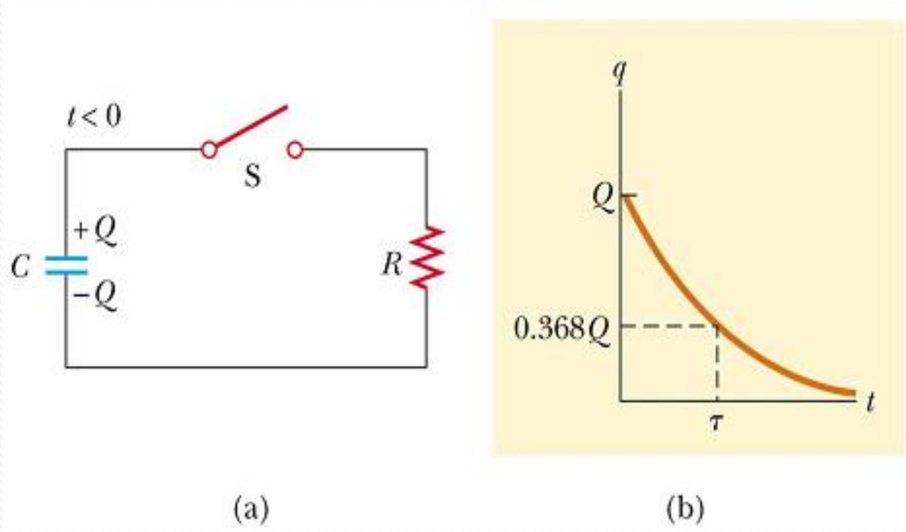
Discharging a capacitor, cont.

Charge: $q = Q\,e^{-t/(RC)}$

Voltage: $V = V_0 e^{-t/(RC)}$

Current: $I = I_0 e^{-t/(RC)}$

$I = I_0 e^{-t/\tau}$



Q is the charge at $t=0$

V_0 is the voltage at $t=0$

I_0 is the current at $t=0$

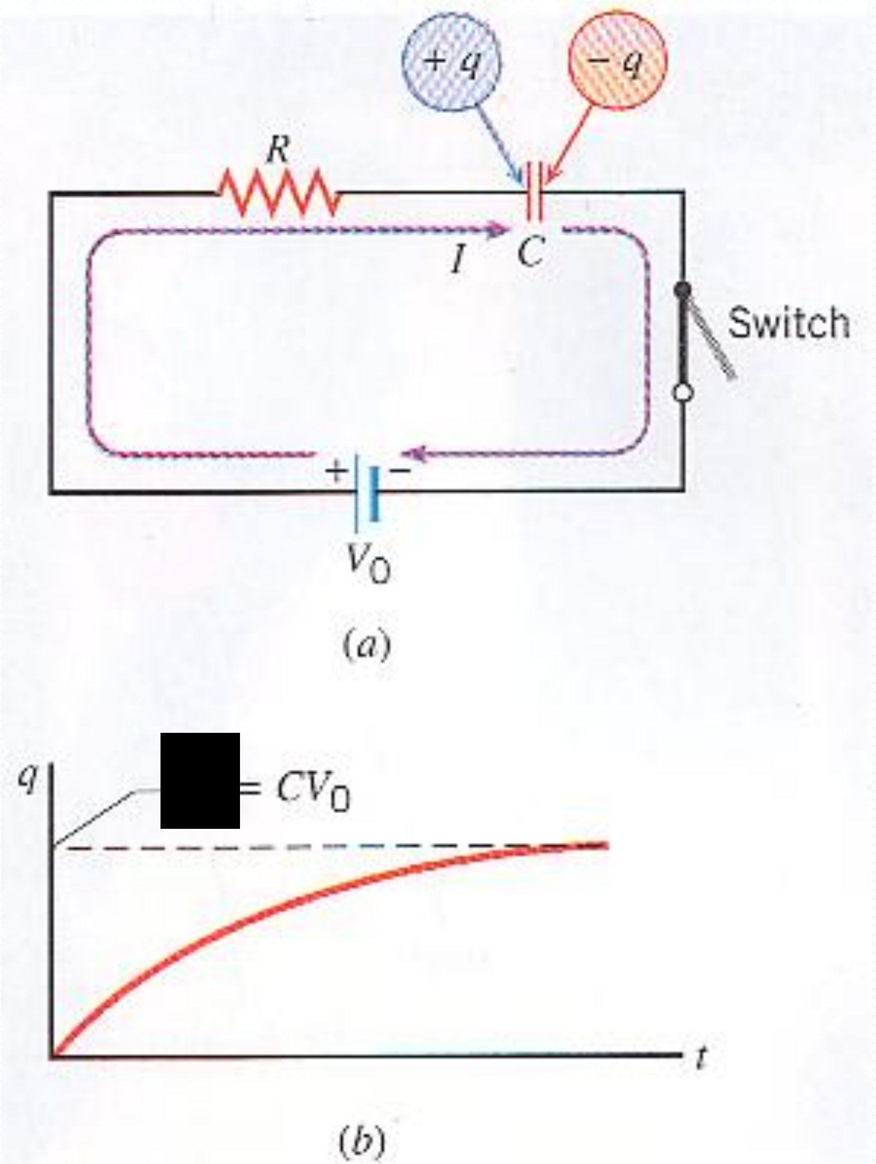
τ is called the time constant; after this time the charge decreases to $Q/e = 0.368Q$.

Charging Capacitor in an RC Circuit

Charging a capacitor: (a) circuit and (b) charge versus time. The charge is not transferred instantaneously to the capacitor.

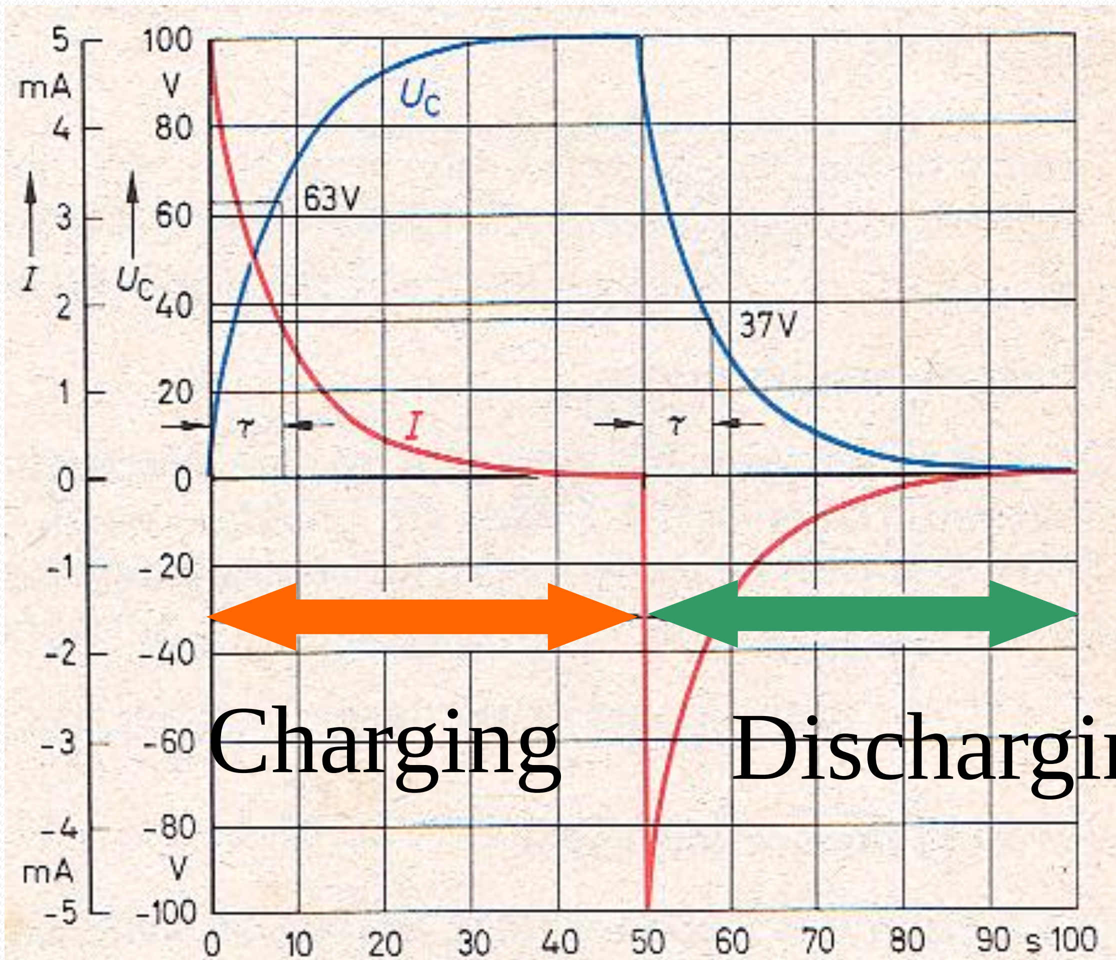
$$q=Q(1-e^{-t/(RC)})$$

At $\tau=RC$ the charge is $(1-e^{-1})Q=0.632Q$



Voltage and current vs. time of a capacitor

Time



Charging

Discharging

Summary

- Discharging

Charge: $q = Q\, e^{-t/(RC)}$

Voltage: $V = V_o e^{-t/(RC)}$

Current: $I = I_o e^{-t/(RC)}$

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

- Charging

Charge: $q = Q\,(1 - e^{-t/(RC)})$

Voltage: $V = V_o\,(1 - e^{-t/(RC)})$

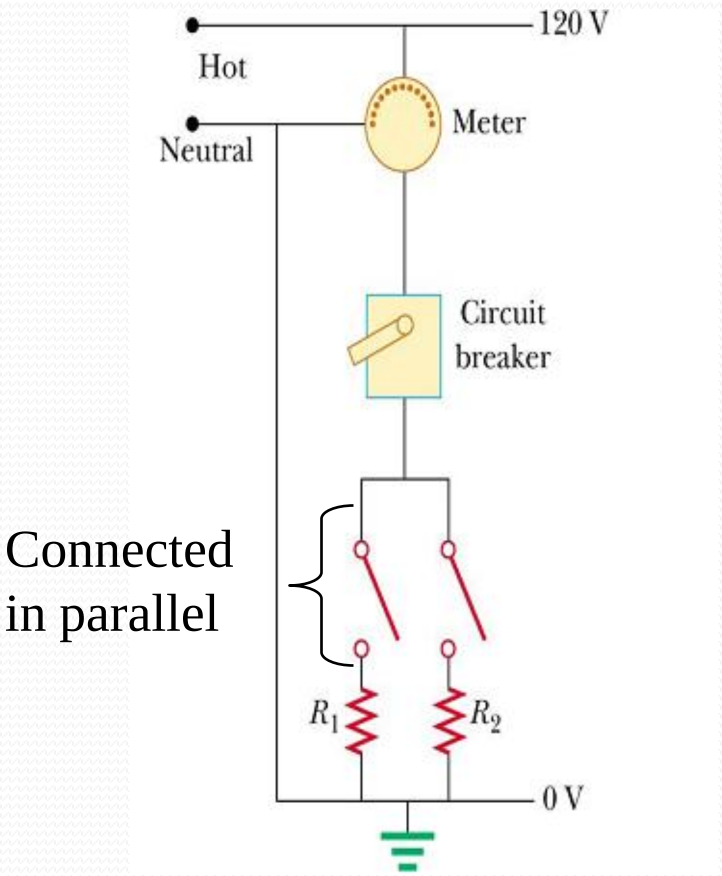
Current: $I = I_o e^{-t/(RC)})$

$I = I_o\, e^{-t/\tau}$

Note: The formula for the current is the same for discharging and charging!

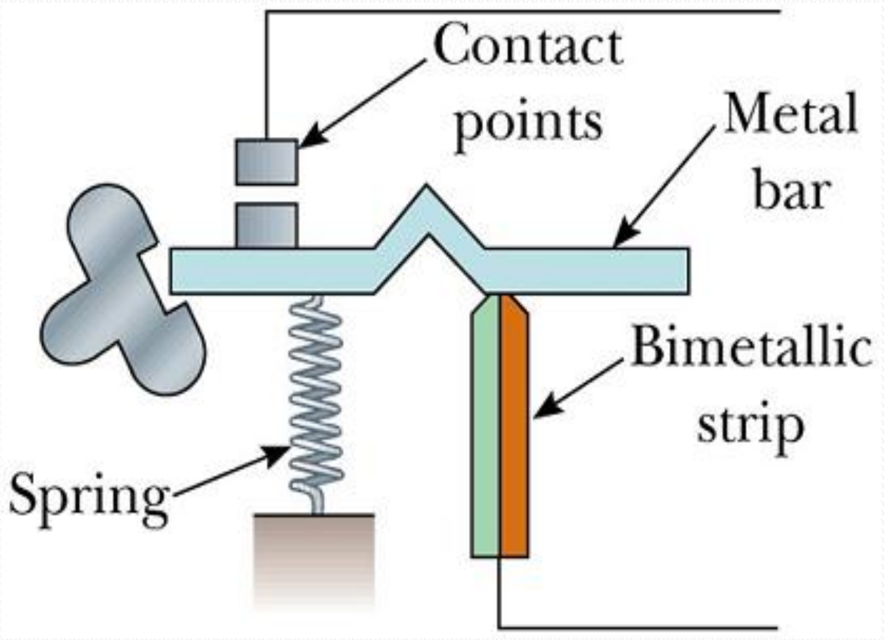
Household Circuits

- In a typical installation, the utility company distributes electric power to individual houses with a pair of wires, or power lines. The voltage between the two wires is 120 V.



Circuit breaker

- In modern homes, circuit breakers are used in place of fuses. When the current exceeds some value, the circuit breaker acts as a switch and opens the circuit.

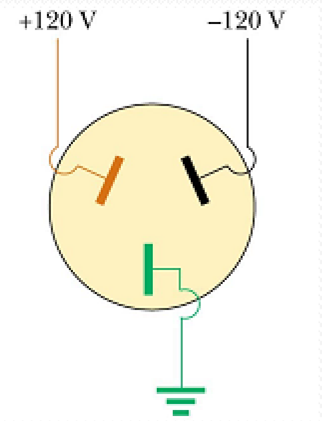


Circuit breaker, cont.

- Current passes through a bimetallic strip, the top of which bends to the left when excessive current heats it and settles in a groove in the spring-loaded metal bar. When this occurs, the bar drops enough to open the circuit at the contact point. In contrast to fuses, circuit breakers recover and are reusable.

Heavy-duty appliances

- Electric ranges and cloth dryers require 240 V to operate. The power company supplies this voltage by providing +120 V and –120 V above and below ground, respectively.

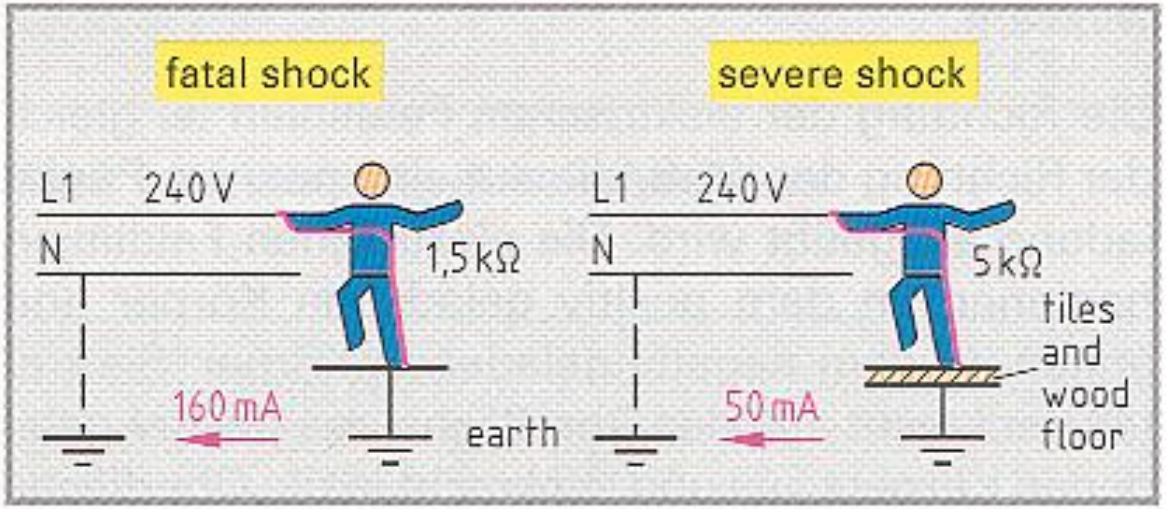


Electrical Safety

- Electric shock can result in fatal burns
- Electric shock can cause the muscles of vital organs (such as the heart) to malfunction
- The degree of damage depends on
  - the magnitude of the current
  - the length of time it acts
  - the part of the body through which it passes

Electrical Safety, cont.

Table: The effect of electric current on humans	
Current in mA	Effect
1	maximum safe current
2-5	begins to be felt by most people
10	muscular spasm, i.e. unable to let go and could become fatal
100	probably fatal if through heart

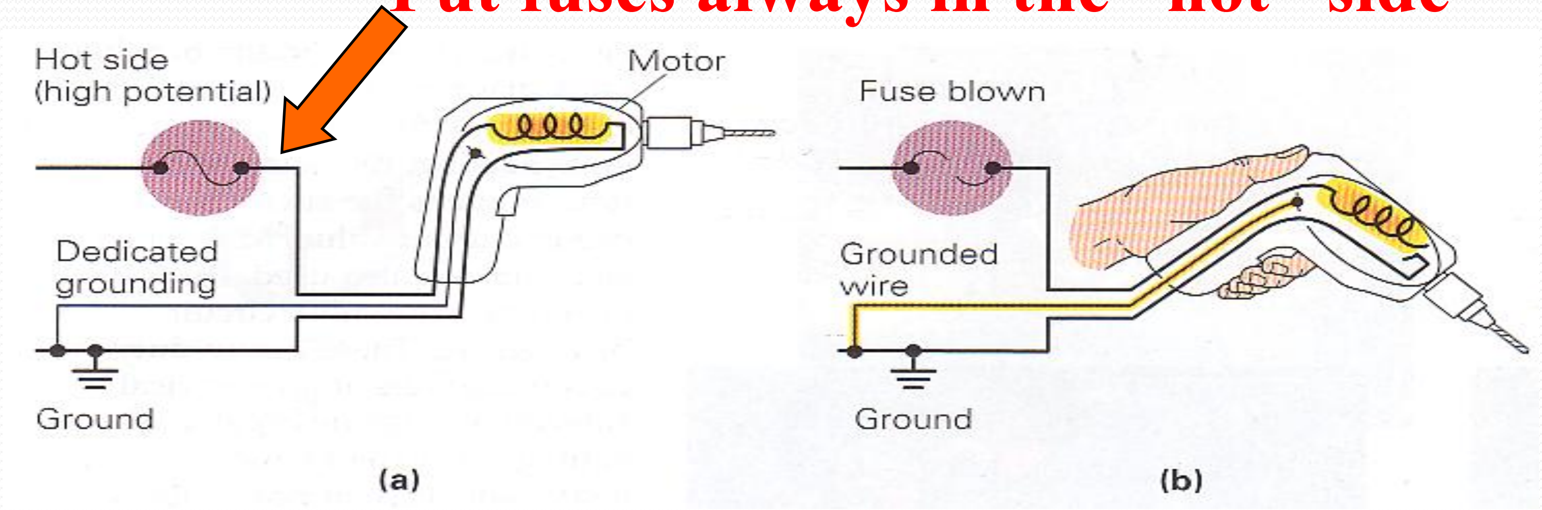


Electrical Safety, cont.

Avoid the touch of high potential as an “appliance”. Possibility of accidents are reduced by dedicated grounding.

Electrical Safety, cont.

Put fuses always in the "hot" side



(a) A third wire is connected from an appliance tool to ground.

(b) If a loose internal wire comes in contact with the grounded casing, the shortening to ground blows the fuse.

Ground Fault Interrupts (GFI)

- Special power outlets
- Used in hazardous areas
- Designed to protect people from electrical shock
- Senses currents (of about 5 mA or greater) leaking to ground
- Shuts off the current when above this level