Electricity and Magnetism

- Physics 259 – L02
- Lecture 34

Chapters 26 & 27

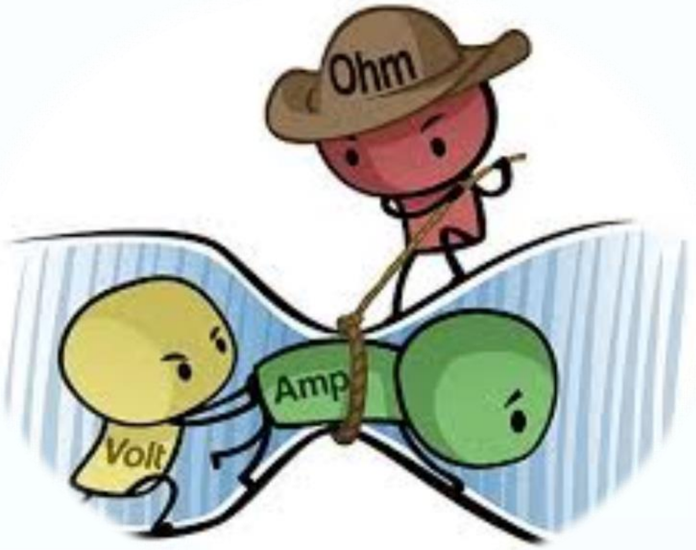
Last time

- Chapter 25- Capacitance

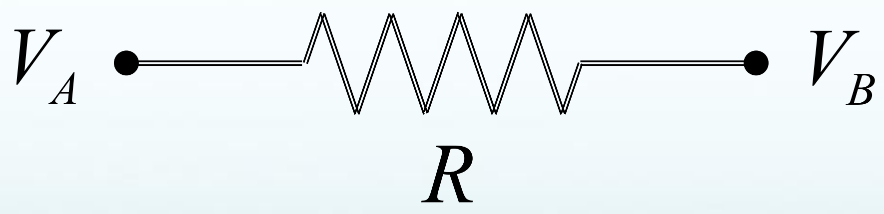
This time

- Chapters 26 and 27

26-4 Ohm's Law



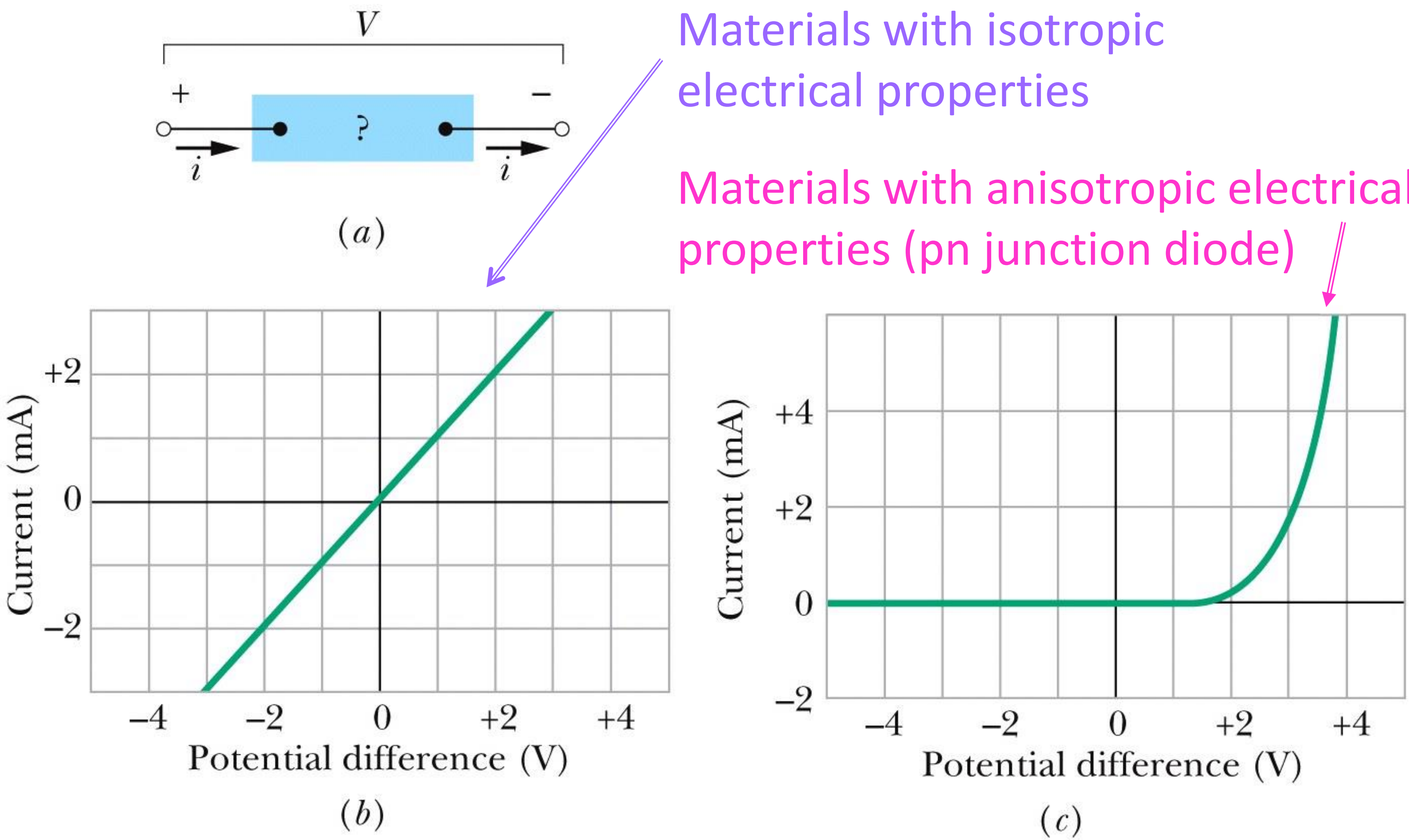
When a voltage difference ΔV is applied across a resistor R, the voltage difference causes electrons to flow through the resistor



This flow of electrons is the electric current I. These quantities are related by Ohm's Law:

$$\boxed{\Delta V = IR}$$

Ohmic vs non-Ohmic devices



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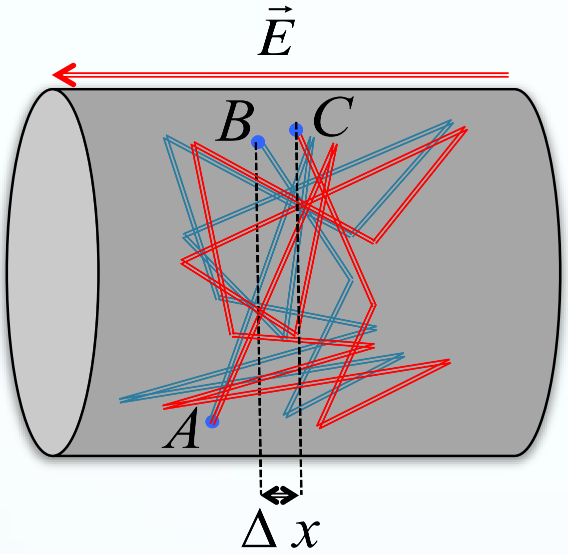
Microscopic view of Ohm's law (resistivity)



Electrons bounce around inside the metal at speeds very high speeds on the order of 0.5% light speed.

When an electric field is applied in the conductor, there is a net force on the electrons, leading to "drift speed"

$$v_d = \frac{J}{ne}$$

microscopic picture of resistivity:

$$\boxed{r = \frac{m}{ne^2 t}}$$

$$\boxed{r - r_0 = r_0 a\left(T - T_0\right)}$$

Temperature Dependent Resistance

$$R - R_0 = R_0 \left(\tfrac{2}{3}a\right)(T - T_0)$$

Proof: Appendix 2-Chapter 26

$$r - r_0 = r_0 a (T - T_0)$$

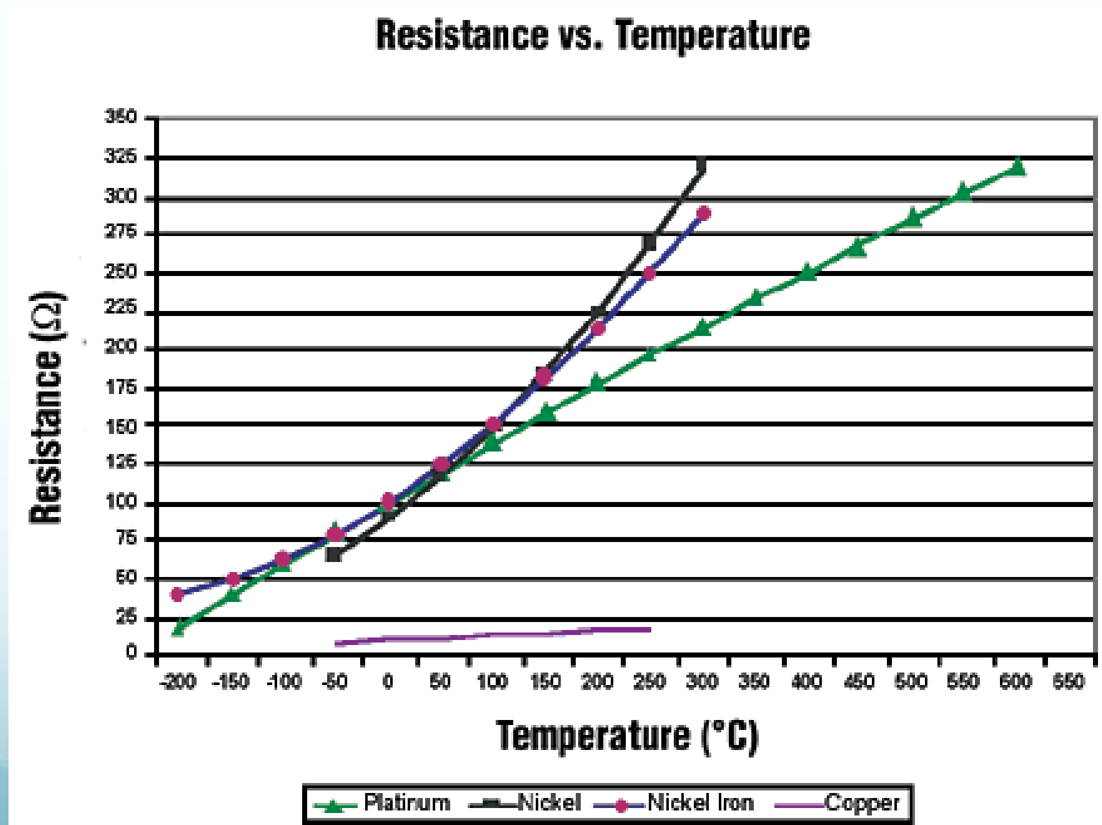


Image from http://archives.sensorsmag.com/articles/0503/52/main.shtml

26-5 Power in circuits

Recall that **POWER** is the **rate at which work is done**

$$P = \frac{W}{\Delta t}$$

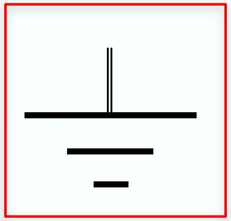
A battery with voltage ΔV raises the **potential energy** of a single charge q by an amount $q\,\Delta V$. This is the **work done** by the battery. For N charges

$$P = \frac{Nq\ \ V}{\Delta t} = \left(\frac{Nq}{\Delta t}\right)\ V = IV$$

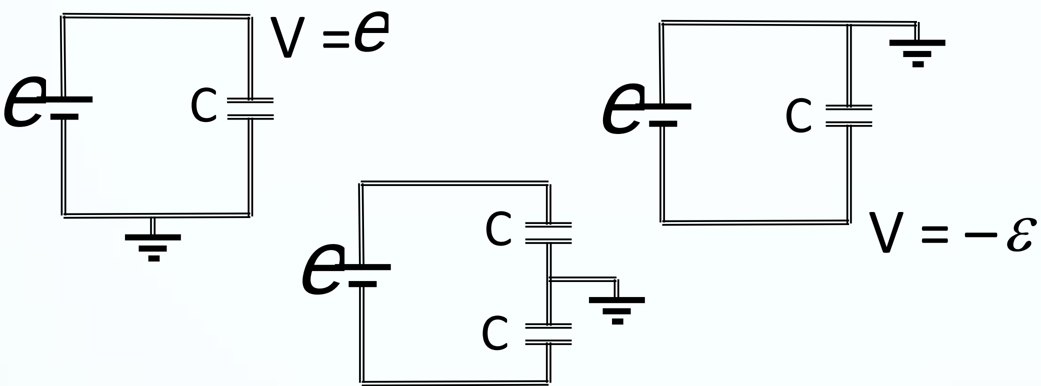
Power in circuits→ $\boxed{P = I\,V = RI^2 = \frac{V^2}{R}}$

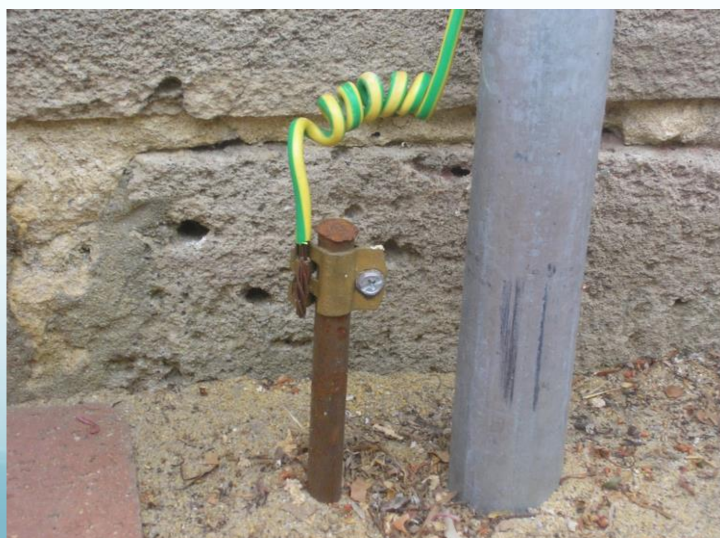
27 Circuits:
continue of last section

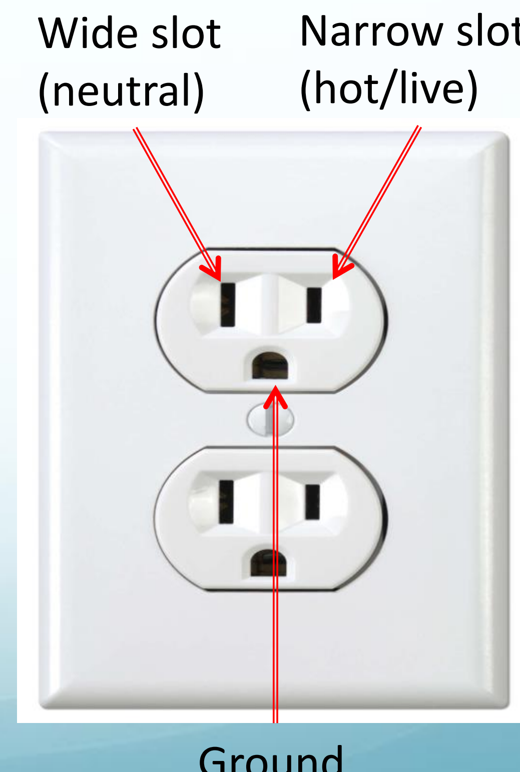
Grounding



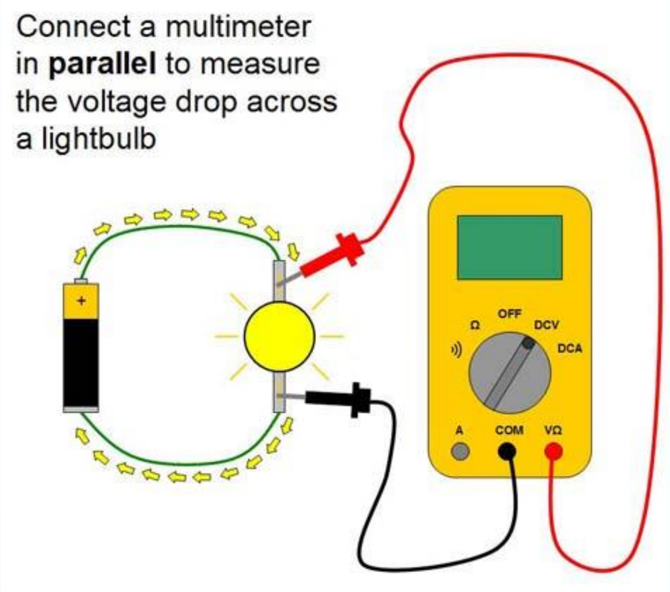
This symbol is called "ground" and it represents the place in the circuit where V=0.







27-3 The Ammeter and The Voltmeter



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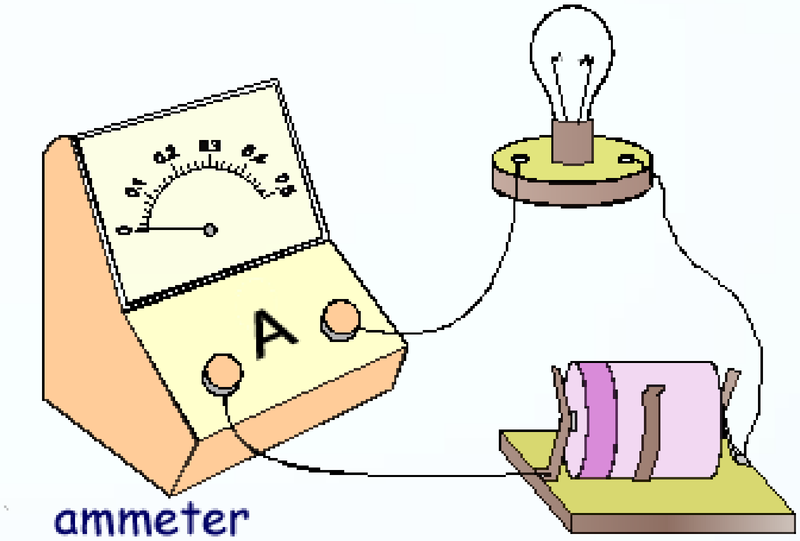

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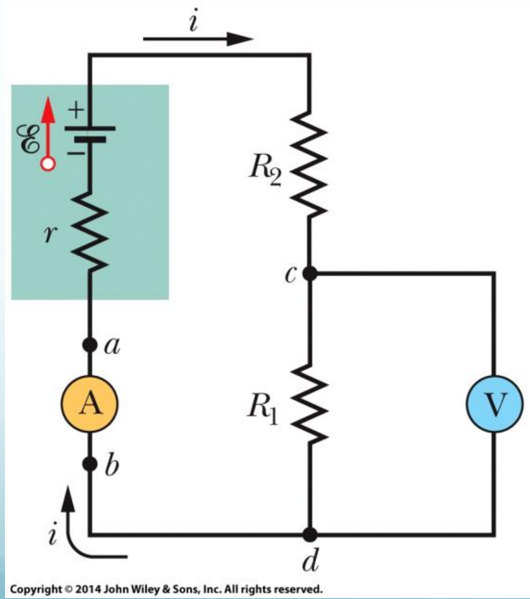
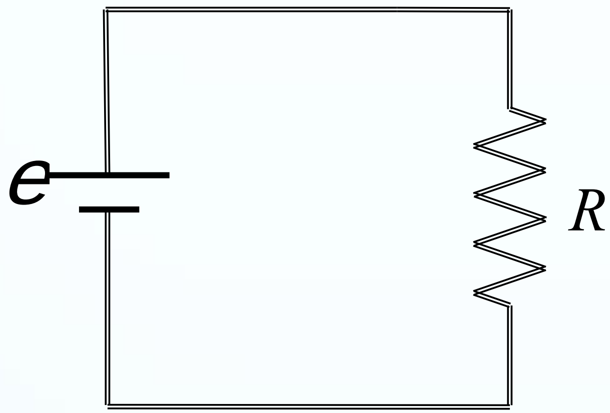
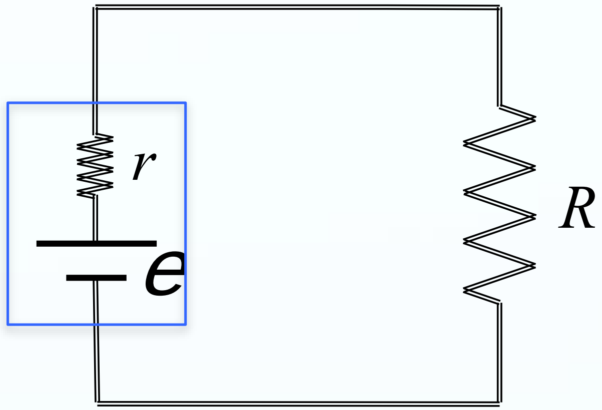


Non-ideal Batteries: internal resistance

Appendix 2-Chapter 26

Every voltage source has **some** internal resistance to it. Usually this can be ignored but not always.





The internal resistance simply acts as a resistor in series with the rest of the circuit.

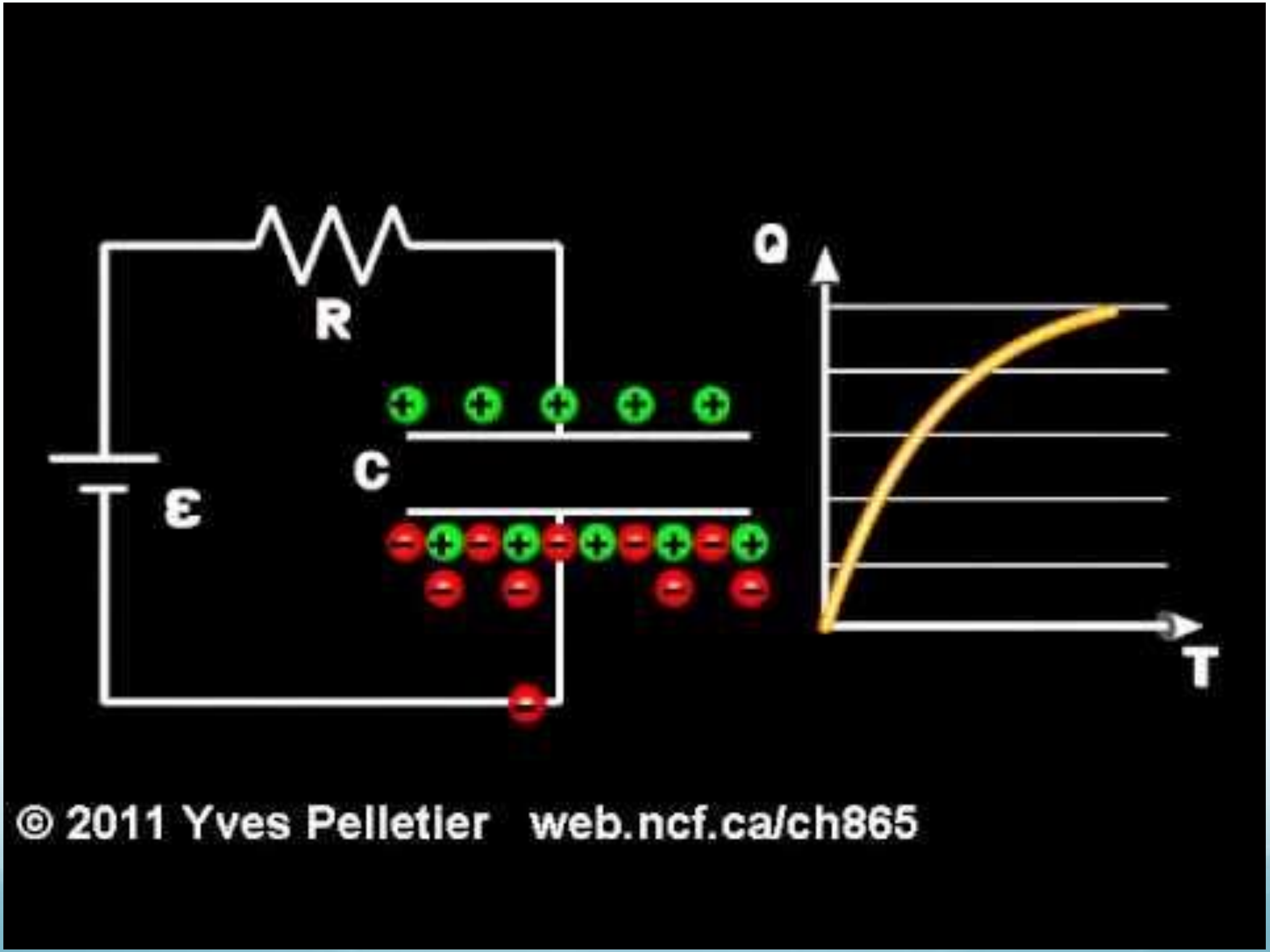
$$e - Ir - IR = 0$$

$$I = \frac{e}{(r+R)}$$

$$P_e = Ie = \frac{e^2}{R+r}$$

$$P_R = I^2 R = \frac{e^2 R}{(R+r)^2}$$

27-4 RC Circuits (resistors + capacitors)

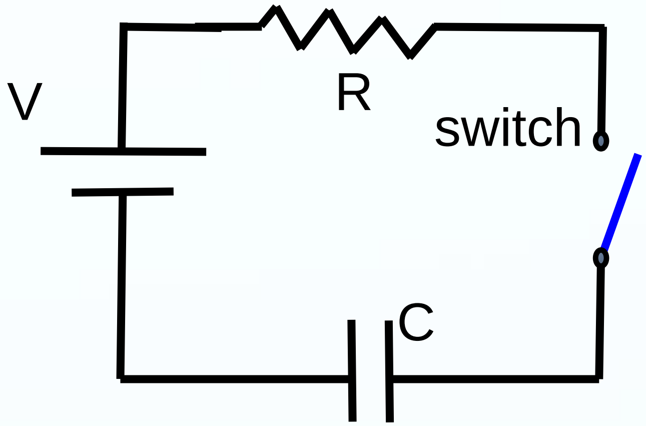


Until now→ steady and continuous currents

many important circuit applications use a combination of capacitors and resistors to produce time dependent currents

Examples: wireless signals in a cordless phone, remote control, etc.

Simple RC Series Circuit



Open switch→

- ✓ no current can flow
- ✓ charge and voltage on capacitor → Zero

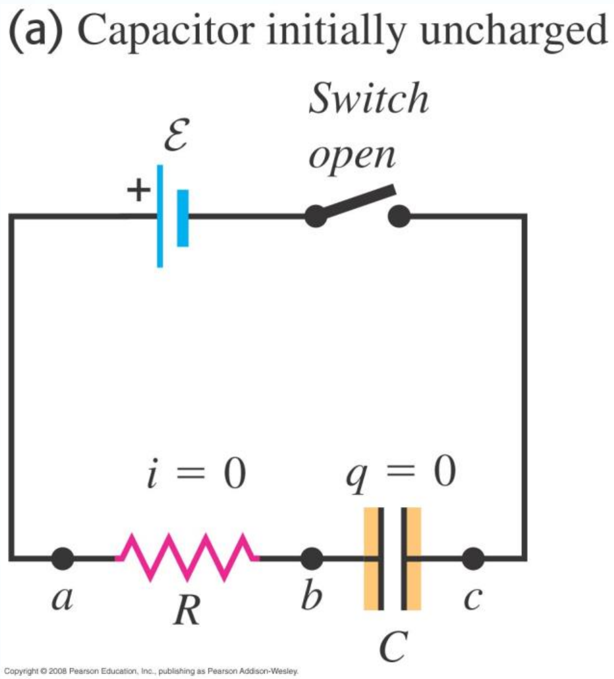
Closed switch for a long time→

- ✓ Charge on capacitor $Q = CV$
- ✓ Voltage across capacitor is *V* and no current flows in the circuit.

What happens immediately after switch is closed or opened?

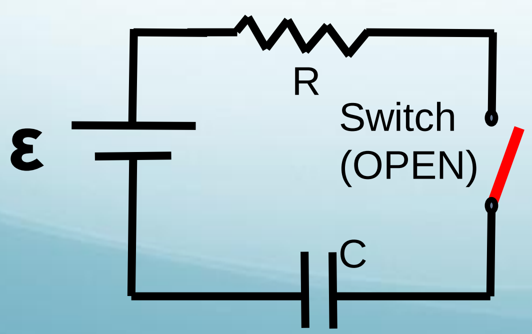
We get time dependent currents!

Case 1: Charging a capacitor

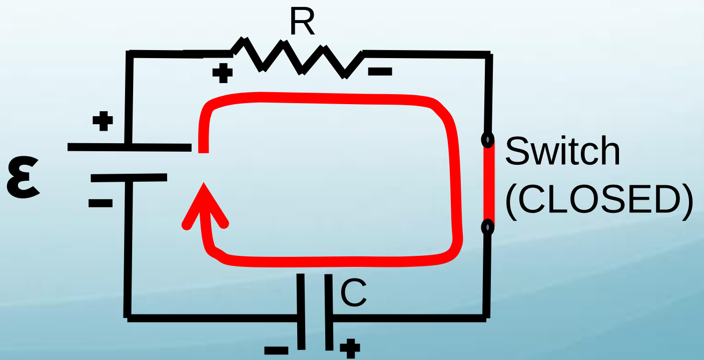


R could be the internal resistance of the battery, resistance of the connecting wires, an actual resistance in the circuit or combination of all the above.

Switch is open for a long time before t=0

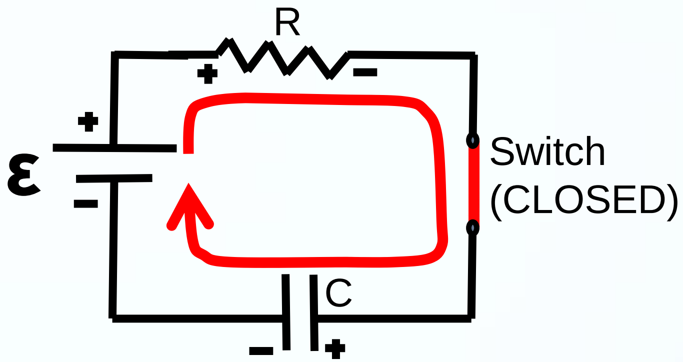


Switch is suddenly closed at t=0



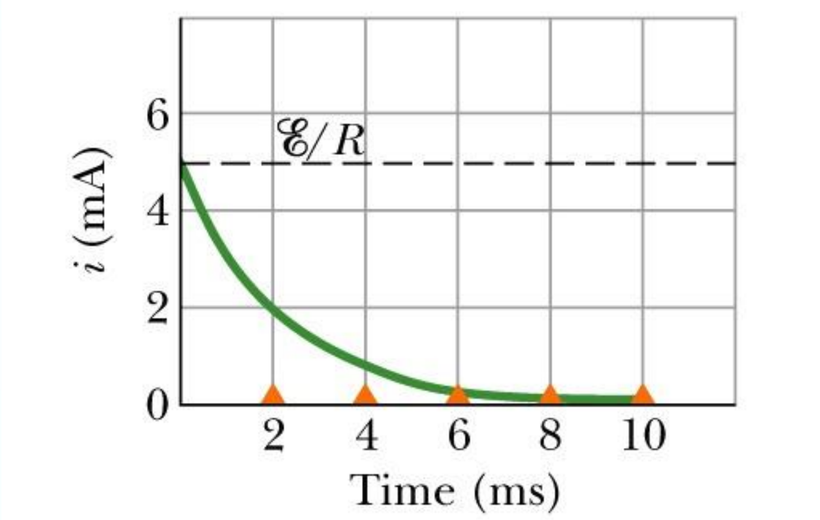
Case 1: Charging a capacitor

Switch is suddenly closed at t=0

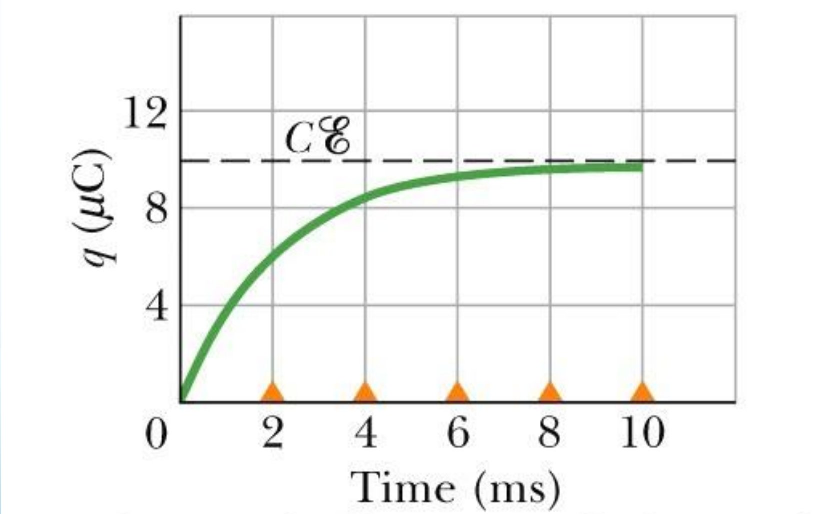


Case 1: Charging a capacitor

$$i = i_0 e^{-t/RC}$$

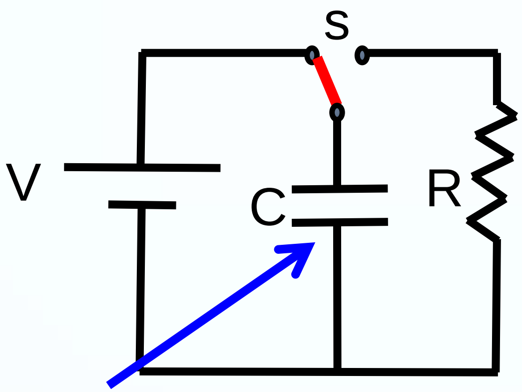


$$q = \varepsilon C\left(1 - e^{-t/RC}\right) = Q_f\left(1 - e^{-t/RC}\right)$$



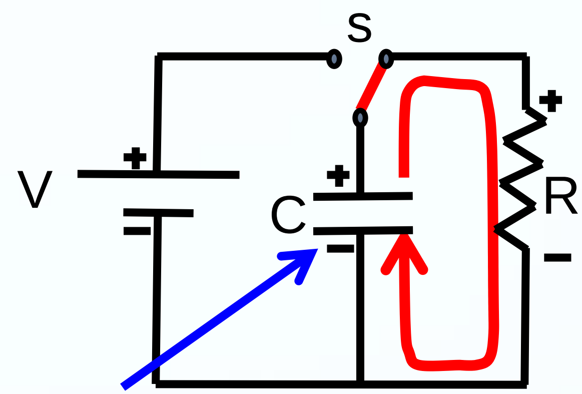
Case 2: Discharging a capacitor

Switch is connected to the left for a long time until t=0-



Capacitor charges up to voltage V

Switch is suddenly flipped to the right at t=0+



Capacitor discharges

Once the switch is flipped to right → $\frac{q(t)}{C} - iR = 0$ → $\frac{q}{RC} = i = -\frac{dq}{dt}$

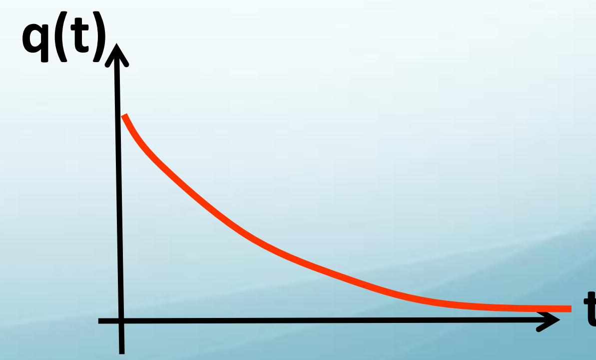
NOTE here dq < 0

Solving for the charge q(t) on the capacitor→

$$\boxed{q(t) = q_0 e^{-t/RC}}$$

$$\boxed{i(t) = i_0 e^{-t/RC}}$$

$$q_0 = CV$$



This section we talked about:

Chapters 26 and 27

See you on Thursday