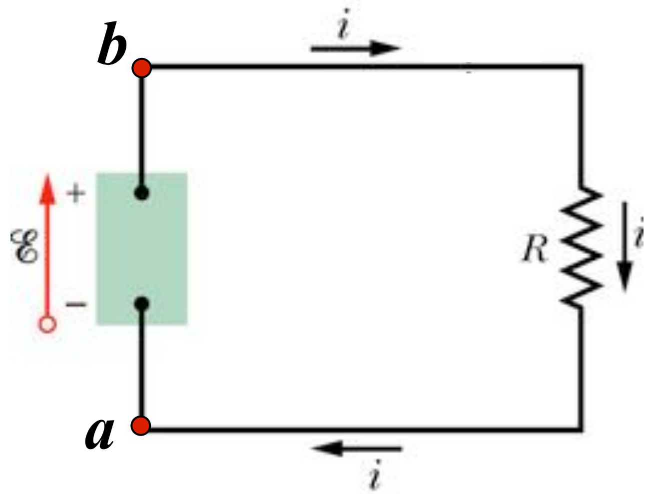
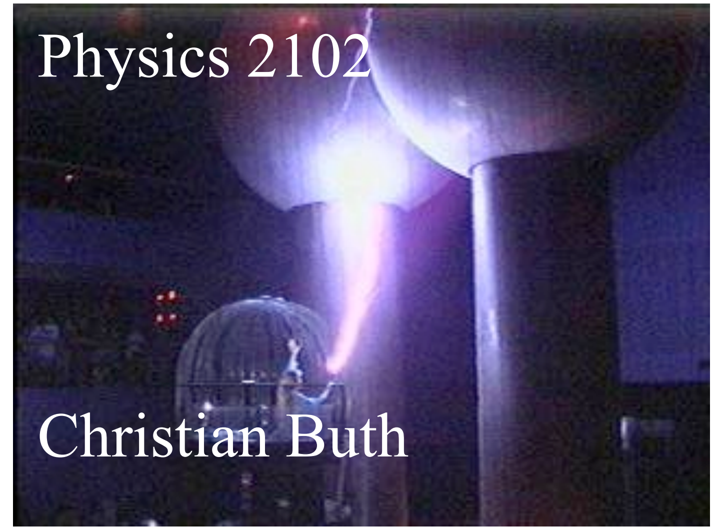
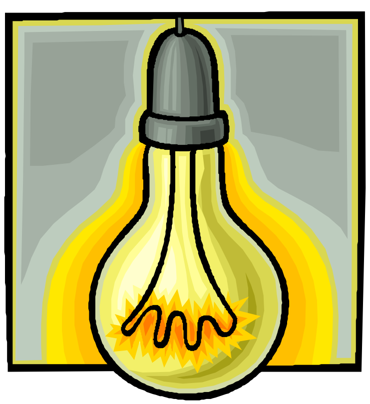




Physics 2102
Lecture 15
DC Circuits 1



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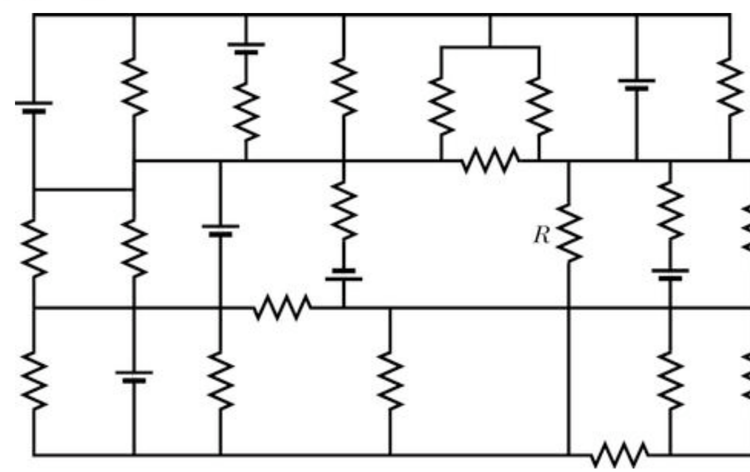


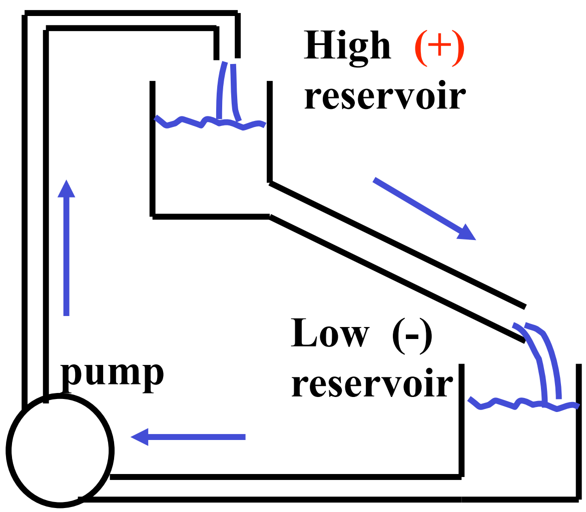
Review

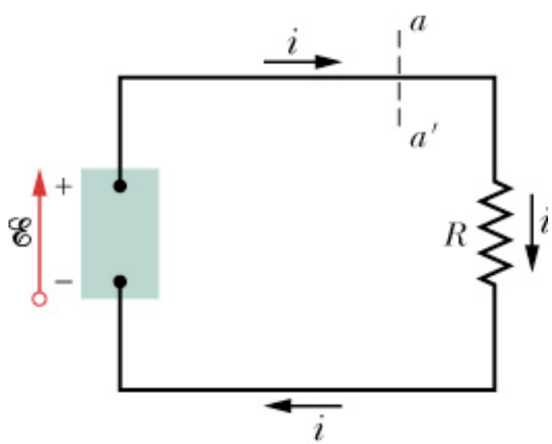
- A **resistor** is a conductor whose resistance does **not** change with the voltage

$$R \equiv \frac{V}{i} \qquad R = \rho \frac{L}{A}$$

- A linear $I - V$ curve is said to be **Ohmic** otherwise non-Ohmic
- **Resistivity** is associated with a **material**, **resistance** with respect to a **device** constructed with the material
- Conductivity : $\sigma = \dfrac{1}{\rho}$
- Resistivity depends on temperature: $\rho = \rho_0 (1+\alpha (T\text{-}T_0))$
- Reason for resistance: conduction electrons **collide** with stationary ionic lattice

Pumping charges





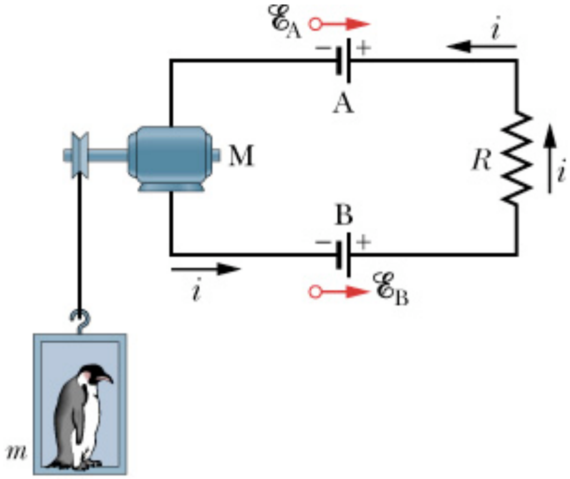
- The battery operates as a "pump" that **moves positive charges** from lower to higher electric potential

- Higher potential: **positive terminal**, lower potential: **negative terminal**

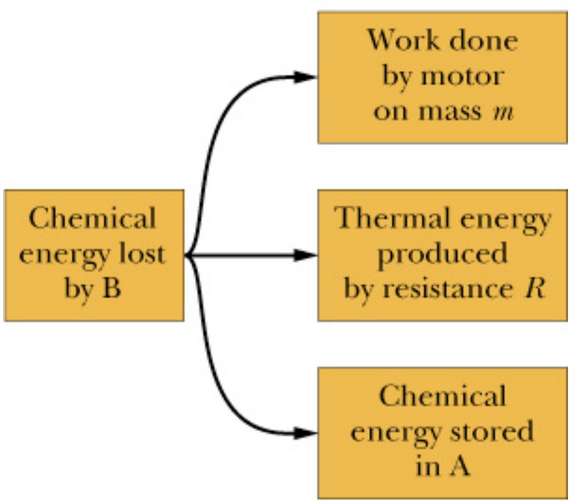
- A battery or electric generator are examples of **electromotive force** (EMF) devices

- Mechanical analog for water flow

Energy Conversion



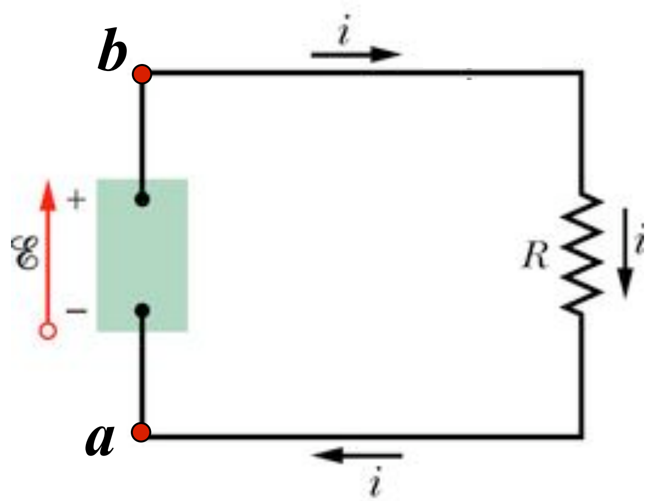
(a)



(b)

- The **energy** from emf B changes form
- **Energy** does mechanical work via the motor
- **Energy** produces thermal energy on the resistor
- **Energy** is converted into chemical energy in emf A

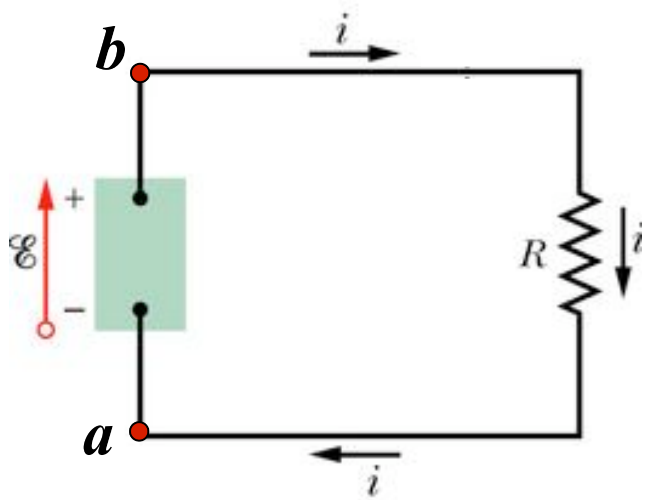
Electromotive Force Devices



- emf devices **transform** one source of energy into electrical energy
- emf device sets up current around circuit by **doing work on charges**
- A battery uses **chemical energy**, a generator **mechanical energy**, a solar cell **energy from light**, etc.

- The difference in potential energy that the device establishes is called the emf and denoted by $E = \mathrm{d}W / \mathrm{d}q$
- E is potential difference between terminals for **no current**
- **Polarity** of emf device indicated by arrow **from negative to positive** terminal

Single Loop Circuits



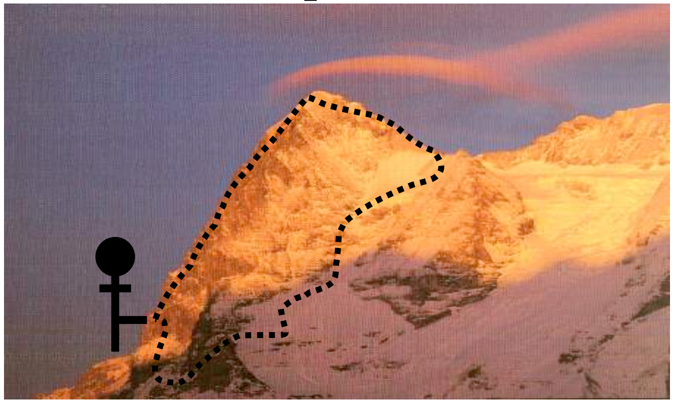
• To calculate the **circulating current**

• Circuit solving consists in "taking a walk" along the wires

• As one "walks" through the circuit (in any direction) one needs to **two rules**:

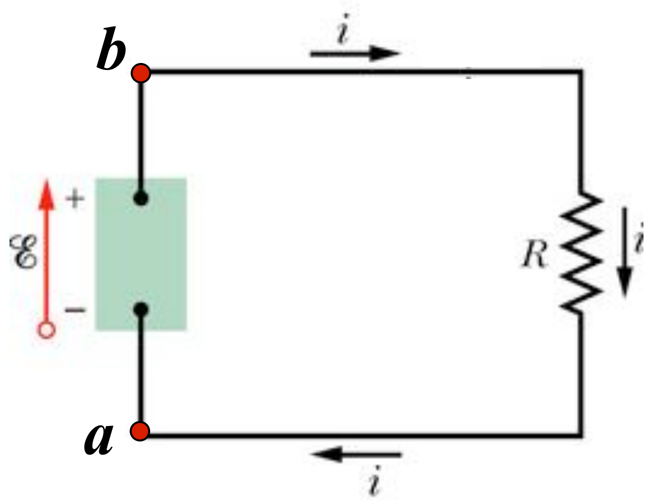
When walking through an EMF, add +E if you flow with the current or −E otherwise. How to remember: current "gains" potential in a battery

When walking through a resistor, add $-iR$, if flowing with the current or $+iR$ otherwise. How to remember: resistors are passive, current flows "potential down"



Example:
Walking clockwise from a: $+E-iR=0$.
Walking counter-clockwise from a: $-E+iR=0$.

Power in electrical circuits 1



- A **current** i flows as indicated
- Electric energy is **converted** by the resistance to **heat**
- How much **work** does the battery do to move a small amount of charge dq from a to b?

$$dW = dU = dq\ V = (dq/dt)\ dt\ V$$

$$= iV\ dt$$

Power in electrical circuits 2

- The battery "power" is the work it does **per unit time**:

$$P=dW/dt=iV$$

- $P=iV$ is true for the battery **pumping charges** through any device

- If the device follows **Ohm's law** (i.e., it is a resistor), then $V=iR$ and the energy loss in the device is called **resistive dissipation**

$$P=iV=i^2R=V^2/R$$

- Unit of power is **Watt**: 1W = 1 V A = 1 J / s

Example

A 1250 W radiant heater is constructed to operate at 115 V.

(a) What will be the current in the heater?
(b) What is the resistance of the heating coil?
(c) How much thermal energy is produced in 1.0 h by the heater?

- Formulas: $P=i^2R=V^2/R$; $V=iR$
- Know P, V; need R to calculate current!
- $P=1250W$; $V=115V \Rightarrow R=V^2/P=(115V)^2/1250W=10.6\ \Omega$
- $i=V/R=115V/10.6\ \Omega=10.8$ A
- Energy? $P=dU/dt \Rightarrow dU=P\,dt = 1250W\times 3600$ sec$= 4.5$ MJ

Example

A 100 W lightbulb is plugged into a standard 120 V outlet.

(a) What is the resistance of the bulb?

(b) What is the current in the bulb?

(c) How much does it cost per month to leave the light turned on continuously? Assume electric energy costs 6¢/kW·h.

(d) Is the resistance different when the bulb is turned off?

- Resistance: $R=V^2/P=144\ \Omega$
- Current, $i=V/R=0.83$ A
- We pay for energy used (kW h):

  $W=Pt=0.1\text{kW} \times (30\times 24)\text{ h} = 72\text{ kW h} \Rightarrow \$4.32$
- (d): Resistance should be the same, but it's not: **resistivity and resistance increase with temperature**. When the bulb is turned off, it is colder than when it is turned on, so the resistance is lower.

Summary

• **Electromotive fore devices** (emf) maintain a potential between their terminals

• **Kirchhoff's loop rule** (KLR):

KLR : The algebraic sum of the changes in potential encountered in a complete traversal of any loop in a circuit is equal to zero.

• When walking through an emf, add $+\mathcal{E}$ if you flow with the current or $-\mathcal{E}$ otherwise

• When walking through a resistor, add $-iR$, if flowing with the current or $+iR$ otherwise