PHY294H

- Professor: Joey Huston
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- Homework will be with Mastering Physics (and an average of 1 hand-written problem per week)
  - **Help-room hours: 12:40-2:40 Tues; 3:00-4:00 PM Friday**
- Quizzes by iclicker (sometimes hand-written)
- Average on exam is around 65; will pass back tomorrow
- Course website: www.pa.msu.edu/~huston/phy294h/index.html
  - lectures will be posted frequently, mostly every day if I can remember to do so

Conductivity and resistivity

TABLE 30.2 Resistivity and conductivity of conducting materials

Material	Resistivity (Ω m)	Conductivity (Ω^{-1} m^{-1})
Aluminum	2.8×10^{-8}	3.5×10^{7}
Copper	1.7×10^{-8}	6.0×10^{7}
Gold	2.4×10^{-8}	4.1×10^{7}
Iron	9.7×10^{-8}	1.0×10^{7}
Silver	1.6×10^{-8}	6.2×10^{7}
Tungsten	5.6×10^{-8}	1.8×10^{7}
Nichrome*	1.5×10^{-6}	6.7×10^{5}
Carbon	3.5×10^{-5}	2.9×10^{4}

*Nickel-chromium alloy used for heating wires.

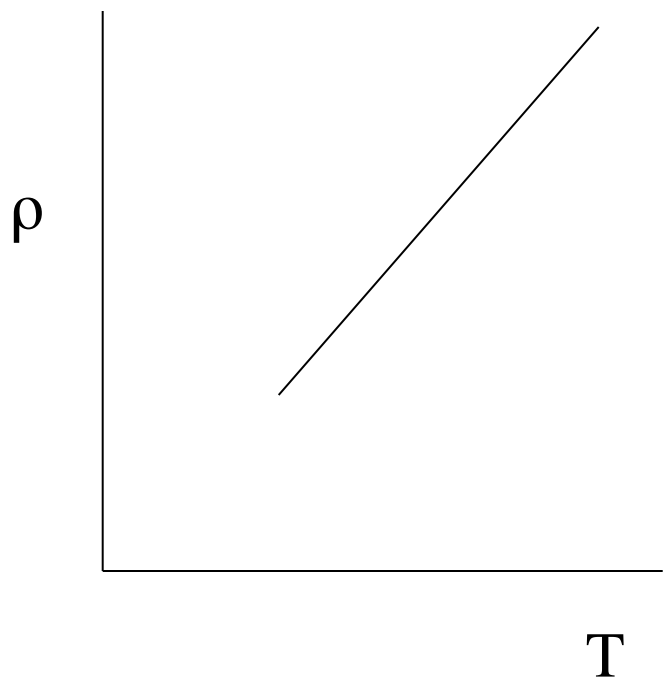
Temperature dependence of resistivity

- Before we just quoted a value of resistivity for each material
- However, the resistivity has a temperature dependence, with most materials obeying the formula

  $\rho=\rho_o[1+\alpha(T-T_o)]$

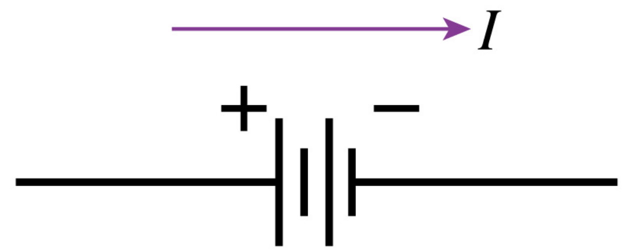
- …where ρ_o is the resistivity at T_o (room temperature), and α is the temperature coefficient.
- Note that α is positive, i.e. the resisitivity increases as the temperature increases and decreases as the temperature decreases
- At some point, it looks like the resistivity would go to zero

Material	Resistivity ρ at 20°C $\mu\Omega \cdot$ cm	Temperature coefficient α at 20°C, °C^{-1}
Aluminum	2.83	0.0039
Brass	6.4–8.4	0.0020
Copper		
Hard-drawn	1.77	0.00382
Annealed	1.72	0.00393
Iron	10.0	0.0050
Silver	1.59	0.0038
Steel	12–88	0.001–0.005

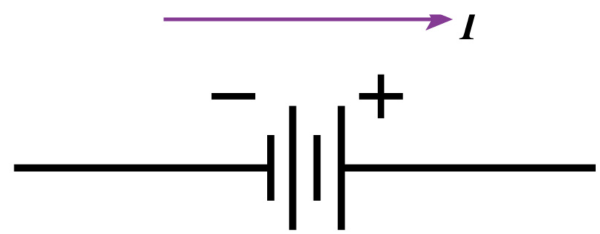


Rules

- Potential decreases in going from + terminal to - terminal
  - $\Delta V = -\varepsilon$
- And increases in going from - terminal to + terminal
- Potential decreases in going across resistor in direction of current flow
  - $\Delta V = -IR$
- And increases when going across resistor against the direction of current flow



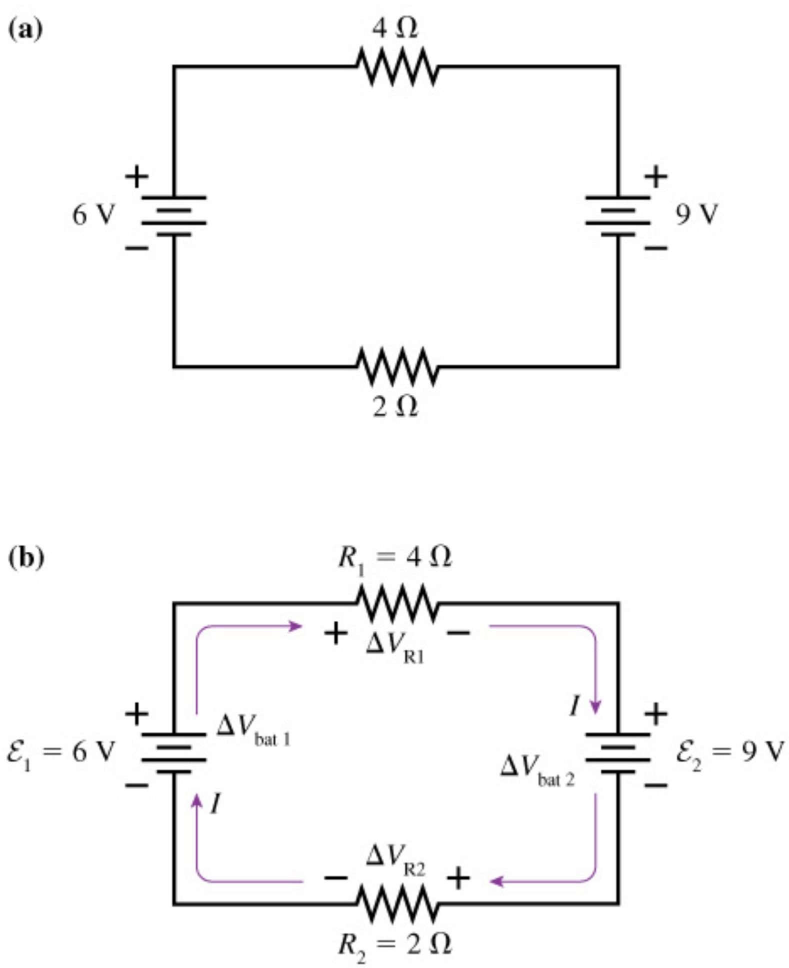
Potential decreases

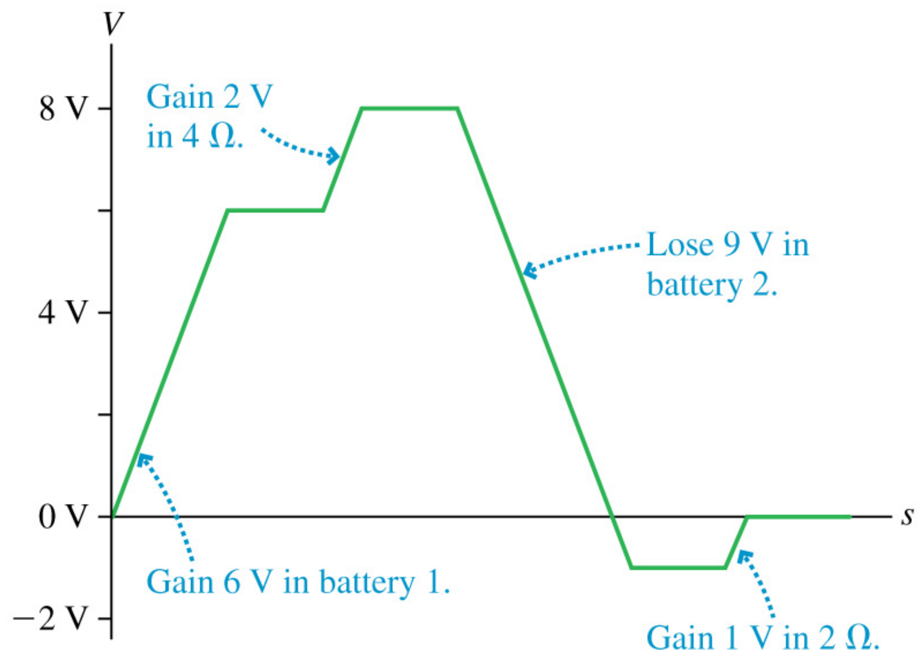


Potential increases

Potential decreases

Simple circuit





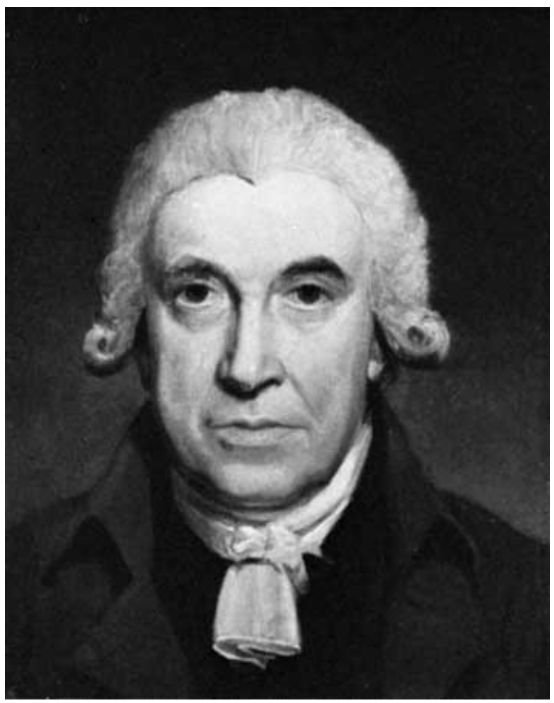
$$\sum_{loop} \Delta V = \varepsilon_1 - IR_1 - \varepsilon_2 - IR_2 = 0$$

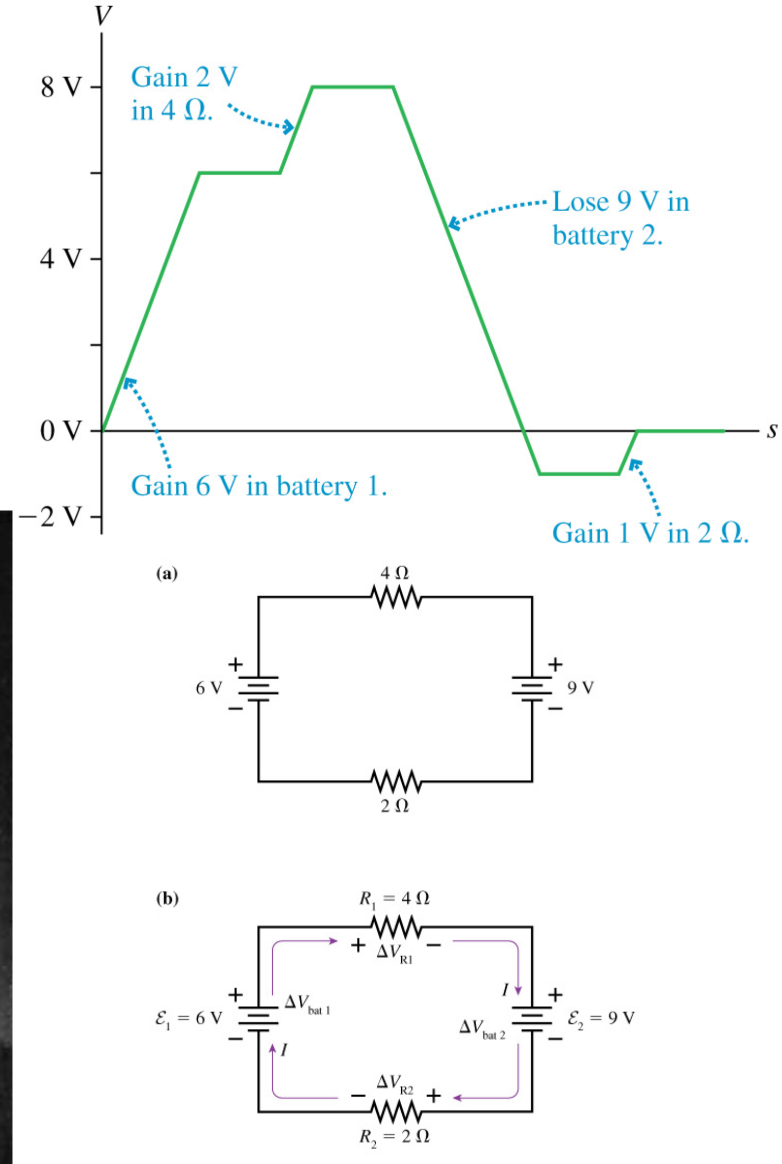
$$I = \frac{\varepsilon_1 - \varepsilon_2}{R_1 + R_2} = \frac{6V - 9V}{4\Omega + 2\Omega} = -0.5A$$

current is opposite direction of what we drew

Energy considerations

- When charge +q goes from - terminal of battery to + terminal it gains a potential energy of $\Delta U = q\varepsilon$
- The rate at which energy is gained is given by $P = \Delta U/dt = dq/dt(\varepsilon) = I\varepsilon$ with units of J/s=W(atts)

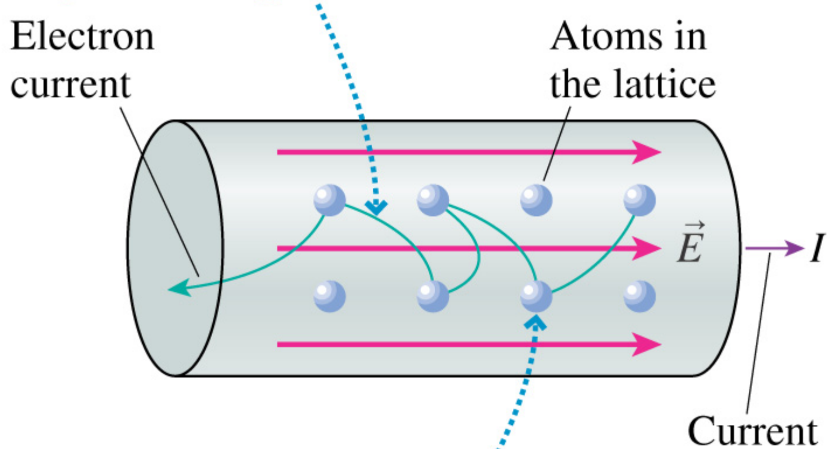




Energy gained is energy lost

- Energy added by battery is lost by electrons during their collisions with atoms and eventually ends up as heat
  - i.e. the resistor gets warm
- Consider the work done by the electric field for an electron travelling a distance d

$$W = F\Delta s = qEd$$



- The energy transferred to the lattice when the electron collides with an atom then is

$$\Delta E_{collision} = \Delta K = qEd$$

- In a length L, the energy transferred is $\Delta E = qEL = q\Delta V_R$
- The power dissipated in the resistor then can be written as

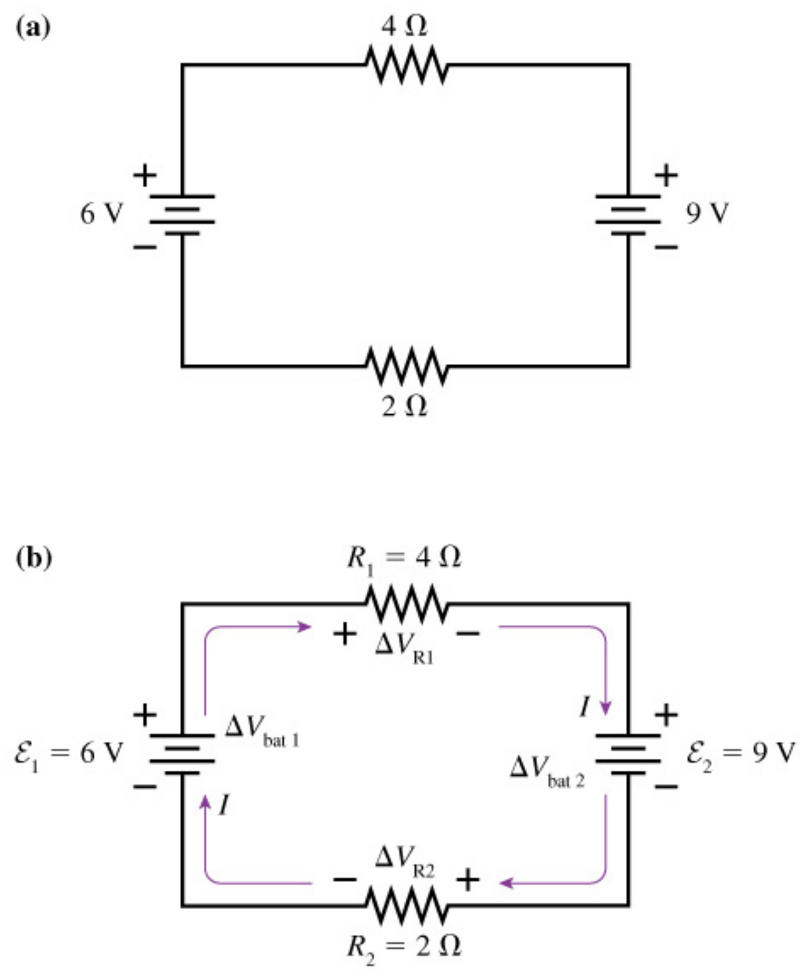
$$P_R = \frac{dE}{dt} = \frac{dq}{dt}\Delta V_R = I\Delta V_R = P_{battery}$$

Power in electrical circuits

- Can write the power in the following forms

$$P = I\Delta V_R = I^2 R = \frac{\Delta V_R^{\;2}}{R}$$

- If I integrate power over time, I have units of energy
  - kW-hr
  - 1000 J/s*3600s =3.6X10^6 J/kW-hr

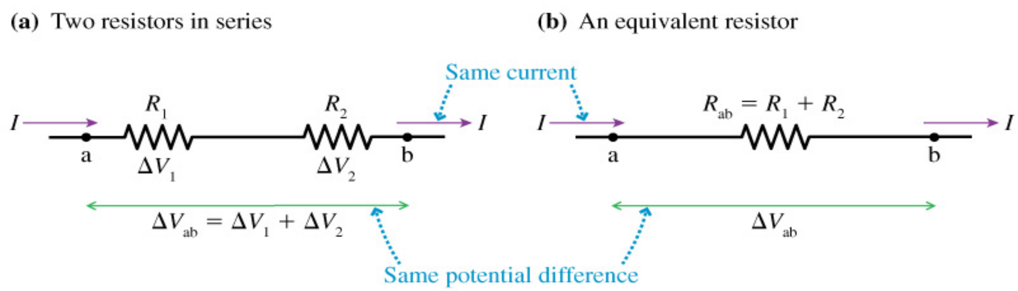


Example

- A 100 W (120V) lightbulb contains a 7.0 cm long tungsten filament. The high-temperature resistivity of tungsten is $9.0 \times 10^{-7}\ \Omega m$. What is the diameter of the filament?

Resistors in series

- Consider two (or more) resistors in series
- The same current passes through both resistors
- The total voltage drop across the two resistors is the sum of the voltage drops across each resistor
- We'd like to find an equivalent resistance for which the current would be the same given the same voltage drop



$$\Delta V_{ab} = \Delta V_a + \Delta V_b = IR_1 + IR_2$$

$$I = \frac{\Delta V_{ab}}{R_1 + R_2} = \frac{\Delta V_{ab}}{R_{eq}}$$

$$R_{eq} = R_1 + R_2 (+R_3 + \ldots)$$