Basics – 2

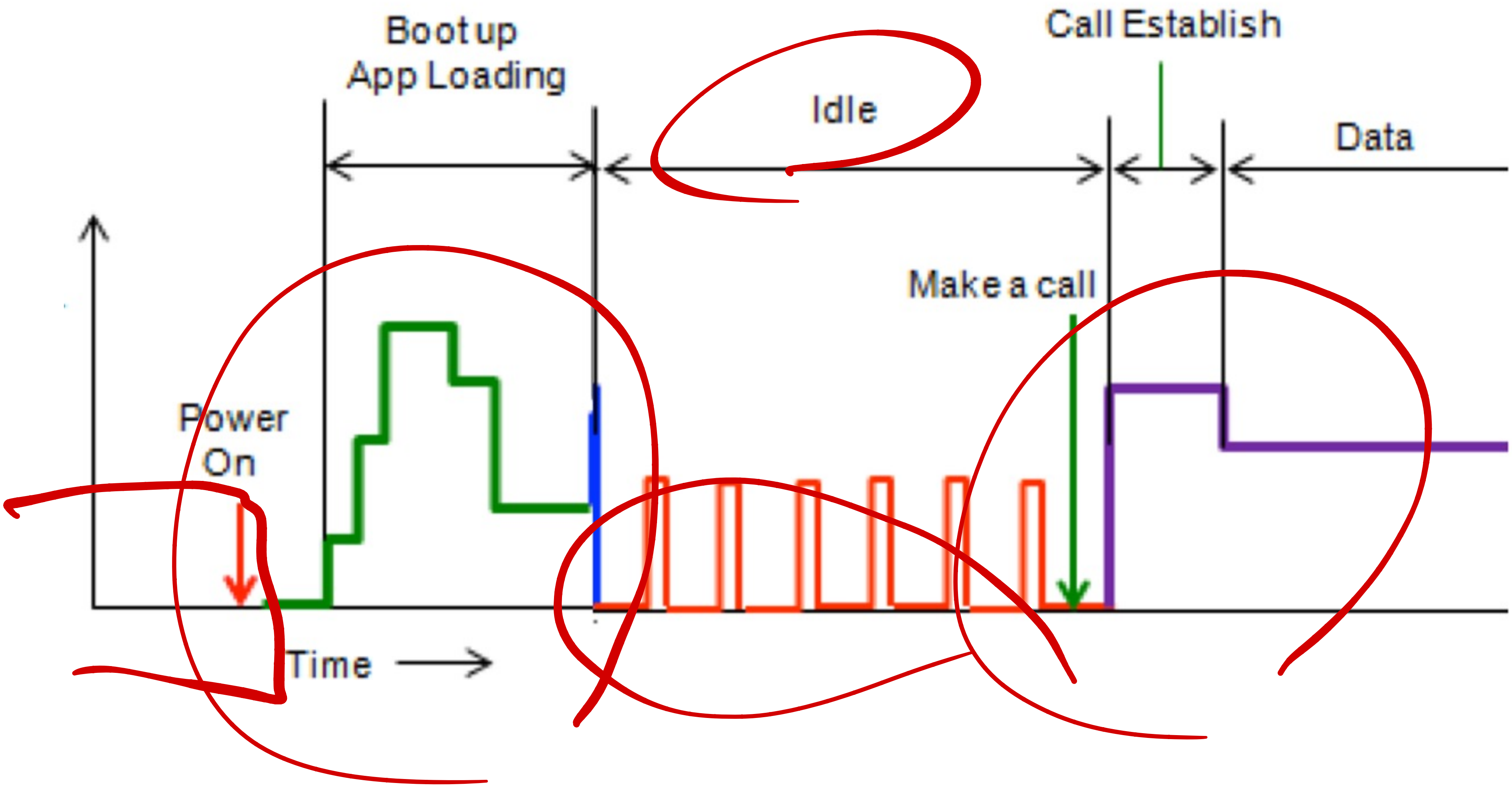
time variation; sources; resistors

Circuit Variables

Current	$i(t)$	amperes	directional
Voltage	$v(t)$	volts	directional
Power	$p(t) = v(t)i(t)$	watts	
Energy	$E(t)$	joules	

- Typically, these are time varying

- As an example – smart phone power usage



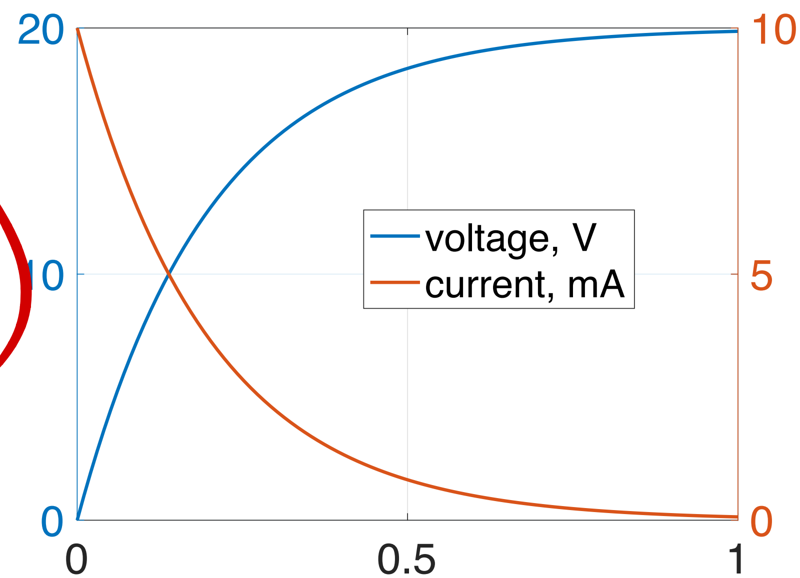
Example: I currently have a 3-year-old iMac on my desk with power consumption of 63 watts (idle) to 240 watts (active computing). A new iMac is better vis-à-vis power with levels of 43-84 Watts, respectively. Can I argue the $1,600 price tag based upon the obvious energy savings?

- Answer:
  - Assumptions:
    - Low/high power usage for a typical day is 20/4
    - Electricity rate of 18 cents/kWh
  - Extra power over a year:
    - High power: $365 * 4 * (240 - 84) = 228$ kWh
    - Low power: $365 * 20 * (63 - 43) = 146$ kWh
    - Savings per year $= (228 + 146) * 0.18 = \$67$

Example: The voltage and current at the terminals of a two-terminal circuit device for $t > 0$ seconds are

$$v(t) = 20\,(1 - e^{-5t})\ \ V$$

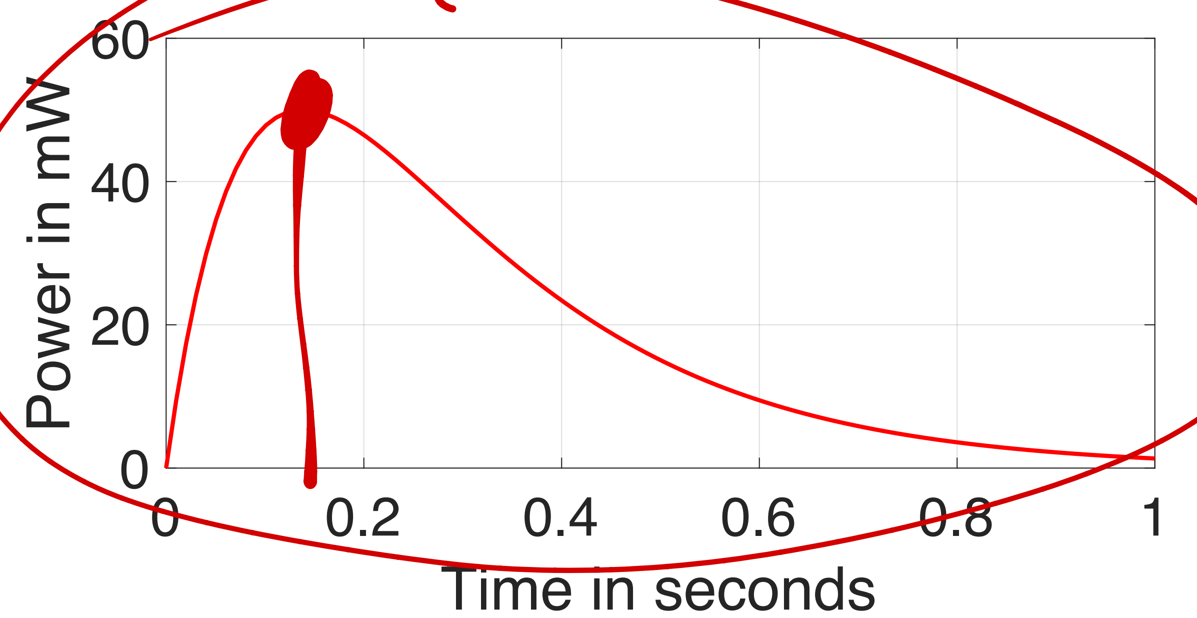
$$i(t) = 10\,e^{-5t}\ \ mA$$



- At what time is the power being delivered to the device a maximum?
- What is that maximum?

- Answer:
  – First, use the fact that power is the product of voltage and current

$$p(t) = v(t) * i(t)$$
$$= 200\,(e^{-5t} - e^{-10t})\text{ mW}$$



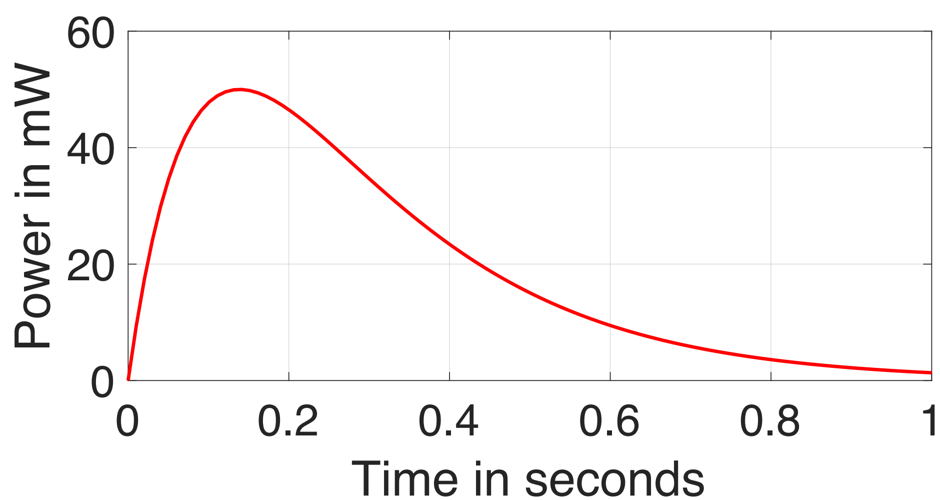
– Calculus gets us the extreme point:

$$\frac{dp(t)}{dt} = 200\left(-5e^{-5t} + 10\, e^{-10t}\right)$$

- This derivative is zero when

$$t = \frac{\ln 2}{5} = 0.139 \text{ sec.}$$

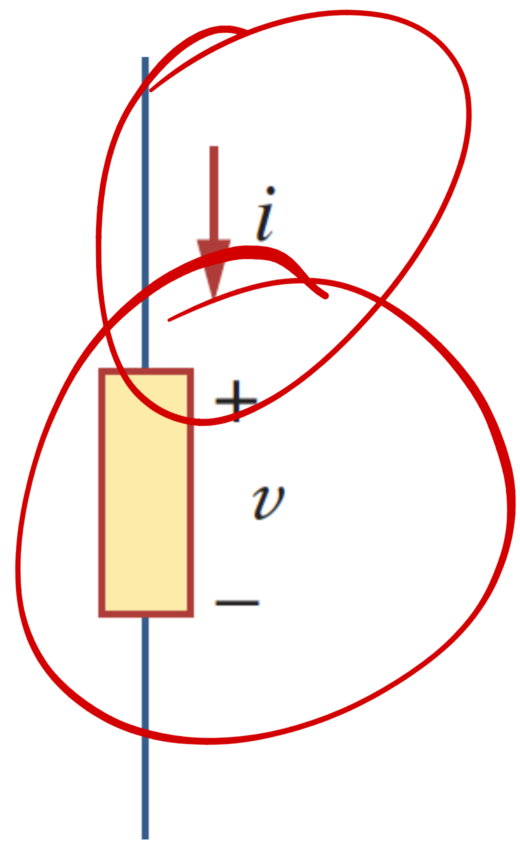
– The peak is $p\left(\frac{\ln 2}{5}\right) = 50$ mW



2 Terminal Devices

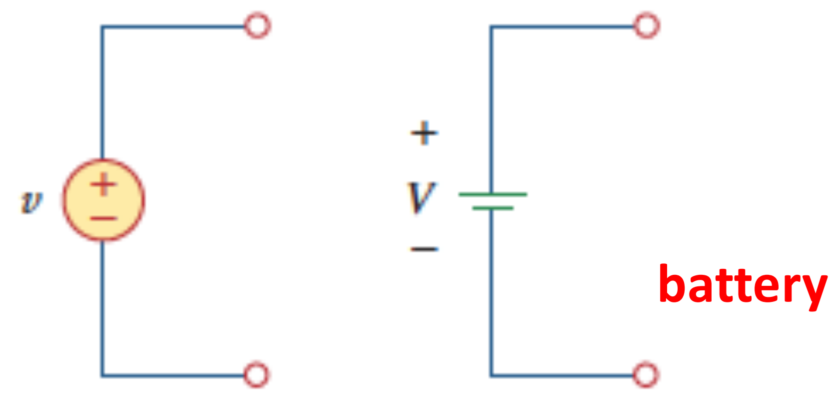
- Typical components for ELE 212/215:
  - Voltage and current sources
  - Resistors, inductors, capacitors
- Each has its own v, i characteristic

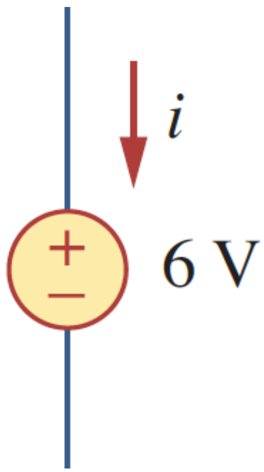
- Passive sign convention
  - Power $p = v\,i$
    - $p > 0$ "absorbed"
    - $p < 0$ "delivered"



Sources

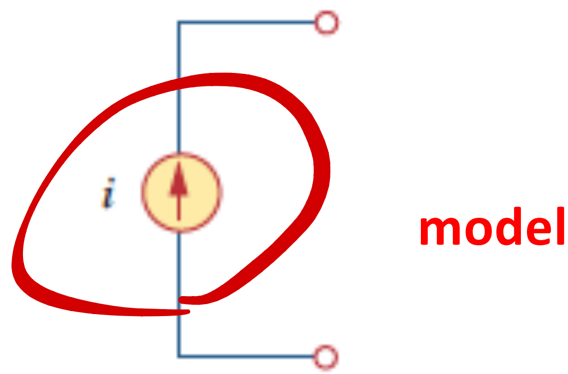
- Voltage source:
  - Fixed voltage
  - Any current necessary
  - Example:

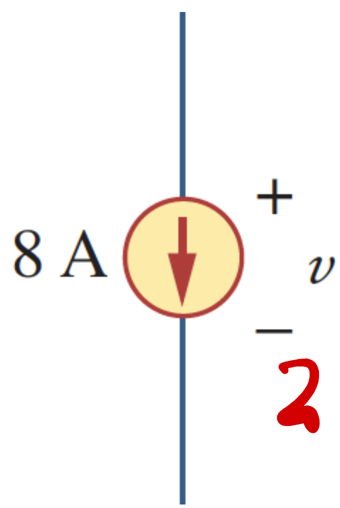




Power $p = v\,i$ can be positive or negative

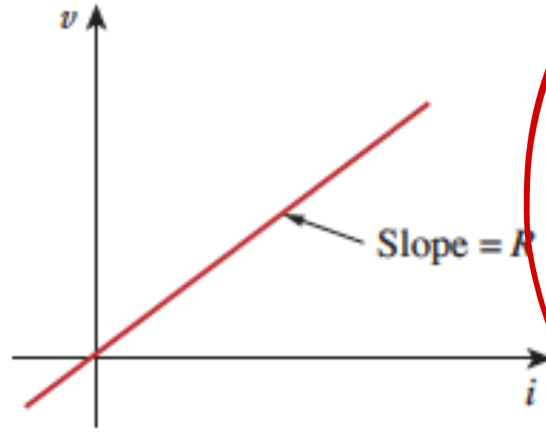
- Current source:
  - Fixed current
  - Any voltage necessary
  - Example:

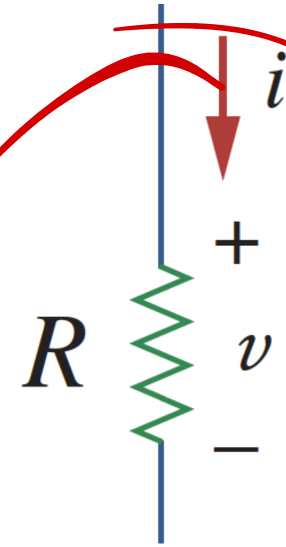




Power $p = v\,i$ can be positive or negative

Resistors





- Ohm's Law

$$v = R\, i$$

- Unit is ohms (Ω, kΩ, MΩ)
  - Also written as $i = \frac{v}{R} = v\, G$
  - G = conductance (mhos, Siemens, ℧)

- Power is $p = v\, i = R\, i^2 = \frac{v^2}{R} = v^2 G$
  - Always positive; power is always absorbed

Example: If the current through a 60 Ω resistor is 0.3 A, what is the voltage across it? How much power is it absorbing?

Ohm's Law $v = R \cdot i$

$= (60)(0.3) = 18\ V$

Power $= v \cdot i = 18 \cdot (.3) = 5.4\ W$

$= \frac{v^2}{R} = \frac{18^2}{60} = \frac{324}{60} = 5.4\ W$

$= i^2 R = (.3)^2\, 60 = 5.4\ W$

Issue of significant figures

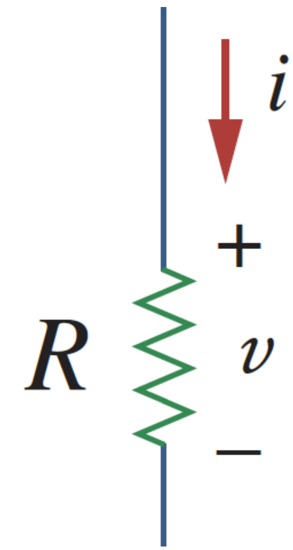
- Consider computing the resistance using Ohm's Law:

  $v = 3.07$ volts

  $i = 29.0$ milliamps

  then

$$R = \frac{3.07 \ \pm \ 0.01}{0.0290 \ \pm \ 0.0001}\ \Omega$$



$$\frac{3.07}{0.0290} = 105.862068 \ \ \Omega$$

$$R \geq \frac{3.06}{0.0291} = 105.15 \qquad\qquad R \leq \frac{3.08}{0.0289} = 106.57$$

$895

Practice problem: I'm thinking of buying an electric car. How much would I save by having a home charger versus using the publicly available charging stations?

- Assumptions:
  - Average 330 miles from 82 kWh (Tesla model 3)
  - Drive 15,000 miles per year
  - Electricity rate of 18 cents/kWh at home vs 42 cents/kWh at the chargers

$$E/yr = \frac{15000}{330} \cdot 82 \cdot \begin{matrix} .18 \\ .42 \end{matrix}$$

0.424 mA

Practice problem: If the voltage across a 33 kΩ resistor is 14 volts, what is the current through the resistor?

5w power rated red

Ohm's Law

$$i = \frac{V}{R} = \frac{14}{33000} =$$

137 volts

Practice problem: If a 150 kΩ resistor has a power rating (i.e. maximum power allowed) of 1/8 watt, what is the maximum voltage that can be applied across the resistor?

for resistor $P = \frac{V^2}{R} \Rightarrow V^2 = P \cdot R$

$$V = \sqrt{P \cdot R}$$

$$= \sqrt{\frac{1}{8} \cdot 150000}$$

3.57 mA

Practice problem: If the voltage across a 56 Ω resistor is 200 mV, what is the current through the resistor?

34.6 mA

Practice problem: If a 100 Ω resistor is absorbing 120 mW, what is the current through the resistor?