# CLASS 15: ELECTRICAL ENERGY & POWER

ENGR 102 – Introduction to Engineering

# Electrical Energy & Power

# Energy and Power



- True understanding of electrical systems comes from understanding how they behave in terms of ***energy***
  - True for dynamic systems in any domain – mechanical, electrical, etc.
- Electrical components can do one of four things:
  - Supply energy
  - Store energy
  - Dissipate energy
  - Transform/transmit/convert energy
- We're also concerned with the ***rate*** at which energy is supplied, stored, dissipated, or transformed
- ***Power*** is the ***rate of energy flow***
  - Unit of energy: joule ($J$)
  - Unit of power: watt ($W$), $1\ W = 1\frac{J}{s}$

# Energy and Power



- Power is the ***rate*** of energy flow
  - The ***time derivative*** of energy

$$P = \frac{dE}{dt}$$

$$[W] = \left[\frac{J}{s}\right]$$

- Similarly, energy is given by the ***integral*** of power

$$E = \int p(t)dt$$

- For constant power, this simplifies to the product of power and time

$$E = P \cdot t$$

$$[J] = \left[\frac{J}{s}\right] \cdot [s]$$

# Electrical Energy



- The power utility company charges us for ***energy***, not power
  - Units: watt-hours (Wh or kWh)
  - For example: $0.12/kWh
- One watt-hour (1 Wh):
  - Quantity of energy equivalent to the consumption of 1 W for 1 hour

$$1\,Wh = 1\frac{J}{s}\cdot 1\,h = 1\frac{J}{s}\cdot 1\,h\cdot\frac{3600\,s}{1\,hr} = 3600\,J$$

$$1\,Wh = 3.6\times 10^{3}J = 3.6\,kJ$$

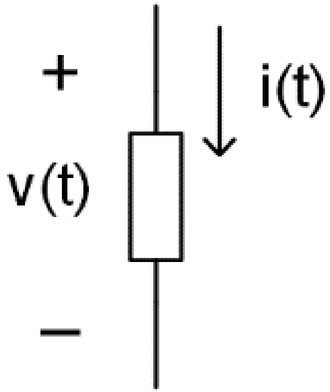
$$1\,kWh = 3.6\times 10^{6}J = 3.6\,MJ$$

# Electrical Power



- A circuit component will have voltage across it and current flowing through it
  - In general, both are functions of time: $v(t)$ and $i(t)$

- Power flowing to/from that component is given by the ***product of voltage and current***




$$p(t) = v(t) \cdot i(t)$$

  - ***Instantaneous power***
  - A function of time

- If $i(t)$ and $v(t)$ are constant (DC) then $p(t)$ is constant as well

$$P = V \cdot I$$

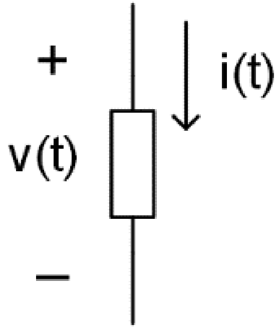
# Power – Passive Sign Convention



- ***Power*** can be ***supplied*** or ***absorbed*** by electrical components
- For any component, power is given by

$$p(t) = v(t) \cdot i(t)$$

- Use the ***passive sign convention*** to determine if power is supplied or absorbed:



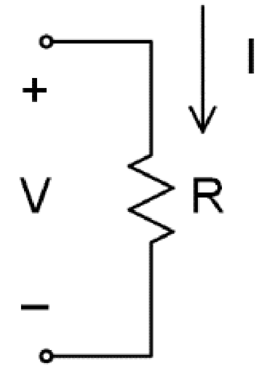

- Positive current flows into the positive voltage terminal
- ***Positive*** power ($p > 0$) indicates power ***absorbed***
- ***Negative*** power ($p < 0$) indicates power ***supplied***

# Power in Resistors



- Resistors ***dissipate*** power
- Rate of power dissipation given by

$$P = V \cdot I$$




- According to Ohm's law

$$V = I \cdot R \quad \text{and} \quad I = V/R$$

- So, ***for resistors*** (***only***), power is given by

$$P = I^2 R$$

and

$$P = \frac{V^2}{R}$$

# Energy & Power



Exercise

- An air-conditioning unit consumes 3.5 kW. If the AC unit runs for 4 hours/day, how much energy does it consume in a month?
- If the cost of electricity is $0.12/kWh, how much does it cost to run the AC for the month?

# Energy & Power



Exercise

- If a home has an average monthly energy consumption of 400 kWh, what is the home's average power consumption?

# Power



Exercise

- A 12 V battery supplies 5 W to a DC motor, how much current flows from the battery to the motor?

# Power



Exercise

- Determine the power supplied or absorbed by each component in the following circuit.