02-Basic Concepts

Text: Chapter 1.1 – 1.5

ECEGR 210

Electrical Circuits I

Overview

- Systems of Units
- Charge and Current
- Voltage
- Power & Energy

System of Units

- Serious confusion and catastrophe can occur if we are not specific about which units a quantity is expressed in
- Consider the differences in
  - $10/gallon
  - $10/liter
  - €10/gallon

System of Units

- In 1999 NASA lost the 125 million dollar Mars Orbiter because one engineering team used metric units while the other used English units

System of Units

- What should we use: Metric or English units?

"…the preferred system of weights and measures for United States trade and commerce"

U.S. Metric Conversion Act, 1975

System of Units

Quantity	Basic Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	Second	s
Current	Ampere	A
Charge	Coulomb	C

See Table 1.1 for more

System of Units: Prefixes

10^{9}: giga (G)

10^{6}: mega (M)

10^{3}: kilo (k)

10^{-1}: deci (d)

10^{-2}: centi (d)

10^{-3}: milli (m)

10^{-6}: micro (μ)

10^{-9}: nano (n)

10^{-12}: pico (p)

See Table 1.2 for more

Charge and Current

- Charge: property of atomic particles
  - Measured in coulombs (C)
  - 1 electron = 1.602×10^{-19} C
  - 1 C is a very large number of electrons!
  - Usual variable assignment: q, Q

- Law of Conservation of Charge: charges cannot be created or destroyed, only transferred

Charge and Current

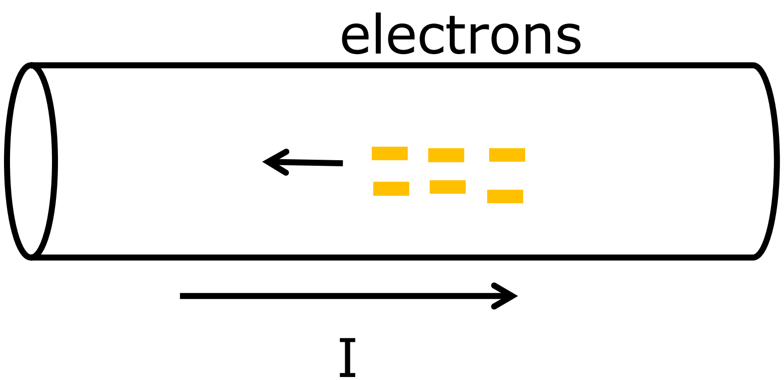
- Electric current is the rate of change of charge with respect to time
  - Measured in amperes (A)
  - 1 A = 1 coulomb/second
  - Usual variable assignment: i, I
- Charge and current relationship

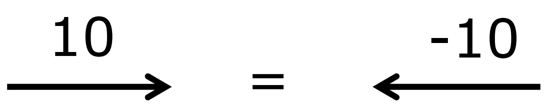
$$i \triangleq \frac{dq}{dt}$$

$$Q \triangleq \int_{t_0}^{t} i\,dt$$

Charge and Current

- Current is referenced to a direction
- Convention is that current flows in direction of positive charges (<u>opposite of electrons</u>, which do the actual movement)





Charge and Current

- Current that does not change in time is known as direct current (dc or DC)
- Current that varies with time is known as time-varying current
- Current that varies sinusoidally with time is known as alternating current (ac or AC)

Voltage

- There is no net movement of charges unless there is an electric field

- Voltage (potential difference): energy required to move a unit charge between two points

$$v_{ab} \triangleq \frac{dw}{dq}$$

where:

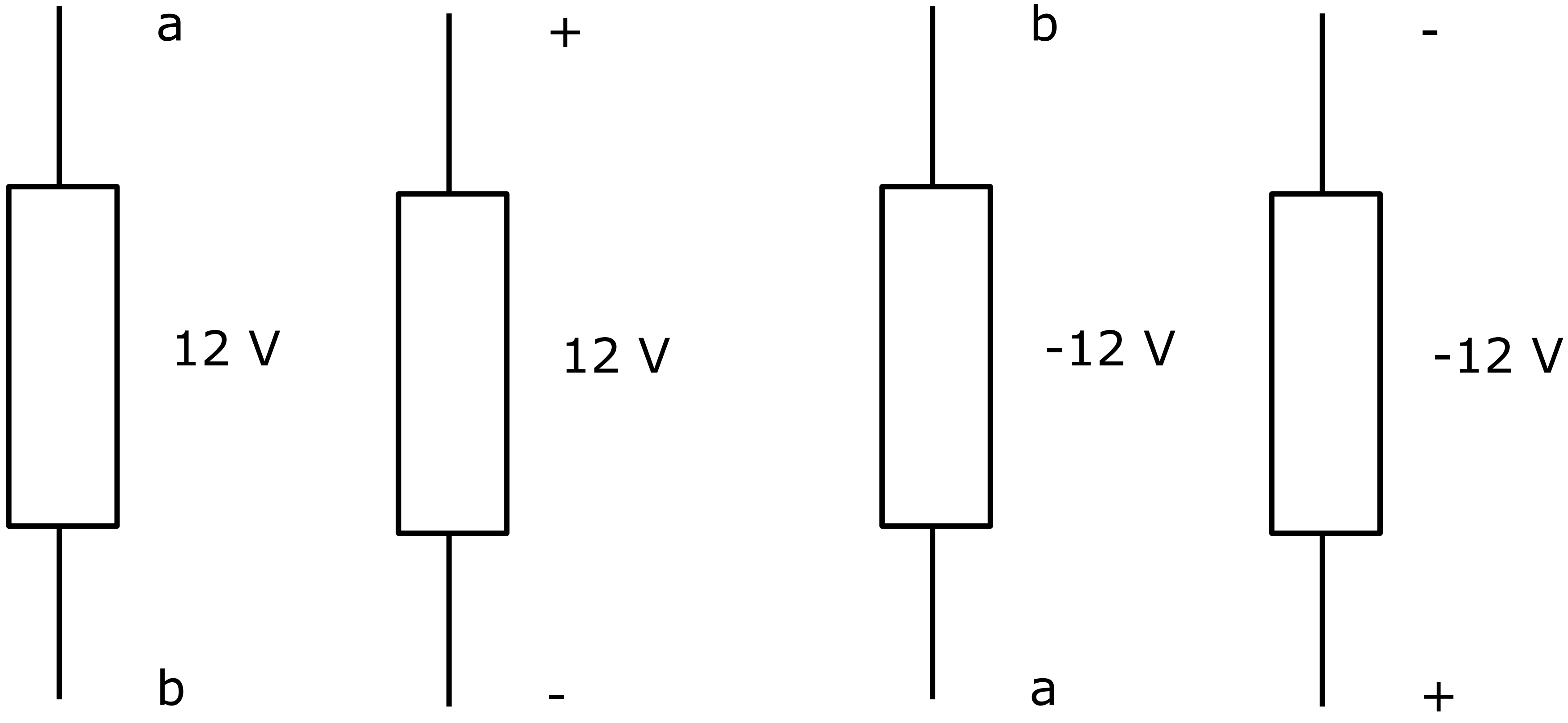
- W: energy (work) in joules (J)
- a, b: points

Voltage

- Voltage
  - Measured in volts (V)
  - 1 V = 1 joule/coulomb
  - Usual variable assignment: v, V (Assuming a,b are known)

- Voltage is a relative measure, it requires two points
- A 12V battery refers to the voltage between its two terminals
- What two points does the 120VAC in an outlet refer to?

Voltage Convention



All are the same using “a to b” convention $V_{ab} = - V_{ba}$

Power & Energy

- Often interested in the “usefulness” of a circuit
  - How much work does it do?
- Power and energy are important concepts

Power & Energy

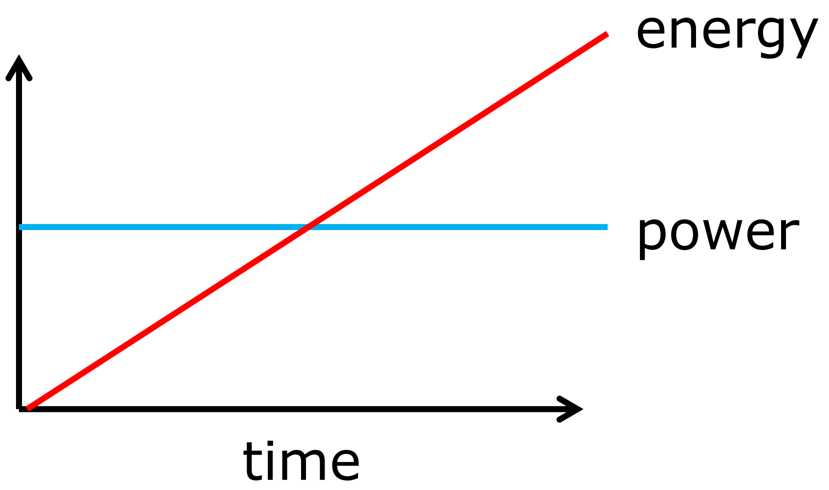
- Power: rate of expending or absorbing energy with respect to time
  - Measured in watts (W)
  - 1 W = 1 joule/second
  - Usual variable assignment: p, P

$$p \triangleq \frac{dw}{dt}$$

$$W \triangleq \int_{t_0}^{t} p\,dt$$

Power & Energy

- Power DOES NOT EQUAL Energy!
- Analogy:
  - Power is to energy as velocity is to distance



Power & Energy

- What is your utility bill usually based on, power or energy?

- What specification are must interested in when buying a heater or motor?

Power & Energy

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  - Energy ($/kWh)

- What specification are must interested in when buying a heater or motor?
  - Power (W)

Power & Energy

- How many joules are there in a kWh?

- What does one kWh of electrical energy cost?

Power & Energy

- How many joules are there in a kWh?
  - 1000 W x 3600 s = 3.6 million
- What does one kWh of electrical energy cost?
  - About $0.11 (National Average)

Power & Energy

- Recall that: 1 V = 1 joule/coulomb
  - Joule is a unit of energy

$$V \times I = \frac{\text{joule}}{\text{coulomb}} = \frac{\text{coulomb}}{\text{seconds}} = \frac{\text{joule}}{\text{seconds}} = \text{Watts}$$

Power & Energy

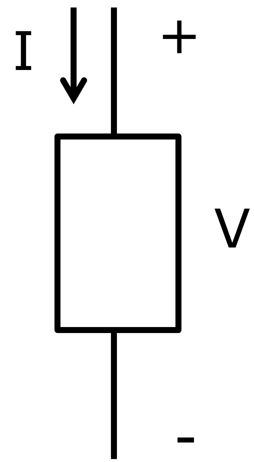
- Voltage multiplied by current equals power
  - $P = VI$
  - Note: engineers have different notions of power (Complex, real, imaginary, instantaneous)
- Power (and energy) must be conserved
  - Implies that power can be positive or negative
  - Sum of power in all elements must equal zero
- How do we interpret the sign?

Power & Energy

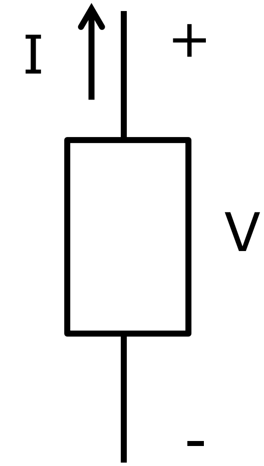
- Positive power: consuming power
  - Motors
  - Heaters
  - Pumps
- Negative power: supplying power
  - Batteries
  - Generators
  - Photovoltaic cells

Power & Energy

- Use *passive* sign convention
  - When current enters the + sign, power is positive



power is positive,
element consumes power



power is negative,
element supplies power

Power & Energy

- Which is supplying power?

Power & Energy

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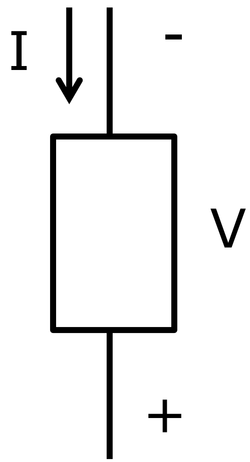

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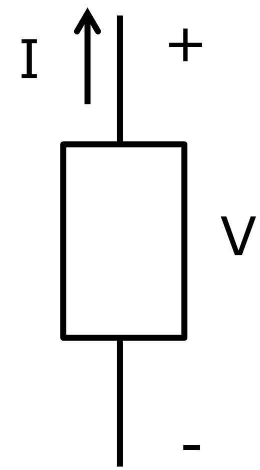


power is negative,
element supplies power

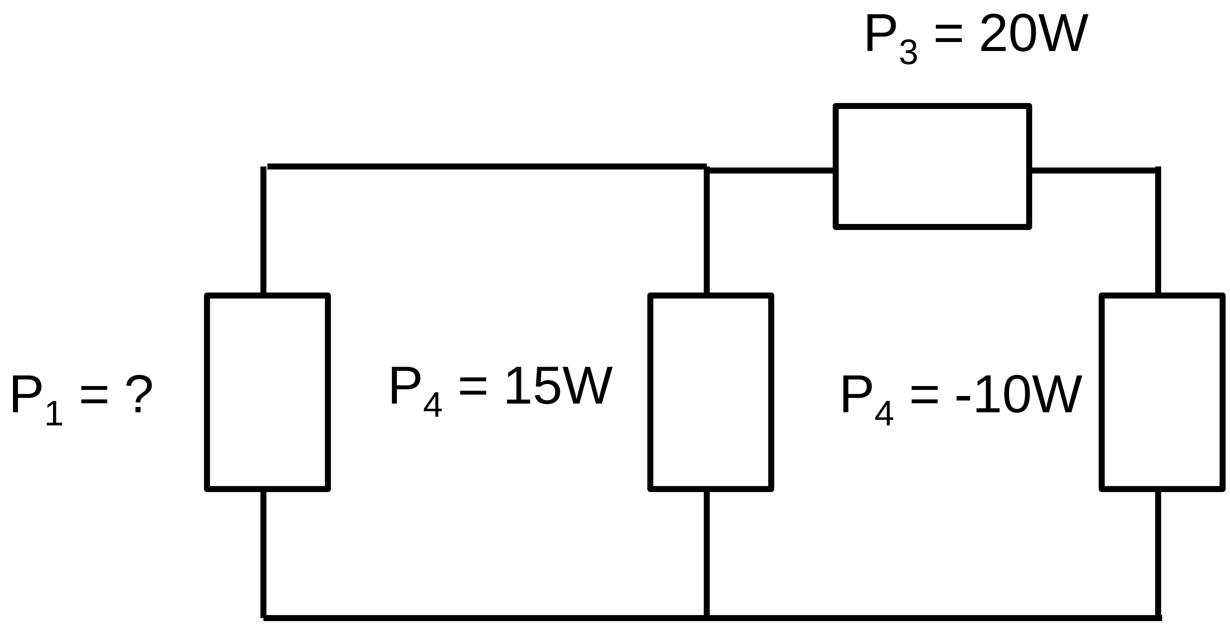
Power & Energy

- Conservation of energy requires that both power and energy be conserved
  - Total power supplied = Total power absorbed
  - Also written as:

$$\sum P = 0$$

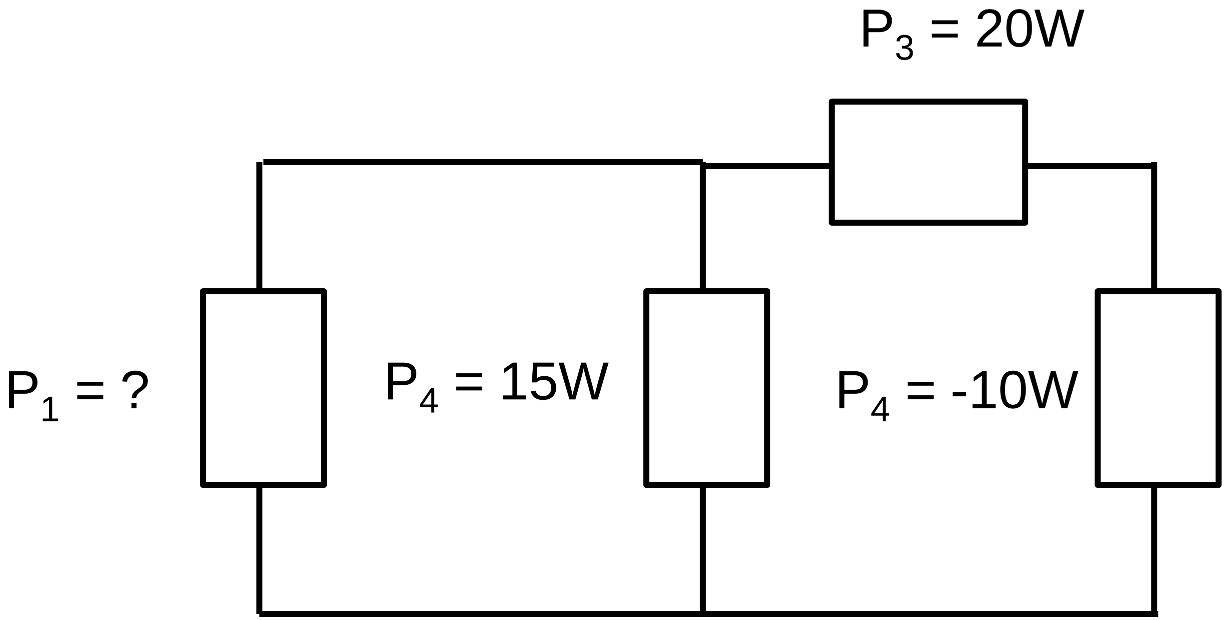
Example

- Find P_1. Is it supplying or absorbing power?



Example

- Find P_1. Is it supplying or absorbing power?
- P_1 = -25W, supplying power



Power & Energy

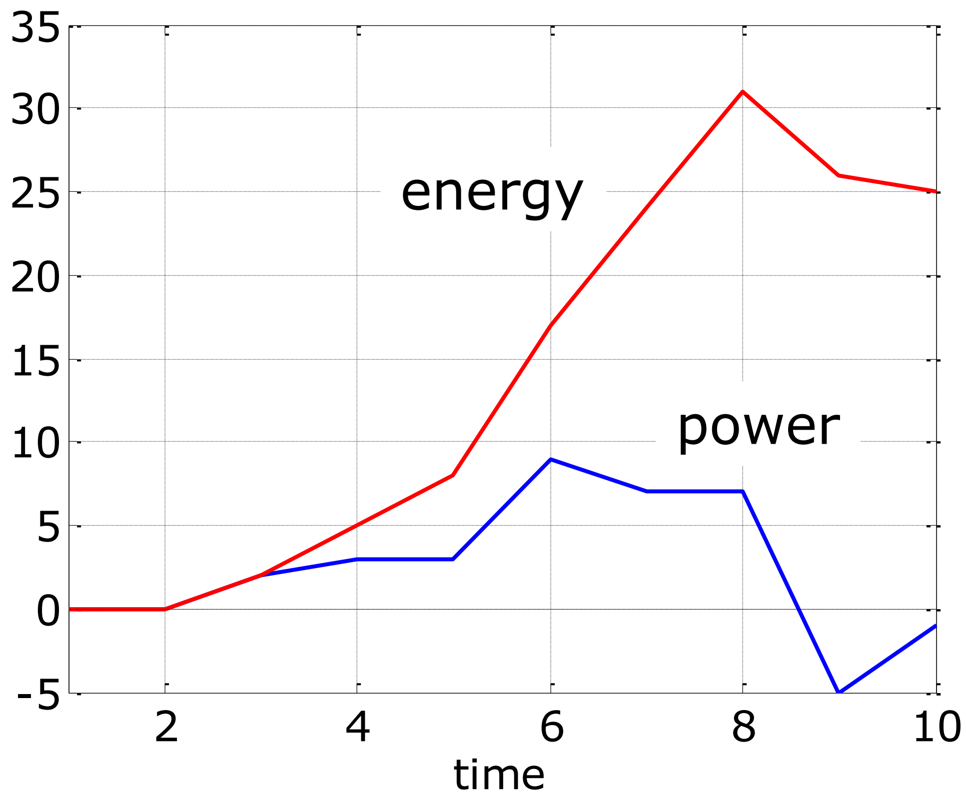
- Energy is found by integrating power with respect to time

$$w = \int_{t_0}^{t} p\,dt = \int_{t_0}^{t} vi\,dt$$

- Power is found by differentiating energy with respect to time

$$p = \frac{dw}{dt}$$

Power & Energy



Example

- Which consumes more energy: a 100 W light bulb over a 2 hour period, or a 0.05W cellular phone charger over a 200 hour period?

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- Light bulb: W = 200 Wh
- Charger: W = 0.05 x 200 = 10Wh

- Think about this when making energy conservation decisions!

Ratings

- Most electric devices have power ratings (or current and voltage ratings)
- This does not imply that these devices always draw the rated power (current)
- Example: laptop battery (DC Rating)
  - 19.5 V
  - 3.34 A
  - P_{rated} = 19.5 x 3.34 = 65.13W

Ratings

- Batteries also have an energy rating
  - Approximate only!
  - Usually in Amp-Hours (Ah)
  - Example: 90 Ah, 12V car battery is rated for 90 x 12 = 1080 Wh
  - Example: 1380 mAh, 3.7V cellular phone battery is rated for 0.138 x 3.7 = 5.1 Wh