Lecture 4 : Power and Energy

- Relationship between Voltage and Energy
- Relationship between Power and Energy
- Energy Efficiency

Voltage and Energy

- **Energy** is **the ability to do work/heat**, measured in joules (J), BTUs, calories, kWh, etc.
- **Voltage** is **the work done per unit charge** (eg. J/C) against a static electric field to move charge between two points

$$\boxed{V = \frac{\Delta \mathrm{E}}{\Delta Q}}$$

- Also, 1 volt ($1\ V$) is the electric potential difference between two points that will impart $1\ J$ of energy per coulomb ($1\ C$) of charge that passes through it.

$$\Delta E = \Delta Q\ V$$

Q: A certain battery imparts 480 pJ to every 1 billion electrons. What is its voltage?

A. 1.5 V
B. $\boxed{\text{3 V}}$
C. 6 V
D. 9 V
E. 12 V

$$\frac{-1.6 \times 10^{-19} C}{electron}$$

Voltage and Energy

$$E = Q\,V$$

Tesla Model S

Q: What is the charge moved through 400 V (EV battery) to provide 800 kJ of energy?

A. $2\ mC$
B. $2\ C$
C. $\boxed{2\ kC}$
D. $2\ MC$
E. $2\ GC$

Q: What is the average current if that energy is provided in five seconds?

A. $1\ \mu A$
B. $4\ mA$
C. $4\ A$
D. $10\ A$
E. $\boxed{400\ A}$

$$I = \frac{\Delta Q}{\Delta t}$$

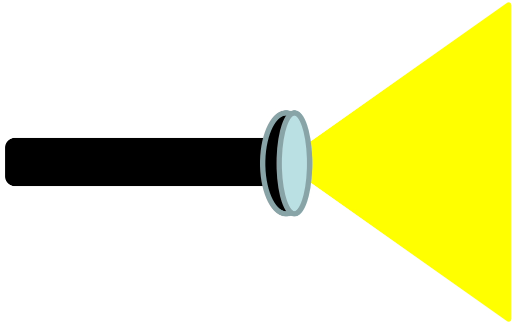
Energy and Power

Power is **the rate at which energy is transferred**.

Power is $(rate\ of\ charge\ flow) \times (potential\ difference)$

Power is $current \times voltage$

$$P = \frac{\Delta E}{\Delta t} = \frac{\Delta Q}{\Delta t}\,V = I\,V$$



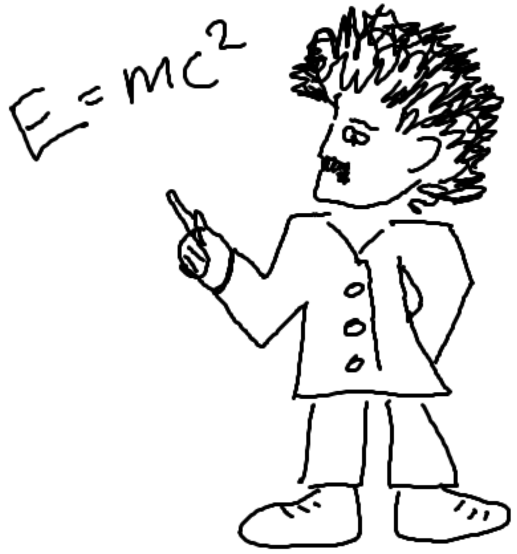
Q: A flashlight bulb dissipates $6\ W$ at $2\ A$. What is the supplied voltage?

A. 1.5 V
B. 3 V
C. 6 V
D. 9 V
E. 12 V

Energy in General

- Energy is the property transferred to do work on or heat an object
- Energy comes in many forms
- Energy is conserved (can change forms)

  Examples: heat, light, electrical energy, chemical, mechanical (e.g. potential, kinetic), mass, etc…



Effects of Energy

- drive to Chicago
- move a couch
- cook an egg
- lift a camel
- launch a satellite
- stay awake in lecture (try!)
- electrocute somebody (don't!)
- send an email (to Brazil or Urbana?)
- *write down some of your own ideas*

Energy Storage

Mechanical Energy

Kinetic Energy

Potential Energy

Electrical Energy Storage

Capacitors

Batteries

Conservation of Energy

$$E_{input} = E_{useful} + E_{waste}$$

Efficiency

- Distance: 200 km
- Elevation Drop: 44 m
- Where is the waste?

Frictional losses on the road, drive train, etc.

$$E_{input} = E_{useful} + E_{waste} = \eta E_{input} + (1-\eta) E_{input}$$

η is called “efficiency”

$(1-\eta)$ is called “losses”

Explore More!

Consider Hyperloop. What are some benefits of Hyperloop technology? What are some cons?

Driving to Chicago…accounting

Q: What minimum energy does it take to accelerate a 2200 kg mass (car) from 0 to 60 mph?

A. $8\ mJ$
B. $1\ J$
C. $80\ J$
D. $1\ kJ$
E. $\boxed{800\ kJ}$

Q: What is the energy *input* needed if the engine/drive train losses are 70%?

A. $2.6\ mJ$
B. $2.6\ J$
C. $26\ J$
D. $2.6\ kJ$
E. $\boxed{2.6\ MJ}$

Q: A certain gas car gets 50 km/gal (avg). How much energy does it take to get to Chicago?

a gallon of gas (120 MJ/gal)

A. $500\ mJ$
B. $500\ J$
C. $500\ kJ$
D. $\boxed{500\ MJ}$
E. $500\ GJ$

Loading camels

Definition of power:

$$P = \frac{\Delta E}{\Delta t}$$ is rate of energy…

vs.

Motor + pulley + harness method

Loading camels: different power; same E!

$$P = \frac{\Delta E}{\Delta t}$$

<u>Loading Camels</u>: What is the average power needed to lift 500 kg by two meters every minute?
<u>Acceleration of Tesla car</u>: What is the power needed to expend 800 kJ in five seconds?

A. $160\ mW$
B. $160\ W$
C. $160\ kW$
D. $160\ MW$
E. $160\ GW$

L4 Learning Objectives

a. Compute voltage, energy, and charge, given two of three
b. Compute power, energy, and time, given two of three
c. Solve energy transfer problems involving mechanical potential and kinetic energy as well as efficiency (or wasted energy) considerations
d. Use a power vs. time plot to describe the difference between power and energy