Conceptual Physics

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$$\text{Energy} \equiv \begin{cases} \text{makes things happen} \\ \text{does work} \\ \text{does not change as things happen} \end{cases}$$

- Last statement ☞ profound and subtle truth
  great discovery of the 19th century
- Energy is not only an intuitive vagary ☞ “I have lots of energy”
- Energy can be measured
  and once you have a certain amount in a close system
  you keep it ☞ but it does change form
- *First law of thermodynamics:*
  energy changes in form but not in amount

- Our world is full of transformation of energy:
  1. Stored chemical energy in muscles ⇒ mechanical energy of movement and heat energy in muscles
  2. Stored gravitational energy of water in a dam ⇒ energy of falling water ⇒ mechanical energy of generators ⇒ electrical energy
  3. Stored nuclear energy in uranium ⇒ kinetic energy of fission fragments ⇒ heat energy in water ⇒ electrical energy
- In all these process
  there is quantity whose amount is same before and after process

that quantity is energy

Second law of thermodynamics is more subtle

- It says that:
  not only can't you increase amount of energy in system
  but in any process you always degrade part of it
  to form which is less useful
- E.g. ☞ chemical energy stored in muscles
  is source of some useful work
  but part of it is also converted to heat
  which can never be entirely recovered for useful work
- Usually ☞ it is entirely wasted
- Many times these losses are due to friction


Laws of Thermodynamics
Via work or via heat, every energy transfer
happen can!

- A long story ☞ with many different units
- In U.S. common units
  - Electrical energy ☞ kilowatt-hour (kWh)
  - Heat energy $\begin{cases} \text{British thermal unit (Btu)} \\ \text{kilocalorie (kcal or Cal)} \end{cases}$
- Since heat and electrical energy can be changed into one another there is fixed relation between units:
  1. 1 kWh = 860 Cal
  2. 1 kWh = $3,412$ Btu
  3. 1 Cal = 3.967 Btu

- 1 Btu raises temperature of 1 pint (1 lb) of water 1°F
- To bring 1 quart (2 lb) of H_2O from 42°F to boiling (212°F) takes

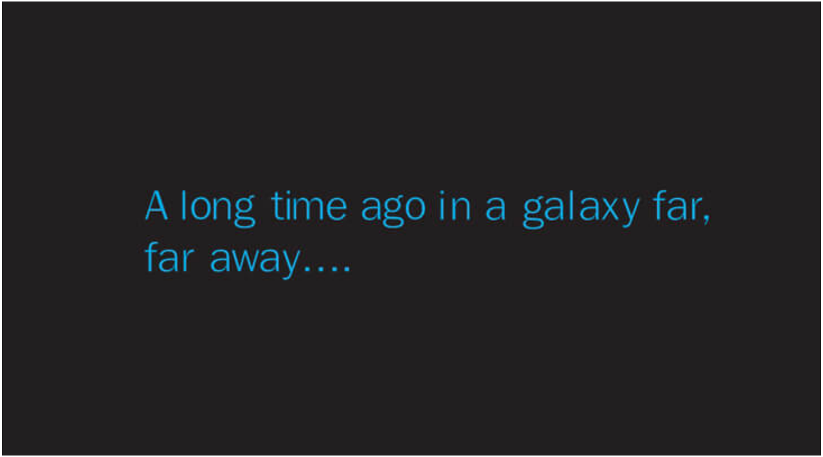
$$2 \times (212 - 42)^\circ\text{F} = 340 \text{ Btu}$$

- A Cal raises the temperature of 1 liter of water 1° C
- kWh ☞ energy supplied by 10 A-current from a 100 V line running for 1 hr
- Energy released in $\left\{ \begin{array}{l} \text{an hour's use of toaster} \\ \text{10 hours' use of 100 W bulb} \end{array} \right.$

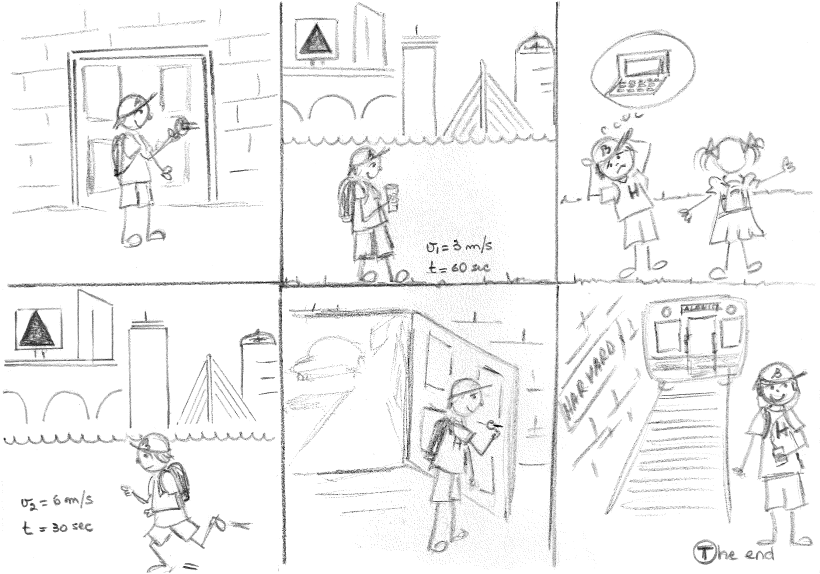
- A $1,000$ W heater running for 1 hr uses 1 kWh
  and shows up as 12¢ on your month bill
- Burning a gallon of gasoline releases 36 kWh of heat
  or $123,000$ Btu or about $31,000$ Cal
- Your daily food consuption (about $2,200$ Cal) is about 2.5 kWh
- If you didn't get rid of heat ☞ you would boil in 3 days
- Compare price of 1 kWh of electricity to 1 kWh of food
  which is about $3.00
- kWh is incredibly cheap for what it does
- Trouble is ☞ we don't really appreciate what it does
- Imagine having no electric lighting
  someone offers you use of 60 W bulb for 2 hr a night for a week
  all for a nickel ☞ you take it!

- A kWh is about $3,400$ Btu ☞ this means that 100 W bulb going for 10 hours submerged under 100 lb of water will raise temperature of that water by 34°F
- If energy is used at 1 kWh/hour we simply say the *power usage* is 1 kW (1 kilowatt)
- So an electric bulb burns at 0.1 kW (100 watts)
- Short and sweet:
  - When I was a little boy I was afraid of the dark
  - Now ☞ when I get the electric bill I'm afraid of the light

- Everything is in motion
- Even stuff that appears to be motionless moves
- But of course ☞ motion is relative
- E.g. ☞ while you are listening this lecture
  you are moving at about $107,000$ km/hr relative to Sun
  you are moving even faster relative to center of Galaxy
- When we discuss motion of something
  we describe motion with respect to something else
- To describe motion of something we need:
  - a reference point ☞ sometimes called the origin
  - a reference of time


A long time ago in a galaxy far,
far away....

- *Position* defines object's location in space wrt origin
- To determine object's location you need measuring stick
- *Displacement* defines change in position that occurs over time
- Note that it is not same to move: { 3 meters north from origin / than / 3 meters south from origin
- To distinguish displacement to north from that to south, east, west
  displacement has: { magnitude (e.g. 3 meters) / and / direction (north, south, east, west)
- Objects with magnitude + direction ☞ generically called *vectors*


$v_1 = 3$ m/s
$t = 60$ sec
$v_2 = 6$ m/s
$t = 30$ sec
HARVARD
The end

- Several ways to analyze 90s
  between Harry left home and he arrived back again

$$\text{average speed} = \frac{\text{distance}}{\text{elapsed time}} = \frac{180\ \text{m} + 180\ \text{m}}{90\ \text{s}} = 4\ \text{m/s}$$

$$\text{average velocity} = \frac{\text{displacement}}{\text{elapsed time}} = \frac{180\ \text{m} - 180\ \text{m}}{90\ \text{s}} = 0\ \text{m/s}$$

- Usually define speed and velocity using instantaneous values
- *instantaneous velocity* ☞ rate of change of position with time
  for very small time interval
- *instantaneous speed* ☞ magnitude of instantaneous velocity

- *Acceleration vector* measures rate at which an object:
  speeds up, slows down, or changes direction
- Say instead of instantly breaking into run
  Harry increased velocity from 3 m/s west to 6 m/s west in 10 s
- If velocity increased at constant rate
  he experienced constant acceleration of 0.3 m/s^2
- If acceleration is constant ☞ $\langle v \rangle = (v_i + v_f)/2 = 4.5$ m/s
- Distance traveled = $\langle v \rangle \ t$ = 45 m
- *Average acceleration* ☞ change in velocity over time interval
- *Instantaneous acceleration* ☞ rate of change of velocity with time
  for a very small time interval
- Just as Harry arrived back ☞ instantaneous acceleration < 0
  because velocity dropped from 6 m/s west to zero

- Two types of energy: *potential* and *kinetic*
- Potential energy ☞ energy stored in object due to its position
- This type of energy is not in use ☞ but is available to do work
- E.g. ☞ a book possesses potential energy
  when it is stationary on top of bookshelf
- Kinetic energy ☞ energy possessed by object due to its motion
- E.g. ☞ if book were to fall off shelf
  it would possess kinetic energy as it fell

- Kinetic energy of object depends on mass and speed v

$$\text{kinetic energy} \equiv K = \frac{1}{2}\, m\, v^2$$

- All energy is either potential or kinetic
- Fantastic thing about this commodity energy
  when conversion from potential to kinetic takes place
  it occurs in definite predictable way
- E.g.-1 ☞ a ton of water dropping over Niagara Falls
  always yields same amout of electrical energy
- E.g- 2 ☞ combustion of a gallon of oil
  always gives same amount of heat (thermal energy)
- All forms of energy have same measure

Scientific Notation

- System based on powers of 10 that shortens notation
- Most useful for expressing very large and very small numbers i.e. ☞ when dealing with numbers containing many digits
- How to write a number in scientific notation:

1.
   - If number is in decimal notation ☞ move decimal point right of its original position and place it after first non-zero digit
   - Exponent of 10 ☞ number of places original decimal point was moved and it will be negative since it was moved to the right
   - E.g. ☞ $0.0000643 \rightarrow 6.43 \times 10^{-5}$
2.
   - If number is greater than 10 ☞ move decimal point left of its original position and place it after first digit
   - Exponent of 10 ☞ number of places original decimal point was moved and it will be positive since it was moved to the left
   - E.g. ☞ $125{,}000 \rightarrow 1.25 \times 10^{5}$

- Visit course website for extra examples