Chapter 03: Energy

The term energy is closely associated with the concepts of force and motion. Matter does not have to be moving to supply energy; matter contains energy. Moving matter and matter that contains energy can be used as energy sources to perform work.

Section 3.1: Work

A Measure of the Change a Force Produces

- Work = force·distance
- Work is a process
- Force and distance are parallel
- If force and distance are perpendicular, no work is done

Positive and Negative

- Same direction: F (+) and d (+), then W = +
- Positive work speeds you up
- Opposite directions: F (+) and d (–), then W = –
- Negative work slows you down

Units of Work

- $W = F \cdot d$
- Joule = (Newton)·(meter)

Power

- $P = \frac{W}{t}$
- Watt = (Joule)/(second)
- 1 kilowatt = 1000 Watts

Horsepower

- Historical artifact!
- James Watt made the comparison, by literally making the comparison
- He estimated that an average pony could lift 220 lb through 100 ft per minute, working a 4-hour shift
- Poor pony!
- $1\text{hp} = 746\text{W}$, and no ponies were harmed in the making of this slide

Section 3.2: Motion, Position, and Energy

What is Energy?

- Energy is a property
- An object's energy enables it to do work
- Doing work on an object changes its energy

Potential Energy: The Energy of Position

- Several types of PE: gravitational, electrical, magnetic, spring
- All depend on where, not how fast
- An object at rest can still have PE

Gravitational PE

- PE is still energy, so it should look like work
- Units of PE are same as KE are same as work: $\text{Joule} = \text{N} \cdot \text{m}$
- $PE = mgh$

PE is Relative

- There is no location you can point to and say, "$PE = 0$ here all the time."
- Think of h as the change in position, not the absolute position
- You may want the floor to be $h = 0$, or you may want the tabletop to be $h = 0$
- The situation should determine where it makes sense to have $h = 0$

Kinetic Energy: The Energy of Motion

- $KE = \frac{1}{2}mv^2$
- No motion, no KE: object at rest has $KE = 0$
- KE can only be (+), cannot be (–)

Same KE?

- Can two objects with different mass have same KE? Of course they can.
- Can two objects with different speed have same KE? Of course they can.
- More mass, less velocity; or, less mass, more velocity

Section 3.3: Energy Flow

Work and Energy

- Doing work on an object changes its energy: $W = \Delta E$
- You can re-write Newton #2 to say this: $\frac{1}{2}mv_i^2 + W = \frac{1}{2}mv_f^2$
- Now separate PE from the rest of the work being done: $(PE_i + KE_i) + W_{nc} = (PE_f + KE_f)$

Energy Forms

- Different forms ≠ different kinds
- Different forms means energy arises for different reasons
- All forms are interchangeable

Mechanical Energy

- Kinetic energy, gravitational PE, spring PE
- Mechanical has to do with the overall bulk motion or position of an object

Chemical Energy

- Form of potential energy: stored by atoms/molecules
- Chemical potential can be released in a chemical reaction
- Logs in the fireplace: the flames you see and the heat you feel are the energy being released as the wood burns (which is a chemical reaction between the wood and the oxygen in the air)

Radiant (Electromagnetic) Energy

- Light, but actually all of the electromagnetic spectrum
- Infrared, visible, UV are actually all the same thing
- Ultimate source of this energy is electron vibrations

Electrical Energy

- Where mechanical and radiant energy intersect
- Many obvious examples of converting electrical to mechanical energy

Nuclear Energy

- It's the nucleus, not the electrons here
- If a nucleus is unstable, it will try to get stable
- It will release energy and/or particles to reconfigure itself

Energy Conversion

- All forms are interchangeable
- Turn on the light: electrical energy converted to light (radiant energy)*
- Eat breakfast, walk across campus: chemical energy converted to mechanical energy*
- Drive across town: chemical energy converted to mechanical energy*
- Turn on the radio: radiant energy converted in mechanical energy
- *Plus radiant energy in the form of heat. There's always waste heat. *Always*.

Energy Conservation

- Move it, don't lose it
- Energy cannot be created or destroyed, but it can change form and/or be transferred form one object to another
- If you think you are seeing a violation of this law, look harder. The energy you think you lost might not be where you thought it should be, but it will be somewhere.

Energy Transfer

- How do you get energy from Object A to Object B?
- It depends; what kind of energy are you transferring, and what are these objects A and B?

Section 3.4: Energy Sources Today

Petroleum

- What's in that barrel of oil? Plenty.
- Problem is, it's not an infinite resource
- Problem is, burning fossil fuels contributes to global climate change

Coal

- Don't even think about it
- Wait, no–you have to think about it
- Why? Because it's far too plentiful and far too dirty

Moving Water

- Sounds great: clean, plentiful, renewable
- Two words: fish ladders
- Unintended consequences/collateral damage

Nuclear

- Highly efficient, but woefully misunderstood
- No serious discussion of energy policy can dismiss nuclear
- There's enough uranium in seawater to power all major cities for thousands of years

Conserving Energy

- Not the same as conservation of energy!
- Do more with less: increase efficiency
- Just use less: why is this so difficult to understand?

Section 3.5: Energy Sources Tomorrow

Solar Technologies

- $1.4\frac{\mathrm{kW}}{\mathrm{m}^2}$: That's how much energy, on average, strikes every square meter every second the sun shines
- Average American household uses 911 kWh per month; if you had a ten $1\mathrm{m}^2$ solar panel operating at 20% efficiency for 6 hours every day, you would generate half of your average electricity consumption
- The inefficient solar cells of the 80s and 90s are literally a thing of the past
- Book states high production cost because solar cells are "handmade;" this is no longer true (go ahead and google "mass production solar cells")

It's All Solar in Origin

- At some level, all renewables are ultimately solar in nature
- Differential heating creates air and ocean currents (wind, OTEC); photosynthesis creates plant matter (biomass)
- Wind and OTEC: no contribution to global climate change; burning biomass does emit greenhouse gases

Geothermal Energy

- Use the Earth's own residual heat of formation
- Not as effectively-infinite as solar, but still a pretty huge energy reserve
- Expensive to harness: everything comes down to economics

Hydrogen

- Holy grail of consumer energy!
- Greater energy density than literally anything except antimatter!
- Soooooo simple...soooooo difficult