Chapter 03: Energy

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)
• 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!
• 1hp = 746W, 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: Joule = N·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: \( W = \Delta KE \)
• You can re-write Newton #2 to say this: \( \frac{1}{2}m(v_f)^2 + W = \frac{1}{2}m(v_i)^2 \)
• 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 not the same as 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
• Example: \( C + O_2 \rightarrow CO_2 \) means that energy is released when carbon and oxygen combine to make carbon dioxide
• Logs in the fireplace: The flames you see and the heat you feel are the energy being released as the wood burns (see the chemical reaction above 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
- 1.4kW/m²: 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 10m² 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!
- Sooooo simple... soooooo difficult