Conservation of Energy

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Based on Physics, 5th Ed. by Resnick, Halliday, Krane (Ch. 13)

1 Work Done on a System by External Forces

- External work can be thought of as a means of transferring energy between the system and the environment
  - Positive external work brings energy into the system. Negative external work takes energy out of the system.
- Internal work - work done on an object by forces exerted by other objects in the system
- External work - work done on an object by forces exerted by objects outside the system boundary. Represented by $W_{ext} = \Delta K + \Delta U$, where ΔK and ΔU are how much the kinetic and potential energy of the system changed by.

2 Internal Energy in a System of Particles

- In order for a force to do work, the point of application must move (so the force exerted by a wall on a skater pushing off from it does no work)
- Internal energy E_{int} = Energy stored in a system of many particles, such as an object that cannot be considered as a particle
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  - Usually due to inter-molecular forces and motions
  - We can extend W_{ext} to include $W_{ext} = \Delta K + \Delta U + \Delta E_{int}$
  - Observed as heat, object deformation, etc. Includes energy dissipated by friction

3 Frictional Work

- Work done by a frictional force cannot be described by fd because an object subject to friction cannot be considered as a particle.

4 Conservation of Energy in a System of Particles

- Law of Conservation of Energy: While energy may change from one form to another within a system, the total amount of energy in an isolated system remains constant. The total energy of a system can be changed by transferring energy in the form of external work.
- A system only contains potential energy if the object causing the potential energy (i.e. the Earth or a spring) is in the system.

5 Center-of-mass Energy

- In one dimension, multiplying $\sum F_{ext,x} = Ma_{CM,x}$ by dx_{CM}, and substituting $a_{CM,x} = \frac{dv_{CM,x}}{dt}$ gives the relation $F_{ext}s_{CM} = \Delta K_{CM}$, where s_{CM} is the net CM displacement.
  - This resembles work-energy theorem, but it's not. Sometimes known as "center-of-mass energy equation"

6 Reactions and Decays

- Exogenic - a nuclear reaction in which some initial internal energy is converted into final kinetic energy. That is, $K_f > K_i$.
  - Analogous to explosive collisions
- Endogenic - a nuclear reaction in which some initial kinetic energy is converted to final internal energy. That is, $K_f < K_i$.
  - Analogous to inelastic collisions
- In an "elastic" nuclear collision, $E_{int,i} = E_{int,f}$ and the particles do not change form,
- Alpha particle - a He-4 nucleus (2 protons and 2 neutrons bound together)
- If an atom at rest decays into two other atoms, the new atoms have equal and opposite linear momenta ($m_A v_A = -m_B v_B$)
- In atomic decay, internal energy is converted to kinetic energy
- Since $(m_A v_A)^2 = (-m_B v_B)^2 => m_A(2K_A) = m_B(2K_B)$, $\frac{m_A}{m_B} = \frac{K_A}{K_B}$ If the atom decays into 3 or more atoms, the problem is much more complex.

7 Energy Transfer by Heat

- In addition to work, a system can also exchange energy with its environment via heat.
- Heat - a means of energy transfer between a system and its environment due to a temperature difference between them

- Symbol of heat transfer: Q
  - Positive Q → increased system energy
  - Negative Q → decreased system energy
- Unit: Joules

- Heat can be thought of as energy in transit between two bodies
  - Not to be confused with temperature, which measures the internal energy of a single body
- Heat transfer is path-dependent
- An increase in temperature causes an increase in the average ¡u¿translational¡/u¿ kinetic energy
- Two objects in contact will undergo heat transfer if their temperatures are different (same temperature → no heat transfer)
- The temperature of a body can be increased without heat transfer (by doing work on it). Heat can be transferred to a body without raising its temperature (ex: changing water from solid to liquid all while at 0 C)
- The First Law of Thermodynamics: The amount of energy inside a system boundary can change due to either heat transferred to or from the environment, or work done by or on the environment. That is, $\Delta E_{tot} = Q + W_{ext}$