Lecture 14, Oct 14, 2021

Potential Energy

- During a collision of a cart with a spring, the kinetic energy is converted into potential energy in the spring
- Potential energy is a form of energy that can be converted back into kinetic energy and is associated with reversible changes (e.g. compressing a spring)

Energy Dissipation

- Energy dissipation is the loss of kinetic energy that cannot be reversed
- This usually happens on an atomic scale; the kinetic energy is converted into motion on an atomic scale, and the chaotic and incoherent behaviour of the particles means the energy cannot be converted back into kinetic energy of the cart
- Textbook uses bending vs crumpling a piece of paper

Energy Classification

- The textbook classifies energy into 4 categories:
  1. Kinetic energy: coherent energy associated with motion of objects (easily calculable)
  2. Potential energy: coherent energy associated with configuration of interacting objects (e.g. gravitational, elastic) (easily calculable)
  3. Source energy: incoherent energy used to produce other forms of energy (e.g. chemical, nuclear, solar) (very hard to calculate)
  4. Thermal energy: incoherent energy associated with the chaotic motion of atoms
- Example of the types of energy:
  - Kinetic energy: a litre of gas moving in a car
  - Thermal energy: heating up a litre of gas by 1 degree (usually cannot be converted into kinetic energy)
  - Potential energy: a litre of gas sitting 1m above the floor (can be converted into kinetic energy)
  - Source energy (chemical): Burning a litre of gas (cannot be directly converted into kinetic energy)
- Coherent forms of energy (kinetic, potential) are usually much smaller than the incoherent forms of energy (source, thermal)
- Coherent energy (mechanical energy) consists of kinetic and potential energy; all the atoms are moving in some coherent direction and this can be converted, reversibly, to and from kinetic energy easily
- Incoherent energy consists of thermal and source (e.g. chemical) energy; all the atoms are moving in random directions so this cannot be converted into kinetic energy reversibly and efficiently
- All energy that is not kinetic energy (potential energy, thermal energy, source energy) are all considered internal energy
- Macroscopic objects eventually lose their kinetic energy (e.g. balls bouncing in a box), but on a microscopic level atomic movements do not stop (the subatomic particles are too small to store the kinetic energy in the particles due to the quantum nature of energy)

Interactions and Acceleration

- Momentum conservation requires $\Delta \vec{p_{tot}} = 0 \implies \Delta \vec{p_1} = -\Delta \vec{p_2}$
- Therefore $\dfrac{\Delta \vec{p_1}}{\Delta t} = -\dfrac{\Delta \vec{p_2}}{\Delta t} \implies \dfrac{m_1 \Delta \vec{v_1}}{\Delta t} = -\dfrac{m_2 \Delta \vec{v_2}}{\Delta t} \implies m_1 \vec{a_1} = m_2 \vec{a_2}$
- Therefore the ratio of accelerations is proportional to the negative inverse of the ratio of masses $\dfrac{\|\vec{a_1}\|}{\|\vec{a_2}\|} = \dfrac{-m_2}{m_1}$
- Example: 1000kg car and 2000kg truck both moving at 25m/s towards each other collides in 0.2s
  - $p_i = 1000\text{kg} \cdot 25\text{m/s} - 2000\text{kg} \cdot 25\text{m/s} = -25000\text{kg m/s}$
  - $v_f = \dfrac{p_f}{m_{tot}} = \dfrac{p_i}{m_{tot}} = \dfrac{-25000\text{kg m/s}}{3000\text{kg}} = 8.3\text{m/s}$

- $a_1 = \frac{-8.3\text{m/s} - 25\text{m/s}}{0.2\text{s}} = -166\text{m/s}^2$ (the car reversed direction so it has a larger acceleration)
- $a_2 = \frac{-8.3\text{m/s} - (-25\text{m/s})}{0.2\text{s}} = +83\text{m/s}^2$ (the truck continues to move in the same direction so it has a smaller acceleration)
- The ratio of accelerations $\frac{a_1}{a_2} = -2 = -\frac{2000\text{kg}}{1000\text{kg}} = -\frac{m_2}{m_1}$

Energy Conversion

- A nondissipative (reversible) interaction converts between kinetic and potential energy; all energy is coherent, no energy is dissipated (e.g. zero friction cart hits spring, which does not heat up)
- A dissipative (nonreversible) interaction could convert between kinetic and potential energy and have some energy lost as thermal energy (e.g. car rolling up a hill)
- Another dissipative interaction could convert source energy to all other forms of energy (e.g. burning gas in a car)
- Another dissipative interaction could convert source energy entirely to thermal energy (e.g. burning gas, a rock sitting outside in a sunny day)