Lecture 15, Oct 18, 2021

Interaction Ranges

- All interactions (e.g. magnetic, collisions) have different ranges
- Some interactions are long-range (e.g. magnetic, gravitational) and work without requiring "contact"
- Other interactions are short-range and only work when objects are "contacting" (e.g. collisions)

Fundamental Interactions

- Electromagnetism and gravity can be characterize by fields
- Moving the charges generates waves in the field
- Strong and weak interactions are caused by fundamental particles such as pions
- Out of the 4 fundamental interactions, gravity is the weakest by many orders of magnitude
- Weak interactions cause the spontaneous decay of nuclei

Nondissipative Interactions

- In any closed system $\Delta E = \Delta K + \Delta U + \Delta E_s + \Delta E_{th} = 0$
- For a non-dissipative system $\Delta E_s = \Delta E_{th} = 0$, i.e. energy is only converted between kinetic and potential forms
- The *mechanical energy* of a system $E_{mech} = K + U$ is the sum of the kinetic and potential energy; for a closed, nondissipative system then $\Delta E_{mech} = 0$
- Example: a cart-spring collision is nondissipative; $\Delta K_{cart} = -\Delta U_{spring}$ as the cart slows down and energy is stored in the spring
- Potential energy is only a function of position $U(x)$ and as a result not depend on the path taken (conservative force); we can calculate this function
- Principle of Potential Energy: **The parts of any closed system always tend to accelerate in the direction that lowers the system's potential energy.**

Local Gravitational Potential Energy

- Suppose a ball falls from x_i to x_f
- $\Delta U_G = -\Delta K_{ball}$ and $a_x = -g$
- $\Delta t = \frac{-\Delta v_x}{g}$
- $\Delta x = v_i \Delta t - \frac{1}{2} g \Delta t^2$, substitute Δt
- $$\begin{aligned} \Delta x &= v_i \frac{-\Delta v_x}{g} - \frac{1}{2} g \left(\frac{\Delta v_x}{g} \right)^2 \\ &= \frac{-\Delta v_x}{2g} \left[2v_{xi} + (v_{xf} - v_{xi}) \right] \\ &= \frac{-\Delta v_x}{2g} (v_{xi} + v_{xf}) \\ &= \frac{-(v_{xf} - v_{xi})}{2g} (v_{xi} + v_{xf}) \\ &= -\frac{1}{2g} (v_{xf}^2 - v_{xi}^2) \end{aligned}$$
- $mg\Delta x = -\frac{1}{2} m (v_{xf}^2 - v_{xi}^2) \implies mg\Delta x + \Delta K_{ball} = 0$ and since $\Delta U_G + \Delta K_{ball} = 0$, $\Delta U_G = mg\Delta x$

Dissipative Interactions

- With dissipative interactions, the energy is not a function of position (e.g. friction); reactions are nonreversible

- $\Delta E = \Delta K + \Delta U + \Delta E_{th}$, if no reversible potential energy, then $\Delta E = \Delta E_{th} + \Delta K = 0 \implies \Delta K = -\Delta E_{th}$, and E_{th} is not a function of position
- Example: Totally elastic collision where $\Delta K = 0$ has $\Delta E_{th} = 0$; for totally collisions, $\Delta K = \frac{1}{2}\mu v_{21,i}(e^2 - 1)$,so $\Delta E_{th} = \frac{1}{2}\mu v_{21,i}(1 - e^2)$