Theme Music:
Earth, Wind, & Fire

Energy

Cartoon:
Dave Coverley

Speed Bump
The Equation of the Day

Potential energy

\[ \vec{F}_{\text{type}} \cdot \Delta \vec{r} = -\Delta U_{\text{type}} \]

type = gravity, electricity, or spring
Foothold ideas: Kinetic Energy and Work

- Newton’s laws tell us how velocity changes. The Work-Energy theorem tells us how speed (independent of direction) changes.

- Kinetic energy = \( \frac{1}{2} mv^2 \)

- Work done by a force = \( F_x \Delta x \) or \( F_\parallel \Delta r \) (part of force \( \parallel \) to displacement)

- Work-energy theorem: \( \Delta (\frac{1}{2} mv^2) = \vec{F}^{net} \cdot \Delta \vec{r} \)
Simplest example:
Consider the motion of two objects during a short time interval while they exert forces on each other.

Momentum change?
Impulse-momentum theorem!

\[ \Delta \vec{p}_A = \vec{F}_{B \rightarrow A} \Delta t \]
\[ \Delta \vec{p}_B = \vec{F}_{A \rightarrow B} \Delta t \]

Add and use N3!

\[ \Delta \vec{p}_A + \Delta \vec{p}_B = \vec{F}_{B \rightarrow A} \Delta t + \vec{F}_{A \rightarrow B} \Delta t = (\vec{F}_{B \rightarrow A} + \vec{F}_{A \rightarrow B}) \Delta t = 0 \]

Momentum Conservation!
Simplest example:
Consider the motion of two objects during a short time interval while they exert forces on each other.

KE change?
Work-energy theorem!

\[ \Delta KE_A = \vec{F}_{B \rightarrow A} \cdot \Delta \vec{r}_A \]

\[ \Delta KE_B = \vec{F}_{A \rightarrow B} \cdot \Delta \vec{r}_B \]

Add and use N3!

\[ \Delta KE_A + \Delta KE_B = \vec{F}_{B \rightarrow A} \cdot \Delta \vec{r}_A + \vec{F}_{A \rightarrow B} \cdot \Delta \vec{r}_B \]

\[ = \vec{F}_{B \rightarrow A} \cdot (\Delta \vec{r}_A - \Delta \vec{r}_B) \neq 0 \]
Foothold ideas: Potential Energy

- For some forces between objects (gravity, electricity, springs) the work only depends on the change in relative position of the objects. Such forces are called \textit{conservative}.

- For these forces, the work done by them can be written as:

$$\mathbf{F} \cdot \Delta \mathbf{r}_{rel} = -\Delta U$$

- $U$ is called a \textit{potential energy} and can be considered an \textit{energy of place belonging to the two objects that can be exchanged with KE}.
Foothold ideas: Potential Energy

- For some forces work only depends on the change in position. Then the work done can be written \( \vec{F} \cdot \Delta \vec{r} = -\Delta U \)

\( U \) is called a potential energy.

- For gravity, \( U_{\text{gravity}} = mgh \)
- For a spring, \( U_{\text{spring}} = \frac{1}{2} kx^2 \)
- For electric force, \( U_{\text{electric}} = k \frac{Q_1 Q_2}{r_{12}} \)