Lecture 17: Potential Energy

<u>Warm-Up Activity</u>

- A spring's potential energy is 0 J at $x = 0$ (equilibrium).
- When you stretch the spring to the right ($x = +3$ cm), the spring's potential energy is 600 J.
- What is the spring's potential energy when you compress the spring to the left ($x = -3cm$)?

(A) 1200 J (B) 600 J (C) 0 J (D) -600 J (E) -1200 J

A Deeper Model for Interactions

- Quantities
  - Energy E
  - Work $W = \int_{r_i}^{r_f} \vec{F} \cdot d\vec{r}$
  - Kinetic Energy $K = \frac{1}{2}mv^2$
- Laws
  - Work-energy theorem $W_{\text{net,ext}} = \Delta E_{\text{total}}$

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Potential Energy

- Potential energy is present when there is an *internal* interaction between objects within a system.
- How do we figure out how much potential energy something has?
  - We can look at the work that the internal interaction would have done if it were external.
- For special kinds of internal forces (called *conservative* forces):

$$\Delta U = -W_{\text{internal}}$$

L17-1: Gravitational Potential Energy

You drop a tennis ball (mass m) off the top of a tall building (height h).

Questions	System 1: Tennis Ball	System 2: Tennis Ball + Earth
External forces?		
$W_{\text{net,ext}}$		
ΔE_{total}		
What kinds of E are there and how have they changed?		

Gravitational Potential Energy

When a mass m in a system changes its height by an amount Δh:

(A) If we don't include the Earth in the system, then the Earth does work on the system equal to

$$W_g = -mg\Delta h.$$

This changes the total energy of the system.

(B) If we include the Earth in the system, then the potential energy of the system changes by an amount

$$\Delta U_g = mg\Delta h.$$

This does not change the total energy of the system.

A Deeper Model for Interactions

- Quantities
  - Energy E
  - Work $W = \int_{r_i}^{r_f} \vec{F} \cdot d\vec{r}$
  - Kinetic Energy $K = \frac{1}{2}mv^2$
  - Potential Energy $U =$ depends on interaction
    You have to tell everyone where zero PE is!
    * Gravity $U_g = mgy$
    * Spring $U_{sp} = \frac{1}{2}kx^2$
- Laws
  - Work-energy theorem $W_{\text{net,ext}} = \Delta E_{\text{total}}$

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L17-2: Second Floor vs. Basement

- An object's gravitational potential energy with the Earth is 0 J on the **first floor**.
- On the **second floor**, 3 meters above the first floor, the gravitational potential energy is 600 J.
- What is the gravitational potential energy when the object is in the basement (3 meters underground)?

(A) 1200 J (B) 600 J (C) 0 J (D) -600 J (E) -1200 J

Solving Problems with Energy

- The energy of a system depends on:
  - *where* each object is located (potential),
  - *how fast* each object is moving (kinetic).
- The **change** in a system's energy is often easy to calculate.

L17-3: Down a Waterslide

- You (mass m) slide down a frictionless waterslide (height h) that makes an angle θ.
- How fast are you moving at the bottom of the waterslide?
  - What system do you want to choose?
  - What kinds of energy do we have?

L17-4: Rock with a Spring

- A rock (mass m) is compressing a horizontal spring with constant k by an amount x_i.
- If you release the rock from rest, how fast is the rock moving when the spring returns to equilibrium?
  - What system do you want to choose?
  - What kinds of energy do we have?
  - Draw a diagram to help!
  - Find the speed of the rock.

Solving Problems with Energy

- The **change** in a system's energy is often easy to calculate.
  - Choose a system.
  - Identify all forms of energy.
  - Draw energy bar diagrams.
    - A simple, descriptive before-and-after sketch is also good for setting up the problem.
    - An energy bar diagram helps you translate from the positions and velocities of the objects into what you expect the energies to be doing over time.
  - Identify each energy symbolically.
    - Organize them in a table!

Main Ideas

- We can solve physics problems from an *energy approach* instead of from a *force approach*.