Lecture 15: Energy and Power

Warm-Up Activity

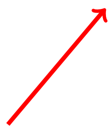
Which of these vectors, when dotted with the red vector below, results in a negative value?

(A) $\longrightarrow$

(B) $\nearrow$

(C) $\longleftarrow$

(D) $\uparrow$



L15-1: The Drop and Bounce

You drop a tennis ball of the top of a tall building. It falls to the ground, bounces, and rises back into the air.

- Identify the different types of energy in this situation and to which object or system these energies belong.
- Describe how energy is transformed within systems and transferred between systems during the drop and bounce.
- Which of the energies, transformations, or transfers do you think you might be able to calculate?

Changing a System's Energy

- The total energy of a system can only change through an *interaction* with something external to the system.
- If that interaction is a force, then the energy transferred to the system is known as *work*.

$$W = \int_{r_i}^{r_f} \vec{F} \cdot d\vec{r}$$

L15-2: The Drop – Part 1

- Consider the system of the tennis ball.
- Starting at the moment you drop the ball and ending right before the ball hits the ground:
  - How much work does the force of gravity do on the tennis ball if you drop it from rest?
  - If you instead throw the ball with an initial vertical speed of v_0, do you think the work done by the gravitational force is *greater than*, *less than*, or *equal to* the original work?

The Work-Energy Theorem

$$W_{\text{net,ext}} = \Delta E_{\text{total}}$$

- The net external work done on a system is equal to the change in total energy of that system.
- What you decide to put in your system is ***absolutely critical!***

L15-2: The Drop – Part 2

- Consider the system of the tennis ball.
- Starting at the moment you drop the ball and ending right before the ball hits the ground:
  - How much work does the force of gravity do on the tennis ball if you drop it from rest?
  - If you instead throw the ball with an initial vertical speed of v_0, do you think the work done by the gravitational force is *greater than*, *less than*, or *equal to* the original work?
  - **What is the speed of the tennis ball right before it hits the ground?**

A Deeper Model for Interactions

- Quantities
  - Energy E
  - Kinetic Energy $K = \frac{1}{2}mv^2$
- Laws
  - Work-energy theorem $W_{\text{net,ext}} = \Delta E_{\text{total}}$

Power

- When the energy of a system changes, we sometimes want to know how *fast* it changes.
- *Power* is the time rate of change of energy:

$$P = \frac{dE}{dt}.$$

- Power is measured in watts (W).

L15-3: The Winch – Part 1

A winch acts a constant force $F_0 = 18,000$ N on a metal block ($m = 500$ kg) to accelerate it across level ground from rest to a final speed of $v_f = 6$ m/s.

- What is the block's change in total energy?
- How far did the winch move the block?
- How much power does this winch use?

L15-3: The Winch – Part 2

You want to use the winch to lift the block into the air at a constant speed: $v = 2$ m/s.

- What force should you set the winch for?
- How far does the winch move the block from $t = 0$ s to $t = 30$ s?
- How much work does the winch do in $\Delta t = 30$ s?
  - Is anything else doing work on the block?
- How much power does the winch use now?

Energy Analysis

- Understanding: Identify a system and the types of energy within the system.
- Calculating: Is your system's energy conserved or not? Once you know, use the work-energy theorem!
- Sensemaking: All the sensemaking strategies you have will work, but a new strategy is sometimes useful: Solve Multiple Ways.
  - You have kinematics and force techniques at your disposal, so you can solve problems with these and compare their results to the results of your energy approach.

Main Ideas

- Energy is a powerful, ubiquitous concept that can help us solve a wide array of physics problems.
- Energy is a *scalar*—it is not a vector.
- There are different forms of energy, and energy can be transferred between objects and between forms.