Goals for Chapter 7

• To use gravitational potential energy in vertical motion

• To use elastic potential energy for a body attached to a spring

• To solve problems involving conservative and nonconservative forces

• To determine the properties of a conservative force from the corresponding potential-energy function

• To use energy diagrams for conservative forces
Introduction

• How do energy concepts apply to the descending duck?

• We will see that we can think of energy as being stored and *transformed* from one form to another.
Gravitational potential energy

- Energy associated with position is called *potential energy*.

- **Gravitational potential energy** is $U_{\text{grav}} = mg y$.

- Figure 7.2 at the right shows how the change in gravitational potential energy is related to the work done by gravity.
The conservation of mechanical energy

- The total *mechanical energy* of a system is the sum of its kinetic energy and potential energy.

- A quantity that always has the same value is called a *conserved* quantity.

- When only the force of gravity does work on a system, the total mechanical energy of that system is conserved. This is an example of the *conservation of mechanical energy*. Figure 7.3 below illustrates this principle.
An example using energy conservation

• Refer to Figure 7.4 below as you follow Example 7.1.

• Notice that the result does *not* depend on our choice for the origin.

\[ v_2 = 0 \]

After the ball leaves your hand, the only force acting on it is gravity ...

\[ v_1 = 20.0 \text{ m/s} \]

\[ m = 0.145 \text{ kg} \]
When forces other than gravity do work

• Refer to Problem-Solving Strategy 7.1.

• Follow the solution of Example 7.2.
Work and energy along a curved path

- We can use the same expression for gravitational potential energy whether the body’s path is curved or straight.
Energy in projectile motion

- Two identical balls leave from the same height with the same speed but at different angles.

- Follow Conceptual Example 7.3 using Figure 7.8.
Motion in a vertical circle with no friction

- Follow Example 7.4 using Figure 7.9.

At each point, the normal force acts perpendicular to the direction of Throcky’s displacement, so only the force of gravity (w) does the work on him.
Motion in a vertical circle with friction

- Revisit the same ramp as in the previous example, but this time with friction.
- Follow Example 7.5 using Figure 7.10.

The friction force \( f \) does negative work on Throcky as he descends, so the total mechanical energy decreases.

\[
\begin{align*}
E &= K + U_{\text{grav}} \\
\text{At point} \ 1 &
\end{align*}
\]

\[
\begin{align*}
E &= K + U_{\text{grav}} \\
\text{At point} \ 2 &
\end{align*}
\]
Moving a crate on an inclined plane with friction

- Follow Example 7.6 using Figure 7.11 to the right.
- Notice that mechanical energy was lost due to friction.

(a) The crate slides up from point 1 to point 2, then back down to its starting position (point 3).

(b) The force of friction does negative work on the crate as it moves, so the total mechanical energy $E = K + U_{grav}$ decreases.

At point 1

At point 2

At point 3
Work done by a spring

- Figure 7.13 below shows how a spring does work on a block as it is stretched and compressed.

(a) Here the spring is neither stretched nor compressed.

(b) As the spring stretches, it does negative work on the block.

(c) As the spring relaxes, it does positive work on the block.

(d) A compressed spring also does positive work on the block as it relaxes.
Elastic potential energy

- A body is *elastic* if it returns to its original shape after being deformed.

- *Elastic potential energy* is the energy stored in an elastic body, such as a spring.

- The elastic potential energy stored in an ideal spring is \[ U_{el} = \frac{1}{2} kx^2. \]

- Figure 7.14 at the right shows a graph of the elastic potential energy for an ideal spring.
Situations with both gravitational and elastic forces

• When a situation involves both gravitational and elastic forces, the total potential energy is the sum of the gravitational potential energy and the elastic potential energy: $U = U_{\text{grav}} + U_{\text{el}}$.

• Figure 7.15 below illustrates such a situation.

• Follow Problem-Solving Strategy 7.2.
Motion with elastic potential energy

- Follow Example 7.7 using Figure 7.16 below.
- Follow Example 7.8.

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**Spring Relaxed**

\[ k = 5.00 \text{ N/m} \]

\[ x = 0 \]

\[ x_1 = 0.100 \text{ m} \]

\[ v_{1x} = 0 \]

**Point 1**

\[ x_2 = 0.080 \text{ m} \]

\[ m = 0.200 \text{ kg} \]

\[ E = K + U_{el} \]

**Point 2**

\[ v_{2x} \]
A system having two potential energies and friction

- In Example 7.9 gravity, a spring, and friction all act on the elevator.

- Follow Example 7.9 using Figure 7.17 at the right.
Conservative and nonconservative forces

- A *conservative force* allows conversion between kinetic and potential energy. Gravity and the spring force are conservative.

- The work done between two points by any conservative force
  a) can be expressed in terms of a *potential energy function*.
  b) is reversible.
  c) is independent of the path between the two points.
  d) is zero if the starting and ending points are the same.

- A force (such as friction) that is not conservative is called a *nonconservative force*, or a *dissipative force*. 
Frictional work depends on the path

- Follow Example 7.10, which shows that the work done by friction depends on the path taken.
Conservative or nonconservative force?

- Follow Example 7.11, which shows how to determine if a force is conservative or nonconservative.
Conservation of energy

• Nonconservative forces do not store potential energy, but they do change the internal energy of a system.

• The law of the conservation of energy means that energy is never created or destroyed; it only changes form.

• This law can be expressed as $\Delta K + \Delta U + \Delta U_{\text{int}} = 0$.

• Follow Conceptual Example 7.12.
Force and potential energy in one dimension

- In one dimension, a conservative force can be obtained from its potential energy function using
  
  \[ F_x(x) = -\frac{dU(x)}{dx} \]

- Figure 7.22 at the right illustrates this point for spring and gravitational forces.

- Follow Example 7.13 for an electric force.
In two dimension, the components of a conservative force can be obtained from its potential energy function using:

\[ F_x = -\frac{\partial U}{\partial x} \quad \text{and} \quad F_y = -\frac{\partial U}{\partial y} \]

Follow Example 7.14 for a puck on a frictionless table.
Energy diagrams

- An *energy diagram* is a graph that shows both the potential-energy function $U(x)$ and the total mechanical energy $E$.

- Figure 7.23 illustrates the energy diagram for a glider attached to a spring on an air track.

![Energy Diagram](image)
Figure 7.24 below helps relate a force to a graph of its corresponding potential-energy function.