بسم الله الرحمن الرحيم

وزارة التعليم العالي
Ministry of Higher Education

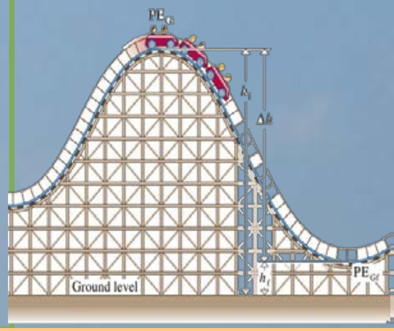
King Saud University
College of Science
Physics & Astronomy Dept.

PHYS 103 (GENERAL PHYSICS)
CHAPTER 8: POTENTIAL ENERGY
LECTURE NO. 12

THIS PRESENTATION HAS BEEN PREPARED BY: *DR. NASSR S. ALZAYED*

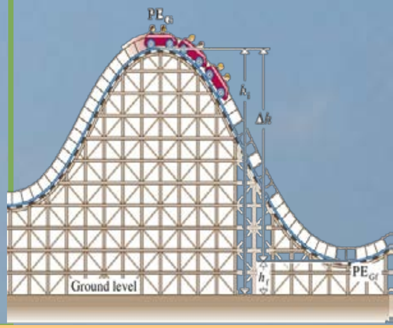
Lecture Outline

- Here is a quick list of the subjects that we will cover in this presentation. It is based on Serway, Ed. 6
- *Introduction*
- 8.3 Conservative and Nonconservative Forces
- 8.4 Changes in Mechanical Energy for Nonconservative Forces
- *Interactive Quiz*
- PROBLEM-SOLVING HINTS
- *Interactive Quiz*
- Example 8.6 Crate Sliding Down a Ramp
- Example 8.8 Let’s Go Skiing!
- 8.5 Relationship Between Conservative Forces and Potential Energy
- *Interactive Quiz*
- *Lecture Summary*
- *End of Presentation*



8.3 Conservative and Nonconservative Forces

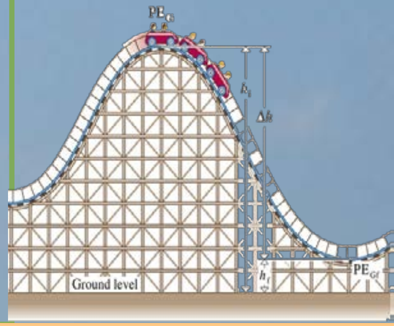
- As an object moves downward near the surface of the Earth, the work done by the gravitational force on the object does not depend on whether it falls vertically or slides down a sloping incline.
- All that matters is the change in the object’s elevation.
- However, the energy loss due to friction on that incline depends on the distance the object slides.
- In other words, the path makes no difference when we consider the work done by the gravitational force, but it does make a difference when we consider the energy loss due to friction forces.
- We can use this varying dependence on path to classify forces as either conservative or nonconservative.
- Of the two forces just mentioned, the gravitational force is conservative and the friction force is nonconservative.



Conservative Forces

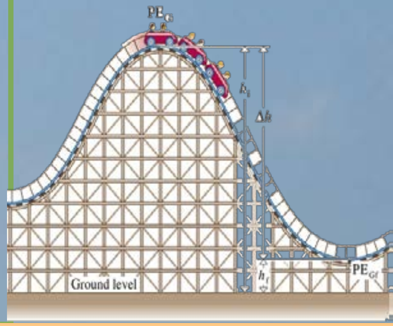
- Conservative forces have these two equivalent properties:
  1. The work done by a conservative force on a particle moving between any two points is independent of the path taken by the particle.
  2. The work done by a conservative force on a particle moving through any closed path is zero.
- Examples of Conservative Forces:
  1. gravitational force
  2. Spring force

- the work done by the gravitational force is $W_g = mgy_i - mgy_f$.
- Hence, W_g depends only on the initial position y_i and final position y_f.
- Closed path means: $y_i = y_f \rightarrow W_g = 0$
- Same thing with Spring: $W_s = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2$ (depends only on initial and final positions). When $x_i = x_f \rightarrow W_s = 0$ (Closed path).



Nonconservative Forces

- A force is nonconservative if it does not satisfy properties 1 and 2 for conservative forces.
- Nonconservative forces acting within a system cause a change in the *mechanical energy* E_{mech} of the system.
- As an example of the path dependence of the work, consider moving a book between two points on a table. If the book is moved in a straight
- line along the path between points A and B; a certain amount of work against the kinetic friction force must be spent to keep the book moving at a constant speed.
- Now, imagine that the book was pushed along a semicircular path. More work must have been performed against friction along this longer path than along the straight path.
- Hence, The work done depends on the path, so the friction force cannot
- be conservative force.



8.4 Changes in Mec. Energy for N.C. Forces

- Consider a body sliding across a surface. As the body moves through a distance *d*, the only force that does work on it is the force of kinetic friction. This force causes a decrease in the kinetic energy of the body. This decrease was calculated in Chapter 7, leading to Equation 7.20, which we repeat here:

$$\Delta K = -f_k d \qquad (8.13)$$

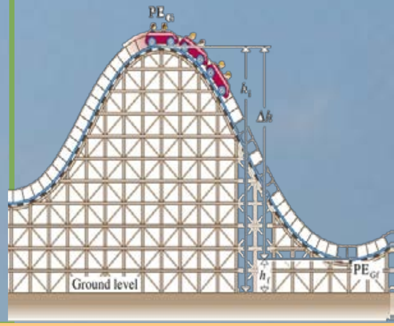
- If there is also a change in potential energy then:

$$\Delta E_{mech} = \Delta K + \Delta U_g = -f_k d$$

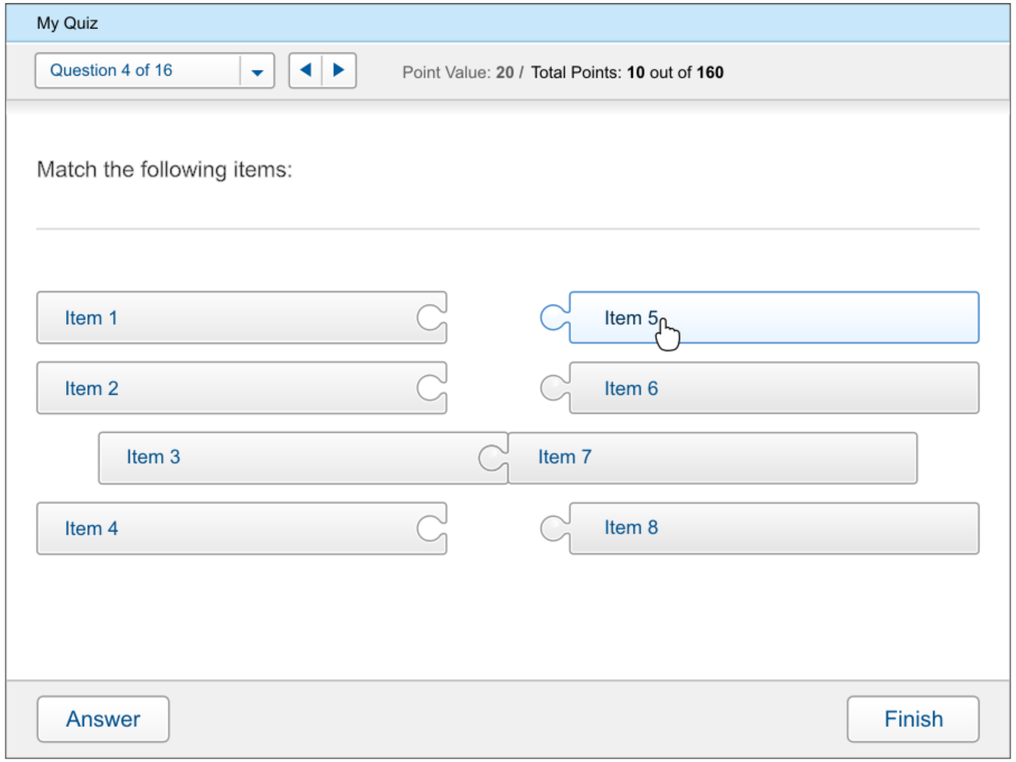
Or in general, for any potential:

$$\Delta E_{mech} = \Delta K + \Delta U = -f_k d \qquad (8.14)$$

- where ΔU is the change in all forms of potential energy.



Quiz 8.9_8.10

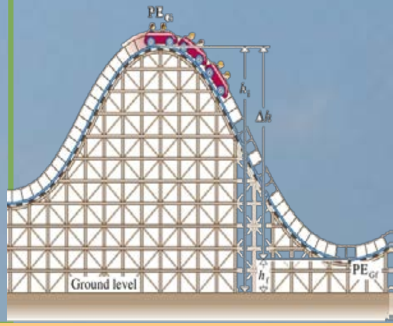


Click the **Quiz** button on
iSpring Pro toolbar to edit your

PROBLEM-SOLVING HINTS

In Isolated Systems—Nonconservative Forces

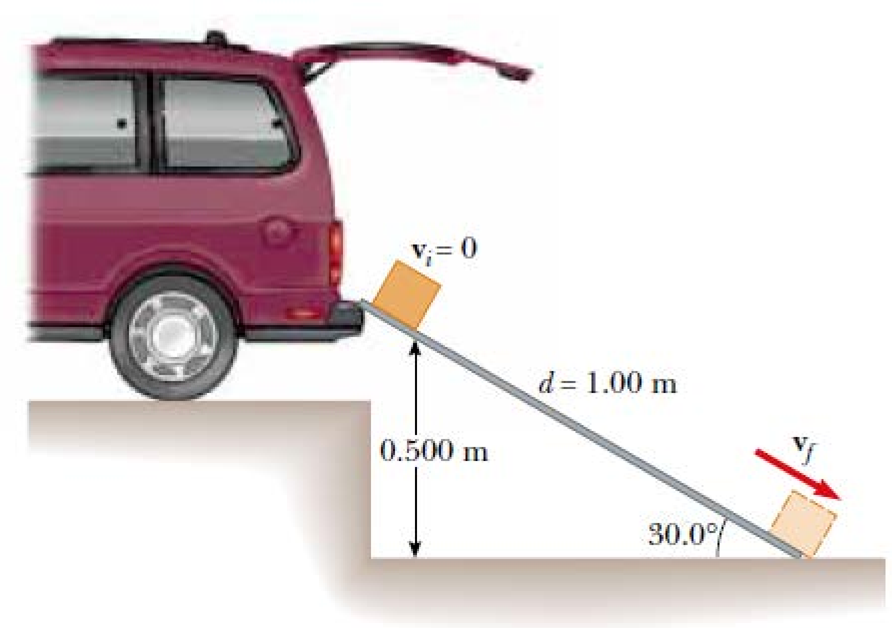
- You should incorporate the following procedure when you apply energy methods to a system in which nonconservative forces are acting:
  - Follow the procedure in the first three bullets of the Problem-Solving Hints in Section 8.2. If nonconservative forces act within the system, the third bullet should tell you to use the techniques of this section.
  - Write expressions for the total initial and total final mechanical energies of the system. The difference between the total final mechanical energy and the total initial mechanical energy equals the change in mechanical energy of the system due to friction.

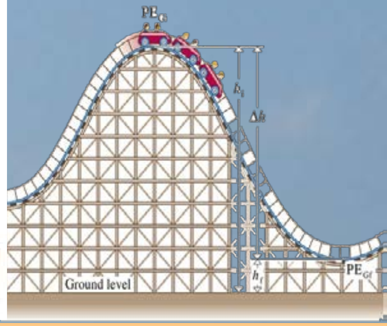


Example 8.6 Crate Sliding Down a Ramp

- A 3.00-kg crate slides down a ramp. The ramp is 1.00 m in length and inclined at an angle of 30.0°, as shown in Figure . The crate starts from rest at the top, experiences a constant friction force of magnitude 5.00 N, and continues to move a short distance on the horizontal floor after it leaves the ramp. Use energy methods to determine the speed of the crate at the bottom of the ramp.

- Because $v_i = 0$, the initial kinetic energy of the system when the crate is at the top of the ramp is zero.
- If the y coordinate is measured from the bottom of the ramp with the upward direction being positive, then $y_i = 0.5$ m.





Example 8.6 (Continued)

- Therefore, the total mechanical energy of the system when the crate is at the top is all potential energy:

$$E_i = K_i + U_i = 0 + U_i = mgy_i = 3\times 9\times 0.5 = 14.7\ J$$

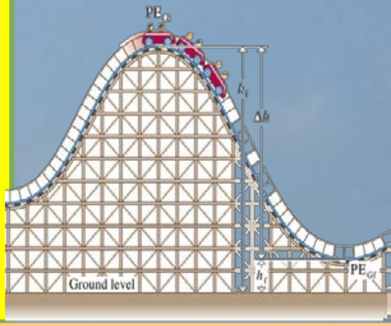
- When the crate reaches the bottom of the ramp, the potential energy of the system is zero because $y_f = 0$:

$$E_f = K_f + U_f = \frac{1}{2}mv_f^{\ 2} + 0$$

$$\therefore E_f - E_i = \frac{1}{2}mv_f^{\ 2} - mgy_i = -f_k d = (-5)(1) = -5\ J \quad (2)$$

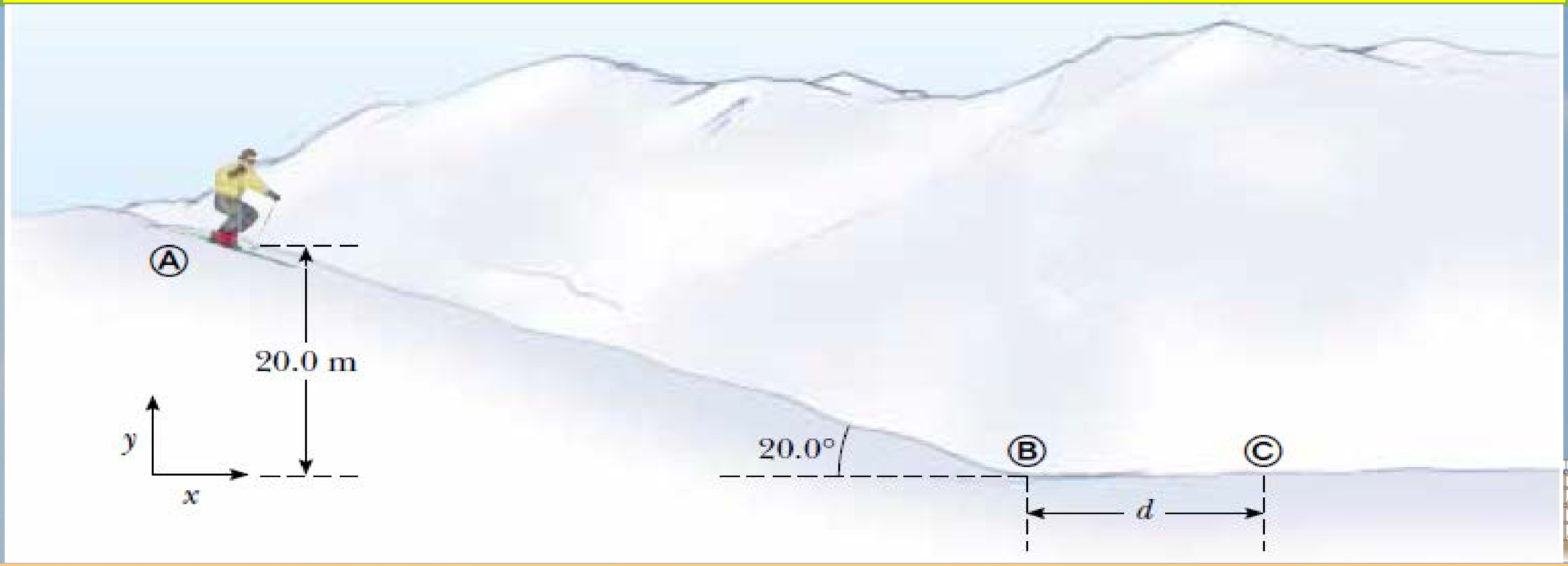
$$\text{(1) and (2):} \frac{1}{2}mv_f^{\ 2} = 14.7 - 5 = 9.7\ J$$

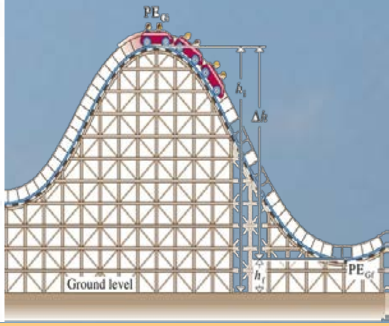
$$\Rightarrow v_f = \sqrt{\frac{(2)(9.7)}{3}} = 2.54\,\text{m/s}$$



Example 8.8 Let's Go Skiing!

- A skier starts from rest at the top of a frictionless incline of height 20.0 m, as shown in Figure. At the bottom of the incline, she encounters a horizontal surface where the coefficient of kinetic friction between the skis and the snow is 0.210. How far does she travel on the horizontal surface before coming to rest, if she simply coasts to a stop?





Example 8.8 Let's Go Skiing! (Continued)

- **Solution**:

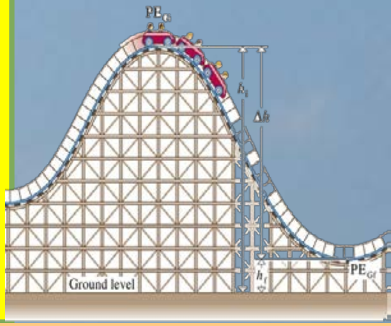
$$\because v_B = \sqrt{2gh} = \sqrt{2(9.8)(20)} = 19.8\, m/s$$

- Between the points B and C, all kinetic energy at the bottom of the incline was lost on frictional work.

$$\because (K_C + U_C) - (K_B + U_B) = \text{work on Friction}$$

$$\therefore 0 + 0 - \frac{1}{2} m v_B{}^2 - 0 = -\mu_k m g d$$

$$\Rightarrow d = \frac{\frac{1}{2} \cancel{m} v_B{}^2}{\mu_k \cancel{m} g} = \frac{\frac{1}{2}(19.8)^2}{(0.21)(9.8)} = 95.2\, m$$



8.5 Conservative Forces and Potential Energy

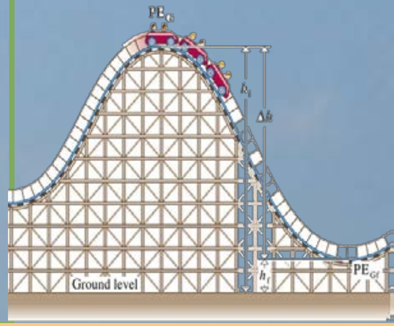
- The work done by a cons. force F as a particle moves along the *x axis is:*

$$W_C = \int_{x_i}^{x_f} F_x dx = -\Delta U \qquad (8.15)$$

$$OR: \Delta U = U_f - U_i = -\int_{x_i}^{x_f} F_x dx \qquad (8.16)$$

- Therefore, ΔU is negative when F_x and dx are in the same direction, as when an object is lowered in a gravitational field or when a spring pushes an object toward equilibrium.
- We can then define the potential energy function as:

$$U_f(x) = -\int_{x_i}^{x_f} F_x dx + U_i \qquad (8.17)$$



8.5 Cons. Forces and Pot. Energy (continued)

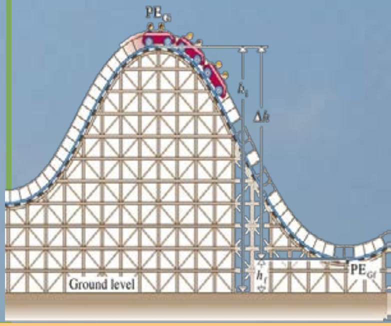
- If the point of application of the force undergoes an infinitesimal displacement *dx, we can express the infinitesimal change in the potential energy of the system dU as*

$$dU = -F_x dx$$

- Therefore, the conservative force is related to the potential energy function through the relationship

$$F_x = -\frac{dU}{dx} \qquad (8.18)$$

- That is, the x component of a conservative force acting on an object within a system equals the negative derivative of the potential energy of the system with respect to x.



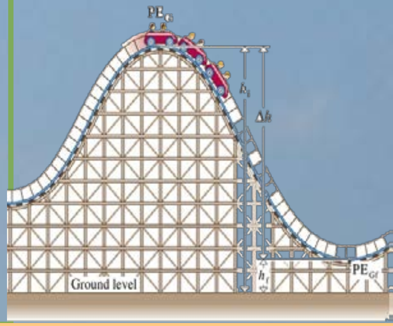
Lecture Summary

- A force is conservative if the work it does on a particle moving between two points is independent of the path the particle takes between the two points, Or if the work it does on a particle is zero when the particle moves through an arbitrary closed path and returns to its initial position. A force that does not meet these criteria is said to be nonconservative.
- The total mechanical energy of a system is defined as the sum of the kinetic energy and the potential energy:

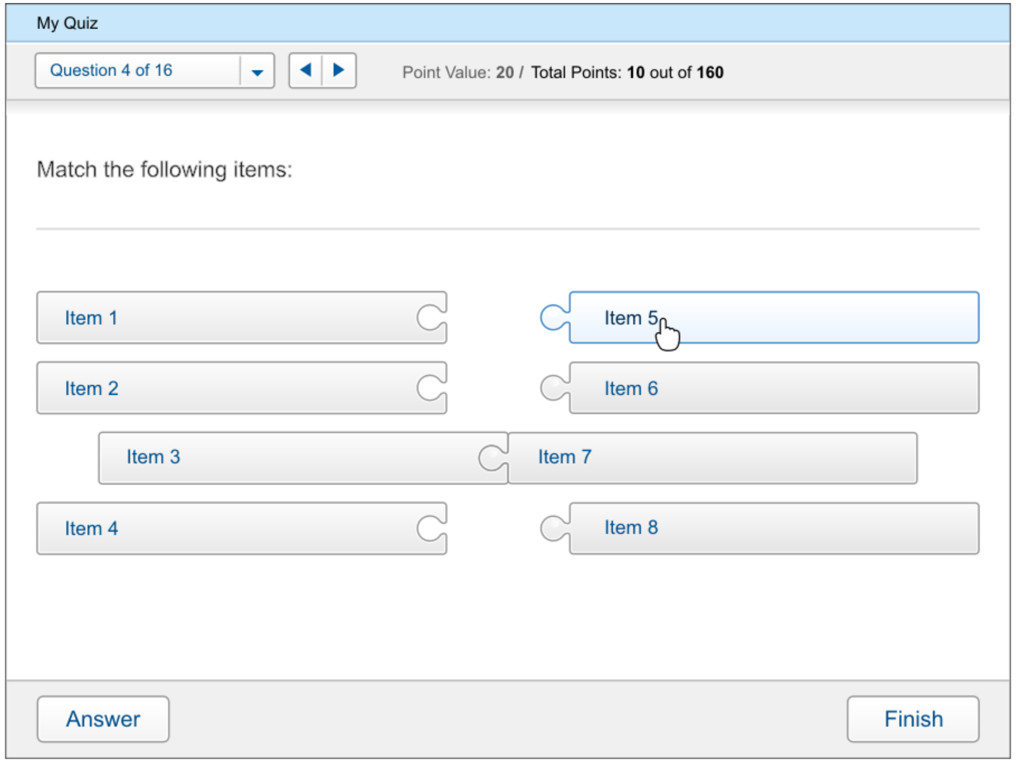
$$E_{mech} = K + U \qquad (8.8)$$

- If a system is isolated and if no nonconservative forces are acting on objects inside the system, then the total mechanical energy of the system is constant:

$$K_f + U_f = K_i + U_i \qquad (8.9)$$



Quiz 8.11



Click the **Quiz** button on iSpring Pro toolbar to edit your quiz


THE END!