بسم الله الرحمن الرحيم

King Saud University
College of Science
Physics & Astronomy Dept.

PHYS 103 (GENERAL PHYSICS)

CHAPTER 8: POTENTIAL ENERGY

LECTURE NO. 11

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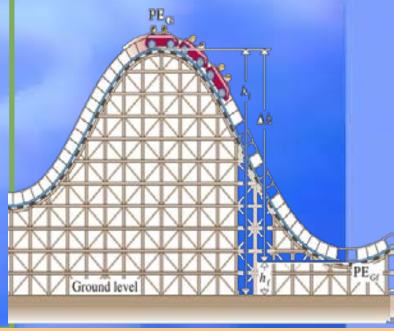
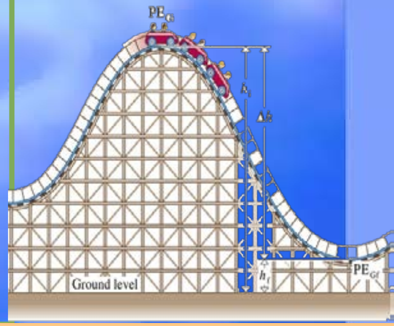
Lecture Outline

- Here is a quick list of the subjects that we will cover in this presentation. It is based on Serway, Ed. 6
- *Introduction*
- *8.1 The System–Conservation of Energy*
- *Interactive Quiz*
- *8.2 Potential Energy of a System*
- *Interactive Quiz*
- *Potential Energy of a Spring*
- *Interactive Quiz*
- *Example 8.2 Ball in Free Fall*
- *Example 8.3 The Pendulum*
- *Example 8.5 The Spring-Loaded Popgun*
- *Lecture Summary*
- *End of Presentation*



Introduction

- The potential energy concept can be used only when dealing with a special class of forces called *conservative forces*.
- When only conservative forces act within an isolated system, the kinetic energy gained (or lost) by the system is balanced by an equal loss (or gain) in potential energy.
- This balancing of the two forms of energy is known as the *principle of conservation of mechanical energy.*
- Potential energy is present in the Universe in various forms, including gravitational, electromagnetic, chemical, and nuclear.
- Furthermore, one form of energy in a system can be converted to another. For example, when a system consists of an electric motor connected to a battery, the chemical energy in the battery is converted to kinetic
- Energy.



8.1 The System–Conservation of Energy

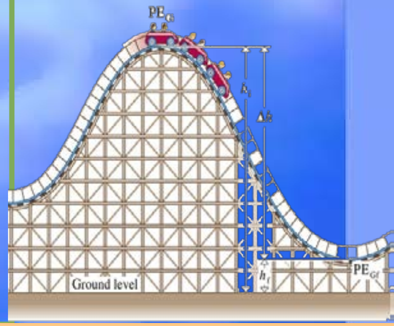
- Let us now derive an expression for the gravitational potential energy (U_g) associated with an object (m) at a given location (y) above the surface of the Earth

$$U_g = mgy \qquad (8.2)$$

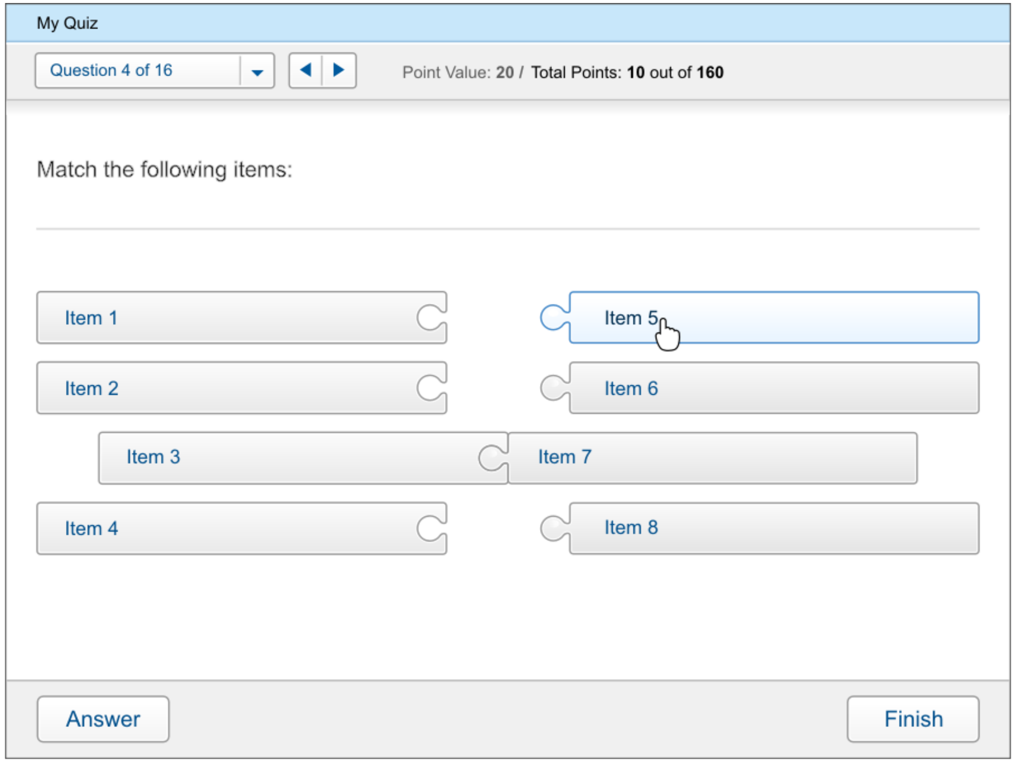
- Mathematical description of the work done on a system that changes the gravitational potential energy of the system is give by:

$$W = \Delta U_g \qquad (8.3)$$

- The gravitational potential energy depends only on the vertical height of the object above the surface of the Earth. The same amount of work must be done on an object–Earth system whether the object is lifted vertically from the Earth or is pushed starting from the same point up a frictionless incline, ending up at the same height



Interactive Quiz 1



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8.2 Potential Energy of a System

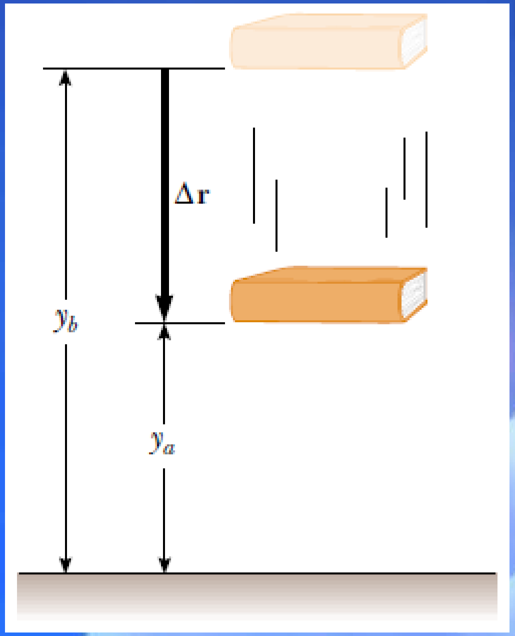
- As the book, shown in the figure, falls back to its original height, from y_b to y_a, the work done by the gravitational force on the book is:

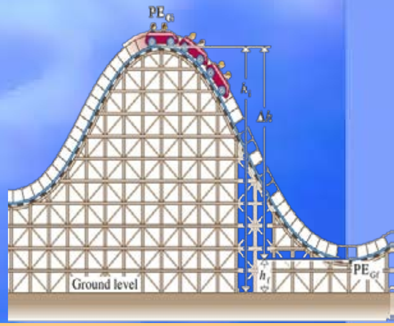
$$W = mgy_b - mgy_a \quad (8.4)$$
$$= \Delta K$$
$$\therefore \Delta K = mgy_b - mgy_a \quad (8.5)$$
$$= -\Delta U_g \quad (8.6)$$
$$\therefore \Delta K + \Delta U_g = 0 \quad (8.7)$$

- Mechanical energy is defined as:

$$E_{mech} = K + U_g$$

Or, in general: $E_{mech} = K + U$ (8.8)





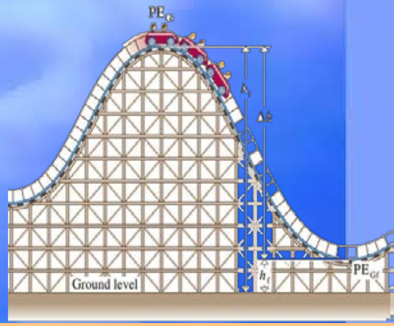
8.2 Potential Energy (continued)

- Let us now write the changes in energy in Equation 8.7 explicitly:

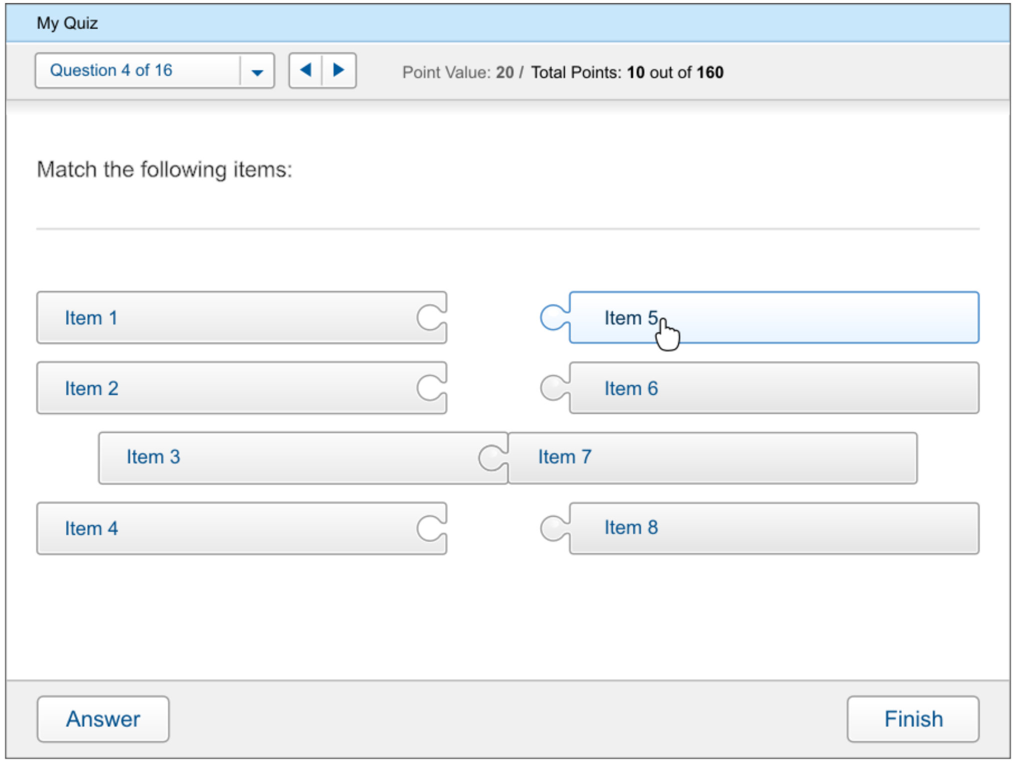
$$(K_f - K_i) + (U_f - U_i) = 0$$

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

- Equation 8.9 is a statement of conservation of mechanical energy for an isolated system.
- An isolated system is one for which there are no energy transfers across
- the boundary.
- The energy in such a system is conserved—the sum of the kinetic and
- Potential energies remains constant.
- This statement assumes that no nonconservative forces act within the system



Interactive Quiz 2



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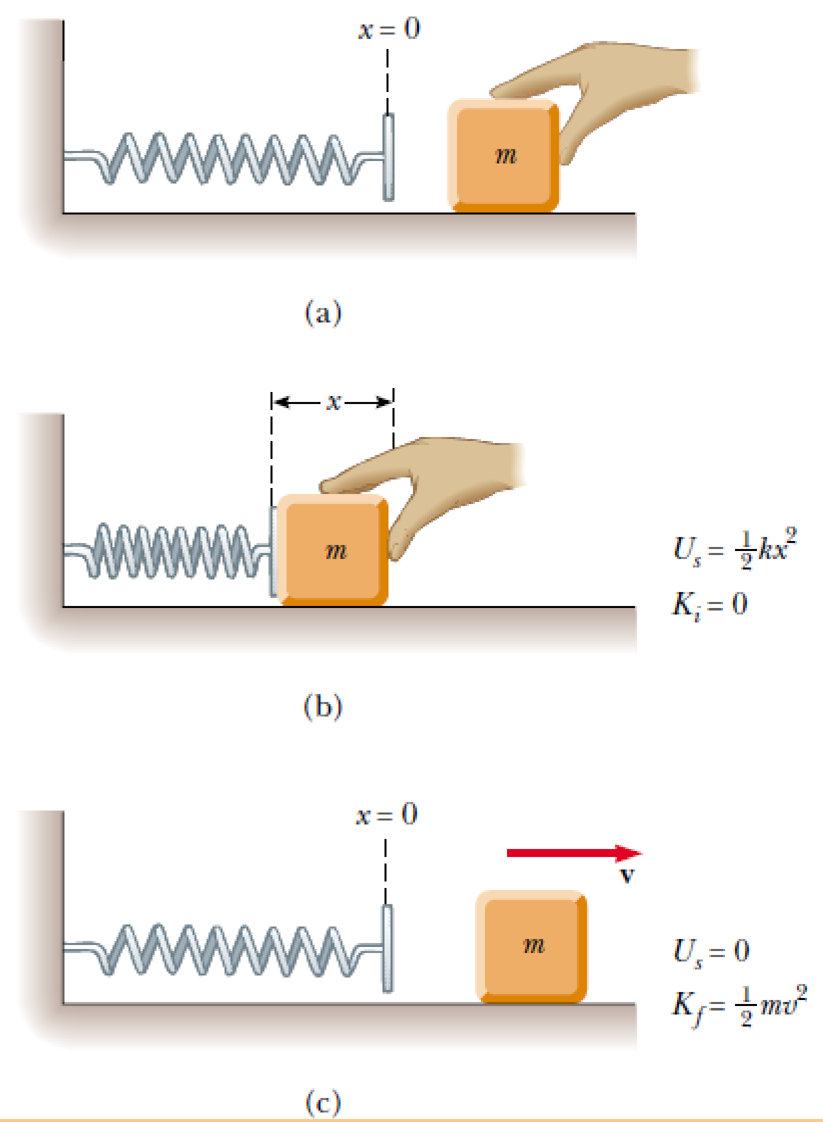
Potential Energy of a Spring

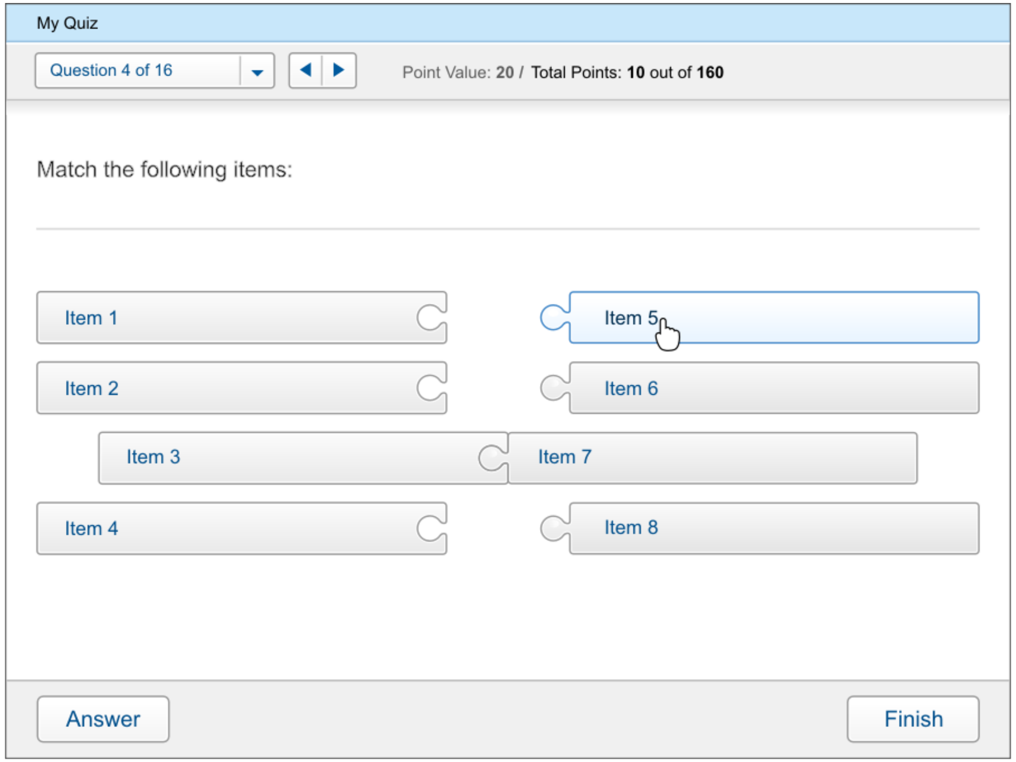
- Potential Energy of a Spring is given by:

$$U_s = \frac{1}{2}Kx^2 \qquad (8.11)$$

- When the block is released from rest, the spring exerts a force on the block and returns.
- to its original length. The stored elastic potential energy is transformed into kinetic energy of the block.
- The elastic potential energy stored in a spring is zero when: x = 0
- Energy is stored in the spring only when the spring is either stretched or compressed.



Interactive Quiz 3



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Example 8.2 Ball in Free Fall

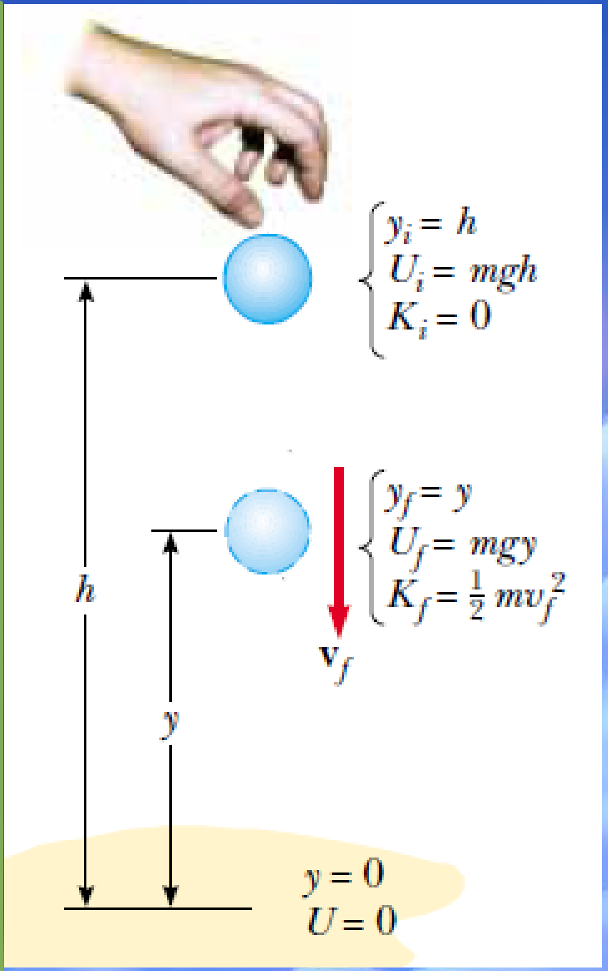
- A ball of mass m is dropped from a height h above the ground, as shown in Figure .
- *Neglecting air resistance, determine the speed of the ball when it is at a height y above the ground.*
- **Solution**:

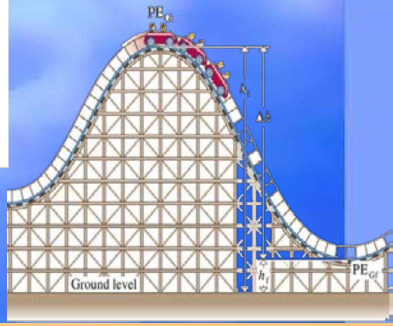
$$\because K_f + U_f = K_i + U_i$$

$$\therefore \frac{1}{2} m v_f^{\,2} + mgy = 0 + mgh$$

$$\Rightarrow v_f^{\,2} = 2g(h - y)$$

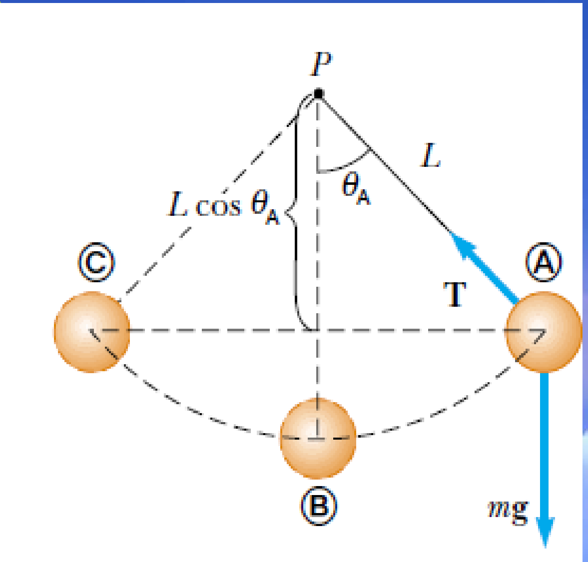
$$\therefore v_f = \sqrt{2g(h - y)}$$





Example 8.3 The Pendulum

- A pendulum consists of a sphere of mass m = 200 gm attached to a light cord of length L =50 cm, as shown in Figure. The sphere is released from rest at point A when the cord makes an angle $\theta_A = 37^o$ with the vertical.
- (A) Find the speed of the sphere when it is at the lowest point B.

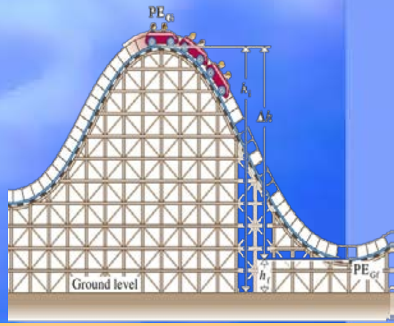


- **Solution:**

$$\because K_B + U_B = K_A + U_A$$

$$\therefore \frac{1}{2} m v_B^{\,2} - mgL = 0 - mgL\cos\theta_A$$

$$\therefore v_B = \sqrt{2gL(1-\cos\theta_A)} = \sqrt{2(9.8)(0.5)(1-\cos 37)} = 1.4\, m/s$$



Example 8.3 The Pendulum (continued)

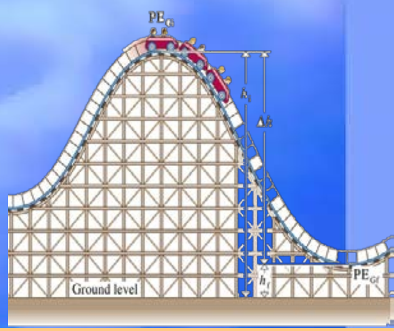
- (B) What is the tension T_B in the cord at B?
- **Solution:**
- Newton's second law gives:

$$\sum F_r = mg - T_B = ma_r = -m\frac{v_B^{\,2}}{L}$$

$$\Rightarrow T_B = mg + m\frac{v_B^{\,2}}{L}$$

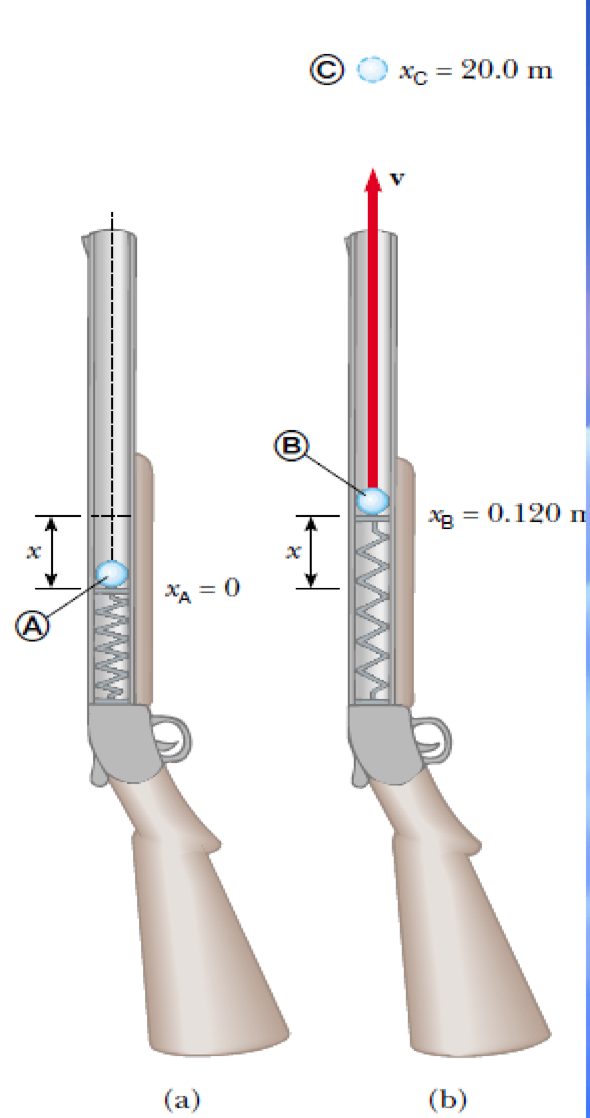
$$\therefore T_B = 0.2 * 9.8 + 0.2\frac{1.98}{0.5}$$

$$\Rightarrow T_B = 1.96 + 0.79 = 2.75\,N$$



Example 8.5 The Spring-Loaded Popgun

- The launching mechanism of a toy gun consists of a spring of unknown spring constant. When the spring is compressed 0.120 m, the gun, when fired vertically, is able to launch a 35.0-g projectile to a maximum height of 20.0 m above the position of the projectile before firing.
- *(A) Neglecting all resistive forces, determine the spring constant.*
- **Solution**:
- Total energy at position (c) for the projectile + spring = Total energy at position (A)
- Hence: $[K_{projectile} + U_{projectile} + U_{spring}]_c$
- $= [K_{projectile} + U_{projectile} + U_{spring}]_A$



Example 8.5 (Continued)

$$\therefore K_C + U_{gC} + U_{sC} = K_A + U_{gA} + U_{sA}$$

$$\Rightarrow \quad 0 + mgh + 0 = 0 + 0 + \frac{1}{2}kx^2$$

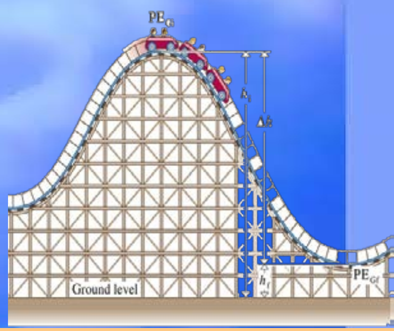
$$\therefore k = \frac{2mgh}{x^2} = \frac{(2)(0.035)(9.8)(20)}{0.12^2} = 953\,\text{N/m}$$

- Find the speed of the projectile as it moves through the equilibrium position of the spring (where $x_B = 0.120$m).

$$\therefore K_B + U_{gB} + U_{sB} = K_A + U_{gA} + U_{sA}$$

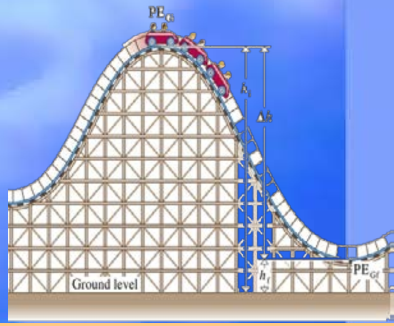
$$\Rightarrow \quad \frac{1}{2}mv_B^2 + mgx_B + 0 = 0 + 0 + \frac{1}{2}kx^2$$

$$\therefore v_B = \sqrt{\frac{kx^2}{m} - 2gx_B} = \sqrt{\frac{(953)(0.12)^2}{0.035} - 2(9.8)(0.12)} = 19.7\,\text{m/s}$$



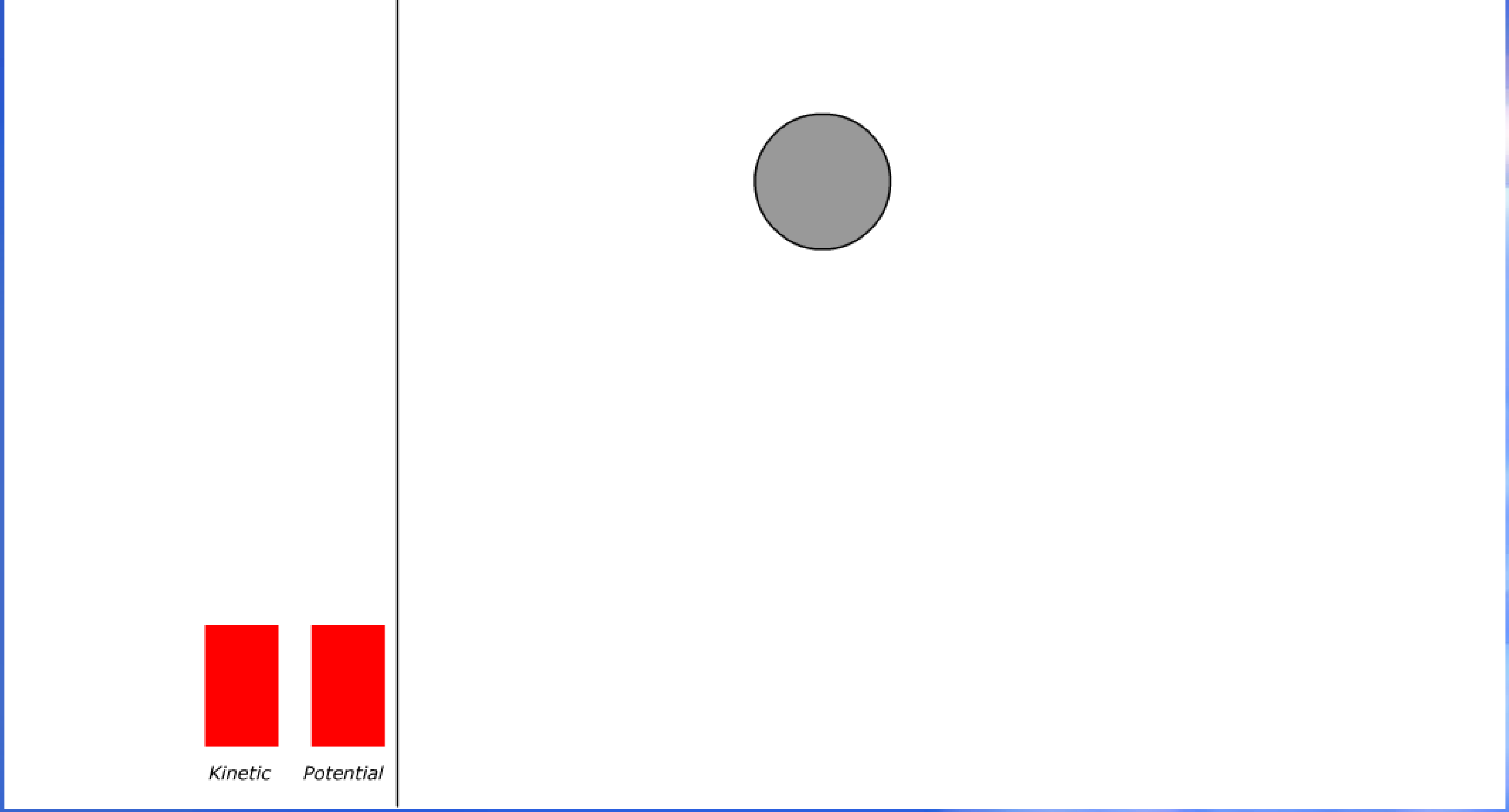
Interactive Flashes

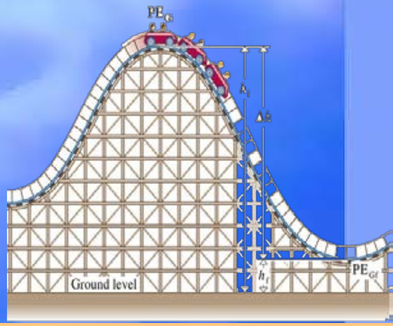
- In the next two flash activities; please play with the flashes and watch for the relationship between: Kinetic Energy and Potential Energy.
- *You will be able to see that if one increase: the other will decrease.*
- *Hence: Total energy shall be fixed for a given system*



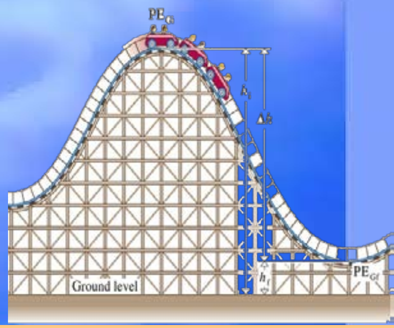
Interactive Flashes

*As the ball changes velocity, the kinetic energy value changes, since KE=mv². It is greatest when the velocity is greatest. Notice that it goes to **zero** when the ball reaches the top of a straight up and down bounce, since the velocity at that point is zero. The potential energy changes with height, since PE=mgh. It is **greatest** at the top of the ball's bounce, and zero when the ball hits the ground, dependent on the ball's height. Try rolling the ball on the ground to see kinetic energy but not potential.*





Interactive Flashes



Lecture Summary

- If a particle of mass *m is at a distance y above the Earth's surface, the gravitational potential* energy of the particle–Earth system is

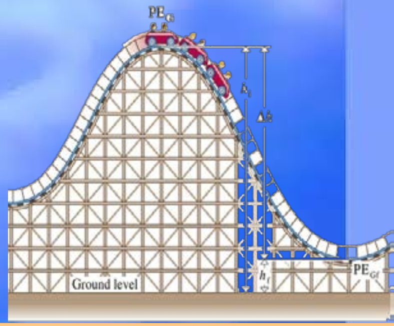
$$U_g = mgy \qquad (8.2)$$

- The elastic potential energy stored in a spring of force constant *k is*

$$U_s = \frac{1}{2}Kx^2 \qquad (8.11)$$

- *Total Energy of A system is:*

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

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