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King Saud University
College of Science
Physics & Astronomy Dept.

PHYS 103 (GENERAL PHYSICS)

CHAPTER 7: ENERGY AND ENERGY TRANSFER

LECTURE NO. 10

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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

- The concept of energy is one of the most important topics in science and engineering.
- In everyday life, we think of energy in terms of fuel for transportation and heating, electricity for lights and appliances, and foods for consumption. However, these ideas do not really define energy
- Energy is present in the Universe in various forms. Every physical process that occurs in the Universe involves energy and energy transfers
- The notion of energy is more abstract, although we do have experiences with energy, such as running out of gasoline, or losing our electrical service if we forget to pay the utility bill.
- Our problem-solving techniques presented in earlier chapters were based on the motion of a particle. This was called the particle model. We begin our new approach by focusing our attention on a system and developing techniques to be used in a system model.

7.1 Systems and Environments

- In the system model, we focus our attention on a small portion of the Universe—the system—and ignore details of the rest of the Universe outside of the system.
- A valid system may:
  - *be a single object or particle*
  - *be a collection of objects or particles*
  - *be a region of space*
  - *vary in size and shape*
- As an example, imagine a force applied to an *object* in empty space. We can define the object as the system. The force applied to it is an influence on the system from the environment that acts across the system boundary
- We shall find that there are a number of mechanisms by which a system can be influenced by its environment. The first of these that we shall investigate is *work*.

7.2 Work Done by a Constant Force

- The work W done on a system by an agent exerting a constant force on the system is the product of the magnitude **F** of the force, the magnitude **Δr** of the displacement of the point of application of the force, and cos θ, where θ is the angle between the force and displacement vectors:

$$W = F\Delta r\cos\theta \qquad (7.1)$$

- if θ = 90°, then W = 0 because cos 90° = 0
- If an applied force **F** is in the same direction as the displacement **Δr**, then θ = 0 and cos 0 = 1. In this case, Equation 7.1 gives:

$$W = F\Delta r$$

- Work is a *scalar quantity*, and its units are force multiplied by length. Therefore, the SI unit of work is the newton.meter (N. m). This combination of units is used so frequently that it has been given a name of its own: the *joule* (J).

Example 7.1 Mr. Clean

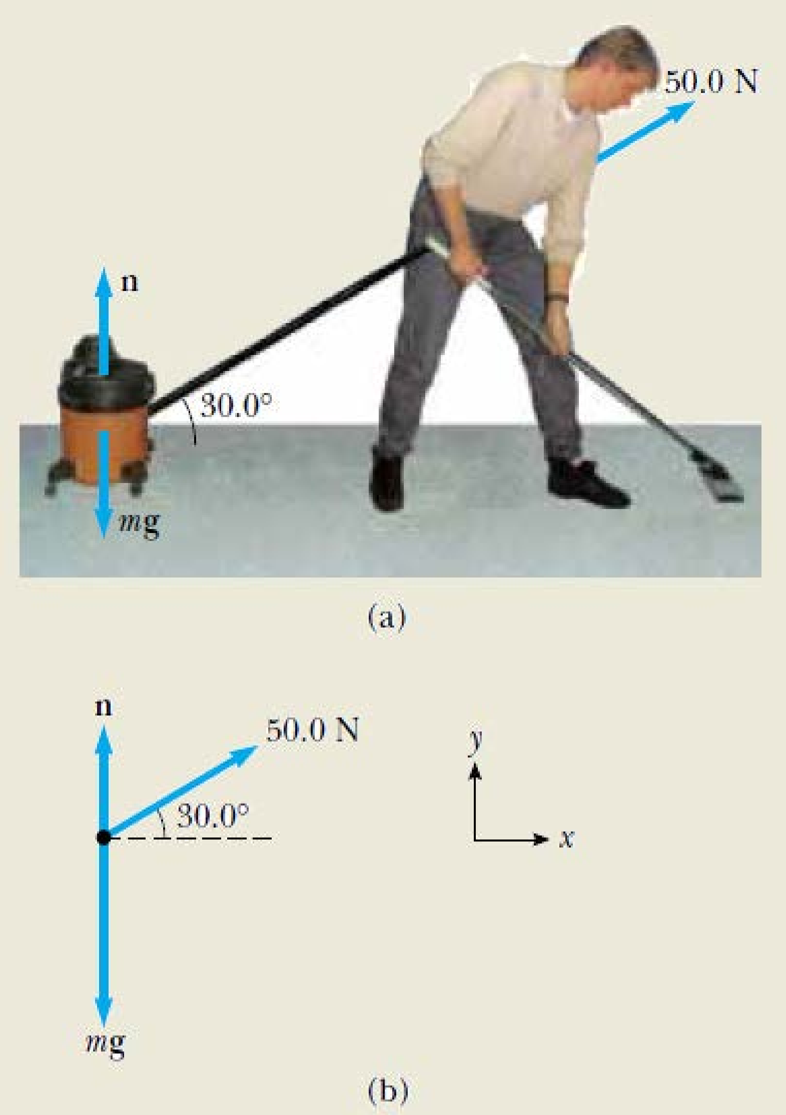
- A man cleaning a floor pulls a vacuum cleaner with a force of magnitude **F** = 50.0 N at an angle of 30.0° with the horizontal. Calculate the work done by the force on the vacuum cleaner as the vacuum cleaner is displaced 3.00 m to the right.
- ***Solution***:

$$F = 50\,N\,,\theta = 30^{o}\,,\Delta r = 3\,m$$

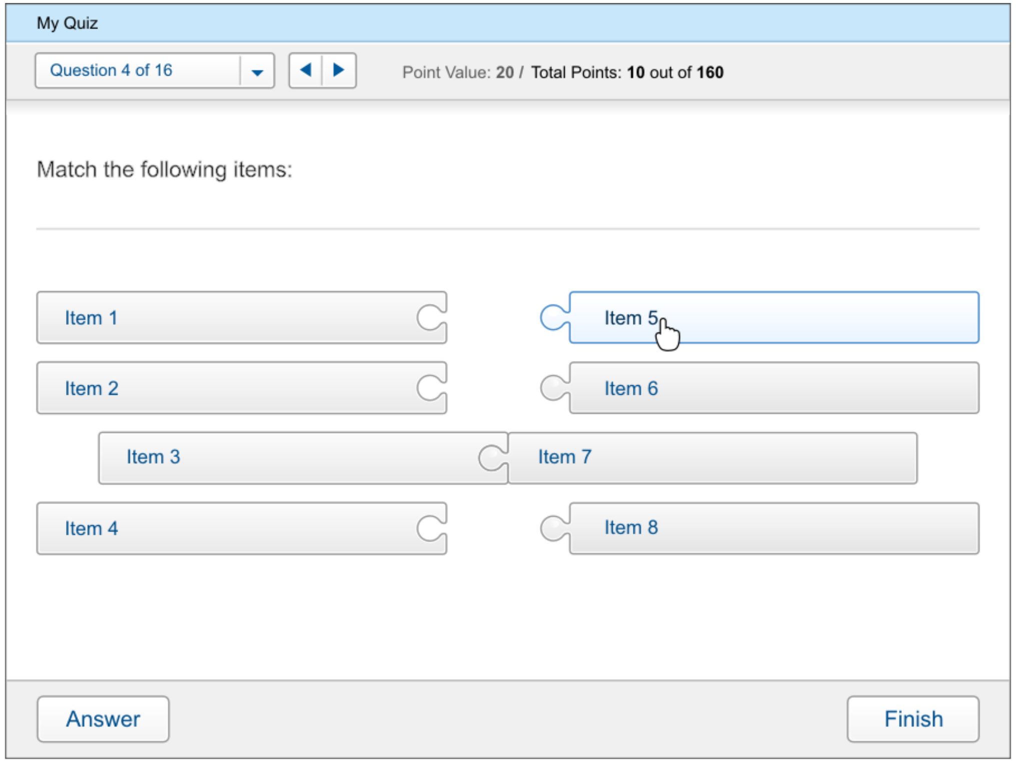
$$\because W = F\,\Delta r\,\cos\theta$$

$$\therefore W = (50)(3)(\cos 30) = 130\,J$$

- Notice: in this situation the normal force **n** and $\mathbf{F}_g$ = mg do no work because θ=90º.



Quiz 7.1 and 7.2



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7.3 The Scalar Product of Two Vectors

- Because of the way the force and displacement vectors are combined in Equation 7.1, it is helpful to use a convenient mathematical tool called the scalar product of two vectors.
- In general; for any two vectors **A** and **B**; Scalar product is defined as:

$$A.B = AB\cos\theta \qquad (7.2)$$

$$\therefore W = F\Delta r\cos\theta = F.\Delta r \qquad (7.3)$$

- In other words, **F.Δr** (“F dot Δr ”) is a shorthand notation for *F*Δr *cos* θ.
- Please note that the scalar product is commutative. That is:

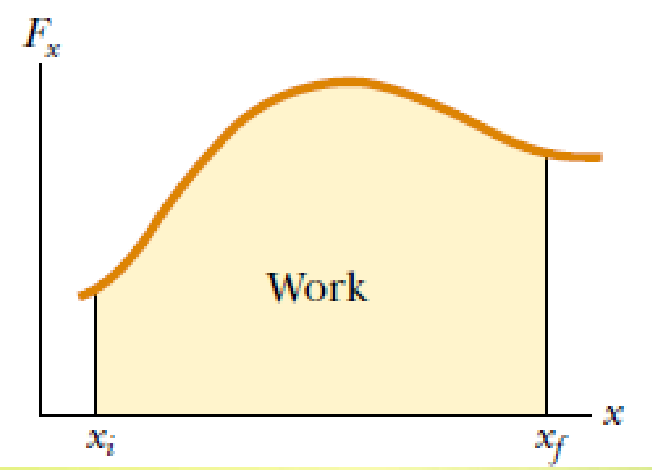
$$A.B = B.A$$

- Although (7.3) defines the work in terms of two vectors, *work is a scalar*. *All types of* energy and energy transfer are scalars. This is a major advantage of the energy approach. We don’t need vector calculations!

7.4 Work Done by a Varying Force

- If a force $\mathbf{F}_x$ is varying with position, x, we can express the work done by $\mathbf{F}_x$ as the particle moves from x_i to x_f as:

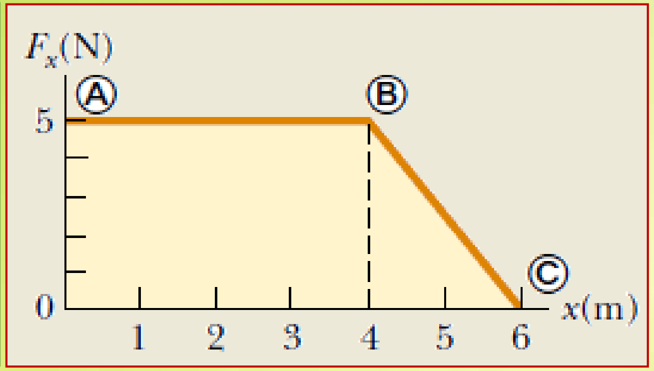
$$W = \int_{x_i}^{x_f} F_x \, dx \qquad (7.7)$$



- The work done by the component $\boldsymbol{F}_x$ *of* the varying force as the particle moves from x_i to x_f is exactly equal to the area under this curve.

Ex. 7.4 Calculating Work Done from a Graph

- A force acting on a particle varies with *x*, as shown in figure. Calculate the work done by the force as the particle moves from *x = 0 to x = 6.0 m.*



- ***Solution***:

$$\because W = \int_{x_i}^{x_f} F_x dx = area$$

$$\therefore W = Area_{A-B} + Area_{B-C} = (5\times4)+(\frac{1}{2}\times2\times5)$$

$$\Rightarrow W = 20+5=25\ J$$

Work Done by a Spring

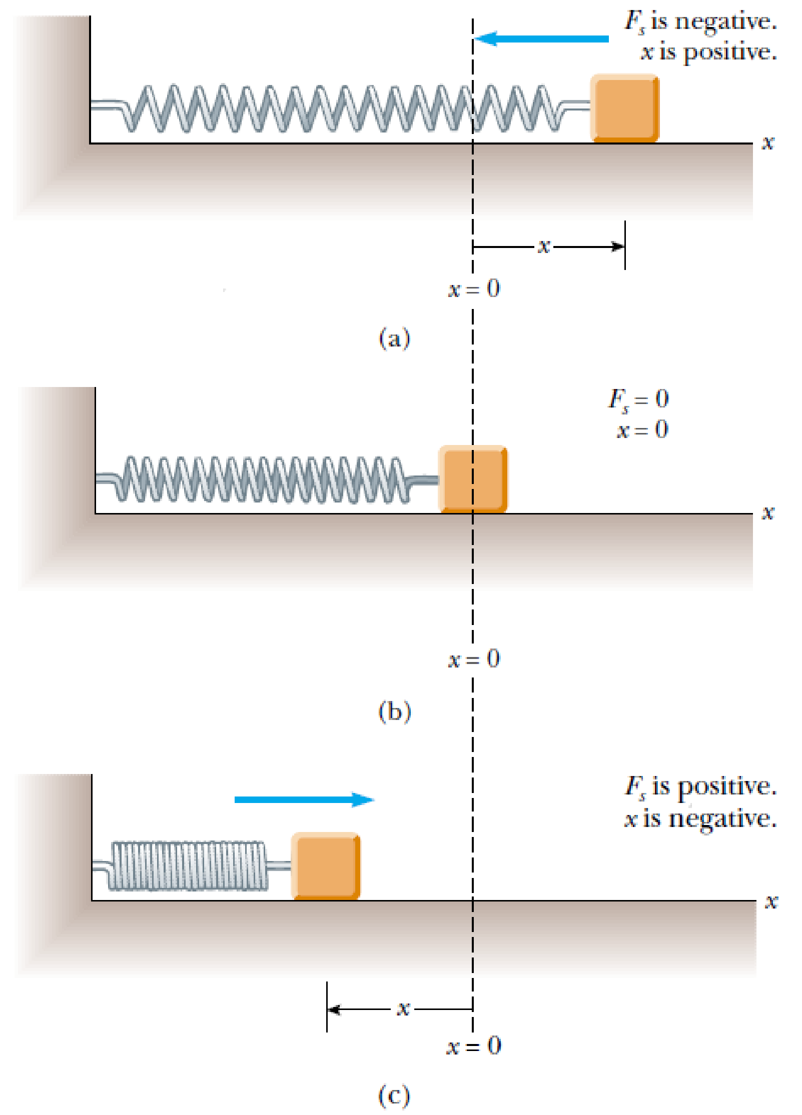
- If the spring is either stretched or compressed a small distance from its equilibrium configuration, it exerts on the block a force that can be expressed as:

$$F_s = -kx \qquad (7.9)$$

- This force law for springs is known as **Hooke's law**.

$$\because W = \int_{x_i}^{x_f} F_s dx = \int_{-x}^{0} (-kx)dx$$

$$\therefore W = \frac{1}{2}kx^2 \qquad (7.10)$$



Example 7.6 Measuring k for a Spring

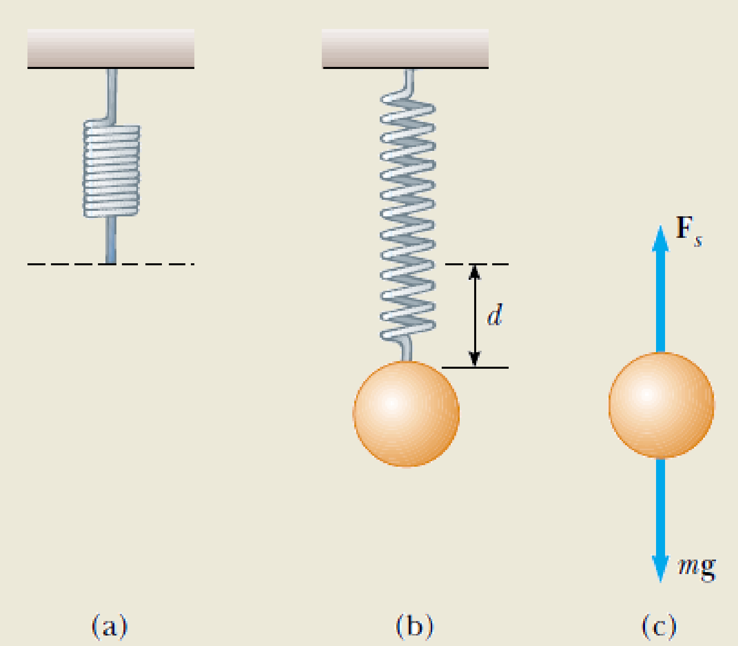
- A common technique used to measure the force constant of a spring is demonstrated by the setup in Figure. The spring is hung vertically, and an object of mass m is attached to its lower end. Under the action of the "load" mg, the spring stretches a distance d from its equilibrium position.
- *(A) If a spring is stretched 2.0 cm by a suspended object having a mass of 0.55 kg, what is the force constant of the spring?*
- ***Solution***:

$$m = 0.55\,kg\,,\ x = 2cm$$

$$\because \left|F_s\right| = kx = mg$$

$$\therefore k\,(2\times10^{-2}) = 0.55\times9.8$$

$$\Rightarrow k = \frac{0.55\times9.8}{2\times10^{-2}} = 2.7\times10^{2}\ \text{N/m}$$



7.5 Kinetic Energy

- When work (W) is applied on a system; its kinetic energy (K) changes from initial value (K_i) to final value (K_f) so that:

$$W = K_f - K_i$$

we define K as: $K = \frac{1}{2} m v^2$

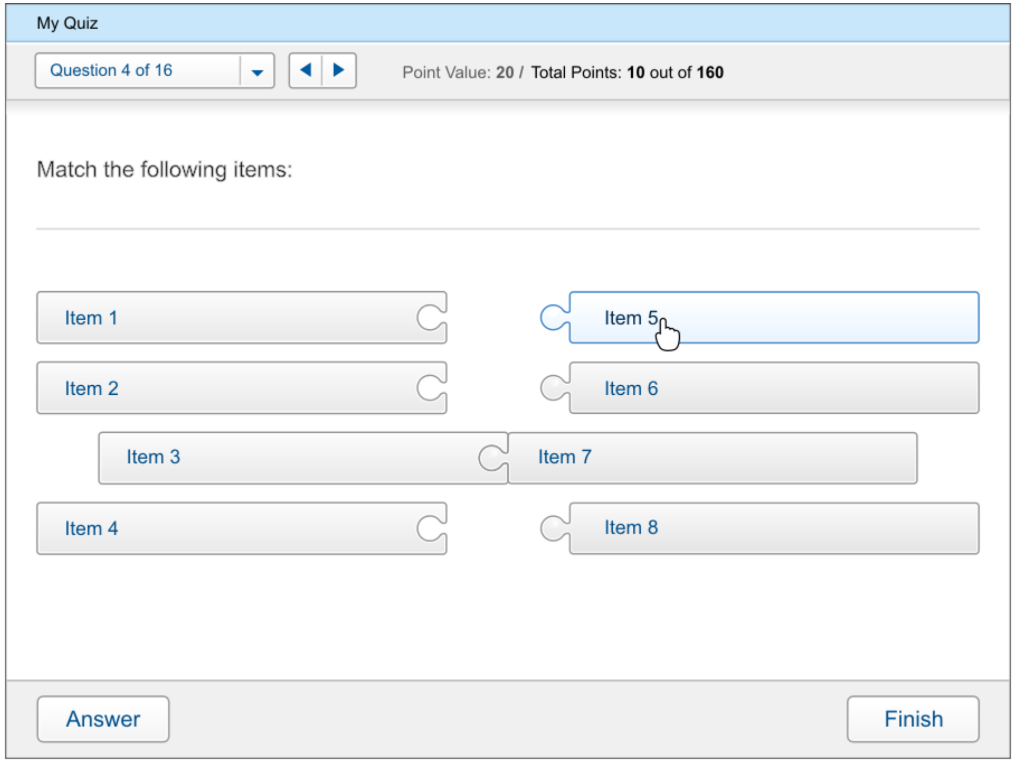
$$\therefore W = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 \qquad (7.14)$$

- the **work–kinetic energy theorem** is defined as:

$$W = K_f - K_i = \Delta K \qquad (7.15)$$

- This theorem indicates that the speed of a particle will **increase** if the net work done on it is **positive**, because the final kinetic energy will be greater than the initial kinetic energy. The speed will **decrease** if the net work is **negative**

Quiz 7.5 and 7.6



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Lecture Summary

- *The work W done on a system by an agent exerting a constant force on the system is the product of the magnitude* ***F*** *of the force, the magnitude Δr of the displacement of the point of application of the force, and cos θ, where θ is the angle between the force and displacement vectors:*

$$W = F\Delta r\cos\theta \qquad (7.1)$$

- *The scalar product (dot product) of two vectors A and B is defined by the relationship:*

$$A.B = AB\cos\theta \qquad (7.2)$$

- *If a force* $\boldsymbol{F_x}$ *is varying with position, x, we can express the work done by* $\boldsymbol{F_x}$ *as the particle moves from x_i to x_f as:*

$$W = \int_{x_i}^{x_f} F_x\,dx \qquad (7.7)$$

Lecture Summary (continued)

- *The kinetic energy of a particle of mass m moving with a speed v is:*

$$K = \frac{1}{2}mv^2 \qquad (7.14)$$

- *The work–kinetic energy theorem states that if work is done on a system by external forces and the only change in the system is in its speed, then*

$$W = K_f - K_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \Delta K \qquad (7.14,16)$$

- *Work Done by a Spring:*

$$\because W = \int_{x_i}^{x_f} F_s dx = \int_{-x}^{0} (-kx)dx$$

$$\therefore W = \frac{1}{2}kx^2 \qquad (7.10)$$

WORK & WORK-ENERGY THEOREM

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THE END!