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Chapter 9 Energy

Summary

THE BIG IDEA **Energy can change from one form to another without a net loss or gain.**

9.1 Work

Work is done when a force acts on an object and the object moves in the direction of the force.

- **Work** is the product of the force on an object and the distance through which the object is moved.
- In the simplest case, when the force is constant, the motion takes place in a straight line in the direction of the force: work = force × distance. In equation form, $W = Fd$.
- Work generally falls into two categories: work done against another force and work done to change the speed of an object. In both categories, work involves a transfer of energy between something and its surroundings.
- The unit of work is the newton-meter (N·m), also called the **joule.** One joule (J) of work is done when a force of 1 N is exerted over a distance of 1 m.

9.2 Power

Power equals the amount of work done divided by the time interval during which the work is done.

- **Power** is the rate at which work is done:

$$\text{power} = \frac{\text{work done}}{\text{time interval}}$$

- A high-power engine does work rapidly. If an engine has twice the power of another engine, this means that it can do twice the work in the same amount of time or the same amount of work in half the time.
- The unit of power is the joule per second, which is also known as the **watt.** One watt (W) of power is expended when one joule of work is done in one second.
- In the United States, we customarily rate engines in units of horsepower and electricity in kilowatts, but either may be used. One horsepower (hp) is the same as 0.75 kW.

9.3 Mechanical Energy

The two forms of mechanical energy are kinetic energy and potential energy.

- The property of an object or system that enables it to do work is **energy.**
- Like work, energy is measured in joules.
- **Mechanical energy** is the energy due to the position of something or the movement of something.

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9.4 Potential Energy

Three examples of potential energy are elastic potential energy, chemical energy, and gravitational potential energy.

- Energy that is stored and held in readiness is called **potential energy** (PE) because in the stored state it has the potential for doing work.
- A stretched or compressed spring, a bow that is drawn back, and a stretched rubber band have *elastic potential energy.*
- The chemical energy in fuels is potential energy at the submicroscopic level. This energy is available when a chemical change in the fuels takes place.
- The potential energy due to the elevated position of an object is *gravitational potential energy.*
- The amount of gravitational potential energy possessed by an elevated object is equal to the work done against gravity in lifting it. Gravitational potential energy = weight × height. In equation form, PE = *mgh*. The height in this equation is the distance above some chosen reference level.

9.5 Kinetic Energy

The kinetic energy of a moving object is equal to the work required to bring it to its speed from rest, or the work the object can do while being brought to rest.

- The energy of motion is **kinetic energy** (KE).
- The kinetic energy of an object is equal to half the object's mass multiplied by the square of its speed. In equation form, this is

  $KE = \frac{1}{2} mv^2$.

- The net force on an object multiplied by the distance along which the force acts equals the object's kinetic energy. In equation form, this is

  $Fd = \frac{1}{2} mv^2$.

9.6 Work-Energy Theorem

The work-energy theorem states that whenever work is done, energy changes.

- The **work-energy theorem** describes the relationship between work and energy.
- Work equals change in kinetic energy. In equation form, Work = ΔKE, where the delta symbol, Δ, means "change in." The work in this equation is the *net* work.
- If you push a box across a floor at a constant speed, you are pushing just hard enough to overcome friction. In this example, the net force and net work are zero, and KE = 0.
- Kinetic energy often appears hidden in different forms of energy. Random molecular motion is sensed as *heat. Sound* consists of molecules vibrating in rhythmic patterns. *Light* energy originates in the motion of electrons in atoms. Electrons in motion make *electric currents.*

9.7 Conservation of Energy

☑ The law of conservation of energy states that energy cannot be created or destroyed. It can be transformed from one form into another, but the total amount of energy never changes.

- The study of the various forms of energy and the transformations from one form into another is the **law of conservation of energy.**
- Everywhere along the path of a pendulum bob, the sum of potential energy and kinetic energy is the same. At the highest points, the energy is only potential energy. At the lowest point, the energy is only kinetic energy.
- The sun shines because some of its nuclear energy is transformed into radiant energy. In nuclear reactors, nuclear energy is transformed into heat.
- Some electric-generating plants transform the energy of falling water into electrical energy. Electrical energy then travels through wires to homes.

9.8 Machines

☑ A machine transfers energy from one place to another or transforms it from one form to another.

- A **machine** is a device used to multiply forces or to change the direction of forces. A machine cannot put out more energy than is put into it.
- A **lever** is a simple machine made of a bar that turns about a fixed point.
- If heat from friction is negligible, the work put into a machine equals the work put out by the machine: work input = work output.
  $(\text{force} \times \text{distance})_{\text{input}} = (\text{force} \times \text{distance})_{\text{output}}$
- The pivot point of a lever is the **fulcrum.**
- The ratio of output force to input force for a machine is called the **mechanical advantage.**
- A type 1 lever has the fulcrum between the input force and the load. If the fulcrum is closer to the load, a small input force exerted through a large distance produces a larger output force over a shorter distance. The directions of input and output are opposite.
- For a type 2 lever, the load is between the fulcrum and the input force. Force is increased at the expense of distance. Input and output forces have the same direction.
- In a type 3 lever, the fulcrum is at one end and the load is at the other. The input force is applied between them. The input and output forces have the same direction.
- A **pulley** is a kind of lever that can be used to change the direction of a force.
- A single pulley with a fixed axis behaves like a type 1 lever. A single pulley with an axis that moves behaves like a type 2 lever.
- A system of pulleys multiplies the force and it may change the direction of the force. The mechanical advantage for a simple pulley system is the same as the number of strands of rope that actually support the load.

9.9 Efficiency

In any machine, some energy is transformed into atomic or molecular kinetic energy—making the machine warmer.

- The **efficiency** of a machine is the ratio of useful energy output to total energy input, or the percentage of the work input that is converted to work output. No real machine can be 100% efficient. The wasted energy is dissipated as heat.
- An inclined plane is a machine. Its *theoretical* mechanical advantage, assuming negligible friction, is the length of the incline divided by the height of the inclined plane.
- Efficiency can also be expressed as the ratio of actual mechanical advantage to the theoretical mechanical advantage.
- To convert efficiency to percent, express it as a decimal and multiply by 100%.

9.10 Energy for Life

There is more energy stored in the molecules in food than there is in the reaction products after the food is metabolized. This energy difference sustains life.

- Most living organisms on this planet feed on various hydrocarbon compounds that release energy when they react with oxygen. In metabolism of food in the body, carbon combines with oxygen to form carbon dioxide.
- Only green plants and certain one-celled organisms can make carbon dioxide combine with water to produce hydrocarbon compounds such as sugar. This process is called *photosynthesis* and requires an energy input, which normally comes from sunlight.

9.11 Sources of Energy

The sun is the source of practically all our energy on Earth.

- Sunlight is directly transformed into electricity by photovoltaic cells or in the flexible solar shingles on the roofs of buildings. We use the energy in sunlight to generate electricity indirectly as well.
- Wind, caused by unequal warming of Earth's surface, is another form of solar power. Wind can be used to turn generator turbines within specially equipped windmills.
- Hydrogen is the least polluting of all fuels. Because it takes energy to make hydrogen (to extract it from water and carbon compounds), it is not a *source* of energy. In a **fuel cell,** hydrogen and oxygen gas are compressed at electrodes to produce water and electric current.
- The most concentrated form of usable energy is stored in nuclear fuels.
- Earth's interior is kept hot by producing a form of nuclear power, radioactivity.
- Geothermal energy is held in underground reservoirs of hot water.

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Chapter 9 Energy

Exercises

9.1 Work (pages 145–146)

1. Circle the letter next to the correct mathematical equation for work.
   a. work = force ÷ distance
   b. work = distance ÷ force
   c. work = force × distance
   d. work = force × distance^2
2. You can use the equation in Question 1 to calculate work when the force is _____ and the motion takes place in _____.
3. You do work if you lift a book one meter above the ground. How does the amount of work change in each of the following cases?
   a. You lift the book twice as high. _____
   b. You lift two identical books one meter above the ground. _____
4. Complete the table by naming the two general categories of work and giving an example of each.

Category of Work	Example

5. The unit of work is the _____.
6. Suppose that you apply a 50-N horizontal force to a 25-kg box, pushing the box 6 meters across the floor. How much work do you do on the box? _____

9.2 Power (pages 146–147)

7. Power is the rate at which _____ is done.
8. Power equals _____ divided by _____.
9. The unit of power is the _____.
10. One megawatt (MW) equals _____ watts.
11. In the United States, we customarily rate engines in units of _____, which is equivalent to _____ kilowatt.

9.3 Mechanical Energy (page 147)

12. Define energy.
13. What is the SI unit of energy? _____

14. Mechanical energy is the energy due to the _____ or _____ of something.

15. What are the two forms of mechanical energy?

a. _____

b. _____

9.4 Potential Energy (pages 148–149)

16. On each line, write *elastic*, *chemical*, or *gravitational* to identify the type of potential energy described.

_____ a. fossil fuels

_____ b. a compressed spring

_____ c. water in a reservoir

_____ d. a stretched rubber band

_____ e. food

_____ f. a bow drawn back

_____ g. electric batteries

17. The amount of gravitational potential energy possessed by an elevated object is equal to the work done against _____ in lifting it.

18. What are two ways to calculate gravitational potential energy?

a. _____ × height

b. _____ × _____ × height

19. Explain what the height is when you calculate an object's gravitational potential energy.

_____

_____

20. How do hydroelectric power stations make use of gravitational potential energy?

_____

_____

_____

9.5 Kinetic Energy (page 150)

21. Kinetic energy is energy of _____.

22. Circle the letter for the equation you can use to find the kinetic energy of an object.

a. $KE = 2mv$ b. $KE = \frac{1}{2}mv$

c. $KE = 2mv^2$ d. $KE = \frac{1}{2}mv^2$

23. Kinetic energy equals the _____ on an object multiplied by the distance the object moves.

24. Is the following sentence true or false? If the speed of an object doubles, the kinetic energy of the object also doubles. _____

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9.6 Work-Energy Theorem (pages 151–152)

25. Express the work-energy theorem.

_____

26. Explain this equation: Work = ΔKE.

_____

27. Is the following sentence true or false? If you push against a heavy refrigerator, and it doesn't slide, then you are not doing work on the refrigerator.

_____

28. Suppose you push against a box so that it moves across a horizontal surface. Explain how to determine the change in kinetic energy in each of the following cases.

a. The surface has no friction. _____

_____

b. The surface has some friction. _____

_____

c. The box moves at a constant speed across a surface that has some friction.

_____

29. Is the following sentence true or false? The maximum friction that the brakes of a car can supply is nearly the same whether the car moves slowly or quickly.

_____

Match each form of hidden kinetic energy with its description.

Form of Kinetic Energy	Description
_____ 30. heat	a. consists of molecules vibrating in rhythmic patterns
_____ 31. sound	b. produced by electrons in motion
_____ 32. electricity	c. results from random molecular motion

9.7 Conservation of Energy (pages 153–154)

33. The energy an arrow delivers to a target is slightly less than the energy it had when it was flying toward the target. What happened to the lost energy?

_____

_____

34. Express the law of conservation of energy.

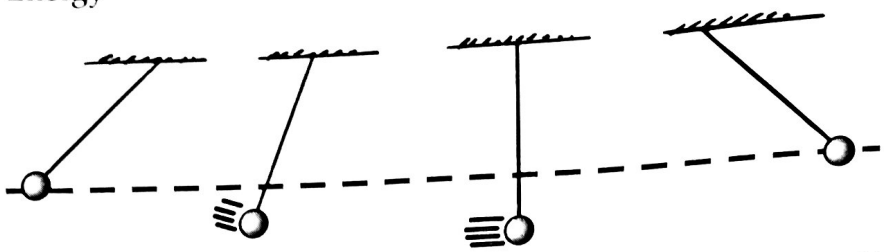
_____

_____

_____

35. The wound spring of a toy car has 10 J of potential energy. Only 8 J of this energy changes to kinetic energy as the car moves. What happens to the remaining 2 J of energy?

_____



36. The figure above shows the energy of a swinging pendulum bob at different points along its path.
    a. If you ignore friction, how does the energy of the bob at the highest points of its path compare to the energy at the lowest point of its path?

    _____

    _____

    b. How does friction affect the pendulum?

    _____

37. The sun shines because some of its nuclear energy is transformed into _____ energy.
38. In nuclear reactors, nuclear energy is transformed into _____.
39. Suppose a person in distress leaps from a burning building onto a firefighter's trampoline near the ground.
    a. Describe the change in potential energy, kinetic energy, and total energy as the person falls.

    _____

    b. Suppose the person has 10,000 J of potential energy just before jumping. What are the person's potential energy and kinetic energy upon reaching the trampoline?

    _____

9.8 Machines (pages 155–157)

40. A machine is a device used to _____ or _____.
41. Circle each letter that describes something a machine can do.
    a. puts out more energy than is put into it
    b. transfers energy from one place to another
    c. transforms energy from one form to another
    d. destroys or creates energy
42. Describe a lever.

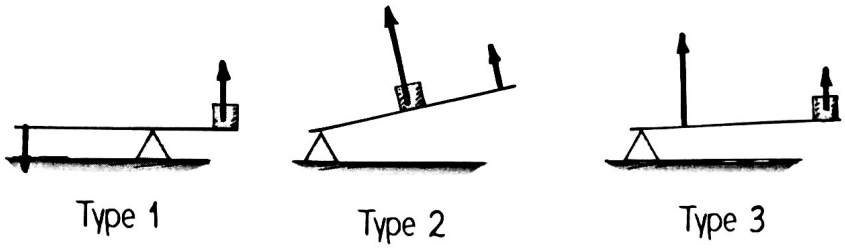
    _____

43. Complete the following mathematical equation for a lever.

    $(\_\_\_\_\_ \times \_\_\_\_\_)_{\text{input}} =$
    $(\_\_\_\_\_ \times \_\_\_\_\_)_{\text{output}}$

44. The pivot point of a lever is called a _____.

45. What are two ways to calculate the mechanical advantage of a machine?
    a. _____
    b. _____



46. The figures above show three types of levers. Give an example of each type.
    a. Type 1: _____
    b. Type 2: _____
    c. Type 3: _____
47. Describe a pulley.

    _____

48. Complete the table about pulleys.

Type of Pulley	Changes direction of the input force?	Multiplies the input force?	Mechanical Advantage
Single pulley with fixed axis			
Single pulley with movable axis			
System of pulleys			

9.9 Efficiency (pages 158–160)

49. Is the following sentence true or false? No real machine can be 100% efficient.

    _____

50. When a simple lever rocks about its fulcrum, or a pulley turns about its axis, a small fraction of input energy is converted into _____ energy.
51. What are two ratios used to relate the efficiency of a machine to energy and work?
    a. _____
    b. _____
52. Suppose you put in 100 J of work on a lever and get out 93 J of work.
    a. What is the efficiency of the lever? _____
    b. How much of the work input is lost as heat? _____

53. Is the following sentence true or false? The lower the efficiency of a machine, the greater the amount of energy wasted as heat. _____

54. Which requires less force: sliding a load up an incline or lifting the load vertically?

_____

55. The length of an incline is 8 m. The height of the elevated end is 2 m. Circle the letter of the inclined plane's theoretical mechanical advantage.

a. 2 b. 4

c. 8 d. 16

56. If the friction of an object against an inclined plane increases, the actual mechanical advantage _____ and the efficiency _____.

57. What ratio can you use to relate the efficiency of a machine to its mechanical advantage?

_____

58. The efficiency of a machine is always less than _____.

59. How can you convert efficiency to percent?

_____

_____

60. Is the following sentence true or false? An automobile engine is a complex machine that transforms mechanical energy into chemical energy.

_____

9.10 Energy for Life (page 160)

61. Most living organisms on this planet feed on various _____ compounds that release energy when they react with _____.

62. Is the following sentence true or false? The amount of energy stored in gasoline is greater than the amount of energy in the products of its combustion.

_____

63. Is the following sentence true or false? There is less energy stored in the molecules of food than there is in the reaction products after the food is metabolized.

_____

64. How does the metabolism of food in the body compare to the burning of fossil fuels in mechanical engines? How are the processes different?

_____

_____

_____

65. What makes life possible on Earth?

_____

_____

_____

9.11 Sources of Energy (pages 161–162)

66. _____ is the source of practically all our energy on Earth.
67. Sunlight is directly transformed into electricity by _____.
68. Sequence the steps by which sunlight can be used indirectly to generate electricity.
    a. _____
    b. _____
    c. _____
    d. _____
69. Wind can be considered a type of solar power because wind is caused by _____.
70. Circle the letter of each correct statement about wind energy.
    a. Wind is a steady form of energy.
    b. Wind power can provide all of our energy needs.
    c. Wind can make a substantial contribution to the energy we use.
    d. Wind energy is practical when the energy is stored for future use.
71. Is the following sentence true or false? Hydrogen is a source of energy. _____
72. In a _____, hydrogen and oxygen gas are compressed at electrodes to produce water and electric current.
73. Earth's interior is kept hot by _____.
74. _____ energy is held in underground reservoirs of hot water.