CHAPTER OUTLINE

Section 1 Work, Power, and Machines

Key Idea questions
> How is work calculated?
> What is the relationship between work and power?
> How do machines make work easier?

What Is Work?

> How is work calculated?

> Work is calculated by multiplying the force by the distance over which the force is applied.

– work = force x distance, or *W* = *Fd*

– The force must be applied in the direction of the object's motion.

- work: the transfer of energy to an object by the application of a force that causes the object to move in the direction of the force

- Work is zero when an object is not moving.

- Work is measured in joules (J):
  $1\ N \cdot m = 1\ J = 1\ kg \cdot m^2/s^2$

Power

> What is the relationship between work and power?

> Power is the rate at which work is done, or how much work is done in a given amount of time.

- power: a quantity that measures the rate at which work is done or energy is transformed

- Power is measured in watts (W):
  1 W = 1 J/s

Machines and Mechanical Advantage

> How do machines make work easier?

> Machines help do work by changing the size of an input force, the direction of the force, or both.

- Mechanical advantage is an important ratio.
- mechanical advantage: a quantity that expresses how much a machine multiplies force or distance

Section 2 Simple Machines

Key Idea questions
> What are the six types of simple machines?
> What are the two principal parts of all levers?
> How does using an inclined plane change the force required to do work?
> What simple machines make up a pair of scissors?

What Are Simple Machines?

> What are the six types of simple machines?

> The six types of simple machines are the simple lever, the pulley, the wheel and axle, the simple inclined plane, the wedge, and the screw.

- Simple machines are divided into two families: the *lever family* and the *inclined plane family.*

The Lever Family

> What are the two principal parts of all levers?

> All levers have a rigid arm that turns around a point called the fulcrum.

- Levers are divided into three classes.
- Pulleys are modified levers.
  – The point in the middle of a pulley is like the fulcrum of a lever.
  – The rest of the pulley behaves like the rigid arm of a first-class lever.
- A wheel and axle is a lever or pulley connected to a shaft.
  – Screwdrivers and cranks are common wheel-and-axel machines.

The Inclined Plane Family

> How does using an inclined plane change the force required to do work?

> Pushing an object up an inclined plane requires less input force than lifting the same object does.

- A wedge is a modified inclined plane.
- A screw is an inclined plane wrapped around a cylinder.

Compound Machines

> What simple machines make up a pair of scissors?

> A pair of scissors uses two first-class levers joined at a common fulcrum; each lever arm has a wedge that cuts into the paper.

- compound machine: a machine made of more than one simple machine

Section 3 What is Energy?

Key Idea questions
> What is the relationship between energy and work?
> Why is potential energy called energy of position?
> What factors does kinetic energy depend on?
> What is nonmechanical energy?

Energy and Work

> What is the relationship between energy and work?

> Whenever work is done, energy is transformed or is transferred from one system to another system.

- energy: the capacity to do work
- Energy is measured in joules (J).

Potential Energy

> Why is potential energy called energy of position?

> Potential energy (*PE*) is sometimes called energy of position because it results from the relative positions of objects in a system.

- potential energy: the energy that an object has because of the position, shape, or condition of the object
- Any object that is stretched or compressed to increase or decrease the distance between its parts has *elastic potential energy.*
  – Examples: stretched bungee cords, compressed springs
- Any system of two or more objects separated by a vertical distance has *gravitational potential energy.*
  – Example: a roller coaster at the top of a hill
- Gravitational potential energy depends on both mass and height.
- *grav. PE = mass × free-fall acceleration × height, or* $PE = mgh$

- The height can be relative.

Kinetic Energy

> What factors does kinetic energy depend on?

> Kinetic energy depends on both the mass and the speed of an object.

- kinetic energy: the energy of an object due to the object's motion
- $KE = \frac{1}{2} \times mass \times speed\ squared$, or $KE = \frac{1}{2}mv^2$
- Kinetic energy depends on speed more than mass.
- Atoms and molecules have kinetic energy.

Other Forms of Energy

> What is nonmechanical energy?

> Energy that lies at the level of the atom is sometimes called *nonmechanical energy*.

- mechanical energy: the amount of work an object can do because of the object's kinetic and potential energies
- In most cases, nonmechanical forms of energy are just special forms of either kinetic or potential energy.
- Chemical reactions involve potential energy.
  - The amount of *chemical energy* associated with a substance depends in part on the relative positions of the atoms it contains.
- Living things get energy from the sun.
  - Plants use *photosynthesis* to turn the energy in sunlight into chemical energy.
- The sun gets energy from nuclear reactions.
  - The sun is fueled by *nuclear fusion* reactions in its core.

- Energy can be stored in fields.
  - Electrical energy results from the location of charged particles in an *electric field.*
  - When electrons move from an area of higher *electric potential* to an area of lower electric potential, they gain energy.
- Light can carry energy across empty space.
  - Light energy travels from the sun to Earth across empty space in the form of *electromagnetic waves*.
  - Electromagnetic waves are made of *electric and magnetic fields,* so light energy is another example of energy stored in a field.

Section 4 Conservation of Energy

Key Idea questions
> How does energy change?
> What is the law of conservation of energy?
> How much of the work done by a machine is actually useful work?

Energy Transformations

> How does energy change?

> Energy readily changes from one form to another.

- Potential energy can become kinetic energy.
  - Example: As a roller coaster car goes down a hill, *PE* changes to *KE*.
- Kinetic energy can become potential energy.
  - Example: The *KE* of a roller coaster car at the bottom of a hill can do work to carry it up another hill.
- Mechanical energy can change to other forms of energy.

The Law of Conservation of Energy

> What is the law of conservation of energy?

> Energy cannot be created or destroyed. In other words, the total amount of energy in the universe never changes, although energy may change from one form to another.

- Energy does not appear or disappear.
  - Whenever the total energy in a system increases, it must be due to energy that enters the system from an external source.
- Thermodynamics describes energy conservation.
  - For any system, the net change in energy equals the energy transferred as work and as heat.

- – This form of the law of energy conservation is called the *first law of thermodynamics.*

- • Systems may be open, closed, or isolated.

  - – *open system:* energy and matter are exchanged with the surroundings

  - – *closed system:* energy but not matter is exchanged

  - – *isolated system:* neither energy nor matter is exchanged

- • Most real-world systems are open.

Efficiency of Machines

> How much of the work done by a machine is actually useful work?

> Only a portion of the work done by any machine is *useful work*— that is, work that the machine is designed or intended to do.

- • Not all of the work done by a machine is useful work.

  - – because of friction, work output < work input

- • Efficiency is the ratio of useful work out to work in.

  - – efficiency: a quantity, usually expressed as a percentage, that measures the ratio of useful work output to work input