THE BIG IDEA

Energy can change from one form to another without a net loss or gain.

Energy may be the most familiar concept in science, yet it is one of the most difficult to define. We observe the effects of energy when something is happening—only when energy is being transferred from one place to another or transformed from one form to another.

9.1 Work

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

9.1 Work

Work is the product of the force on an object and the distance through which the object is moved: the quantity *force* × *distance*

We do work when we lift a load against Earth's gravity. The heavier the load or the higher we lift it, the more work we do.

9.1 Work

If the force is constant and the motion takes place in a straight line in the direction of the force, the work done on an object by a net force is the product of the force and the distance through which the object is moved.

work = net force × distance

$W = Fd$

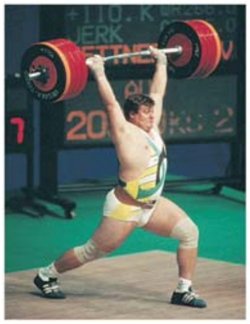
9.1 Work

If we lift two loads, we do twice as much work as lifting one load the same distance, because the *force* needed is twice as great.

If we lift one load twice as far, we do twice as much work because the *distance* is twice as great.

9.1 Work

Work is done in lifting the barbell. If the barbell could be lifted twice as high, the weight lifter would have to do twice as much work.

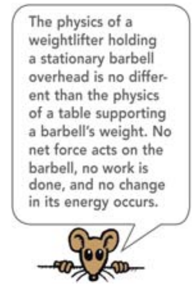


9.1 Work

While the weight lifter is holding a barbell over his head, he may get really tired, but he does no work on the barbell.

Work may be done on the muscles by stretching and squeezing them, but this work is not done on the barbell.

When the weight lifter raises the barbell, he is doing work on it.



9.1 Work

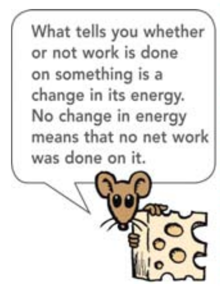
Some work is done against another force.

- An archer stretches her bowstring, doing work against the elastic forces of the bow.
- When the ram of a pile driver is raised, work is required to raise the ram against the force of gravity.
- When you do push-ups, you do work against your own weight.

9.1 Work

Some work is done to change the speed of an object.

- Bringing an automobile up to speed or in slowing it down involves work.
- In both categories, work involves a transfer of energy between something and its surroundings.



9.1 Work

The unit of measurement for work combines a unit of force, N, with a unit of distance, m.

- 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 (lifting an apple over your head).

9.1 Work

Larger units are required to describe greater work.

- Kilojoules (kJ) are thousands of joules. The weight lifter does work on the order of kilojoules.
- Megajoules (MJ) are millions of joules. To stop a loaded truck going at 100 km/h takes megajoules of work.

9.1 Work

think!

Suppose that you apply a 60-N horizontal force to a 32-kg package, which pushes it 4 meters across a mailroom floor. How much work do you do on the package?

9.1 Work

think!

Suppose that you apply a 60-N horizontal force to a 32-kg package, which pushes it 4 meters across a mailroom floor. How much work do you do on the package?

Answer:

$W = Fd = 60\ \text{N} \times 4\ \text{m} = 240\ \text{J}$

9.1 Work

CONCEPT CHECK **When is work done on an object?**

9.2 Power

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

9.2 Power

When carrying a load up some stairs, you do the same amount of work whether you walk or run up the stairs.

Power is the rate at which work is done.

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

9.2 Power

A high-power engine does work rapidly.

- An engine that delivers twice the power of another engine does not necessarily produce twice as much work or go twice as fast.
- Twice the power means the engine can do twice the work in the same amount of time or the same amount of work in half the time.
- A powerful engine can get an automobile up to a given speed in less time than a less powerful engine can.

9.2 Power

The unit of power is the joule per second, also known as the **watt.**

- One watt (W) of power is expended when one joule of work is done in one second.
- One kilowatt (kW) equals 1000 watts.
- One megawatt (MW) equals one million watts.

9.2 Power

The three main engines of the space shuttle can develop 33,000 MW of power when fuel is burned at the enormous rate of 3400 kg/s.

9.2 Power

In the United States, we customarily rate engines in units of horsepower and electricity in kilowatts, but either may be used.

In the metric system of units, automobiles are rated in kilowatts. One horsepower (hp) is the same as 0.75 kW, so an engine rated at 134 hp is a 100-kW engine.

9.2 Power

think!

If a forklift is replaced with a new forklift that has twice the power, how much greater a load can it lift in the same amount of time? If it lifts the same load, how much faster can it operate?

9.2 Power

think!

If a forklift is replaced with a new forklift that has twice the power, how much greater a load can it lift in the same amount of time? If it lifts the same load, how much faster can it operate?

Answer:

The forklift that delivers twice the power will lift twice the load in the same time, or the same load in half the time.

9.2 Power

CONCEPT CHECK **How can you calculate power?**

9 Energy — Conceptual Physics

9.3 Mechanical Energy

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

9 Energy — Conceptual Physics

9.3 Mechanical Energy

When work is done by an archer in drawing back a bowstring, the bent bow acquires the ability to do work on the arrow.

When work is done to raise the heavy ram of a pile driver, the ram acquires the ability to do work on the object it hits when it falls.

When work is done to wind a spring mechanism, the spring acquires the ability to do work on various gears to run a clock, ring a bell, or sound an alarm.

9 Energy — Conceptual Physics

9.3 Mechanical Energy

Something has been acquired that enables the object to do work.

It may be in the form of a compression of atoms in the material of an object; a physical separation of attracting bodies; or a rearrangement of electric charges in the molecules of a substance.

9 Energy — Conceptual Physics

9.3 Mechanical 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.

9 Energy — Conceptual Physics

9.3 Mechanical Energy

CONCEPT CHECK **What are the two forms of mechanical energy?**

9 Energy — Conceptual Physics

9.4 Potential Energy

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

9.4 Potential Energy

An object may store energy by virtue of its position.

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.

9.4 Potential Energy

Elastic Potential Energy

A stretched or compressed spring has a potential for doing work.

When a bow is drawn back, energy is stored in the bow. The bow can do work on the arrow.

A stretched rubber band has potential energy because of its position.

These types of potential energy are *elastic potential energy.*

9.4 Potential Energy

Chemical Energy

The chemical energy in fuels is also potential energy.

It is energy of position at the submicroscopic level. This energy is available when the positions of electric charges within and between molecules are altered and a chemical change takes place.

9.4 Potential Energy

Gravitational Potential Energy

Work is required to elevate objects against Earth's gravity.

The potential energy due to elevated positions is *gravitational potential energy.*

Water in an elevated reservoir and the raised ram of a pile driver have gravitational potential energy.

9.4 Potential Energy

The amount of gravitational potential energy possessed by an elevated object is equal to the work done against gravity to lift it.

The upward force required while moving at constant velocity is equal to the weight, mg, of the object, so the work done in lifting it through a height h is the product mgh.

gravitational potential energy = weight × height

$PE = mgh$

9.4 Potential Energy

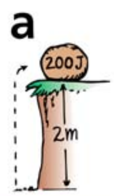
Note that the height is the distance above some chosen reference level, such as the ground or the floor of a building.

The gravitational potential energy, mgh, is relative to that level and depends only on mg and h.

9.4 Potential Energy

The potential energy of the 100-N boulder with respect to the ground below is 200 J in each case.

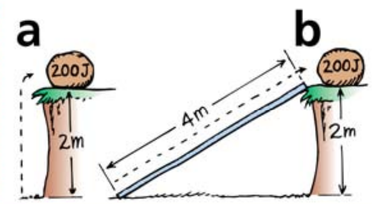
a. The boulder is lifted with 100 N of force.



9.4 Potential Energy

The potential energy of the 100-N boulder with respect to the ground below is 200 J in each case.

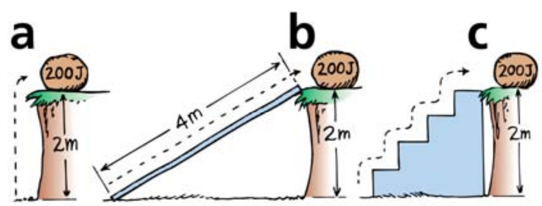
a. The boulder is lifted with 100 N of force.
b. The boulder is pushed up the 4-m incline with 50 N of force.



9.4 Potential Energy

The potential energy of the 100-N boulder with respect to the ground below is 200 J in each case.

a. The boulder is lifted with 100 N of force.
b. The boulder is pushed up the 4-m incline with 50 N of force.
c. The boulder is lifted with 100 N of force up each 0.5-m stair.



9.4 Potential Energy

Hydroelectric power stations use gravitational potential energy.

- Water from an upper reservoir flows through a long tunnel to an electric generator.
- Gravitational potential energy of the water is converted to electrical energy.
- Power stations *buy* electricity at night, when there is much less demand, and pump water from a lower reservoir back up to the upper reservoir. This process is called *pumped storage.*
- The pumped storage system helps to smooth out differences between energy demand and supply.

9.4 Potential Energy

think!

You lift a 100-N boulder 1 m.

a. How much work is done on the boulder?

b. What power is expended if you lift the boulder in a time of 2 s?

c. What is the gravitational potential energy of the boulder in the lifted position?

9.4 Potential Energy

think!

You lift a 100-N boulder 1 m.

a. How much work is done on the boulder?

b. What power is expended if you lift the boulder in a time of 2 s?

c. What is the gravitational potential energy of the boulder in the lifted position?

Answer:

a. $W = Fd$ = 100 N·m = 100 J

b. Power = 100 J / 2 s = 50 W

c. Relative to its starting position, the boulder's PE is 100 J. Relative to some other reference level, its PE would be some other value.

9.4 Potential Energy

CONCEPT CHECK

Name three examples of potential energy.

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.

9.5 Kinetic Energy

If an object is moving, then it is capable of doing work. It has energy of motion, or **kinetic energy** (KE).

- The kinetic energy of an object depends on the mass of the object as well as its speed.
- It is equal to half the mass multiplied by the square of the speed.

$$\text{kinetic energy} = \frac{1}{2}\text{mass} \times \text{speed}^2$$

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

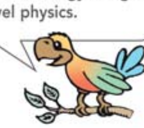
9.5 Kinetic Energy

When you throw a ball, you do work on it to give it speed as it leaves your hand. The moving ball can then hit something and push it, doing work on what it hits.

$$\text{net force} \times \text{distance} = \text{kinetic energy}$$

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

Understanding the distinction between momentum and kinetic energy is high-level physics.



9.5 Kinetic Energy

Note that the speed is squared, so if the speed of an object is doubled, its kinetic energy is quadrupled ($2^2 = 4$).

- It takes four times the work to double the speed.
- An object moving twice as fast takes four times as much work to stop.

9.5 Kinetic Energy

CONCEPT CHECK

How are work and the kinetic energy of a moving object related?

9.6 Work-Energy Theorem

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

9.6 Work-Energy Theorem

To increase the kinetic energy of an object, work must be done on the object.

If an object is moving, work is required to bring it to rest.

The change in kinetic energy is equal to the net work done.

The **work-energy theorem** describes the relationship between work and energy.

9.6 Work-Energy Theorem

We abbreviate “change in” with the delta symbol, Δ

Work = ΔKE

Work equals the change in kinetic energy.

The work in this equation is the *net* work—that is, the work based on the net force.

9.6 Work-Energy Theorem

If there is no change in an object’s kinetic energy, then no net work was done on it.

Push against a box on a floor.

- If it doesn’t slide, then you are not doing work on the box.
- On a very slippery floor, if there is no friction at all, the work of your push times the distance of your push appears as kinetic energy of the box.

9.6 Work-Energy Theorem

- If there is some friction, it is the *net* force of your push minus the frictional force that is multiplied by distance to give the gain in kinetic energy.
- If the box moves at a constant speed, you are pushing just hard enough to overcome friction. The net force and net work are zero, and, according to the work-energy theorem, ΔKE = 0. The kinetic energy doesn’t change.

9.6 Work-Energy Theorem

The work-energy theorem applies to decreasing speed as well.

The more kinetic energy something has, the more work is required to stop it.

Twice as much kinetic energy means twice as much work.

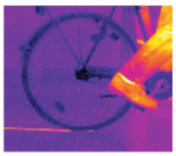
9 Energy

Conceptual Physics

9.6 Work-Energy Theorem

Due to friction, energy is transferred both into the floor and into the tire when the bicycle skids to a stop.

a. An infrared camera reveals the heated tire track on the floor.



a

9 Energy

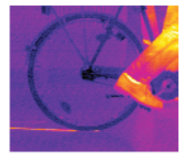
Conceptual Physics

9.6 Work-Energy Theorem

Due to friction, energy is transferred both into the floor and into the tire when the bicycle skids to a stop.

a. An infrared camera reveals the heated tire track on the floor.

b. The warmth of the tire is also revealed.



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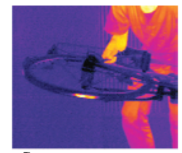

b

9 Energy

Conceptual Physics

9.6 Work-Energy Theorem

When a car brakes, the work is the friction force supplied by the brakes multiplied by the distance over which the friction force acts.

A car moving at twice the speed of another has four times as much kinetic energy, and will require four times as much work to stop.

The frictional force is nearly the same for both cars, so the faster one takes four times as much distance to stop.

Kinetic energy depends on speed *squared*.

9 Energy

Conceptual Physics

9.6 Work-Energy Theorem

Typical stopping distances for cars equipped with antilock brakes traveling at various speeds. The work done to stop the car is friction force × distance of slide.

9 Energy

Conceptual Physics

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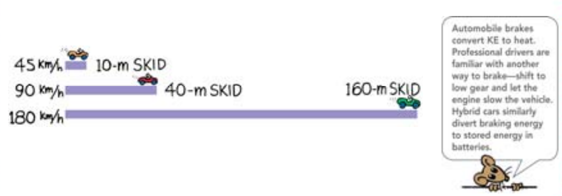


9.6 Work-Energy Theorem

Kinetic energy often appears hidden in different forms of energy, such as heat, sound, light, and electricity.

- Random molecular motion is sensed as heat.
- Sound consists of molecules vibrating in rhythmic patterns.
- Light energy originates in the motion of electrons within atoms.

Electrons in motion make electric currents.

9.6 Work-Energy Theorem

think!

A friend says that if you do 100 J of work on a moving cart, the cart will gain 100 J of KE. Another friend says this depends on whether or not there is friction. What is your opinion of these statements?

9.6 Work-Energy Theorem

think!

A friend says that if you do 100 J of work on a moving cart, the cart will gain 100 J of KE. Another friend says this depends on whether or not there is friction. What is your opinion of these statements?

Answer:

Careful. Although you do 100 J of work on the cart, this may not mean the cart gains 100 J of KE. How much KE the cart gains depends on the net work done on it.

9.6 Work-Energy Theorem

think!

When the brakes of a car are locked, the car skids to a stop. How much farther will the car skid if it's moving 3 times as fast?

9.6 Work-Energy Theorem

think!

When the brakes of a car are locked, the car skids to a stop. How much farther will the car skid if it's moving 3 times as fast?

Answer:

Nine times farther. The car has nine times as much kinetic energy when it travels three times as fast:

$$\frac{1}{2}m(3v)^2 = \frac{1}{2}m(9v)^2 = \left(9\frac{1}{2}mv^2\right)$$

9.6 Work-Energy Theorem

CONCEPT CHECK **What is the work-energy theorem?**

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.

9.7 Conservation of Energy

More important than knowing *what energy is*, is understanding how it behaves—*how it transforms*.

We can understand nearly every process that occurs in nature if we analyze it in terms of a transformation of energy from one form to another.

9.7 Conservation of Energy

Potential energy will become the kinetic energy of the arrow.

9.7 Conservation of Energy

As you draw back the arrow in a bow, you do work stretching the bow.

- The bow then has potential energy.
- When released, the arrow has kinetic energy equal to this potential energy.
- It delivers this energy to its target.

9.7 Conservation of Energy

The small distance the arrow moves multiplied by the average force of impact doesn't quite match the kinetic energy of the target.

However, the arrow and target are a bit warmer by the energy difference.

Energy changes from one form to another without a net loss or a net gain.

9.7 Conservation of Energy

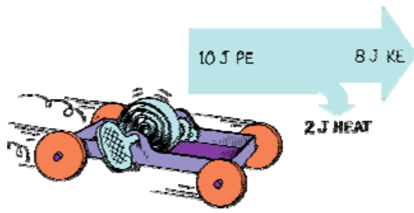
The study of the forms of energy and the transformations from one form into another is the **law of conservation of energy.**

For any system in its entirety—as simple as a swinging pendulum or as complex as an exploding galaxy—there is one quantity that does not change: energy.

Energy may change form, but the total energy stays the same.

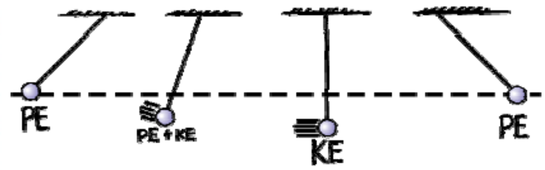
9.7 Conservation of Energy

Part of the PE of the wound spring changes into KE. The remaining PE goes into heating the machinery and the surroundings due to friction. No energy is lost.



9.7 Conservation of Energy

Everywhere along the path of the pendulum bob, the sum of PE and KE is the same. Because of the work done against friction, this energy will eventually be transformed into heat.



9.7 Conservation of Energy

When the woman leaps from the burning building, the sum of her PE and KE remains constant at each successive position all the way down to the ground.

9.7 Conservation of Energy

Each atom that makes up matter is a concentrated bundle of energy.

When the nuclei of atoms rearrange themselves, enormous amounts of energy can be released.

The sun shines because some of its nuclear energy is transformed into radiant energy.

In nuclear reactors, nuclear energy is transformed into heat.

9.7 Conservation of Energy

Enormous compression due to gravity in the deep, hot interior of the sun causes hydrogen nuclei to fuse and become helium nuclei.

- This high-temperature welding of atomic nuclei is called *thermonuclear fusion.*
- This process releases radiant energy, some of which reaches Earth.
- Part of this energy falls on plants, and some of the plants later become coal.

9.7 Conservation of Energy

- Another part supports life in the food chain that begins with microscopic marine animals and plants, and later gets stored in oil.
- Part of the sun's energy is used to evaporate water from the ocean.
- Some water returns to Earth as rain that is trapped behind a dam.

9.7 Conservation of Energy

The water behind a dam has potential energy that is used to power a generating plant below the dam.

- The generating plant transforms the energy of falling water into electrical energy.
- Electrical energy travels through wires to homes where it is used for lighting, heating, cooking, and operating electric toothbrushes.

9.7 Conservation of Energy

CONCEPT CHECK

What does the law of conservation of energy state?

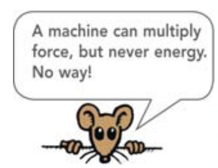
9.8 Machines

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

9.8 Machines

A **machine** is a device used to multiply forces or simply to change the direction of forces.

The concept that underlies every machine is the conservation of energy. A machine cannot put out more energy than is put into it.



9.8 Machines

Levers

A **lever** is a simple machine made of a bar that turns about a fixed point. If the heat from friction is small enough to neglect, the work input will be equal to the work output.

work input = work output

Since work equals force times distance, we can say

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

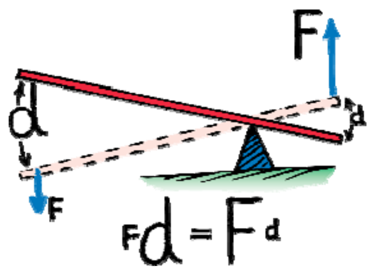
9.8 Machines

The pivot point, or **fulcrum,** of the lever can be relatively close to the load.

- Then a small input force exerted through a large distance will produce a large output force over a short distance.
- In this way, a lever can multiply forces.
- However, no machine can multiply work or energy.

9.8 Machines

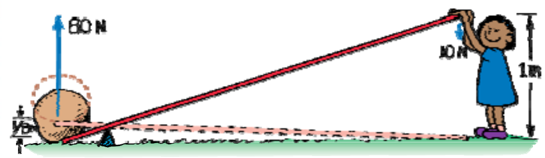
In the lever, the work (force × distance) done at one end is equal to the work done on the load at the other end.



9.8 Machines

The output force is eight times the input force.

The output distance is one eighth of the input distance.



9.8 Machines

The child pushes down 10 N and lifts an 80-N load.

The ratio of output force to input force for a machine is called the **mechanical advantage.**

The mechanical advantage is (80 N)/(10 N), or 8.

Neglecting friction, the mechanical advantage can also be determined by the ratio of input distance to output distance.

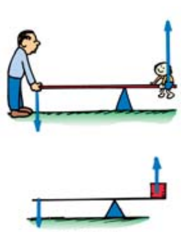
9.8 Machines

There are three common ways to set up a lever:

- A type 1 lever has the fulcrum between the force and the load, or between input and output.
- A type 2 lever has the load between the fulcrum and the input force.
- A type 3 lever has the fulcrum at one end and the load at the other.

9.8 Machines

The three basic types of levers are shown here.



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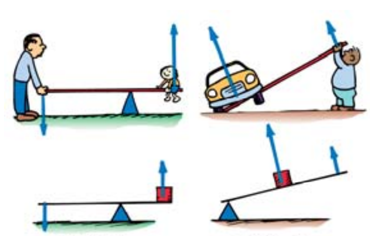

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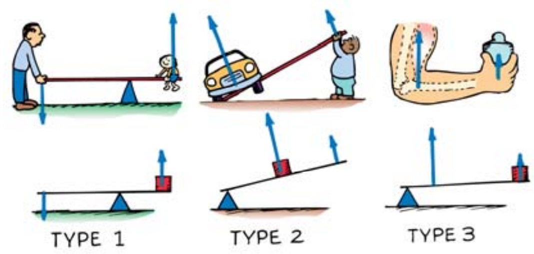


9.8 Machines

- For a type 1 lever, push down on one end and you lift a load at the other. The directions of input and output are opposite.
- For a type 2 lever, you *lift* the end of the lever. Since the input and output forces are on the same side of the fulcrum, the forces have the same direction.
- For a type 3 lever, the input force is applied between the fulcrum and the load. The input and output forces are on the same side of the fulcrum and have the same direction.

9.8 Machines

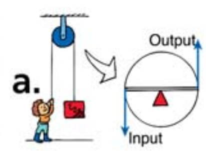
Pulleys

A **pulley** is basically a kind of lever that can be used to change the direction of a force.

Properly used, a pulley or system of pulleys can multiply forces.

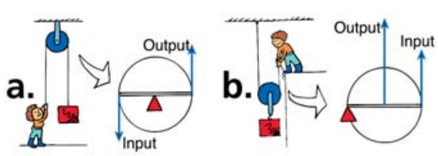
9.8 Machines

a. A pulley can change the direction of a force.



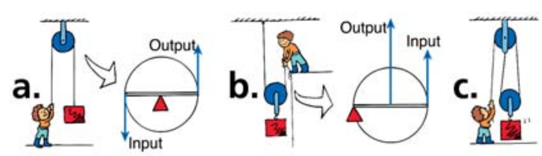
9.8 Machines

a. A pulley can change the direction of a force.
b. A pulley multiplies force.



9.8 Machines

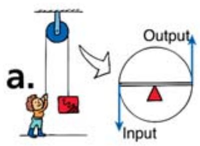
a. A pulley can change the direction of a force.
b. A pulley multiplies force.
c. Two pulleys can change the direction and multiply force.



9.8 Machines

This single pulley behaves like a type 1 lever.

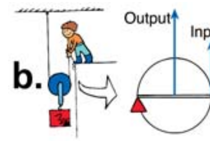
- The axis of the pulley acts as the fulcrum.
- Both lever distances (the radius of the pulley) are equal so the pulley does not multiply force.
- It changes the direction of the applied force.
- The mechanical advantage equals 1.



9.8 Machines

This single pulley acts as a type 2 lever.

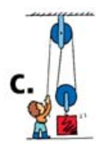
- The fulcrum is at the left end of the “lever” where the supporting rope makes contact with the pulley.
- The load is halfway between the fulcrum and the input.
- 1 N of input will support a 2-N load, so the mechanical advantage is 2.
- The load is now supported by two strands of rope, each supporting half the load.



9.8 Machines

The mechanical advantage for simple pulley systems is the same as the number of strands of rope that actually support the load.

- The mechanical advantage of this simple system is 2.
- Although three strands of rope are shown, only two strands actually support the load.
- The upper pulley serves only to change the direction of the force.

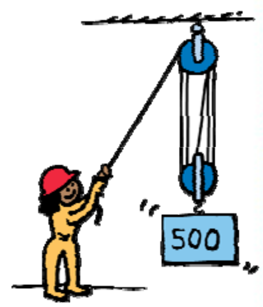


9.8 Machines

When the rope is pulled 5 m with a force of 100 N, a 500-N load is lifted 1 m.

The mechanical advantage is (500 N)/(100 N), or 5.

Force is multiplied at the expense of distance.



9.8 Machines

CONCEPT CHECK **How does a machine use energy?**

9.9 Efficiency

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

9.9 Efficiency

The previous examples of machines were considered to be *ideal* because all the work input was transferred to work output.

In a real machine, when a simple lever rocks about its fulcrum, or a pulley turns about its axis, a small fraction of input energy is converted into thermal energy.

9.9 Efficiency

The **efficiency** of a machine is the ratio of useful energy output to total energy input—the percentage of the work input that is converted to work output.

$$\text{efficiency} = \frac{\text{useful work output}}{\text{total work input}}$$

To convert efficiency to percent, you multiply by 100%. An ideal machine would have 100% efficiency. No real machine can be 100% efficient. Wasted energy is dissipated as heat.

9.9 Efficiency

If we put in 100 J of work on a lever and get out 98 J of work, the lever is 98% efficient. We lose 2 J of work input as heat.

In a pulley system, a larger fraction of input energy is lost as heat. For example, if we do 100 J of work, the friction on the pulleys as they turn and rub on their axle can dissipate 40 J of heat energy. This pulley system has an efficiency of 60%.

9.9 Efficiency

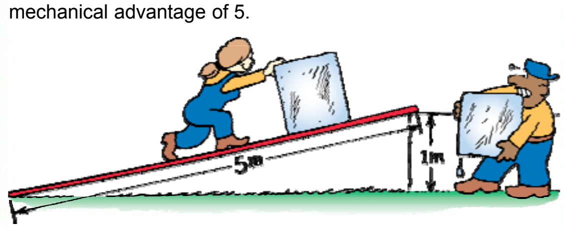
Inclined Planes

An inclined plane is a machine.

Sliding a load up an incline requires less force than lifting it vertically.

9.9 Efficiency

Pushing the block of ice 5 times farther up the incline than the vertical distance it's lifted requires a force of only one fifth its weight. If friction is negligible, we need apply only one fifth of the force. The inclined plane shown has a *theoretical* mechanical advantage of 5.



9.9 Efficiency

An icy plank used to slide a block of ice up to some height might have an efficiency of almost 100%.

When the load is a wooden crate sliding on a wooden plank, both the actual mechanical advantage and the efficiency will be considerably less.

Friction will require you to exert more force (a greater work input) without any increase in work output.

9.9 Efficiency

Efficiency can be expressed as the ratio of actual mechanical advantage to theoretical mechanical advantage.

$$\text{efficiency} = \frac{\text{actual mechanical advantage}}{\text{theoretical mechanical advantage}}$$

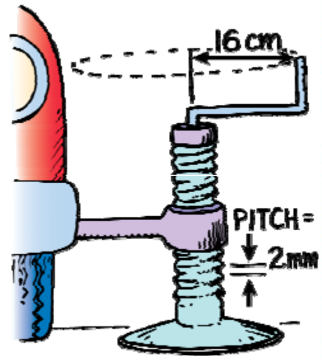
Efficiency will always be a fraction less than 1.

9.9 Efficiency

Complex Machines

This auto jack shown is an inclined plane wrapped around a cylinder.

A single turn of the handle raises the load a relatively small distance.



9.9 Efficiency

If the circular distance the handle is moved is 500 times greater than the distance between ridges, then the theoretical mechanical advantage of the jack is 500.

There is a great deal of friction in the jack, so the efficiency might be about 20%.

This means the jack actually multiplies force by about 100 times, so the actual mechanical advantage is about 100.

9.9 Efficiency

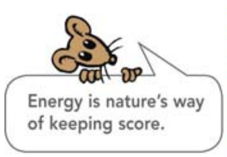
An automobile engine is a machine that transforms chemical energy stored in fuel into mechanical energy.

- The molecules of the gasoline break up as the fuel burns.
- Carbon atoms from the gasoline combine with oxygen atoms to form carbon dioxide. Hydrogen atoms combine with oxygen, and energy is released.
- The converted energy is used to run the engine.

9.9 Efficiency

Transforming 100% of thermal energy into mechanical energy is not possible.

- Some heat must flow from the engine.
- Friction adds more to the energy loss.
- Even the best-designed gasoline-powered automobile engines are unlikely to be more than 35% efficient.



9.9 Efficiency

think!

A child on a sled (total weight 500 N) is pulled up a 10-m slope that elevates her a vertical distance of 1 m. What is the theoretical mechanical advantage of the slope?

9.9 Efficiency

think!

A child on a sled (total weight 500 N) is pulled up a 10-m slope that elevates her a vertical distance of 1 m. What is the theoretical mechanical advantage of the slope?

Answer: The ideal, or theoretical, mechanical advantage is

input distance / output distance = 10 m / 1 m = 10

9.9 Efficiency

CONCEPT CHECK **Why can't a machine be 100% efficient?**

9.10 Energy for Life

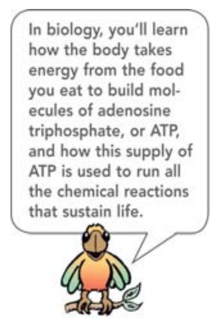
There is more energy stored in the molecules in food than there is in the reaction products after the food is metabolized. This energy difference sustains life.

9.10 Energy for Life

Every living cell in every organism is a machine. Like any machine, living cells need an energy supply.

In metabolism, carbon combines with oxygen to form carbon dioxide.

During metabolism, the reaction rate is much slower than combustion and energy is released as it is needed by the body.



9.10 Energy for Life

Only green plants and certain one-celled organisms can make carbon dioxide combine with water to produce hydrocarbon compounds such as sugar.

This process—*photosynthesis*—requires an energy input, which normally comes from sunlight.

Green plants are able to use the energy of sunlight to make food that gives us and all other organisms energy.

9.10 Energy for Life

CONCEPT CHECK **What role does energy play in sustaining life?**

9.11 Sources of Energy

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

9.11 Sources of Energy

Solar Power

Sunlight is directly transformed into electricity by photovoltaic cells.

We use the energy in sunlight to generate electricity indirectly as well: sunlight evaporates water, which later falls as rain; rainwater flows into rivers and into generator turbines as it returns to the sea.

9.11 Sources of Energy

Solar shingles look like traditional asphalt shingles but they are hooked into a home's electrical system.

9.11 Sources of Energy

Wind, caused by unequal warming of Earth's surface, is another form of solar power.

The energy of wind can be used to turn generator turbines within specially equipped windmills.

Harnessing the wind is very practical when the energy it produces is stored for future use, such as in the form of hydrogen.

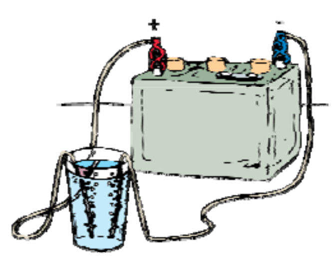
9.11 Sources of Energy

Fuel Cells

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.

9.11 Sources of Energy

An electric current can break water down into hydrogen and oxygen, a process called electrolysis.



9.11 Sources of Energy

If you make the electrolysis process run backward, you have a fuel cell.

In a **fuel cell,** hydrogen and oxygen gas are compressed at electrodes to produce water and electric current.

Watch for the growth of fuel-cell technology. The major hurdle for this technology is not the device itself, but with acquiring hydrogen fuel economically. One way is via solar cells.

9.11 Sources of Energy

Nuclear and Geothermal Energy

The most concentrated form of usable energy is stored in uranium and plutonium, which are nuclear fuels.

Earth's interior is kept hot by producing a form of nuclear power, radioactivity, which has been with us since the Earth was formed.

9.11 Sources of Energy

A byproduct of radioactivity in Earth's interior is geothermal energy.

Geothermal energy is held in underground reservoirs of hot water.

In these places, heated water near Earth's surface is tapped to provide steam for running turbogenerators.

9.11 Sources of Energy

CONCEPT CHECK **What is the source of practically all of our energy on Earth?**

Assessment Questions

1. Raising an auto in a service station requires work. Raising it twice as high requires
   a. half as much work.
   b. the same work.
   c. twice the work.
   d. four times the work.

Assessment Questions

1. Raising an auto in a service station requires work. Raising it twice as high requires
   a. half as much work.
   b. the same work.
   c. twice the work.
   d. four times the work.

Answer: C

Assessment Questions

2. Raising an auto in a service station requires work. Raising it in half the time requires
   a. half the power.
   b. the same power.
   c. twice the power.
   d. four times the power.

Assessment Questions

2. Raising an auto in a service station requires work. Raising it in half the time requires
   a. half the power.
   b. the same power.
   c. twice the power.
   d. four times the power.

Answer: C

Assessment Questions

3. The energy due to the position of something or the energy due to motion is called
   a. potential energy.
   b. kinetic energy.
   c. mechanical energy.
   d. conservation of energy.

Assessment Questions

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Answer: C

Assessment Questions

4. After you place a book on a high shelf, we say the book has increased
   a. elastic potential energy.
   b. chemical energy.
   c. kinetic energy.
   d. gravitational potential energy.

Assessment Questions

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   a. elastic potential energy.
   b. chemical energy.
   c. kinetic energy.
   d. gravitational potential energy.

Answer: D

9 Energy — Conceptual Physics

Assessment Questions

5. An empty truck traveling at 10 km/h has kinetic energy. How much kinetic energy does it have when it is loaded so its mass is twice, and its speed is increased to twice?
   a. the same KE
   b. twice the KE
   c. four times the KE
   d. more than four times the KE

9 Energy — Conceptual Physics

Assessment Questions

5. An empty truck traveling at 10 km/h has kinetic energy. How much kinetic energy does it have when it is loaded so its mass is twice, and its speed is increased to twice?
   a. the same KE
   b. twice the KE
   c. four times the KE
   d. more than four times the KE

Answer: D

9 Energy — Conceptual Physics

Assessment Questions

6. Which of the following equations is most useful for solving a problem that asks for the distance a fast-moving crate slides across a factory floor in coming to a stop?
   a. $F = ma$
   b. $Ft = \Delta mv$
   c. $KE = 1/2mv^2$
   d. $Fd = \Delta 1/2mv^2$

9 Energy — Conceptual Physics

Assessment Questions

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   c. $KE = 1/2mv^2$
   d. $Fd = \Delta 1/2mv^2$

Answer: D

9 Energy — Conceptual Physics

Assessment Questions

7. A boulder at the top of a vertical cliff has a potential energy of 100 MJ relative to the ground below. It rolls off the cliff. When it is halfway to the ground its kinetic energy is
   a. the same as its potential energy at that point.
   b. negligible.
   c. about 60 MJ.
   d. more than 60 MJ.

9 Energy — Conceptual Physics

Assessment Questions

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Answer: A

Assessment Questions

8. In an ideal pulley system, a woman lifts a 100-N crate by pulling a rope downward with a force of 25 N. For every 1-meter length of rope she pulls downward, the crate rises
   a. 25 centimeters.
   b. 45 centimeters.
   c. 50 centimeters.
   d. 100 centimeters.

Assessment Questions

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Answer: A

Assessment Questions

9. When 100 J are put into a device that puts out 40 J, the efficiency of the device is
   a. 40%.
   b. 50%.
   c. 60%.
   d. 140%.

Assessment Questions

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Assessment Questions

10. An energy supply is needed for the operation of a(n)
    a. automobile.
    b. living cell.
    c. machine.
    d. all of these

Assessment Questions

10. An energy supply is needed for the operation of a(n)
    a. automobile.
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    c. machine.
    d. all of these

Answer: D

Assessment Questions

11. The main sources of energy on Earth are
    a. solar and nuclear.
    b. gasoline and fuel cells.
    c. wind and tidal.
    d. potential energy and kinetic energy.

9 Energy
PresentationEXPRESS Conceptual Physics

Assessment Questions

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Answer: A