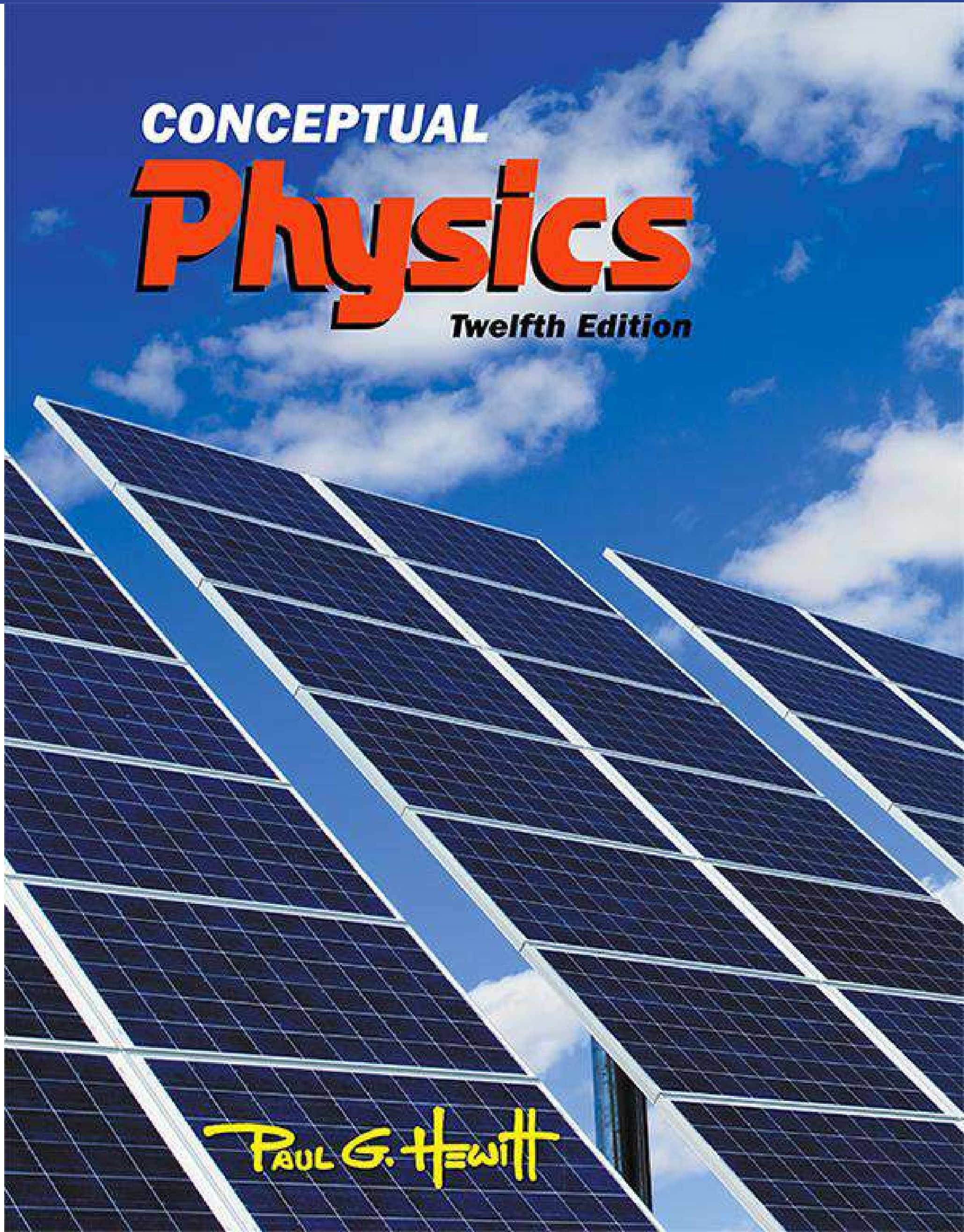
Lecture Outline

# Energy



# This lecture will help you understand:

- Energy
- Work
- Power
- Mechanical Energy: Potential and Kinetic
- Work-Energy Theorem
- Conservation of Energy
- Machines
- Efficiency
- Recycled Energy
- Energy for Life
- Sources of Energy

# Energy

- A combination of energy and matter make up the universe.
- Energy
  - Mover of substances
  - Both a thing and a process
  - Observed when it is being transferred or being transformed
  - A conserved quantity

# Energy, Continued

- Property of a system that enables it to do work
- Anything that can be turned into heat
  - Example: Electromagnetic waves from the Sun
- Matter
  - Substance we can see, smell, and feel
  - Occupies space

# Work

- Work
  - involves force and distance.
  - is force x distance.
  - in equation form: $W = Fd$.

- Two things occur whenever work is done:
  - application of force
  - movement of something by that force

# Work
# CHECK YOUR NEIGHBOR

If you push against a stationary brick wall for several minutes, you do no work

A. on the wall.
B. at all.
C. Both of the above.
D. None of the above.

# Work
# CHECK YOUR ANSWER

If you push against a stationary brick wall for several minutes, you do no work

**A. on the wall.**

**Explanation:**

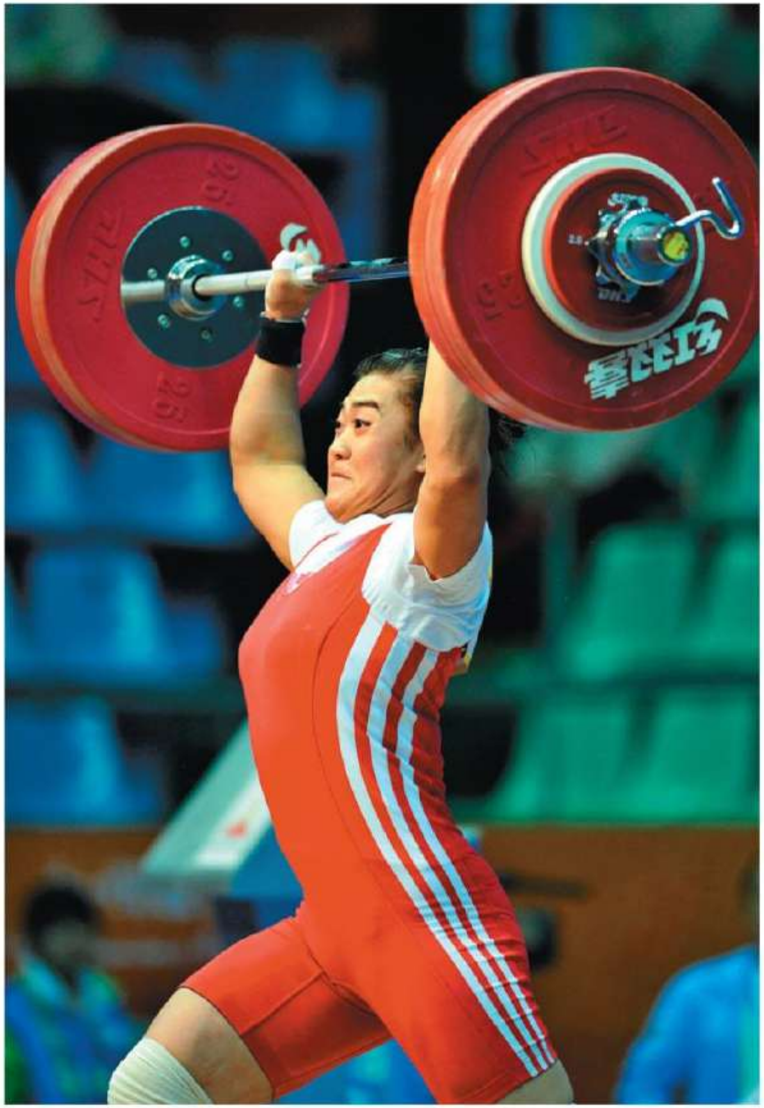
You may do work on your muscles, but not on the wall.

# Work, Continued

- Examples:
  - Twice as much work is done in lifting 2 loads 1 story high versus lifting 1 load the same vertical distance.
    - Reason: force needed to lift twice the load is twice as much.
  - Twice as much work is done in lifting a load 2 stories instead of 1 story.
    - Reason: distance is twice as great.

# Work, Continued-1

- Example:
  - a weightlifter raising a barbell from the floor does work on the barbell.
- Unit of work:
  - newton-meter (Nm) or joule (J)



# Work
# CHECK YOUR NEIGHBOR, Continued

Work is done in lifting a barbell. How much work is done in lifting a barbell that is twice as heavy the same distance?

A. Twice as much
B. Half as much
C. The same
D. Depends on the speed of the lift

# Work
# CHECK YOUR ANSWER, Continued

Work is done in lifting a barbell. How much work is done in lifting a barbell that is twice as heavy the same distance?

**A. Twice as much**

**Explanation:**

This is in accord with work = force x distance. Twice the force for the same distance means twice the work done on the barbell.

# Work
# CHECK YOUR NEIGHBOR, Continued-1

You do work when pushing a cart with a constant force. If you push the cart twice as far, then the work you do is

A. less than twice as much.
B. twice as much.
C. more than twice as much.
D. zero.

# Work
# CHECK YOUR ANSWER, Continued-1

You do work when pushing a cart with a constant force. If you push the cart twice as far, then the work you do is

B. **twice as much.**

# Power

- Power:
  - Measure of how fast work is done
  - In equation form:

$$Power = \frac{work\ done}{time\ interval}$$

# Power, Continued

- Example:
  - A worker uses more power running up the stairs than climbing the same stairs slowly.
  - Twice the power of an engine can do twice the work of one engine in the same amount of time, or twice the work of one engine in half the time or at a rate at which energy is changed from one *form* to another.

# Power, Continued-1

- Unit of power
  - joule per second, called the watt after James Watt, developer of the steam engine
    - 1 joule/second = 1 watt
    - 1 kilowatt = 1000 watts

# Power
# CHECK YOUR NEIGHBOR

A job can be done slowly or quickly. Both may require the same amount of work, but different amounts of

A. energy.
B. momentum.
C. power.
D. impulse.

# Power
## CHECK YOUR ANSWER

A job can be done slowly or quickly. Both may require the same amount of work, but different amounts of

**C. power.**

**Comment:**

Power is the rate at which work is done.

# Mechanical Energy

- Mechanical energy is due to position or to motion, or both.
- There are two forms of mechanical energy:
  - Potential energy
  - Kinetic energy

# Potential Energy

- Stored energy held in readiness with a potential for doing work
- Example:
  - A stretched bow has stored energy that can do work on an arrow.
  - A stretched rubber band of a slingshot has stored energy and is capable of doing work.

# Potential Energy—Gravitational

- Potential energy due to elevated position
- Example:
  - water in an elevated reservoir
  - raised ram of a pile driver

# Potential Energy—Gravitational, Continued

- Equal to the work done (force required to move it upward x the vertical distance moved against gravity) in lifting it
- In equation form:
  - Potential energy

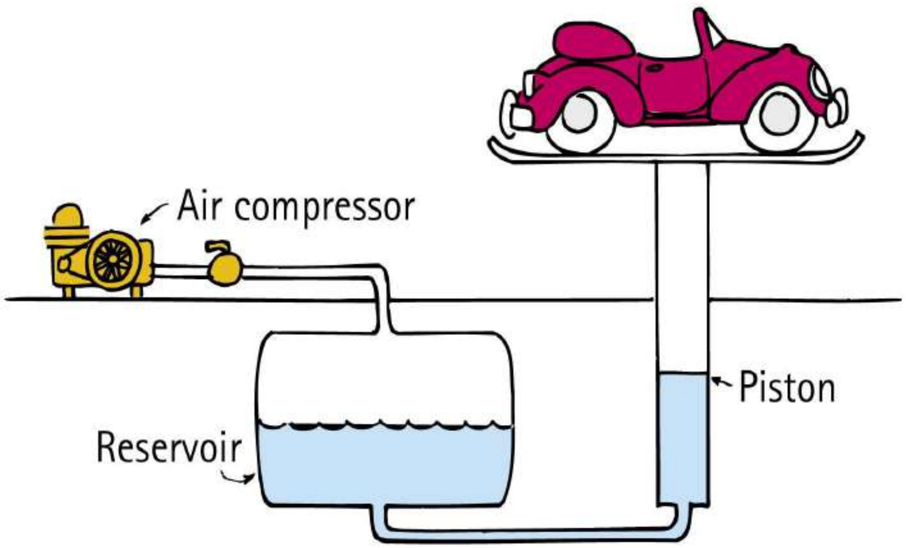
    = mass x acceleration due to gravity x height

    = $mgh$

# Potential Energy
# CHECK YOUR NEIGHBOR

Does a car hoisted for repairs in a service station have increased potential energy relative to the floor?

A. Yes
B. No
C. Sometimes
D. Not enough information



# Potential Energy
# CHECK YOUR ANSWER

Does a car hoisted for repairs in a service station have increased potential energy relative to the floor?

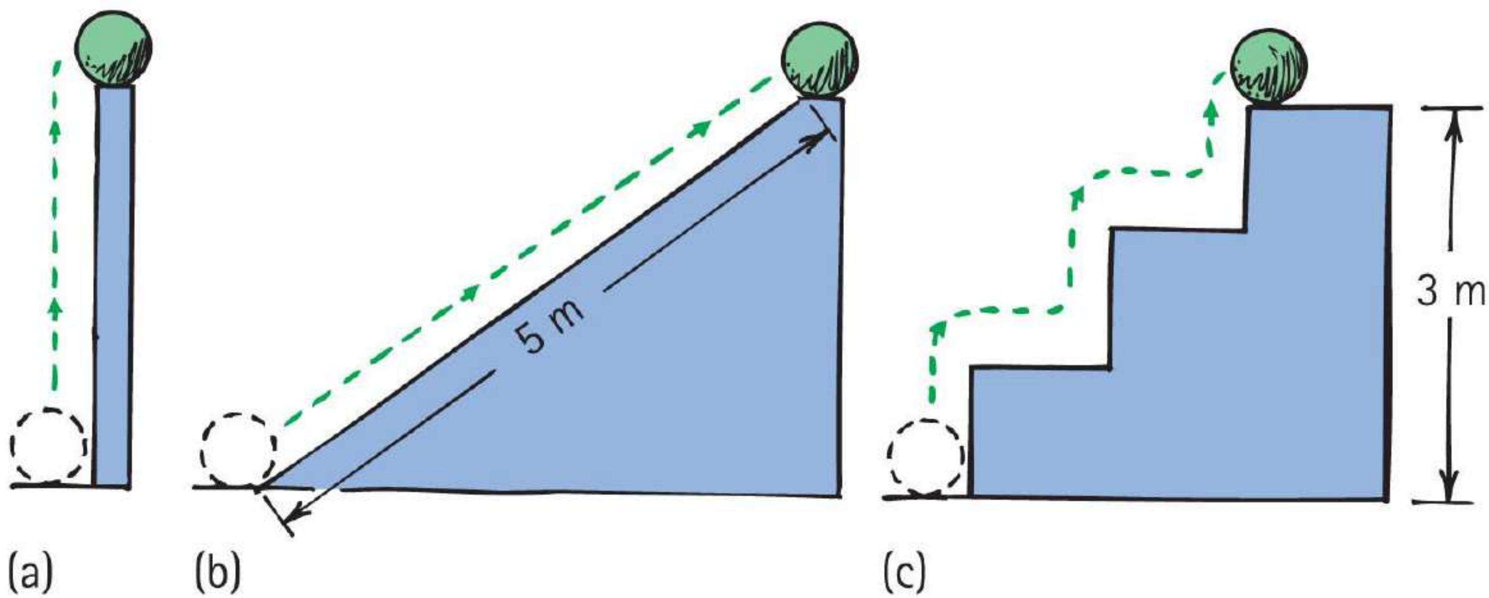
**A. Yes**

**Comment:**

If the car were twice as heavy, its increase in potential energy would be twice as great.

# Potential Energy, Continued

- Example: Potential energy of 10-N ball is the same in all 3 cases because work done in elevating it is the same.



# Kinetic Energy

- Energy of motion
- Depends on the mass of the object and square of its speed
- Include the proportional constant 1/2 and kinetic energy = 1/2 x mass x speed x speed
- If object speed is doubled ⇒ kinetic energy is quadrupled.

# Kinetic Energy
# CHECK YOUR NEIGHBOR

Must a car with momentum have kinetic energy?

A. Yes, due to motion alone
B. Yes, when motion is nonaccelerated
C. Yes, because speed is a scalar and velocity is a vector quantity
D. No

# Kinetic Energy
# CHECK YOUR ANSWER

Must a car with momentum have kinetic energy?

**A. Yes, due to motion alone**

**Explanation:**

Acceleration, speed being a scalar, and velocity being a vector quantity are irrelevant. Any moving object has both momentum and kinetic energy.

# Kinetic Energy, Continued

- Kinetic energy and work of a moving object
  - Equal to the work required to bring it from rest to that speed, or the work the object can do while being brought to rest
  - In equation form: net force x distance = kinetic energy, or $Fd = 1/2\ mv^2$

# Work-Energy Theorem

- Work-energy theorem
  - Gain or reduction of energy is the result of work.
  - In equation form: work = change in kinetic energy ($W = \Delta KE$).
  - Doubling speed of an object requires 4 times the work.

# Work-Energy Theorem, Continued

- Applies to decreasing speed:
  - reducing the speed of an object or bringing it to a halt

- Example: Applying the brakes to slow a moving car, work is done on it (the friction force supplied by the brakes x distance).

# Work-Energy Theorem
# CHECK YOUR NEIGHBOR

Consider a problem that asks for the distance of a fast-moving crate sliding across a factory floor and then coming to a stop. The most useful equation for solving this problem is

A. $F = ma$.
B. $Ft = \Delta mv$.
C. $KE = {}^1/_2 mv^2$.
D. $Fd = \Delta {}^1/_2 mv^2$.

# Work-Energy Theorem
# CHECK YOUR ANSWER

Consider a problem that asks for the distance of a fast-moving crate sliding across a factory floor and then coming to a stop. The most useful equation for solving this problem is

**D.** $Fd = \Delta {}^{1}/_{2}mv^2$.

**Comment:**

The work-energy theorem is the physicist's favorite starting point for solving many motion-related problems.

# Work-Energy Theorem
# CHECK YOUR NEIGHBOR, Continued

The work done in bringing a moving car to a stop is the force of tire friction x stopping distance. If the initial speed of the car is doubled, the stopping distance is

A. actually less.
B. about the same.
C. twice.
D. None of the above.

# Work-Energy Theorem
# CHECK YOUR ANSWER, Continued

The work done in bringing a moving car to a stop is the force of tire friction x stopping distance. If the initial speed of the car is doubled, the stopping distance is

D. **None of the above.**

**Explanation:**

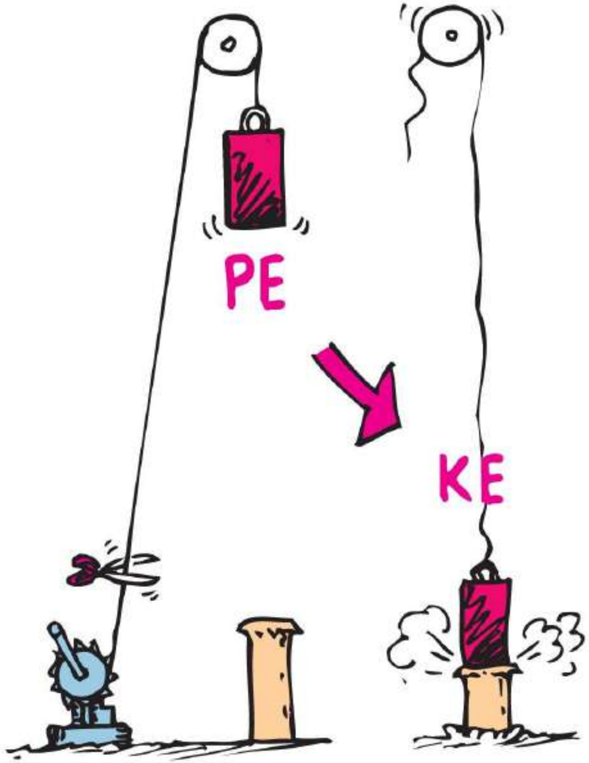
Twice the speed means four times the kinetic energy and four times the stopping distance.

# Conservation of Energy

- Law of conservation of energy
  - Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes.

# Conservation of Energy, Continued

- Example: Energy transforms without net loss or net gain in the operation of a pile driver.



# Conservation of Energy
## A situation to ponder…

- Consider the system of a bow and arrow. In drawing the bow, we do work on the system and give it potential energy. When the bowstring is released, most of the potential energy is transferred to the arrow as kinetic energy and some as heat to the bow.

# A situation to ponder… CHECK YOUR NEIGHBOR

Suppose the potential energy of a drawn bow is 50 joules and the kinetic energy of the shot arrow is 40 joules. Then

A. energy is not conserved.
B. 10 joules go to warming the bow.
C. 10 joules go to warming the target.
D. 10 joules are mysteriously missing.

# A situation to ponder… CHECK YOUR ANSWER

Suppose the potential energy of a drawn bow is 50 joules and the kinetic energy of the shot arrow is 40 joules. Then

C. **10 joules go to warming the bow.**

**Explanation:**

The total energy of the drawn bow, which includes the poised arrow, is 50 joules. The arrow gets 40 joules and the remaining 10 joules warms the bow—still in the initial system.

# Kinetic Energy and Momentum Compared

- Similarities between momentum and kinetic energy:
  - Both are properties of moving things.
- Difference between momentum and kinetic energy:
  - Momentum is a vector quantity and therefore is directional and can be canceled.
  - Kinetic energy is a scalar quantity and can never be canceled.

# Kinetic Energy and Momentum Compared, Continued

- Velocity dependence
  - Momentum depends on velocity.
  - Kinetic energy depends on the square of velocity.
  - Example: An object moving with twice the velocity of another with the same mass, has twice the momentum but 4 times the kinetic energy.

# Machines

- Machine
  - Device for multiplying forces or changing the direction of forces
  - Cannot create energy but can transform energy from one form to another, or transfer energy from one location to another
  - Cannot multiply work or energy

# Machines, Continued

- Principle of a machine
  - Conservation of energy concept:

    Work input = work output

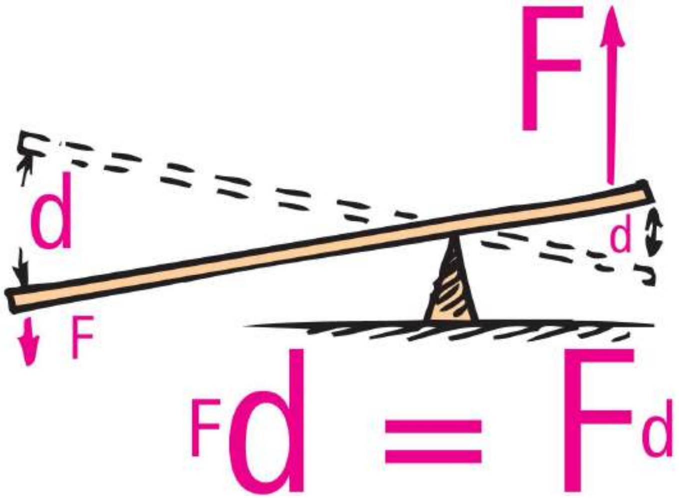
  - Input force x input distance =

    Output force x output distance

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

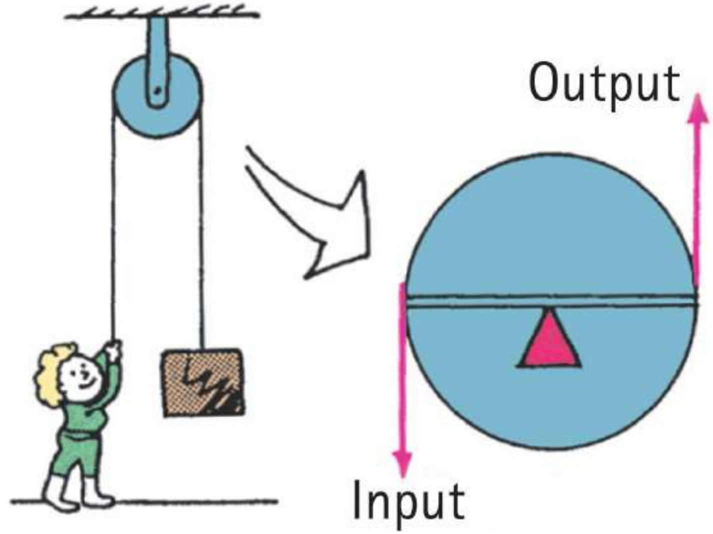
# Machines, Continued-1

- Simplest machine
  - Lever
    - rotates on a point of support called the fulcrum
    - allows small force over a large distance and large force over a short distance



# Machines, Continued-2

- Pulley
  - operates like a lever with equal arms— changes the direction of the input force

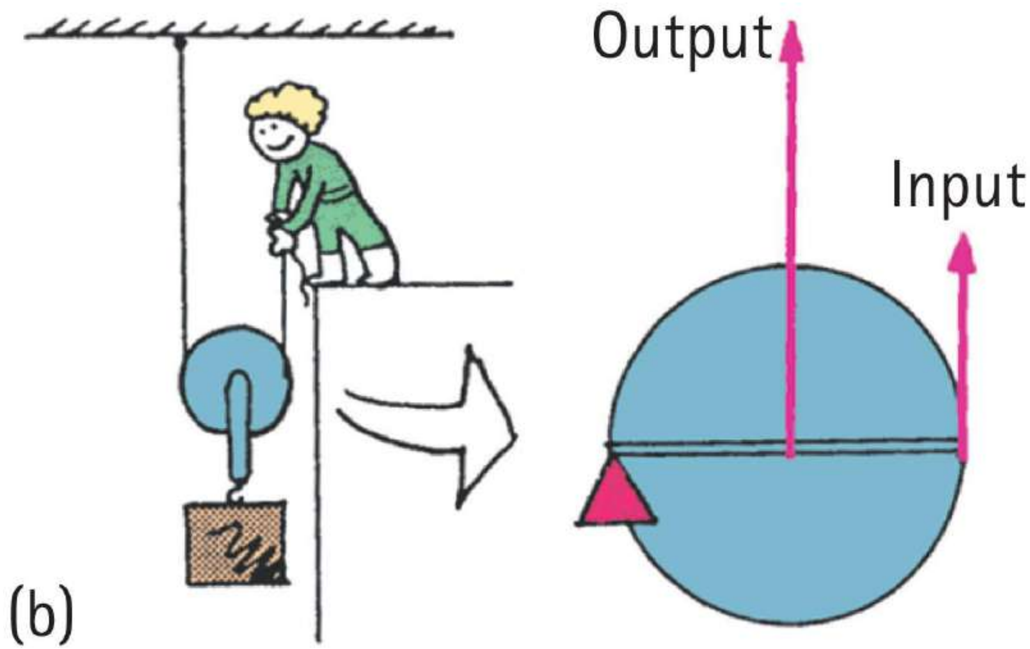



(a)

- Example:
  - This pulley arrangement can allow a load to be lifted with half the input force.

# Machines, Continued-3

- Operates as a system of pulleys (block and tackle)
- Multiplies force



# Machines
# CHECK YOUR NEIGHBOR

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. 50 centimeters.
B. 45 centimeters.
C. 25 centimeters.
D. None of the above.

# Machines
# CHECK YOUR ANSWER

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

C. **25 centimeters.**

**Explanation:**

Work in = work out; *Fd* in = *Fd* out.

One-fourth of 1 m = 25 cm.

# Efficiency

- Efficiency
  - Percentage of work put into a machine that is converted into useful work output
  - In equation form:

$$Efficiency = \frac{useful\ energy\ output}{total\ energy\ input}$$

# Efficiency
# CHECK YOUR NEIGHBOR

A certain machine is 30% efficient. This means the machine will convert

A. 30% of the energy input to useful work—
   70% of the energy input will be wasted.
B. 70% of the energy input to useful work—30% of the energy input will be wasted.
C. Both of the above.
D. None of the above.

# Efficiency
# CHECK YOUR ANSWER

A certain machine is 30% efficient. This means the machine will convert

A. **30% of the energy input to useful work—70% of the energy input will be wasted.**

# Recycled Energy

- Re-employment of energy that otherwise would be wasted.
- Edison used heat from his power plant in New York City to heat buildings.
- Typical power plants waste about 30% of their energy to heat because they are built away from buildings and other places that use heat.

# Energy for Life

- Body is a machine, so it needs energy.
- Our cells feed on hydrocarbons that release energy when they react with oxygen (like gasoline burned in an automobile).
- There is more energy stored in the food than in the products after metabolism.

# Sources of Energy

- Sources of energy
  - Sun
    - Example:
      - Sunlight evaporates water; water falls as rain; rain flows into rivers and into generator turbines; then back to the sea to repeat the cycle.
      - Sunlight can be transformed into electricity by photovoltaic cells.
      - Wind power turns generator turbines.

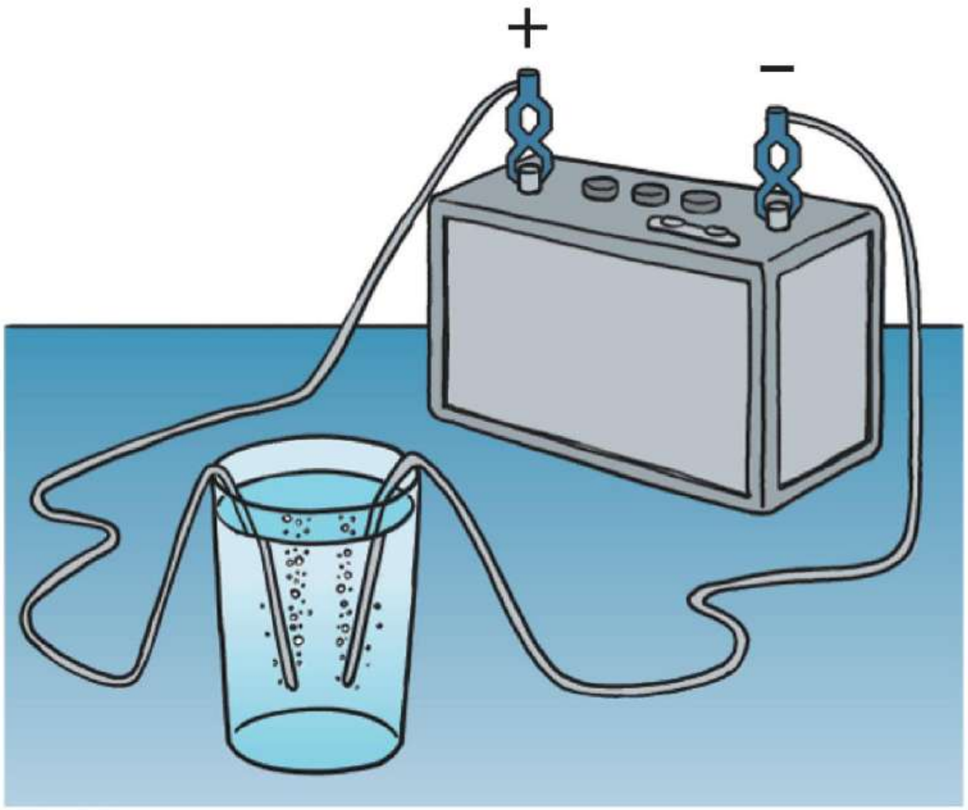
# Sources of Energy, Continued

- Sources of energy
  - Sun
    - Example:
      - Photovoltaic cells on rooftops catch the solar energy and convert it to electricity.

- More energy from the Sun hits Earth in 1 hour than all of the energy consumed by humans in an entire year!

# Sources of Energy, Continued-1

- Fuel cell
  - Runs opposite to the battery shown (where electricity separates water into hydrogen and oxygen).
  - In a fuel cell, hydrogen and oxygen are compressed at electrodes and electric current is produced at electrodes.



# Sources of Energy, Continued-2

- Concentrated energy
  - Nuclear power
    - stored in uranium and plutonium
    - by-product is geothermal energy
      - held in underground reservoirs of hot water to provide steam that can drive turbogenerators

# Sources of Energy, Continued-3

- Dry-rock geothermal power is a producer of electricity.
  - Water is put into cavities in deep, dry, hot rock. Water turns to steam and reaches a turbine, at the surface. After exiting the turbine, it is returned to the cavity for reuse.