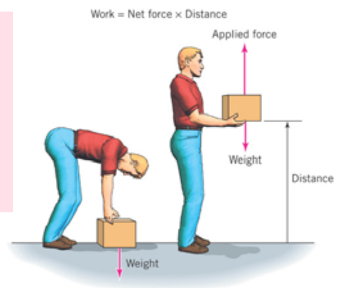
Chap 8 Kinetic and Potential Energy

WORK

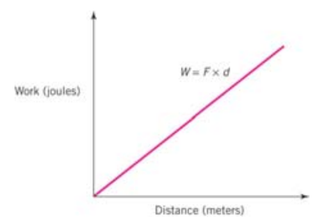
Work is done whenever a force is exerted over a distance. The amount of work done is proportional to both the force and the distance.



$$W = F \cdot d$$

SI Unit of Work:

newton x meter = joule (J)



What if force and displacement don't point in the same direction?

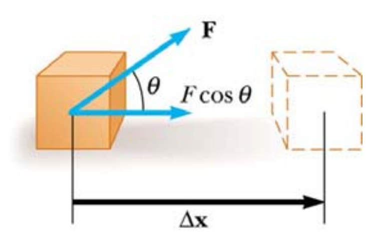
Work is the product of force and the distance traveled in the direction of the force. Alternatively, it is the product of displacement and the component of force in the direction of the displacement.

The **work** done on an object by a constant force F is

$$W = (F \cos\theta) \Delta x ,$$

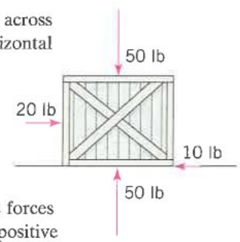
Where F is the magnitude of the force, Δx is the magnitude of the displacement, and θ is the angle between the force and the displacement.

Work does not depend on velocity or time. It can be positive or negative (when $\cos\theta < 0$).

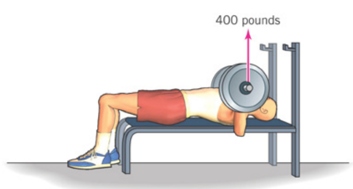


Work

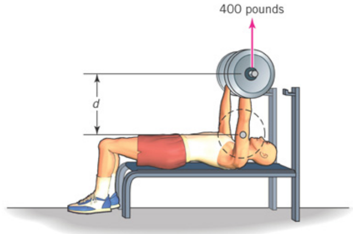
A 50-pound crate is pushed across the floor by a 20-pound horizontal force. Aside from the pushing force and gravity, there is also a 50-pound force exerted upward on the crate and a 10-pound frictional force, as shown in the figure. Which of these forces does no work? Which does positive work? Which does negative work?



Work Against Gravity



(a)



(b)

$$W = F \cdot d = mg \cdot d$$

How much work against gravity do you do when you climb a flight of stairs 3 meters high? Compare this work to the energy consumed by a 60-watt lightbulb in an hour. How many flights of stairs would you have to climb to equal the work of the lightbulb?

What Changes When Work Is Done?

Without external forces, Newton's first law tells us that the velocity of an object does not change. When an external force F is applied to the object, an acceleration a = F/m takes place. If the work done on the object is positive, the velocity of the object increases. By how much does the velocity increase or decrease? Is this increase or decrease in velocity related to the work done?

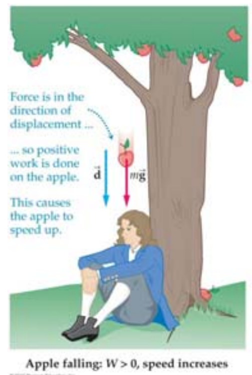
If the force acted on an object with mass m, originally at rest, for a distance of d, the acceleration is a=F/m

$$d = \tfrac{1}{2}at^2 = \frac{a^2t^2}{2a}$$

The final velocity is $v = at$

$$W = F \cdot d = ma\frac{v^2}{2a} = \frac{mv^2}{2}$$

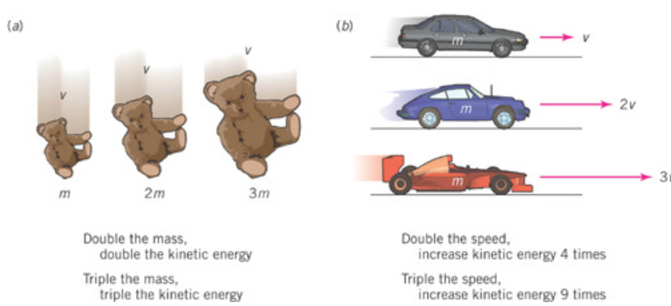
When work is done, the quantity $mv^2/2$ changes by the amount of work done.



Kinetic Energy

Kinetic energy equals the mass of the moving object times the square of the object's velocity, multiplied by the constant ½.

$$K.E. = \frac{1}{2}mv^2$$



Work and Kinetic Energy

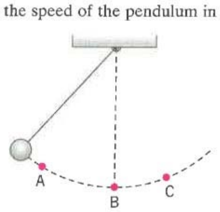
The change in kinetic energy of an object equals the net work done on that object.

2. Would you rather be hit by a 1-kilogram mass traveling 10 meters per second, or a 2-kilogram mass traveling 5 meters per second?

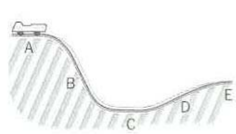
3. Compared to a car moving at 10 miles per hour, how much kinetic energy does that same car have when it moves at 20 miles per hour? At 30 miles per hour? At 60 miles per hour? What do these numbers suggest to you about the difficulty of stopping a car as its speed increases?

Work and Kinetic Energy

A pendulum swings left to right in the figure. At wh
cations in the pendulum's swing is the gravitational
doing positive work? Negative work? No work? What is happening to the speed of the pendulum in each case?



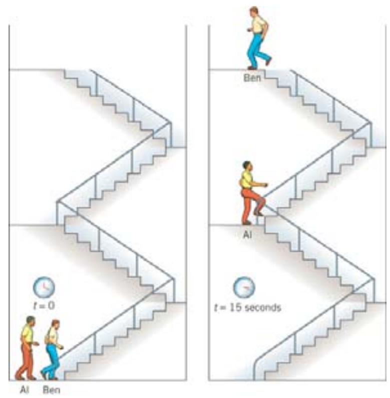
5. Where in the roller coaster ride shown in the figure is the gravitational force doing positive work? Negative work? No work? What is happening to the speed of the car in each case?



Power

POWER is the amount of work done divided by the time it takes to do it. Power is the rate at which work is done, or, equivalently, the rate at which energy is expended.

$$P = \frac{W}{t} \quad \text{or} \quad P = \frac{E}{t}$$



SI Unit of power:

joule / sec = watt

2. Two construction cranes are each able to lift a maxi load of 20,000 N to a height of 100 meters. However crane can lift that load in $\frac{1}{3}$ the time it takes the other. much more power does the faster crane have?

3. As a freely falling object picks up downward speed, happens to the power supplied by the gravitational fc Does it increase, decrease, or stay the same?

Power Examples

4. A small air compressor operates on a 1.5-horsepower electric motor for 8 hours a day. How much energy is consumed by the motor daily? If electricity costs 10 cents a kilowatt-hour, how much does it cost to run the compressor each day? (*Note:* 1 horsepower equals about 750 watts.)

7. Georgie was pulling her brother (20 kg) in a 10-kg sled with a constant force of 25 newtons for one block (100 meters).

a. What is the work done by Georgie?

b. How long would a 100-watt lightbulb have to glow to produce the same amount of energy expended by Georgie?

8. A woman weight lifter can lift a 150-lb weight from the floor to a stand 3.5 feet off the ground. What is the total work done by the woman in ft-lb and joules?

9. The stair stepper is a novel exercise machine that attempts to reproduce the work done against gravity by walking up stairs. With each step, Brad (60 kg) simulates stepping up a distance of 0.2 meters with this machine. If Brad exercises for 15 minutes a day with a stair stepper at a frequency of 60 steps per minute, what is the total work done by Brad each day?

Types of Energy

Kinetic Energy $$K.E. = \frac{1}{2}mv^2$$

Potential Energy $$P.E. = mgh$$

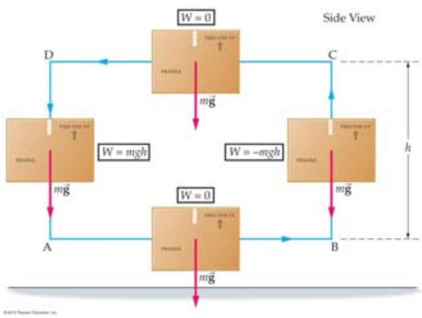
The gravitational potential energy of any object equals its weight (gravitational force) times its height above the ground.

Potential energy is a useful concept only for forces that are "conservative". Beside gravitational force, another example of conservative force is the elastic force of an ideal spring.

Work done against Gravitation

Potential Energy and Conservation of Energy

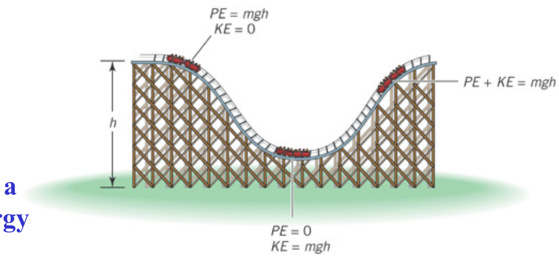
Conservative Force: **is one that does zero total work on any closed path.**



Force is conservative, if the work done by a force in going from an arbitrary point A to an arbitrary point B is independent of the path from A to B.

Energy Conservation

In a closed system, neglecting any frictional forces, the total amount of kinetic and gravitational potential energy is conserved.



FREE FALL

The kinetic energy at the end of a fall is equal to the potential energy at the beginning.

$$mgh = \tfrac{1}{2}mv^2$$

$$gh = \tfrac{1}{2}v^2 \qquad v = \sqrt{2gh}$$

Projectile Motion

The Work-Energy Theorem

The total potential and kinetic energy of an object in a given state is equal to the work that was done to bring the object to that state.

12. In the absence of air resistance, a falling rock gains kinetic energy and loses potential energy, with the total energy of the rock remaining constant. In the presence of air resistance, however, the rock eventually reaches terminal velocity. Now the kinetic energy is constant, but the potential energy continues to decrease as the rock falls toward the ground. What has happened to this missing energy?

13. According to the work-energy theorem, if work is done on an object, its potential and/or kinetic energy changes. Consider a car that accelerates from rest on a flat road. What force did the work that increased the car's kinetic energy?

Example Problems

13. You throw a softball (250 g) straight up into the air. It reaches a maximum altitude of 15 meters and then returns to you. (Assume the ball departed from and returned to ground level.)

a. What is the gravitational potential energy (in joules) of the softball at its highest position?

b. What is the kinetic energy of the softball as soon as it leaves your hand? (Assume that there are no energy losses by the softball while it is in the air.)

c. What is the kinetic energy of the softball when it returns to your hand?

d. From the kinetic energy, calculate the velocity of the ball.

16. While skiing in Jackson, Wyoming, your friend Ben (65 kg) started his descent down the bunny run, 25 meters above the bottom of the run. If he started at rest and conv all of his gravitational potential energy into kinetic er

a. What is Ben's kinetic energy at the bottom of the b run?

b. What is his final velocity?

c. Is this speed reasonable?

17. Lora (50 kg) is an expert skier. If she starts at 3 m/s a top of the lynx run, which is 85 meters above the bo what is her final speed if she converts all her gravitat potential energy into kinetic energy? What is her fin netic energy at the bottom of the ski run?