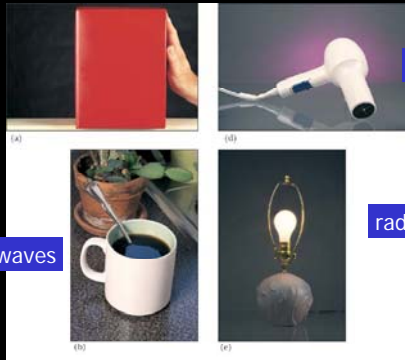


Chapter 5: Energy

work



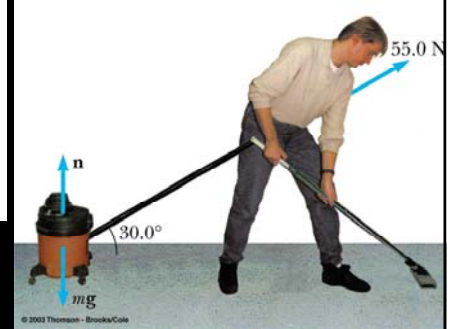
heat

Mechanical waves

radiation

Work: example

The vacuum cleaner is displaced 3.00 m to the right as Mr. Clean does his cleaning. Calculate the work done by the 55.0 N force on the vacuum cleaner.



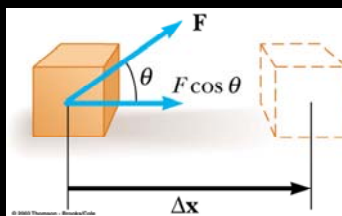
Work

The work done by a constant force on an object is defined as a product of the component of the force along the direction of displacement and the magnitude of the displacement

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

Note that Work is a scalar!

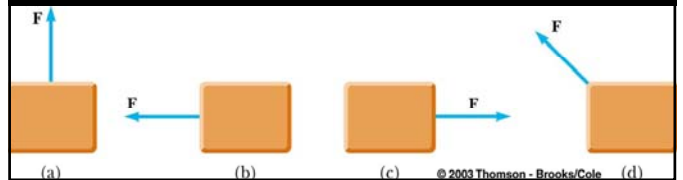
Units
 $1J \equiv 1Nm$



Work: problem

In all four cases the force has the same magnitude and the displacement of the object is to the right and of the same magnitude. Which corresponds to

1. No work done? (a,b,c,d)
2. Most positive work done? (a,b,c,d)



Work-Kinetic Energy Theorem

The kinetic energy of an object with mass m moving with a speed v is a scalar quantity given by

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

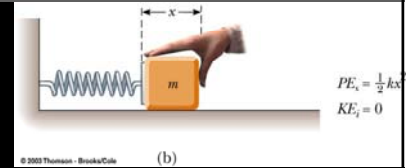
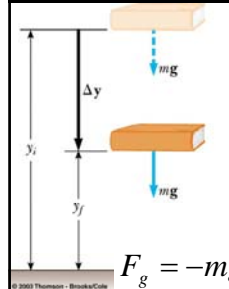
When work is done by a net force on an object and the only change in the object is its speed, the work done is equal to the change in the object's kinetic energy.

$$W_{net} = KE_f - KE_i = \Delta KE$$

Potential Energy: gravitational and elastic

Gravitational Potential energy

$$PE = mgy$$

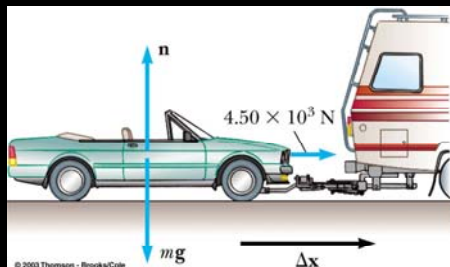


Hooke's Law $F_{el} = -kx$

Potential energy stored in a spring $PE = \frac{1}{2}kx^2$

Work-Kinetic energy: example

A car of mass $1.40 \times 10^3 \text{ kg}$ being towed has a net force of $4.50 \times 10^3 \text{ N}$ applied. The car starts from rest and travels down a horizontal highway. Find the speed of the car after it has traveled 100.0 m . (Ignore losses due to friction and air resistance)



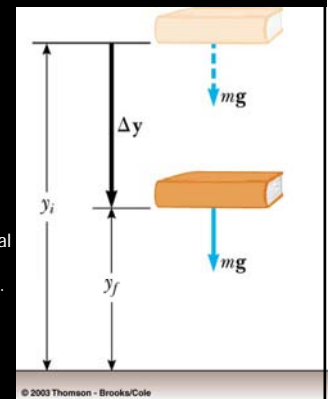
Kinetic and gravitational potential energy

The book is initially at a certain height and has maximum potential energy.

As it falls it transforms its potential energy into kinetic energy: its velocity increases.

When it reaches the ground its potential energy is completely transformed into kinetic energy: its velocity is maximum.

When it hits the ground all its kinetic energy is transformed into heat.

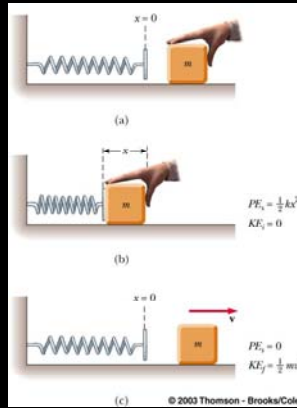


Kinetic and potential energy of a spring

The spring at rest has no potential energy. The block at rest has not kinetic energy

The compressed spring has potential energy. If the block is at rest, its initial kinetic energy is zero

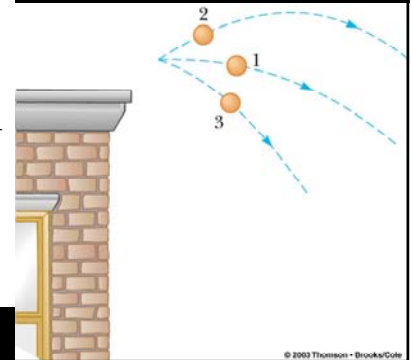
When the spring extends to its normal length all the potential energy is transferred into kinetic energy of the block.



Energy conservation: quiz

Three balls are thrown with the same initial speed. The first is thrown horizontally, the second at some angle above the horizontal and the third at some angle below the horizontal. Neglecting air resistance, which one reaches the ground with largest speed?

- 1
- 2
- 3
- All have the same speed

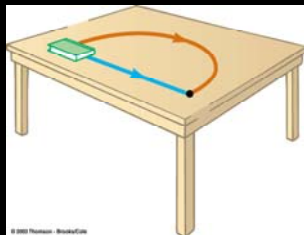


Conservative and non-conservative Forces

A force is conservative if the work it does on an object moving between two points is independent of the path the object takes.

Otherwise we say it is a non-conservative force.

Is the muscular force conservative?



Conservation of Mechanical Energy

In any isolated system of objects that interact only through conservative forces, the total mechanical energy of the system (the sum of the kinetic and potential energy) remains constant.

$$KE_f + PE_f = KE_i + PE_i$$

If gravity is the only force doing work then:

$$\frac{1}{2}mv_f^2 + mgy_f = \frac{1}{2}mv_i^2 + mgy_i$$

Energy Balance

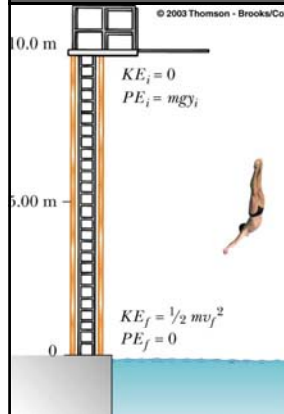
If there is a non-conservative force that is dissipative (friction, air resistance) its work is negative and the mechanical energy of the system will reduce.

$$KE_f + PE_f = KE_i + PE_i - W_{diss}$$

If there is a non-conservative external force that is pumping energy into the system, its work is positive and the mechanical energy of the system will increase.

$$KE_f + PE_f = KE_i + PE_i + W_{Ext}$$

Energy conservation: example



A diver of mass m drops from a board 10.0 m above the water surface.

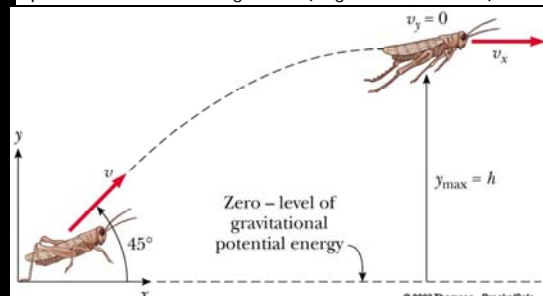
- Use conservation of mechanical energy to find his speed 5.00 m above the water surface.
- Find the speed of the diver just before he strikes the water.

Strategy applying energy conservation

- define your system
- select a location for the zero gravitational potential energy
- determine whether all forces are conservative
- define the initial and final point to consider
- if mechanical energy is conserved, write down the initial mechanical energy and the final mechanical energy and solve for the unknown
- if there is a non-conservative force, calculate the work done by it and write down the energy balance equation

Energy conservation: example

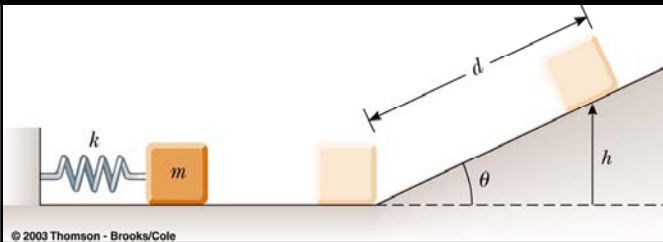
A powerful grasshopper launches itself at an angle 45° above the horizontal and rises vertically about 1.0 m. With what speed v does it leave the ground? (Neglect air resistance)



Energy conservation: example

A 0.50 Kg block rests on a horizontal, frictionless surface. The block is pressed against a light spring having $k=80.0$ N/m. The spring is compressed a distance of 2.0 cm to point A, and released.

- Find the speed of the block when it is at the bottom of the incline B
- Find the maximum distance d the block travels up the incline if the angle is 25° .



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Power

TABLE 5.2 Maximum Power Output from Humans for Various Time Periods

Power	Time
2 hp or 1 500 W	6 s
1 hp or 750 W	60 s
0.35 hp or 260 W	35 min
0.2 hp or 150 W	5 h
0.1 hp or 75 W (Safe daily level)	8 h

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Power

Power is the time rate of energy transfer

$$\bar{P} \equiv \frac{W}{\Delta t}$$

SI Units: $1W=1$ J/s

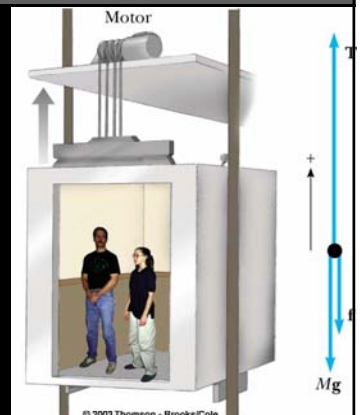
Conversion: $1hp=746$ W

Prove that for a constant force over time:

$$\bar{P} = F\bar{v}$$

Power: example

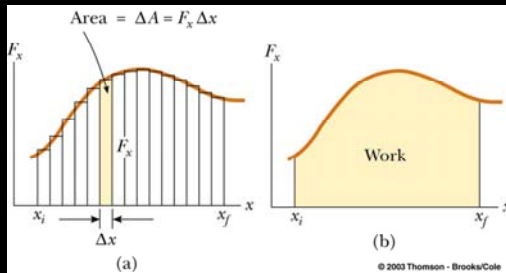
A 1000 Kg elevator carries a maximum load of 800 Kg. A constant frictional force of 4000N retards its motion upward. What minimum power (in kilo-Watt and horse power) must the motor deliver to lift the fully loaded elevator at a constant speed of 3.00 m/s?



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Work done by a varying force

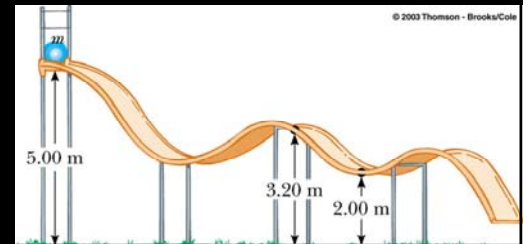
The work done by a variable force acting on an object that undergoes a displacement is equal to the area under the graph F_x versus x .



More problems

A bead of mass $m=5.00$ Kg is released from point A and slides on the frictionless track. Determine:

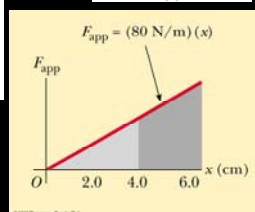
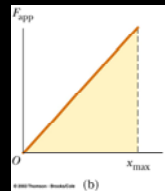
- The bead's speed at points B and C
- The net work done by the force of gravity in moving the bead from A to C



Work done by a varying force: example

One end of a horizontal spring ($k=2000$ N/m) is held fixed while an external force is applied to the free end, stretching it slowly from $x=0$ to $x=4.0$ cm.

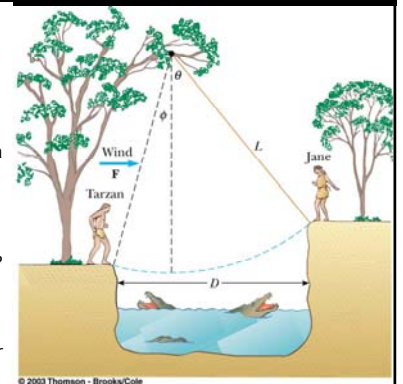
- Find the work done by the applied force.
- Find the additional work done in stretching the spring from 4.0 cm to 7.0 cm.



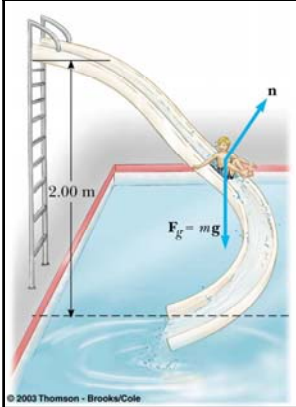
More problems

Jane ($m=50.0$ Kg) needs to swing across a river filled with crocodiles in order to rescue Tarzan ($m=80.0$ Kg). However she must swing into a constant horizontal wind force F on a vine that is initially at an angle 50.0° ($D=50.0$ m, $F=110$ N, $L=40.0$ m)

- With what minimum speed must Jane begin her swing?
- Once the rescue is complete they must jump back. With what minimum speed must they begin their swing?



More problems



A child of mass $m=20.0$ Kg takes a ride on an irregular curved water slide of height 2.00 m. He starts from rest at the top.

- Determine the speed of the child at the bottom, assuming no friction process.
- If a friction force acts on the child, and he arrives at the bottom of the slide with a speed $v=3.00$ m/s, by how much does the mechanical energy of the system decrease due to this force?