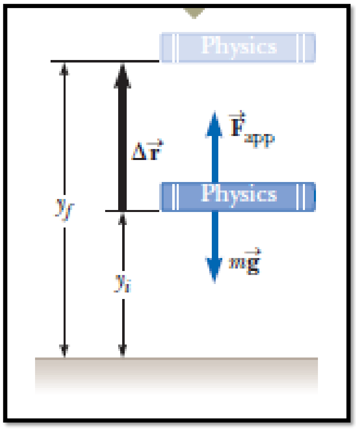
Potential energy

Potential Energy of a System

- **Potential energy** is associated with the *position* of the object within some system

- Gravitational Potential Energy is the energy associated with the relative position of an object in space near the Earth’s surface

Potential Energy of a System



he system is the Earth and the book :

Let us consider a mass (m) at an initial height (y_i) above the ground to a final height y_f as in Figure.

The work W done by the gravitational force as the mass undergoes a downward displacement ($\Delta\vec{r} = \Delta y\hat{j}$) is

$$W_{ext} = (\vec{F}_{app}) \cdot (\Delta\vec{r}) = (mg\hat{j}) \cdot [(y_f - y_i)\hat{j}] = mgy_f - mgy_i$$

This quantity is called potential energy:

$$PE = mgy$$

Potential Energy of a System

The **gravitational potential energy** U_g:

$$U_g = mgy$$

- The units of gravitational potential energy are joules, the same as the units of work and kinetic energy.
- Potential energy, like work and kinetic energy, is a scalar quantity.

Using our definition of gravitational potential energy, we can rewrite :

$$W_{ext} = \Delta U_g$$

which describes that the net external work done on the system in this situation appears as a change in the gravitational potential energy of the system.

Potential Energy of a System

- Gravitational potential energy depends only on the vertical height of the object above the surface of the Earth.
- In solving problems, you must choose a reference configuration for which the gravitational potential energy of the system is set equal to some reference value, which is normally zero.

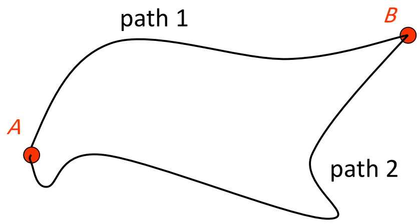
Conservative Forces:

* The work done by a conservative force on a particle moving between any two points is independent of the path taken by the particle.

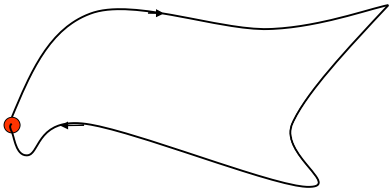
* The work done by a conservative force on a particle moving through any closed path is zero.

* A closed path is one in which the beginning and ending points are the same.

* Examples of conservative forces:
  Gravity
  Spring force



$W_1 = W_2$



Total work is zero.

Conservative Forces:

This can be done only for conservative forces.
In general: $W_{int} = -\Delta U$

W_{int} is used as a reminder that the work is done by one member of the system on another member and is internal to the system.

* Positive work done by an outside agent on a system causes an increase in the potential energy of the system.

* Work done on a component of a system by a conservative force internal to an isolated system causes a decrease in the potential energy of the system

Isolated System (Energy)

Isolated systems

- Total energy of the system is constant
- This means that energy cannot be created nor destroyed.
- For an isolated system, $\Delta E_{mech} = 0$
  Remember $E_{mec} = K + U_g$
  Then $\Delta K + \Delta U_g = 0$
  This is ***conservation of energy*** for an isolated system with conservative forces acting.
- The changes in energy can be written out and rearranged.

$$K_f + U_f = K_i + U_i$$

- The total mechanical energy is conserved and remains the same at all times $\frac{1}{2}mv_i^2 + mgy_i = \frac{1}{2}mv_f^2 + mgy_f$

Nonconservative Forces:

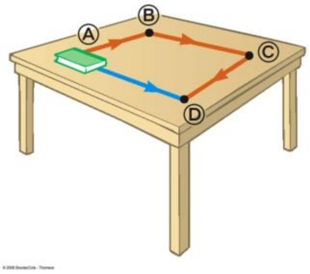
A force is nonconservative if the work it does on an object depends on the path taken by the object between its final and starting points.

- The work depends upon the movement path
- For a non-conservative force, potential energy can NOT be defined
- As the book moves through a distance d, the only force that does work on it is the force of kinetic friction.
- This force causes a decrease in the kinetic energy of the book. This decrease was calculated

$$\Delta K = -f_k d$$

- the mechanical energy of the system changes because of the force of kinetic friction

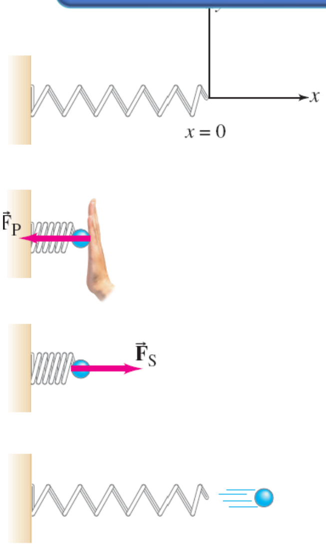
$$\boxed{\Delta E_{\text{mech}} = \Delta K + \Delta U_g = -f_k d}$$



8.2 Analysis Model: Isolated System (Energy)

conservative force e.g : $F_g = mg$	Nonconservative force e.g : $f_s = \mu_s n$
acts on an isolated system	acts on a non-isolated system
Caused no change of a mechanical energy $\Delta E_{mech} = 0$ $E_{f,mech} = E_{i,mech}$	Caused a change in a mechanical energy $\Delta E_{mech} = E_{int}$ $\Delta E_{mech} = - f_s . d$ $E_{f,mech} \neq E_{i,mech}$
$E_{mech} = K + U$ $\Delta E_{mech} = \Delta K + \Delta U = 0$	$E_{f,mech} = E_{i,mech} + E_{int}$ $\Delta E_{mech} = \Delta K + \Delta U = - f_s . d$
$\Delta K = - \Delta U$ $W_{net} = \Delta K$ $W_{net} = - \Delta U$	$W_{net} = \Delta E_{mech} = \Delta K + \Delta U = - f_s . d$

Elastic Potential Energy



A spring has potential energy, called elastic potential energy, when it is compressed. The force required to compress or stretch a spring is:

$$F_S = -kx,$$

where k is called the spring constant.

The potential energy is:

$$U_{el}(x) = \tfrac{1}{2}kx^2.$$

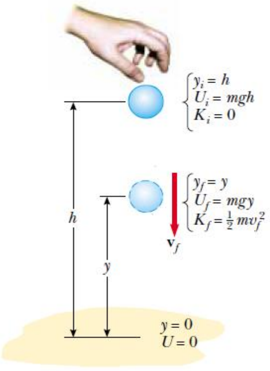
Example

Example 8.2 Ball in Free Fall

A ball of mass m is dropped from a height h above the ground, as shown in Figure 8.6.

(A) Neglecting air resistance, determine the speed of the ball when it is at a height y above the ground.

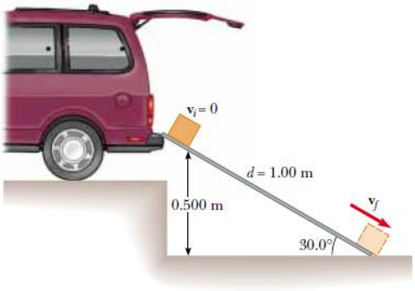
(B) Determine the speed of the ball at y if at the instant of release it already has an initial upward speed v_i at the initial altitude h.



Example

Example 8.6 Crate Sliding Down a Ramp

A 3.00-kg crate slides down a ramp. The ramp is 1.00 m in length and inclined at an angle of 30.0°, as shown in Figure 8.11. The crate starts from rest at the top, experiences a constant friction force of magnitude 5.00 N, and continues to move a short distance on the horizontal floor after it leaves the ramp. Use energy methods to determine the speed of the crate at the bottom of the ramp.



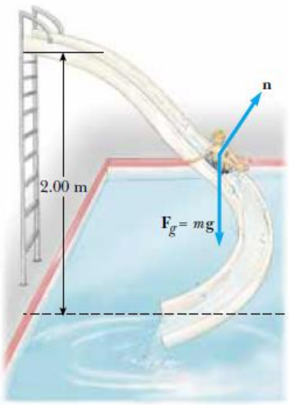
Example

Example 8.7 Motion on a Curved Track

A child of mass m rides on an irregularly curved slide of height $h = 2.00$ m, as shown in Figure 8.12. The child starts from rest at the top.

(A) Determine his speed at the bottom, assuming no friction is present.

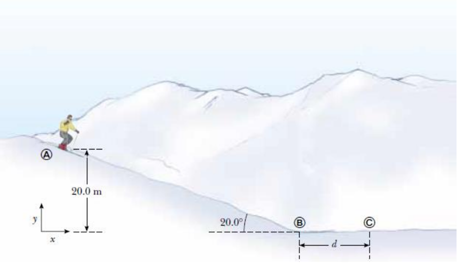
(B) If a force of kinetic friction acts on the child, how much mechanical energy does the system lose? Assume that $v_f = 3.00$ m/s and $m = 20.0$ kg.



Example

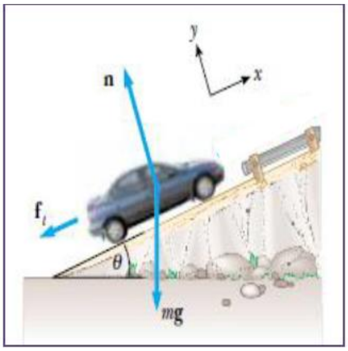
Example 8.8 Let's Go Skiing!

A skier starts from rest at the top of a frictionless incline of height 20.0 m, as shown in Figure 8.13. At the bottom of the incline, she encounters a horizontal surface where the coefficient of kinetic friction between the skis and the snow is 0.210. How far does she travel on the horizontal surface before coming to rest, if she simply coasts to a stop?

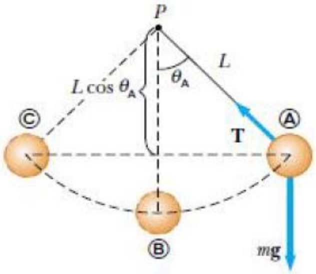


Consider a car of mass 30 kg that is slide 5m and it is at angle θ = 20 with respect to the ground , starts from rest at the bottom of the slide. The μ_k =0.2

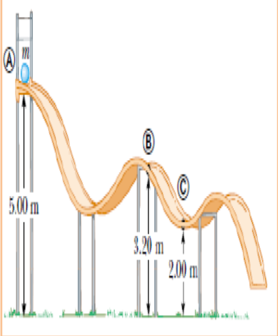
What is the total work done by the friction force on the car ?



This simple pendulum consists of a small sphere of mass *m attached to* a massless cord of length *l*. The sphere is released from rest (without a push) at $t = 0$, where the cord makes an angle θ to the vertical.
Find the speed of the sphere when it is at the lowest point B.



24 - A particle of mass $m = 5$kg is released from point A and slides on the frictionless track shown in Figure. Determine
(a) the particle's speed at points B and C and
(b) the net work done by the gravitational force in moving the particle from A to C.



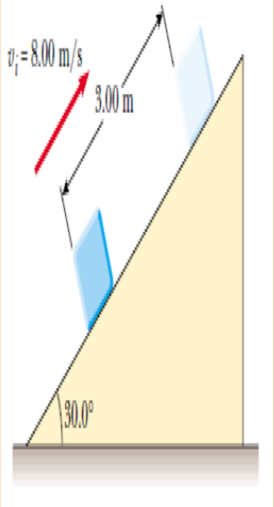
33 - A 5.00-kg block is set into motion up an inclined plane with an initial speed of 8.00 m/s .The block comes to rest after traveling 3.00 m along the plane, which is inclined at an angle of 30.0° to the horizontal. For this motion determine

(a) the change in the block's kinetic energy,

(b) the change in the potential energy of the block–Earth system

(c) the friction force exerted on the block (assumed to be constant).

(d) What is the coefficient of kinetic friction?



Power

Power is the time rate of energy transfer.
The ***instantaneous power*** is defined as

$$P \equiv \frac{dE}{dt}$$

Using work as the energy transfer method, this can also be written as

$$P_{avg} = \frac{W}{\Delta t}$$

The SI unit of power is called the watt.
1 watt = 1 joule / second = 1 kg · m^2 / s^3