Potential Energy and Conservation of Energy

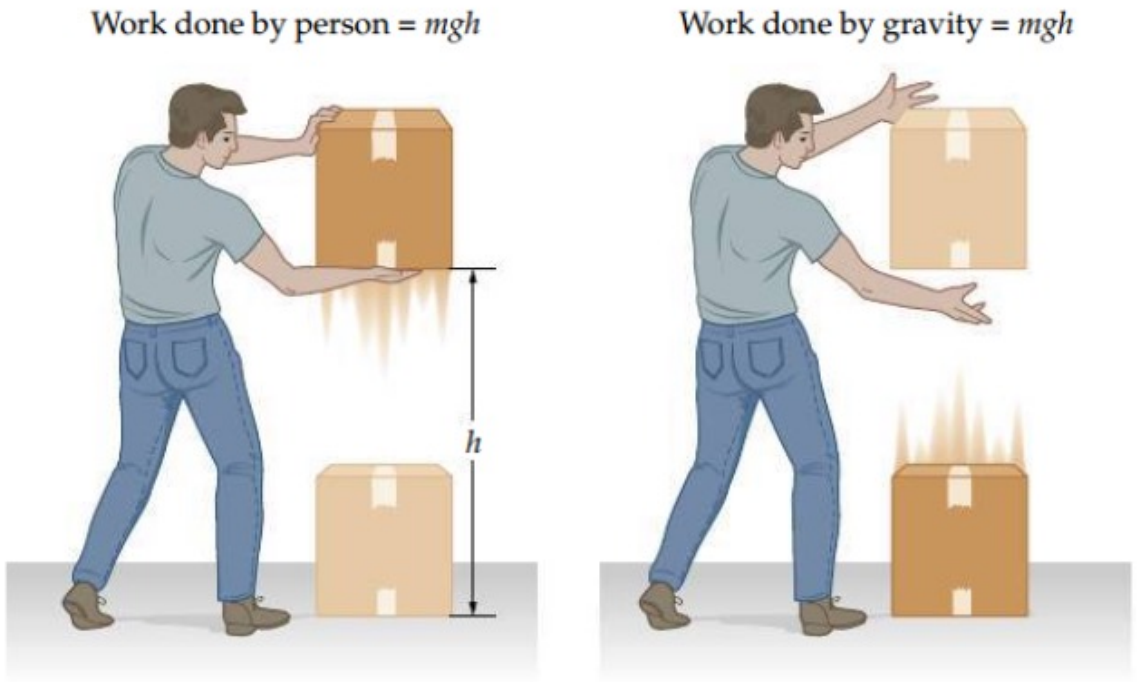
Chapter 8

Units of Chapter 8

- Conservative and Non-conservative Forces
- Potential Energy and the Work Done by Conservative Forces
- Conservation of Mechanical Energy
- Work done by non conservative forces.

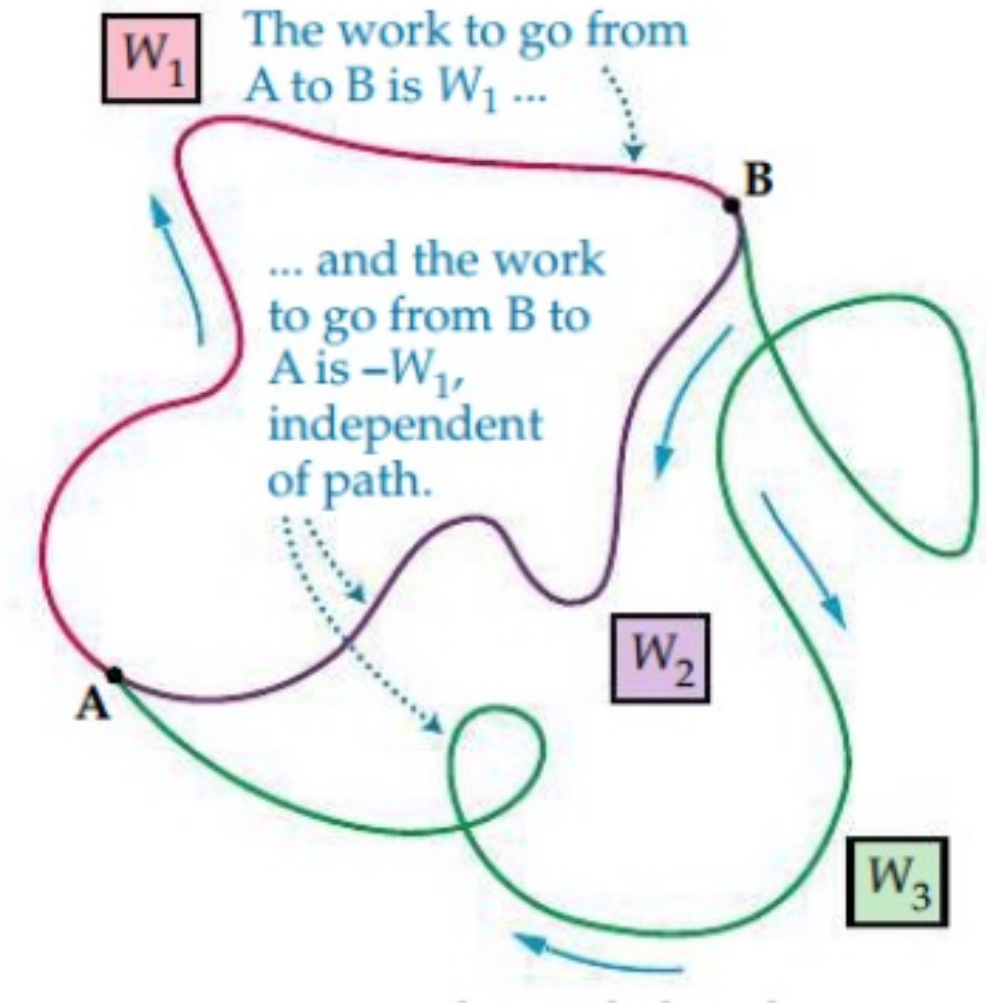
8-1 Conservative and Non-conservative Forces.

- ✓ **Conservative force**: the work it does is stored in the form of energy that can be released later.
- ✓ Conservative force is a force does zero total work on any closed path.
- ✓ Example: gravity, spring force, electrical force



8-1 Conservative and Non-conservative Forces.

- ✓ 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, the force is conservative.

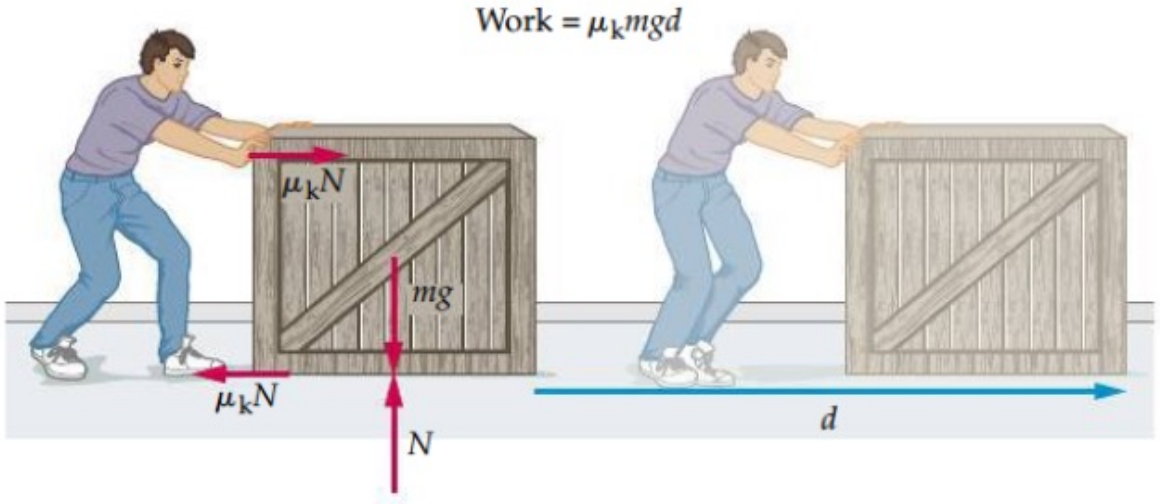


8-1 Conservative and Non-conservative Forces.

Non – Conservative force :-Forces that do not store energy are called non-conservative or **dissipative forces**.

The work done by a nonconservative force on a closed path is nonzero. The work is also path dependent.

Example: friction force, Tension, air resistance.



The difference between conservative and non-conservative force.

Conservative force:-

- Forces that store energy are called **conservative forces**. Gravity is a conservative force
- work done by a force depends only on the initial and final states and not on the path taken.

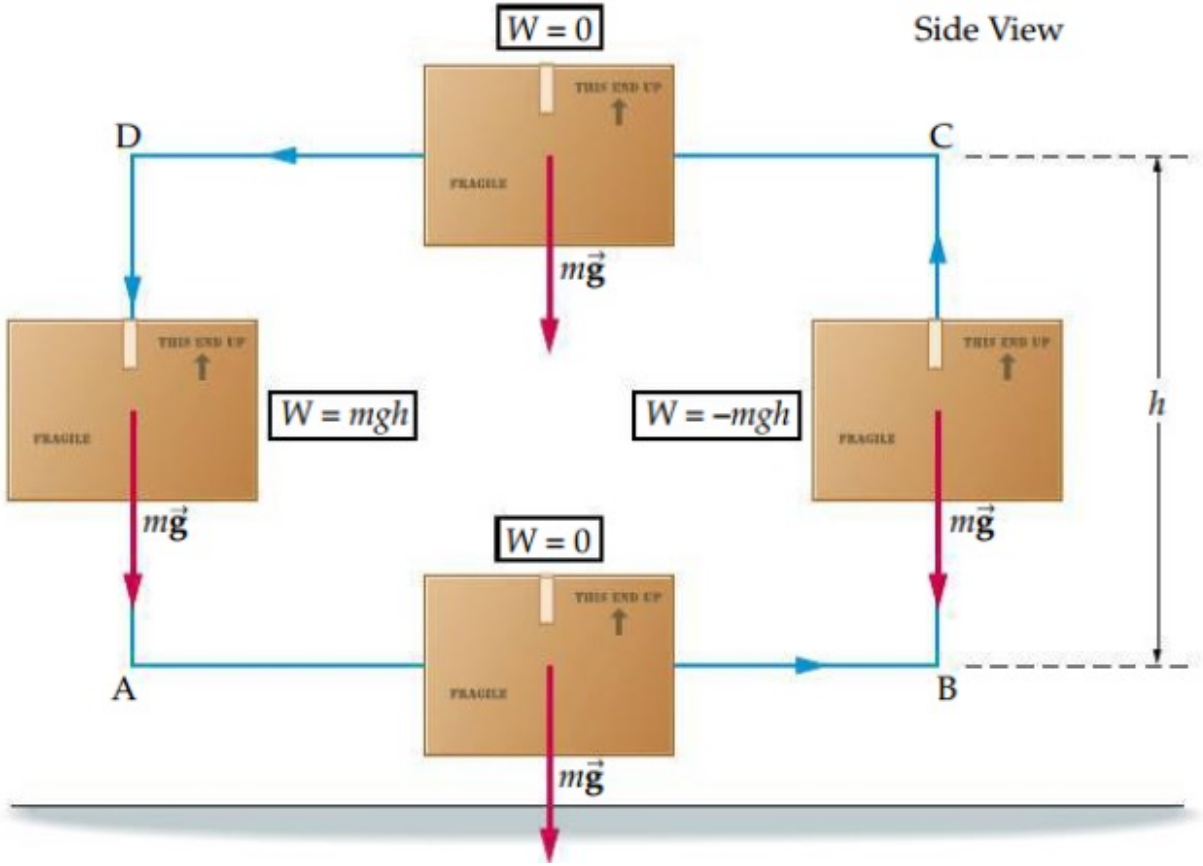
Non-conservative forces:

- Forces that do not store energy are called **non-conservative** or dissipative forces. Friction is a non-conservative force.

Example.

Consider a box of mass m moves along the path shown in the picture?

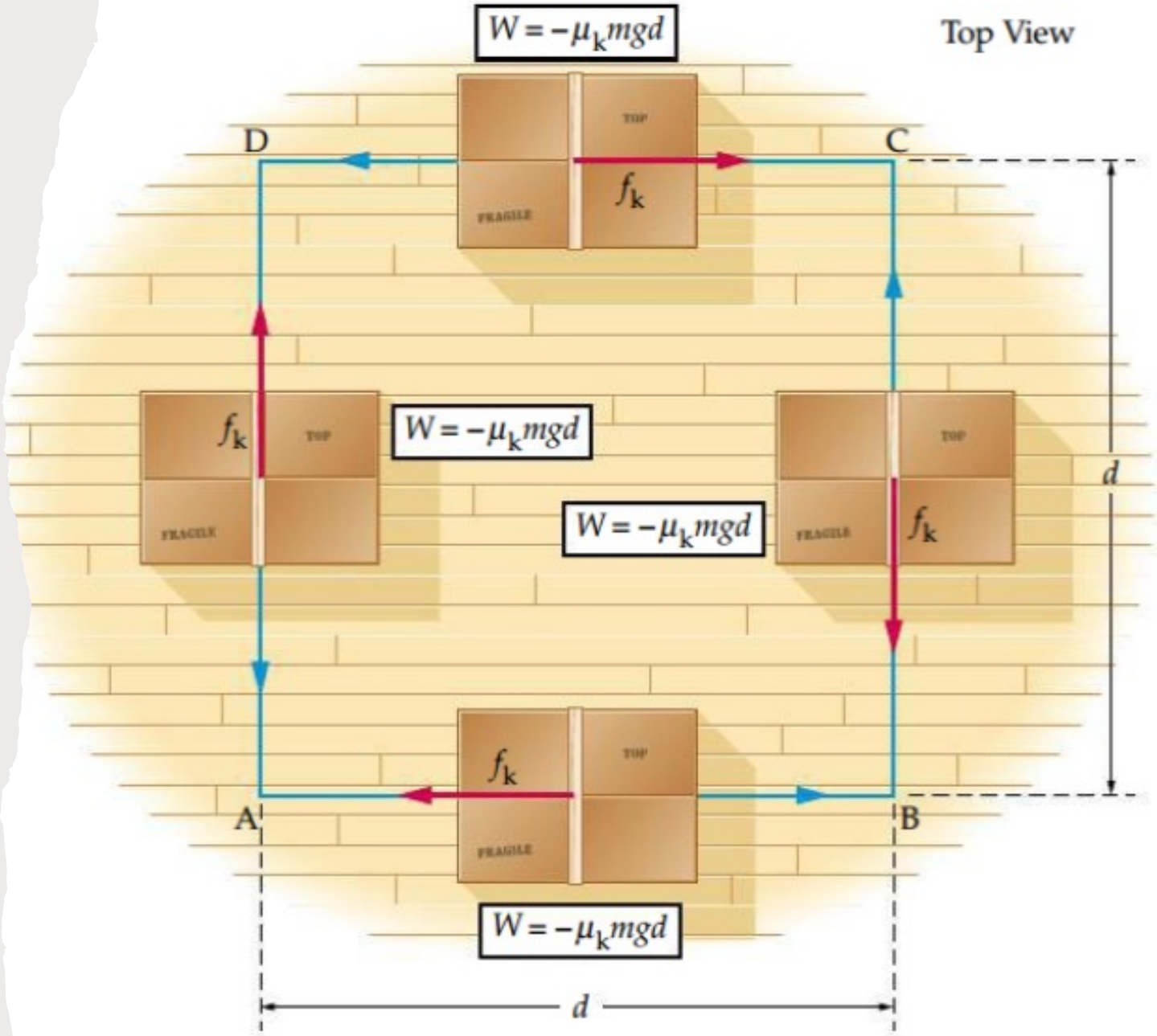
What is the total work done by gravity?



Example.

Consider a box of mass m moves along the path shown in the picture?

What is the total work done by friction?



Example 8-1

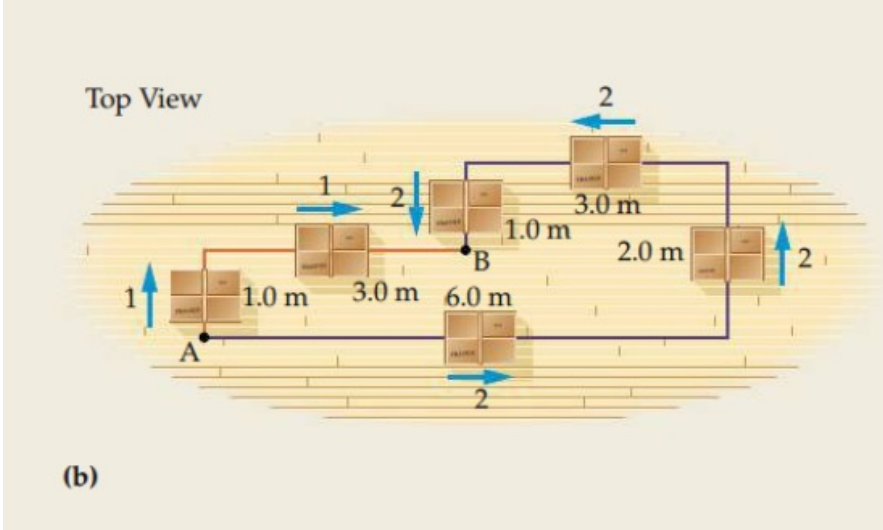
A 4.57 kg box is moved with constant speed from A to B along the two paths shown.

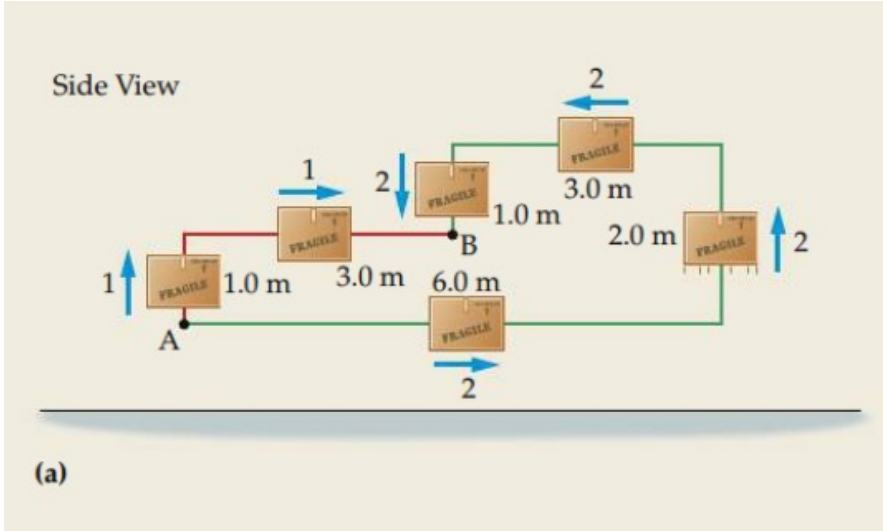
A)Calculate the work done by gravity on each of these paths?

Answers :W1 = -45J , W2 = -45J

B)The same box is pushed across a floor from A to B along path1 and path2 At right(refer to book).If the coefficient of kinetic friction between the box and the surface is 0.63,how much work is done by friction along each path?

Answers: W1 = -110J , W2 = -340J





8-2- The Work Done by Conservative Forces

Potential energy , U, can store energy in a system, that can be converted to kinetic or other forms of energy.

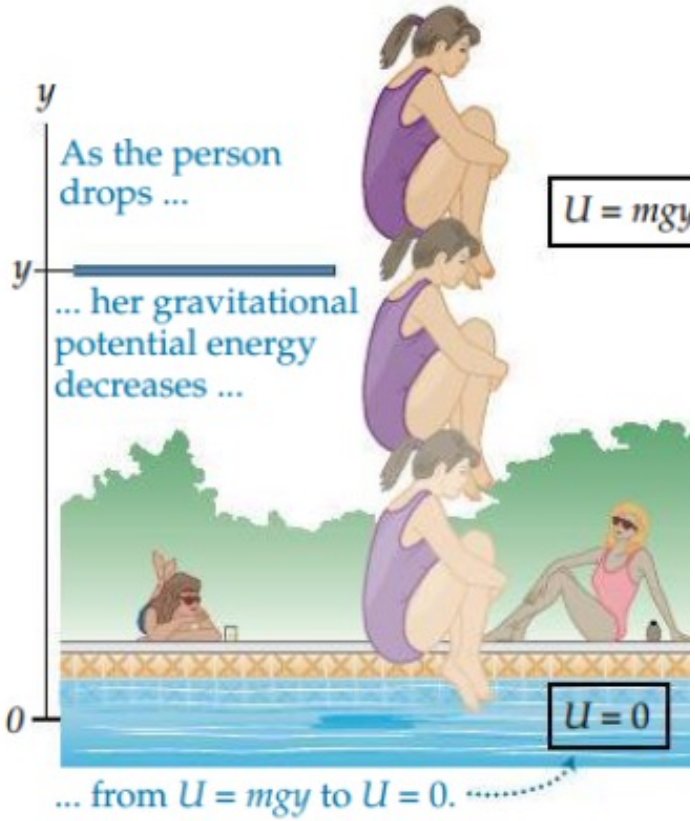
The work W_c is negative of the change in potential energy.

$$W_c = U_i - U_f = -(U_f - U_i) = -\Delta U$$

Gravitational potential energy:

$$W_c = -\Delta U = mgy$$

- Potential Energy depends only on height y, Independent of horizontal position,
- Scalar quantity,
- SI unit: joule, J



Exercise 8-1

Find the gravitational potential energy of a system consisting of a 65-kg person on a 3.0-m high diving board. Let U=0 be at water level.

Answer: U= 1900 J

Note: Any location can be chosen for $U = 0$. once the choice is made, it must be used consistently.

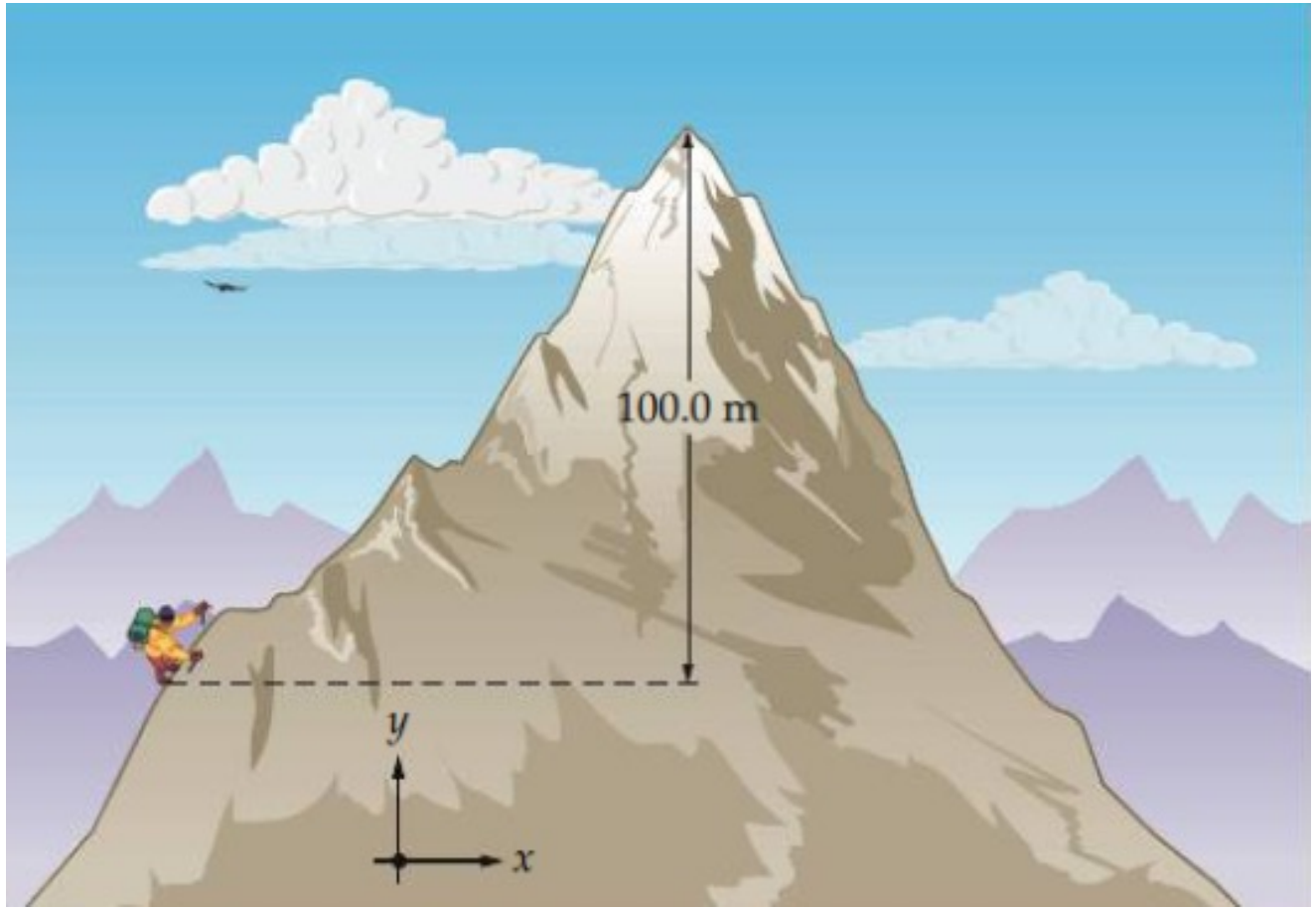
Example 2

An 82kg mountain climber is in the final stage of ascent of 4301m high Pikes peak.

A)What is the change in gravitational potential energy as the climber gains the last 100m of altitude? Let U=0 be at sea level?

b) What is the change in gravitational potential energy as the climber gains the last 100m of altitude? Let U=0 be at the top of peak?

Answer:
$\Delta U = 80{,}400\ J$

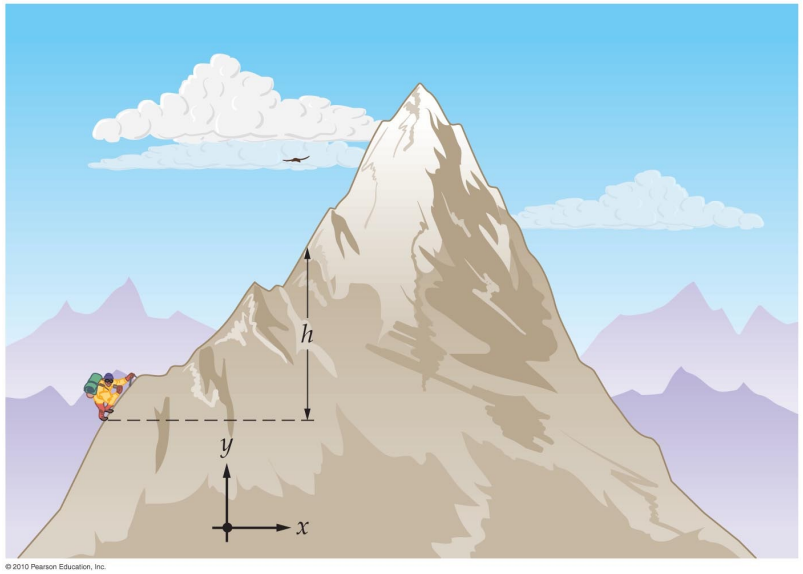


Example 3

Converting Food Energy To Mechanical Energy

- A candy par called the Mountain Bar has a calories of 212Cal=2121kcal, which is equivalent to an energy of 8.87 x 10^5 J . If an 81 kg mountain climber eats a Mountain Bar and magically converts it all to potential energy, what gain of altitude would be possible?

- Answer : h=1120 m



Conservation of Mechanical Energy

- Definition: Mechanical Energy (E) is the sum of potential and kinetic energies

$$E = U + K$$

- Conservation of Mechanical Energy: Mechanical energy is **conserved** in systems involving **only conservative forces**
- **Proof:** work-enery thoerem $W_{\text{tot}} = \Delta K$, but $W_{\text{tot}} = W_c$ (assuming only conservative forces involved). Also, $W_c = -\Delta U \Rightarrow \Delta K = -\Delta U \Rightarrow$

$$\Delta K + \Delta U = 0.$$

That is:

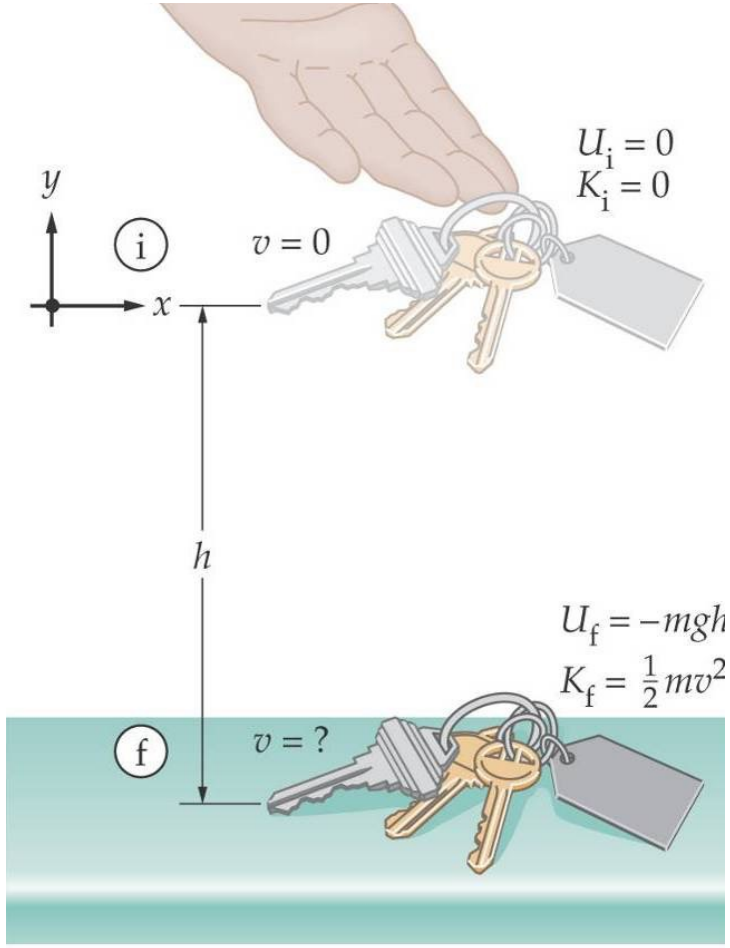
$$\boxed{U_f + K_f = U_i + K_i}$$

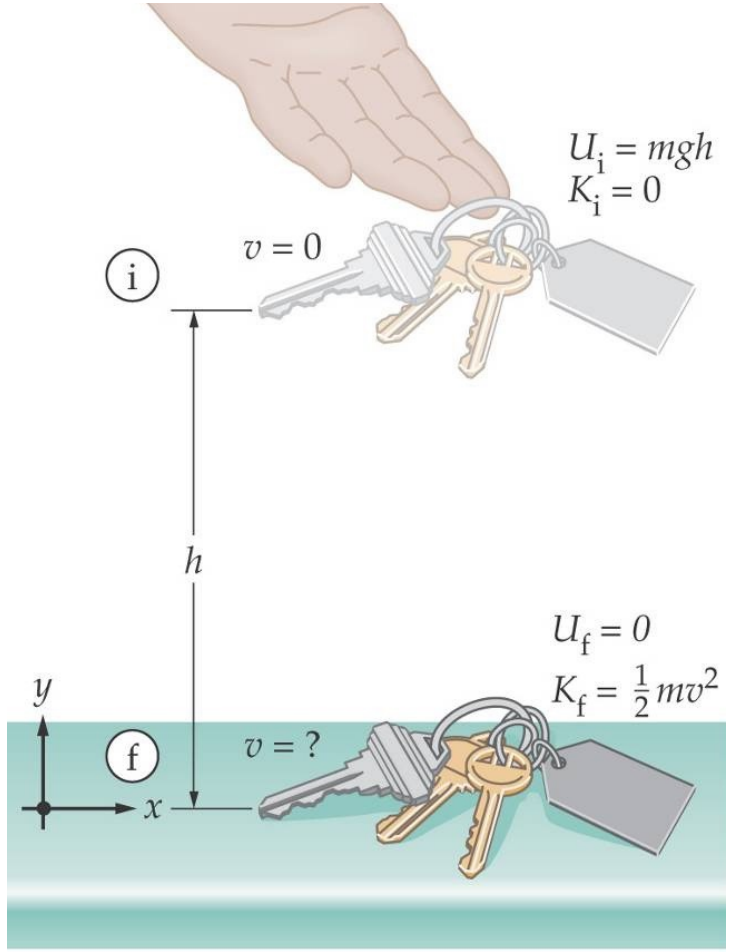
- OR:

$$\text{Mechanical Energy} = E = U + K = \text{constant}$$

http://www.physics-chemistry-interactive-flash-animation.com/mechanics_forces_gravitation_energy_interactive/oscillations_simple_gravity_pendulum_forces_speed_energy.htm

Conservation of Mechanical Energy





Energy conservation can make kinematics problems easier to solve.

Example: find the speed of the keys just before they hit the ground?

Conservation of Mechanical Energy

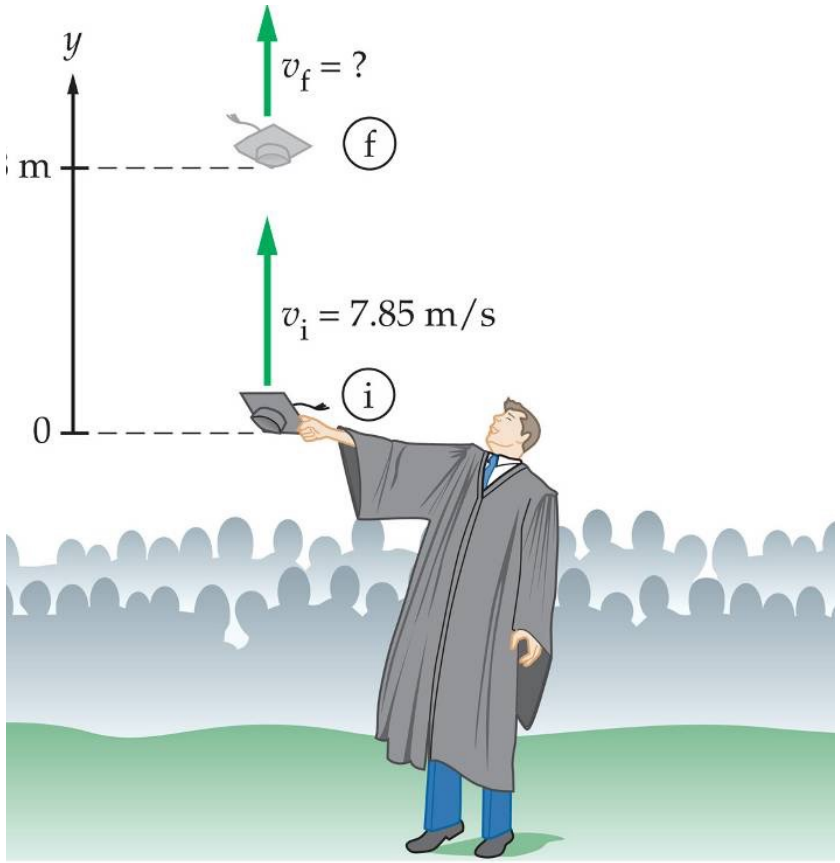
Example: At the end of a graduation ceremony, the graduates fling their caps into the air. Suppose a 0.120 kg cap is thrown straight upward with a speed of 7.85 m/s and that frictional forces can be ignored.

(a) Use kinematics to find the speed of the cap when it has risen 1.18 m above the fling point.

(Ans. 6.2 m/s)

(b) Show that the total mechanical energy of the cap is unchanged.

(Ans. E = 3.7 J)



Remark: Energy and Kinematics

- Note: starting with the conservation of energy:

$$E = U_i + K_i = U_f + K_f$$

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

$$2gy_i + v_i^2 = 2gy_f + v_f^2$$

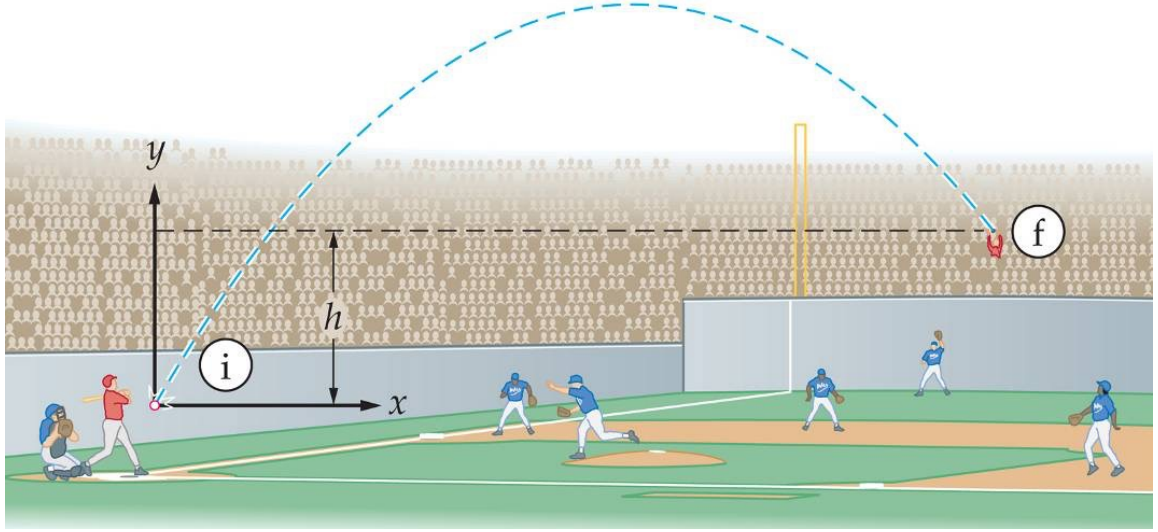
$$\boxed{v_f^2 = v_i^2 + 2g\left(y_i - y_f\right) = v_i^2 - 2g\Delta y}$$

Conservation of Mechanical Energy

Exercise: A player hits a 0.15 kg baseball over the outfield fence. The ball leaves the bat with a speed of 36.0 m/s and a fan in the bleachers catches it 7.2 m above the point where it was hit. Neglect air resistance.

(a) What is the kinetic energy K_f of the ball when caught?
(Ans. 86 J)

(b) What is the speed v_f of the ball when caught.
(Ans. 34 m/s)

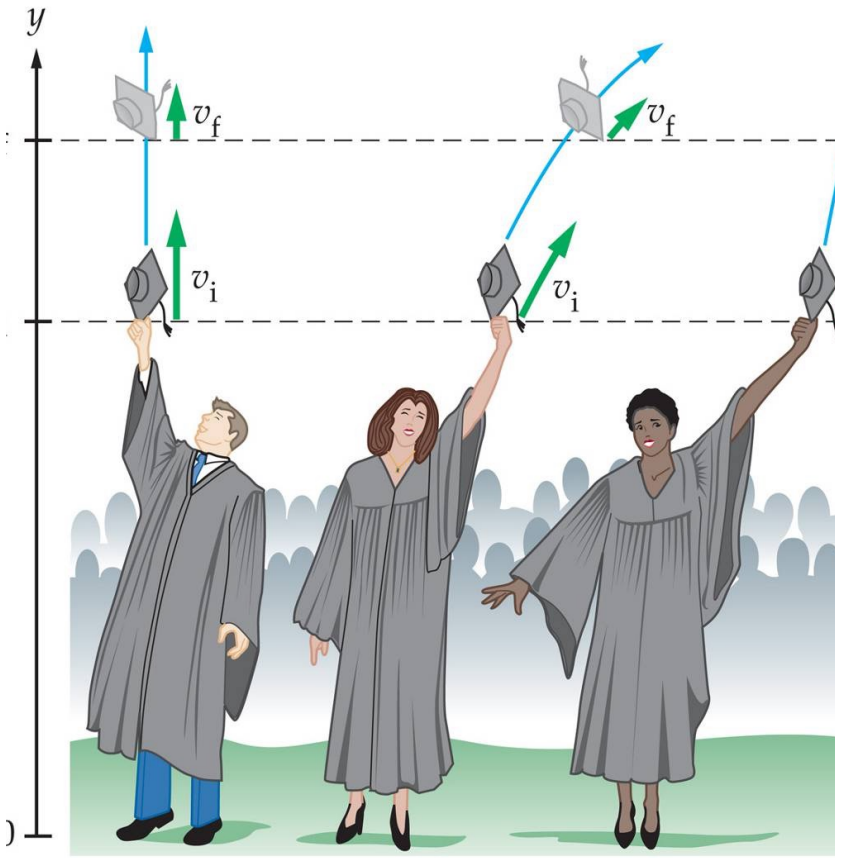


Conservation of Mechanical Energy

Energy is a scalar

The **speed** of the cap is v_i at height y_i and its speed is v_f at height y_f **independent of the path** between the two heights.

Thus, the angle at which the cap is launched does not change this result, as long as v_i is large enough to carry the cap to height y_f.



Work Done by Nonconservative Forces

- In the **presence of nonconservative** forces, the total **mechanical energy is not conserved**:
  - Starting with the work energy theorem: $W_{total} = \Delta K$
  - But $W_{total} = W_c + W_{nc} = -\Delta U + W_{nc}$ (here W_{nc} is the work by the nonconservative forces)
  - Hence: $W_{nc} - \Delta U = \Delta K$; or

$$\Delta U + \Delta K = \Delta E = W_{nc}$$

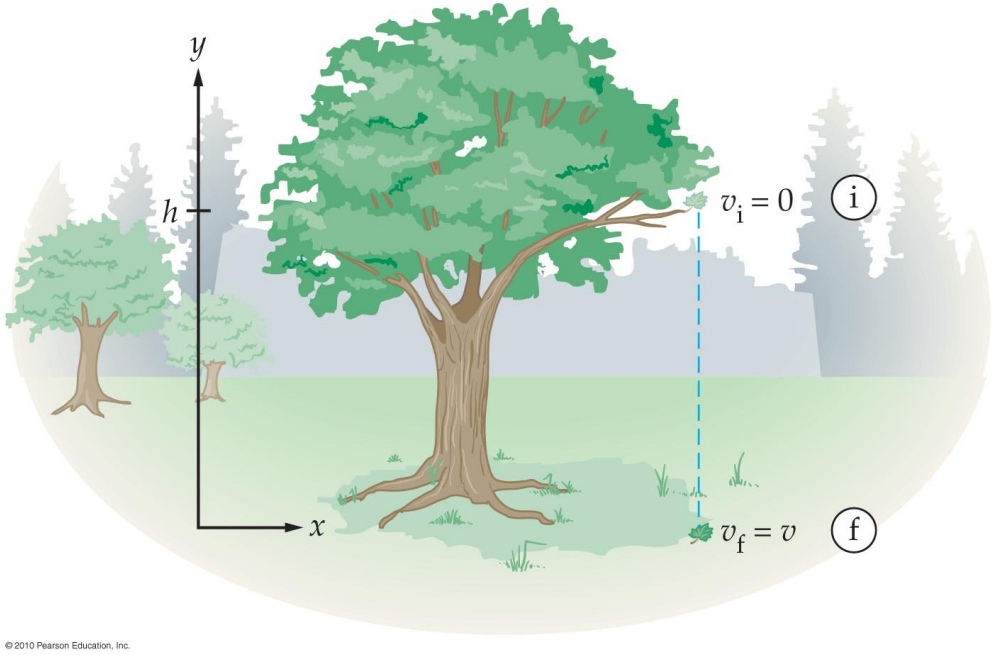
- **The work of nonconservative force is equal the change in the mechanical energy**.

Example 9

- Deep in the forest, a 17.0 g leaf falls from a tree and drops straight to the ground. If its initial height was 5.30 m and its speed on landing was 1.3 m/s, how much non conservative work was done on the leaf?

Answers :

E_i=0.884 J , E_f= 0.014 J , W_{nc} = - 0.870 J



Problem

- Q40) Catching a wave, a 77-Kg surfer starts with speed of 1.3m/s, drops through a height of 1.65m,and ends with a speed of 8.2m/s. How much non-conservative work was done on the surfer.—

Ans. : 1300J

Summary of Chapter 8

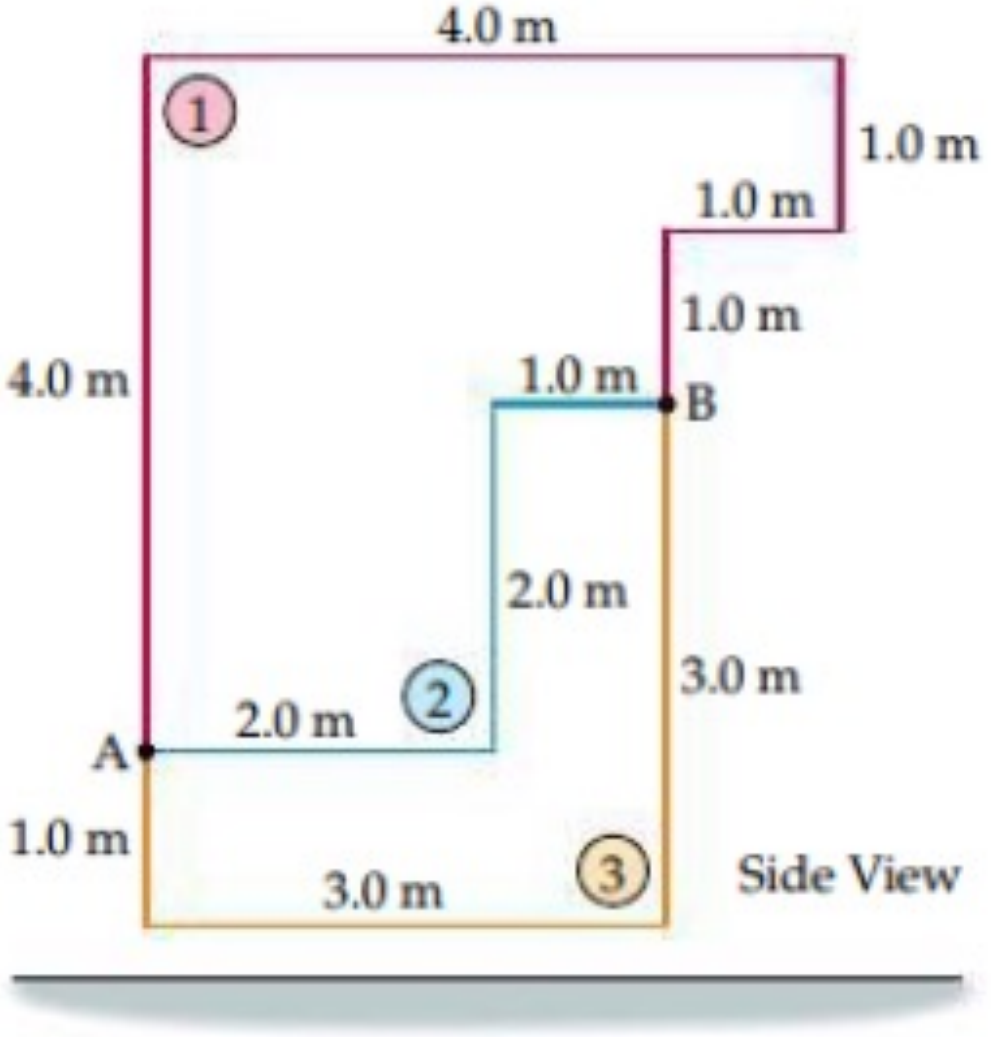
- Conservative forces conserve mechanical energy
- Non-conservative forces convert mechanical energy into other forms
- Conservative force does zero work on any closed path
- Work done by a conservative force is independent of path
- Conservative forces: gravity, spring
- Work done by nonconservative force on closed path is not zero, and depends on the path

Summary of Chapter 8

- Nonconservative forces: friction, air resistance, tension
- Energy in the form of potential energy can be converted to kinetic or other forms
- Work done by a conservative force is the negative of the change in the potential energy
- Mechanical energy is the sum of the kinetic and potential energies; it is conserved only in systems with purely conservative forces
- Nonconservative forces change a system's mechanical energy
- Work done by nonconservative forces equals change in a system's mechanical energy

Exercise

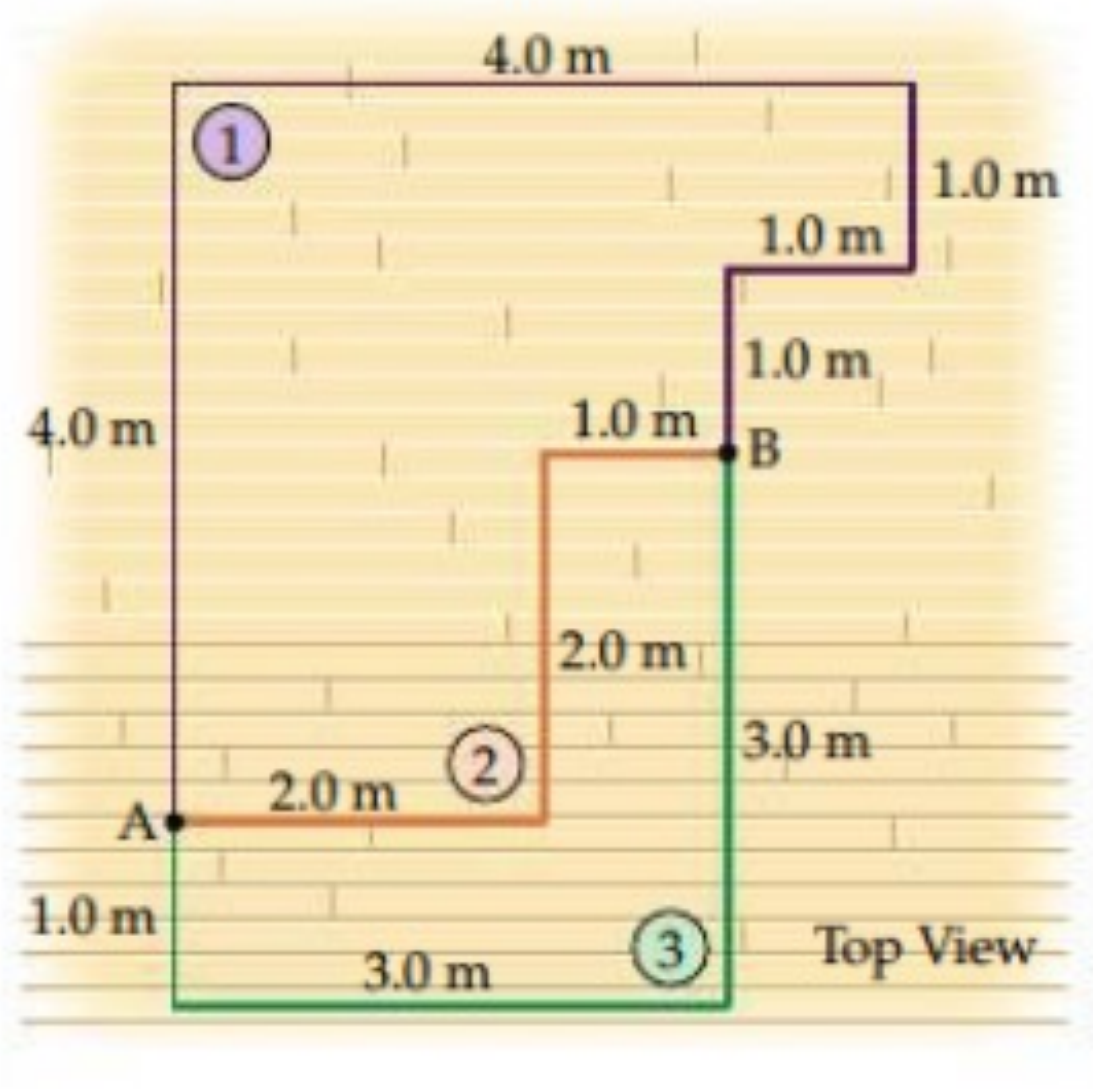
Calculate the work done by gravity as a 3.2-kg box is moved from point A to point B in the Figure along paths 1,2, and 3.



Answers :
$W_1 = -63J$,
$W_2 = -63J$,
$W_3 = -63J$

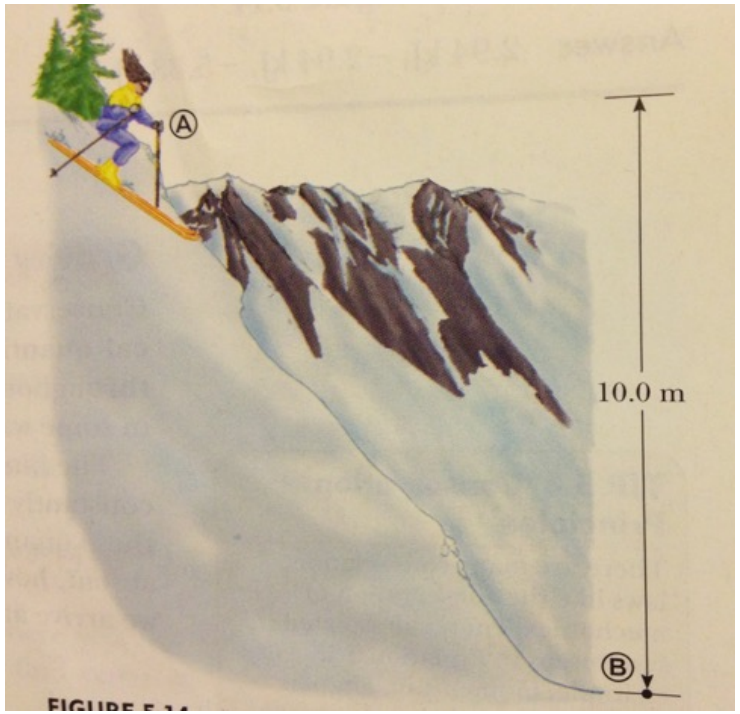
Exercise

Calculate the work done by friction as a 3.7-kg box is slid along a floor from point A to point B in the Figure along paths 1,2, and 3. Assume that the coefficient of kinetic friction between the box and the floor is 0.26



Answers:
$W_1 = -104J,$
$W_2 = -47J,$
$W_3 = -66J$

Exercise



A 60.0 kg skier is at the top of a slope, as shown in Figure. At the initial point (A), she is 10.0m vertically above point (B).

a) Setting the zero level for gravitational potential energy at (B), find the gravitational potential energy of this system when the skier is at (A)and then at (B), finally, find the change in potential energy at the skier-Earth system as the skier goes from point (A) to point (B).

b) Repeat this problem with the zero level at point (A).

c) Repeat again, with the zero level 2.00m higher than point (B). Answer : $\Delta U = -5886$ J

Exercise

How much potential energy is lost by a 5Kg object to kinetic energy due a decrease in height of 4.5 m?

Ans. $PE = 225\ J$

As an Acapulco cliff driver drops to the water from a height of 46m, his gravitational potential energy decreases by 25,000J.-----Find the divers weight in Newton's?

Ans. : 540N

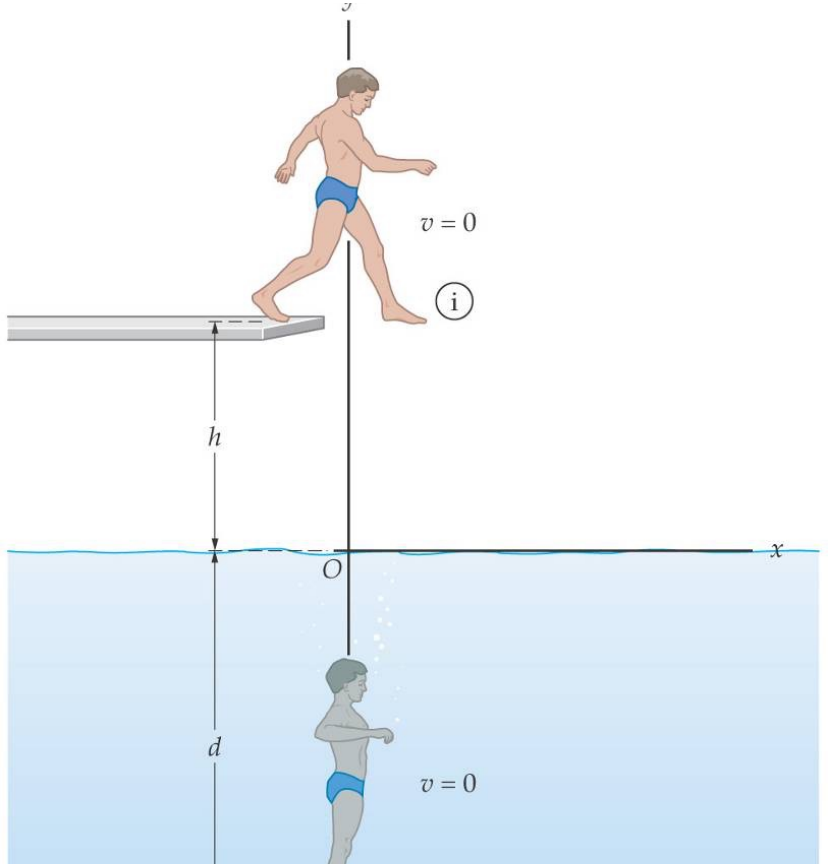
Q24)At an amusement park, a swimmer uses a water slide to enter the main pool, If the swimmer starts at rest, slides without friction, and descends through a vertical height of 2.32m, what is her speed at the bottom of slide?

Ans. : 6.73m/s

Exercise

Example: A 95.0 kg diver steps off a diving board and drops into the water, 3.00 m below. At some depth d below the water's surface, the diver comes to rest. If the nonconservative work done on the diver is $W_{\text{nc}} = -5120$ J, what is the depth d?

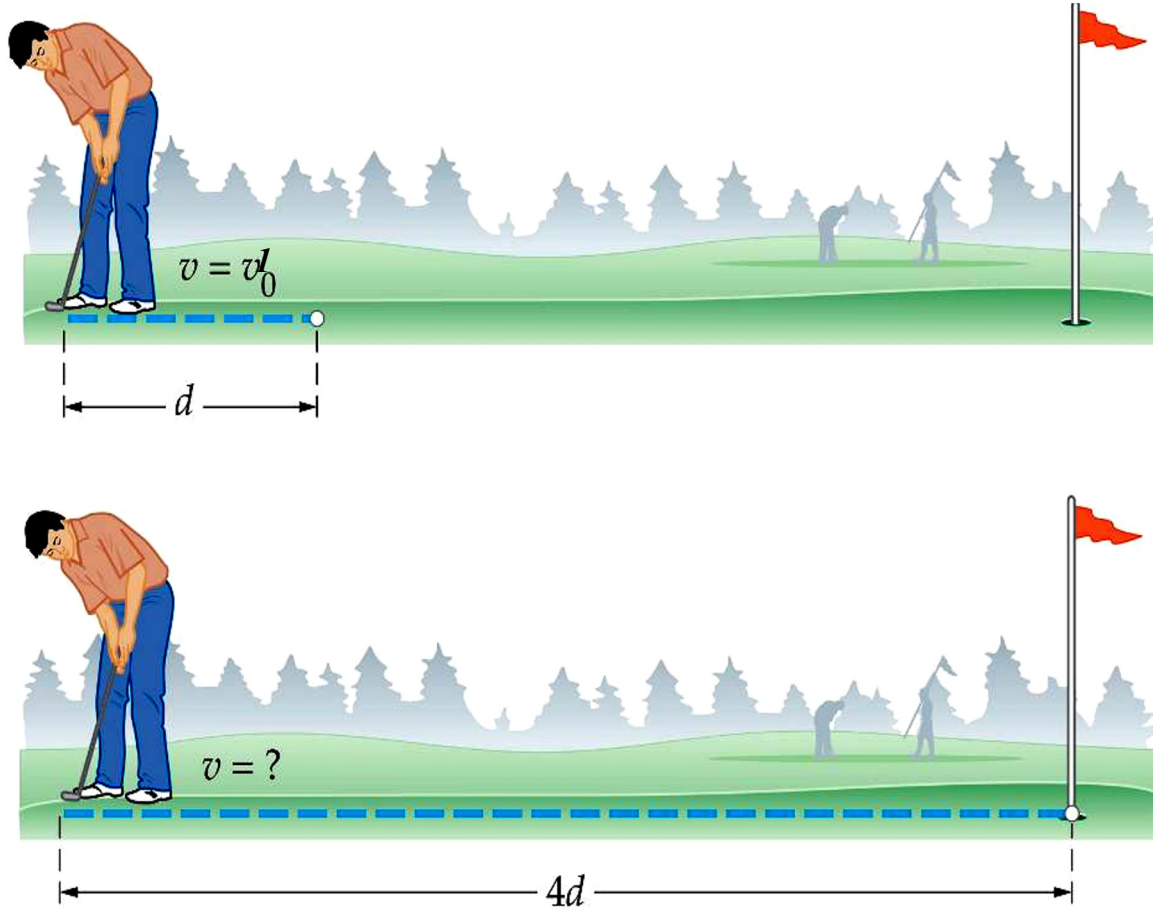
(Ans. 2.49 m)



Exercise

Example: A golfer misjudges a putt, giving the ball an initial speed v_1, which sends the ball a distance d that is only one quarter of the distance to the hole. If the nonconservative force F due to the resistance of the grass is constant, what initial speed v_2 would have been needed to putt the ball from its initial position to the hole?

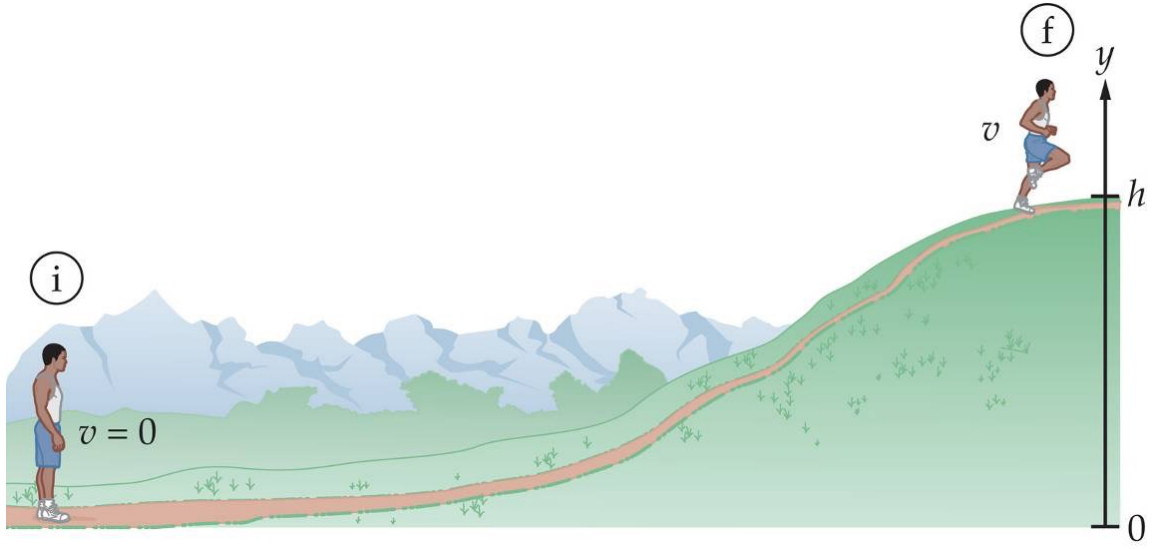
(Ans. $v_2 = 2v_1$)



Exercise

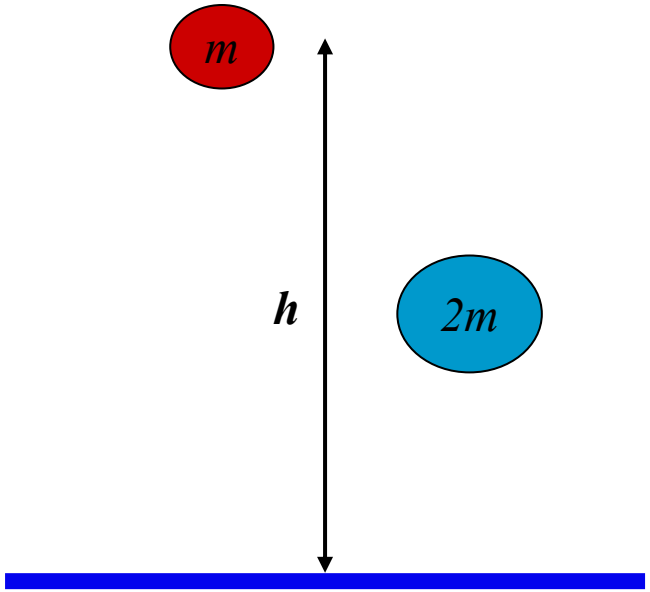
Example: An $80.0\ \mathrm{kg}$ jogger starts from rest and runs uphill into a stiff breeze. At the top of the hill the jogger has done work $W_{nc1} = +18000\ \mathrm{J}$, air resistance has done work $W_{nc2} = -4420\ \mathrm{J}$, and the jogger's speed is $3.50\ \mathrm{m/s}$. Find the height of the hill.

(Ans. 16.68 m)



Conservation of Mechanical Energy

Exercise: When a ball of mass m is dropped from height h, its kinetic energy just before landing is K. If a 2nd ball of mass $2m$ is dropped from height $h/2$, what is its kinetic energy just before landing?



(a) K/4 (b) K/2 (c) K (d) 2K (e) 4K