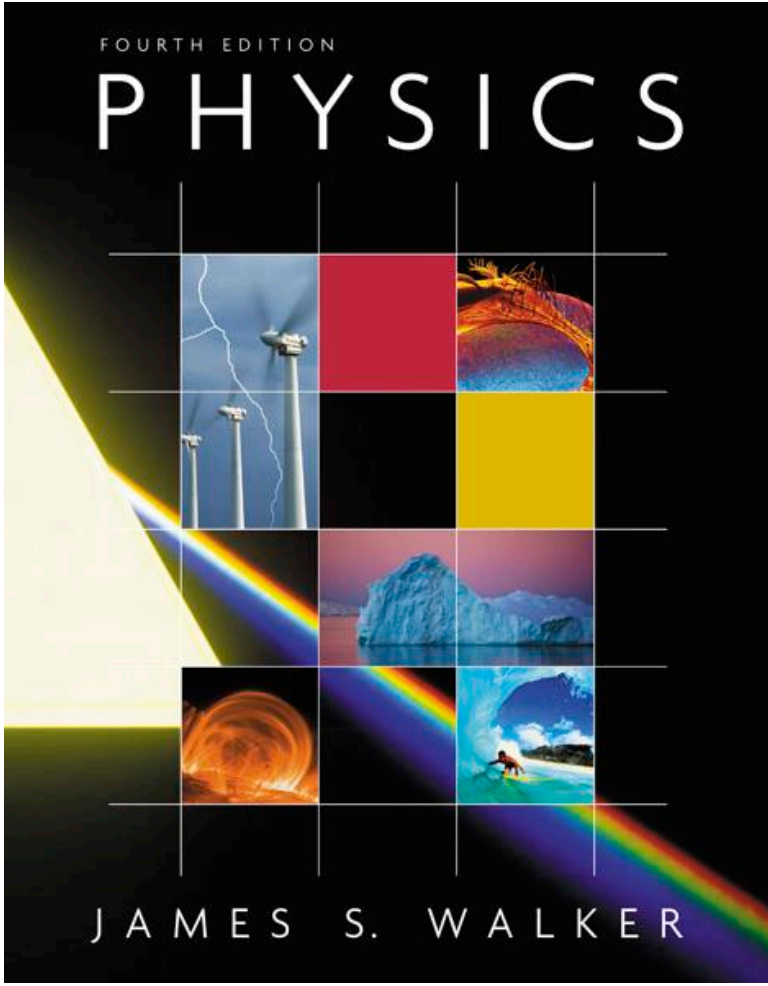


Lecture Outline

Chapter 8

Physics, 4th Edition

James S. Walker

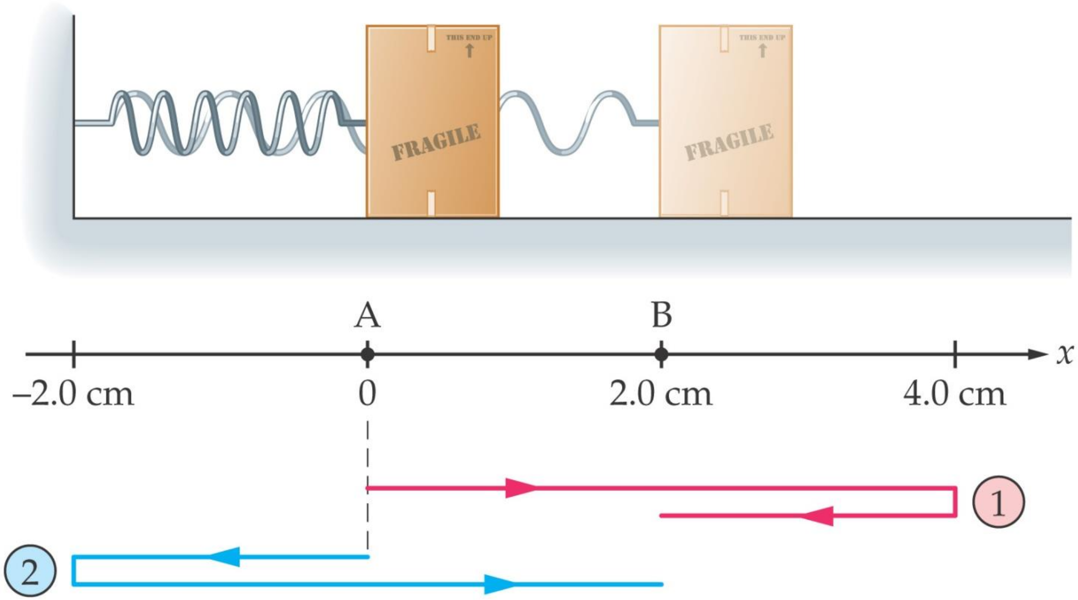
work $= fd\cos\theta$

$f_c = mg \longrightarrow$ work $= mgd\cos\theta$

$f_{nc} = f_k \longrightarrow$ work $= \mu_k mgd\cos\theta$

Chapter 8

Potential Energy and Conservation of Energy



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 at a later time when I apply force then release, it will go back to the original place → spring force.

Example of a conservative force: gravity

Also: the work done by a **conservative force** moving an object around a closed path is **zero;**

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

Example of a non-conservative force: friction

the work done by a **non conservative force** moving an object around a closed path is **not equal to zero;**

Ex:

moving a box, it will not go back to the original position when released, what will happen to the energy?

ib will turn to thermal,

Kinebic $\longrightarrow$ therm

- 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.

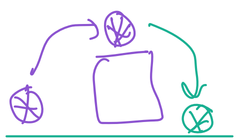
- Forces that do not store energy are called **non-conservative or dissipative forces**. Friction is a non-conservative force.

Conservative and Non-Conservative Force

A- Conservative Force: A force that offers a two way conversion between kinetic energy and potential energy is called a conservative force**. It conserves mechanical energy.** The work done by such force always have these properties:

1- It can be expressed as s difference between the initial and final values of potential energy.
2- It is reversible.

3- It is independent of the path of the bodyand depends only on the starting and end points.
4- When starting and end points are same, the total work done is zero.



eg. Gravitational force, Electric force, Spring force

B- Non-Conservative Force: It does not conserve mechanical energy.

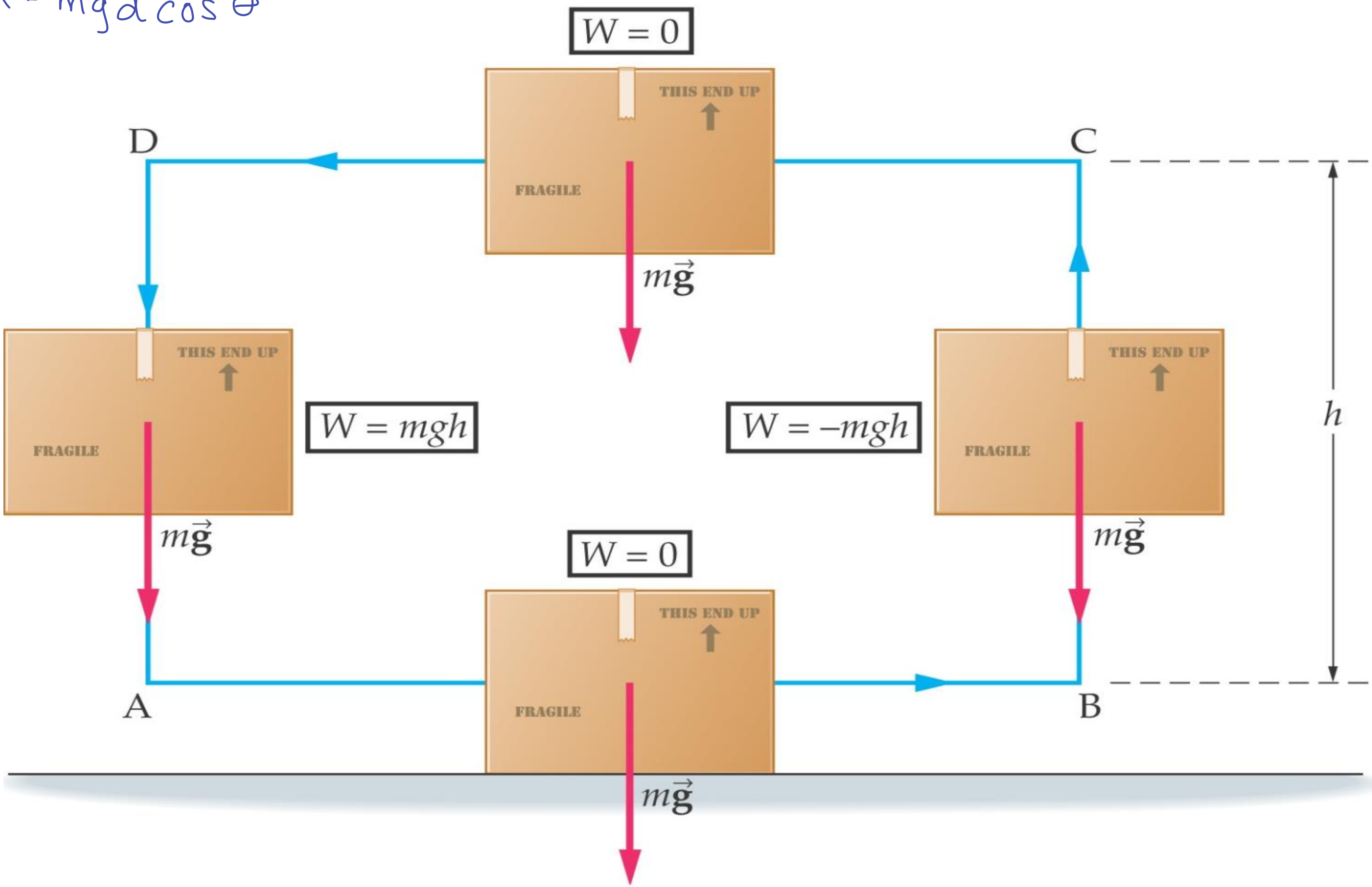
All forces that are not conservative are non-conservative forces.

eg. Force of friction

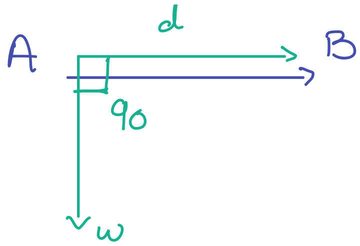
8-1- Conservative and Non-conservative Forces

Work done by gravity on a closed path is zero:

work = mgd cos θ



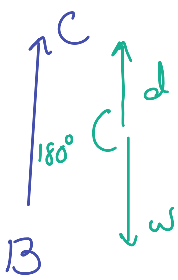
1



$\theta = 90$

work = zero

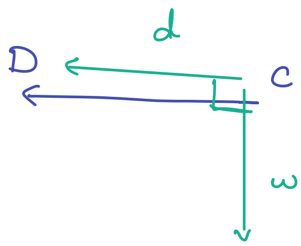
2



$\theta = 180°$

$mgd \cos 180$

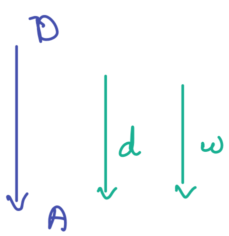
3



$\theta = 90°$

work = zero

4



$mgd \cos 0$

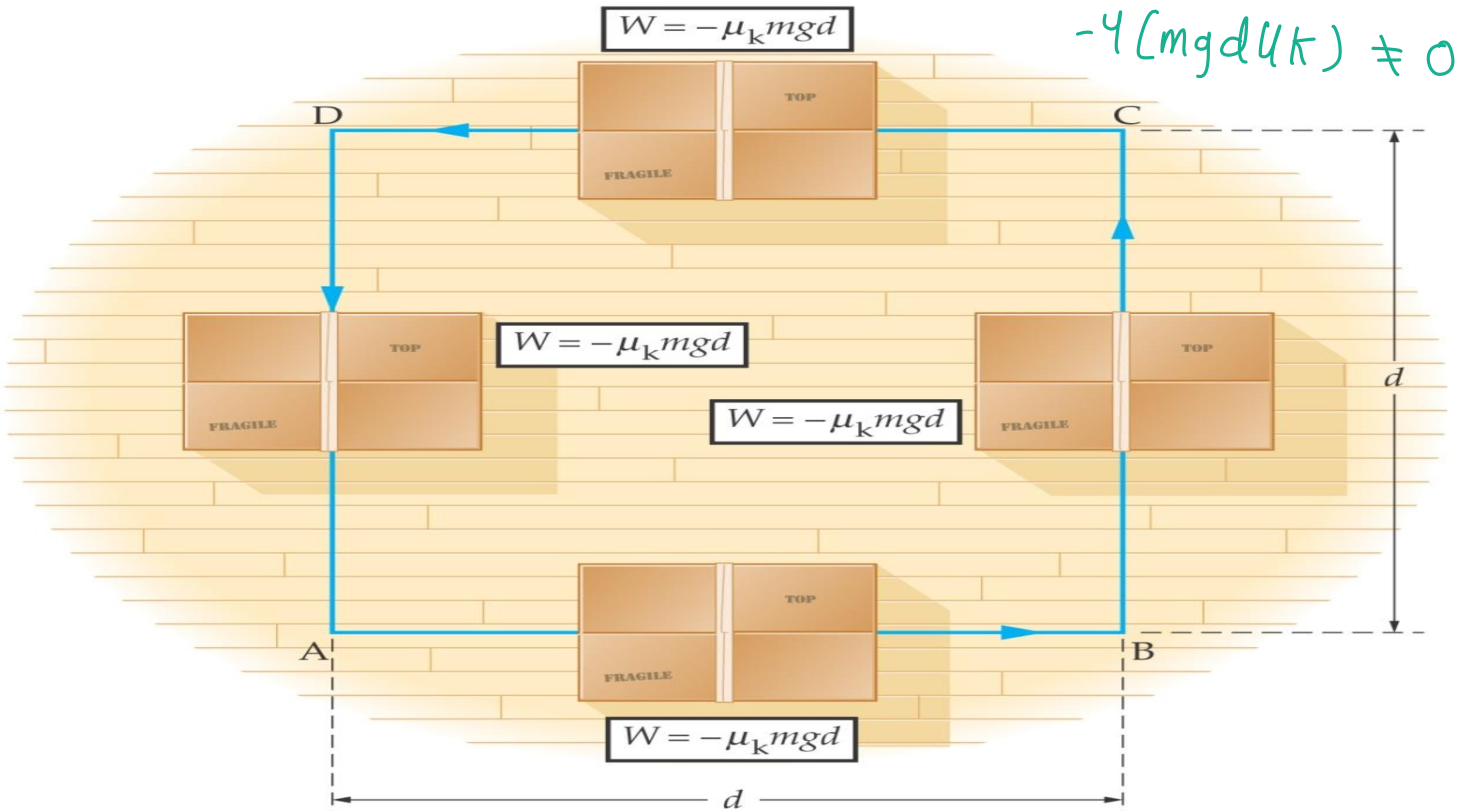
zero + $mgd \cos 180$ + zero + $mgd \cos 0$

$-mgd + mgd$ = zero

8-1-- Conservative and Non-conservative Forces

Work done by friction on a closed path is not zero: $4(\mu_k \times mgd)(-1)$

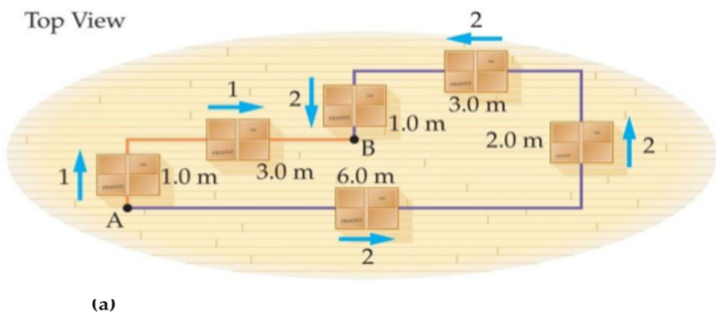
$-4(mgd\mu_k) \neq 0$



Example:- 8-1(pg—220)

- 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?

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



$m = 4.57\ kg \qquad u_k = 0.63$

$w = F_n d \cos\theta$

$u_k N d \cos\theta \qquad \rightarrow N = w$

$$\boxed{u_k m g d \cos\theta}$$

Path(1): $0.63(4.57)(9.81)(3+1)\cos 180$

$= -113\ J$

Path(2): $0.63(4.57)(9.81)(6+2+3+1)\cos 180$

$= -339\ J$

Work in Closed path:

$A \longrightarrow B \longrightarrow$ Path 1 $\longrightarrow -113\ J$

$B \longrightarrow A \longrightarrow$ Path 2 $\longrightarrow +339\ J$

$-113 + 339 = 226\ J$

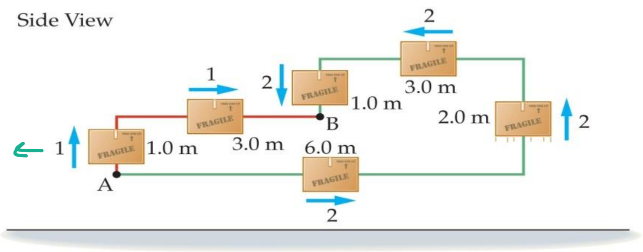
Example:- 8-1(pg—220)

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

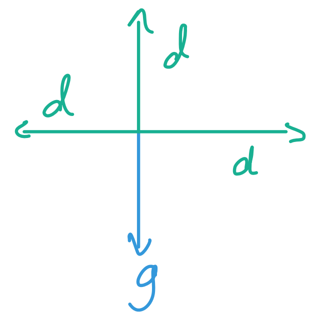
$m = 4.57\ Kg$

180



$work = f\, g\, d \cos\theta$

$$\boxed{= mg\, d \cos\theta}$$



Path (1) : $mgd\cos 180 + mgd\cos 90$

$(4.57)(9.81)(1)\cos 180 + (4.57)(9.81)(3)(0)$

$= -45\,J$

Path (2) :

$mgd\cos 90 + mgd\cos 180 + mgd\cos 90 + mgd\cos(0)$

$0 + (4.57)(9.81)(2)\cos(180) + 0 + (4.57)(9.81)(1)(1)$

$= -45\,J$

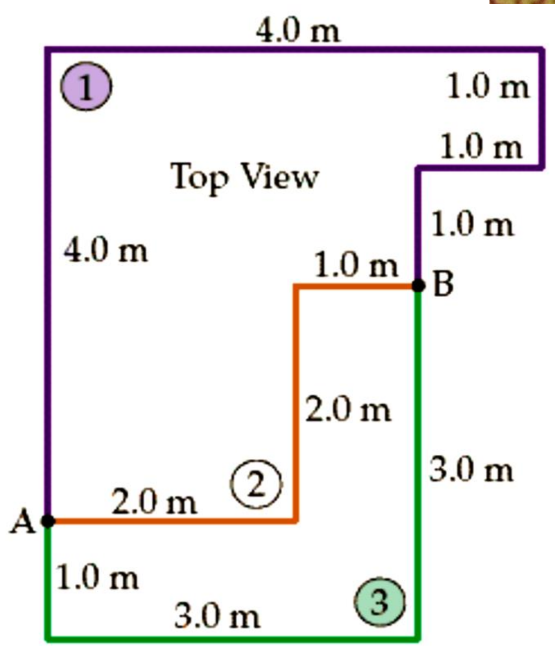
Conservative force, they equal each other.

Work in Closed Path: $\rightsquigarrow$ has to $= 0$

$A \rightarrow B \quad -45\,J$

$B \rightarrow A \quad +45\,J$ $\Big\} + =$ zero ✓

Solution: W1 = -104J , W2 = -47J, W3 =-66J



the time on the way

CISES

...und in the back of the book. **IP** *denotes an integrated problem, with both con-* ...terest; **CE** *indicates a conceptual exercise.* **Predict/Explain** *problems ask for* ...tion among three provided. On all problems, red bullets (•, ••, •••) are used to

3\. • Calculate the work done by friction as a 3.7-kg box is slid along a floor from point A to point B in **Figure 8–16** along paths 1, 2, and 3. Assume that the coefficient of kinetic friction between the box and the floor is 0.26.

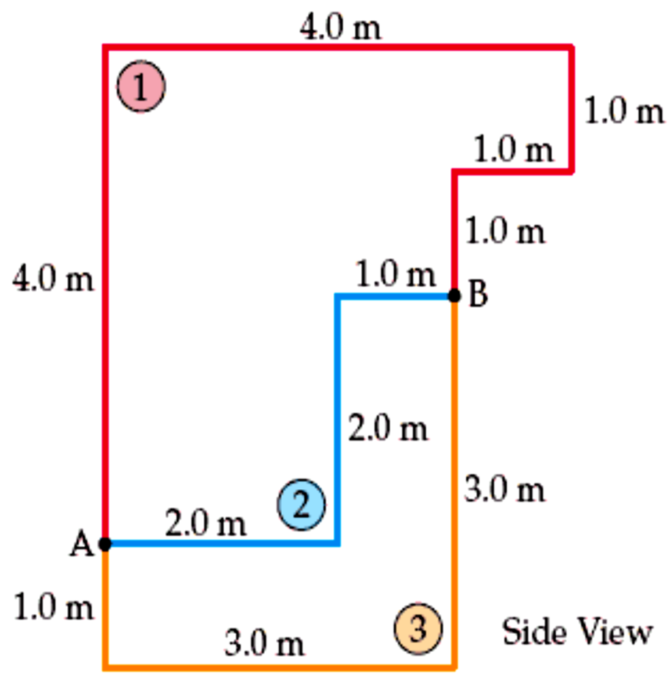
4.0 m

1.0 m

4.0 m

H.W

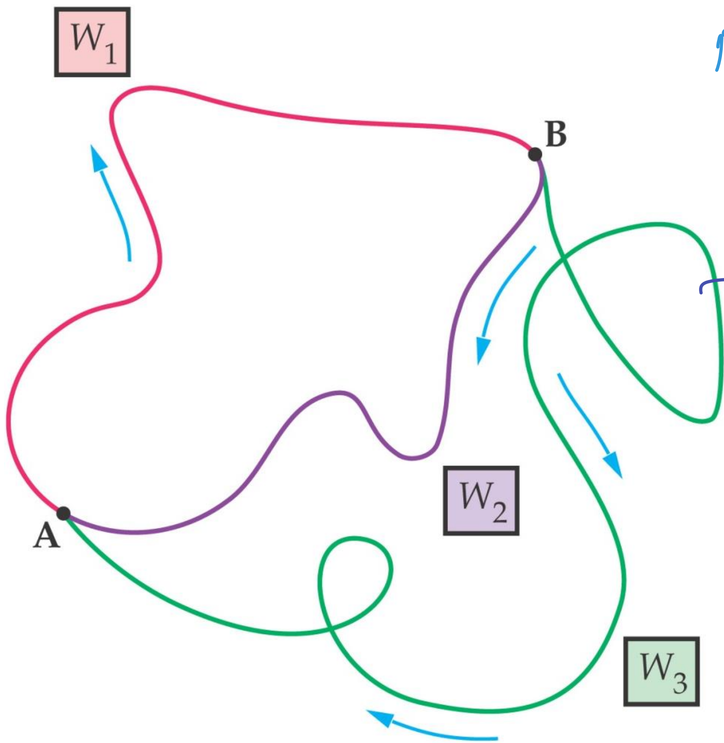
Solution:-W1 = - 63J, W2= -63J ,W3 = -63J



gravity
+ friction

8-1-- Conservative and Non-conservative Forces

The work done by a conservative force is zero on any closed path:



$A \rightarrow B = w_1$

$B \rightarrow A = w_2$

$w_1 = w_2$

$w_1 - w_2 = \text{zero}$

$A \rightarrow B = w_1$

$B \rightarrow A = w_3$

$w_1 = w_3$

$w_1 - w_3 = \text{zero}$

$w_2 = w_3$

Absent

8-2- The Work Done by Conservative Forces

If we pick up a ball and put it on the shelf, we have done work on the ball. We can get that energy back if the ball falls back off the shelf; in the meantime, we say the energy is stored as potential energy.

Definition of Potential Energy, *U*

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

SI unit: joule, J (8-1)

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

$U = mgh$ $E = U + K$

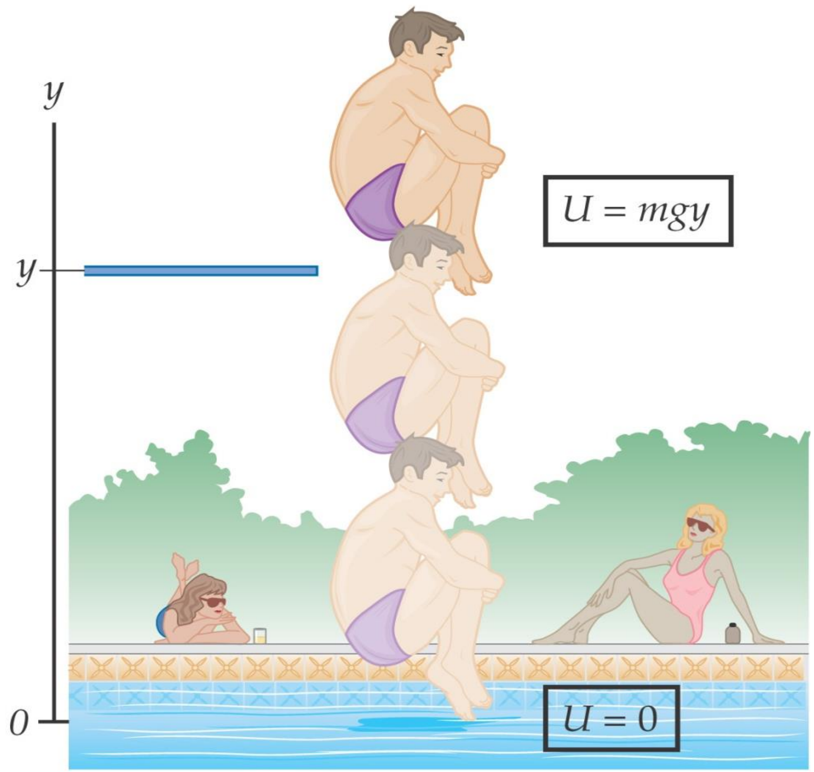
$E_i = E_f$

8-2-- The Work Done by Conservative Forces

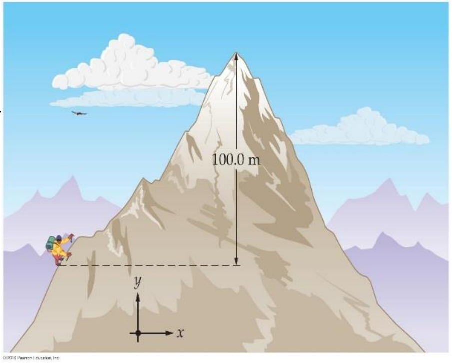
like gravity ← work$_c$ = $-\Delta U$

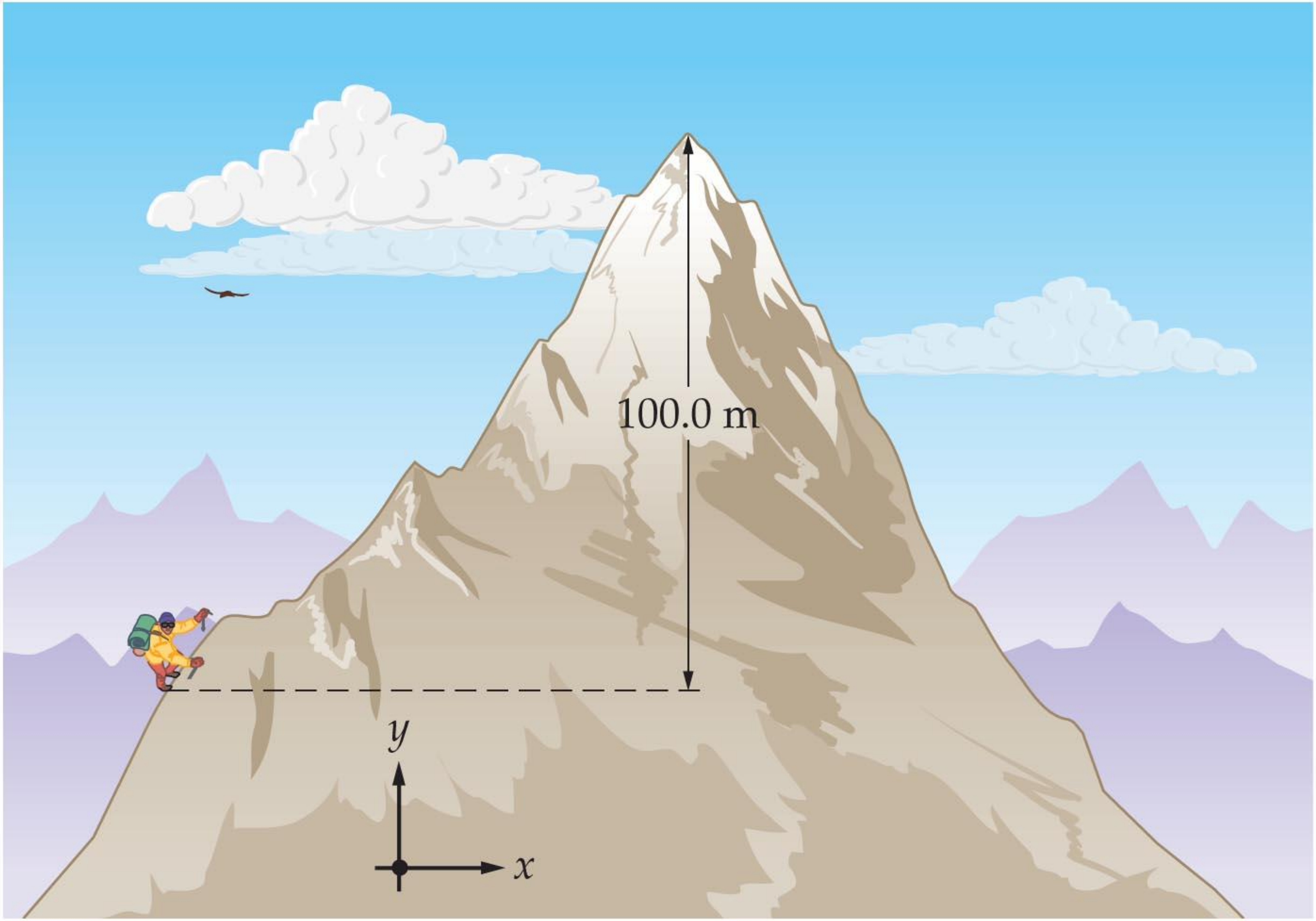
Gravitational potential energy:

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



- Exercise : 8—1Find the gravitational potential energy of a system consisting of 65kg person on a 3.0m high diving board.Let U = 0 be at water level.
- Sol:- 1900J
- Example: 8-2
- An 82kg mountain climber is in the final stage of ascent of 4301m high pikes peak. What is the change in gravitational potential energy as the climber gains the last 100m of altitude? Let U=0 be
- A) at sea level b) at the top of peak
- Sol:- a)$\Delta U = 80{,}400J$, b) $\Delta U = 80{,}400J$
- Example:- 8—3 Assignment




100.0 m
y
x

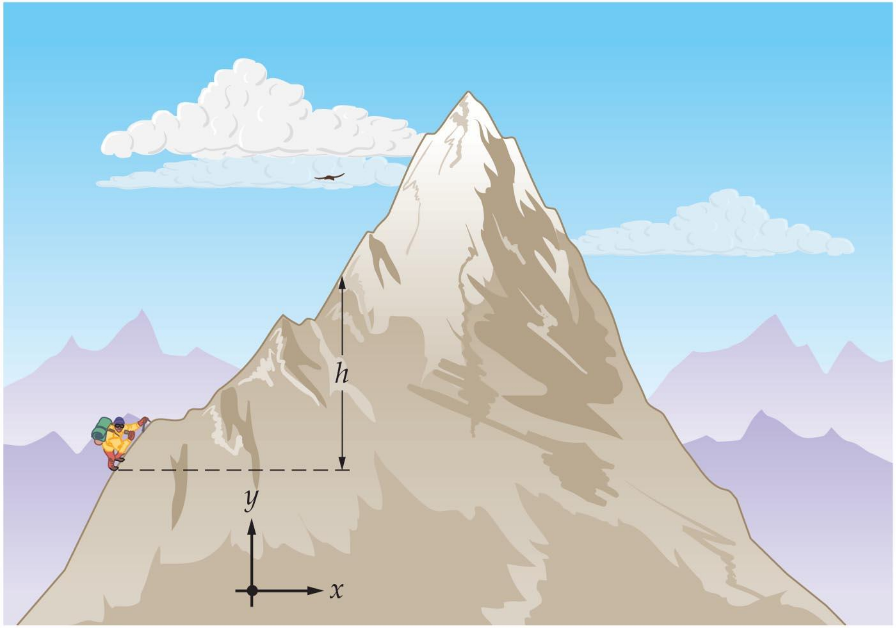
Problem

- Q9) 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

Converting Food Energy To Mechanical Energy

- Example 3 Read & Solve

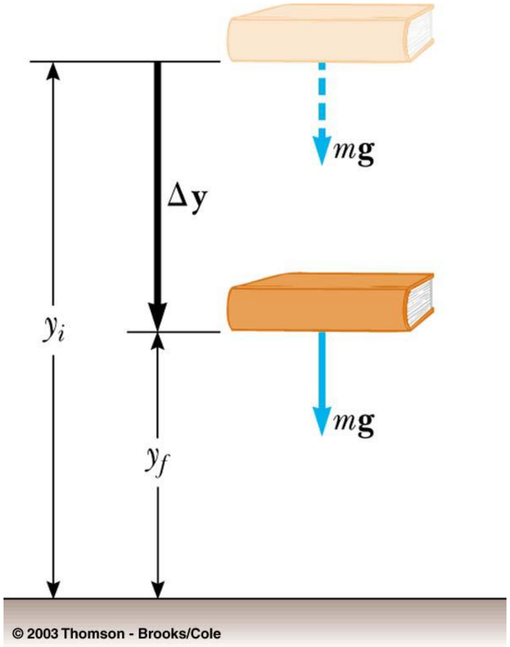


gravitational work & gravitational potential energy:

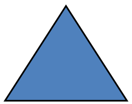
- The work done by the external agent on the system (object and Earth) as the object undergoes this downward displacement is given as :

$$W_g = -(U_f - U_i) = -\Delta U_g$$

- If an object falls from one point another inside a gravitational field, the force of gravity will do positive work on the object and the gravitational potential energy will decrease by the same amount.

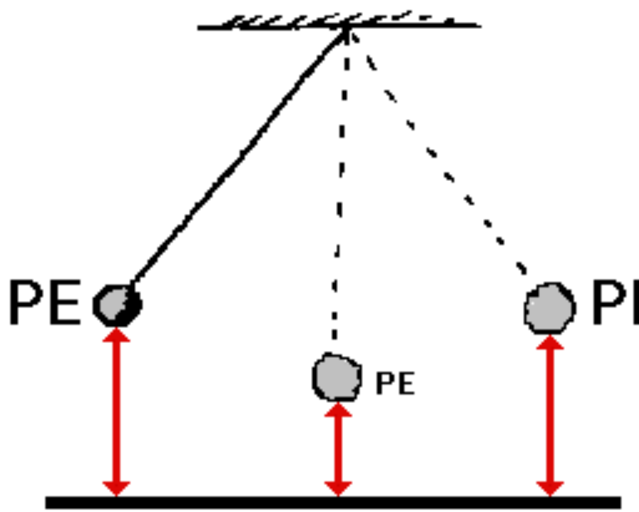


Gravitational Potential Energy



- After an object has been lifted to a height, work is done.
- $PE = W = F \times d = mgh$

Potential Energy is maximum at the maximum HEIGHT



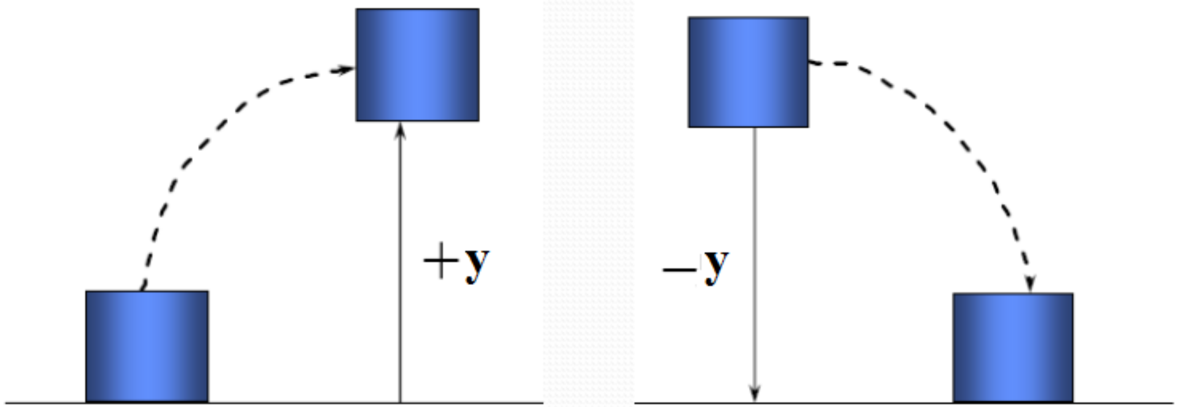
Potential Energy (P.E.)

$\Delta PE = +mg\mathbf{y}$

$\Delta PE > 0$

$\Delta PE = -mg\mathbf{y}$

$\Delta PE < 0$



energy due to the **change of position** in gravitational field

The negative sign in the PE equation is necessary to account for the direction of gravity

(PE > 0 when y > 0

PE < 0 when y < 0)

$W_g = mgh$ (Depends only on **y**!)

Potential Energy Calculation

- How much potential energy is lost by a 5Kg object to kinetic energy due a decrease in height of 4.5 m
- PE = mgh
- PE = (5Kg)(10 m/s^2)(4.5 m)
- PE = 225 Kg m^2/s^2
- PE = 225 J

tions, as in Figure 5.13. When the book is at Ⓐ, ...
energy is the surface of the desk. When the book is at Ⓑ, the floor might be
convenient reference level. Finally, a location such as Ⓒ, where the book is h
a window, would suggest choosing the surface of Earth as the zero level of
tial energy. The choice, however, makes no difference: Any of the three re
levels could be used as the zero level, regardless of whether the book is at Ⓐ
Ⓒ. Example 5.4 illustrates this important point.

EXAMPLE 5.4 Wax Your Skis

Goal Calculate the change in gravitational potential energy for different choices of reference level.

Problem A 60.0-kg skier is at the top of a slope, as shown in Figure 5.14. At the initial point Ⓐ, she is 10.0 m vertically above point Ⓑ. **(a)** Setting the zero level for gravitational potential energy at Ⓑ, find the gravitational potential energy of this system when the skier is at Ⓐ and then at Ⓑ. Finally, find the change in potential energy of the skier–Earth system as the skier goes from point Ⓐ to point Ⓑ. **(b)** Repeat this problem with the zero level at point Ⓐ. **(c)** Repeat again, with the zero level 2.00 m higher than point Ⓑ.

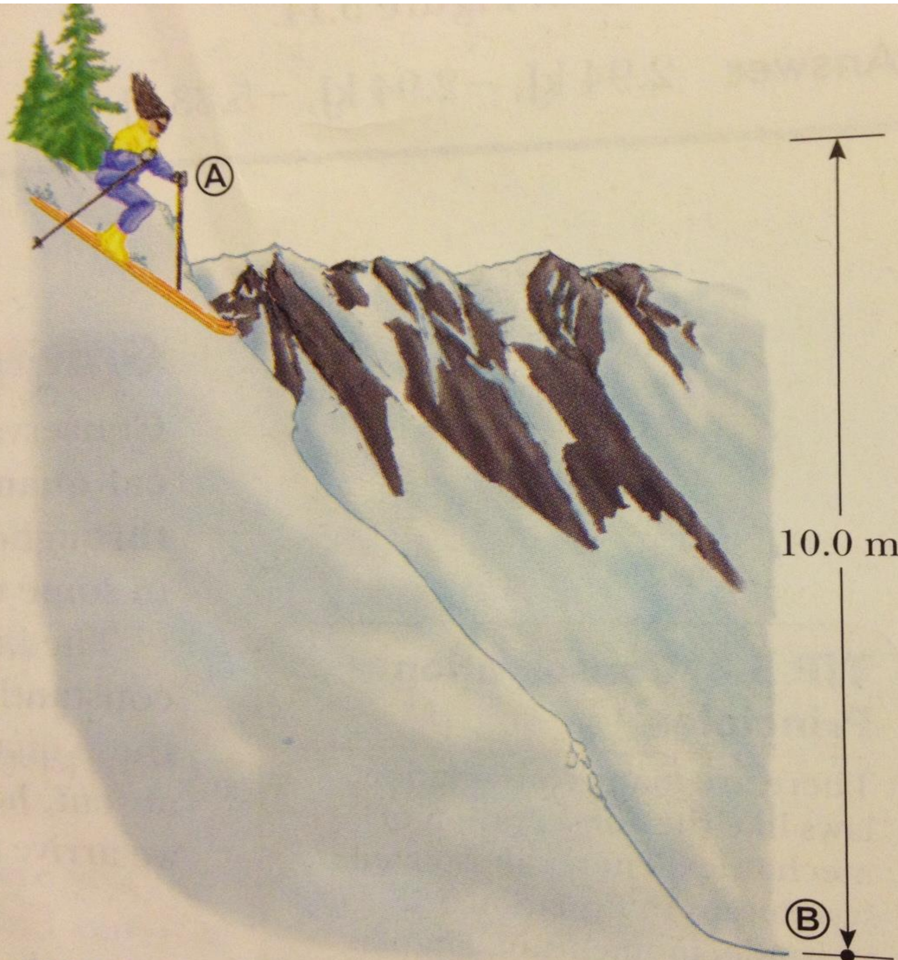


FIGURE 5.14

8-3-- Conservation of Mechanical Energy

Definition of mechanical energy:

$$E = U + K \tag{8-6}$$

Using this definition and considering only conservative forces, we find:

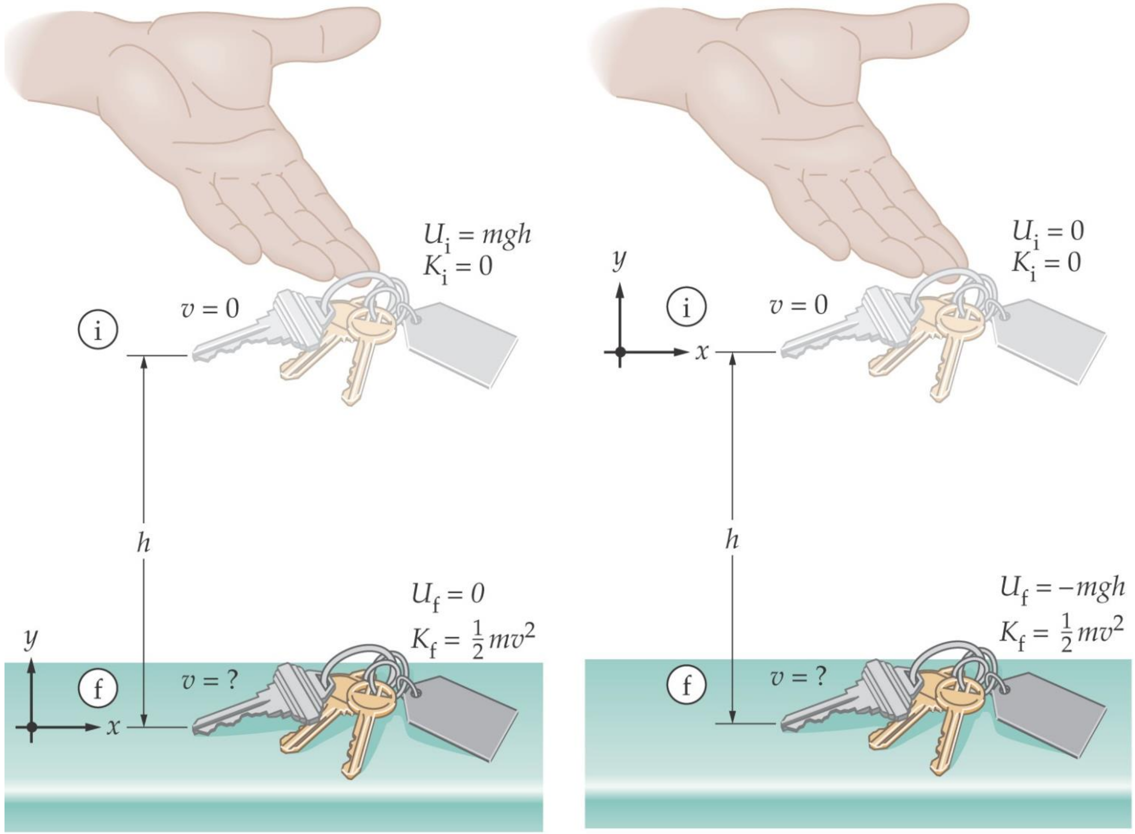
$$E_f = E_i$$

Or equivalently:

$$E = \text{constant}$$

8-3-- Conservation of Mechanical Energy

Energy conservation can make kinematics problems much easier to solve:



The Law of Conservation of Energy

Energy in a system may take on various forms (e.g. kinetic, potential, heat, light).

The law of conservation of energy states that energy may neither be created nor destroyed. Therefore the sum of all the energies in the system is a constant.

$$K_i + U_i = K_f + U_f$$

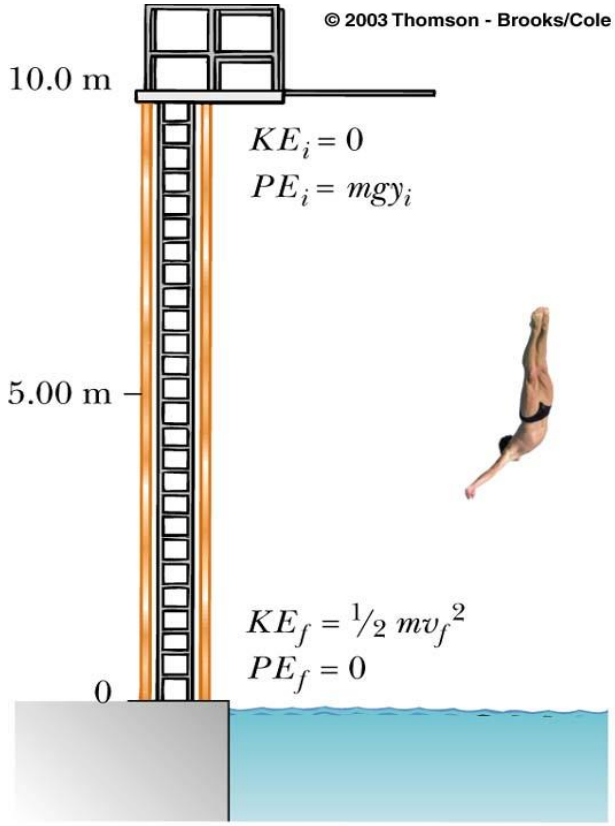
$$\frac{1}{2} m v_i^2 + mgh_i = \frac{1}{2} m v_f^2 + mgh_f$$

Absent

$$\frac{1}{2} m v_i^2 + mgy_i = \frac{1}{2} m v_f^2 + mgy_f$$

Example

A diver of mass *m* drops from a board 10.0 m above the water surface, as in the Figure. Find his speed 5.00 m above the water surface. Neglect air resistance.



Ans.:

his speed 5.00 m above the water surface = 9.9 m/s

Example

$u = 0$ in sea level

$hf = 5m \rightarrow vf = ?$

mass $= m$

$Hi = 8\,m$

$$mgh_i + \frac{1}{2} m v_i^{\,=0} = mgh_f + \frac{1}{2} m v_f^2$$

$$m(9.81)(10) + 0 = (m)(9.81)(5) + \frac{1}{2} m v_f^2$$

$$\frac{1}{2} m v_f^2 = mg(10) - mg(5)$$

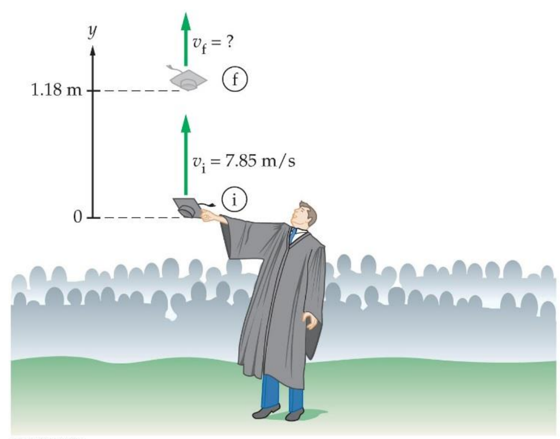
$$m \div \frac{1}{2} \cancel{m} v_f^2 = 5 \cancel{m} g \div m$$

$$\frac{1}{2} v_f^2 = 5g$$

$$v_f = \sqrt{\frac{5 \times 9.81}{\frac{1}{2}}} = 9.$$

Example 8-5

- At the end of graduation ceremony, graduates fling their caps into the air. Suppose a 0.120-kg cap is thrown straight upward with an initial speed of 7.85m/s, and the frictional forces can be ignored.
- A) use kinematics to find the speed of the cap when it is at 1.18m above the release point,
- B) Show that mechanical energy at release point is the same as mechanical energy 1.18m above the release point.
- Sol:- a) $V_y = 6.20$m/s
- B) $E_i = 3.70$J , $E_f = 3.70$J



Example 8-5

$m = 0.120$ Kg
$v_i = -7.85$ m/s
$h_i = 0$
$h_f = 1.18$ m
$v_f = ?$

A) Using Equations of Motion

$$v_f^2 = v_i^2 + 2a\Delta x$$

in y axis

$$v_f^2 = v_i^2 + 2g\Delta y$$

$$v_f = \sqrt{v_i^2 + 2g\Delta y}$$

$$v_f = \sqrt{(7.85)^2 + (2(-9.81)(1.18-0)}$$

$$\vec{v_f} = (6.2 \ m/s)\Delta y$$

B) $E_i = U_i + K_i = mg\cancel{h_i} + \frac{1}{2} m v_i^2$

$h_i = 0$

$$\frac{1}{2}(0.120)(7.85)^2 = 3.7 \ J$$

$E_f = U_f + K_f = mgh_f + \frac{1}{2} m v_f^2$

$$(0.120 \cdot 9.81 \cdot 1.18) + \frac{1}{2}(0.120)(6.2)^2 = 3.7 \ J$$

Mechanical energy is conserved.

Problem

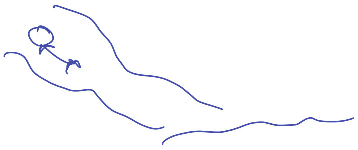
- Q24)At an amusement park, a swimmer uses a water slide to enter the main pool, If the swimmer starts at rest, slides without friction, and descends through a vertical height of 2.32m, what is her speed at the bottom of slide?

Ans. : 6.73m/s

$v_i = 0$ $h = 2.32\ m$

$v_f = ?$

Problem



$$v_f = \sqrt{2Hg}$$

Same steps for the kegs.

$$= \sqrt{2(2.32)(9.81)}$$

$$= 6.7\ \text{m/s}$$

8-4 Work Done by Nonconservative Forces

In the presence of nonconservative forces, the total mechanical energy is not conserved:

Finding work total by c & nc, not with ΔK

$W_{total} = \Delta K$

$$W_{\text{total}} = W_{\text{c}} + W_{\text{nc}}$$

$$= -\Delta U + W_{\text{nc}} = \Delta K$$

Solving,

$$W_{\text{nc}} = \Delta U + \Delta K = \Delta E \qquad (8\text{-}9)$$

$$Work_{Total} = \Delta K$$

$$Work_c = -\Delta U$$

$$Work_{total} = Work_c + Work_{nc}$$

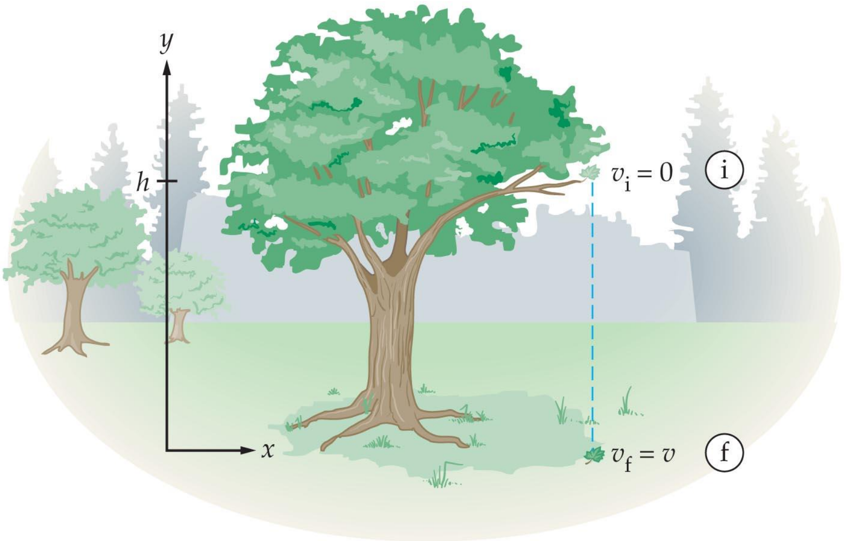
$$\Delta K = -\Delta U + Work_{nc}$$

$$Work_{nc} = \Delta K + \Delta U \longrightarrow \Delta(K+U) \longrightarrow \Delta E$$

$$Work_{nc} = \Delta E \rightarrow E_f - E_i$$

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?



Example 9

$h_i = 5.3\,m$

$v_i = 0$

$h_f = 0$

$v_f = 1.3\,m/s$

$m = 1.70 \times 10^{-3}\,kg$

$W_{nc} = \Delta E = E_f - E_i$

1) $E_f = U_f + K_f$

$= \cancel{mgh_f} + mgv_f^2$

$= (1.70 \times 10^{-3})(9.81)(1.3)^2$

$= 0.014\,J$

2) $E_i = U_i + K_i$

$= mgh_i + mg\cancel{v_i}^2$

$= (1.70 \times 10^{-3})(9.81)(5.3)$

$= 0.88\,J$

3) $Work_{nc} = (0.014) - (0.088)$

$= -0.86\,J$

Same idea

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

Summary of Chapter 8

- Work done by nonconservative force on closed path is not zero, and depends on the path

- 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

Summary of Chapter 8

- 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