Conservation of Energy

by

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P4.2C Explain how energy is conserved in common systems (e.g., light incident on a transparent material, light incident on a leaf, mechanical energy in a collision).

P4.2e Explain the energy transformation as an object (e.g., skydiver) falls at a steady velocity.

Items;

1- Mechanical Energy.

2- Conservation of Energy.

MECHANICAL ENERGY

Mechanical energy (E) of an object is the sum of the kinetic energy (KE) and potential energy (PE).

$$E = KE + PE$$

THE PRINCIPLE OF CONSERVATION OF MECHANICAL ENERGY

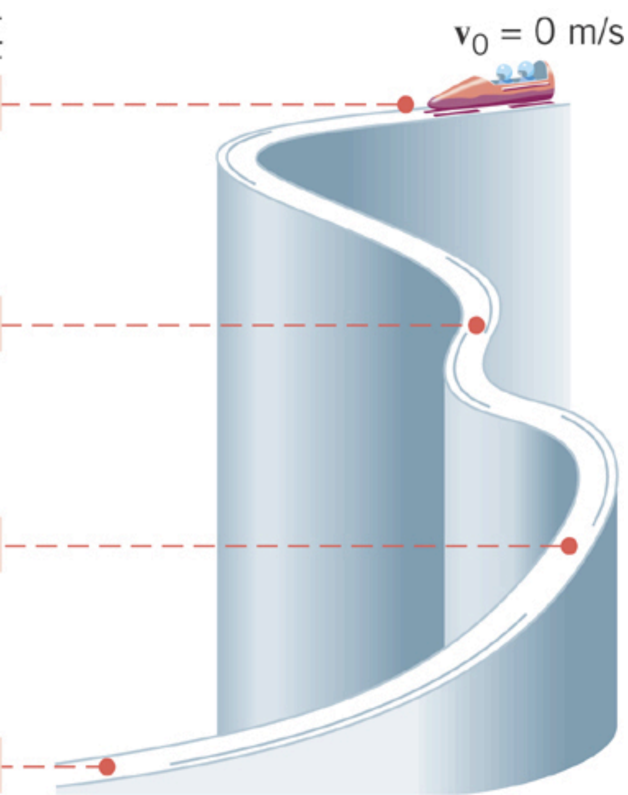
$$\boxed{E = KE + PE = \text{constant}}$$

Energy can neither be created nor destroyed, but can only be converted from one form to another. KE can converted to PE. PE can be converted to KE. The total mechanical energy of an object remains constant as the object moves, provided that the net work done is zero.

Example 1: A Sled;

Below is a picture of a sled starting a rest (Vo = 0 m/s) and sliding down. Note that the mechanical energy (E = KE + PE) is constant along the way and is equal to 600000 joules, at every spot of the pathway. Explanation is in next page.

KE	PE	E = KE + PE
0 J	600 000 J	600 000 J
200 000 J	400 000 J	600 000 J
400 000 J	200 000 J	600 000 J
600 000 J	0 J	600 000 J



Explanation:

Potential Energy is related to the height (h) of the object: PE = m g h

Kinetic Energy is related to the speed (v) of the object: KE = 1/2 m v^2

As the sled moves down the PE is converted to KE as explained below:

a) the height decreases. So, the potential energy (PE) decreases from 600000 joules to 400000 joules to 200000 joules and finally 0 Joules at the surface of the earth where h = 0.

b) the speed increases. So, the the kinetic energy (KE) increases from 0 joules to 200000 joules to 400000 joules to 600000 joules at the bottom where the speed is maximum.

c) but the total mechanical energy is always the same. E = KE + PE = 600000 joules at every spot of the pathway.

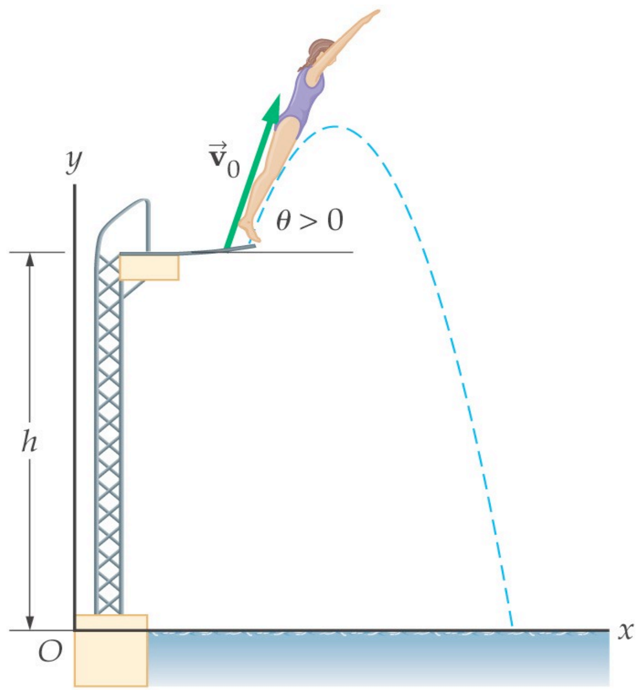
***Example 2:** A Falling Rock;*

A rock was at rest at the top of a cliff of height 78.4 meter. Then, the rock fell to the bottom of the cliff. It took the rock 4 seconds to reach the bottom. Data was collected in the table below. Notice the change in kinetic and potential energy. The total energy remains the same.

a) Time Δt (s)	b) Speed v (m/s)	c) Height h (m)	d) Kinetic Energy KE (J)	e) Potential Energy PE (J)	f) Total Energy E (J)
0	0	78.4	0	384	384
1	9.8	73.5	24.0	360	384
2	19.6	58.8	96.0	288	384
3	29,4	34.3	216	168	384
4	39.2	0	384	0	384

Example 3: *Diving from an Edge;*

A 56 Kg diver runs and dives from the edge of a board into the water which is located 4.0 m below. She is moving at 8.0 m/s the instant she leaves the board. We are considering the initial state is the moment when she leaves the board. The final state would be the moment she enters the water. Consider the water level as the reference level.



Determine the following:

a) her gravitational potential energy relative to water surface when she leaves the board,

b) her kinetic energy when she leaves the board'

c) her total mechanical energy relative to the water surface just before she enters the water below,

d) the speed at which she enters the water.

Data Table							
m	h	v_o	g	$PE_{initial}$	$KE_{initial}$	E_{total}	v_f
56 kg	4.0 m	8.0 m/s	9.8 N/kg	?	?	?	?

a) $PE_{initial} = m\ g\ h = 56 \times 9.8 \times 4 = 2200$ J

b) $KE_{initial} = 1/2\ m\ v_i^2 = 1/2 \times 56 \times 8^2 = 1800$ J

c) $E_{total} = KE + PE = 2200 + 1800 = 4000$ J

The total mechanical energy remains constant if friction and air resistance can be ignored. Therefore, the total mechanical energy of the diver the instant she enters the water is still the same:

$$E_{total} = 4000 \text{ J}$$

d) When she enters the water, she is at reference level. Her height above the water $h_f = 0$ m. So, the potential energy PE = mgh = 0 J.

All the mechanical energy is now kinetic energy:

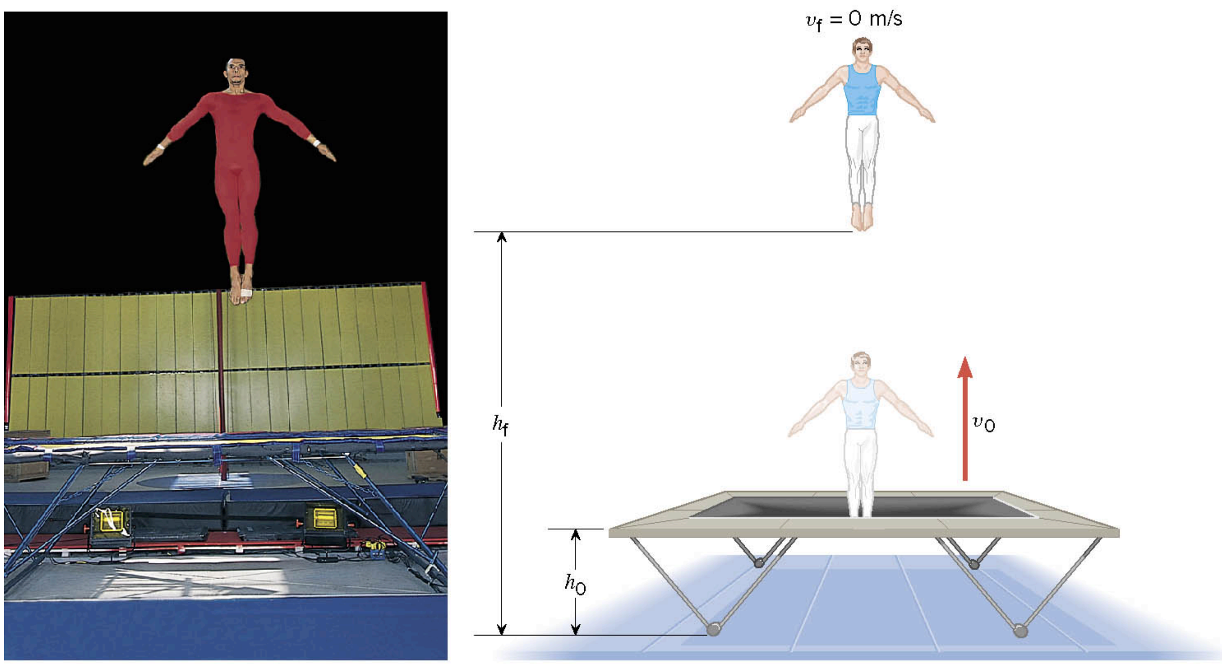
$$4000 = KE = 1/2\ m\ v_f^2 = 1/2\ (56) \times v_f^2 = 28\ v_f^2$$

$$v_f^2 = 4000/28 = 140 \text{ J/kg}$$

$$v = 12 \text{ m/s}$$

Example 4: *A Gymnast on a Trampoline*.

The gymnast of mass m leaves the trampoline at an initial speed v_o and reaches a final speed v_f of zero before falling back down. Calculate initial speed v_o.



(a) (b)

Work-Energy Theorem:

$$W = \text{KE}_f - \text{KE}_o = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_o^2$$

$= -1/2\ m$

v_o^2 (because $v_f = 0$ m/s)

Only the gravitational force acts on the gymnast in the air. The gravitational force is the net force and the work is the work done by gravity:

$$W_{\text{gravity}} = mg(h_o - h_f)$$

Therefore;

$$m\,g\,(h_o - h_f) = -1/2\ m\ v_o^2$$

Simplifying m:

$$g\,(h_o - h_f) = -1/2\ v_o^2$$

$$v_o = \sqrt{-2g(h_o - h_f)}$$

Example 5: *Conservation of Energy, Application;*

Energy is conserved in common systems such as:

- light incident on a transparent material,
- light incident on a leaf,
- mechanical energy in a collision,

References:

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Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current. www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

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