Gravitational Potential Energy

by

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P4.1e Using the formula for work, derive a formula for change in potential energy of an object lifted a distance h.

P4.3e Calculate the changes in kinetic and potential energy in simple mechanical systems (e.g., pendulums, roller coasters, ski lifts) using the formulas for kinetic energy and potential energy.

P4.3A Identify the form of energy in given situations (e.g., moving objects, stretched springs, rocks on cliffs, energy in food).

Items:

1- Gravitational Potential Energy.

2- Work - Energy Theorem.

DEFINITION OF GRAVITATIONAL POTENTIAL ENERGY

Gravitational Potential Energy (PE) is the stored energy.

It is the energy that an object has because of its position (height) above the surface of the Earth. The height h of the object can be relative to an arbitrary zero level.

If an object of mass (m) is at the height (h) above the surface of the Earth. Then, it has a potential energy (PE) is given by the formula:

POTENTIAL ENERGY (PE)
$\mathrm{PE} = mgh$ $1\,\mathrm{N}\cdot\mathrm{m} = 1\ \mathrm{joule}\,(\mathrm{J})$

m is the mass of the object, in kilograms

g is the gravitational field strength. It is a constant value. $g = 9.8\ m/s^2$

h is the height or the vertical displacement the object is moved, in meter

The higher the object, the higher is its potential energy.

Example 1:

How much gravitational potential energy does a rock of mass = 4.0 kg rock gain if it is lifted to the height = 25 m?

Data Table			
m	PE	h	g
4.0 kg	?	25 m	$9.8\ m/s^2$

$$PE = m\ g\ h$$

$$= (4.0)(9.8)(25) = 9.8 \times 10^2\ J.$$

No machine can operate without fuel. Gasoline is the fuel for automobiles. Food is the fuel for the human body. Food gives you the ability to do work. It gives you energy.

Energy (E) is the ability to do work. Work (W) is the transfer of energy.

Both work and energy have the same unit, the joule (J) . So if you do 5000 J of work on an object, you have transferred 5000 J of your energy to it.

$$\mathbf{W = \Delta E}$$

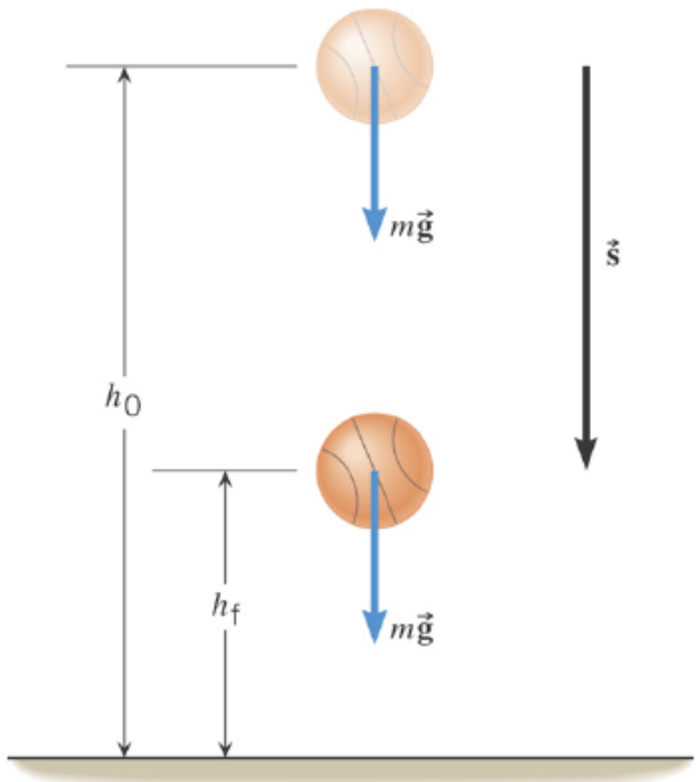
W is the work done on an object, in joules

ΔE is the change in energy of the objects, in joules.

Moving objects and waves transfer energy from one location to another. Moving objects also transfer energy to other objects during interactions (e.g. sunlight transfers energy from the sun to the Earth. The ground gets warm.

Work and Gravitational Potential Energy.

A basketball of mass m, accelerates downward from an initial height (h_o) to a final height (h_f). What is the work done by gravity ($W_{gravity}$) on the basketball?



THE WORK-ENERGY THEOREM:

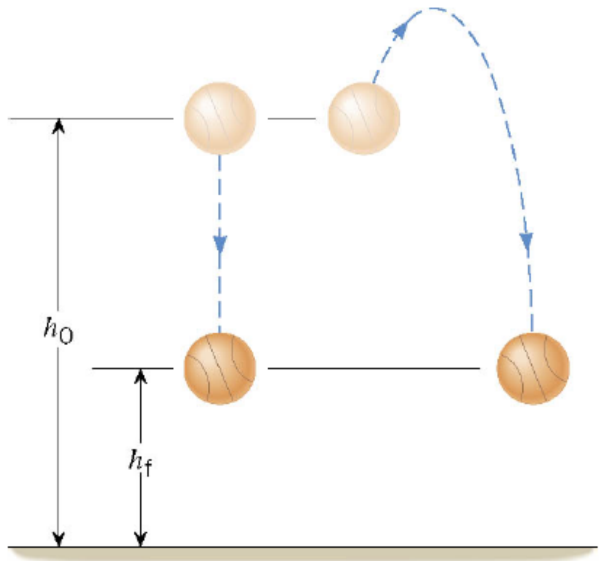
The work done by gravity equals the change in potential energy between the initial position and the final position.

Work-Energy Theorem
$W_{\text{gravity}} = mg\left(h_o - h_f\right)$

So, the work done by gravity in accelerating the basketball downward from h_o to h_f.

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

The work done on the system depends only on the final position and the initial position. It is independent of the route or path taken. Example is below.

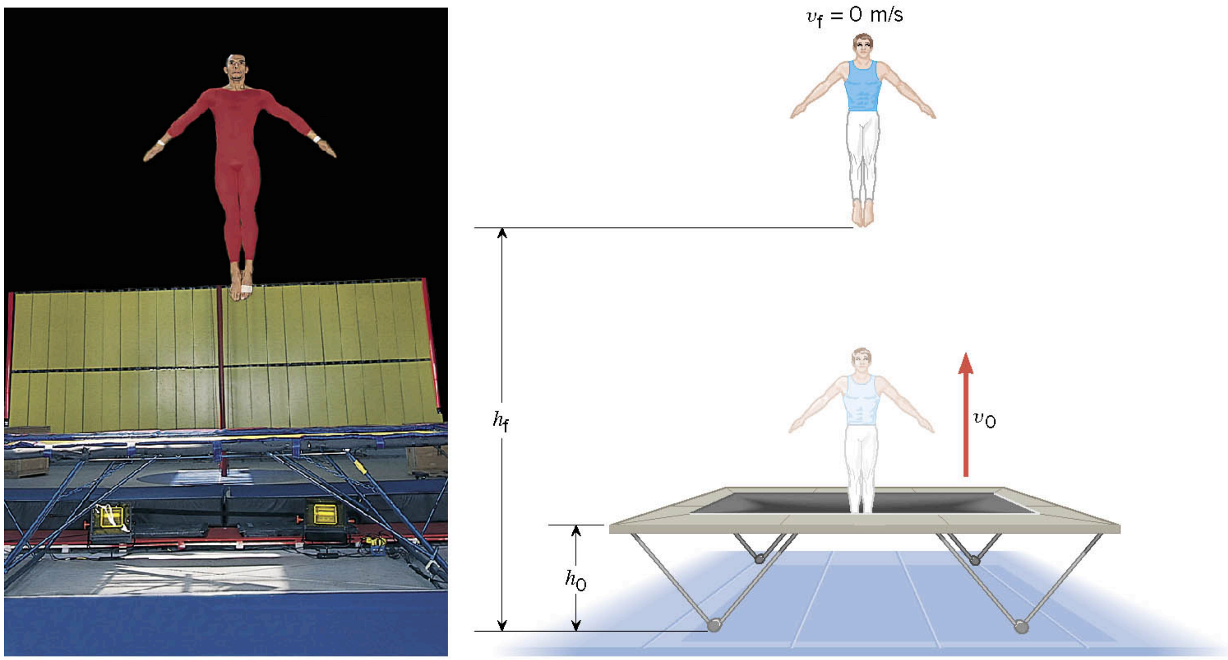


We have two balls coming from the same initial position with hight h_o to a final position h_f. They follow two different routes. One accelerates straight and one accelerates as a projectile. $W_{gravity}$ is the same for any path taken between h_o and h_f because they both have the same initial and final positions.

Both balls have the same $W_{gravity}$.

Example 2: *A Gymnast on a Trampoline*.

The gymnast of mass m leaves the trampoline at an initial height h_o and reaches a maximum height h_f before falling back down.



(a) (b)

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:

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

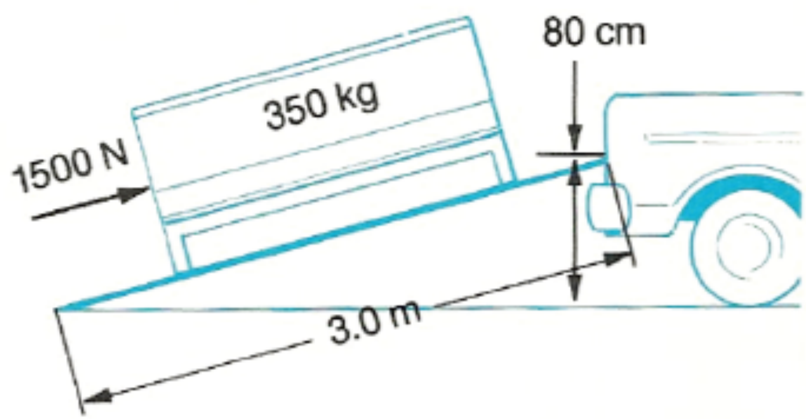
Example 3: *Sliding a Piano*

A family uses several planks to slide a 350 kg piano onto the back of a pickup truck. The box in back of the pickup truck is 80 cm above the ground and the planks are are 3.0 m long. If an average force of 1500 N is required to slide the piano up to the planks.

a) Find the work done in loading the piano (energy input).

b) How much "useful work" is done (energy output)?

c) What is the efficiency of the planks as a simple machine to load the piano?



Data Table							
Δd	F	m	Δh	g	W	$W_{gravity}$	$Efficiency$
3.0 m	1500 N	350 kg	80 cm = 0.8 m	9.8 N/kg	?	?	?

a) $W = F \Delta d$

$= 1500 \times 3.0$

$= 4.5 \times 10^3$ J

b) $W_{gravity} = \Delta E$

$= m g \Delta h$

$= 350 \times 9.8 \times 0.8$

$= 2.7 \times 10^3$ J

c) Efficiency = (useful energy output / energy input) x 100

$$= (2.7 \times 10^3 / 4.5 \times 10^3) \times 100$$

= 60 %

The Planks are 60 % efficient when used as a machine to load the piano onto the pickup truck.

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/*

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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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