Chapter 7

1

ENERGY OF A SYSTEM

1

Lecture 03

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Work And Gravitational Potential Energy

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Work and Gravitational Potential Energy

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- Potential energy is energy determined by the configuration of a system in which the components of the system interact by forces.
- The forces are internal to the system.
- Can be associated with only specific types of forces acting between members of a system
- Potential energy is always associated with a system of two or more interacting objects.

3

Work and Gravitational Potential Energy

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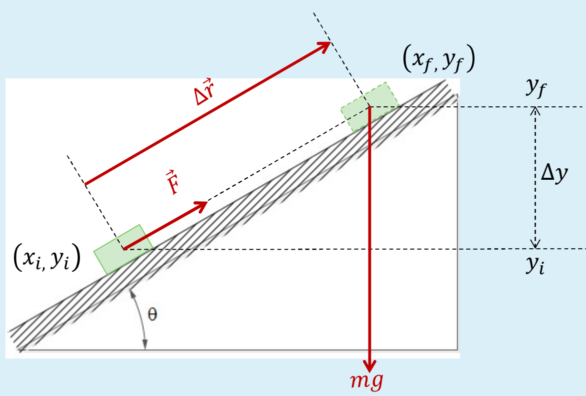
- Assume the book in the figure is lifted with constant speed.
- There is NO change in kinetic energy.



$$\Delta\vec{r} = (x_f - x_i)\hat{\imath} + (y_f - y_i)\hat{\jmath}$$

$$\vec{F}_g = -mg\hat{\jmath}$$

4

Work and Gravitational Potential Energy

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The work done by the gravitational force is:

$$W_{mg} = \vec{F}_g \cdot \Delta\vec{r}$$

$$W_{mg} = -mg\hat{\jmath} \cdot \left[(x_f - x_i)\hat{\imath} + (y_f - y_i)\hat{\jmath}\right]$$

$$W_{mg} = -mg(y_f - y_i)$$

$$W_{mg} = -(mgy_f - mgy_i)$$

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Work and Gravitational Potential Energy

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Gravitational Potential Energy

- is the energy stored in an object as the result of its vertical position or height.
- For an object of mass m and at a height y, its gravitational potential energy is given by:

$$U_g = mgy$$

- Is a scalar could be: positive, negative or zero.
- SI units:
- $kg.\frac{m}{s^2}.m = kg.m^2/s^2 = Joule$
- A zero height position must first assigned. Typically, the ground.
- Any position can be assigned as a zero height position.

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Work and Gravitational Potential Energy

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The work done by the gravitational force is:

$$W_{mg} = -mg(y_f - y_i)$$

The work done by the gravitational force along a closed path is zero $(y_f = y_i)$.

- A closed path is one for which the beginning point and the endpoint are identical.

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Work and Gravitational Potential Energy

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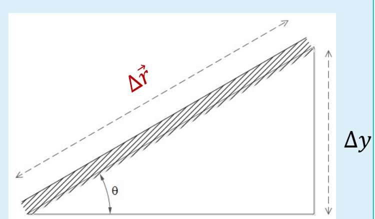
The work done by the gravitational force is:

$$W_{mg} = -mg(y_f - y_i)$$

$$W_{mg} = -mg\Delta y$$

$$W_{mg} = -mg\Delta r sin\theta$$

The work done by the gravitational force is path independent.



$$sin\theta = \frac{\Delta y}{\Delta r}$$

$$\Delta y = \Delta r sin\theta$$

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Work and Gravitational Potential Energy

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The work done by the gravitational force is:

$$W_{mg} = -mg(y_f - y_i)$$

$$W_{mg} = -(mgy_f - mgy_i)$$

$$W_{mg} = -(U_{gf} - U_{gi})$$

$$W_{mg} = -\Delta U$$

The work done by the gravitational force equals the decrease in potential energy.

Choosing reference level for U_(g)

Saturday, 30 January, 2021 15:10

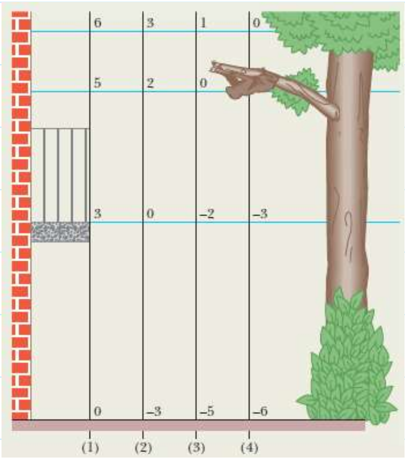
Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY,2014.
H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

A 2 kg sloth hangs 5 m above the ground.

- What is the gravitational potential energy of the sloth–Earth system if we take the reference point $y = 0$ to be:
  - at the ground,
  - at a balcony floor that is 3 m above the ground,
  - at the limb, and
  - 1 m above the limb?

- The sloth drops to the ground. For each choice of reference point, what is the change in the potential energy of the sloth–Earth system due to the fall?



Solution

For choice (1) the sloth is at $y = 5.0m$, and:
$U = mgy = (2.0kg)(9.8m/s^2)(5.0m) = 98J$
For the other choices, the values of U are:
(2) $U = mgy = mg(2.0m) = 39J$
(3) $U = mgy = mg(0) = 0J$
(4) $U = mgy = mg(-1.0m) = -19.6J$

Solution

The change in potential energy does not depend on the choice of the reference point for $y = 0$; instead, it depends on the change in height Δy.

For all four situations, we have the same $\Delta y = -5.0m$. Thus, for (1) to (4):
$\Delta U = mg\Delta y = (2.0kg)(9.8m/s^2)(-5.0m) = -98J$

Calculating work by F_(ext)

Saturday, 30 January, 2021 15:11

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

- R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
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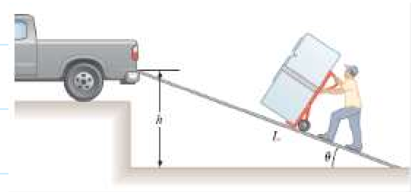
A man wishes to load a refrigerator onto a truck using a ramp at angle θ as shown. Suppose the refrigerator is wheeled on a hand truck up the ramp at constant speed. Determine the work done by the man.



Solution

Since the speed is constant, then, according to the $W - \Delta K$ theorem, the work done by the net force is zero.

$W_{net} = W_{by\,\text{man}} + W_{by\,\text{gravity}} = 0$

Therefore:

$W_{by\,\text{man}} = -W_{by\,\text{gravity}} = -{}^{-}mgh = mgh$

The work depends only on the height of the ramp. Although less force is required with a longer ramp, the point of application of that force moves through a greater displacement.

Calculating work by F_(g)

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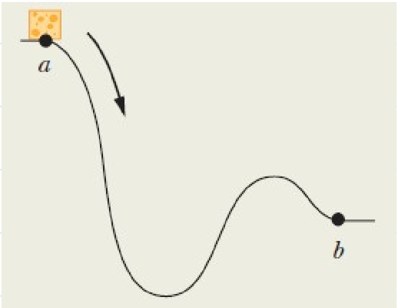
The figure shows a 2 kg block of slippery cheese that slides along a frictionless track from point (a) to point (b). The cheese travels through a total distance of 2 m along the track, and a net vertical distance of 0.8 m. How much work is done on the cheese by the gravitational force during the slide?



Solution

We cannot calculate the work by using $(W_g = mgd\cos\theta)$ The reason is that the angle θ between the directions of the gravitational force $\vec{F}_g$ and the displacement $\vec{d}$ varies along the track in an unknown way. Because $\vec{F}_g$ is a conservative force, we can find the work by choosing some other path between a and b.

Along the horizontal segment, the angle θ is a constant $(90°)$.
$W_h = mgd\cos 90° = 0$

Along the vertical segment, the displacement d is 0.80 m and, with $\vec{F}_g$ and $\vec{d}$ both downward, the angle θ is a constant $(0°)$.
$W_v = mgd\cos 0° = (2.0kg)(9.8m/s^2)(0.80m)(1) = 15.7J$

The total work
$W = W_h + W_v = 0 + 15.7J = 15.7J$
This is also the work done as the cheese slides along the track from a to b.