Section 4: Introduction to Energy

Energy (E) is defined as the capacity to do work (scalar.)

Mechanical Energy- the energy due to the position of something or the movement of something

Mechanical Energy can be divided into two categories

1) Potential Energy (PE): Stored energy or energy due to position
2) Kinetic Energy (KE): Energy due to motion

The unit for all energy and work is the Joule.
A. Potential Energy

- To gain potential energy (PE) WORK MUST BE DONE ON THE SYSTEM.
- There are many ways to store energy, each resulting in a different name for potential energy. Two of the most common types are:
  - Gravitational Potential Energy
  - Elastic Potential Energy

i) Gravitational potential energy refers to potential energy that is stored every time something is lifted against gravity. As long as it is held in that position it has gravitational potential energy.

The potential energy is equal to the amount of work done to raise it to that position.

\[
E_g = W = Fd = mgh
\]

where m - the mass of the object in kg
    g - the acceleration due to gravity 9.8 m/s^2
    h is the height of the object above or below some reference point.

\(E_g - \text{Gravitational Potential Energy (Joules)}\)

If the object is above the reference point h is positive and if h is below the reference point is negative.
Gravitational Potential Energy near the surface of the Earth:

\[ W = mg \times \Delta h \]

E = \frac{\text{Work}}{\text{Win}}

Change \ \frac{\text{in}}{\text{E}_{g}}

All 3 have same \ \text{E}_{g}, \ \text{b, c height above ground is the same.}
Gravitational potential energy of an object depend on two factors:

1) Mass of the object
2) Distance it is raised.

Note: The more work that is done on an object in lifting it, the more gravitational potential energy it will have.

Examples

A) A Roller Coaster
   At the top of a roller coaster, the potential energy is the greatest.

B) A Waterfall
   A waterfall’s potential energy can be used to drive turbines and to hydo-electricity.
\[ E_g = w = Fd = mgd \]
\[ E_g = mg \cdot h \]
A 1.20 kg book is on a bookshelf 2.00 m above the floor. The table top is 1.20 m above the floor.

A) What is the gravitational potential of the book relative to the table top?

\[ m = 1.20 \text{ kg} \]
\[ g = 9.8 \text{ m/s}^2 \]
\[ h = 0.80 \text{ m} \]

\[ E_g = mgh \]
\[ E_g = (1.20 \text{ kg})(9.8 \text{ m/s}^2)(0.80 \text{ m}) \]
\[ E_g = 9.45 \text{ J} \]

B) Calculate the gravitational potential energy relative to the floor.

\[ h = 2.00 \text{ m} \]
\[ E_g = mgh \]
\[ = (1.20 \text{ kg})(9.8 \text{ m/s}^2)(2.0 \text{ m}) \]
\[ = 23.55 \text{ J} \]

The gravitational potential energy of a 1300 kg car changes by 2.9 MJ as it climbs up a hill. If the car is initially at an altitude of 130 m, what will be its altitude when it is finished?

\[ m = 1300 \text{ kg} \]
\[ \Delta E_g = 2.9 \times 10^6 \text{ J} \]

\[ \text{altitude} = 130 \text{ m} \]

\[ \Delta h \]

\[ \frac{E_g}{mg} = \frac{mg}{mg} \]
\[ \frac{2.9 \times 10^6 \text{ J}}{(1300 \text{ kg})(9.8 \text{ m/s}^2)} \]
\[ a_28 \text{ m} = \Delta h \]

\[ \text{altitude} = a_28 \text{ m} + 130 \text{ m} \]
\[ = 358 \text{ m} \]
3 A 2.0 kg watermelon rolls off a 0.75 m high table onto a chair that is 0.45 m high before it finally hits the floor. While it is still on the table, what is the gravitational potential energy relative to:

A) the table  B) the chair  C) the floor

\[ \begin{align*}
&\text{a) } h = 0.75 \, \text{m} - 0.45 \, \text{m} \\
&h = 0.30 \, \text{m} \\
&E_g = mg \cdot h \\
&E_g = (2.0 \, \text{kg})(9.8 \, \text{m/s}^2)(0.30 \, \text{m}) \\
&E_g = 5.9 \, \text{J}
\end{align*} \]

4 In the picture, the 2.4 kg paint can is 2.7 m above ground level. What is the gravitational potential energy of the can with respect to the 4th rung which is 1.8 m above ground level?

\[ \begin{align*}
&h = 2.7 \, \text{m} - 1.8 \, \text{m} = 0.9 \, \text{m} \\
&E_g = mg \cdot h \\
&= (2.4 \, \text{kg})(9.8 \, \text{m/s}^2)(0.9 \, \text{m}) \\
&= 21 \, \text{J}
\end{align*} \]
5. What percentage of its gravitational potential energy does a squash ball lose if it falls from 3.0 m and returns to a height of 0.76 m after bouncing once?

\[
\begin{align*}
\text{at } 1: & \quad E_{g1} = mgh_1 \\
\text{at } 2: & \quad E_{g2} = mgh_2
\end{align*}
\]

\[
\% \text{ of } E_g \text{ left at position 2:} \quad \frac{E_{g2}}{E_{g1}} = \frac{mgh_2}{mgh_1} = \frac{0.76\text{ m}}{3.0\text{ m}}
\]

\[
\text{Percentage} = 25\% \quad (\text{lost})
\]

\[
\therefore \text{The squash ball lost } 75\% \quad (100 - 25 = 75)
\]
6. Jake pushes a box up a ramp, exerting a force of 350 N. He walks on the ramp, pushing the box for 25.0 m. If the box has a mass of 50.0 kg, what is the height of the ramp and the angle it makes with the horizontal. The ramp is 100% efficient.

\[ W_{in} = Fd \]
\[ = (350 \text{N})(25 \text{m}) \]
\[ = 8750 \text{J} \]

\[ W_{in} = W_{out} \quad \Delta E_g = 8750 \text{J} \]

\[ E_g = \frac{mg \cdot h}{mg} \]
\[ \frac{8750 \text{J}}{(50 \text{kg})(9.8 \text{m/s}^2)} = h \]
\[ 18 \text{m} = h \]

\[ \sin \theta = \frac{0}{h} = \frac{18 \text{m}}{25 \text{m}} \]
\[ \theta = 46^\circ \]

Do questions 1 and 3 page 338, questions 64, 65, 67 - 70 page 372. For # 65 use a mass of 55 kg.