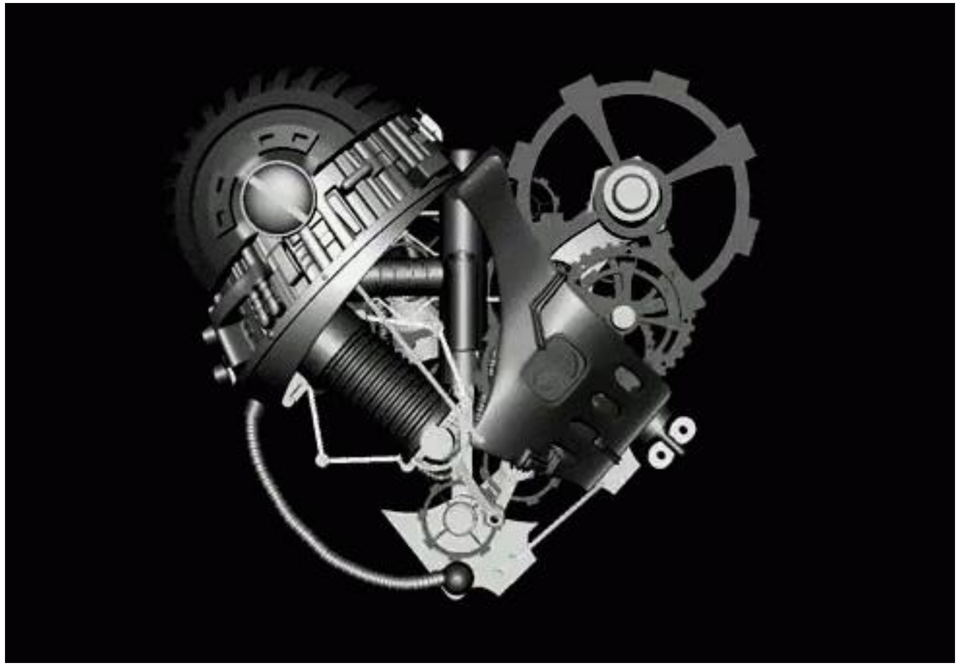
Grade 12 – Physics



Unit 1: Mechanics

Chapter 1: Energy

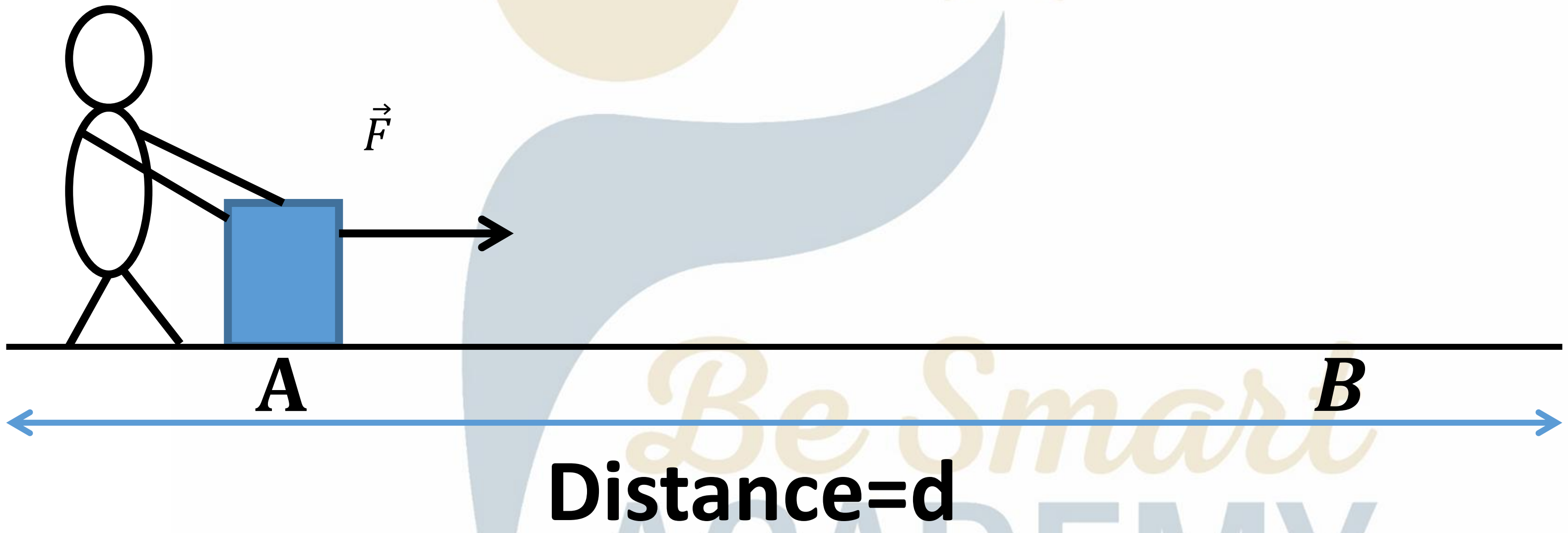
Prepared & presented by: Mr. Mohamad Seif

OBJECTIVES

1 Recall the definition of work of a constant force

Recall Work of a constant force

Force causes Displacement ➡ Work is done



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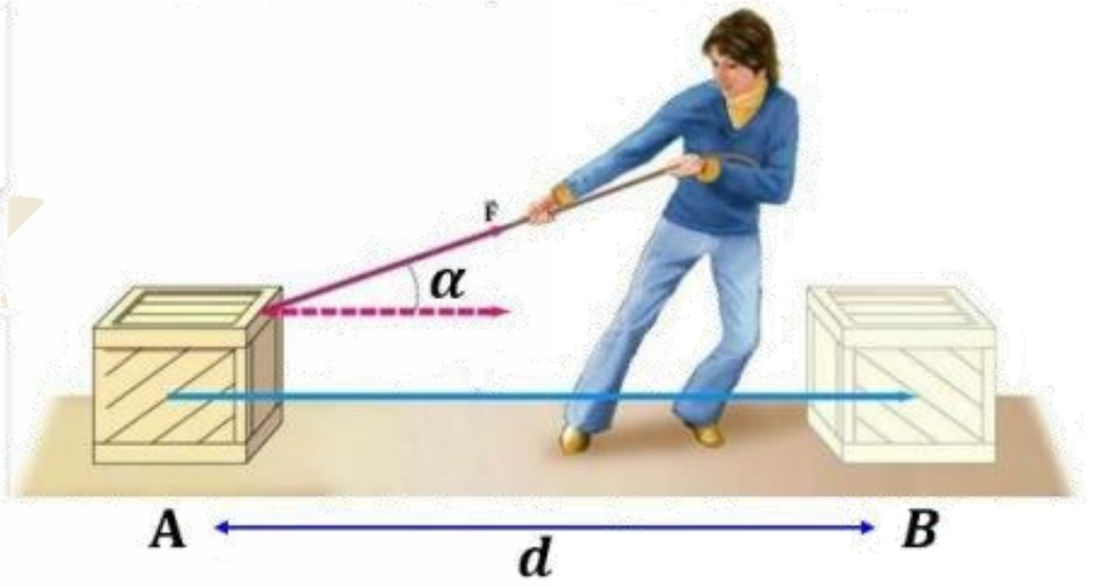
Recall Work of a constant force

The work done by constant force:



$$W_{\vec{F}} = F \times AB \times \cos(\alpha)$$

$W_{\vec{F}}$: **work done by the force, expressed in Joule J.**

F: applied force, expressed in Newton N

AB: is the distance covered by the box, expressed in meter m.

α: angle between the force and the displacement, expressed in degree.

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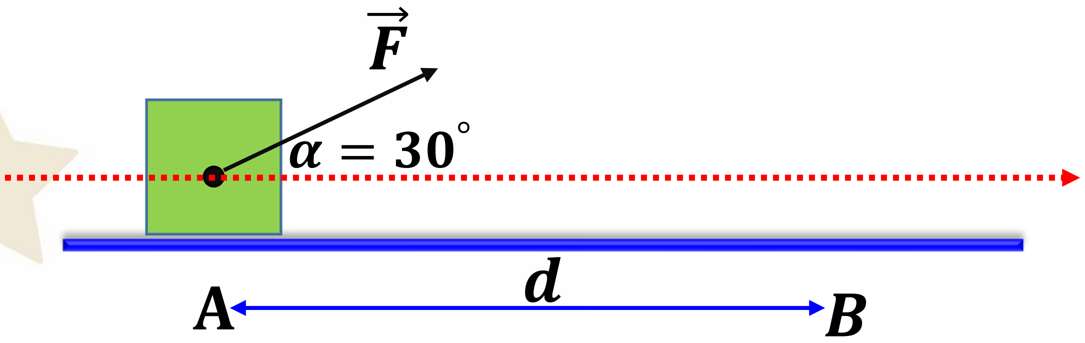
Work done by constant force

Application 1:



A box of mass $m = 750g$ slides on a rough surface AB.

The box moves under the action of a force $F = 0.75N$ making an angle $\alpha = 30^{\circ}$ with the horizontal.

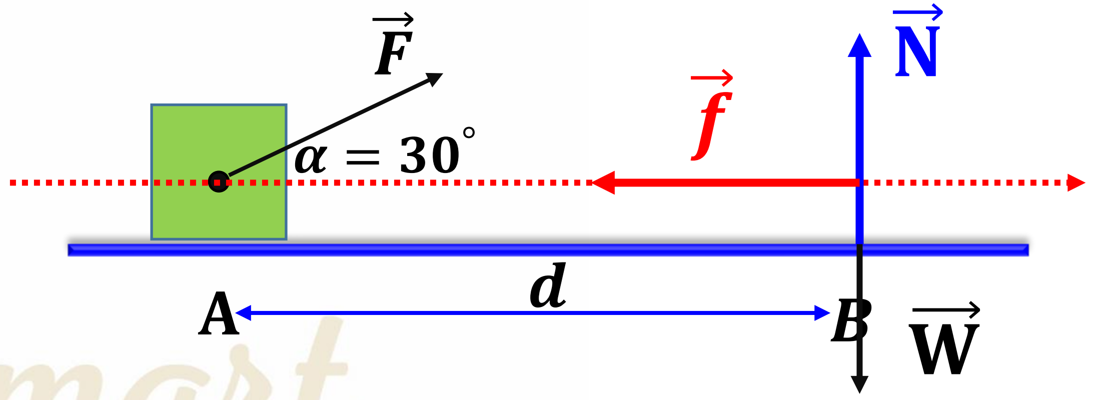
The magnitude of friction between the box and the surface is $f_r = 2N$.

Given AB $= 150$cm and g $= 10$N/kg.

Work done by constant force

$m = 0.75Kg$; $F = 0.75N$; $\alpha = 30^{\circ}$; $f_r = 2N$; $AB = 1.5m$ and $g = 10N/kg$.

1)Name all the forces acting on the block, then represent the forces on the figure.



The forces are:

- Weight: $\vec{W}$
- Normal: $\vec{N}$
- Friction: $\vec{f}$
- Tractive force: $\vec{F}$

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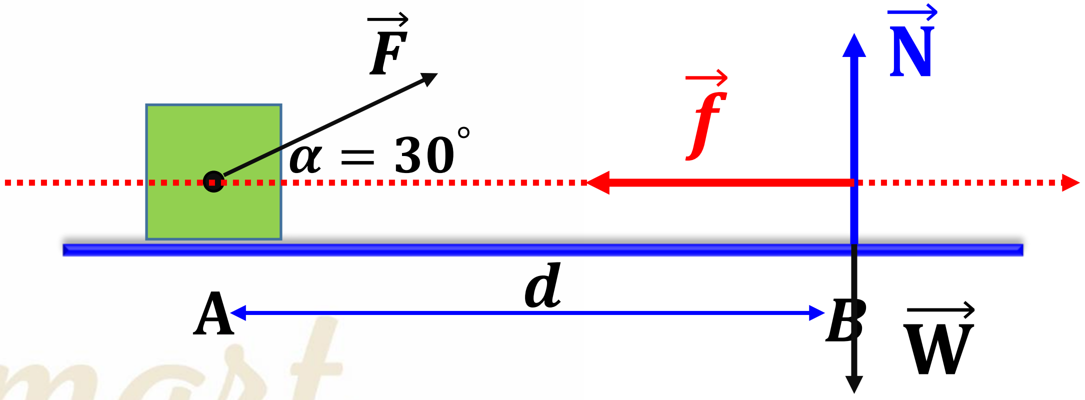
Work done by constant force

$m = 0.75Kg$; $F = 0.75N$; $\alpha = 30^{\circ}$; $f_r = 2N$; $AB = 1.5m$ and $g = 10N/kg$.

2)Calculate the work done by each force.



Work done by normal force:

$$W_{\vec{N}} = N \times d \times \cos(\overrightarrow{N}; d)$$

$$W_{\vec{N}} = N \times AB \times \cos(90) \Rightarrow W_{\vec{N}} = 0J$$

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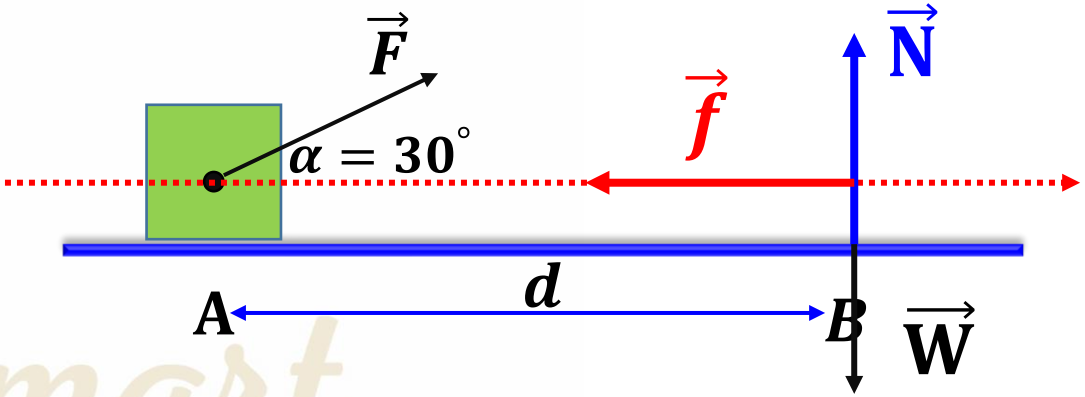
Work done by constant force

$m = 0.75Kg$; $F = 0.75N$; $\alpha = 30^{\circ}$; $f_r = 2N$; $AB = 1.5m$ and $g = 10N/kg$.

2)Calculate the work done by each force.



Work done by friction force:

$$W_{\vec{f}} = f \times d \times \cos(\vec{f}; \vec{d})$$

$$W_{\vec{f}} = f \times AB \times \cos(180)$$

$$W_{\vec{f}} = 2 \times 1.5 \times (-1)$$

$$W_{\vec{f}} = -3J$$

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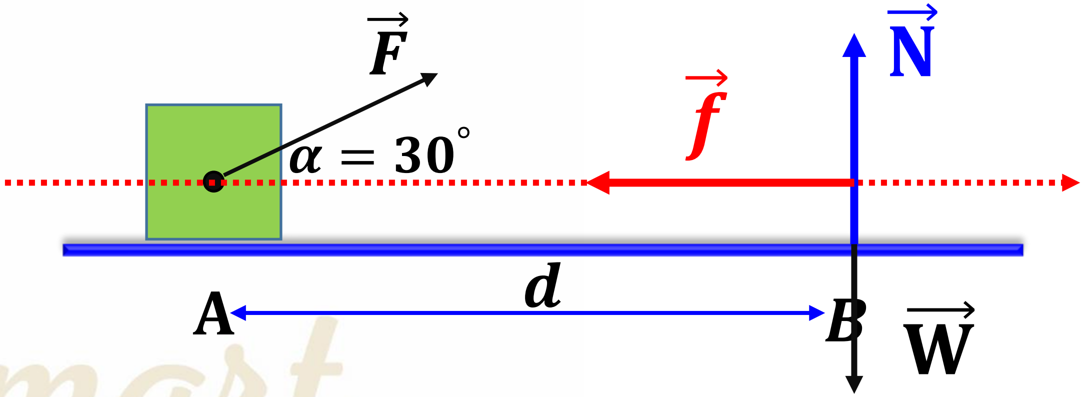
Work done by constant force

$m = 0.75Kg$; $F = 0.75N$; $\alpha = 30^\circ$; $f_r = 2N$; $AB = 1.5m$ and $g = 10N/kg$.

2)Calculate the work done by each force.



Work done by tractive force :

$$W_{\vec{F}} = F \times d \times cos(\vec{F}; \vec{d})$$

$$W_{\vec{F}} = 0.75 \times 1.5 \times cos(30)$$

$$W_{\vec{F}} = 0.97J$$

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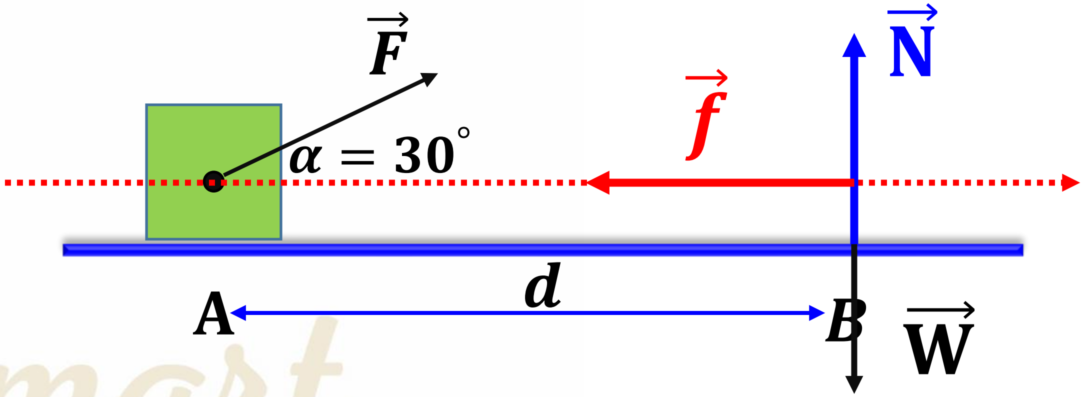
Work done by constant force

$m = 0.75Kg$; $F = 0.75N$; $\alpha = 30^\circ$; $f_r = 2N$; $AB = 1.5m$ and $g = 10N/kg$.

2)Calculate the work done by each force.



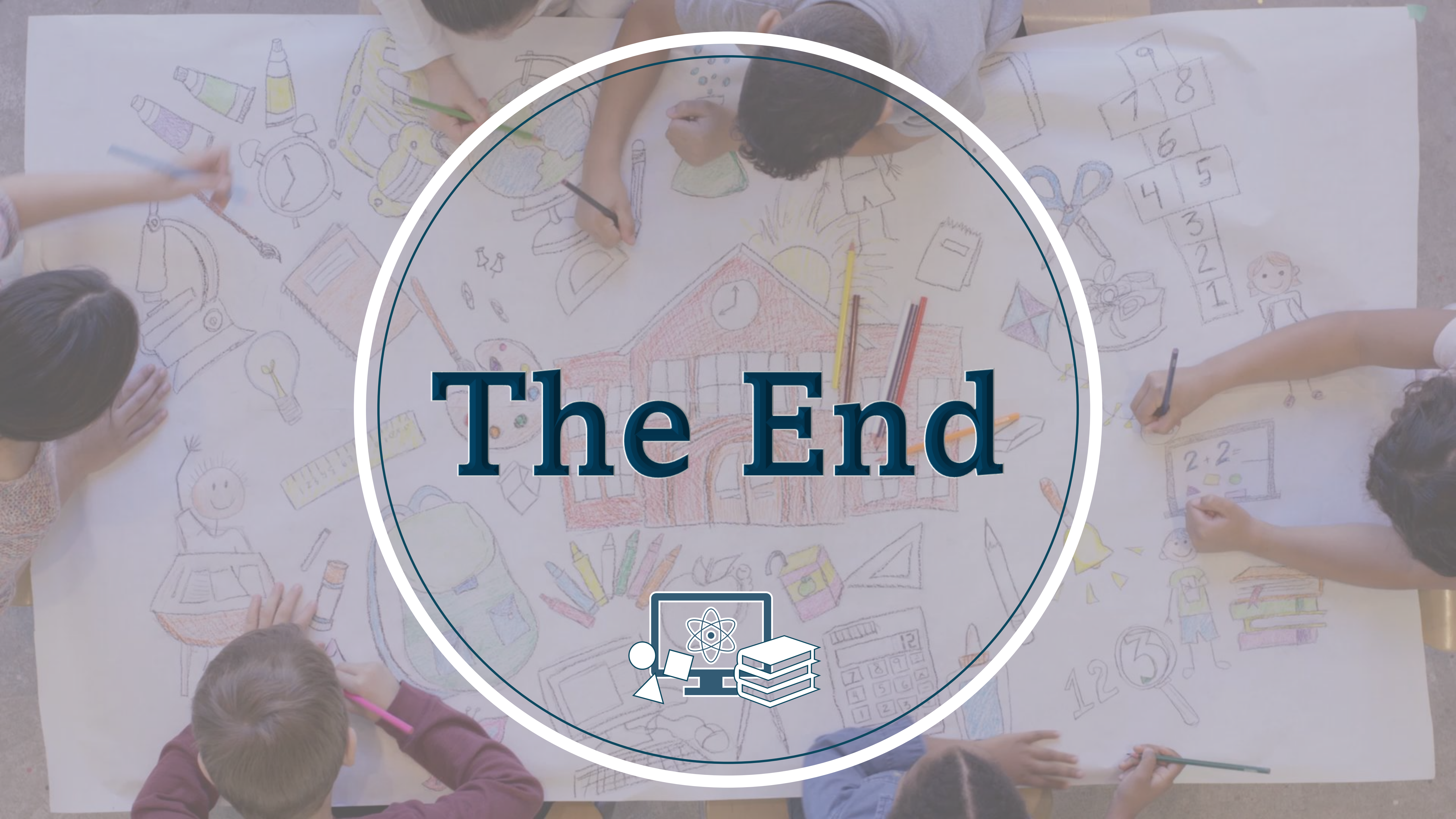
Work done by weight :

$$W_{\vec{W}} = mg(h_i - h_f)$$

$$W_{\vec{W}} = 0.75 \times 1.5(0 - 0)$$

$$W_{\vec{W}} = 0J$$

The End



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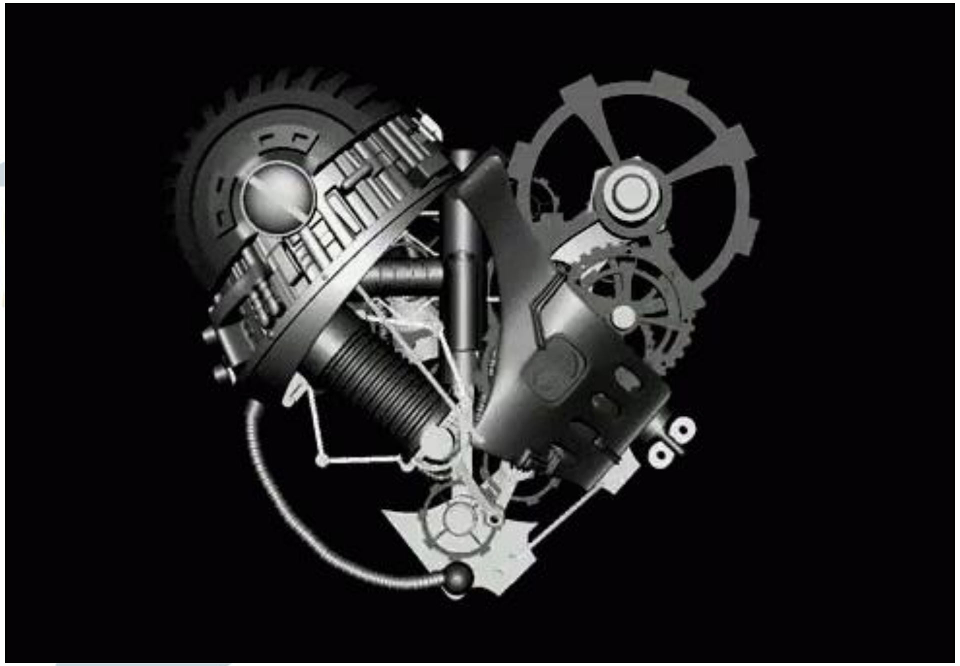

Unit 1: Mechanics

Chapter 1: Energy

Prepared & presented by: Mr. Mohamad Seif

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OBJECTIVES

1 Recall the definition of energy and its types.

2 Determine the Kinetic energy

Energy

Energy: Is the ability to do work.

Object has energy → Work can be done

Energy, as work, is expressed in Joules (J).

- **Energy exists in many forms.**
- **Energy can be transferred from one object to another.**
- **Energy can be changed from one form to another.**
- **Energy cannot be created or destroyed.**

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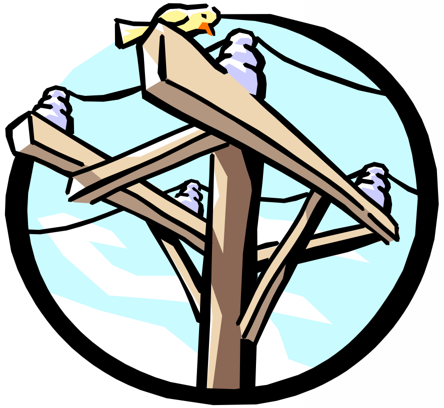
Energy

Forms of energy

Electric



Nuclear

Mechanical

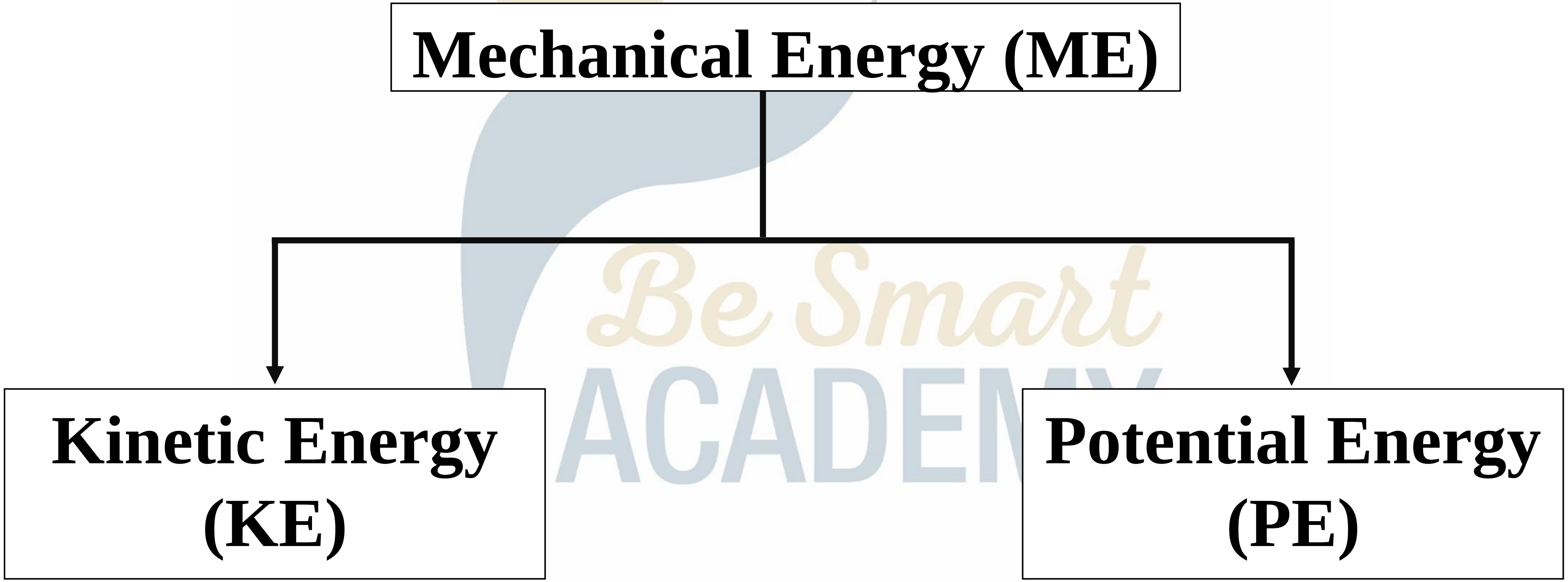
Radiant

Thermal

In this lesson we will study mechanical energy

Energy

Mechanical Energy (ME): of a system is the sum of its macroscopic kinetic energy KE and macroscopic potential energy PE:



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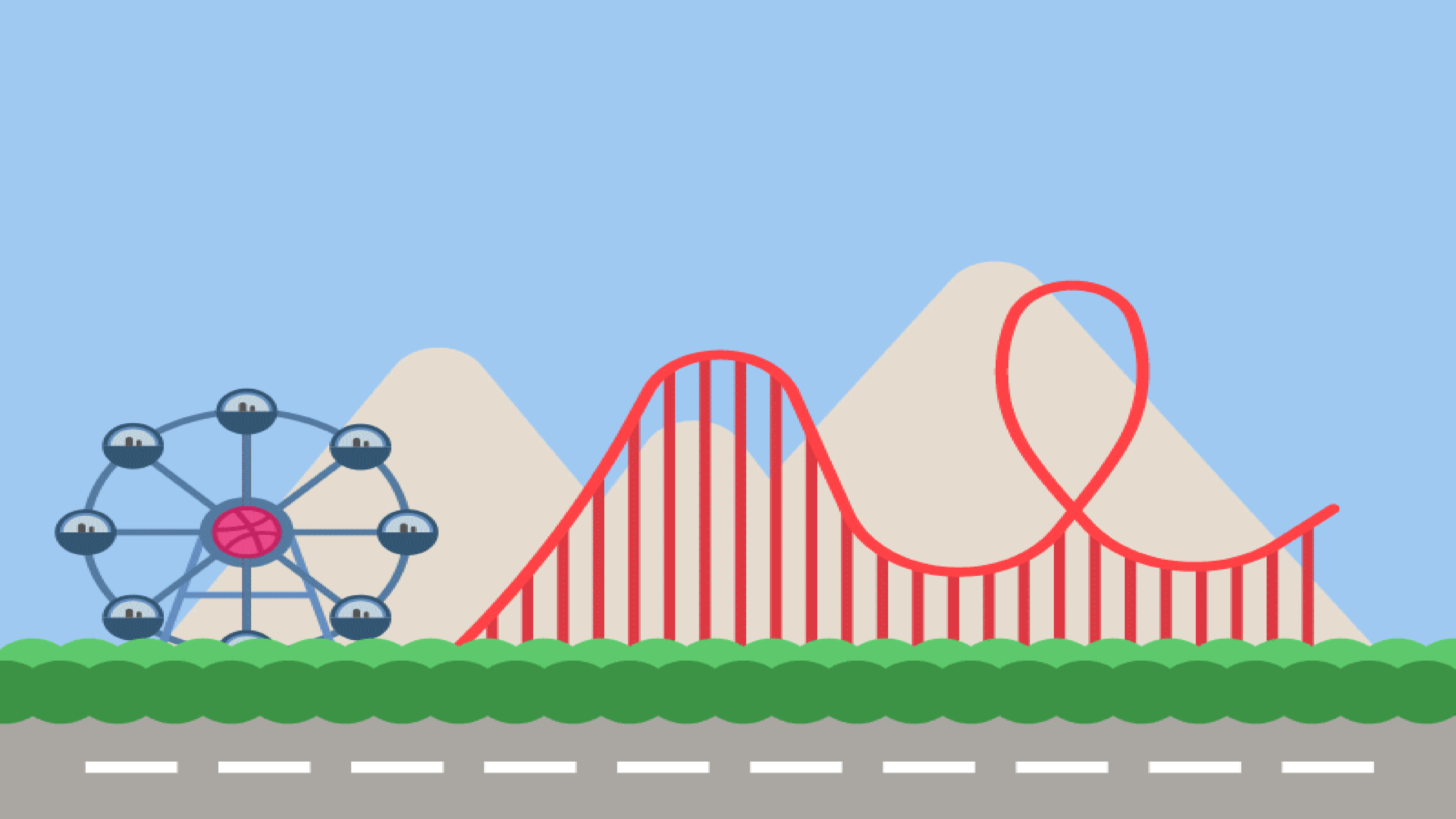


Kinetic Energy (KE)

Kinetic Energy (KE): Energy possessed by a body due to its motion.

Kinetic Energy (KE)

- **Translational motion** → **Kinetic Energy of Translation**

  $$KE_{trans} = 1/2mV^2$$

- **Rotational motion** → **Kinetic Energy of Rotation (GS)**

  $$KE_{rot} = 1/2I\theta'^2$$

Kinetic Energy (KE)

Kinetic Energy of Translation (KE_{trans}):

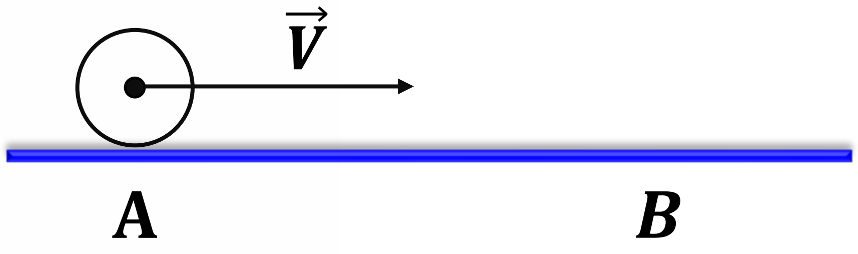
$$KE_{trans} = \frac{1}{2} m V^2$$

- m: mass of the body, expressed in (kg).
- V: The velocity of the body, expressed in m/s.
- KE_{trans}: Kinetic energy, expressed in (J).

Kinetic Energy (KE)

Application 2:

A ball of mass $m = 2Kg$ starts its motion from rest from A and reaches B with a speed v = 3m/s as shown in the figure.



Calculate the kinetic energy of the ball at A and at B.

$$KE_A = 1/2mV^2$$

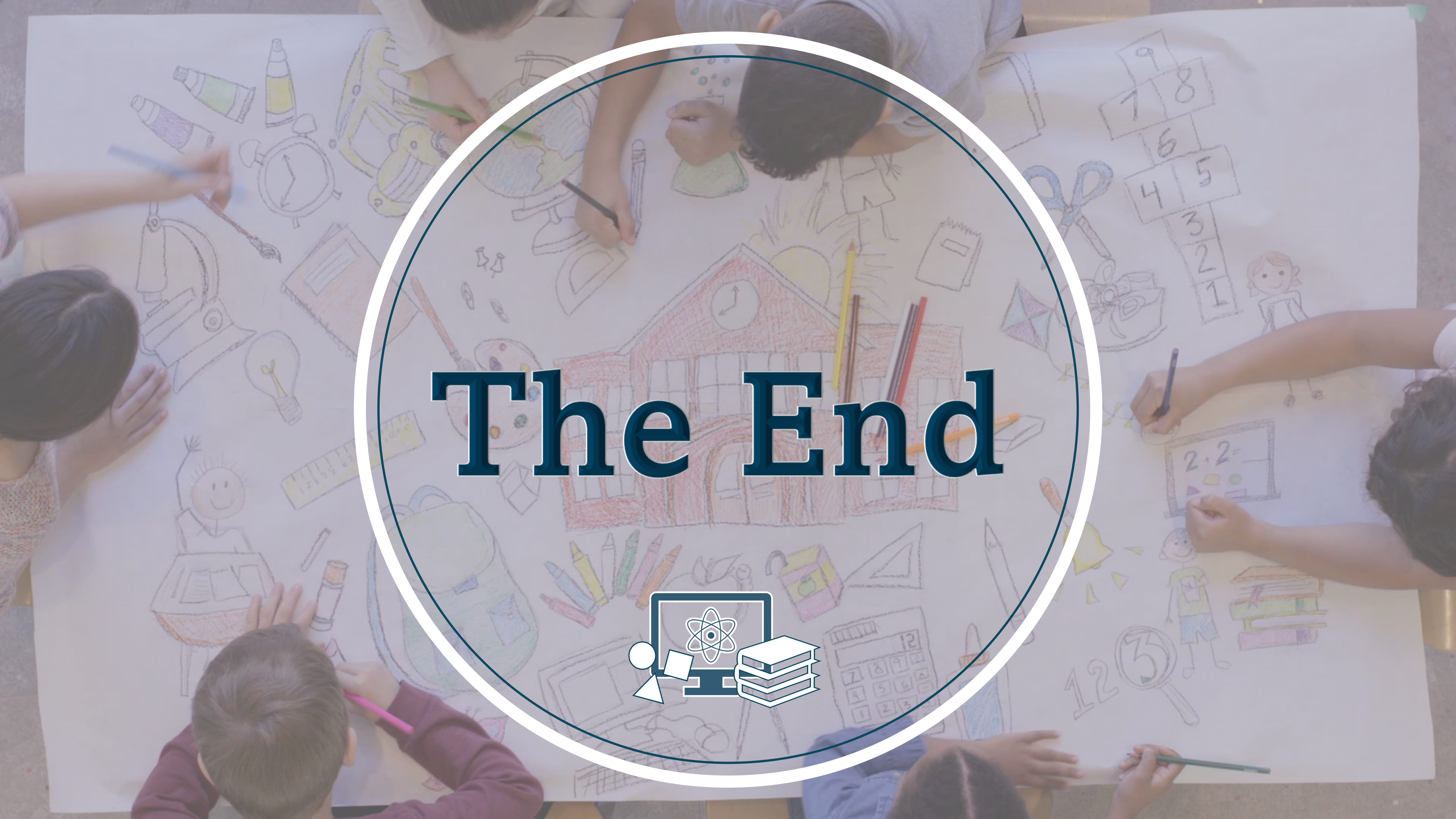
$$KE_A = 0.5 \times 2 \times (0)^2$$

$$KE_A = 0J$$

$$KE_B = 1/2mV^2$$

$$KE_B = 0.5 \times 2 \times (3)^2$$

$$KE_B = 9J$$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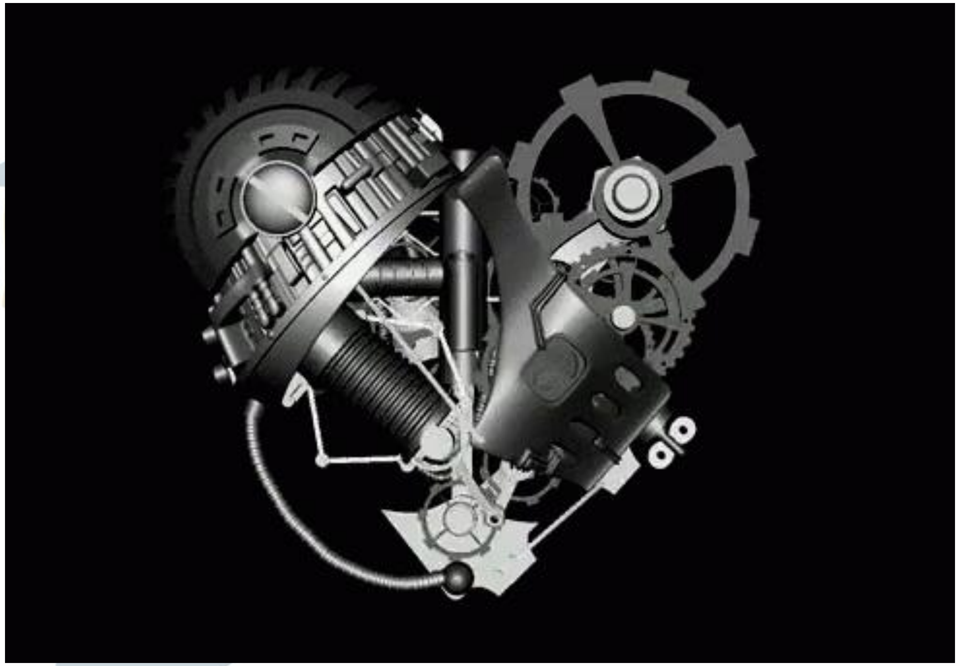

Unit 1: Mechanics

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Chapter 1: Energy

Prepared & presented by: Mr. Mohamad Seif

OBJECTIVES

1. Determine the Gravitational potential energy

Potential Energy (PE)

Potential Energy (PE): is a form of energy stored in the body

Potential Energy (PE)

- **Gravitational potential energy**

  $$PE_g = mgh$$

- **Elastic potential energy**

  $$PE_e = \frac{1}{2}kx^2$$

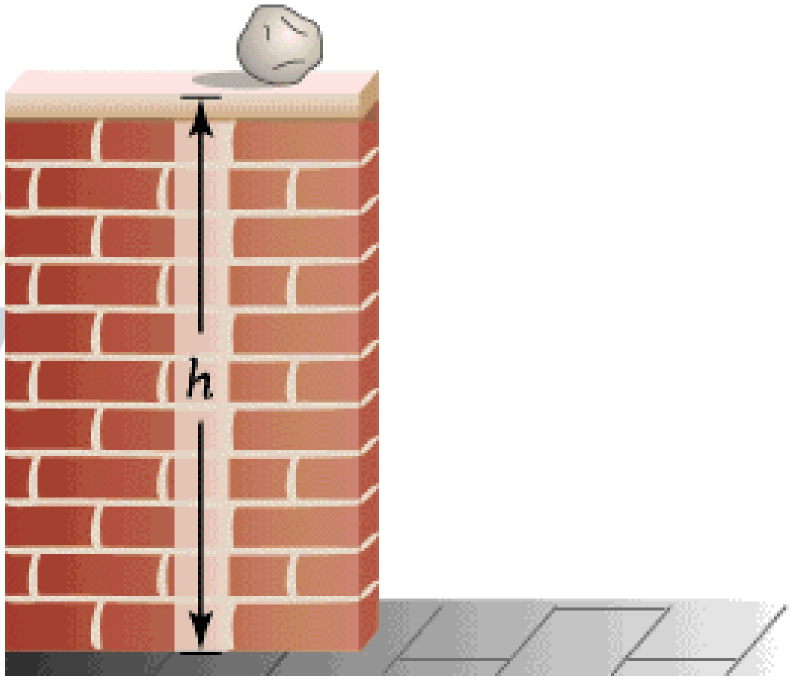
Gravitational Potential Energy (GPE)

Gravitational Potential Energy (GPE):

Gravitational Potential Energy is the energy stored in a body due to the relative position of the system with respect to the reference

$$PE_g = mgh$$

- m: **mass of the body, expressed in kg.**
- g: **gravity, g=10N/kg.**
- h: **height of the body from the reference expressed in m**



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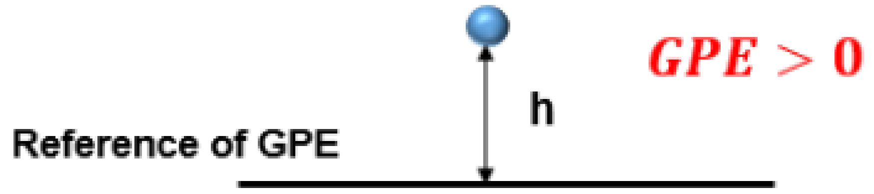
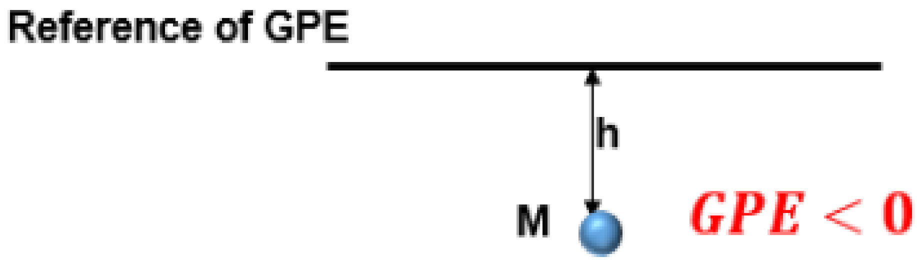
Gravitational Potential Energy (GPE)

If the body above reference, then h>0



If the body on reference, then h=0

If the body below reference, then h<0



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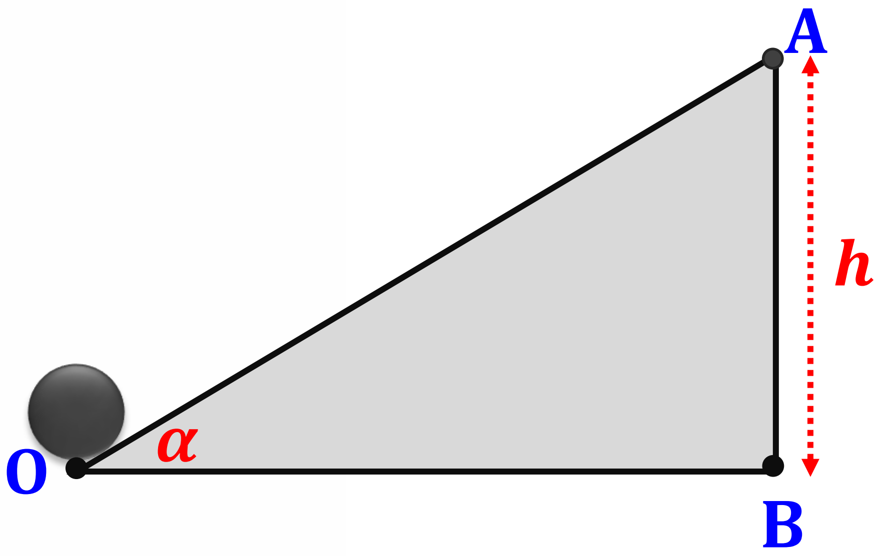
Gravitational Potential Energy (GPE)/ inclined plane

Application 4:

A ball (S) of mass $m = 1.2Kg$ moves up an inclined plane making an angle $\alpha = 30^{\circ}$ with the horizontal starting from the bottom O.



The ball reaches point A at a height h from the ground, where $OA = 1.5m$

Take the horizontal line passing through B as a reference level for gravitational potential energy. Given $g = 10N/kg$

Calculate GPE of the system (ball-earth) at point A.

Gravitational Potential Energy (GPE)/ inclined plane

$m = 1.2Kg$; OA $= 1.5m; \alpha = 30$; g = 10N/kg;

The gravitational potential energy is:

$$GPE_A = mgh$$

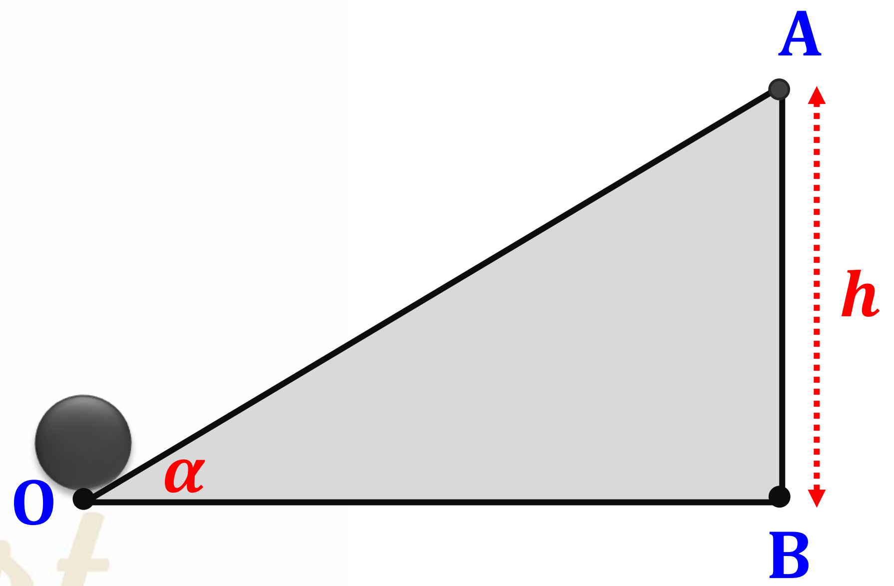
For the triangle AOB: $sin\alpha = \frac{opp}{hyp}$

$$sin\alpha = \frac{h}{OA} \rightarrow h = OAsin\alpha$$

$$GPE = mgh = mg(OAsin\alpha)$$

$$GPE = 1.2 \times 10 \times 1.5 \times sin30$$

$$GPE = 9J$$



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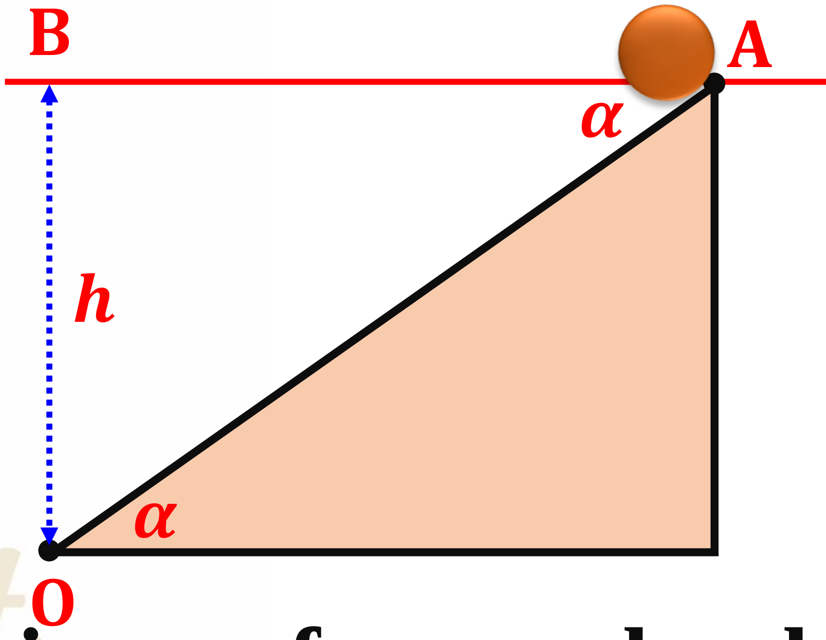
Gravitational Potential Energy (GPE)/ inclined plane

Application 5:

A ball of mass $m = 2\text{kg}$ at the top A of an inclined plane making an angle $\alpha = 60^{\circ}$ with the horizontal.



The ball moves down and reaches point O, where $AO = 90cm$.

The horizontal plane passing through A is a reference level for gravitational potential energy. Given $g = 10\text{N/kg}$

Calculate GPE of the system (ball-earth) at point O.

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Gravitational Potential Energy (GPE)/ inclined plane

$m = 2Kg$; $AO = 0.9m$; $\alpha = 60^\circ$; g = 10N/kg

The gravitational potential energy is:

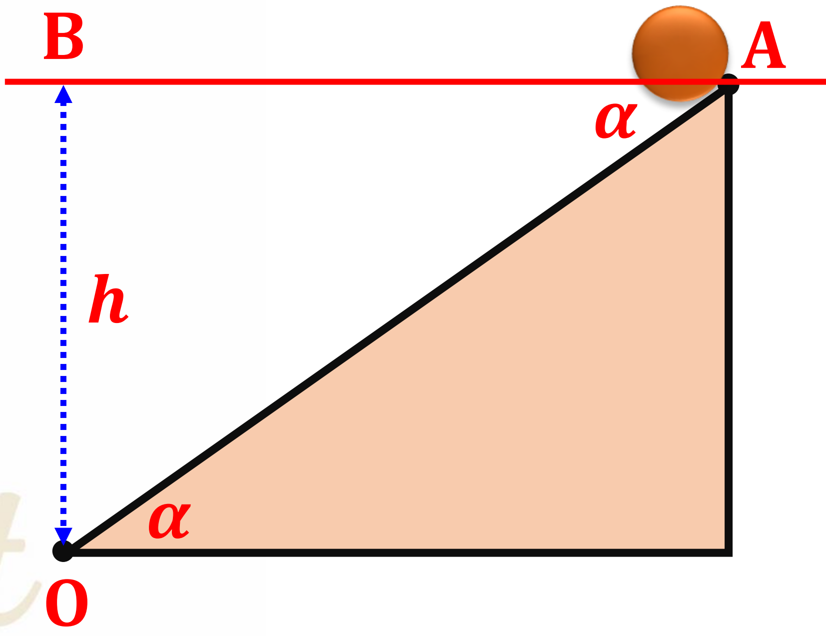
$$GPE = mgh$$

For the triangle AOB: $sin\alpha = \frac{opp}{hyp}$

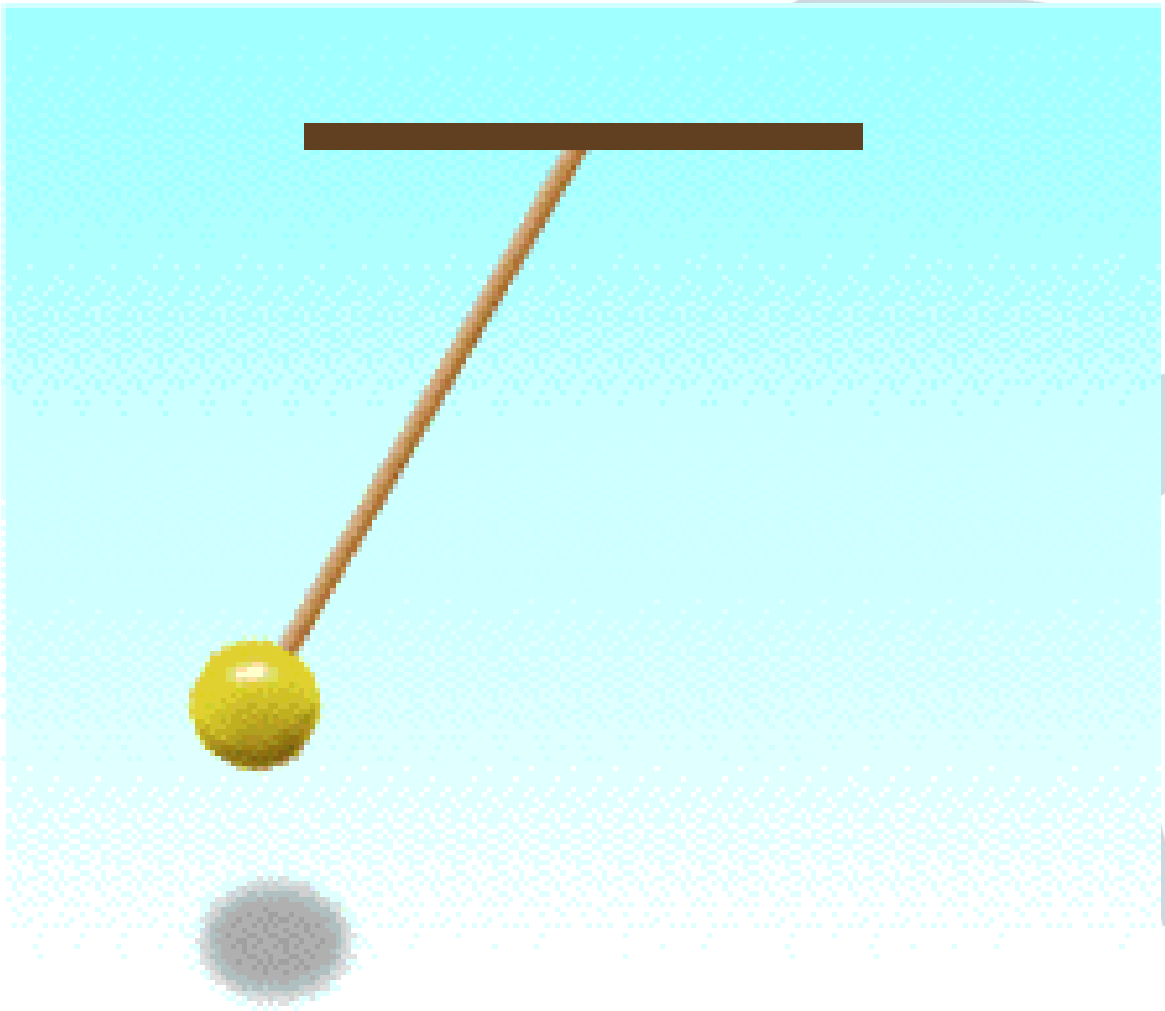
$$sin\alpha = \frac{-h}{AO} \rightarrow h = -AOsin\alpha$$

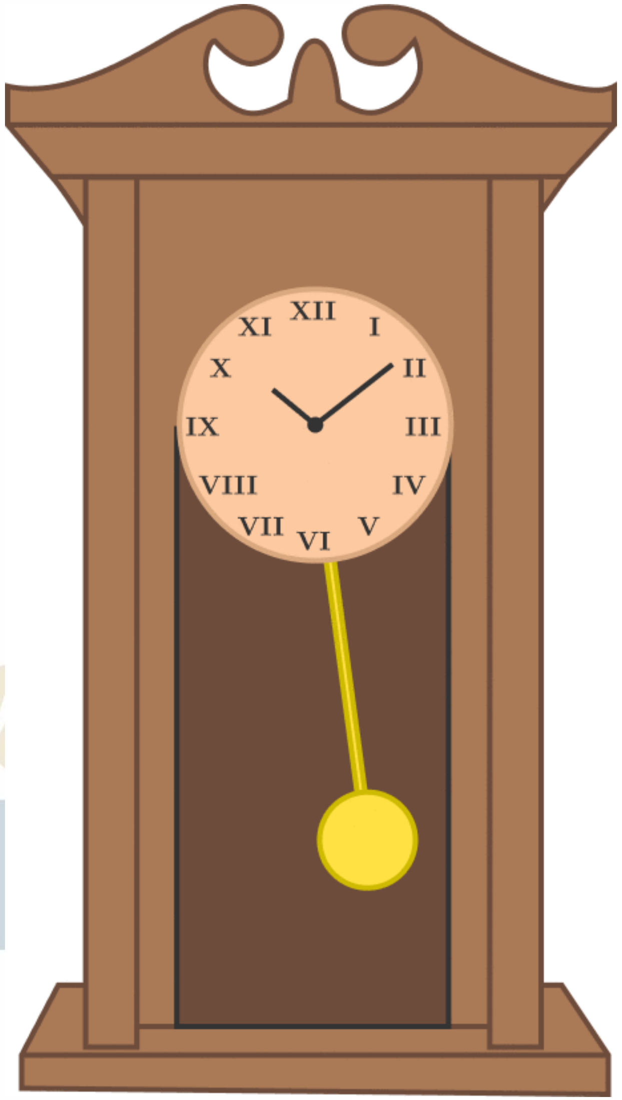
$$GPE = mg(-AOsin\alpha)$$

$$GPE = 2 \times 10 \times (-0.9 \times sin60) \Rightarrow GPE = -15.6J$$



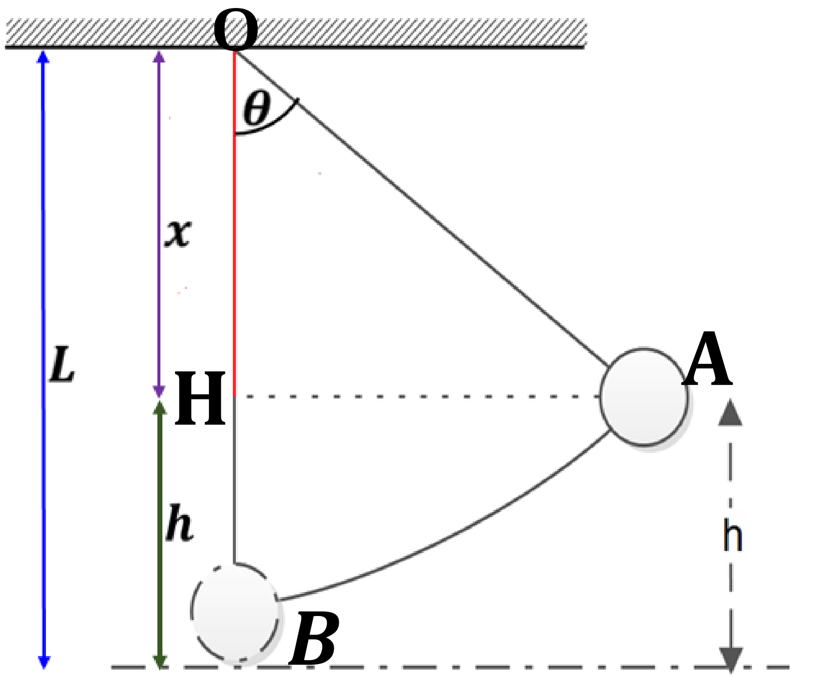
Gravitational Potential Energy/ Pendulum





Gravitational Potential Energy (GPE)/ Pendulum

Gravitational potential energy at point A at a height h above the reference level:



The gravitational potential energy:

$$GPE_A = mgh$$

$$L = h + x \rightarrow h = (L - x)$$

For the triangle AOH: $cos\theta = \frac{adj}{hyp} = \frac{x}{L}$ ➡ $x = Lcos\theta$

➡ $h = (L - x) = L - Lcos\theta$ ➡ $h = L(1 - cos\theta)$

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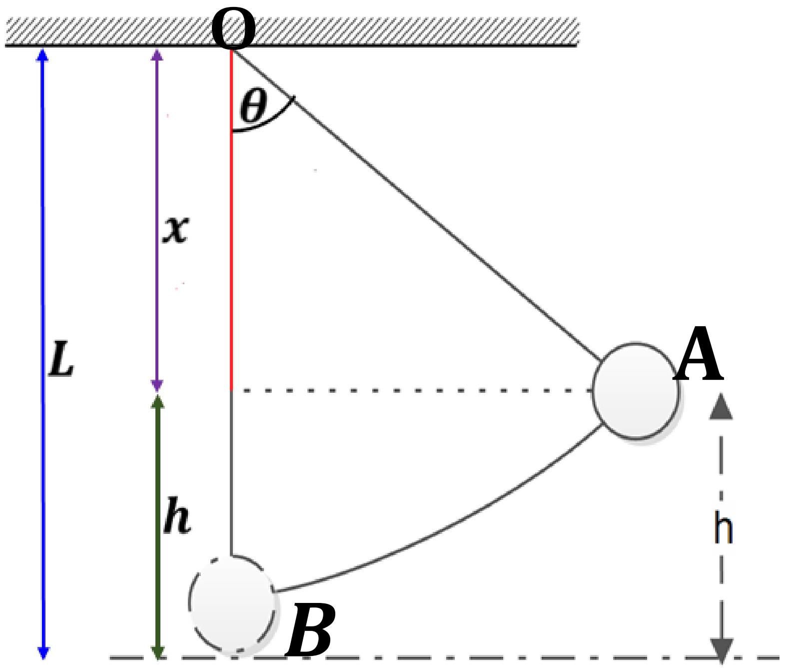
Gravitational Potential Energy (GPE)/ Pendulum

Application 6:

A pendulum is formed of a massless and inextensible string of length $L = 90cm$, having one of its ends O fixed to a support while the other end carries a particle (S) of mass $m = 200\ g$.

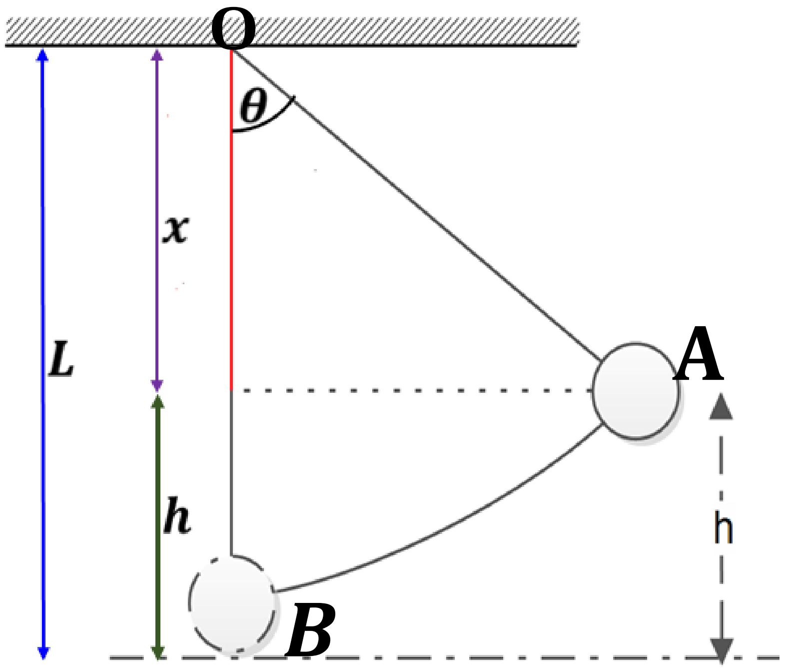


The pendulum is shifted from its equilibrium position to point A making an angle $\theta = 30^{\circ}$.

The horizontal plane passing through B is a reference level for gravitational potential energy. Given $g = 10N/kg$.

Gravitational Potential Energy (GPE)/ Pendulum

Calculate GPE of the system (pendulum-earth) at point A when it making angle $\theta = 30^\circ$ with the equilibrium position.

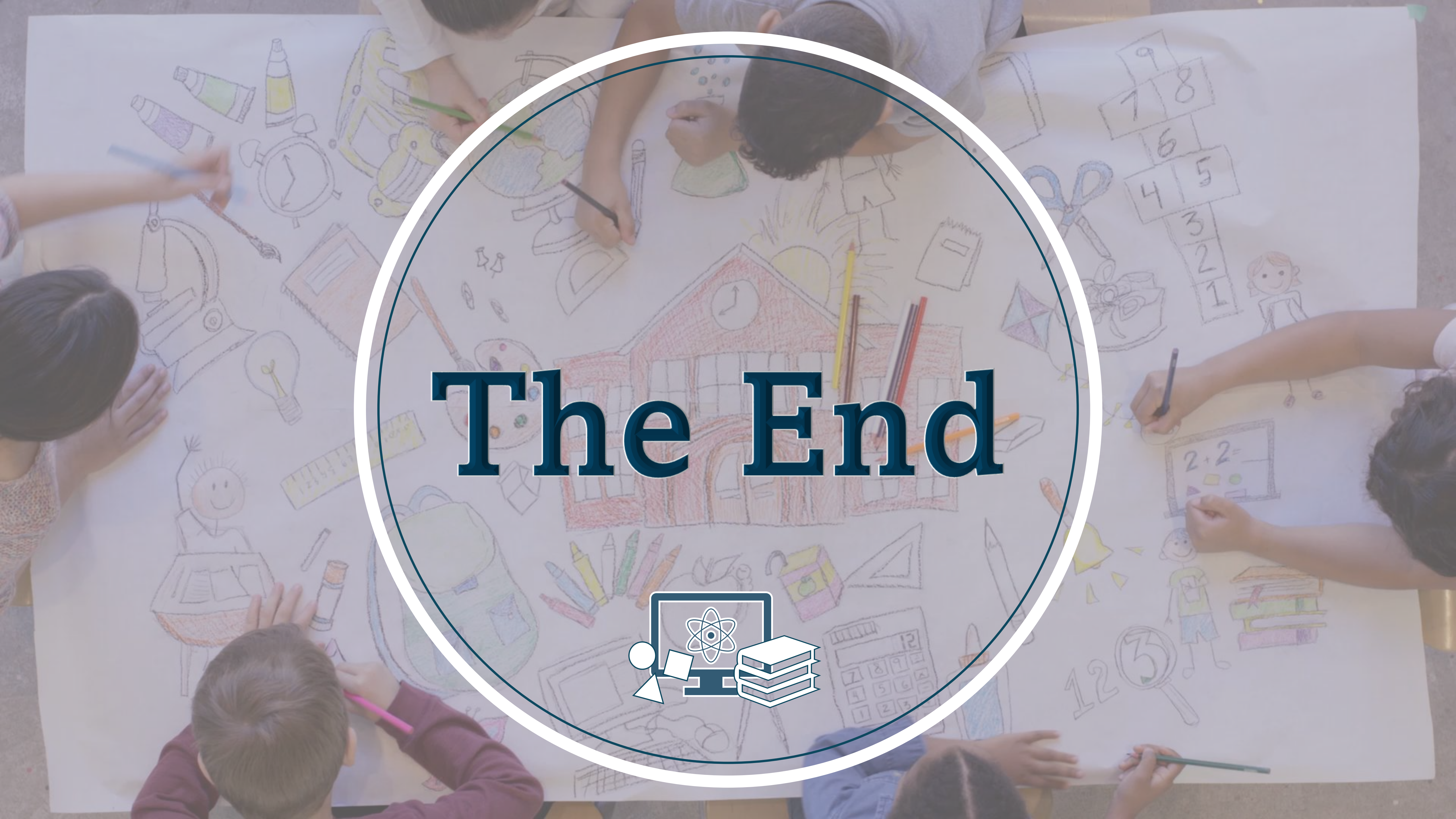


$$m = 2kg;\ L = 0.9m;\ \theta = 30;\ g = 10N/kg$$

$$GPE_A = mgh = mgL(1 - cos\theta)$$

$$GPE_A = 2 \times 10 \times 0.9(1 - cos30)$$

$$PE_g = 2.4J$$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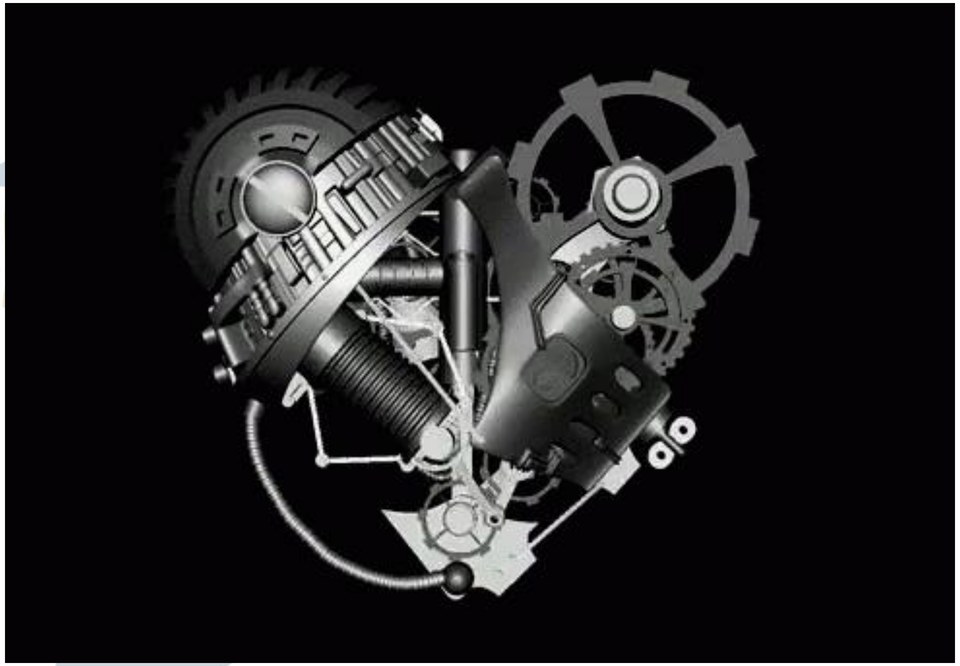


Unit 1: Mechanics

Be Smart ACADEMY

Chapter 1: Energy

Prepared & presented by: Mr. Mohamad Seif

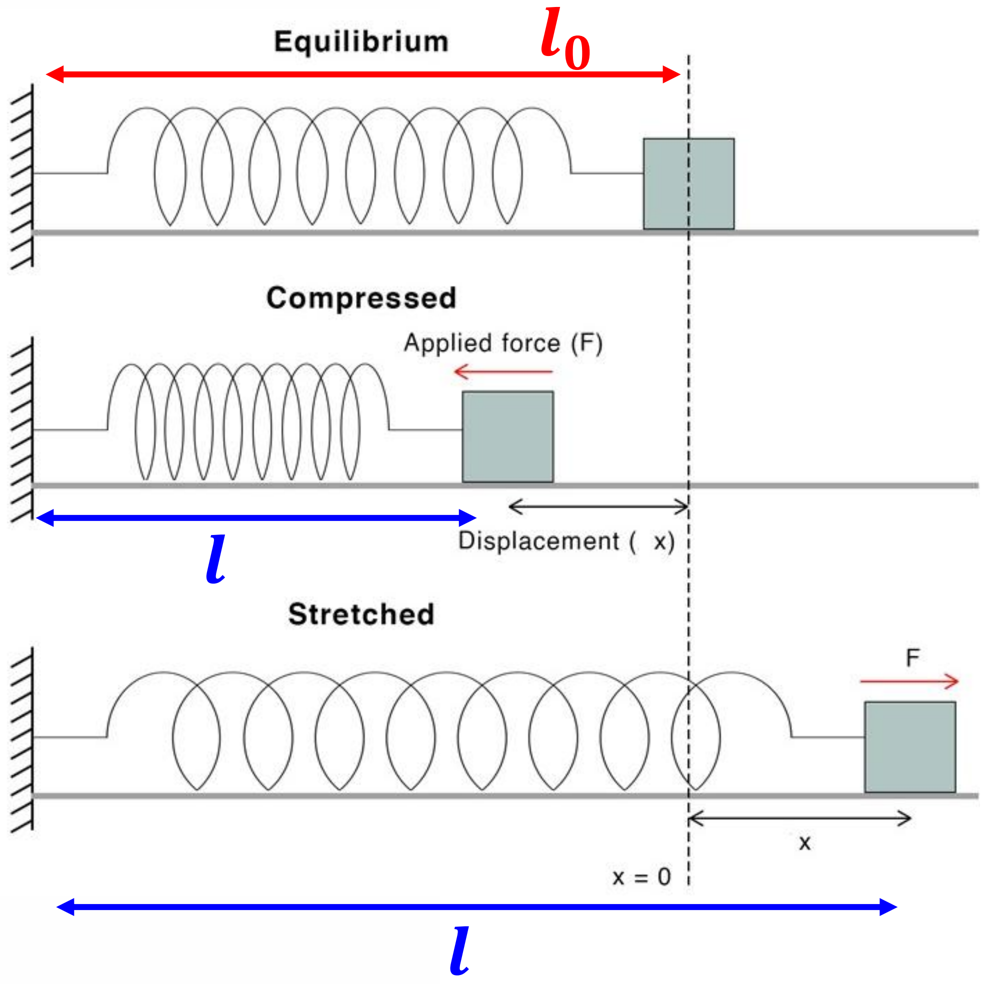
OBJECTIVES

1	**Determine the Elastic Potential energy of a particle**

Elastic Potential Energy (EPE)

Elastic Potential Energy (EPE): is stored in elastic objects such as rubber bands, springs, …

$$EPE = \frac{1}{2}kx^2$$



l_0: initial length

$$x = \begin{cases} l - l_0 \ (elongation \\ l_0 - l \ (compression) \end{cases}$$

Elastic Potential Energy (EPE)

$$EPE = \frac{1}{2}kx^2$$

- EPE: elastic potential energy, expressed in J.
- K: spring constant (stiffness) expressed in N/m.
- x: The compression or elongation of the spring, expressed in m.

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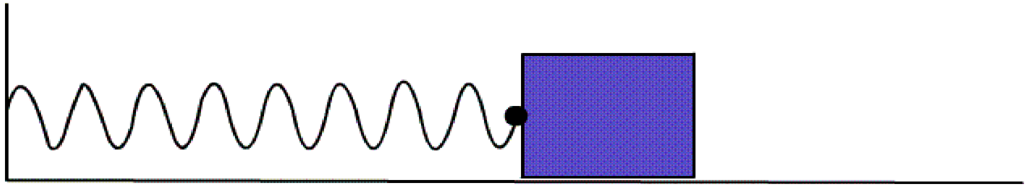
Elastic Potential Energy (EPE)

$$EPE = \frac{1}{2}kx^2$$



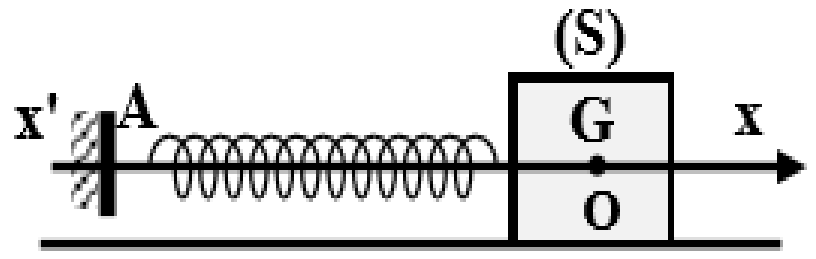
Horizontal spring

Vertical spring

Elastic Potential Energy (EPE)

Application 7:

Consider a box (S) of mass $m = 500g$ is connected to a spring (R) of free length $l_0 = 25cm$.



Doc. 1

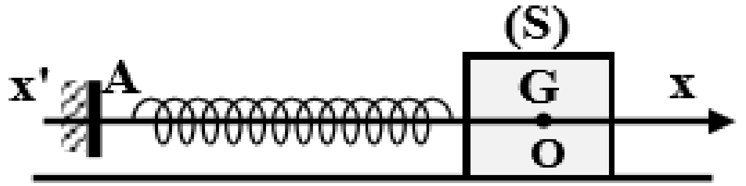
The stiffens of the spring is $k = 20N/m$
The spring is elongated by a distance x and become has a length $l = 35cm$.

1. Calculate the variation in length Δl.
2. Calculate the elastic potential energy stored in the spring when it is elongated by $x = \Delta L$

Elastic Potential Energy (EPE)

$m = 500\text{g}; l_0 = 25cm; k = 20N/m; l = 35cm.$

1.Calculate the variation in length Δl.



Doc. 1

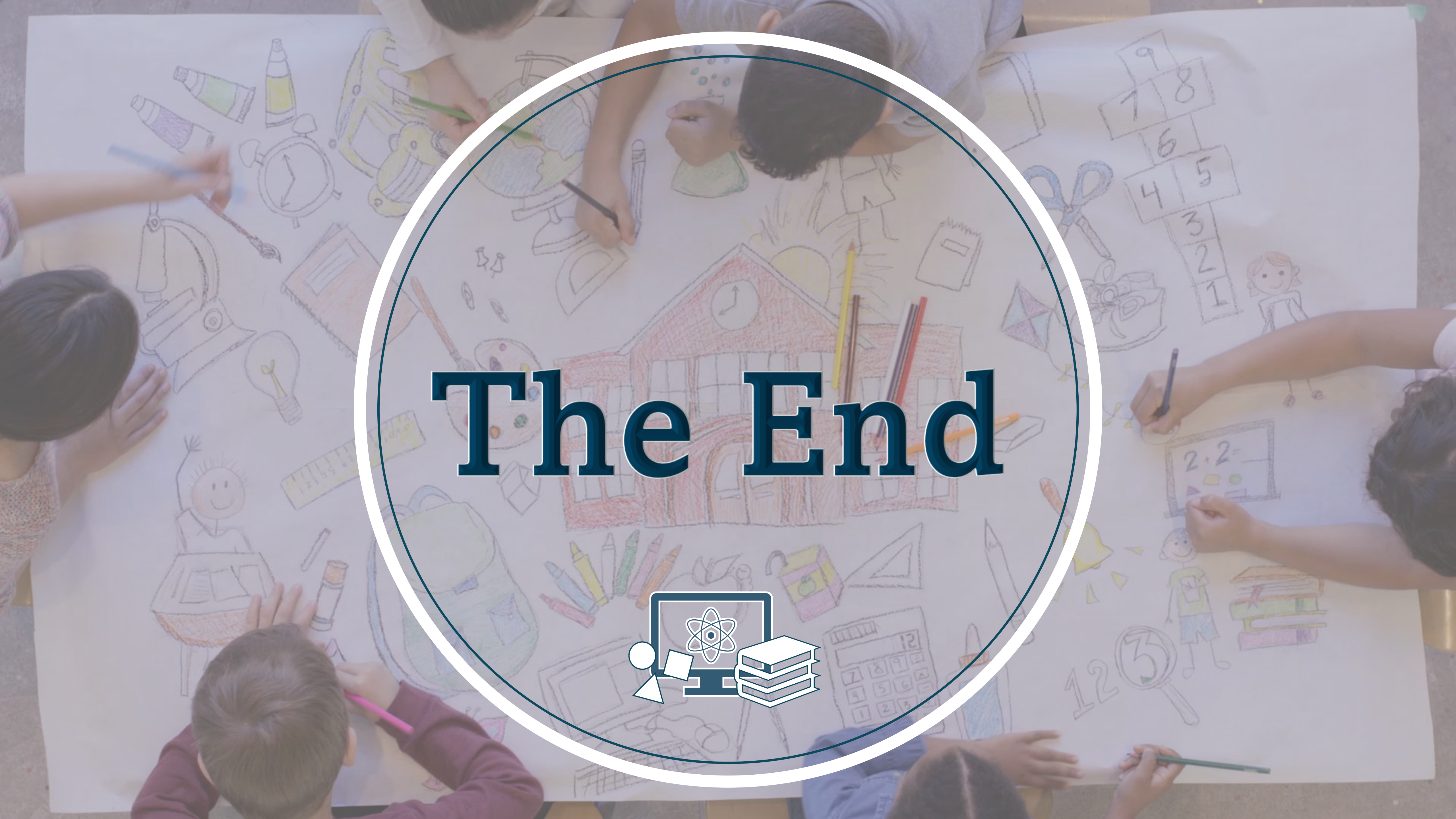
$$x = \Delta L = l - l_0$$

$x = 35 - 25$ → $x = 10cm = 0.1m$

2.Calculate the elastic potential energy stored in the spring when it is elongated by $x = \Delta L$

$\text{EPE} = 1/2\text{kx}^2$ → $\text{EPE} = 0.5 \times (20) \times (0.1)^2$

→ $\text{EPE} = 0.1\text{J}$



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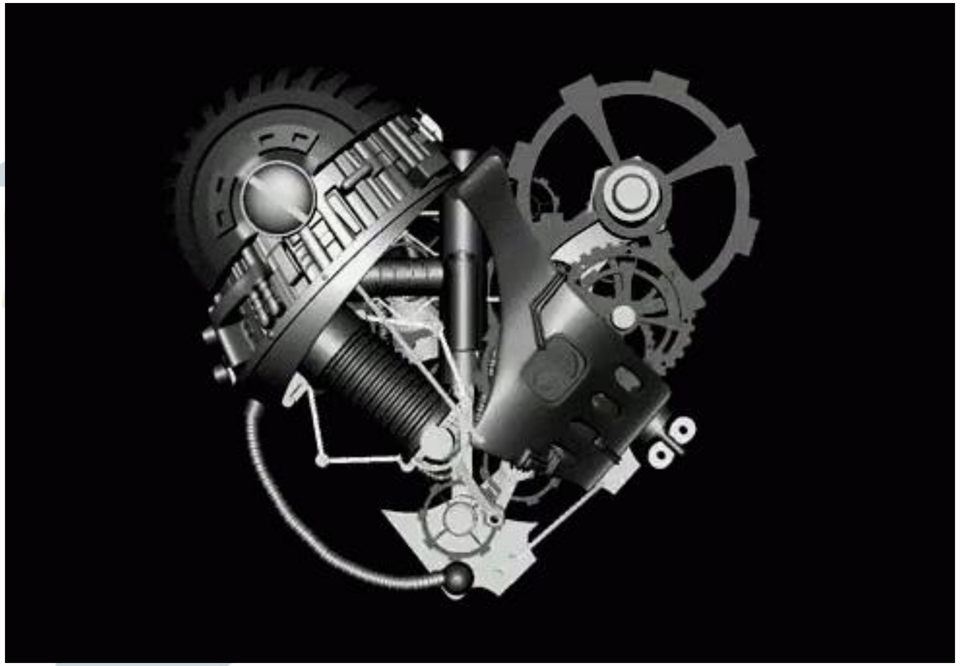
Grade 12 – Physics



Unit 1: Mechanics

Chapter 1: Energy

Be Smart ACADEMY

Prepared & presented by: Mr. Mohamad Seif

OBJECTIVES

1. Determine the mechanical energy of a particle
2. Determine the internal energy of a particle
3. Determine the total energy of a system

Mechanical Energy (ME)

The Mechanical Energy of a system at a certain point is:

the sum of kinetic energy and potential energy of a system at a certain point, expressed in J

$$\mathbf{ME = KE + PE_g + PE_e}$$

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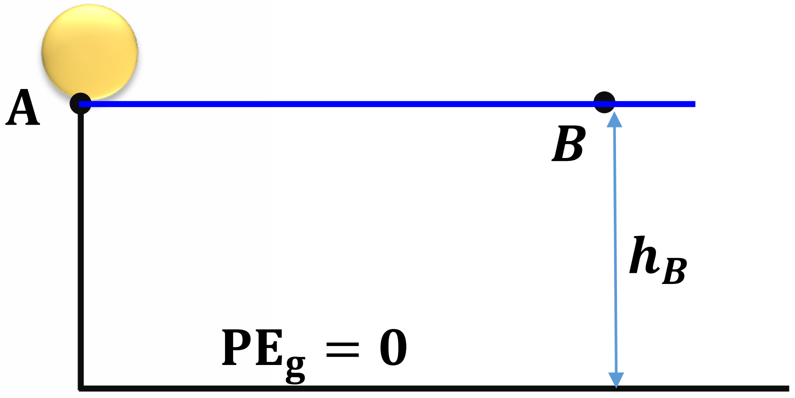
Mechanical Energy (ME)

Application 8:

A particle (S) of mass of $m = 1.25Kg$ starts its motion from rest from A.

The particle reaches point B, 3.1m above the ground with a speed of 2.5m/s.



Take the ground as reference level for gravitational potential energy.
Given $g = 10N/kg$.

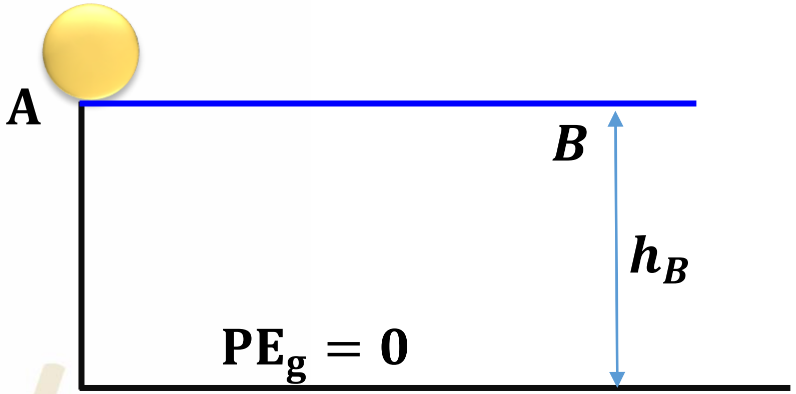
1)Calculate the mechanical energy of the system[(S)-earth] at point A.

2)Calculate the mechanical energy of the system[(S)-earth] at point B

Mechanical Energy (ME)

$m = 1.25kg; h_A = h_B = 3.1m; V_B = 2.5m/s;$ g=10N/kg.

1)Calculate the mechanical energy of the system[(S)-earth] at point A.



$$ME_A = KE_A + (GPE)_A$$

$$ME_A = \frac{1}{2}mV_A^2 + mgh_A$$

$$ME_A = 0.5 \times 1.25 \times (0)^2 + 1.25 \times 10 \times 3.1$$

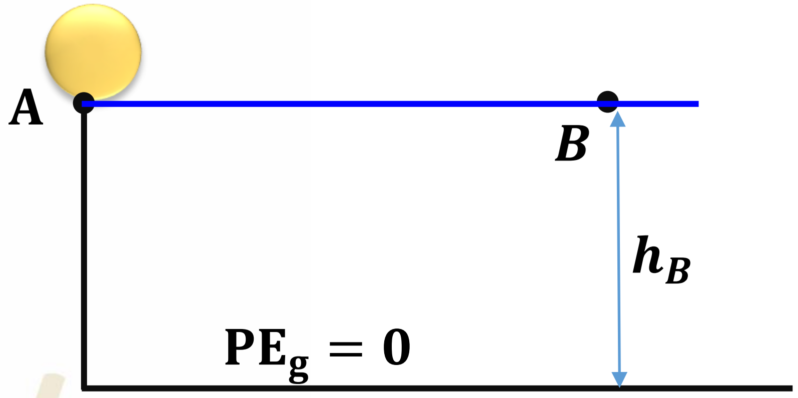
$$ME_A = 0 + 38.75$$

$$ME = 38.75J$$

Mechanical Energy (ME)

$m = 1.25kg;\ h_A = h_B = 3.1m;\ V_B = 2.5m/s;$ g=10N/kg.

2) Calculate the mechanical energy of the system[(S)-earth] at point B.



$$ME_B = KE_B + (GPE)_B$$

$$ME_B = \frac{1}{2}mV_B^2 + mgh_B$$

$$\Rightarrow ME_B = 0.5 \times 1.25 \times (2.5)^2 + 1.25 \times 10 \times 3.1$$

$$\Rightarrow ME_A = 3.9 + 38.75 \Rightarrow \mathrm{ME} = 42.65\mathrm{J}$$

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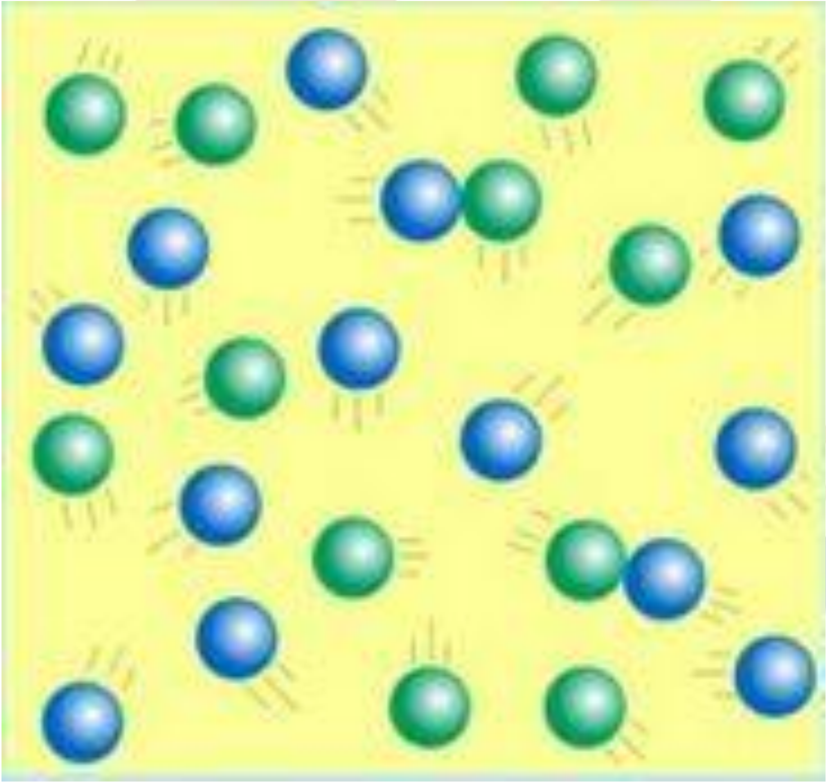
Mechanical Energy: ME = KE + PE

- **Kinetic (KE) (motion)**
  - **Translation** $(KE_{tran} = 1/2mV^2)$
  - **Rotation** <u>**(GS)**</u> $(KE_{rot} = 1/2I\theta'^2)$
- **Potential (PE) (position)**
  - **Gravitational** $(GPE = mgh)$
  - **Elastic** $(EPE = 1/2\text{k}x^2)$

Internal Energy (Thermal energy): U

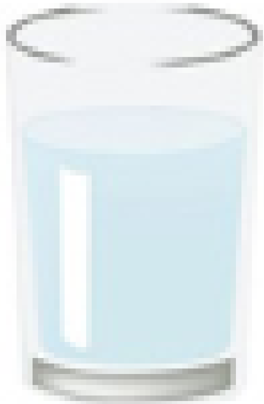
Internal Energy (U): is defined as the energy due to the random, disordered motion of molecules of a body



Internal Energy (Thermal energy): U

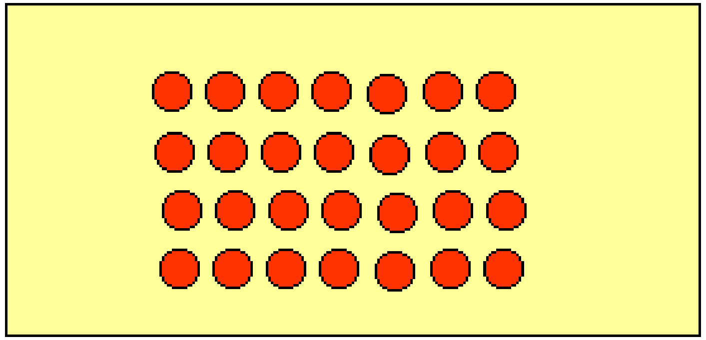
$U = KE_{Microscopic}$(change of temperature)+$PE_{Microscopic}$(change of state)

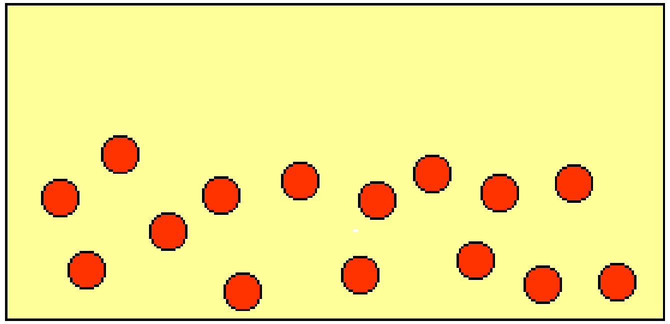
Solid

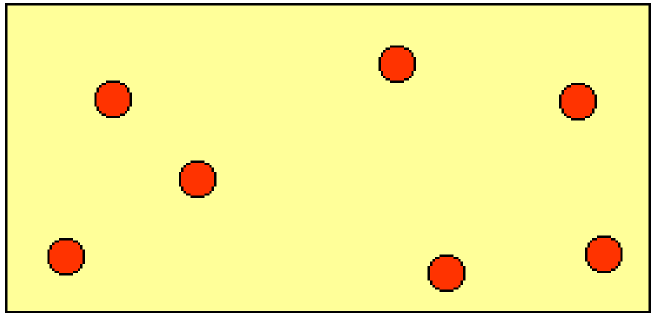


Liquid

Gas







Total Energy of the system (E)

Total Energy = Mechanical Energy + Internal Energy (Thermal)

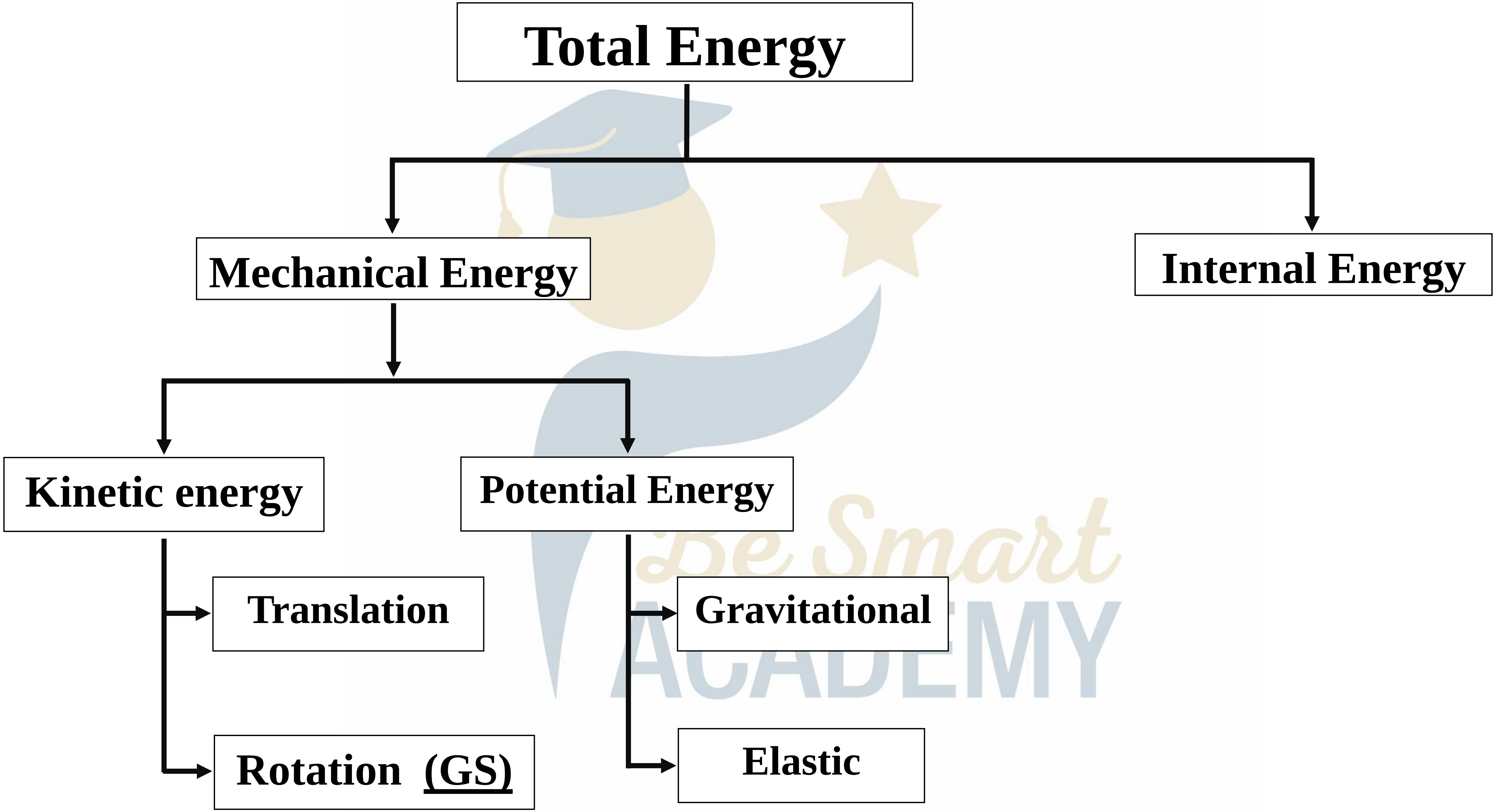
Energy – isolated system: system does not exchange energy with surrounding

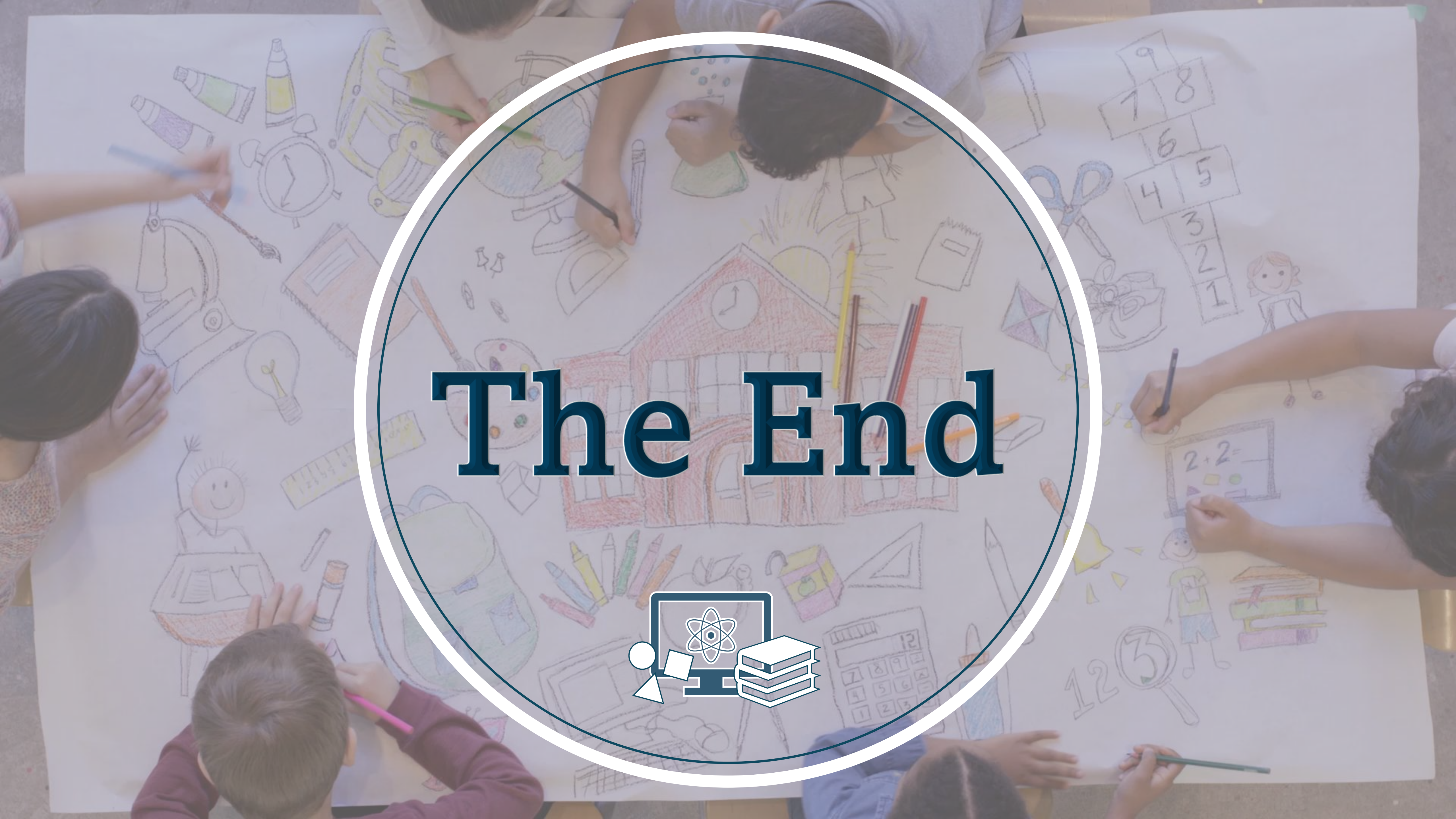
The total energy is conserved:

$$E = ME + U = constant$$

$$\Rightarrow \Delta E = \Delta ME + \Delta U = 0$$

$$\Rightarrow \Delta U = -\Delta ME$$


Total Energy
Mechanical Energy
Internal Energy
Kinetic energy
Potential Energy
Translation
Rotation (GS)
Gravitational
Elastic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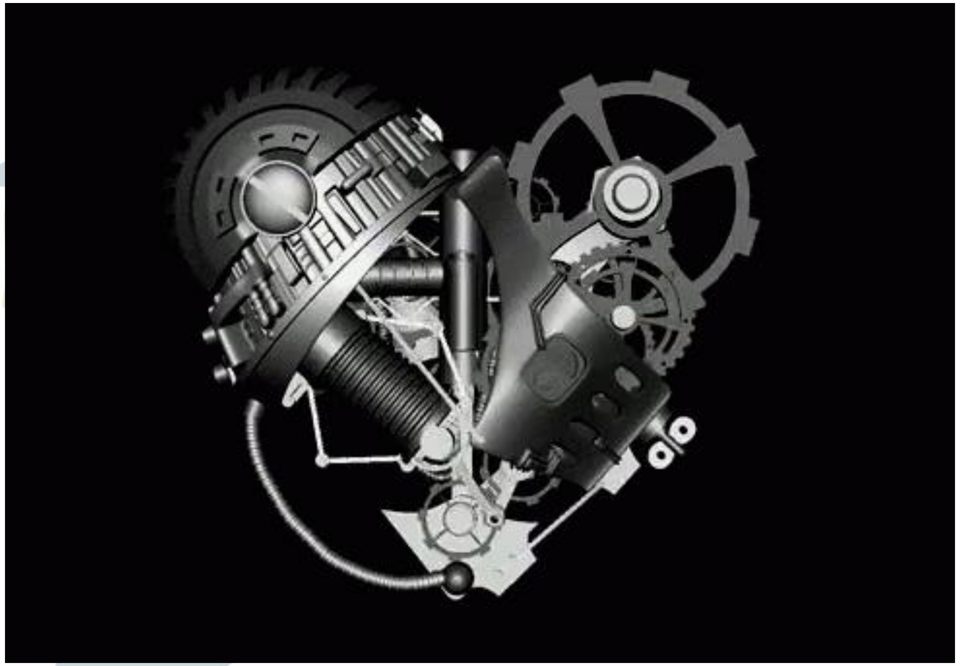
Grade 12 – Physics



Unit 1: Mechanics

Chapter 1: Energy

Prepared & presented by: Mr. Mohamad Seif

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OBJECTIVES

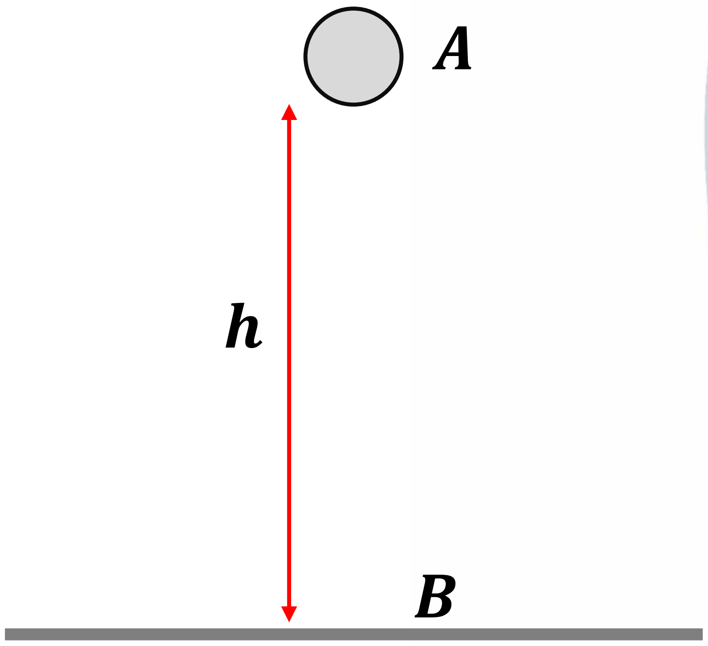
1. Apply the principle of conservation of ME energy
2. Apply the principle of non-conservation of ME energy

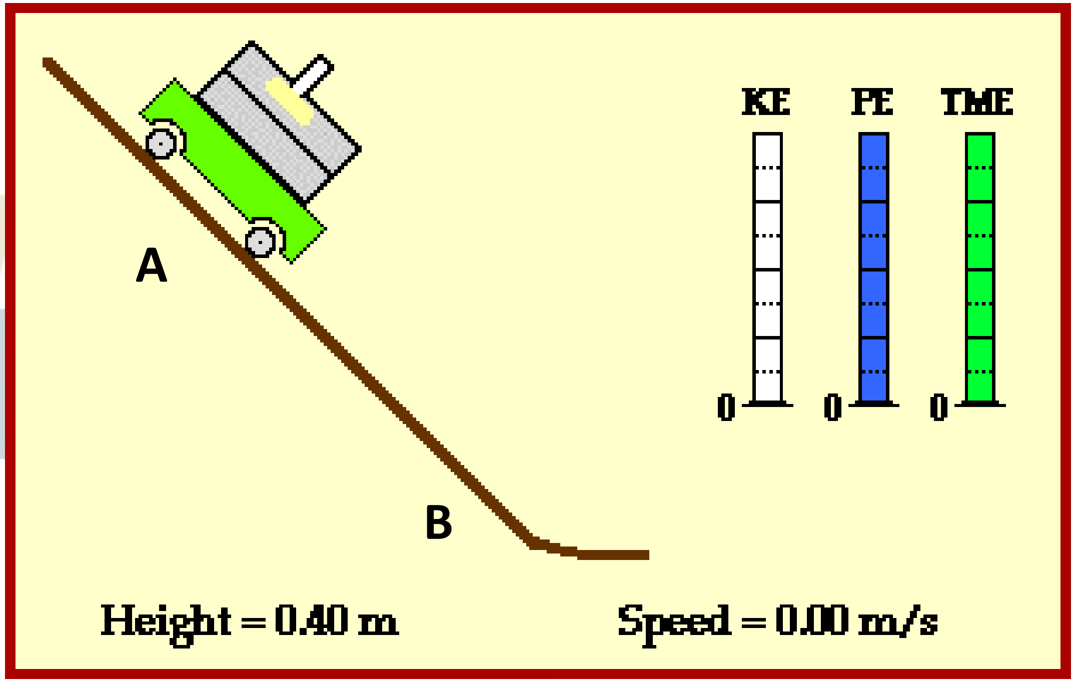
Conservation of Mechanical Energy

A body moves from point A to point B. The mechanical energy of the system is conserved if:

The non-conservative forces (friction, air resistance, braking force, traction forces, damping force…) are zero or neglected. (ex: $f_r = 0$).

$$ME_A = ME_B$$

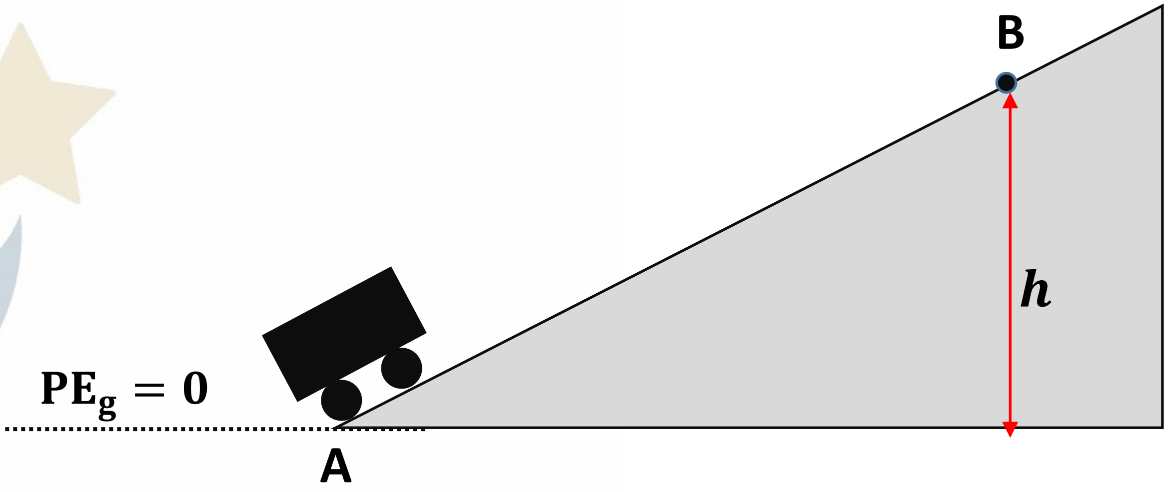




Conservation of Mechanical Energy

Application 9:

A car considered as a particle of mass 500kg starts with a speed of 20m/s from the bottom A of an inclined plane making an angle $\alpha = 30^{\circ}$ with the horizontal.



The car cuts 35.1m reaches point B at a height h above the ground with a speed of 7m/s.

1.Calculate the mechanical energy of the system[car-earth] at point A.

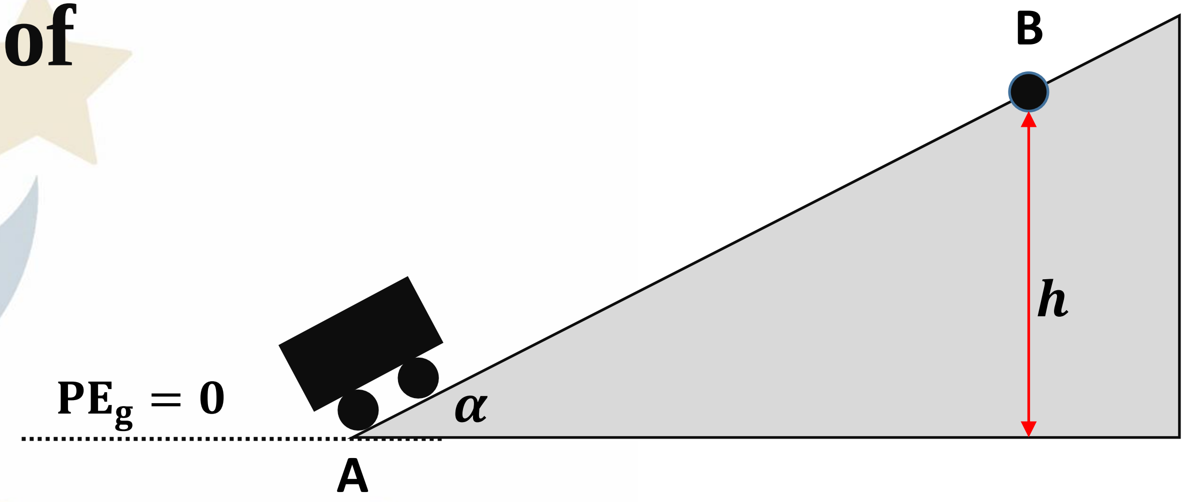
2.Calculate the mechanical energy of the system[car-earth] at point B.

3.Compare the mechanical energy at A and B, then deduce

Conservation of Mechanical Energy

$m = 500kg; V_A = 20m/s; \alpha = 30^{\circ}; AB = 35.1m; V_B = 7m/s$

1.Calculate the mechanical energy of the system[car-earth] at point A.



$$ME_A = KE_A + PE_A$$

$$\Rightarrow ME_A = \frac{1}{2}mV_A^2 + mgh_A$$

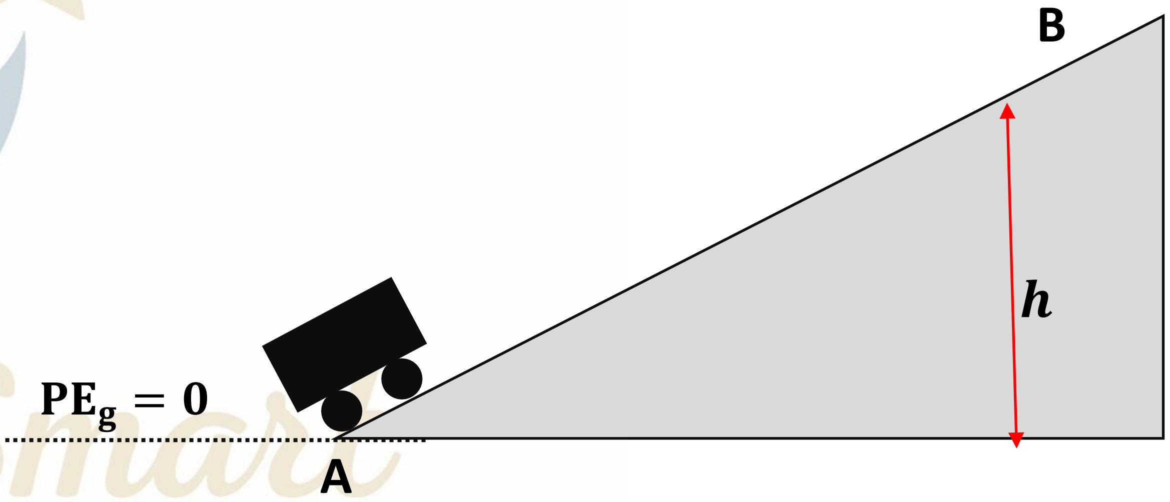
$$\Rightarrow ME_A = \frac{1}{2} \times 500 \times (20)^2 + 0 \Rightarrow ME_A = 100,000J$$

Conservation of Mechanical Energy

$m = 500kg; V_A = 20m/s; \alpha = 30^{\circ}; AB = 35.1m; V_B = 7m/s$

2.Calculate the mechanical energy of the system[car-earth] at point B.

$$ME_B = KE_B + PE_B$$



$$ME_B = \frac{1}{2}mV_B^2 + mgh_B$$

$$ME_B = \frac{1}{2}mV_B^2 + mgAB.\sin\alpha$$

$$\sin\alpha = \frac{h}{AB} \rightarrow h = AB.\sin\alpha$$

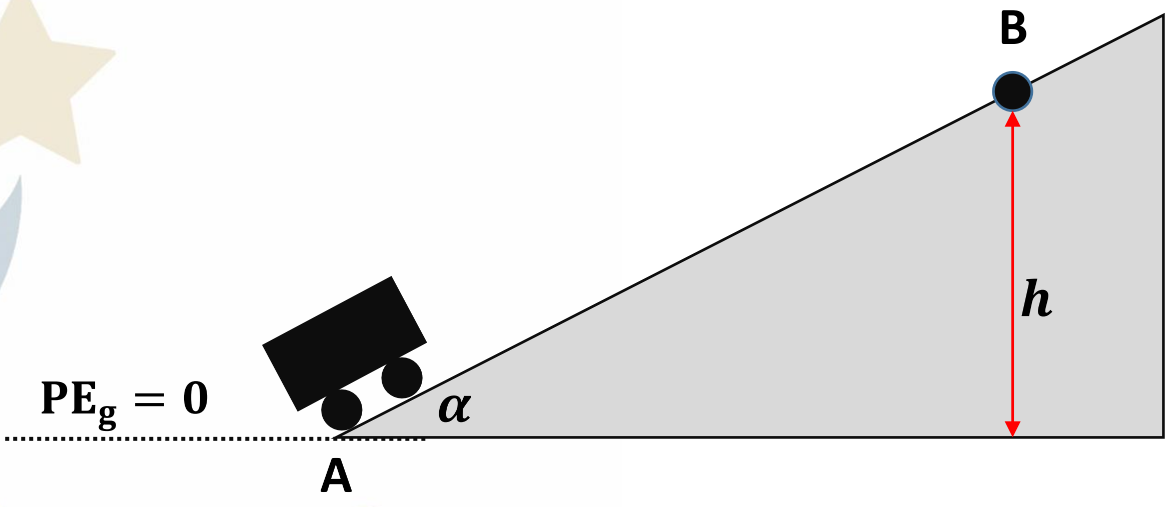
$$ME_B = 0.5 \times 500 \times (7)^2 + 500 \times 10 \times 35.1 \times \sin 30$$

$$ME_B = 100,000J$$

Conservation of Mechanical Energy

3.Compare the mechanical energy at A and B, then deduce.

$$ME_A = ME_B = 100,000J$$



Then the mechanical energy is conserved.

The frictional forces are neglected ($f_r = 0$).

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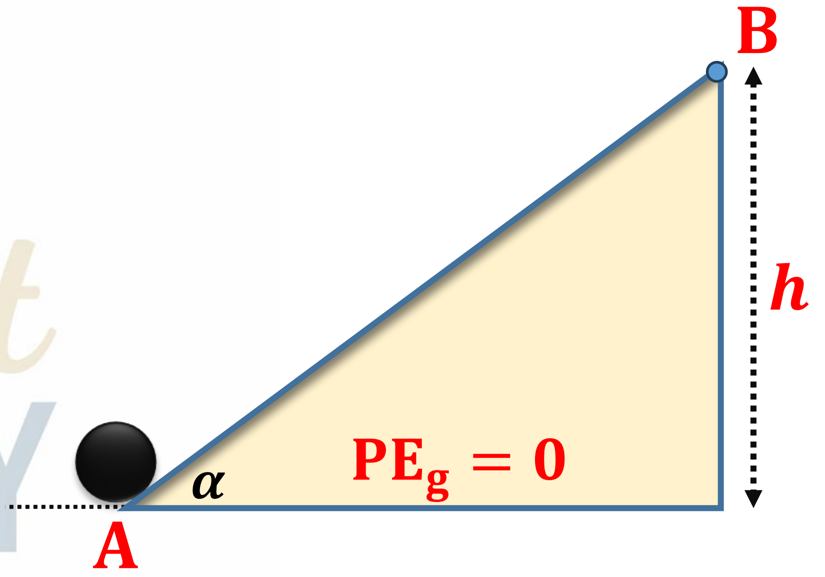
Non – conservation of Mechanical Energy

A particle moves from point A to point B. If the non-conservative forces acting on the body is not neglected, then:

The mechanical energy of the system[body-earth] is NOT conserved. ($f_r \neq 0$)

$$ME_A \neq ME_B$$



The variation of mechanical energy between these two points equal to sum of work done by these forces.

$$\Delta M.E = \sum W_{non-cons}$$

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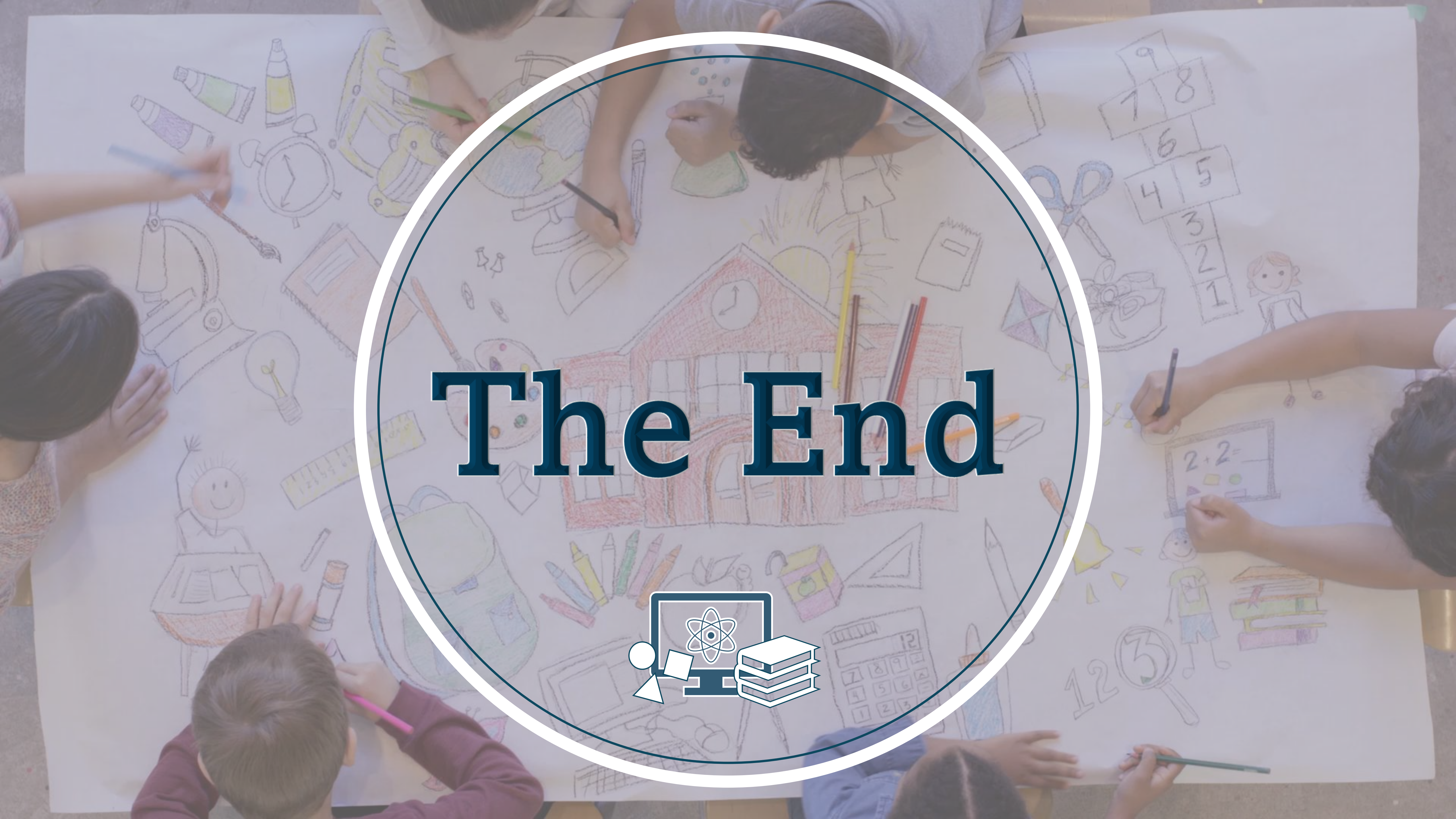
The work done by friction appears as a heat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