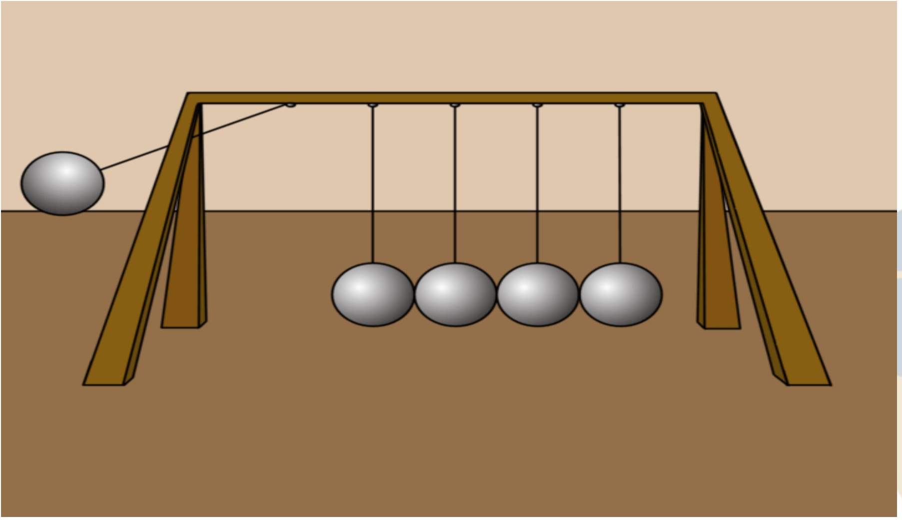


Physics - Grade 11 S

Unit Two: Mechanics

Chapter 8 – Newton's Second Law

Prepared & Presented by: Mr. Mohamad Seif

Objectives

Introduction about Mechanics

Definition of a Force

Effect of a Force

Characteristics of a force

Be Smart ACADEMY

Introduction

Mechanics: Mechanics is a branch of physics that studies the state (motion or rest) of an object (or system) and taking into consideration its causes.

Mechanics

- **Kinematics**: Concerned with the description of motion without reference to the cause of motion
- **Statics**: Concerned with analysis of loads (forces, torque…) acting on a system during static equilibrium.
- **Dynamics**: Concerned with the study of motion with reference to the cause of motion (force, energy…)

In this chapter we will study dynamics

Definition of a Force

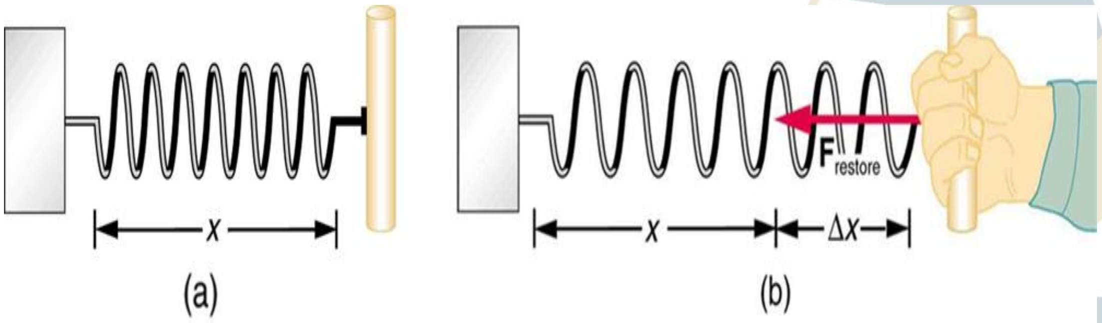
What is Forces (mechanical action)?

When you squeeze a ball, you apply a certain action called a force or mechanical action.

When you push or pull a car, you apply a certain action called a force or mechanical action.

Definition of a Force

What is Forces (mechanical action)?



When you elongate or compress the spring, you exerts a certain action called a force or mechanical action.

When you kick a ball, you apply a certain action called a force or mechanical action.

Definition of a Force

What is Forces?

A force is a mechanical action exerted by an object (A) on another object (B).

Effect of a force

When a force is applied to a certain object, this force may have an effect on this object. A force is capable to:

1. **Set a body in motion:** a body at rest and set it in a motion
   - Example: A girl pulls a wagon.

2. **Deformation of a body:** change the shape of the body
   - Example: A person Changes the form of a tank.

Effect of a force

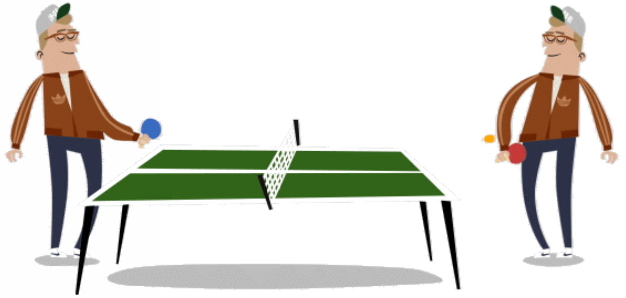
3. Modify the motion of a body:

a. Stop the motion: a body was in motion, a force stop the body.

- ➢Example: a goalkeeper catch the ball.

b. Change the direction & speed

- ➢Example: a persons play tinis ball goalkeeper catch the ball.



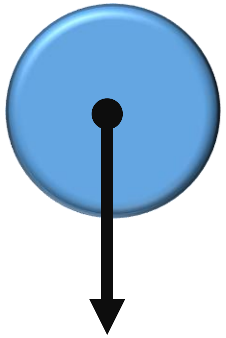
Characteristics of a force

- Point of Application
- Line of Action
- Direction
- Magnitude

Characteristics of a force

1. **Point of application:** is the point where the applied force starts.

The point of application may be center of gravity or point of contacts between the two bodies.



The point of application is the center of this ball.

The point of application is the point of contact between the hands of the boy and the car

Characteristics of a force

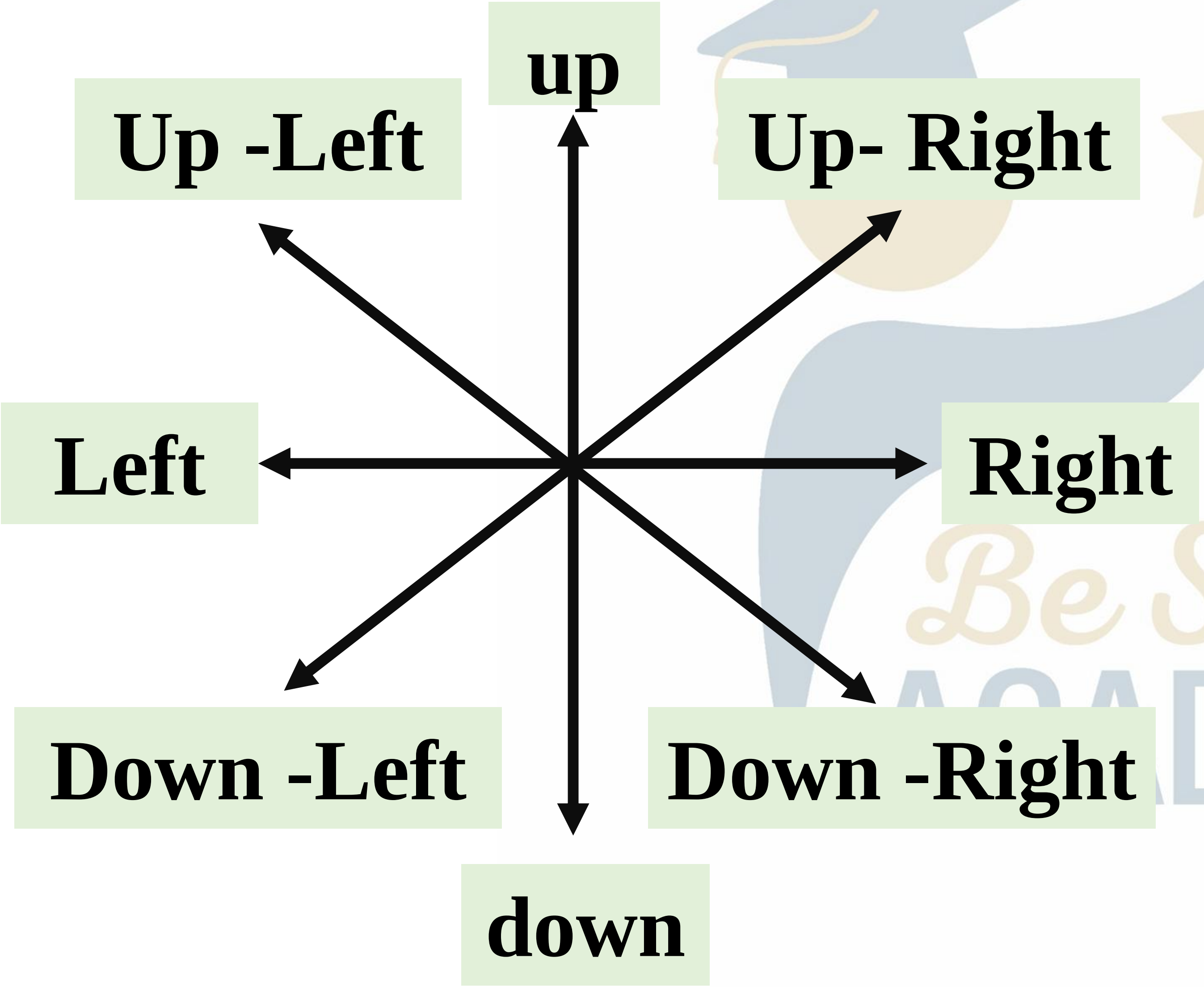
2. **Line of action:** is the line containing the force that applied on the body.

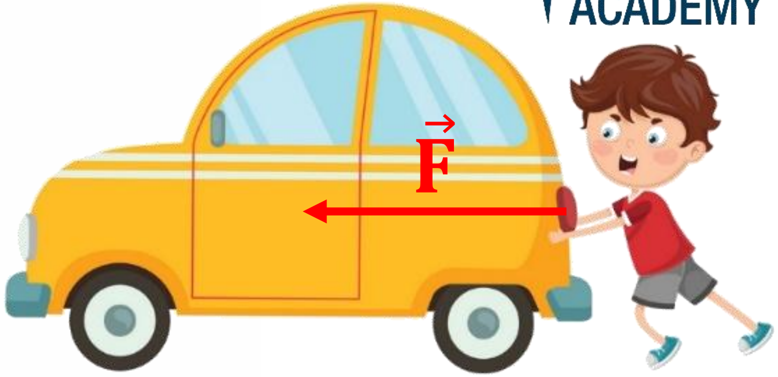
The line of action may be: horizontal, vertical or oblique.

The line of action is Horizontal.	The line of action is vertical.	The line of action is oblique.

Characteristics of a force

3.Direction: it refers to how the force is directed:





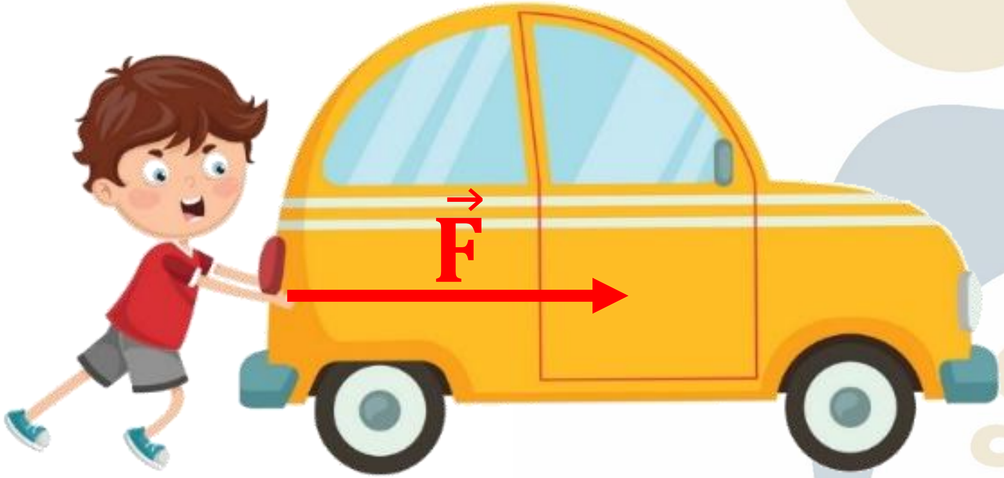
Direction: Left

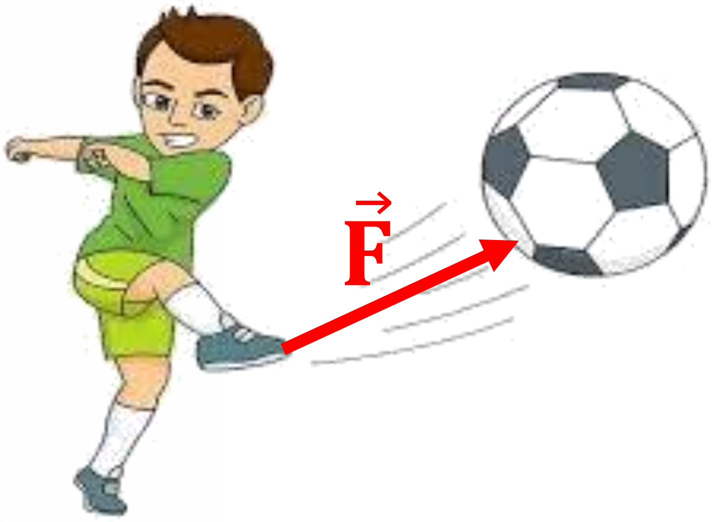
Direction: up-Left

Characteristics of a force

4.Magnitude: is the value of the applied force.

The SI unit of a force is Newton (N)





A boy pushes a car by a force of magnitude F=500N

A player kick the ball by a force of magnitude F=200N

Characteristics of a force

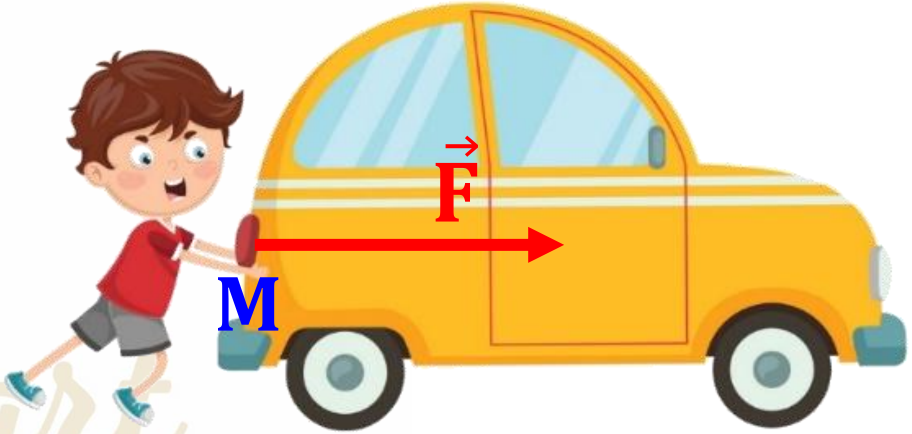
Characteristics of a Force ($\vec{F}$)				
Point of application	Contact point		Center of gravity	
Line of action	Horizontal	Vertical	Oblique	
Direction	Right Left	Down Up	Up to right Up to left	Down to right Down to right
magnitude	Given or to be calculated			

Characteristics of a force

Application1:

A boy is pushing a stationary car by a force $\vec{F}$ of magnitude $F = 250N$ as shown in the figure below.

1. Give a definition of a force.



A force is a mechanical action exerted by a body on the car.

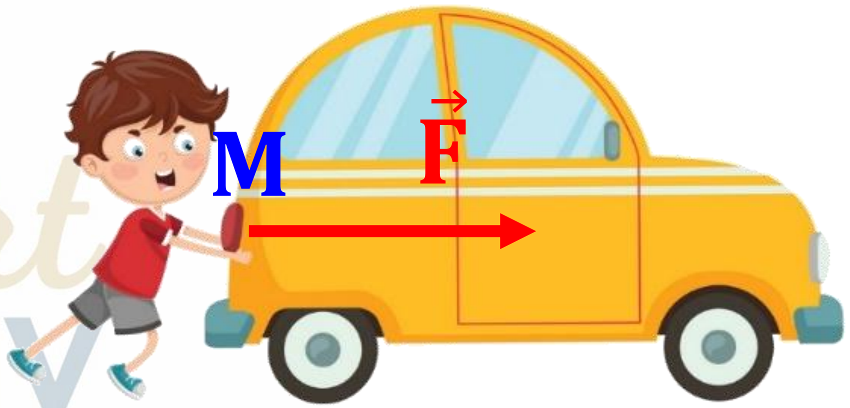
Characteristics of a force

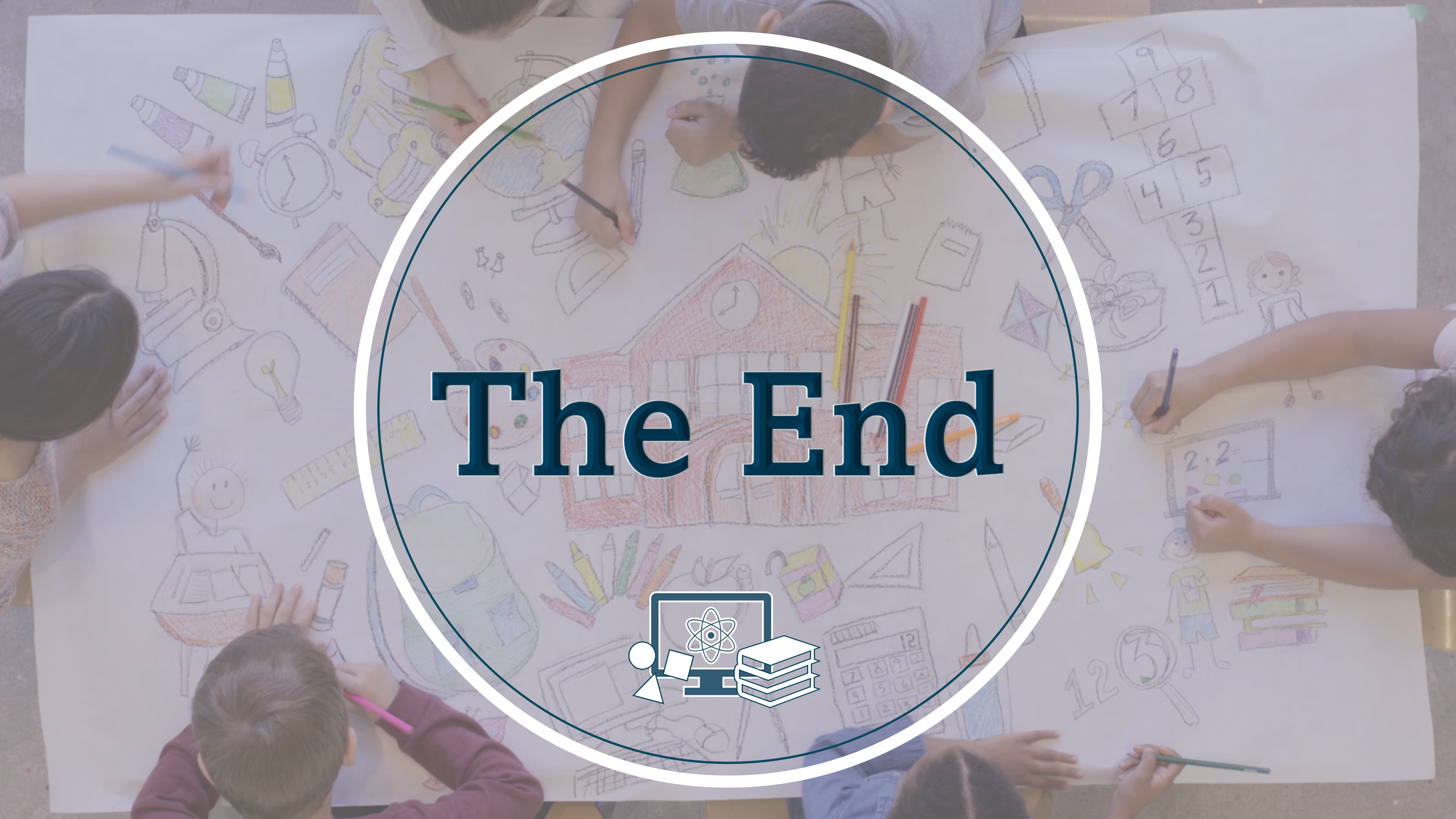
2. Give the effect of the force done the boy on the car.

The force exerted by the boy on the car set the car in motion

3. Give the characteristics of the above applied force.

- Point of application: point M
- Line of action: Horizontal
- Direction: To right.
- Magnitude: F=250N

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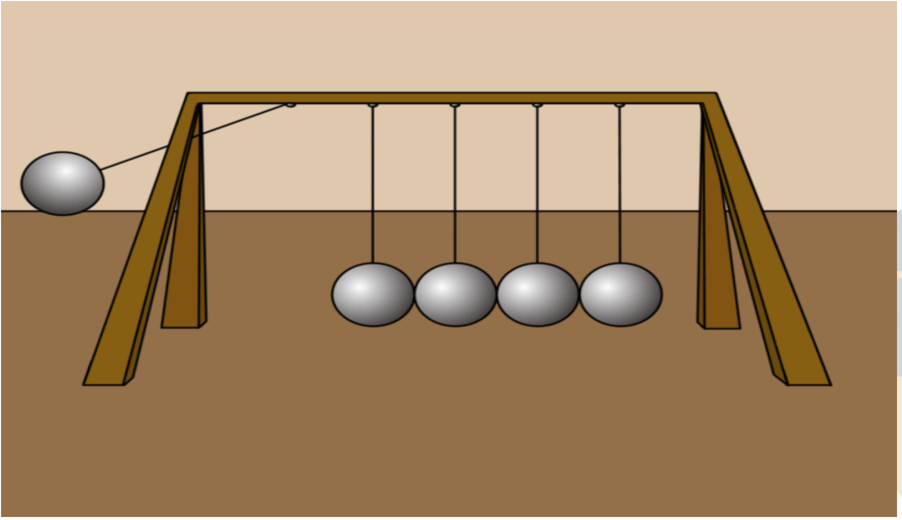
Be Smart Academy



Physics - Grade 11 S

Unit Two: Mechanics

Chapter 8 – Newton's Second Law

Prepared & Presented by: Mr. Mohamad Seif

Objectives

Classification of forces

Forces acting from a distance

Contact forces

Free body diagram

Classification of force vector

Types of forces

Contact forces

Forces exerted by body (A) on another body (B), due to contact between the two bodies.

Acting from a distance

are forces exerted by a body (A) on another body (B), but without contact between the two bodies.

Classification of forces

Types of forces

- **Forces acting from a distance**
  - Weight ($\overrightarrow{W}$)
  - Electric force ($\vec{F}_e$)
  - Magnetic force ($\vec{F}_m$)
- **Contact forces**
  - Muscular force ($\vec{F}$)
  - Tension ($\vec{T}$)
  - Friction force ($\vec{f}_r$)
  - Normal reaction ($\vec{N}$)

Forces acting from a distance:

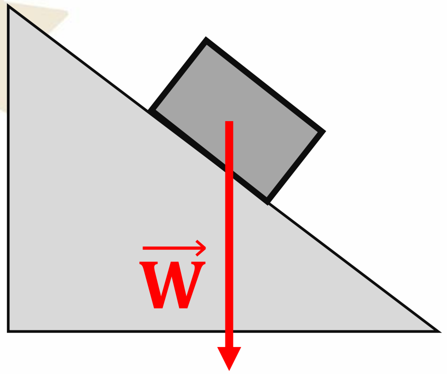
No contact between the two bodies.

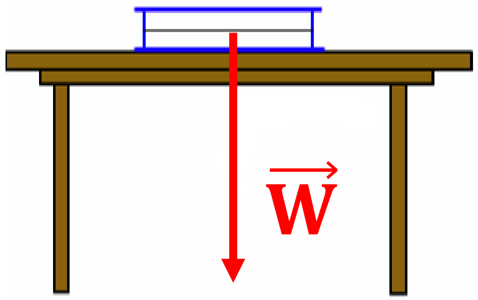
1. **Weight (gravitational force) $\overrightarrow{W}$:**
2. **Electric force ($\overrightarrow{F}_e$).**
3. **Magnetic force ($\overrightarrow{F}_m$)**

The point of application of all these forces is the center of gravity of the body

Contact Forces

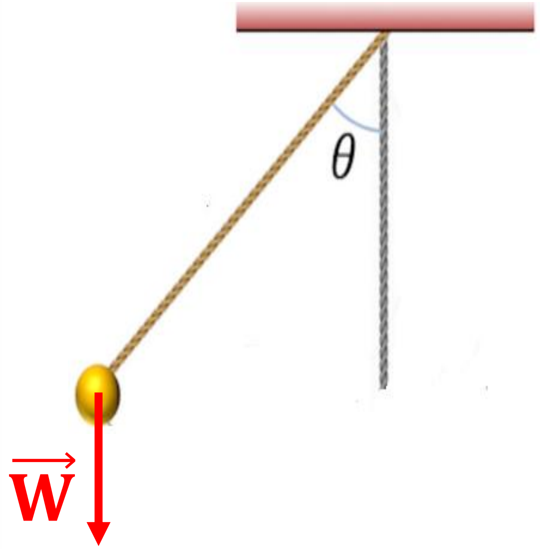
Weight ($\overrightarrow{W}$): **Weight is gravitational force exerted by the Earth on the bodies.**





Characteristics of weight ($\overrightarrow{W}$):

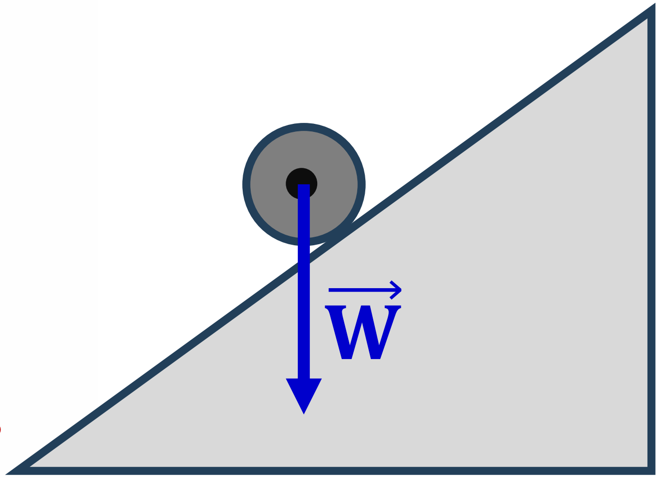
- **Point of application: G (center of gravity)**
- **Line of action: always vertical**
- **Direction: always downward**
- **Magnitude: w = m x g**



Forces acting from a distance

Application 2:

A car considered as a particle of mass $m = 500kg$ moves up an inclined plane as shown in the figure.



Determine the characteristics of the weight. Given g = 10N / kg.

- **Point of application:** Center of gravity of the car.
- **Line of action:** Vertical.
- **Direction:** Downward.
- **Magnitude of weight:** $W = m \times g = 500 \times 10 = 5000N$

Contact Forces

Normal Reaction of support($\vec{N}$): the force exerted by the surface on the body. It is always perpendicular to surface of motion.

Characteristics of Normal ($\vec{N}$):

- Point of application: contact point.
- Line of action: fig (1):oblique; fig (2): vertical.
- Direction: fig (1): up-right; fig (2) up-ward

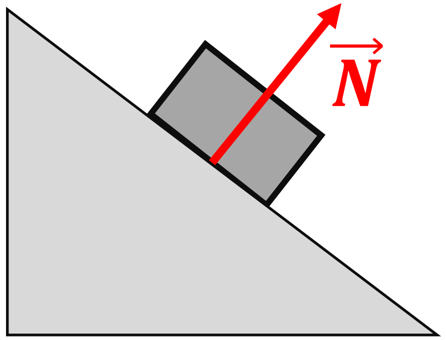


Fig 1

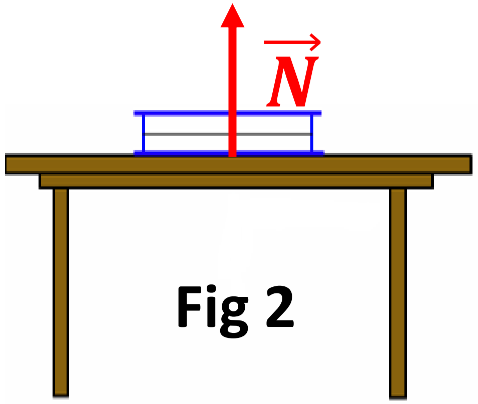
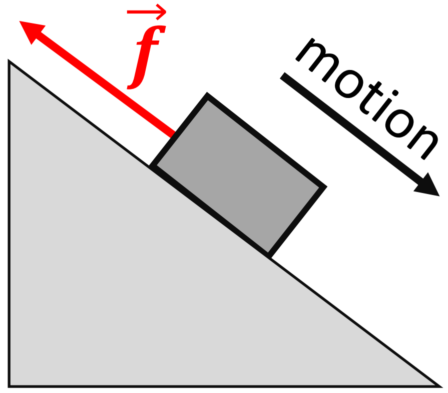


Fig 2

Friction force ($\vec{f}$): **the friction force exist when the body moves a rough plane. Friction ($\vec{f}$) always opposite to the direction of motion of the object.**

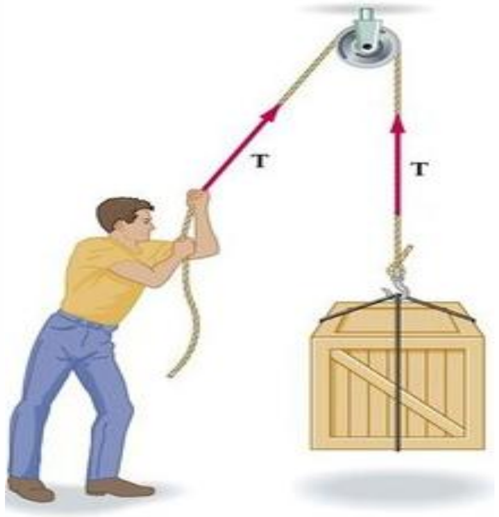
Characteristics of friction ($\vec{f}$):

- **Point of application: contact point.**
- **Line of action: fig (1):oblique.**
- **Direction: fig (1): up-left.**
- **Magnitude: given or to be calculated.**



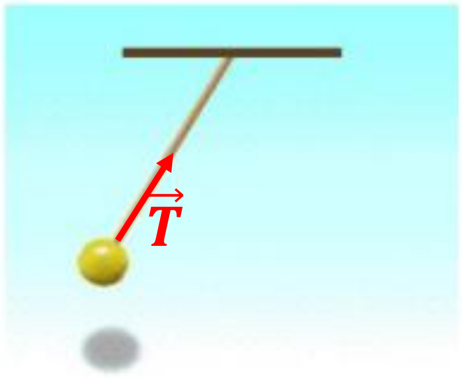
Contact Forces

Tension force ($\vec{T}$): the tension force is a force exerted by a spring or string on the body.
Tension always directed along the string.



Characteristics of Tension ($\vec{T}$):

- Point of application: contact point.
- Line of action: fig (1):oblique.
- Direction: fig (1): up-Right.
- Magnitude: given or to be calculated.



Free body Diagram

- It is a technique used to illustrate all the external forces acting on a body.
- The body is <u>represented by a single isolated point</u> (or free body).
- Only <u>external forces</u> are shown on the figure, because only external forces affect the motion.

Free body Diagram

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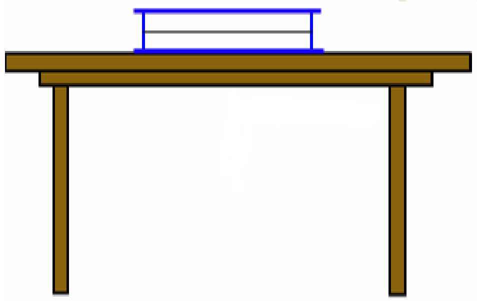
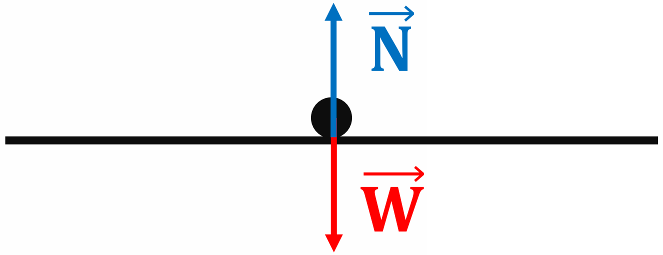
<tr><th>Real figure</th><th>Free body diagram</th></tr>
<tr><td></td><td>
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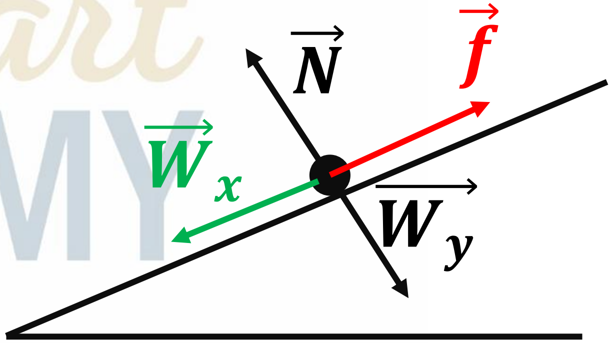
</td><td>
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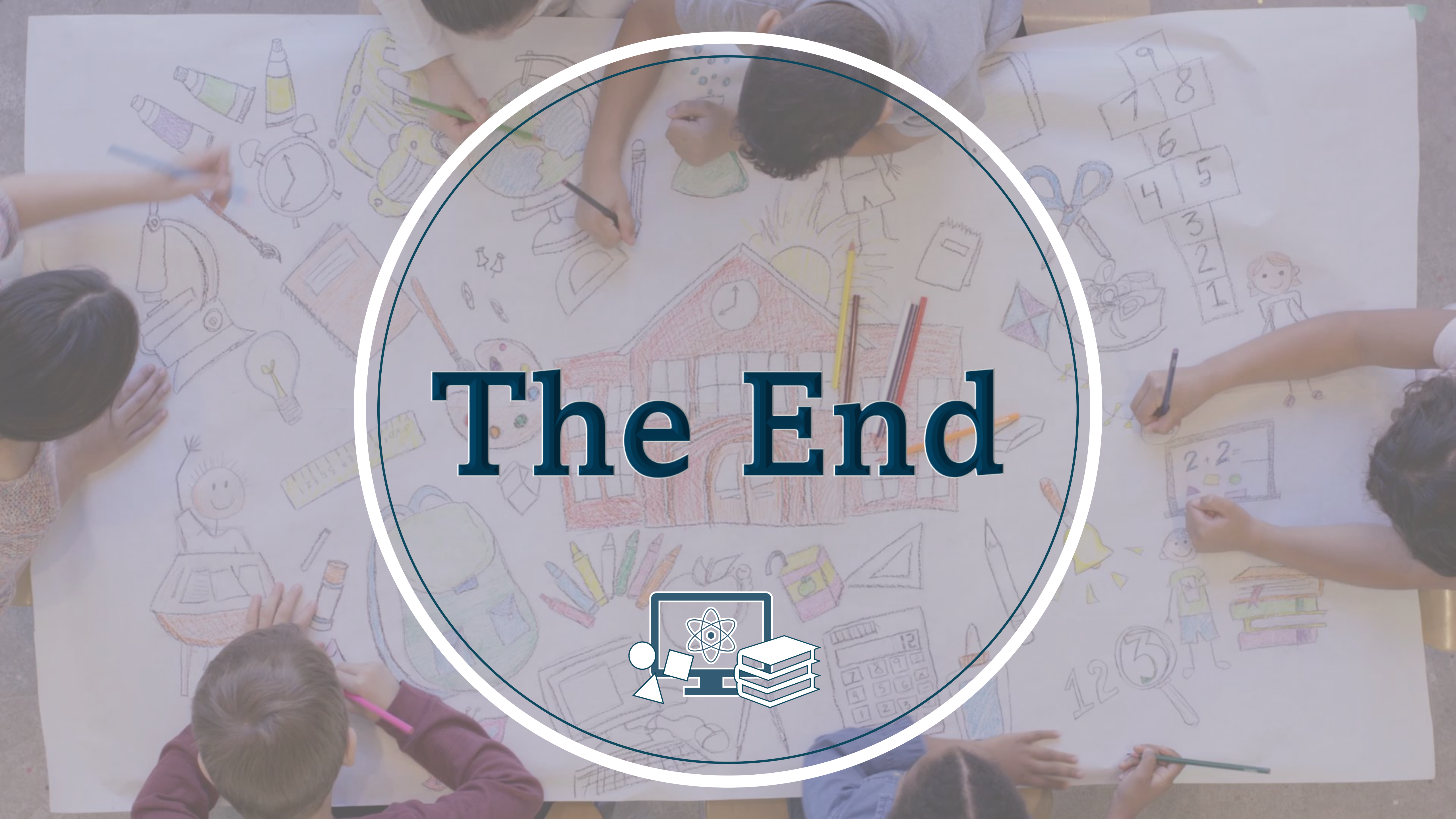

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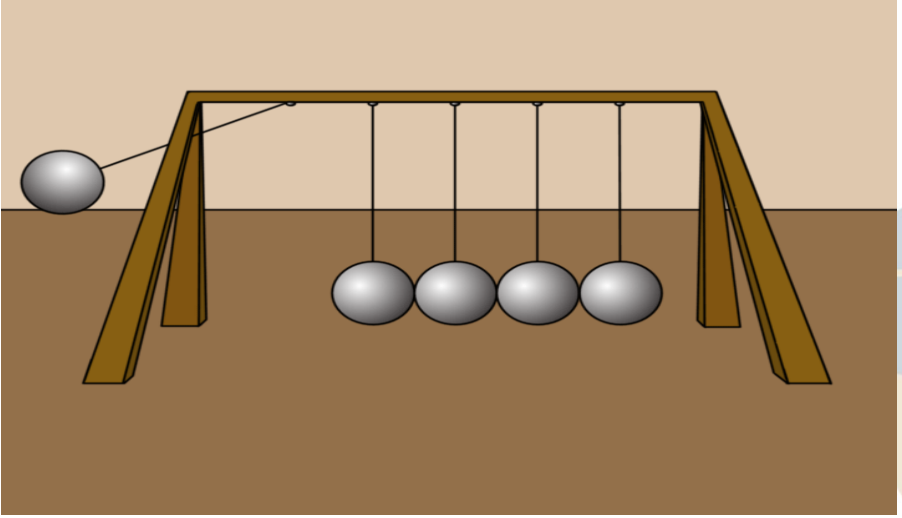


Physics - Grade 11 S

Unit Two: Mechanics

Chapter 8 – Newton’s Second Law

Prepared & Presented by: Mr. Mohamad Seif

Objectives

Force Projection

Uniform rectilinear motion.

Uniformly accelerated rectilinear motion.

Uniformly decelerated rectilinear motion

Force projection

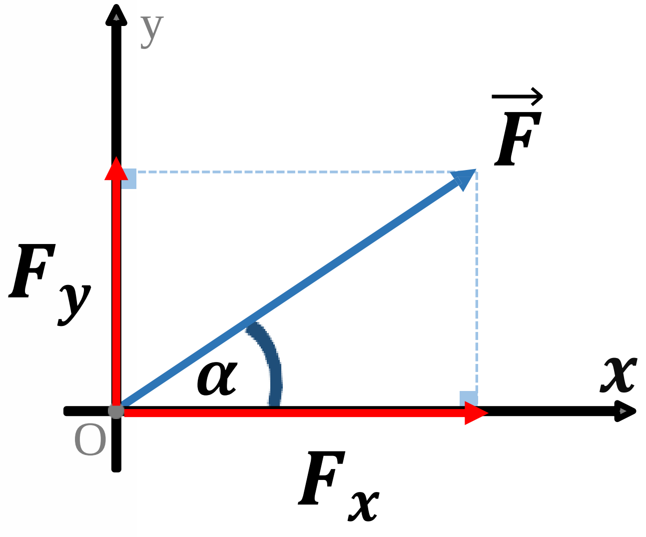
Consider a force $\vec{F}$ lying in x-y plane, making an angle α with the horizontal axis.

The force $\vec{F}$ can be decomposed to its components F_x *and* F_y

$$\vec{F} = F_x\vec{i} + F_y\vec{j}$$

$$\cos(\alpha) = \frac{F_x}{F} \Rightarrow F_x = F\cos(\alpha)$$

$$\sin(\alpha) = \frac{F_y}{F} \Rightarrow F_y = F\sin(\alpha)$$



The magnitude of $\vec{F}$ is:

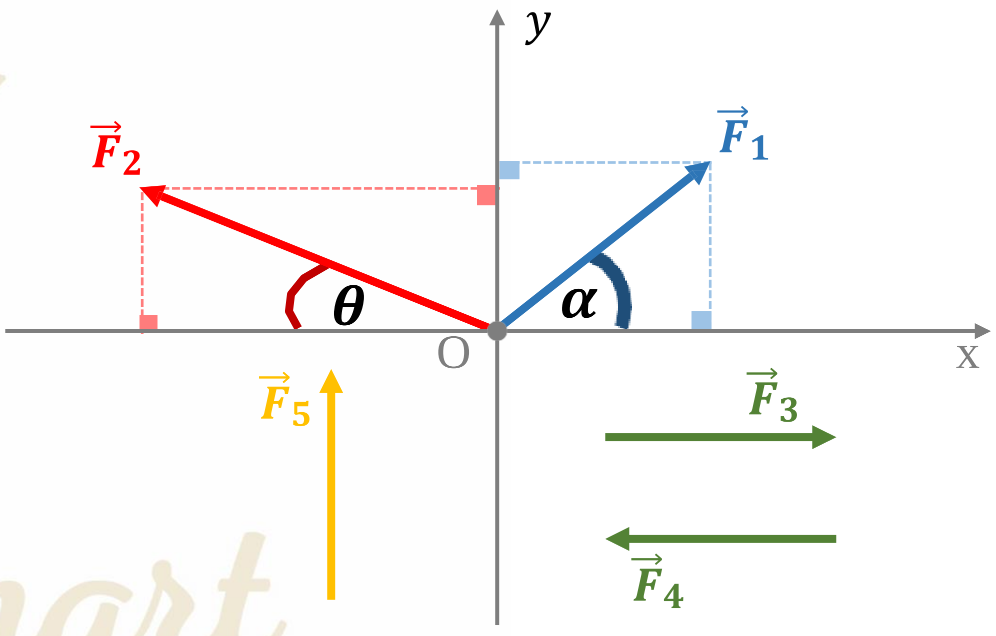
$$F = \sqrt{F_x^2 + F_y^2}$$

Force projection

Application 3: Determine the components of each force.

$$\vec{F}_1 = \begin{cases} F_{1(x)} = F_1 cos(\alpha) \\ F_{1(y)} = F_1 sin(\alpha) \end{cases}$$

$$\vec{F}_2 = \begin{cases} F_{2(x)} = -F_2 cos(\theta) \\ F_{2(y)} = F_2 sin(\theta) \end{cases}$$

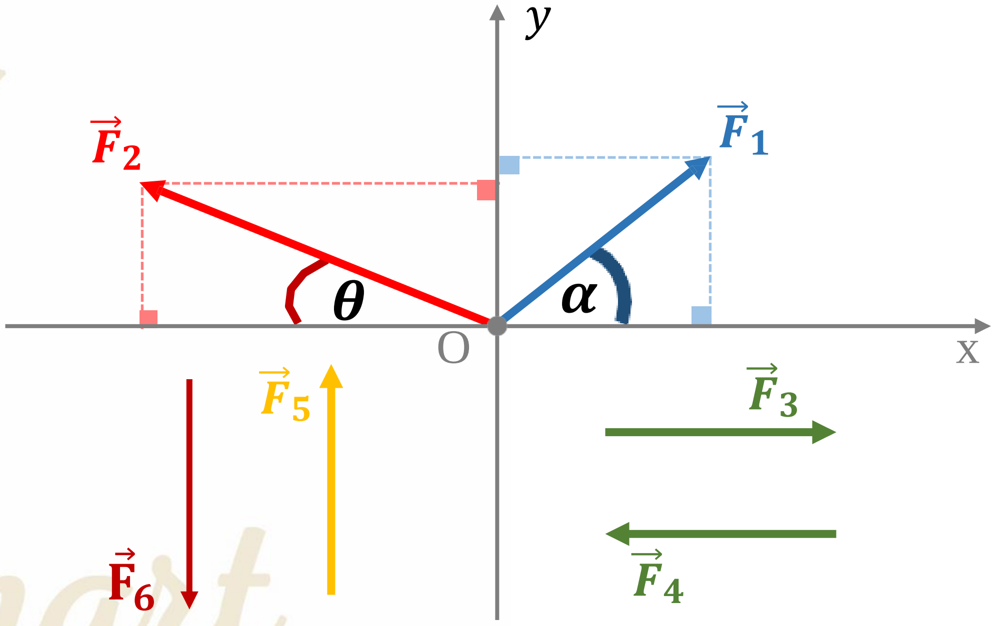


$$\vec{F}_3 = \begin{cases} F_{3(x)} = F_3 \\ F_{3(y)} = 0 \end{cases}$$

Force projection

$$\vec{F}_4 = \begin{cases} F_{4(x)} = -F_4 \\ F_{4(y)} = 0 \end{cases}$$

$$\vec{F}_5 = \begin{cases} F_{5(x)} = 0 \\ F_{5(y)} = F_5 \end{cases}$$



$$\vec{F}_6 = \begin{cases} F_{6(x)} = 0 \\ F_{6(y)} = -F_6 \end{cases}$$

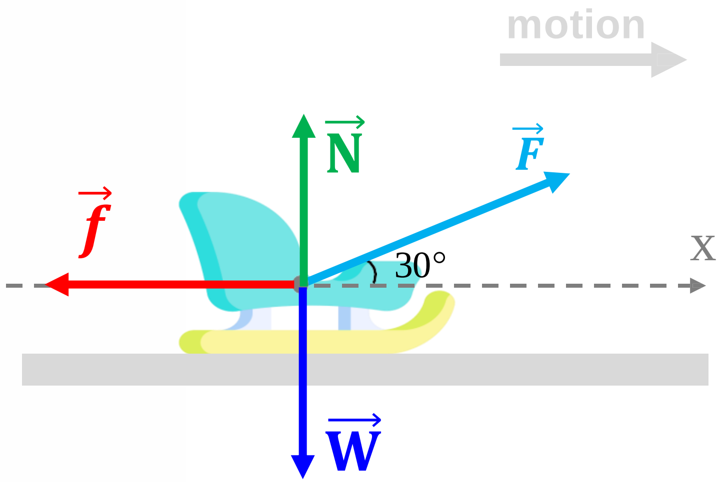
Force projection

Application 4:

A sled is pulled on a horizontal track by a force $\vec{F}$ making an angle of 30°.

The track exerts on the sled a friction force of constant value

1. Name and represent on the figure, without scale, the forces acting on the box.



The forces acting on the sled are:

- Pushing force: $\vec{F}$
- Weight: $\vec{W} = m\vec{g}$
- Friction force: $\vec{f}$
- Normal reaction: $\vec{N}$

Force projection

2. Determine the projection of each force along x-axis and y-axis.

The Weight $\overrightarrow{W}$ is perpendicular to x-axis (downward):

$W_x = 0$ **And** $W_y = -mg$

The Pushing force $\vec{F}$ makes 30° with the positive x-axis:

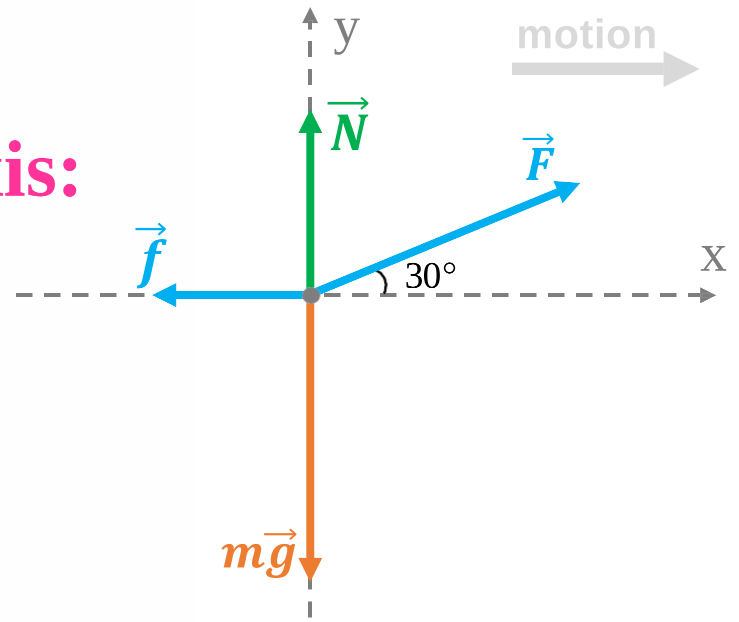
$F_x = F\cos(30^{\circ})$ **And** $F_y = F\sin(30^{\circ})$

The Friction force $\vec{f}$ is opposite to x-axis:

$f_x = -f$ **And** $f_y = -0$

Normal reaction $\vec{N}$ is perpendicular to x-axis (upward):

$N_x = 0$ **And** $W_y = N$

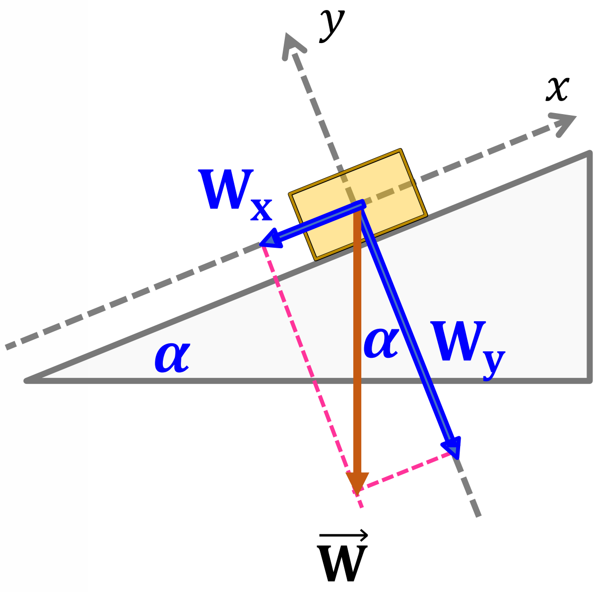


Force projection

Note: projection of weight along inclined plane:

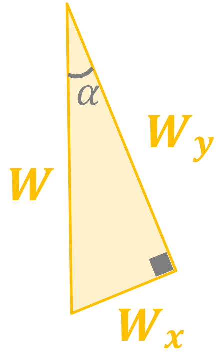
The Weight ($W = mg$) is always directed vertically downward:

$$\vec{W} = \vec{W}_x + \vec{W}_y = W_x\vec{i} + W_y\vec{j}$$



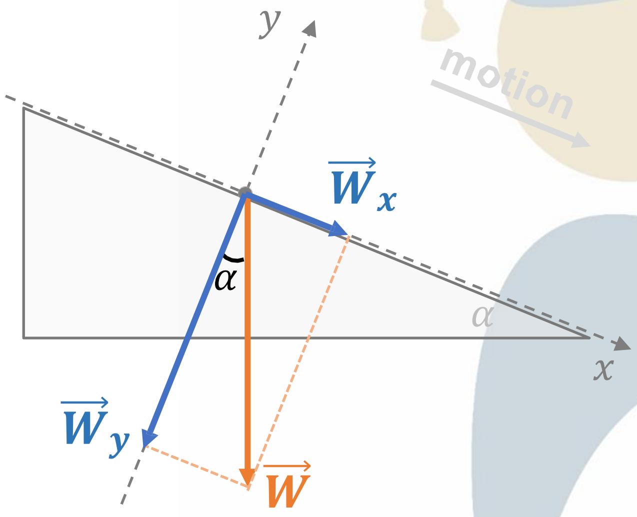
$$sin\alpha = \frac{|W_x|}{W} \Rightarrow |W_x| = W sin\alpha$$

$$cos\alpha = \frac{|W_y|}{W} \Rightarrow |W_y| = W cos\alpha$$



Force projection

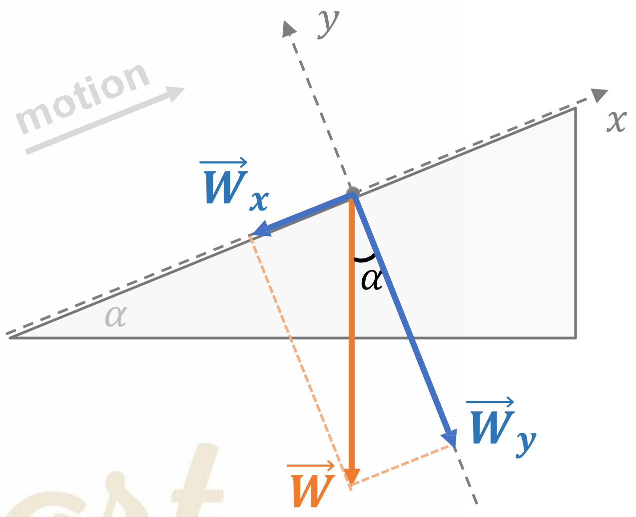
Downward motion



$$W_x = \ mg \sin a$$

$$W_y = -mg \cos a$$

Upward motion



$$W_x = -\ mg \sin a$$

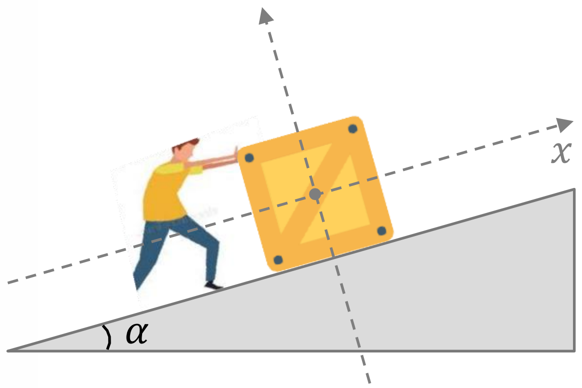
$$W_y = -mg \cos a$$

Force projection

Application 5:

An worker is pushing a 40 kg box up an incline by applying a pushing force $\vec{F}$ which is directed parallel to the incline upwards.

During its motion, the box is under the action of a friction force $\vec{f}$ of magnitude 160 N, a normal force $\vec{N}$ of magnitude 320 N and the pushing force F of magnitude 500 N.



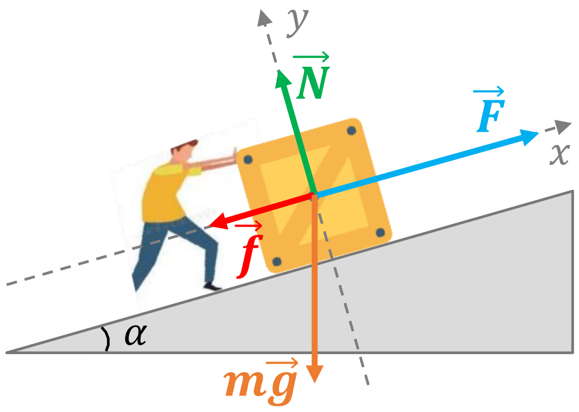
Use $g = 10m/s^2$; $sin\alpha = 0.6$ and $cos\alpha = 0.8$

1. **Name and represent on the figure the forces acting on the box.**
2. **Determine for each force the components along x-axis and y-axis.**
3. **Deduce the magnitude and the direction of the resultant force $\vec{F}_{res}$ acting on the box.**

Force projection

1. Draw on the figure the forces acting on the box.

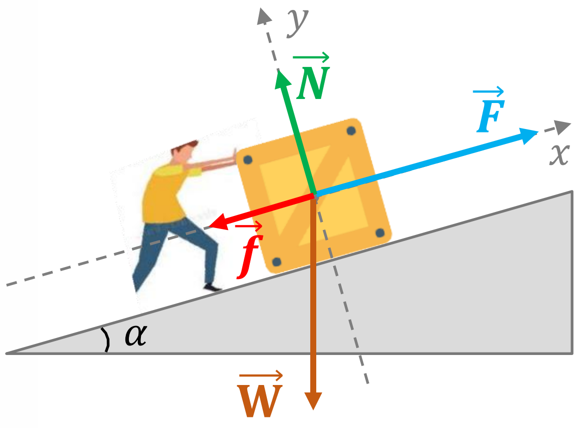
The forces acting on the sled are:



- Pushing force: $\vec{F}$
- Weight: $\vec{W} = m\vec{g}$
- Normal reaction: $\vec{N}$
- Friction force: $\vec{f}$

Force projection

2. Determine for each force the components along x-axis and y-axis.



The Pushing force $\vec{F}$ is along the positive x-axis:

$F_x = F = 500N$ **And** $F_y = 0N$

The Friction force $\vec{f}$ is along the negative x-axis (opposite to motion):

$f_x = -f = -160N$ **And** $f_y = 0N$

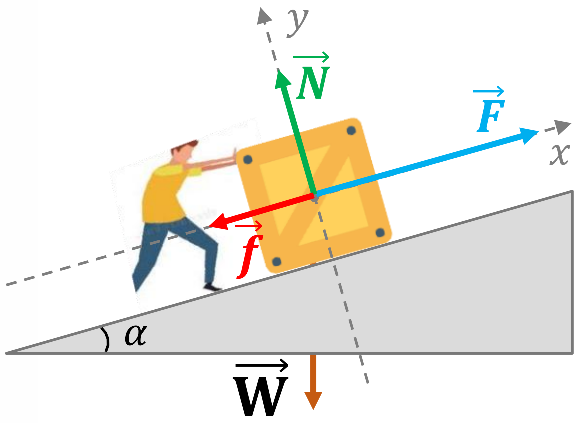
The normal force $\vec{N}$ is along the positive y-axis:

$N_x = 0N$ **And** $N_y = 320N$

Force projection

The Weight ($\vec{W}$) is directed vertically downward:

$$\vec{W} = \vec{W}_x + \vec{W}_y = W_x\vec{i} + W_y\vec{j}$$



But W_x is along the negative x-axis and W_y is along the negative y-axis, then

$W_x = -W sin\alpha$ ➡ $W_x = -mg sin\alpha$

$W_x = -40 \times 10 \times 0.6$ ➡ $W_x = -240N$

$W_y = -W cos\alpha$ ➡ $W_y = -mg cos\alpha$

$W_y = -40 \times 10 \times 0.8$ ➡ $W_y = -320N$

Force projection

3. Deduce the magnitude and the direction of the resultant force $\vec{F}_{res}$ acting on the box.

$$\vec{F}_{res} = \vec{W} + \vec{N} + \vec{F} + \vec{f}$$

$$\vec{F}_{res} = -240\vec{i} - 320\vec{j} + 0\vec{i} + 320\vec{j} + 500\vec{i} + 0\vec{j} - 160\vec{i} + 0\vec{j}$$

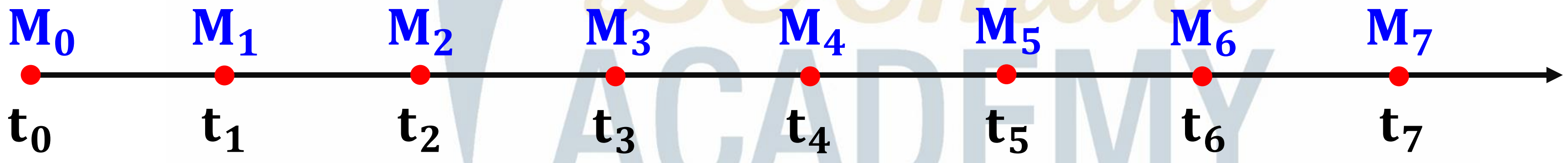
$$\vec{F}_{res} = 100\vec{i} + 0\vec{j}$$

$$\vec{F}_{res} = 100\vec{i}$$

Uniform Rectilinear Motion (U.R.M)

Uniform Rectilinear Motion: when the speed is constant during motion

- **Distance:** The distance covered during equal interval of time are **equal.**
- **Speed:** The speed between any two instants is **equal**.
- **Acceleration:** because the speed is constant then the acceleration is zero ($a = 0$).



Time equation of motion ➡

$$X = Vt + x_0$$

Uniformly Accelerated Rectilinear Motion (U.A.R.M)

- The average and instantaneous speeds increases with time.
- The acceleration(a) is constant over time and positive (a>0).

Time equations:

The position

$$x = \frac{1}{2}at^2 + V_0 t + x_0$$

The speed:

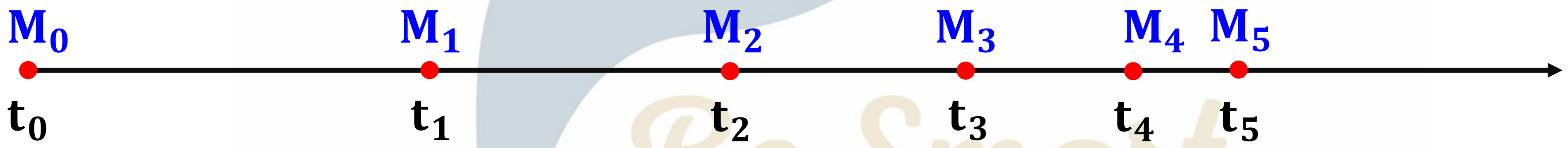
$$v = at + v_0$$

Relation of V and x:

$$v^2 - v_0^2 = 2a(x - x_0)$$

Uniformly decelerated Rectilinear Motion (U.D.R.M)

- The distance traveled during interval of time decrease with time.
- The average and instantaneous speeds decreases with time.
- The acceleration(a) is constant over time and negative (a<0).



Time equations:

The position:

$$x = \frac{1}{2}at^2 + V_0 t + x_0$$

The speed:

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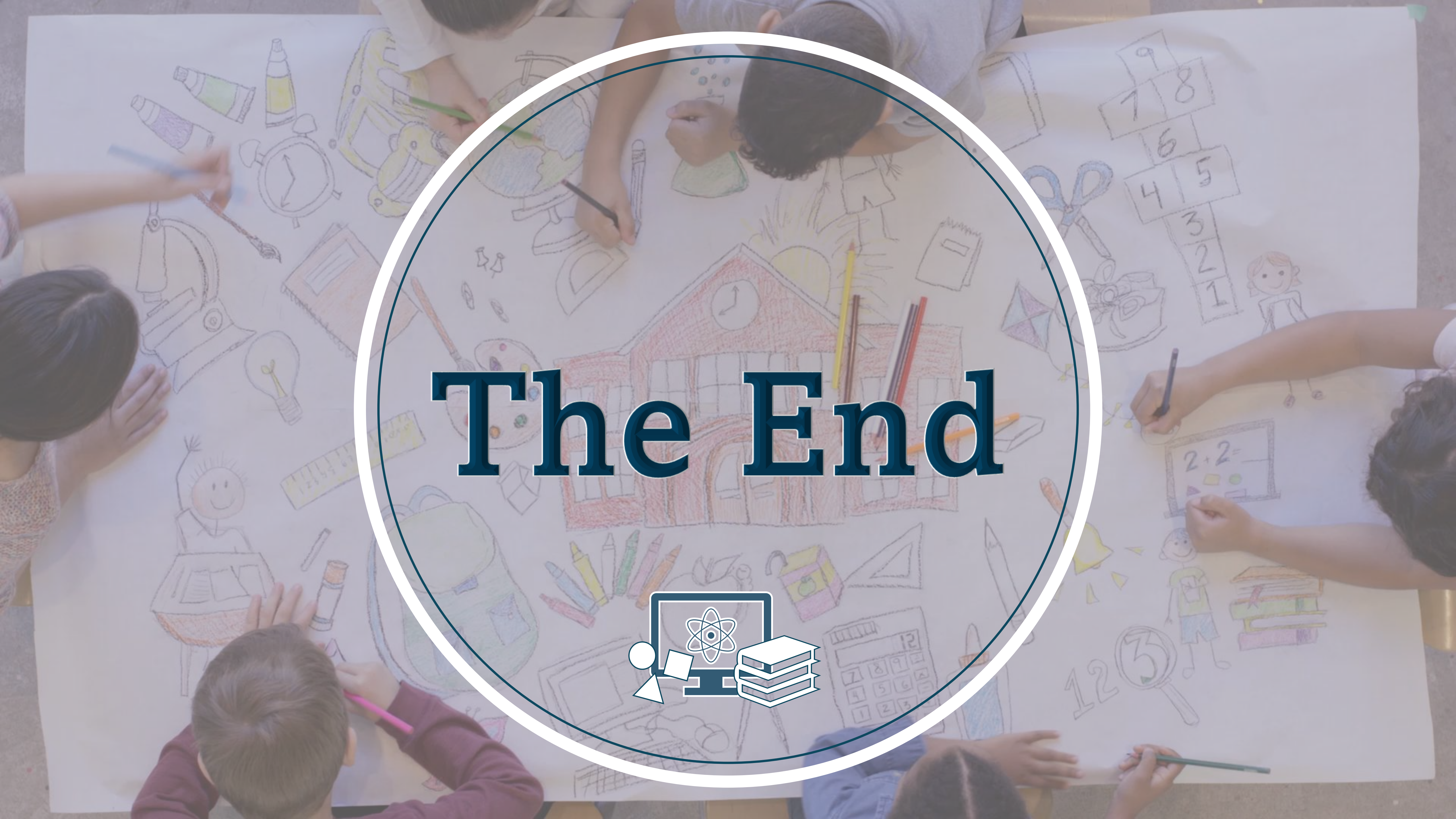
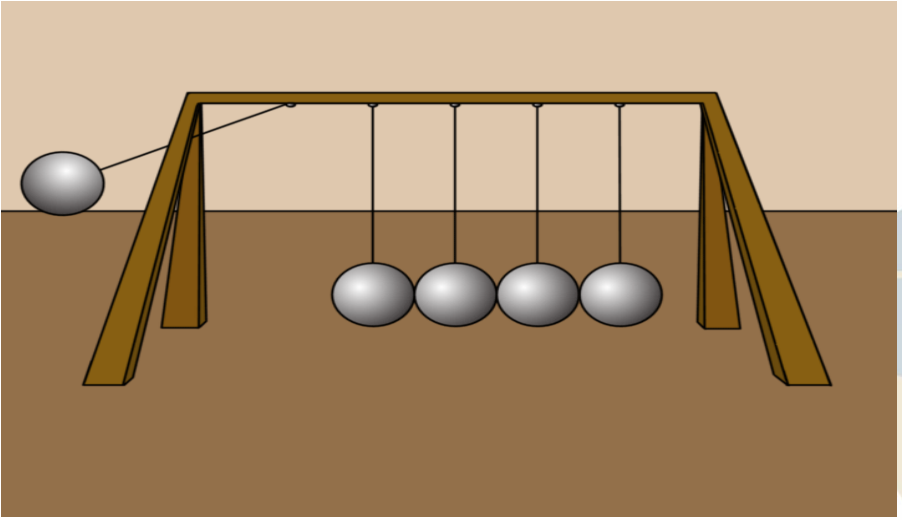

The End



Physics - Grade 11 S

Unit Two: Mechanics

Chapter 8 – Newton’s Second Law

Prepared & Presented by: Mr. Mohamad Seif

Objectives

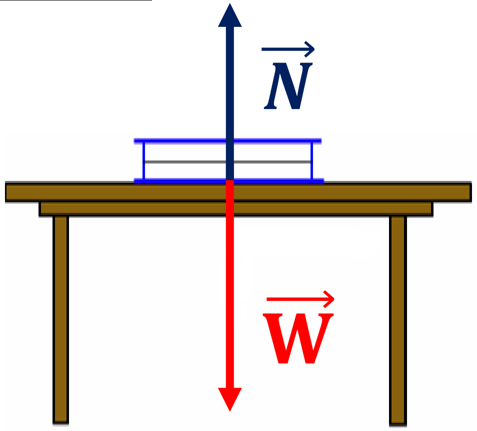
Newton's First Law

Newton's Third Law

Newton's Second Law

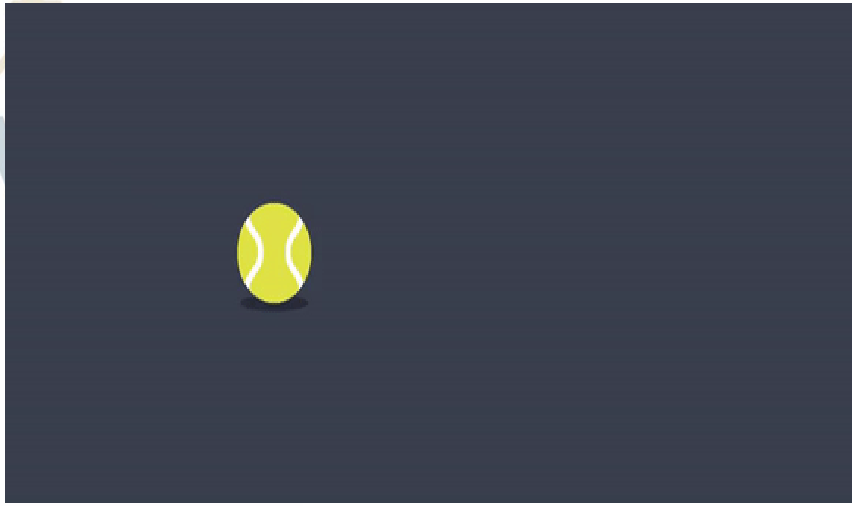
Newton’s first law

Newton's first law: **An object at rest remains at rest, or if in motion, remains in motion at a constant velocity <u>unless acted on by a net external force</u>.**



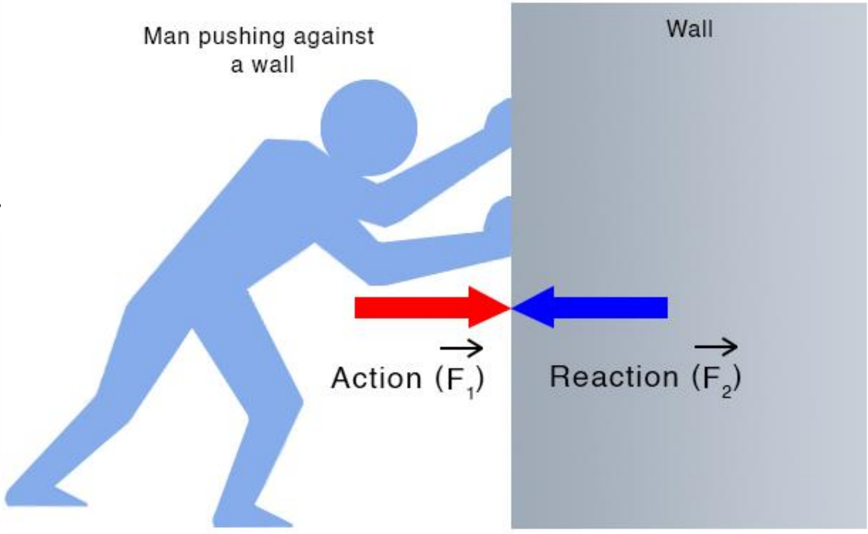
The sum of the external forces (the resultant force) applied to an object is null.

$$\sum \vec{F}_{ext} = \vec{0}$$



Newton's Third Law

Newton's third law: If body A exerts on body B a force $\vec{F}_{A/B}$, then B exerts on A by a force $\vec{F}_{B/A}$.



These two forces are equal in magnitude and opposite in direction.

$$\vec{F}_{A/B} = -\vec{F}_{B/A}$$

magnitude: ➡ $F_{A/B} = F_{B/A}$

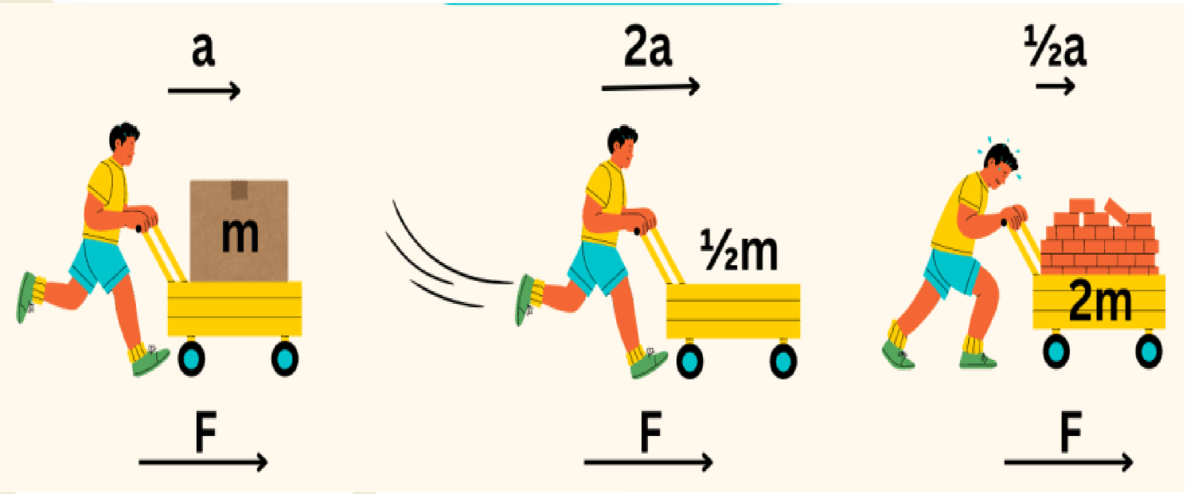
In other words, for every action there is an equal and opposite reaction.

Newton's Second Law (fundamental principle of dynamics)

The acceleration of a system is directly proportional , and in the same direction as the net external force acting on the system, and inversely proportional to its mass.

The sum of the external forces (the resultant force) applied to an object is null.

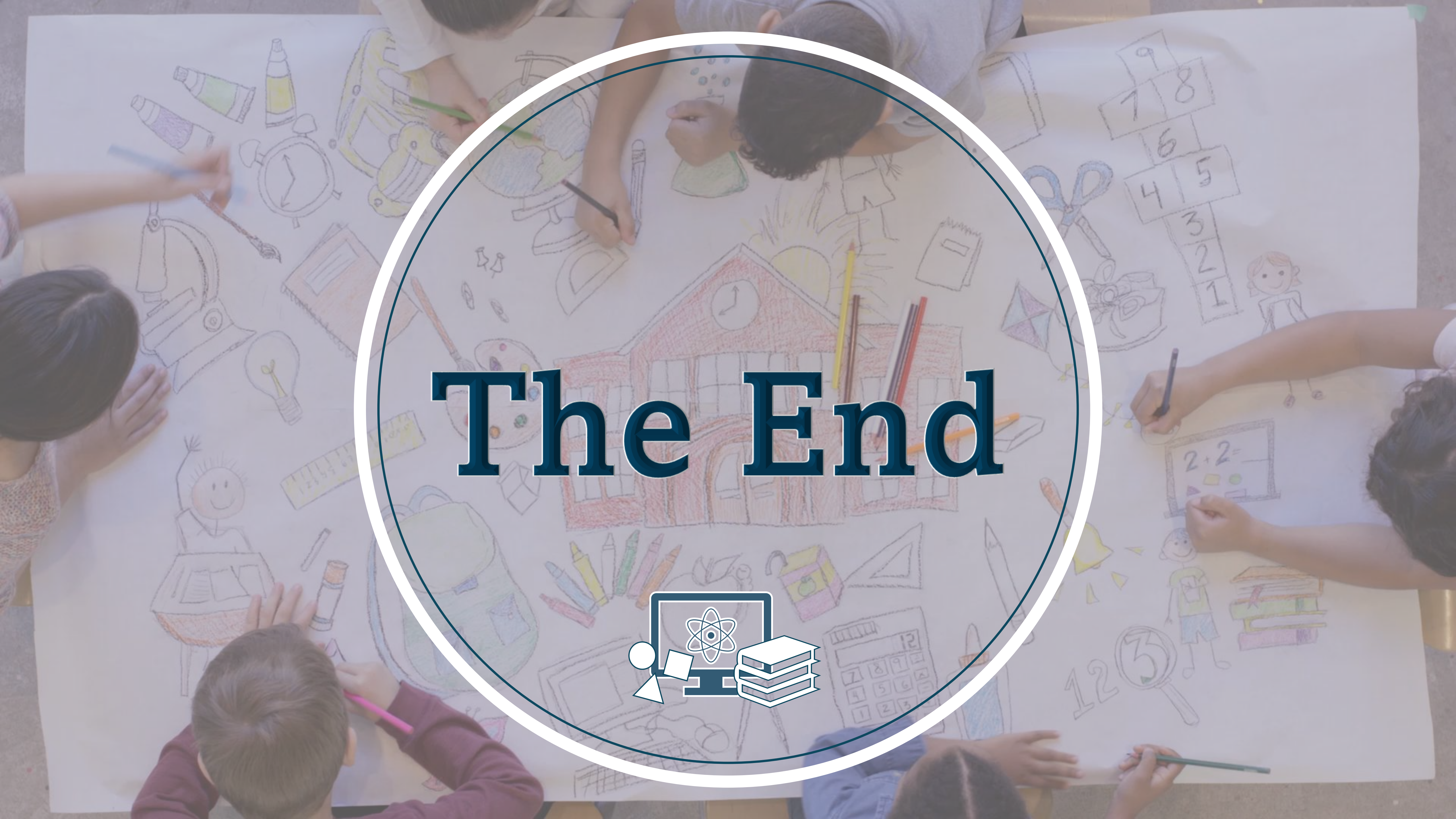
$$\sum \vec{F}_{ext} = m\vec{a}$$



As the mass of the body increases, the acceleration of the body decreases.

Strategy of problem solving

1. Specify all the forces acting on the body.
2. Represent the forces applied on the object (free body diagram).
3. Apply newton’s second law to determine the unknown.
4. Do a projection of the forces along the direction of motion.
5. Specify the type of motion.
6. Apply the equation of motion related to the type of motion to determine anther unknown.



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