# PHYSICS

# Newton's Law of Motion

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# Chapter Description

- **Aims**
  - Students need to know how to explain, apply and solve the problems regarding the Newton's Law.
- **Expected Outcomes**
  1) Able to describe Newton's law of motion.
  2) Able to solve problems related Newton's law of motion.
  3) Able to draw forces acting on free body diagram.
  4) Apply the Newton's law in horizontal motion, vertical motion and motion along a slope.
- **References**

  - Cutnell, J. D. and Johnson, K. W., 2010. Physics, 8th edition, Wiley, Asia.
  - Young, H. D. and Freedman, R. A., 2006. University Physics with Modern Physics. 12th edition, Pearson, San Francisco.
  - Giancoli, D. C., 2009. Physics for scientists and engineers: with modern Physics. Pearson Prentice Hall, United States of America.
  - Halliday, D. and Resnick, R., 2008. Fundamentals of Physics Extended, 8th edition. Wiley International Student Edition, Asia.

# Content

3.1 Newton's First Law and Inertia

3.2 Newton's Second Law

3.3 Newton's Third Law

3.4 Forces of Friction

# Force

- Is an action whether you pull or push.
- In other words, it can be interaction to change the motion of an object; from rest to move or from moving to rest.
- To accelerate an object, a force is always required.
- Force is a vector quantity (have a magnitude and direction).

# Newton's First Law

- States that " An object at rest stays at rest and object in motion stays in motion with the same speed and in the same direction unless there are some external force acted on it.
- This law is also can called as the Law of Inertia.
- Inertia: the tendency of an object to maintain it state of rest or of uniform velocity in a straight line

# Example 1

- A LRT train comes to a sudden stop at one station, and all of the travel bags on the floor start to slide forward. What force causes it happen?
- Answer:-

  It is not a force, this happen because an inertia. The travel bags tend to maintain its initial condition.

# Example 2

- Determine the force is needed to maintain a plastic ball rolling on a frictionless floor with a constant velocity.
- Answer:-

It doesn't need any force to maintain its initial condition because the object in motion will stays in motion.

# Newton's Second Law

- If a net force is applied on the object, what happen?

  - the velocity of the object will change either increase or decrease depends on its situation.

- It's mean that a net force causes an acceleration
- But, what is precisely relationship between force and acceleration?

# Newton's Second Law

- Newton 2nd law of motion states that the acceleration is directly proportional to force and inversely proportional to mass

$$a \propto F \qquad a \propto \frac{1}{m}$$

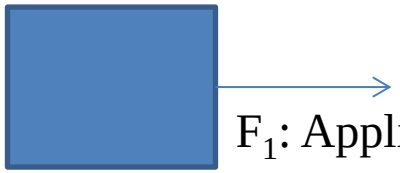
- Hence,

$$F = ma$$

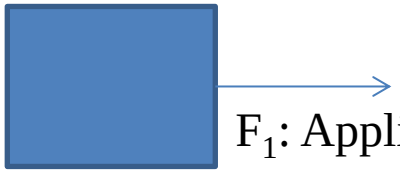
- SI unit :- Newton (N)

# Example 3

- A 10 kg horse replica is placed on a table. A horizontal force of 32 N is applied to the replica. Calculate the acceleration of the replica.



$F_1$: Applied force (32N)



$F_1$: Applied force (32N)

$$F = ma$$

$$32\,\text{N} = (10\ \text{kg})(a)$$

$$a = 3.2\,\text{ms}^{-2}$$

# Newton's Third Law

- The effect of forces on motion has been described in Newton's Second Law.
- Newton realized that things are not so- one-sided.
- Because, according to Newton's second law, net force act on object at rest or move at constant velocity are zero. So, there must be another force on the object to balance it

# Newton's Third Law

- Newton Third law of motion states that for every action, there is an equal and opposite reaction.


A boss sit down on the chair, there are two forces acting

- a force on the chair due to gravitational pull
- a force on your body due to reaction force on the chair

# Free Body Diagram

- Also call a force diagram
- Use to analyze the force acting on a body
- It is a simplified sketch of a complicated system
- The possible forces that could be acting such as push or pull, normal force, friction force, weight, and buoyant force.

# Free Body Diagram Concept

- THINGS to be considered:

1) The **TENSION** of a cord:

   - ALL direction of tension force must be **AWAY** from the subject (focus) of FBD.

2) The **SPRING** force:

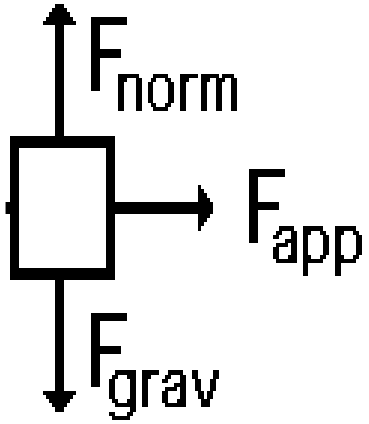
   - ALL direction of spring force must be **AWAY** from the subject (focus) of FBD.

# Free Body Diagram

- PROCEDURE:
  1) Draw an outlined shape: **simple sketch** of the object
  2) Show ALL forces: **sketch all forces** available on the object (FBD)
  3) Identify each force: **label each force** with magnitude and direction & use letters to represent the UNKNOWN magnitudes and direction
  4) Resolve force: **resolve all forces** into its components (x-component & y-component)
  5) **Solve** the unknown: apply Newton 2nd Law

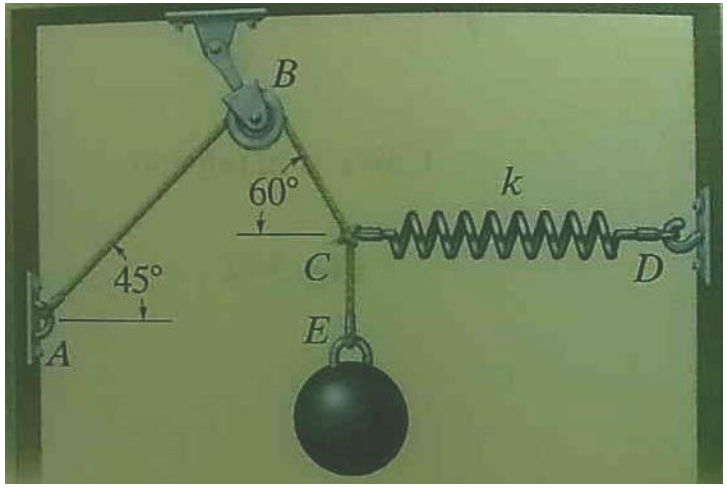
# Example 4

- Raju pull the box of chocolate to the right in order to move it across a floor (frictionless). Draw the FBD for this situation.



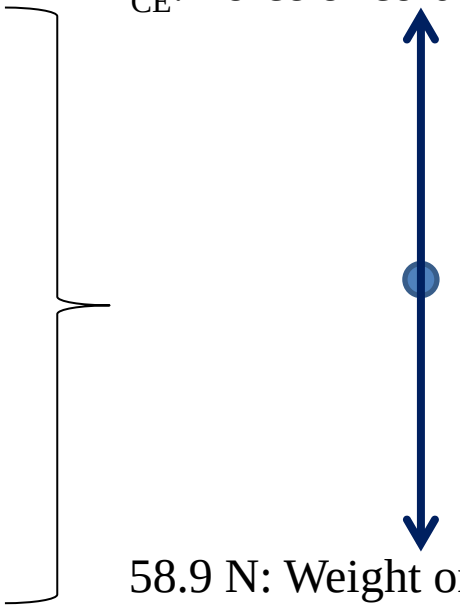
# Example 5

- Consider a system as shown in figure below. Draw the FBD of the sphere.



- REMEMBER the FBD procedures?
- Simplify the system & Include all forces.

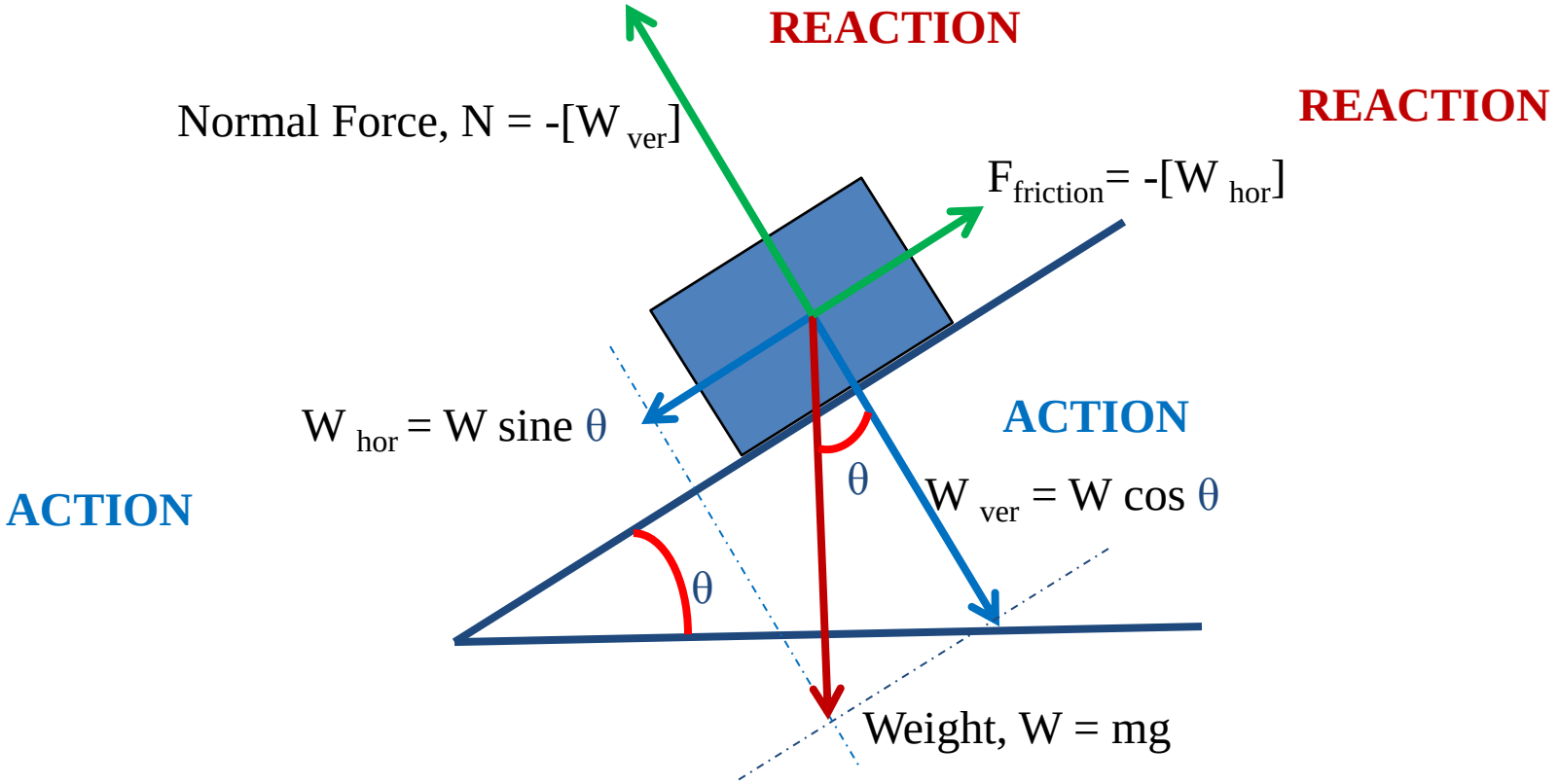
$F_{CE}$: Force of cord CE acting on sphere



58.9 N: Weight or gravity force acting on sphere

# Example 6

- A lorry is moving down the hill at constant acceleration. Draw the FBD for this situation.



# Example 7

- A parcel with a mass of 10 kg is resting on the frictionless floor. Determine

(a) the weight of the box and the normal force exerted on it by the floor.

(b) the normal force exerted on the parcel by the floor if you pushes down on the parcel with a force of 40 N.

(c) the normal force exerted on the parcel by the floor if you pulls upward on the parcel with a force of 40 N.

# (a) Weight and Normal force:

Weight:

$$w = mg = (10\ \text{kg})(9.8\ \text{m/s}^2) = 98\ \text{N}$$

Normal force:

$\Sigma F_y = ma_y$ The box is at rest $a_y = 0$

$F_N - mg = 0$ $\therefore F_N = mg = 98\ \text{N}$

# (b)Normal force:

Normal force:

$\Sigma F_y = ma_y$ The box is at rest $a_y = 0$

$F_N - F_P - mg = 0 \quad \therefore F_N = mg + F_P = 98\ \text{N} + 40\ \text{N} = 138\ \text{N}$

(c) Normal force:

Normal force:

$\Sigma F_y = ma_y$ The box is at rest $a_y = 0$

$F_N + F_P - mg = 0$ $\therefore F_N = mg - F_P = 98\ \text{N} - 40\ \text{N} = 58\ \text{N}$

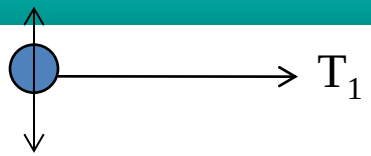
# Example 8

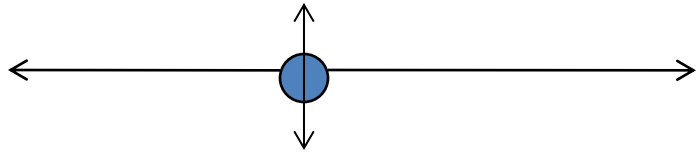
- 2 blocks, each of mass $m_1$ & $m_2$ are connected by a light string and pulled towards to the right. Assume they lie on a smooth, horizontal surface. Given $m_1$= 3.5kg, $m_2$ = 2kg and the acceleration of the system is 2m/s$^2$.

  (a) Draw a free body diagram for each block.

  (b) Write the force equation for each block.

  (c) Calculate the tension in each string.

(a) For $m_1$:  $T_1$

For $m_2$: $T_1$  $T_2$

(b) Force equation on $m_1$:

$F_x = m_1 a$

$T_1 = m_1 a$

Force equation on $m_2$:

$F_x = m_2 a$

$T_2 - T_1 = m_2 a$

(c) Calculate the tension in each string:

Find $T_1$, from:

$T_1 = m_1 a$

$= (3.5\ kg)\ (2 m/s^2)$

$= \underline{\mathbf{7\ N}}$

Find $T_2$, from:

$T_2 - T1 = m_2 a$

$T_2 - 7N = (2kg)\ (2m/s^2)$

$T_2 = \underline{\mathbf{11N}}$

# Forces of Friction

- Is a force resisting the relative motion of solid surfaces, fluid layers, or material elements in contact
- Friction force will exist when two solid surface in contact
- Friction force is always against the object movement.

# Types of Friction

- ***Dry friction*** is a force between two solid surfaces in contact Dry friction is also subdivided into:
  1) ***static friction*** between non-moving surfaces
  2) ***kinetic friction*** between moving surfaces

- ***Lubricated friction***
- ***Fluid friction***
- ***Skin friction***
- ***Internal friction***

# Static Friction

- Is the friction between the static object and surface where you try to move the object but the object remain at rest.
- The static frictional force is given by

$$f_s = \mu_s F_N$$

# Kinetic Friction

- Is the friction between the static object and surface where the static frictional force is not concern and the object start to slide
- The static frictional force is given by

$$f_k = \mu_k F_N$$

# Kinetic Friction

- Once two surfaces begin sliding over one another, the statics frictional force is no longer any concern, instead a type of friction known as **kinetic friction** is produced.
- The magnitude $f_k$ of the kinetic frictional force is given by

$$f_k = \mu_k F_N$$

Where; $\mu_k$ is the coefficient of kinetic friction,
$F_N$ is the magnitude of the normal force

| Material | Coefficient of Statics Friction, $\mu_s$ | Coefficient of Kinetic Friction, $\mu_f$ |
|---|---|---|
| Glass on glass (dry) | 0.94 | 0.4 |
| Ice on ice (clean, 0°C | 0.1 | 0.02 |
| Rubber on dry concrete | 1.0 | 0.8 |
| Rubber on wet concrete | 0.7 | 0.5 |
| Steel on steel (dry hard steel) | 0.78 | 0.42 |
| Steel on ice | 0.1 | 0.05 |

# Example 9

- A 10 kg box is placed on a table. A horizontal force of 32 N is applied to the box. A frictional force of 7 N is present between the surface and the box. Calculate the acceleration of the box.

Weight:

$$w = mg = (10\ \text{kg})(9.8\ \text{m/s}^2) = 98\ \text{N}$$





($2.5\ \text{m/s}^2$)

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# END