23	october 2022 Week 3	Chapter 4

4-1 Force:-

Mechanics: The study of the motion of objects. Force and energy are related concepts from this field. which is divided into two parts:

1. Kinematics: The description of how objects move. (without taking the cause into account.)
   ↓ (v, a, x, NOT Force)
2. Dynamics: Deals with Force and why objects move as they do (we take the cause into account.)

* In this chapter we will discuss Dynamics.

Force: Any kind of a push or a pull on an object. which is divided into two parts:

1. Contact Forces: The force is exerted when one object concanct with another.
2. Non-Contact Forces: Such as a falling object because of the force of gravity (g).

4-2 Newton's First Law of Motion:-

"Every object continues in its state of rest, or of uniform velocity in a straight line, as long as no net force acts on it."

It's sometimes called (The law of Inertia)

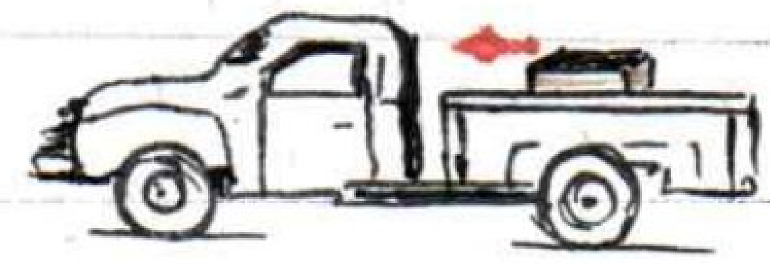
* Inertia: The tendency of an object to maintain its state of rest or of uniform velocity in a straight line.

* A net of force changes the object state's of motion from:-

Rest ⇄ Motion, accelerate ⇄ decelerate

Example (1)

A truck is moving to the left. Suddenly, the driver applies the brakes and it stops, what will happen to the box?

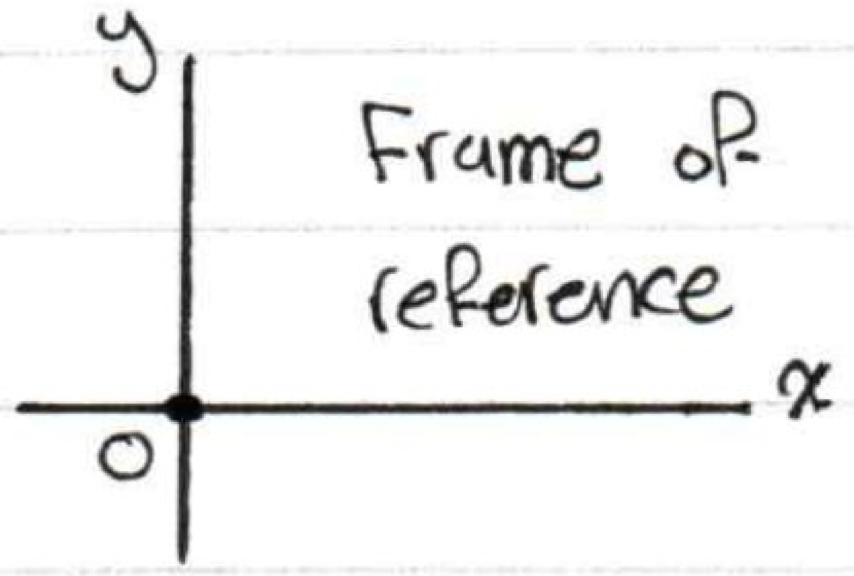


Sol. The truck stopped because a net of force acted on it, so it changed its state of motion (to a rest). But it didn't act on the box, so the box will complete its motion to the left. **The box needs a net force to to act on it to stop it or reduce its velocity.**

* Inertial Reference Frames

Newton's first law doesn't hold in every reference frame, in order to hold in a frame it must NOT accelerate : either at rest or moving at constant $\vec{v}$ in a straight line.

* Accelerating reference frames are called "noninertial".



* If you are in a car that is accelerating or decelerating, then it's a noninertial frame of reference. Newton's laws will give wrong answers (they don't hold).

4-3 Mass:-

It is a measure of the inertia of an object.

* The more mass an object has
↓
the greater the force needed to give (a).

* As we discussed in chapter 1-5 the unit of mass is the **Kilogram**.

Mass (measure of resistance of motion)	Weight (Gravitational force on an object)
- Scalar	- Vector [Force]
- Does Not change with location.	- Depends on location - $g_{moon} = \frac{1}{6}(g_{earth})$

4-4 Newton's Second Law of Motion :-

What happens if a net Force is exerted on an object ?

" The acceleration of an object is directly proportional to the net Force acting on it, and is inversely proportional to the object's mass. The direction of the acceleration is in the direction of the net Force acting on it."

This is Newton's second law of motion. ***

$$* \sum \vec{F} = \vec{a} \cdot m *$$

$$\vec{a} = \frac{1}{m} \cdot \sum \vec{F}$$

(g) is always vertically downwards parallel ($\sum \vec{F}$) (For free fall)

This vector equation valid in any inertial reference frame, so it can be written in component form in rectangular coordinates as :-

$\sum F_x = ma_x$, $\sum F_y = ma_y$, $\sum F_z = ma_z$

Example (1)

Find the net force required to give :-

a) a 1000 Kg car acceleration at $\frac{1}{2}g$.

$\sum \vec{F} = m \cdot \vec{a}$, $\frac{1}{2}g = \frac{1}{2} \cdot (10) = 5 \ m/s^2$

$= (1000 \ Kg) \cdot (5 \ m/s^2) = 5000 \ N.$

b) a 200 g apple at the same rate.

$(200 g) \cdot 10^{-3} \frac{Kg}{g} = 0.2 \ Kg \Rightarrow \sum \vec{F} = (0.2 \ Kg) \cdot (5 \ m/s^2)$

$= 1 N.$

4-5 Newton's Third Law of Motion :-

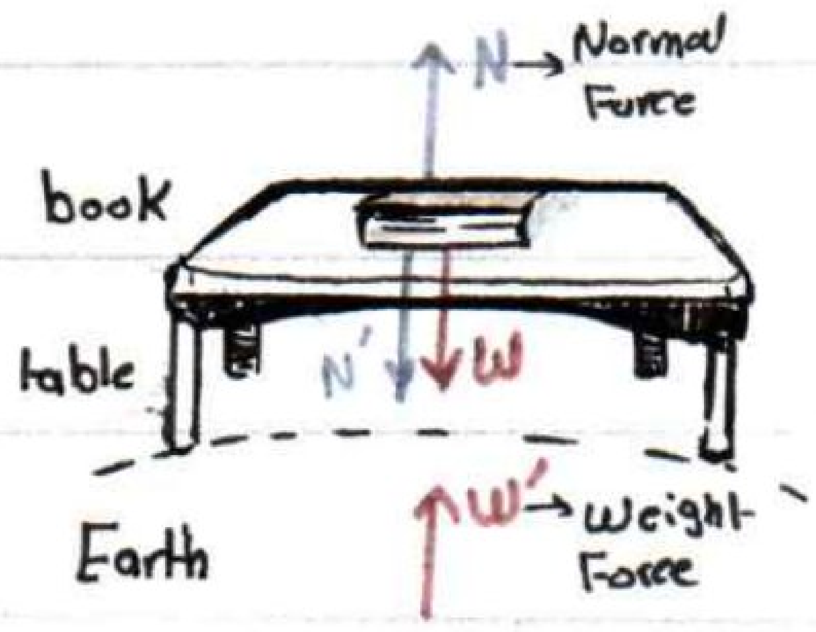
Newton's second law, like the first law, is valid only in inertial reference frames, in noninertial reference frame of a car that begins accelerating, even though the net force on it is zero. Thus $\sum \vec{F} = m\vec{a}$ DOES NOT work $\left[\sum \vec{F} = 0 \text{ but } \vec{a} \neq 0\right]$

That's why we should study Newton's 3rd law.

" Each action has a reaction equals to it in magnitude and opposite to it in direction."

Example (1)

Find the pairs of action reaction forces.



W : Force of Earth on book (Action).

W' : Force of book on Earth (Reaction).

$$W = -W'$$

*Note : Action and reaction are acting on different objects.

*Note : We can call the action → reaction
reaction → action

N : Force of table on book (Action).

N' : Force of book on table (Reaction).

$$N = -N'$$

4-6 Weight - Gravity and the Normal Force :-

1 Gravitational Force : It is the force which acts vertically downward, toward the center of the Earth.

* The magnitude of the force of gravity on an object (mg) is called **weight**.
* In SI units $g = 9.80\ m/s^2$ or $9.80\ N/Kg$
* When an object is at rest on the Earth, the gravitational force DOES NOT disappear.

Why then doesn't the object move ?

There must be another force on the object to balance the (g) force.

2 The Normal Force : The first example in section 4-5 shows how the table is compressed slightly beneath the object, due to its elasticity it pushes up on the object as shown.

(When a contact force acts perpendicular to the common surface of contact is called the Normal Force.)

*Note:- The 2 forces shown in ex. 1 section 4-5 are NOT the action and reaction forces of Newton's third law because they act on the same object, [1] N is not always equal to W, how? [2] →

4-7 Free-Body Diagrams :-

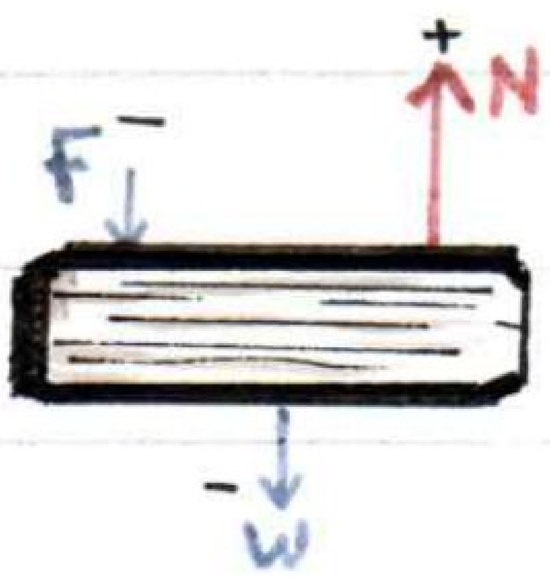
A diagram that shows all the external forces acting on an object

*Note:- Do NOT show forces the chosen object exerts on other objects.

*Note:- If your problem involves more than one object → separate each one in single diagram.

Example (1)

Consider ($\vec{F}$) a force that acts on the book

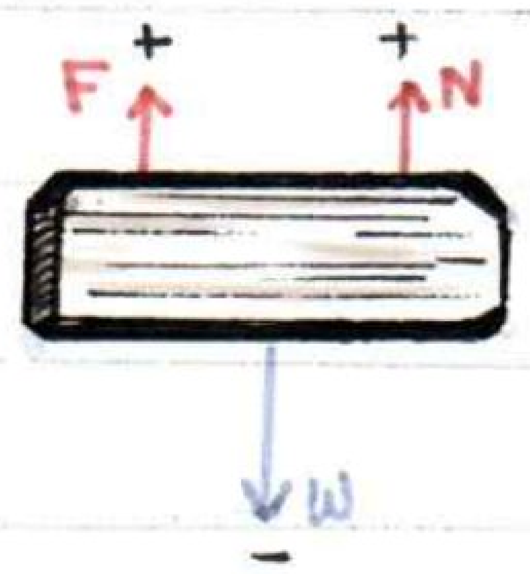


$N - F - W = 0$

$\therefore N = F + W \quad \Rightarrow \quad \Sigma F_y = ma_y = 0$

$\therefore N > W$

Example (2)



$N + F - W = 0$

$\therefore W = N + F$

$\therefore W > N \quad \Rightarrow \quad \Sigma F_y = ma_y = 0$

* Clearly N could be > W or > W or = W so N CanNOT be a reaction to W

*Note:- You can consider ↑ as y-negative direction and ↓ as y-positive direction and you will get the same answers. (at rest)

4-8 Solving Problems with Newton's Laws :-

Example (1)

An object of mass (m) is at rest and suspended by a string. Find the tension in the string.

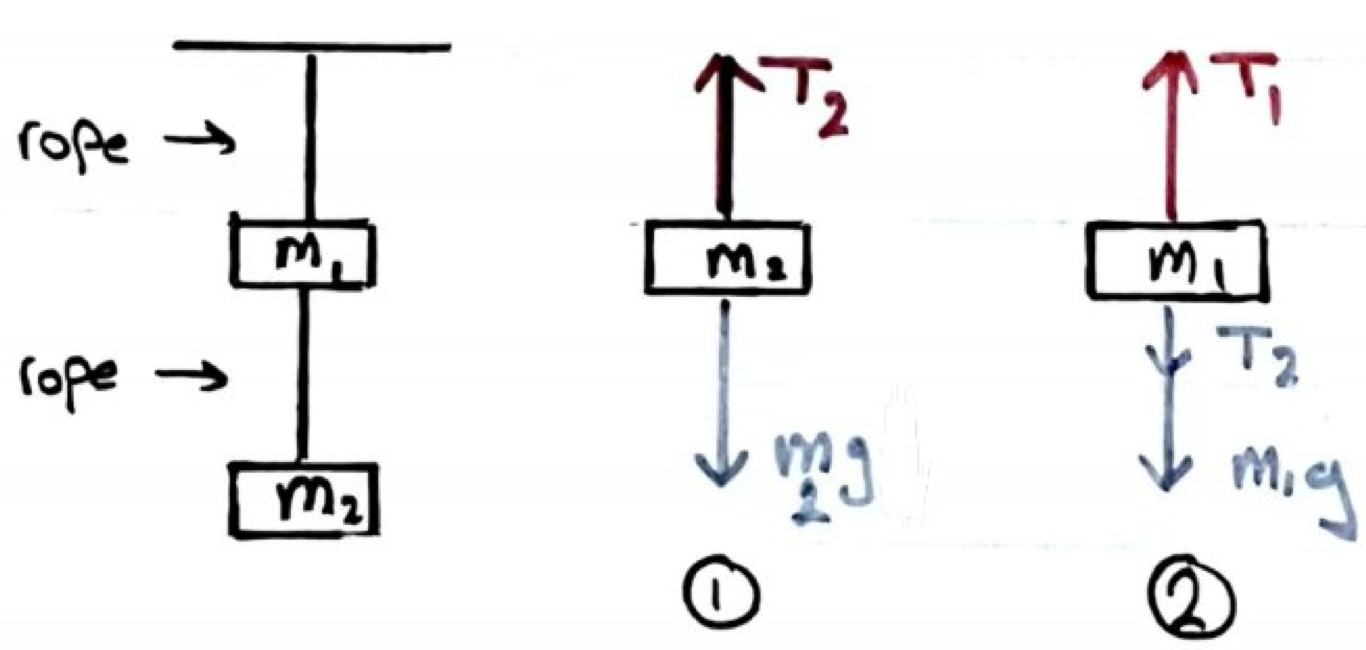
$\Sigma F_y = 0.$

$T - mg = 0 \Rightarrow T = mg.$

*Note:- Same as when object is moving up at a constant velocity.

Example (2)

The figure shows two masses m_1 and m_2 at rest and suspended by two strings. Find T_1 and T_2 in the two strings.



① $T_2 - m_2 g = 0 \Rightarrow T_2 = m_2 g \ldots (1)$

② $T_1 - T_2 - m_1 g = 0 \Rightarrow T_1 = T_2 + m_1 g \ldots (2)$

$T_1 = m_2 g + m_1 g$

$T_1 = g(m_2 + m_1)$

Example (3)

Consider the same example (1) but accelerating :-

(a) at $2 m/s^2$ upward.

$T - mg = ma_y \quad (a_y = 2 m/s^2 \uparrow)$

$T = mg + ma_y \Rightarrow T = m(g+2)$

(b) at $2 m/s^2$ downward.

$T - mg = ma_y \quad (a_y = -2 m/s^2 \downarrow)$

$T = mg + ma_y \Rightarrow T = m(g-2)$

* or *

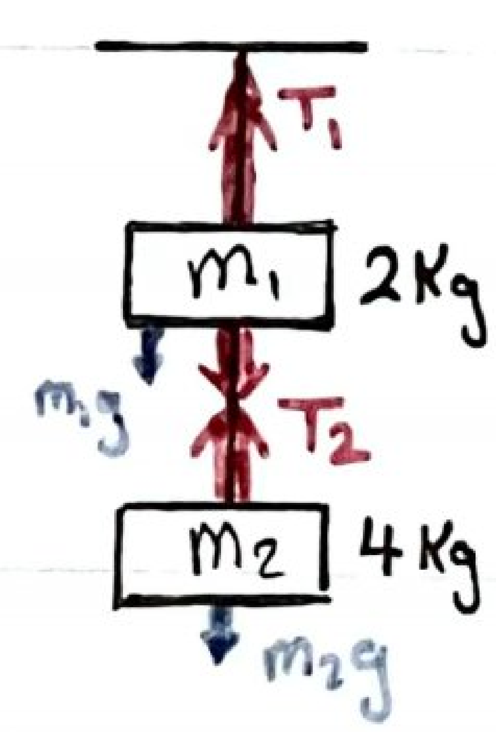
$mg - T = ma_y \quad (a_y = 2 m/s^2 \downarrow)$

$T = m(g - a_y) \Rightarrow T = m(g-2)$

*Note:- For a moving object take the direction of motion as positive.

Example (4)

Consider the same example (2) but accelerating at $2 m/s^2$ upward.



$\Sigma F_2 = m_2 a$

$T_2 - m_2 g = m_2 a$

$T_2 - (4)\cdot(10) = (4)(2)$

$T_2 = 48 N$, North ..①

$\Sigma F_1 = m_1 a$

$T_1 - m_1 g - T_2 = m_2 a$

$T_1 - (2)\cdot(10) - 48 = (2)\cdot(2)$

$T_1 = 72 N$, North