

# Chapter 5

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## The laws of motion

# The Laws of Motion

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Kinematic: the description of an object in motion included its position, velocity, and acceleration.

Dynamic: studies the causes of motion.

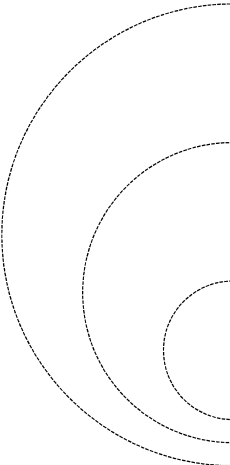
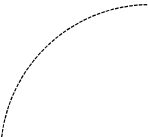

Two main factors need to be addressed to answer questions about why the motion of an object will change.

- Forces acting on the object
- The mass of the object

Will start with three basic laws of motion, formulated by sir Isaac Newton

## Force ( $\vec{F}$ )

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	<p>Forces are what cause an acceleration.</p>
	<p>Forces are vectors.</p>
	<p>SI units: Newton</p>

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## Classes of Forces

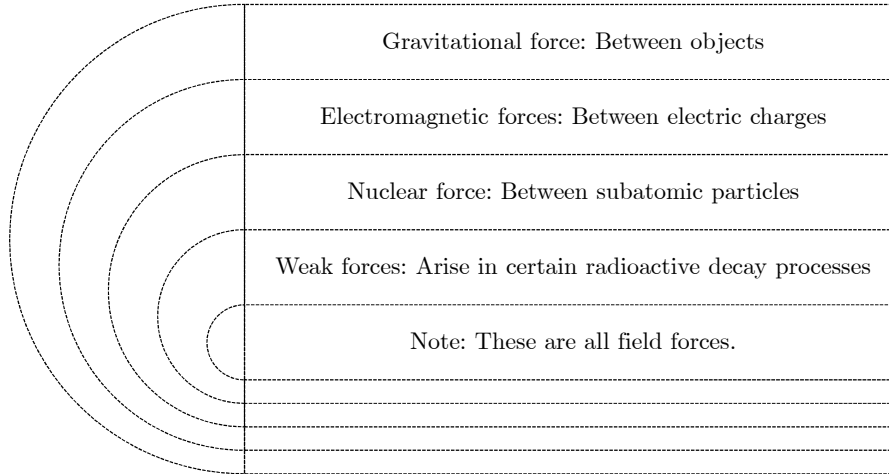
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<b>Contact forces</b>	<b>Field forces</b>
<ul style="list-style-type: none"> <li>• involve physical contact between two objects               <ul style="list-style-type: none"> <li>○ Pull or Push</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• act through empty space               <ul style="list-style-type: none"> <li>○ No physical contact is required</li> <li>○ The gravitational force</li> <li>○ The electric force</li> <li>○ The magnetic force</li> </ul> </li> </ul>

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## Fundamental Forces

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## Newton's First Law

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"In the absence of external forces, an object at rest remains at rest, and an object in motion remains in motion with constant velocity."

Mathematically:

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

Objects in equilibrium are:

- at rest and remains at rest,
- moving with constant velocity.

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## Newton's First Law

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Newton's First Law describes what happens in the absence of a force. Does not describe zero net force

Also tells us that when no force acts on an object, the acceleration of the object is zero

Can conclude that any isolated object is either at rest or moving at a constant velocity

The First Law also allows the definition of force.

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## Inertia and Mass

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Inertia: is the tendency of an object to resist any attempt to change its velocity.

Mass is the measure of inertia.

- Mass is a scalar quantity.
- Mass is a basic quantity.
- The SI unit of mass is kg.

Masses can be defined in terms of the accelerations produced by a given force acting on them:

$$\frac{m_1}{m_2} = \frac{a_2}{a_1}$$

The magnitude of the acceleration acting on an object is inversely proportional to its mass.

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## Mass vs. Weight

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Mass and weight are two different quantities.

Weight is equal to the magnitude of the gravitational force exerted on the object.

- Weight will vary with location.
- $W_{Earth} = 120\text{ N}$ ;  $W_{Moon} \cong 20\text{ N}$
- $m_{Earth} = 2\text{ kg}$ ;  $m_{Moon} = 2\text{ kg}$

## Newton's Second Law

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“The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.”

Mathematically,

$$\vec{a} = \frac{\Sigma \vec{F}}{m} \Leftrightarrow \Sigma \vec{F} = m\vec{a}$$

## Newton's Second Law

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$\Sigma \vec{F}$  is the net force

- This is the vector sum of all the forces acting on the object.
- May also be called the total force, resultant force.
- The SI unit of force is the Newton (N).
- $1 \text{ N} = 1 \text{ kg}\cdot\text{m}/\text{s}^2$

Newton's Second Law can be expressed in terms of components:

- $\Sigma F_x = ma_x$
- $\Sigma F_y = ma_y$
- $\Sigma F_z = ma_z$

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## Newton's Third Law

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“If two objects interact, the force  $\vec{F}_{12}$  exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force  $\vec{F}_{21}$  exerted by object 2 on object 1.”

Mathematically:

$$\vec{F}_{12} = -\vec{F}_{21}$$

- Note on notation:  $\vec{F}_{AB}$  is the force exerted *by* A *on* B.
- One of the forces is the action force, the other is the reaction force.
- It doesn't matter which is considered the action and which the reaction.

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## Action-Reaction

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The force  $\vec{F}_{12}$  exerted by charge 1 on charge 2 is equal in magnitude and opposite in direction to  $\vec{F}_{21}$  exerted by charge 2 on charge 1.

$$\vec{F}_{12} = -\vec{F}_{21}$$

The diagram illustrates two point charges,  $q_1$  and  $q_2$ , positioned vertically. Charge  $q_1$  is at the top and is marked with a '+' sign. Charge  $q_2$  is at the bottom and is marked with a '-' sign. A downward-pointing arrow labeled  $\vec{F}_{21}$  originates from  $q_1$  and points towards  $q_2$ . An upward-pointing arrow labeled  $\vec{F}_{12}$  originates from  $q_2$  and points towards  $q_1$ . The two arrows are of equal length and are collinear, pointing in opposite directions.

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## Action-Reaction

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The action and reaction forces are:

- of the same magnitude
- in opposite directions
- acting on different objects
- of the same type.

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## Some Particular Forces

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The Gravitational Force

The Normal Force

Forces of Tension

Forces of Friction

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## The Gravitational Force

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The gravitational force,  $\vec{F}_g$ , is the force that the earth exerts on an object.

This force is directed toward the center of the earth (downward).

From Newton's Second Law:

$$\vec{F}_g = m\vec{g}$$

Its magnitude is called the weight of the object.

- $Weight = |\vec{F}_g| = mg$
- SI units of weight is Newton
- Kilogram is not a unit of weight.

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## More About Weight

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Because it is dependent on  $g$ , the weight varies with location.

- $g$ , and therefore the weight, is less at higher altitudes.
- This can be extended to other planets.

Weight is not an inherent property of the object.

- The weight is a property of a *system* of items: the object and the Earth.

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## The Normal Force, $\vec{n}$

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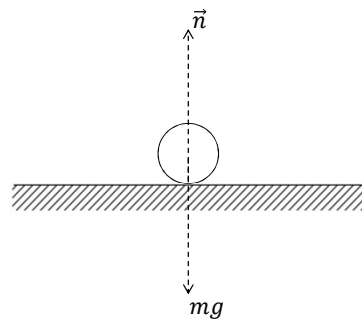
Whenever an object rests on a surface, the surface pushes on the object with a force called the normal force.

Normal means perpendicular.

The normal force is the force that prevents the object from falling through the surface.

It is always perpendicular to the surface.

It isn't always equals the weight.



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## Forces of Tension, $\vec{T}$

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When a rope is attached to a body and pulled, the rope is said to be in tension.

The rope's function is to transfer force between two bodies.

The tension in the rope is defined as the force that the rope exerts on the body.

