Newton's Laws of Motion

© Kari Eloranta

2015

Jyväskylän Lyseon lukio

November 30, 2015

2.2.4 Newton's First Law of Motion

Definition of Newton's First Law of Motion (Law of Inertia)

An object at rest remains at rest, and an object in motion continues to move at constant speed along a straight line, unless acted upon by an unbalanced force.

- For example, a ball rolls on a floor along a straight line very easily, because the resistive forces on the ball are so small.

Definition of inertial frame of reference

An inertial frame of reference is a reference frame in which Newton's First Law is valid.

- An inertial frame of reference cannot be in accelerated motion.

- The laws of physics are valid as such in inertial reference frames only.

- Question. Is the observer in the physics class room in an inertial frame of reference?

2.2.8 Newton's Second Law of Motion

- Usually, several external forces act on an object.

- As an example, consider a book on a table. The gravitational force $\vec{G}$ pulls the book towards the center of the Earth, and the normal force exerted by the table on the book $\vec{N}$ pushes the book up. Since the forces are equal in magnitude, but opposite in direction, they cancel each other out.

- The net force $\Sigma\vec{F}$ is the vector sum of the external forces acting on an object.

Definition of Newton's Second Law of Motion
The net force is equal to the mass of the object multiplied by its acceleration.

- Any force on the object is a result of an interaction between the object and its surroundings.

2.2.8 Newton's Second Law of Motion

Newton's Second Law as an Equation

The net force is
$$\Sigma \vec{F} = m\vec{a} \tag{1}$$
where m is the mass of the object, and $\vec{a}$ the acceleration of the object.

- For the calculation of the net force we first have to find all the forces acting on the object.

- First, we identify distant interactions. If the object is electrically neutral, the only distant interaction is gravitational interaction. The resulting force is the force of gravity.

- Second, we identify contact interactions. The examples of contact forces include normal force, friction, tension force and buoyant force.

2.2.14 Newton's Third Law of Motion

Definition of Newton's Third Law of Motion
When two bodies interact, they exert equal but opposite forces on one another.

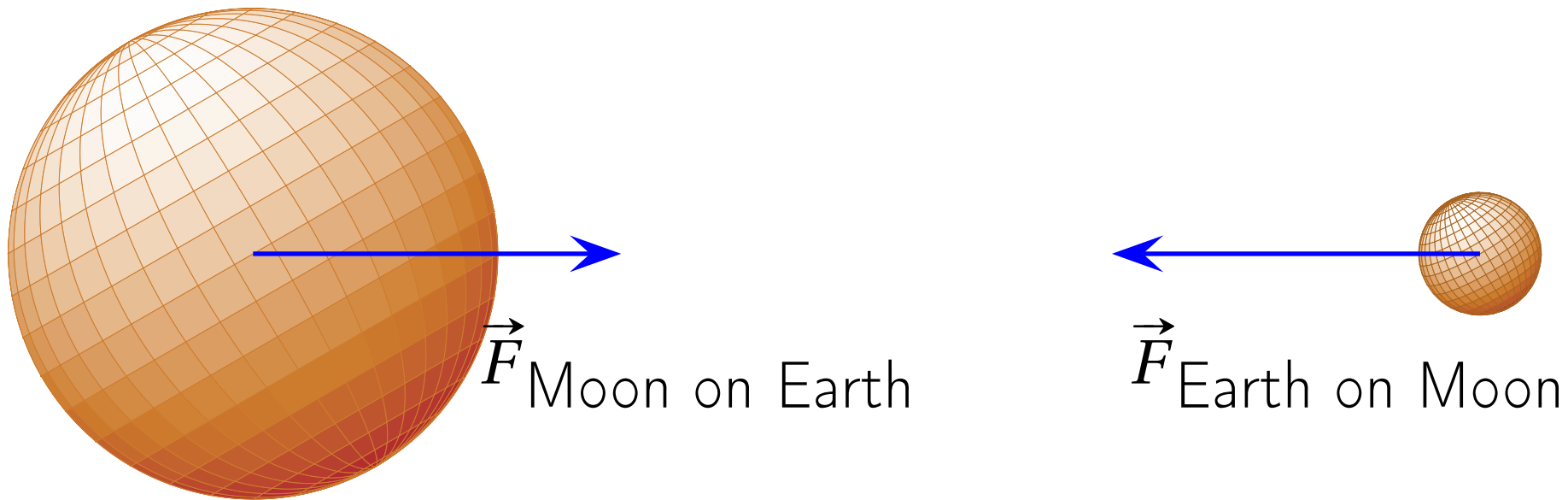$\vec{F}$Moon on Earth $\qquad$ $\vec{F}$Earth on Moon

Figure: According to Newton's Third Law of Motion the gravitational interaction between the Earth and Moon results in the equal but opposite forces on them.

2.2.14 Newton's Third Law of Motion

- Both objects feel the forces simultaneously: if the force on the first object changes, the force on the second object changes exactly at the same moment.

- Force applied to the first object is always applied by the second object and vice versa.

- The force and reaction force act on different objects. Thus, they cannot each other out.

- The force and reaction force are caused by the same interaction. For example, the weight of a book is caused by the gravitational interaction between the book and the Earth. The normal force on the book is caused by the contact interaction between the book and table. As a result, normal force cannot be the reaction force to the weight.

2.2.10 Introduction to Linear Momentum

- When two bodies interact with each other they exert equal but opposite forces on one another according to Newton's Third Law of Motion.

- As an example, consider two carts A and B (masses m_A and m_B) on a cart track connected to each other by a spring. When the carts are pushed together, the spring exerts equal and opposite forces on the carts.
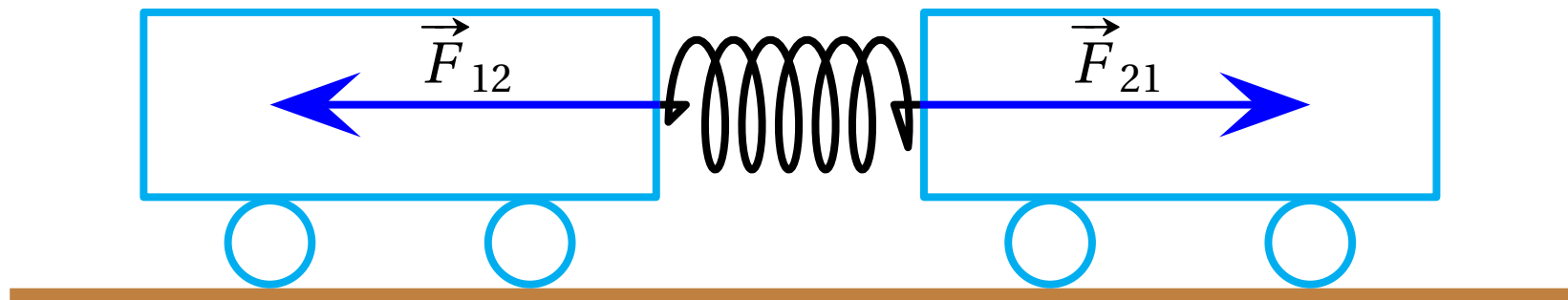

Figure: As the spring is compressed, it exerts a force on each cart. The force exerted by the spring on cart 1, $\vec{F}_{12}$, is equal in magnitude to the force exerted by the spring on cart 2, $\vec{F}_{21}$.