Phys 111: Lecture 6

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Homework Wk #3 Due Today 9/12/19

Exam #1 Tuesday 9/24/19

Today's Topics

1. Forces
2. Force Laws
3. Types of Forces

Force: A force is any push or pull acted upon one object by a second object that will cause a change in motion in the second object unless countered by an other force.

- Forces are vector quantities as direction matters.
- Forces are a cause and acceleration is the effect. (or balancing)
- Some forces don't require mechanical contact ("touch").
- SI unit: 1 newton $= 1\ N = 1\ kg \cdot m/s^2$

Inertia: Inertia is the natural tendency of an object to resist changes to its current motion. Mass is the quantitative measure of the inertia of an object.

- Mass is a measure of how much matter (stuff) an object is made of.
- Mass is a scalar quantity
- Objects with more mass require more force for the same acceleration.
- SI unit: 1 kilogram $= 1\ kg$

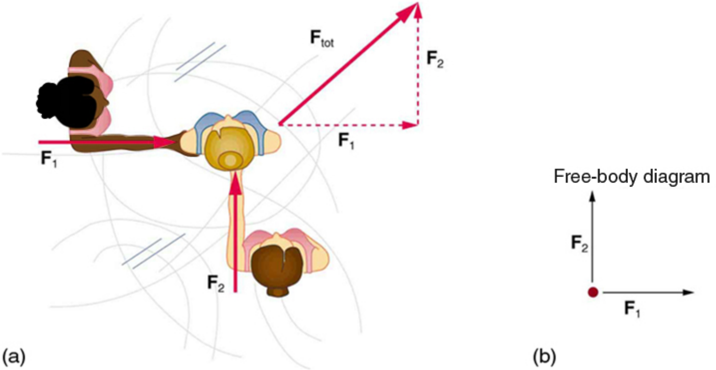

Figure: 5.6 Force Diagrams

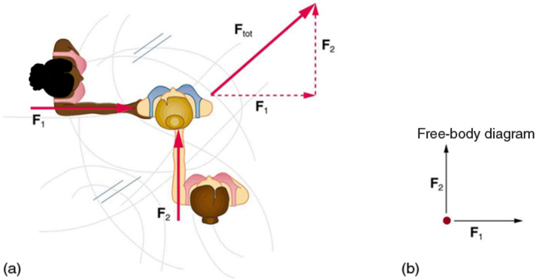

Figure: 5.6 Force Diagrams

- Note how the two forces applied to the third skater are added up as any two vectors would be.
- Note how simplified the free-body diagram is compared to a realistic sketch of the event.

Newton's 1st Law

An object continues in a state of rest or in a state of motion at a constant velocity (constant speed in a constant direction), unless compelled to change that state by a net force.

In other words, the motion of an object won't change without a force to cause the change.

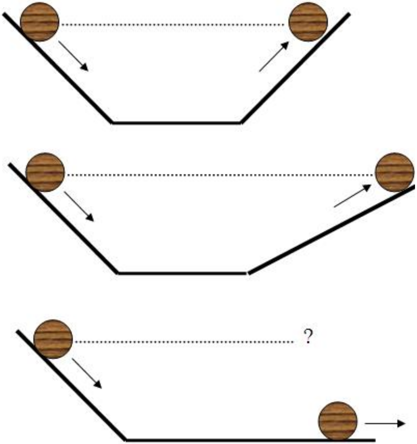

Figure: 6.1 Galileo's thought experiment for law of inertia

Newton's 2^{nd} Law In Words

If you observe the velocity of an object changing, then there is a net force causing that acceleration. Conversely, if the velocity of an object is not changing, then there are either no forces or completely balanced forces acting on said object.

Math

$$\sum_i \mathbf{F}_i = m\mathbf{a}$$

$$\mathbf{a} = \frac{1}{m}\sum_i \mathbf{F}_i$$

Concept Check #1

C&J FOC 4.2.1 An object is moving at a constant velocity. All but one of the following statements could be true. Which one cannot be true?

a. No forces act on the object.

b. A single force acts on the object.

c. Two forces act simultaneously on the object.

d. Three forces act simultaneously on the object.

C&J 4.3.3 Two horizontal forces, $\mathbf{F}_1$ and $\mathbf{F}_2$, are acting on a box, but only $\mathbf{F}_1$ is shown in the drawing. $\mathbf{F}_2$ can point either to the right or to the left. The box moves only along the x axis. There is no friction between the box and the surface. Suppose that $\mathbf{F}_1 = 9.0\ N$ and the mass of the box is $3.0\ kg$. Find the magnitude and direction of $\mathbf{F}_2$ when the acceleration of the box is

a. $+5.0\ m/s^2$

b. $-5.0\ m/s^2$

c. $0\ m/s^2$

C&J 4.3.3 Suppose that $\mathbf{F}_1 = 9.0\ N$ and the mass of the box is $3.0\ kg$. Find the magnitude and direction of $\mathbf{F}_2$ when the acceleration of the box is

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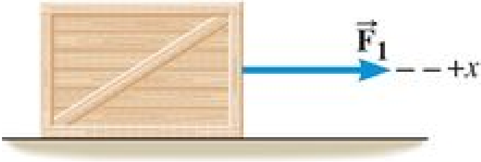

Figure: 6. Two, 1D forces on a block

"Use The Force Luke"

Newton's first law (and also the second law) can appear to be invalid to certain observers. These observers are said to be in a non-inertial reference frame.

Inertial Reference Frames A reference frame which is moving with constant velocity. A non-accelerating reference frame.

Non-inertial Reference Frames A reference frame that is accelerating.

"You'll find that many of the truths we cling to depend greatly on our own point of view" - Ben Kenobi

Newton's 3rd Law

"Semi-formal" An object can't interact with itself and so it won't feel a force until it can interact with a second object.

"Formal" Whenever one object exerts a force on a second object, the second object exerts an oppositely directed force of equal magnitude on the first object.

C&J 4.6.14 A billiard ball strikes and rebounds from the cushion of a pool table perpendicularly. The mass of the ball is $0.38\ kg$. The ball approaches the cushion with a velocity of $+2.1\ m/s$ and rebounds with a velocity of $-2.0\ m/s$. The ball remains in contact with the cushion for a time of $3.3 \times 10^{-3}\ s$. What is the average net force (magnitude and direction) exerted

a. on the ball by the cushion?

b. on the cushion by the ball?

Fundamental forces are the ones that are truly unique, in the sense that all other forces can be explained in terms of them.

To Date

- Gravitational - Non-chemical attraction of matter
- Strong Nuclear - Binds Nuclei of Atoms
- Electroweak - Electromagnetism; Chemical Effects

Gravitational Force

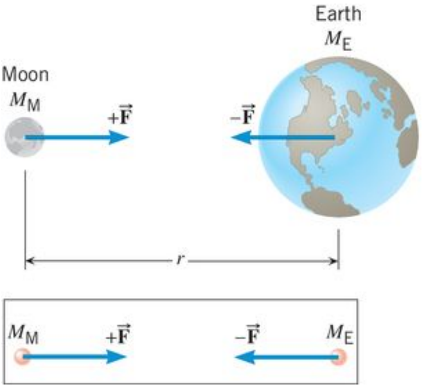

Figure: 6.2 Gravitational force between Earth and Moon

$$\mathbf{F}_G = G\frac{m_1 m_2}{r^2}\hat{\mathbf{r}}$$

Normal Force

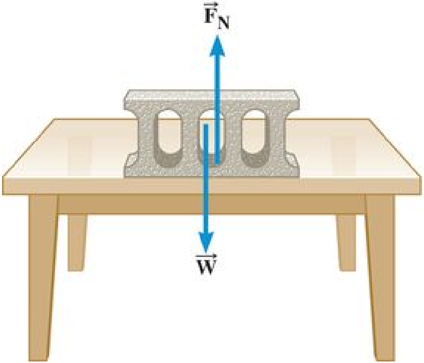

Figure: 6.3 Normal force on block from table

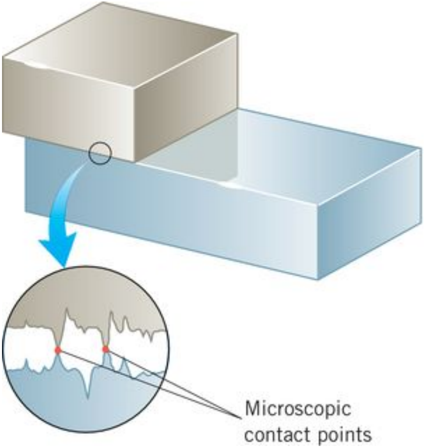

Figure: 6.4 Source of friction

Static Friction Force

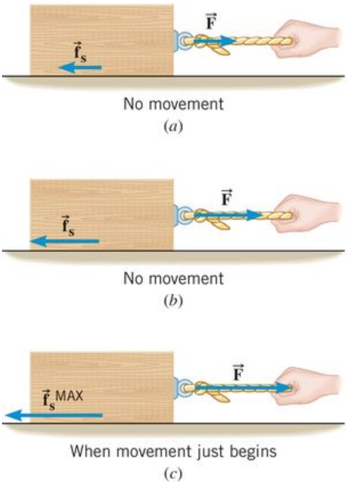

Figure: 6.5 Static friction keeps objects from moving

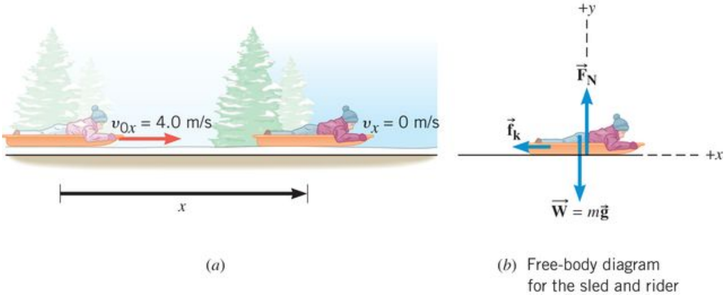

Figure: 6.6 Friction that slows down an object

Tension Force

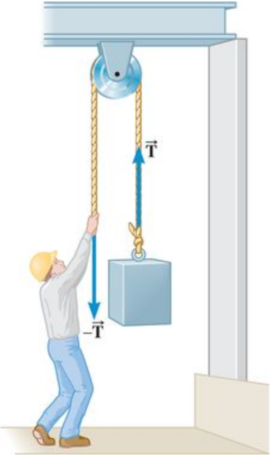

Figure: 6.7 Tension force in a simple machine

More Types of Forces

Non-exhaustive List

- Compression Forces
- Air Resistance (Drag)
- Centripetal Force
- Centrifugal Force
- Vibration Forces

1. **Changes in motion are caused by forces. No force, no change in velocity.**
2. **Net acceleration is directly caused by net force.**
3. **Forces arise from interactions. “It takes two to tango.”**

C&J 4.3.1 An airplane has a mass of $3.1 \times 10^4\ kg$ and takes off under the influence of a constant net force of $3.7 \times 10^4\ N$. What is the net force that acts on the plane's $78.0\ kg$ pilot?

C&J 4.4.12 At an instant when a soccer ball is in contact with the foot of a player kicking it, the horizontal or x component of the ball's acceleration is $810\ m/s^2$ and the vertical or y component of its acceleration is $1100\ m/s^2$. The ball's mass is $0.43\ kg$. What is the magnitude of the net force acting on the soccer ball at this instant?

C&J 4.4.11 Only two forces act on an object (mass $= 3.00\ kg$), as in the drawing. Find the magnitude and direction (relative to the x axis) of the acceleration of the object.

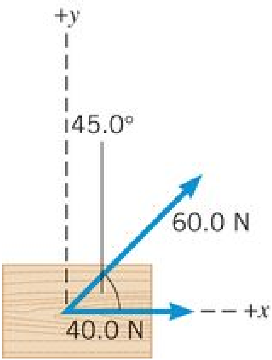

Figure: 6.8 2D forces on a block