# Chapter 4:

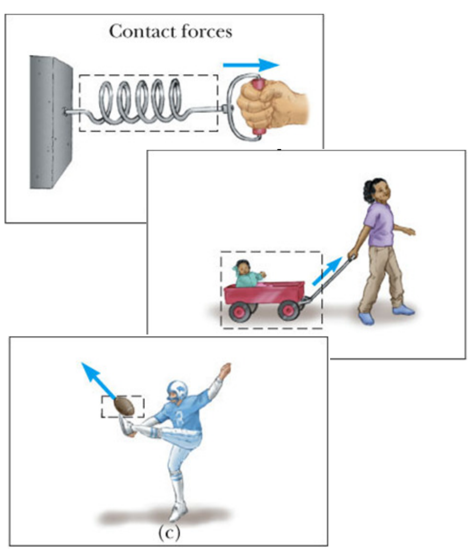
# The Laws of Motion

On the **MACROSCOPIC** and **SLOW** frame of reference.

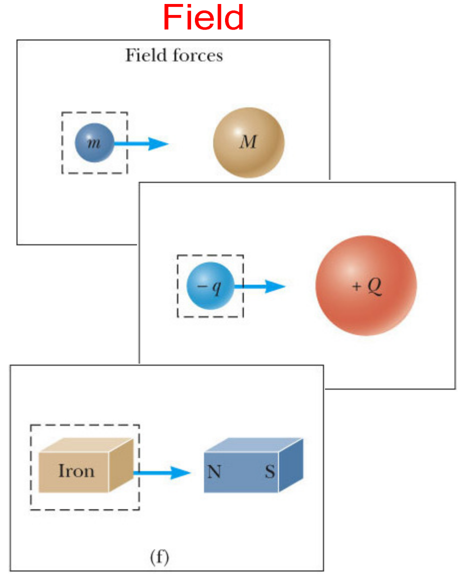
# Forces

A push or a pull on an object

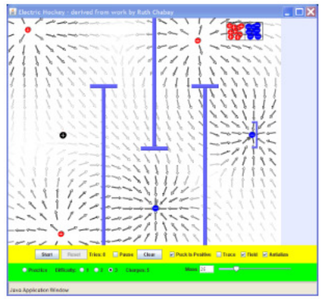
## Contact




## Field



# Field Forces



Pushing without anything to push

# Netwon's First Law

An object moves with a velocity that is constant in magnitude and direction unless acted on by a nonzero net force.

## Inertia

An object's tendency to continue its original state of motion.

## Mass

A **MEASURE** of the object's resistance to changes in its motion due to a force.

# Newton's Second Law

*Lex II: Mutationem motus proportionalem esse vi motrici impressae, et fieri secundum lineam rectam qua vis illa imprimitur.*

Law II: The alteration of motion is ever proportional to the motive force impress'd; and is made in the direction of the right line in which that force is impress'd.

# Newton's Second Law

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

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

# Newton's Second Law

More preferred way of looking at the equation

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

$$\Sigma\vec{F}_x=m\vec{a}_x \quad \Sigma\vec{F}_y=m\vec{a}_y$$

# Newton's Second Law

Unit

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

N

$kg\,\frac{m}{s^2} \rightarrow \frac{kgm}{s^2}$

Newton

Force nec.

# Gravitational Force

$F_g = mg$

$$F_g = G\frac{m_1 m_2}{r^2}$$

r ↑ Fg ↓
by square
multiple

$F_g = G\frac{m_E\, M_2}{r^2}$

$F_g = 6.67\times10^{-11}\frac{5.98\times10^{24}\,kg}{(6.38\times10^{6})^2}\, M_2$

$F_g = 9.80$

1 An object accelerates at 5 m/s². What would be the acceleration of the object if the force pushing it tripled and the mass was was cut in half?

A 7.50 m/s²
B 5.00 m/s²
C 30.0 m/s²
D 45.0 m/s²

$a = 5\ m/s^2$
because of F
$15\ m/s^2$
becase of m   m↓ F↑
$30\ m/s^2$

# True and False - Newton's Second

Grade: «grade»
Subject: «subject»
Date: «date»

Which of the following statements are true?

1. An object can move even when no force acts on it.
2. If an object isn't moving, no external forces act on it.
3. If a single force acts on an object, the object accelerates.
4. If an object accelerates, a force is acting on it.
5. If an object isn't accelerating, no external force is acting on it.
6. If the net force acting on an object is in the positive x-direction, the object moves only in the positive x-direction.

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1

True

False

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False

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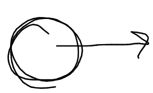

3

True

False

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True

False

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5

True

False

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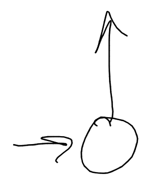
6

True

False



# Weight

Grade: «grade»

Subject: «subject»

Date: «date»

1 If gold were sold by weight, would you rather buy it in Denver or in Death Valley? If it were sold by mass, in which of the two locations would you prefer to buy it?

2 If it were sold by mass, in which of the two locations would you prefer to buy it?

A Denver
B Death Valley

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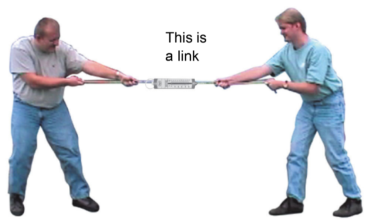
A Denver
B Death Valley

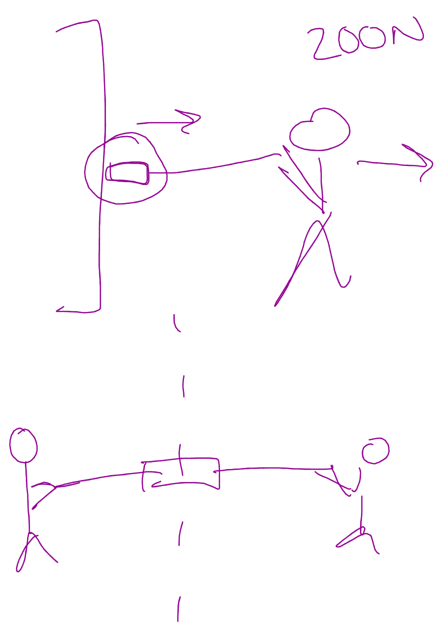
# Newton's Third Law

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




1 In a tug-of-war between two athletes, each pulls on the rope with a force of 200 N. What is the tension in the rope?

A 400 N
B 300 N
C 200 N
D 100 N



# Problem Solving

**PROBLEM-SOLVING STRATEGY**

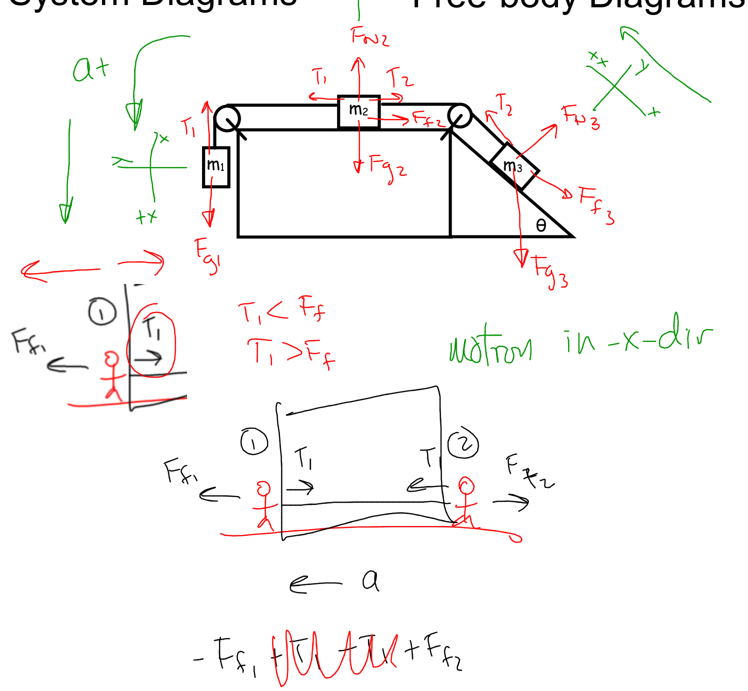
**NEWTON'S SECOND LAW**

Problems involving Newton's second law can be very complex. The following protocol breaks the solution process down into smaller, intermediate goals:

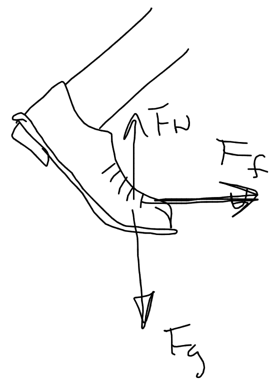
1. **Read** the problem carefully at least once.
2. **Draw** a picture of the system, identify the object of primary interest, and indicate forces with arrows.
3. **Label** each force in the picture in a way that will bring to mind what physical quantity the label stands for (e.g., *T* for tension).
4. **Draw** a free-body diagram of the object of interest, based on the labeled picture. If additional objects are involved, draw separate free-body diagrams for them. Choose convenient coordinates for each object.
5. **Apply Newton's second law**. The *x*- and *y*-components of Newton's second law should be taken from the vector equation and written individually. This usually results in two equations and two unknowns.
6. **Solve** for the desired unknown quantity, and substitute the numbers.

# Problem Solving

System Diagrams Free-body Diagrams



on object




by object