

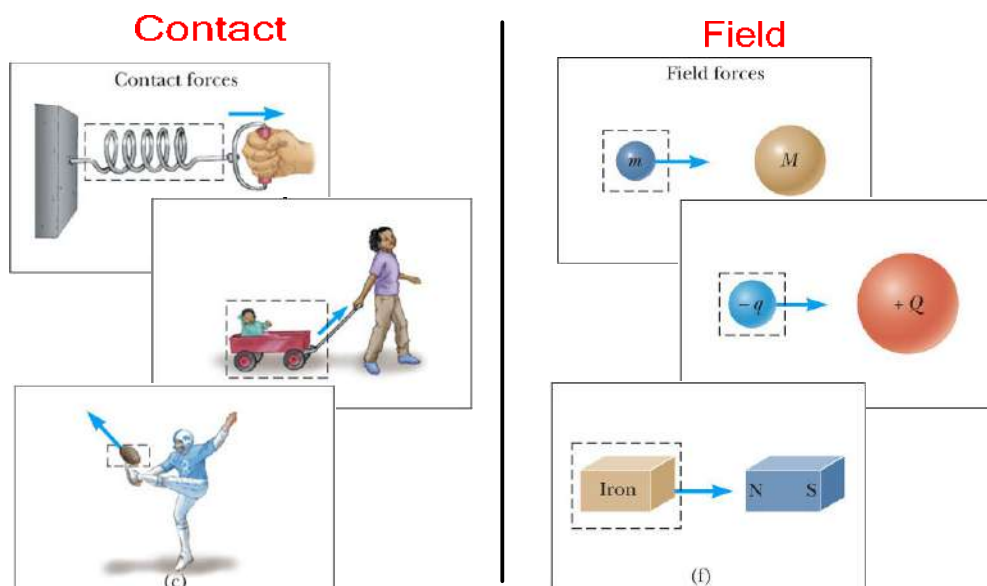
# Chapter 4:

## The Laws of Motion

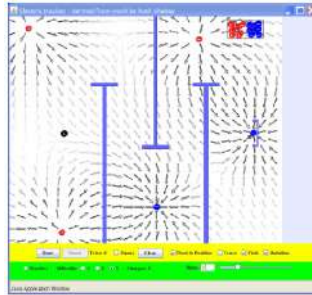
On the **MACROSCOPIC** and **SLOW** frame of reference.

### Forces

A push or a pull on an object



# Field Forces



Pushing without anything to push

## Newton'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.*

## Newton's Second Law

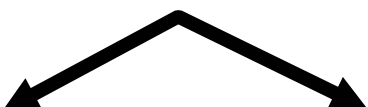


The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.

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

# 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

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

$$\text{kg} \frac{\text{m}}{\text{s}^2} = \boxed{\frac{\text{kg} \cdot \text{m}}{\text{s}^2}}$$

N

Newton  
Force nec.

# Gravitational Force

$$F_g = mg$$

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

$r \uparrow$   $F_g \downarrow$   
by square  
multiple

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

$$F_g = \frac{6.67 \times 10^{-11} \frac{5.98 \times 10^{24} \text{ kg}}{(6.38 \times 10^6)^2} M_2$$

$$F_g = 9.80$$

- 1 An object accelerates at  $5 \text{ m/s}^2$ . What would be the acceleration of the object if the force pushing it tripled and the mass was cut in half?

A  $7.50 \text{ m/s}^2$

B  $5.00 \text{ m/s}^2$

C  $30.0 \text{ m/s}^2$

D  $45.0 \text{ m/s}^2$

$a = 5 \text{ m/s}^2$   
because of  $F$

$15 \text{ m/s}^2$   
because of  $m$   $\downarrow$   $F \uparrow$

$30 \text{ m/s}^2$

# 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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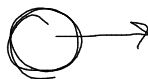
2

True

False

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3

True

False



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4

True

False

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5

True

False

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6. If the net force acting on an object is in the positive x-direction, the object moves only in the positive x-direction. *F*

6

True  
False



# Weight

Grade: «grade»

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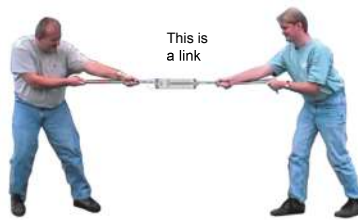
- 1 If gold were sold by weight, would you rather buy it in Denver or in Death Valley? If it were sold by mass, in which of the two locations would you prefer to buy it?
- 2 If it were sold by mass, in which of the two locations would you prefer to buy it?

A Denver  
B Death Valley

- 2 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?
- A Denver  
B Death Valley

# Newton's Third Law

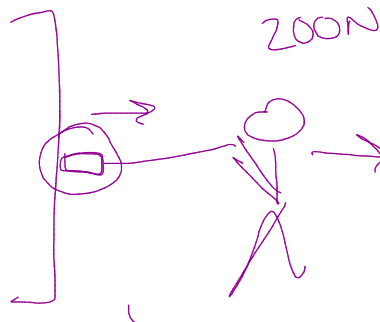
If object 1 and object 2 interact, the force  $\vec{F}_{12}$  exerted by **object 1** on **object 2** is equal in magnitude but opposite in direction to the force  $\vec{F}_{21}$  exerted by **object 2** to on **object 1**.



exerted  
acts on

- 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

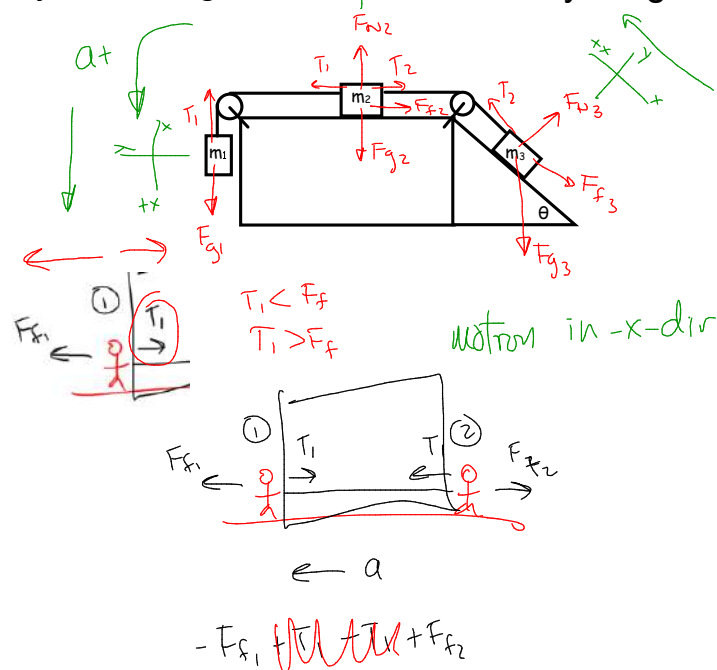
### NEWTON'S SECOND LAW

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

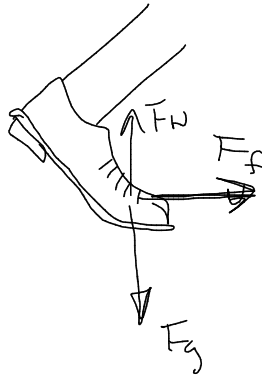
1. Read the problem carefully at least once.
2. Draw a picture of the system, identify the object of primary interest, and indicate forces with arrows.
3. Label each force in the picture in a way that will bring to mind what physical quantity the label stands for (e.g.,  $T$  for tension).
4. Draw a 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

