Basic Kinetic Concepts

• Inertia:
  – Natural property of a body to resist a change in state of motion (i.e., state of motion defined by velocity, \( \Delta \) state of motion = acceleration)

Newton’s 1st Law: Inertia

• A body will stay at rest...
• A body will continue to move with the same velocity unless...
• A net force acts on the body
  – e.g., to speed up or slow down an object’s motion, and/or to change an object’s direction of motion, and object’s inertia must be overcome.
Mass

- **Quantity of matter** of which a body is composed (a measure of “stuff”)
- Direct measure of a body’s resistance to change in *linear* motion
  - e.g., it is more difficult to change the motion of a large object (large mass) than a small object
  - large mass (e.g., shot) vs. small mass (e.g., tennis ball). Which requires more effort (i.e., force)?

Definitions

- **Force**:  
  - Effect of one body on another  
  - A push or a pull applied to an object  
  - That which is needed to change the state of motion (i.e., velocity) of an object
- **Acceleration**:  
  - Rate of change of *velocity* of an object with respect to time.  
    - Describes the change in state of motion of an object (i.e., $\Delta$ velocity)
Newton’s 2nd Law:
\[ \Sigma F = ma \]

\( \Sigma F = \text{“Net force”} = \text{Sum of all forces} \)

\( m = \text{mass (a measure of inertia)} \)

\( a = \text{linear acceleration} \)

**Example**

- What average net force must a baseball catcher apply to an 80 mph (35.8 m/s) pitch to stop it over a time of .025 s? (mass = 4.5 oz = 0.13 kg)
  
  – Know:
    
    \[ m = .13 \text{ kg}; \ t = 0.025 \text{ s}; \ v_i = 35.8 \text{ m/s}; \ v_f = 0 \text{ m/s} \]
  
  – Need:
    
    \( F \)
  
  – Use:
    
    \[ F = ma \quad \text{...but...we must find } a \text{ first and } a = (v_f - v_i)/t \]
  
  – Answer:
    
    \[ F = ma = 0.13 \text{ kg} \times (0 \text{ m/s} - 35.8 \text{ m/s})/0.025 \text{ s} = -186.2 \text{ N} \]
• Things to consider:
  – The meaning of a negative force
  – Average v. instantaneous force
  – The effect of \( \Delta t \) on \( F \)

• Important interpretations of the \( \Sigma F = ma \) relationship:
  – Cause (\( \Sigma F \)) and effect (\( a \)) relationship: the most important concept in this class!
    • \( a \) directly proportional to and in the same direction as \( \Sigma F \)
    • To produce a given \( a \), it takes a larger \( \Sigma F \) for a more massive object

Newton’s 3rd Law: Action/Reaction

• Action-reaction: describes how objects interact with one another.
  – If one body exerts a force on a second body, the second exerts back on the first a force of equal magnitude but opposite direction
  – example: Vertical jumping
    • “Action” force is applied by person (via muscles) and acts on ground.
    • “Reaction” force is applied by ground and acts on person.
Newton’s Law of Gravitation

• A fundamental physical principle that describes the concept of gravity...
• Any two particles of matter (any objects or bodies) attract one another with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them (i.e., distance between their centers).

\[ F = G \cdot \frac{(m_1 \cdot m_2)}{l^2} \]

G = gravitational constant = 6.7 x 10^{-11} N⋅m^2/kg^2
• Like it or not, there is a force of attraction between you and the person sitting next to you.
  – However, this force is so small that you don’t notice it.
  – When one of the objects is the earth (with its huge mass), the force of attraction (i.e. gravity) is very significant.

Example

\[ F = G \cdot \frac{(m_1 \cdot m_2)}{l^2} \]

• Two students sitting 1.5 m apart

\[ F = \left(6.7 \times 10^{-11} \text{ N} \cdot \text{m}^2 / \text{kg}^2\right) \cdot \frac{(70 \text{ kg})(50 \text{ kg})}{(1.5 \text{ m})^2} \]
\[ F = 10422 \times 10^{-11} \approx 1.04 \times 10^{-7} \text{ N} \]

• Attraction between earth and student

\[ F = \left(6.7 \times 10^{-11} \text{ N} \cdot \text{m}^2 / \text{kg}^2\right) \cdot \frac{(5.98 \times 10^{24} \text{ kg})(50 \text{ kg})}{(6.38 \times 10^6 \text{ m})^2} \]
\[ F = 4.92 \times 10^1 \approx 491 \text{ N} \]
Weight

- Question: Is earth’s gravitational attraction the same for all objects on or near the earth’s surface?
- Answer: NO...this force is dependent on the involved masses and the distance between the CM of the object and the CM of the earth.

Weight vs. Mass

- Are weight and mass the same thing? NO (Why or why not)
  - An objects weight represents the force of attraction between the earth and the object. Mass represents the quantity of matter or stuff of which a body is composed.
- Simplified relationship for the link between weight and mass on earth:
  \[ W = mg \]

where \[ g = G \cdot \frac{m_{earth}}{r^2} \]