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# Chapter 1: General Principles
## Main goals and learning objectives

- Introduce the basic ideas of *Mechanics*
- Give a concise statement of Newto~~w~~n's laws of motion and gravitation
- Review the principles for applying the SI system of units
- Examine standard procedures for performing numerical calculations
- Outline a general guide for solving problems

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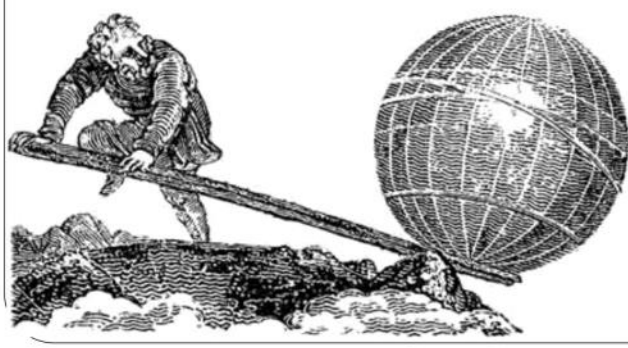
# What is "statics"?

- Science
  - Life
  - Physical
    - Astronomy
    - Physics
      - Relativity
      - Mechanics
      - Thermo
      - More!
    - Chemistry
    - More!
  - Social
  - More!

- Mechanics: Study of what happens to a "thing" when forces are applied to it



- The study of forces acting on bodies and their resulting motion, or lack of motion.

Statics: – bodies that are in static equilibrium

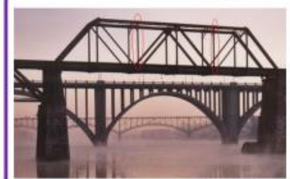
# Mechanics

Mechanics is a branch of the physical sciences that is concerned with the **state of rest or motion of bodies that are subjected to the action of forces**

Goal for engineers:

* Design objects that are intended to remain in static equilibrium

**Rigid Bodies**



Statics


Dynamics

TAM 212

**Deformable Bodies**

Solid Mechanics

TAM 251

**Fluids**

Compressible and incompressible

TAM 335

# Which forces?

victorstuff.com

www.ashvegas.com

- Mechanics: State of rest or motion of bodies subjected **to forces**

☆ Four fundamental forces:

1. weak
2. strong
3. electromagnetic
4. gravitational

action at a distance

attraction/repulsion

attraction

contact vs. field forces

gravitational force

[illegible] force

normal force
friction force

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## Fundamental concepts

**Basic quantities:** (dimensions)

- length
- time
- mass
- force

**Idealizations:**

- Particle:
  has mass but size is neglected
- Rigid Body:
  shape of the body does not change before/after applied force
- Concentrated Force:
  force applied over a small area compared to size of body

**Understanding and applying these things allows for amazing achievements in engineering! (airplanes, robotics, etc)**

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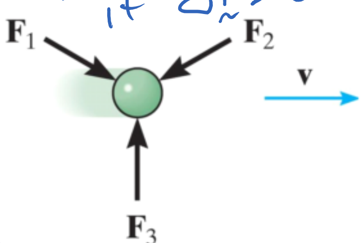
# Newton's laws of motion

Conservation of linear momentum, $\underset{\sim}{p}$

**First law:**

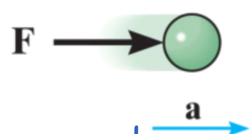
An object remains at rest or moves with constant velocity unless acted upon by a net force.

$\underset{\sim}{p} = \text{const.}$ if $\sum \underset{\sim}{F} = 0$




**Second law:** a particle acted upon by an unbalanced force **F** experiences an acceleration **a** that is proportional to the particle mass *m*:

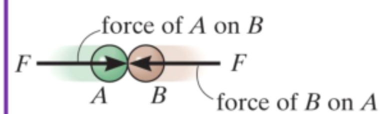
$$\boxed{\sum \underset{\sim}{F} = m \cdot \underset{\sim}{a}}$$




$$\sum \underset{\sim}{F} = \frac{d}{dt}\underset{\sim}{p}$$

$$= \frac{d}{dt}(m \cdot \underset{\sim}{v})$$

**Third law:** the mutual forces of action and reaction between two particles are equal, opposite and colinear.



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# Newton's law of gravitational attraction

The mutual **force F of gravitation** between two particles of mass $m_1$ and $m_2$ is given by:

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

$G$ is the universal constant of gravitation (small number)
$r$ is the distance between the two particles

Figure: 01_PH003
The astronaut's weight is diminished, since she is far removed from the gravitational field of the earth.

**Weight** is the force exerted by the earth on a particle at the earth's surface:

$$W = m \cdot \frac{G \cdot M_e}{r_e^2} = m \cdot g$$

mass of particle

$$g = \frac{G \cdot M_e}{r_e^2}$$

$M_e$ is the mass of the earth
$r_e$ is the distance between the earth's center and the particle near the surface
g is the acceleration due to the gravity

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## Units

**TABLE 1–1 Systems of Units**

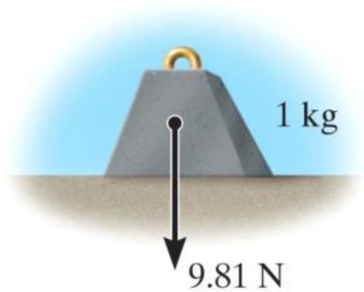
| Name | Length | Time | Mass | Force |
|---|---|---|---|---|
| International System of Units SI | meter | second | kilogram | $\boxed{\text{newton*}}$ |
| | m | s | kg | N $\left(\frac{kg \cdot m}{s^2}\right)$ |
| U.S. Customary FPS | foot | second | $\boxed{\text{slug*}}$ | pound |
| | ft | s | $\left(\frac{lb \cdot s^2}{ft}\right)$ | lb |

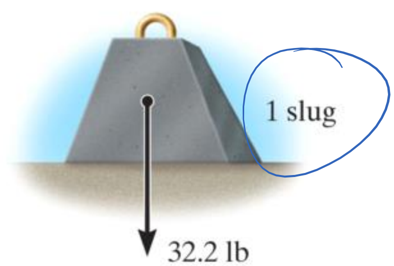
*Derived unit.



dimensions

units




$$G = 66.73 \times 10^{-12} \frac{m^3}{kg \cdot s^2}$$

$$g = 9.81 \frac{m}{s^2}$$

$$g = 32.2 \frac{ft}{s^2}$$

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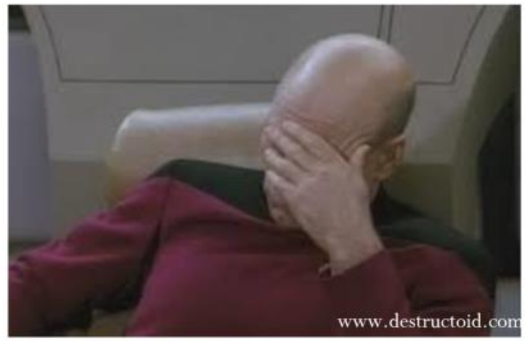
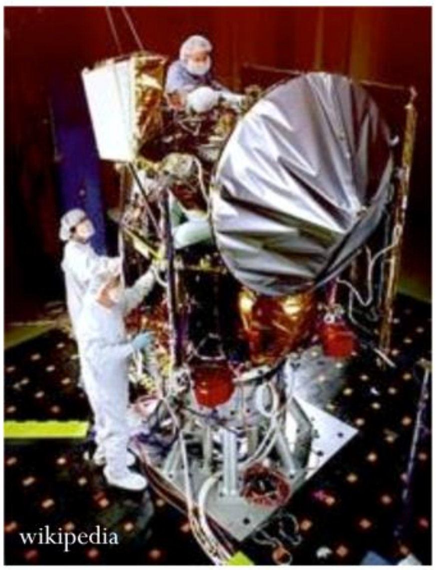
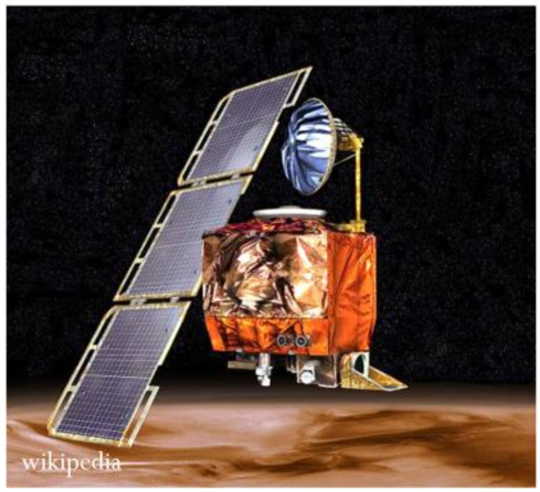
## Why so picky? Units matter...

- A national power company mixed up prices quoted in kilo-Watt-hour (kWh) and therms.
  - Actual price = $50,000
  - Paid while trading on the market: $800,000
- In Canada, a plane ran out of fuel because the pilot mistook liters for gallons! He landed the plane safely without power on an emergency airstrip.




Mars climate orbiter -- $327.6 million

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CNN STYLE FASHION DESIGN ARCHITECTURE ARTS AUTOS LUXURY

# The 'super-tall' age is here: World welcomes 100th mammoth skyscraper


$h = 1400$ ft

Approx.
9 football fields

# Numerical Calculations

## Dimensional Homogeneity

Equations ***must*** be dimensionally homogeneous, i.e., each term must be expressed in the same units. Consider the following example:

the kinematic equation

position of a particle

$$X(t) = V_0 \cdot t + \frac{1}{2} \cdot a_0 t^2$$

$$\text{length} = \left(\frac{\text{length}}{\text{time}}\right)\text{time} + \left(\frac{\text{length}}{\text{time}^2}\right)\text{time}^2$$

$$= \text{length} + \text{length}$$

# Numerical Calculations

## Significant figures

The number of significant figures contained in any number determines the accuracy of the number. Use 3 significant figures for final answers. For intermediate steps, use symbolic notation, store numbers in calculators or use more significant figures, in order to maintain precision.


**Example 1:** If $d$ = 3.2 in., $w$ = 1.413 in., and $h$ = 2.7 in., then