Announcements

- Got i-Clicker?
- Practice PrairieLearn Homework and Quiz now live
- MATLAB clinic starts tonight, check Piazza post for details
- Remember to go through the course website
  - Office hours are posted (Schedule)
- Recommended reading: Hibbeler chapters 1-2

- Upcoming deadlines:
- Tuesday (1/22)
  - PrairieLearn HW1
- Friday (1/25)
  - Written Assignment 1

Lecture Objectives

- What is “statics”?
- Newton’s laws of motion
- Newton’s law of gravitational attraction
- Force vectors and vector operations

Chapter 1: General Principles

What is “statics”?

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

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**

Rigid Bodies

Statics

Dynamics

Deformable Bodies

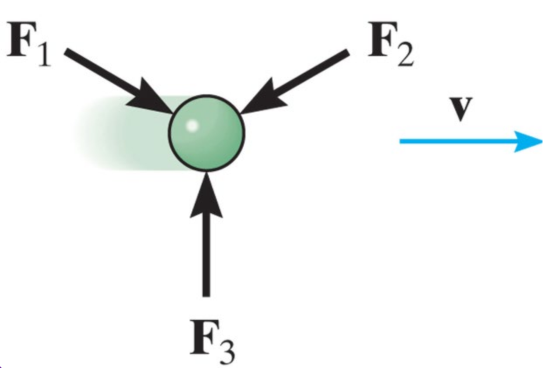
Solid Mechanics

Fluids

Compressible and incompressible

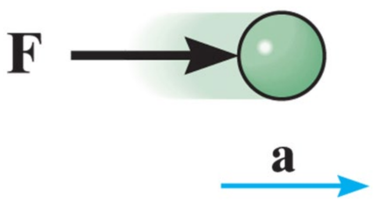
Newton's laws of motion

First law:
Particle at rest (or moving in a straight line with constant velocity) stays that way unless another force comes in.

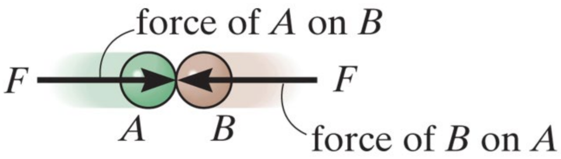


Second law: a particle acted upon by an unbalanced force **F** experiences an acceleration **a** that is proportional to the particle mass *m*:

$$F = ma$$



Third law: the mutual forces of action and reaction between two particles are ____equal____, ____opposite____ and ____collinear____.



victorstuff.com

state of rest or motion of bodies that are subjected to the action of forces

Which forces?

www.ashvegas.com

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:

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

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

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

$$F = mg, g = G\frac{M_e}{r_e^2}$$

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

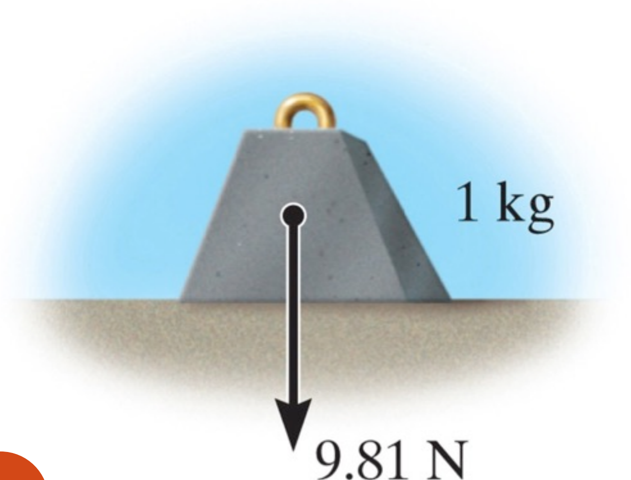
Figure: 01_PH003
The astronaut's weight is diminished, since she is far removed from the gravitational field of the earth.

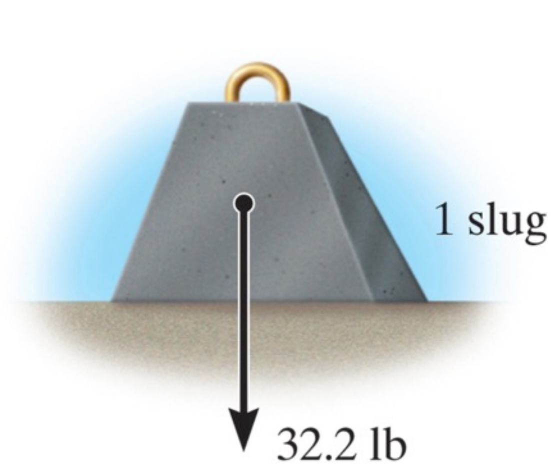
Units

TABLE 1–1 Systems of Units

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

*Derived unit.





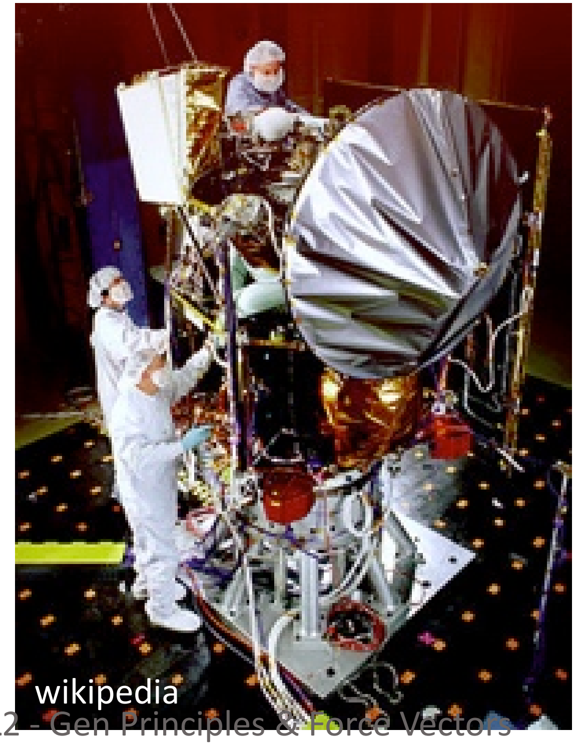
$$G = 66.73 \times 10^{-12} \frac{m^3}{kg \cdot s^2}$$

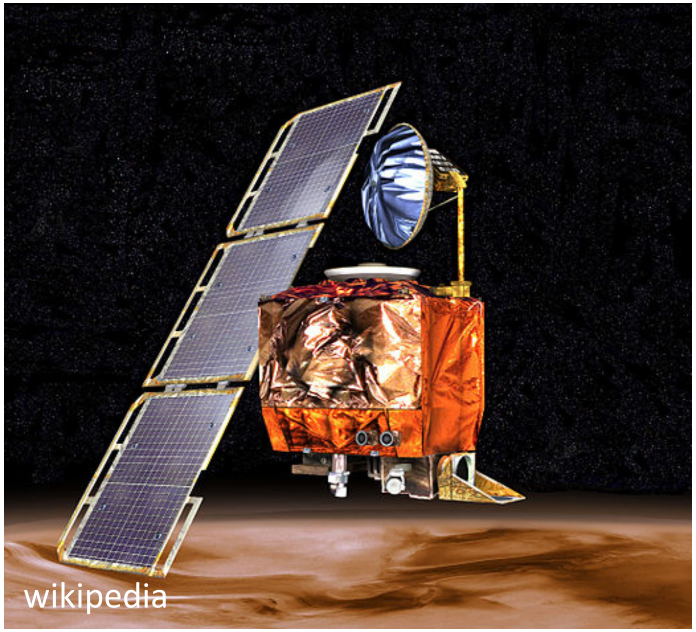
$$g = 9.81 \frac{m}{s^2}$$

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

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

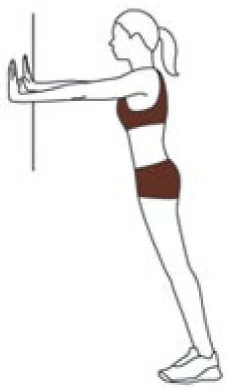
Numerical Calculations

Significant figures

The number of significant figures contained in any number determines the accuracy of the number. Use 3 or > 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.

Force vectors

A force—the action of one body on another—can be treated as a vector, since forces obey all the rules that vectors do.



Scalars and vectors

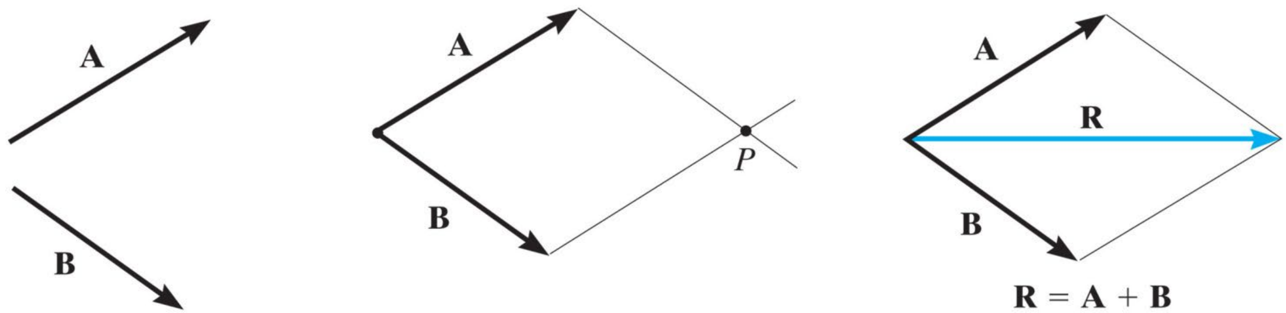
	Scalar	**Vector**
Examples	Mass, Volume, Time	Force, Velocity
Characteristics	It has a magnitude	It has a magnitude and direction
Special notation used in TAM 210/211	None	Bold font or symbols ("→") Ex:

<u>Multiplication or division of a vector by a scalar</u>

$$\boldsymbol{B} = \alpha\, \boldsymbol{A}$$

Vector addition

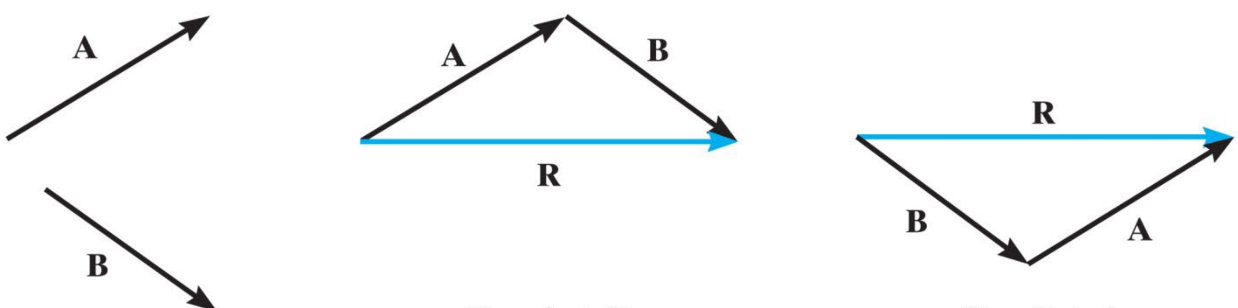
All vector quantities obey the parallelogram law of addition $\boldsymbol{R} = \boldsymbol{A} + \boldsymbol{B}$



R = **A** + **B**

Parallelogram law

Commutative law: $\boldsymbol{R} = \boldsymbol{A} + \boldsymbol{B} = \boldsymbol{B} + \boldsymbol{A}$



R = **A** + **B**

Triangle rule

R = **B** + **A**

Triangle rule

Associative law: $\boldsymbol{A} + (\boldsymbol{B} + \boldsymbol{C}) = (\boldsymbol{A} + \boldsymbol{B}) + \boldsymbol{C}$

Vector subtraction:

$$\boldsymbol{R} = \boldsymbol{A} - \boldsymbol{B} = \boldsymbol{A} + (-\boldsymbol{B})$$

$(-\boldsymbol{B})$ has the same magnitude as $\boldsymbol{B}$ but is in opposite direction.

Scalar/Vector multiplication:

$$\alpha(\boldsymbol{A} + \boldsymbol{B}) = \alpha\,\boldsymbol{A} + \alpha\,\boldsymbol{B}$$

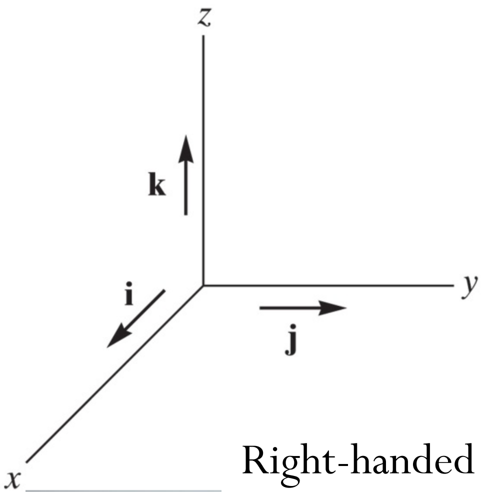
$$(\alpha + \beta)\boldsymbol{A} = \alpha\,\boldsymbol{A} + \beta\,\boldsymbol{A}$$

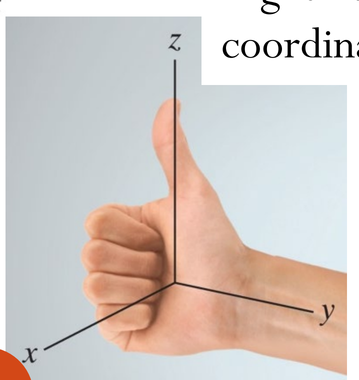
Cartesian vectors

Rectangular coordinate system: formed by 3 mutually perpendicular axes, the *x, y, z* axes, with unit vectors $\hat{i}$, $\hat{j}$, $\hat{k}$ in these directions.

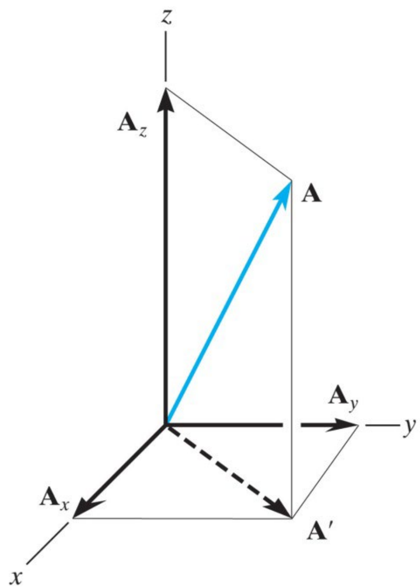
Note that we use the special notation "^" to identify *basis vectors* (instead of the "→" notation)

$(\hat{i},\ \hat{j},\ \hat{k})$ or $(\boldsymbol{i},\ \boldsymbol{j},\ \boldsymbol{k})$



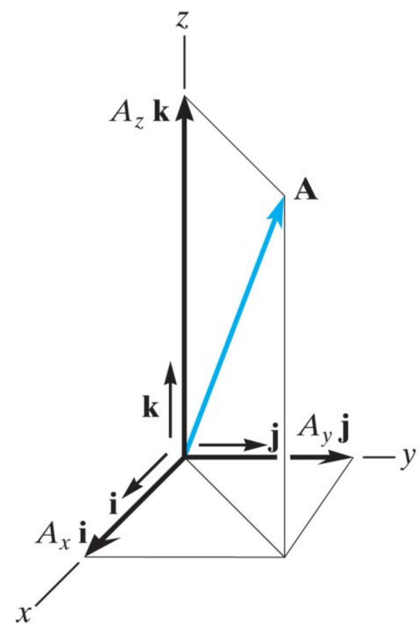


Right-handed coordinate system



Rectangular components of a vector

$$\boldsymbol{A} = \boldsymbol{A}_x + \boldsymbol{A}_y + \boldsymbol{A}_z$$

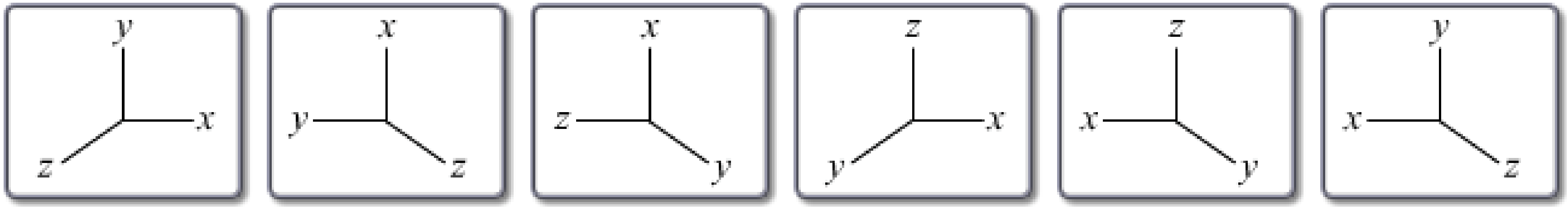


Cartesian vector representation

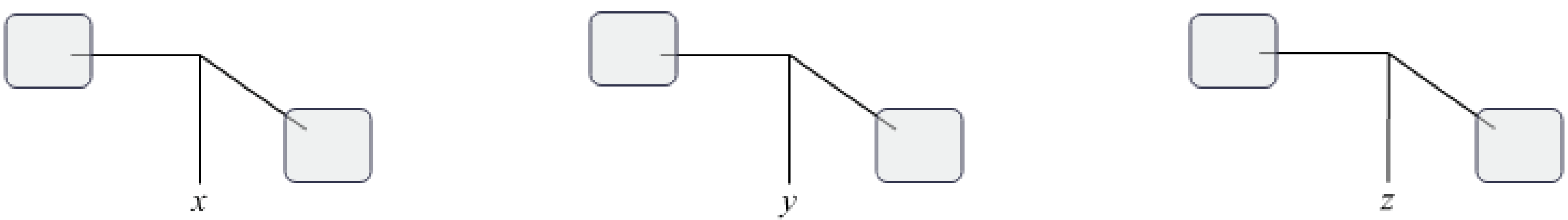
$$\boldsymbol{A} = A_x\,\boldsymbol{i} + A_y\,\boldsymbol{j} + A_z\,\boldsymbol{k}$$

Right-hand Rule

Sort the following coordinate systems into Cartesian and non-Cartesian.

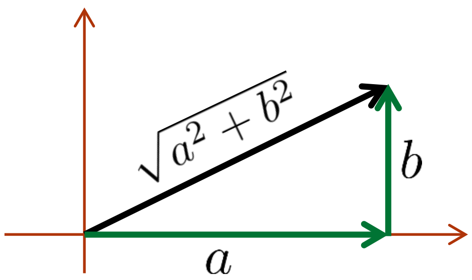


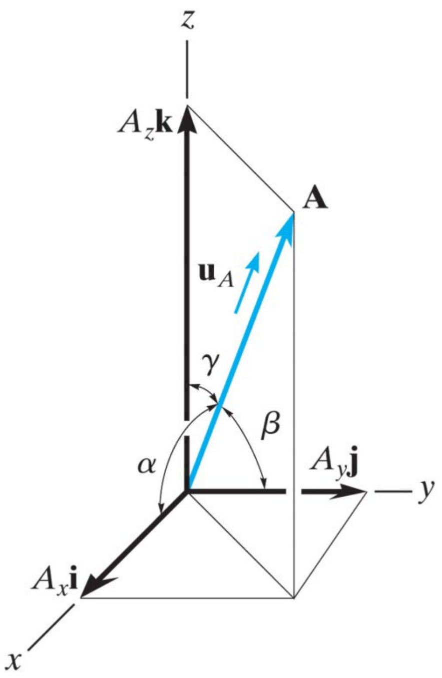
Label the missing coordinate axes in Cartesian coordinate system.



Magnitude of Cartesian vectors

$$A = |\boldsymbol{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

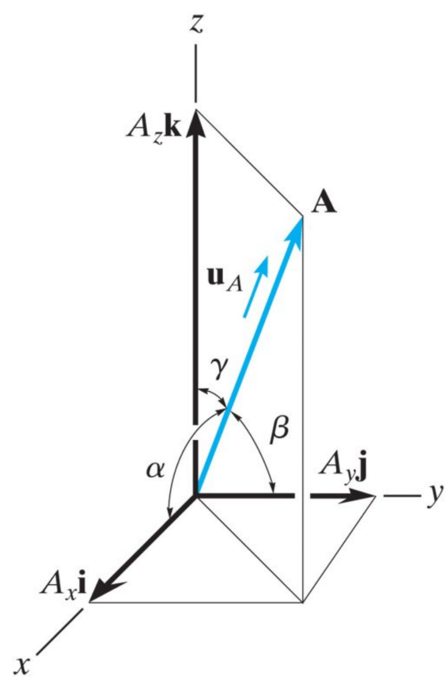




Direction of Cartesian vectors

Expressing the direction using a unit vector:

$$\boldsymbol{u}_A = \frac{\boldsymbol{A}}{A} = \frac{A_x}{A}\,\boldsymbol{i} + \frac{A_y}{A}\,\boldsymbol{j} + \frac{A_z}{A}\,\boldsymbol{k}$$



Direction cosines are the components of the unit vector:

$$\cos(\alpha) = \frac{A_x}{A}$$

$$\cos(\beta) = \frac{A_y}{A}$$

$$\cos(\gamma) = \frac{A_z}{A}$$

Addition of Cartesian vectors

$$\boldsymbol{R} = \boldsymbol{A} + \boldsymbol{B} = (A_x + B_x)\,\boldsymbol{i} + (A_y + B_y)\,\boldsymbol{j} + (A_z + B_z)\,\boldsymbol{k}$$