To do…

- Register i>clicker (Compass)

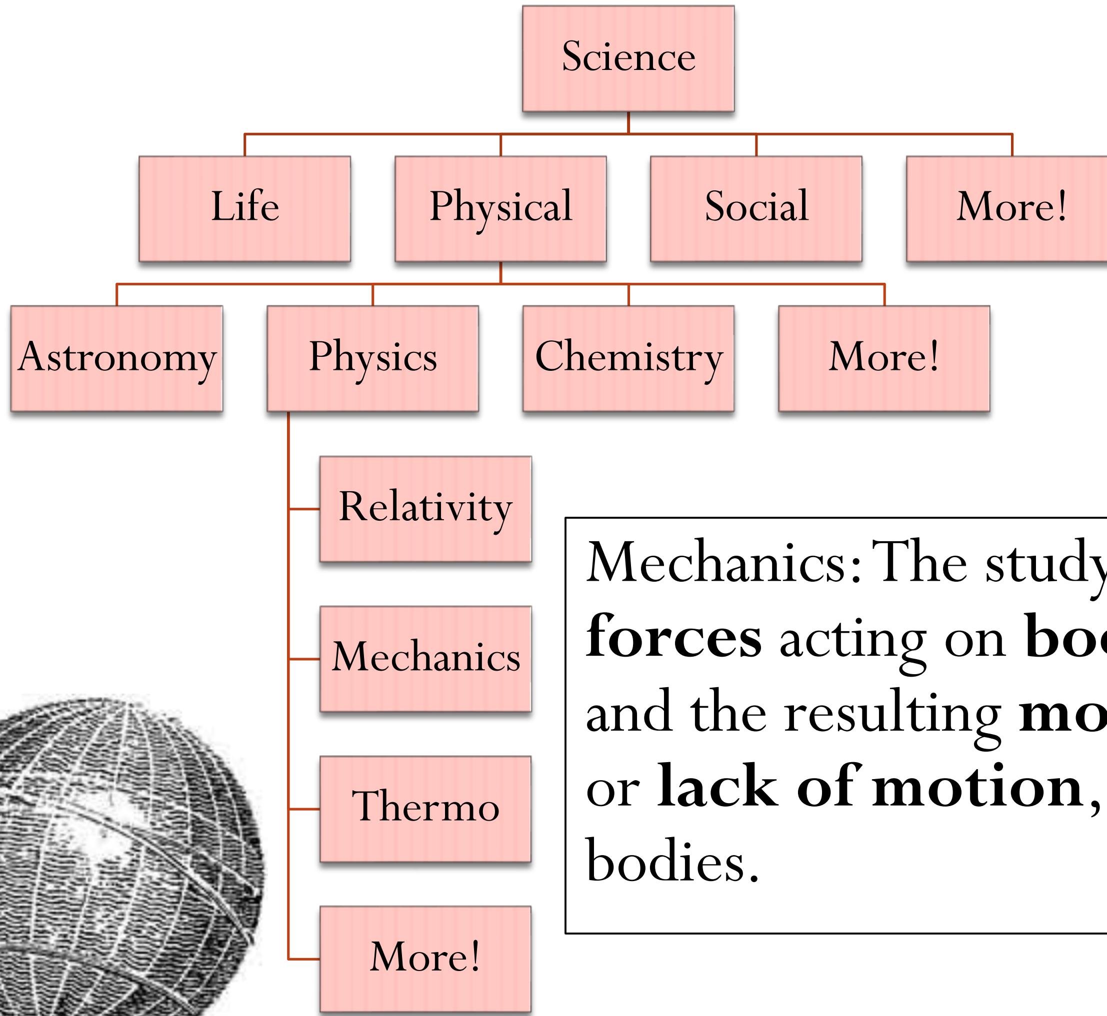
- MasteringEngineering HW1 due **Today**
- WA due **Today**
- PrairieLearn HW1 due **Monday**
- PrairieLearn HW2 due **Thursday**

- MATLAB clinic next week

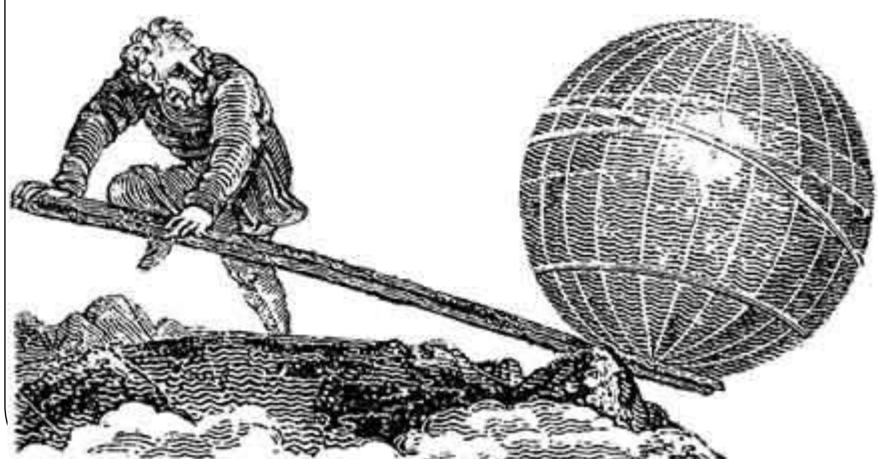
Chapter 1: General Principles
Main goals and learning objectives

- Introduce the basic ideas of *Mechanics*
- Give a concise statement of Newtown'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

What is "Statics"?



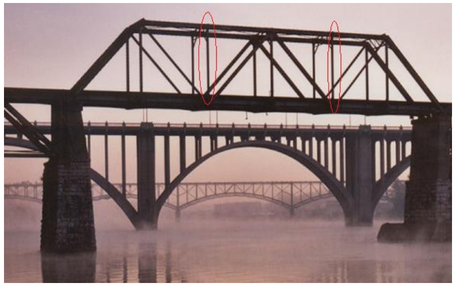
Mechanics: The study of **forces** acting on **bodies**, and the resulting **motion**, or **lack of motion**, of the bodies.



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

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Which forces?

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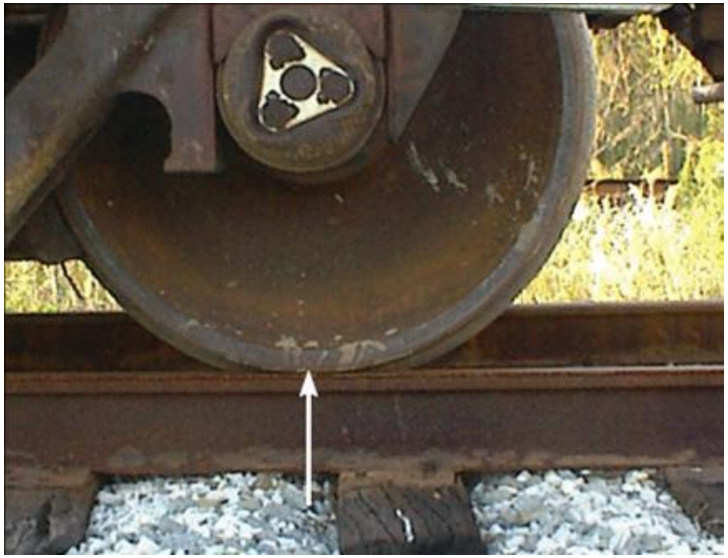
- Mechanics: State of rest or motion of bodies subjected **to forces**

Fundamental concepts



Basic quantities:

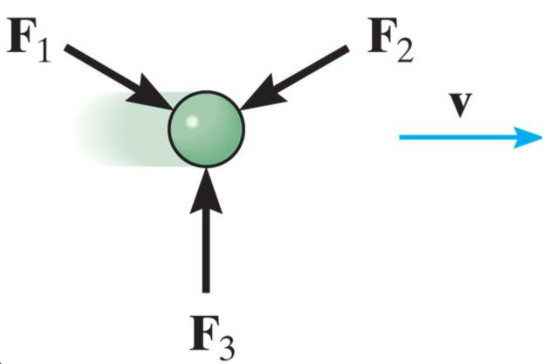
Idealizations:

- <u>Particle</u>:
- <u>Rigid Body</u>:
- <u>Concentrated Force</u>:

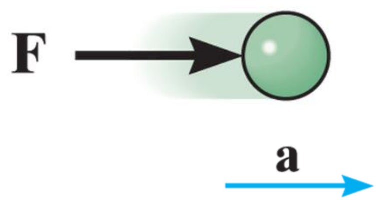
Understanding and applying these things allows for amazing achievements in engineering! (airplanes, robotics, etc)

Newton's laws of motion

First law:

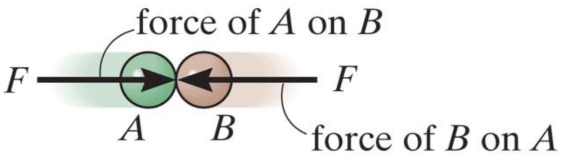


Second law: a particle acted upon by an unbalanced force **F** experiences an acceleration **a** that is proportional to the particle mass *m*:



Third law: the mutual forces of action and reaction between two particles are

________________,
________________ and
_________________.



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:

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:

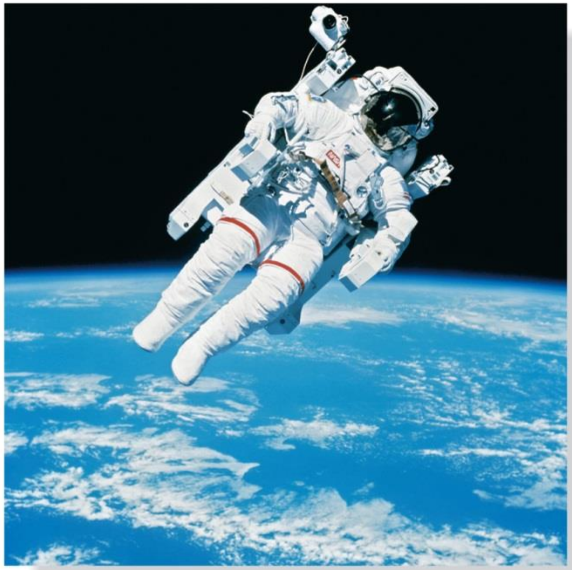


Figure: 01_PH003
The astronaut's weight is diminished, since she is far removed from the gravitational field of the earth.

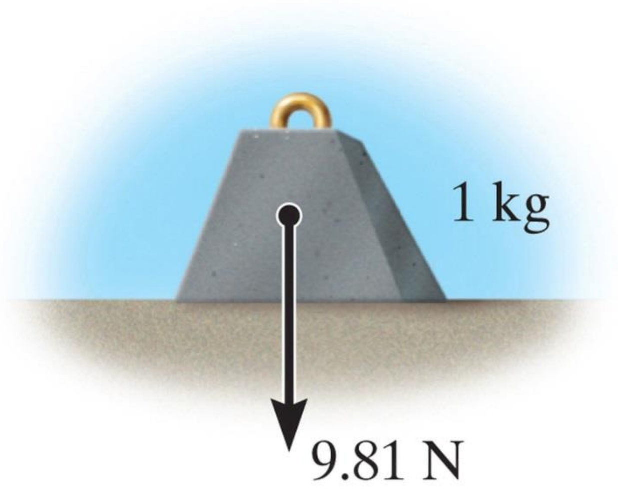
M_e is the mass of the earth
r_e is the distance between the earth's center and the particle near the surface
g is the acceleration due to the gravity

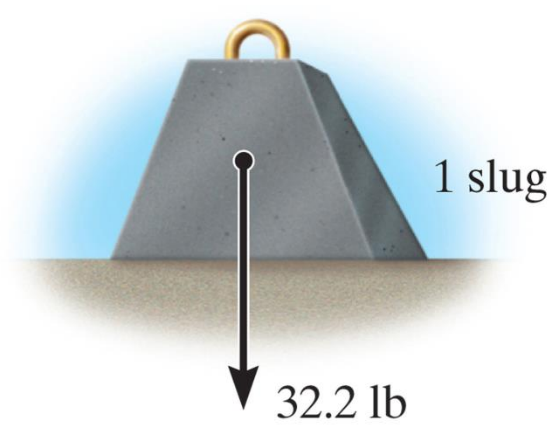
Units

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.





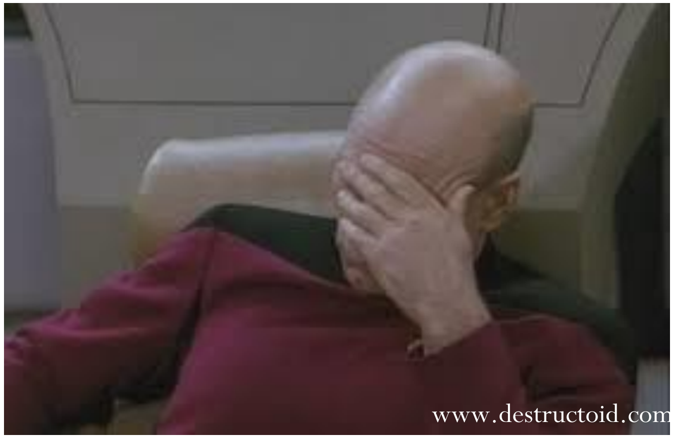
$$G = 66.73 \times 10^{-12} \frac{m^3}{kg \cdot s^2}$$

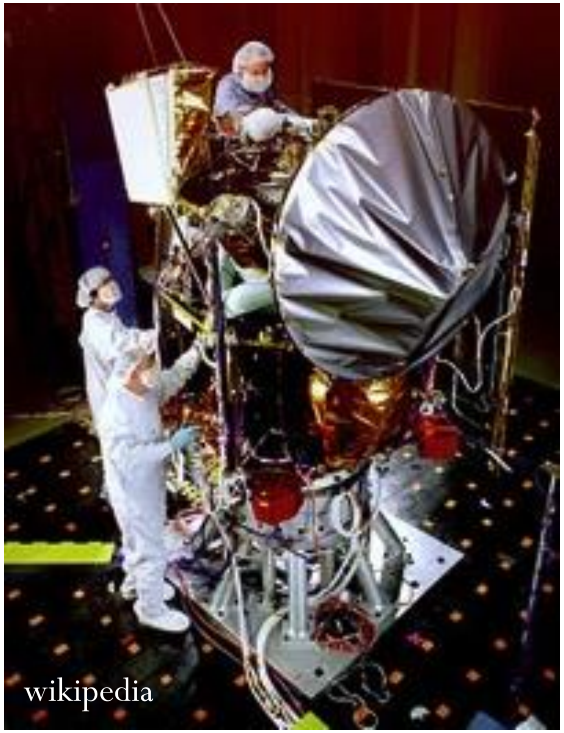
$$g = 9.81 \frac{m}{s^2}$$

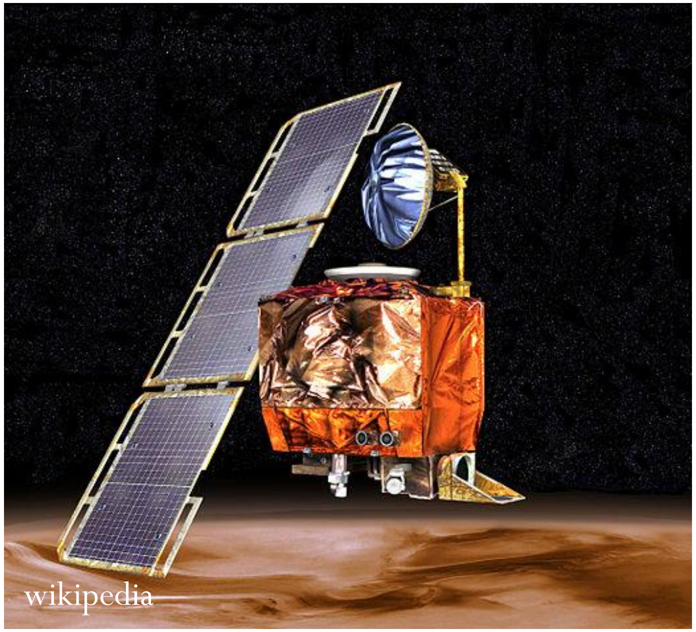
$$g = 32.2 \frac{ft}{s^2}$$

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

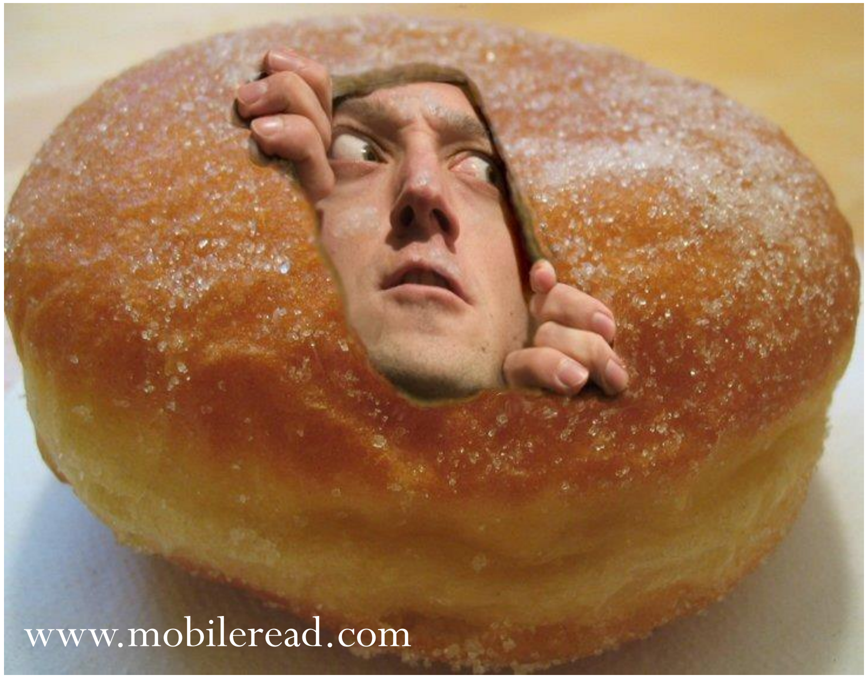
CNN STYLE FASHION DESIGN ARCHITECTURE ARTS AUTOS LUXURY

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

Numerical Calculations

Dimensional Homogeneity

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



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

General procedure for analysis

1. Read the problem carefully; write it down carefully.

2. Model the problem: Draw given diagrams neatly and construct additional figures as necessary.

3. Apply principles needed.

4. Solve problem symbolically. Make sure equations are dimensionally homogeneous.

5. Substitute numbers. Provide proper units *throughout*. Check significant figures. Box the final answer(s).

6. See if answer is reasonable.

Most effective way to learn engineering mechanics is to ***solve problems! PRACTICE!!!***

Problem

(a) Using the base units of the SI system, show that Newton's law of gravitation is a dimensionally homogeneous equation that gives F in newtons.

(b) Compute the gravitational force acting between two identical spheres that are touching each other. The mass of each sphere is 150 kg, and the radius is 275 mm.

Chapter 2: Force vectors
Main goals and learning objectives

Define scalars, vectors and vector operations and use them to analyze forces acting on objects

- Add forces and resolve them into components
- Express force and position in Cartesian vector form
- Determine a vector's magnitude and direction
- Introduce the dot product and use it to find the angle between two vectors or the projection of one vector onto another

Scalars and vectors

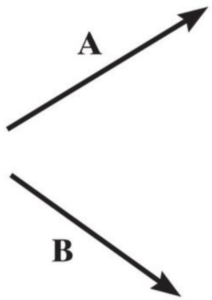
	Scalar	**Vector**
Examples	Mass, Volume, Time	Force, Velocity
Characteristics	It has a magnitude	It has a magnitude and direction
Special notation used in TAM 210/211	None	Bold font or vector symbol Ex: $\boldsymbol{A}$ or $\underset{\sim}{A}$

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

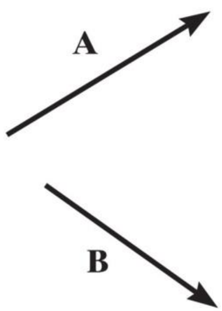
$$\boldsymbol{B} = \alpha\, \boldsymbol{A}$$

Vector addition

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



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



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.

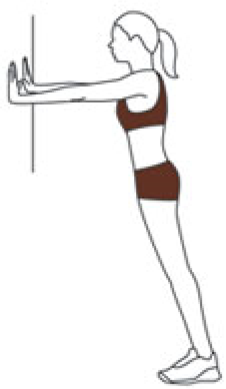
Scalar/Vector multiplication:

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

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

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.

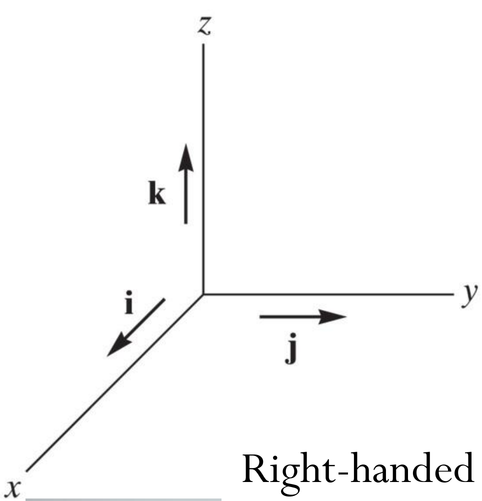


Cartesian vectors

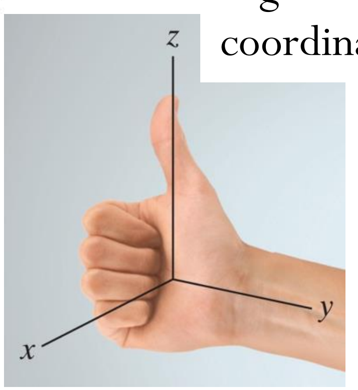
Rectangular coordinate system: formed by 3 mutually perpendicular axes, the *x*, *y*, *z* axes, with unit vectors $\hat{i}$, $\hat{j}$, $\hat{k}$ in these directions.

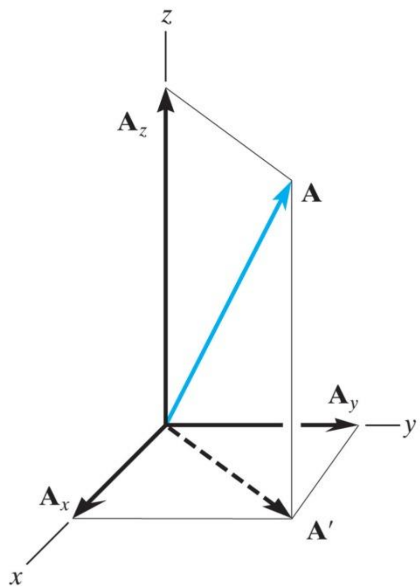
Note that we use the special notation "^" to identify *basis vectors* (instead of the "~" notation)

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

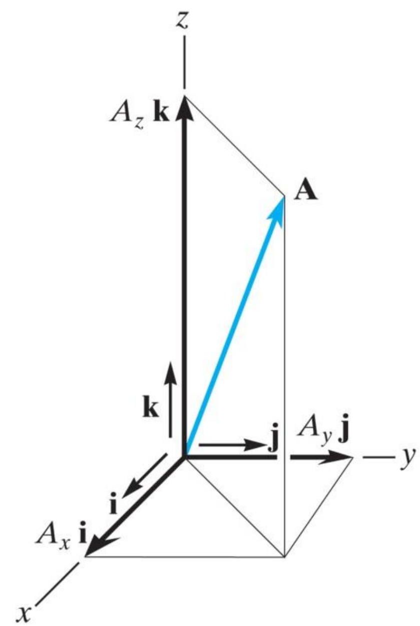


Right-handed coordinate system





Rectangular components of a vector



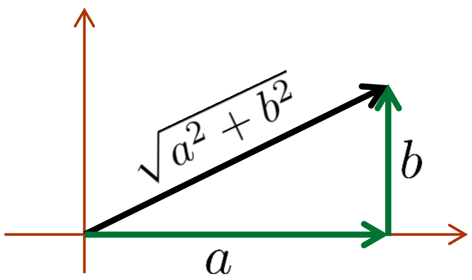
Cartesian vector representation

$\boldsymbol{A} =$

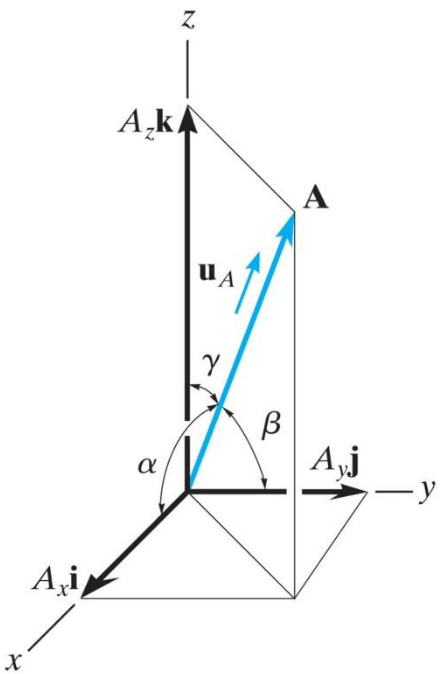
$\boldsymbol{A} =$

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:

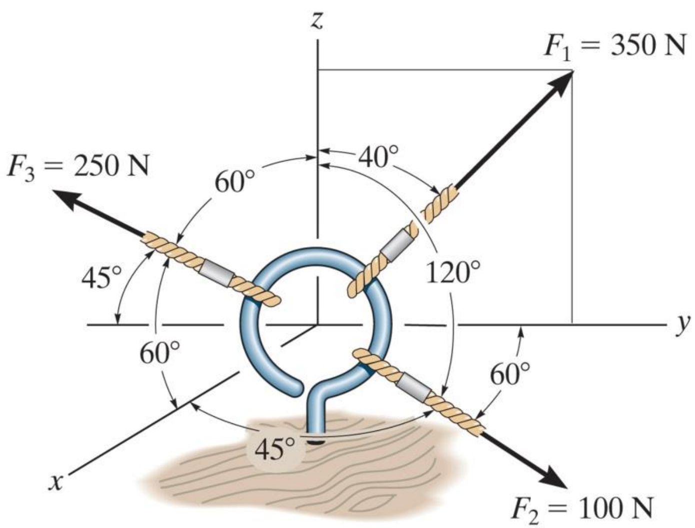
$$\boldsymbol{u}_A = \frac{\boldsymbol{A}}{A}$$

Direction cosines are the components of the unit vector:

Addition of Cartesian vectors

$$\boldsymbol{R} = \boldsymbol{A} + \boldsymbol{B} =$$

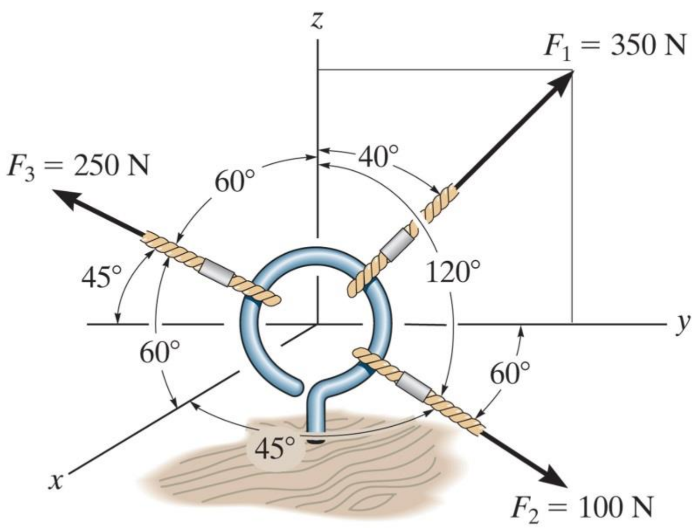
Example



The cables attached to the screw eye are subjected to the three forces shown.

(a) Express each force vector using the Cartesian vector form (components form).

Example

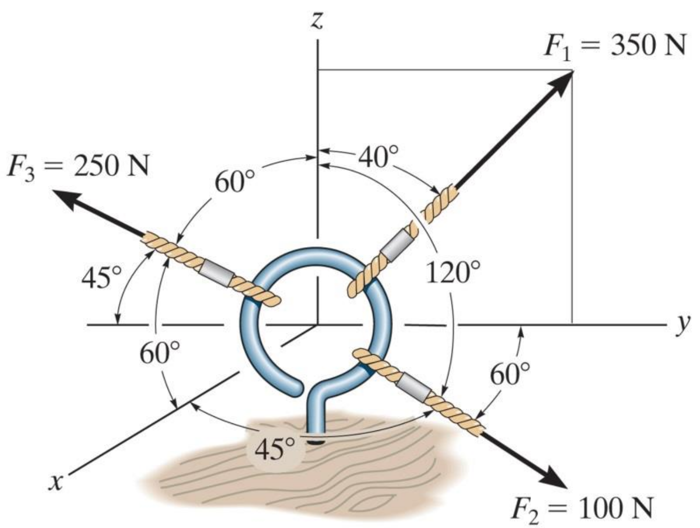


The cables attached to the screw eye are subjected to the three forces shown.

(a) Express each force vector using the Cartesian vector form (components form).

(b) Determine the magnitude of the resultant force vector

Example



The cables attached to the screw eye are subjected to the three forces shown.

(a) Express each force vector using the Cartesian vector form (components form).

(b) Determine the magnitude of the resultant force vector

(c) Determine the direction cosines of the resultant force vector