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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

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Lecture Objectives

- What is "statics"?
- Newton's laws of motion
- Newton's law of gravitational attraction
- Force vectors and vector operations

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Chapter 1: General Principles

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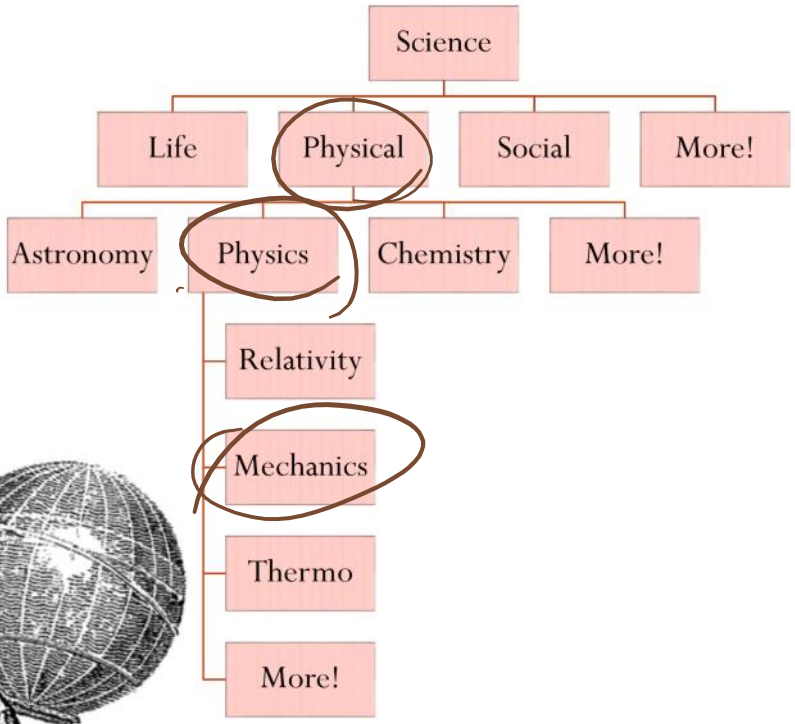
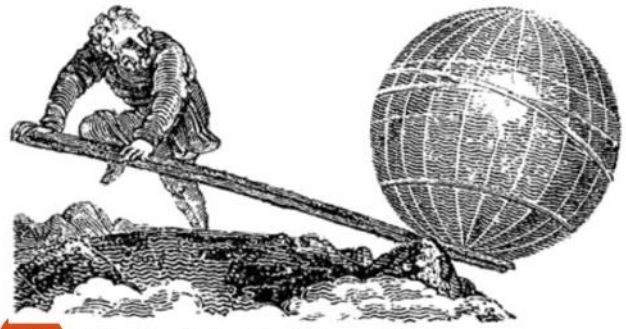
What is "statics"?





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

Linkage example

TAM 210/211 Statics

TAM 212 Dynamics

Deformable Bodies

TAM 251

Solid Mechanics

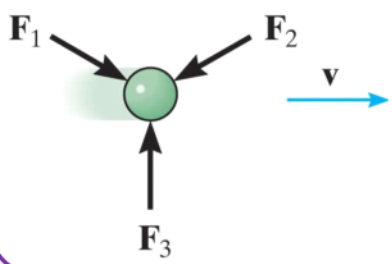
Fluids

Compressible and incompressible

Newton's laws of motion

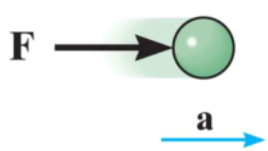
TAM 210/211

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



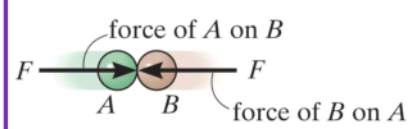
Second law: a particle acted upon by an unbalanced force **F** experiences an acceleration **a** that is proportional to the particle mass m:

$$F = ma$$



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

___equal___,
___opposite___ and
___collinear___.



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

TAM 210/211: gravity & contact forces only

www.ashvegas.com

Which forces?

* - gravity
- electromag
- strong (nucleus)
* - normal
* - friction...

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

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:

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

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

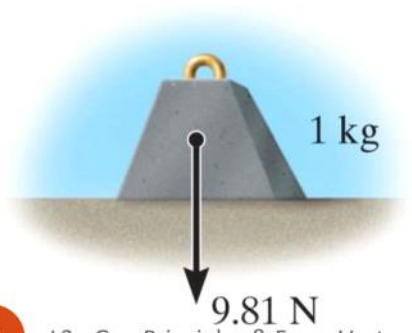
Units

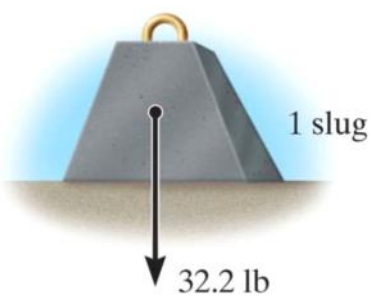
TABLE 1–1 Systems of Units

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.

$W = mg$





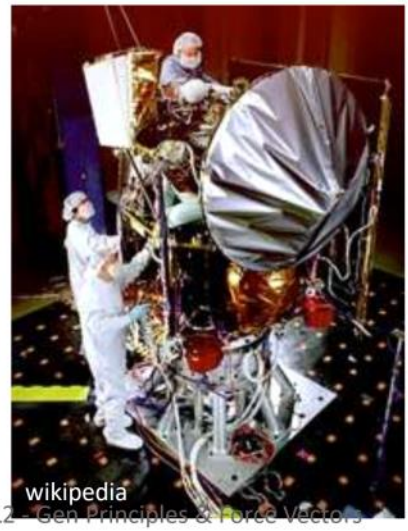
$$G = 66.73 \times 10^{-12} \frac{m^3}{kg \cdot s^2}$$

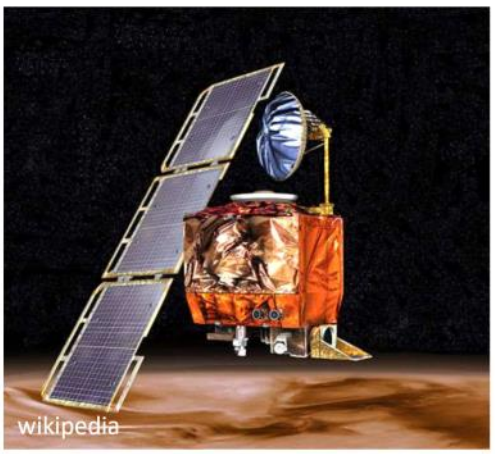
$$g = 9.81 \frac{m}{s^2}$$

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

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.

1% error.

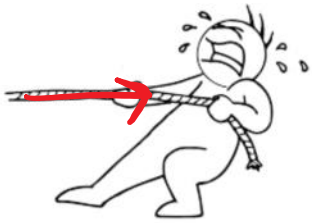
Answer: 1354.76585 N

→ 1350 N

✗ 1400 N

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.



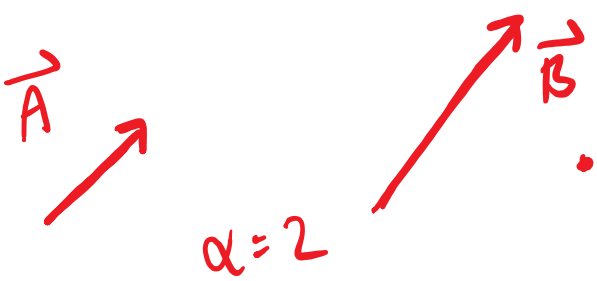
Force = magnitude & direction

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: $\boldsymbol{A}$, $\vec{A}$

Multiplication or division of a vector by a scalar

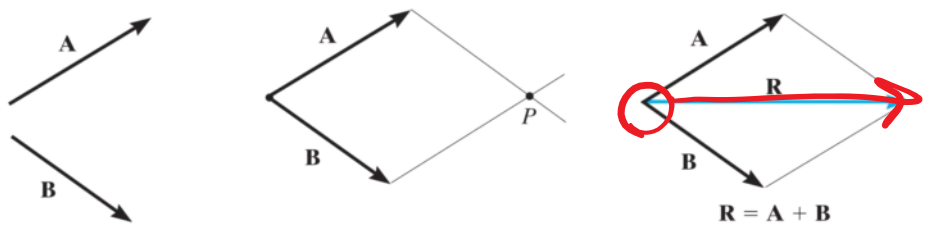
$$\boldsymbol{B} = \alpha \boldsymbol{A}$$



- magnitude 2x
- direction stays the same

Vector addition

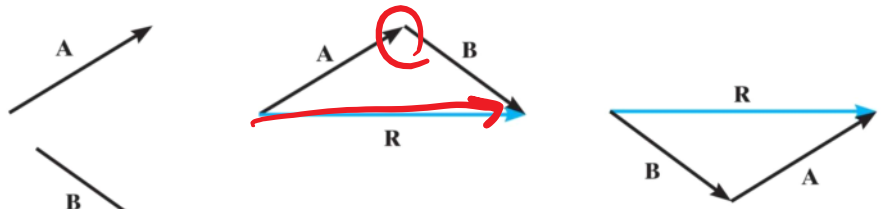
All vector quantities obey the parallelogram law of addition $\boldsymbol{R} = \boldsymbol{A} + \boldsymbol{B}$



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.

$\vec{B}$

$\alpha = -1$ $\alpha\vec{B}$

equal in magnitude

opposite in direction

Scalar/Vector multiplication:

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

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

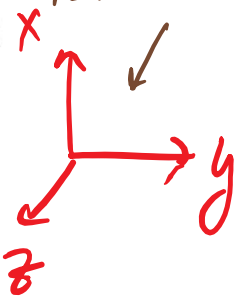
Cartesian vectors

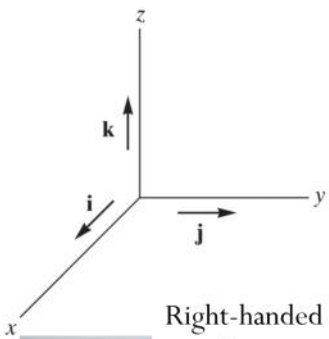
Rectangular coordinate system: formed by 3 mutually perpendicular axes, the x, y, z axes, with unit vectors $\hat{i}$, $\hat{j}$, $\hat{k}$ in these directions.

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

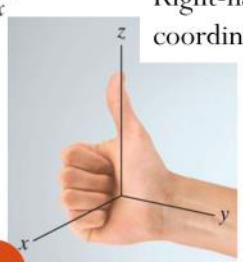
$(\hat{i}, \hat{j}, \hat{k})$ or $(\boldsymbol{i}, \boldsymbol{j}, \boldsymbol{k})$

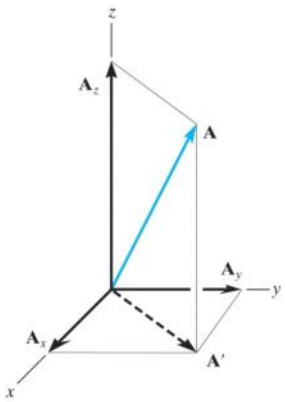
Non-Cartesian



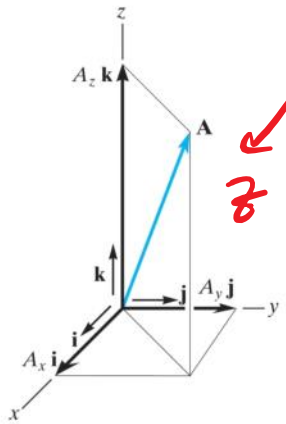


Right-handed coordinate system



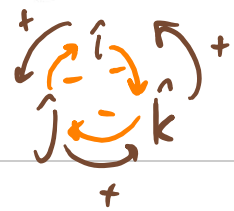


Rectangular components of a vector



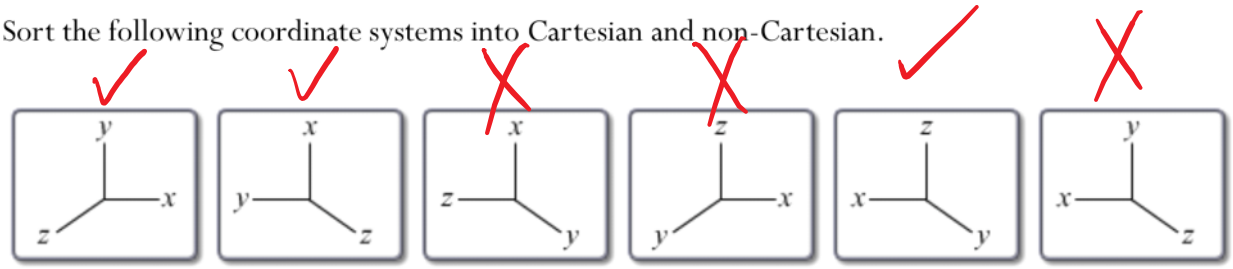
Cartesian vector representation

$$\boldsymbol{A} = \boldsymbol{A}_x + \boldsymbol{A}_y + \boldsymbol{A}_z \qquad \boldsymbol{A} = A_x\,\boldsymbol{i} + A_y\,\boldsymbol{j} + A_z\,\boldsymbol{k}$$

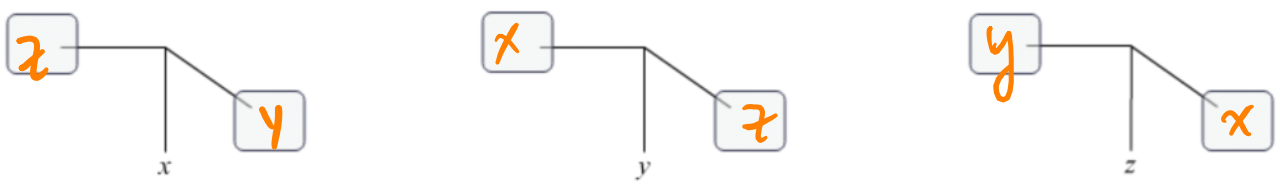


Right-hand Rule

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

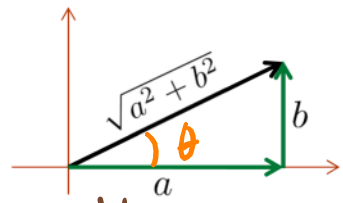


Label the missing coordinate axes in Cartesian coordinate system.



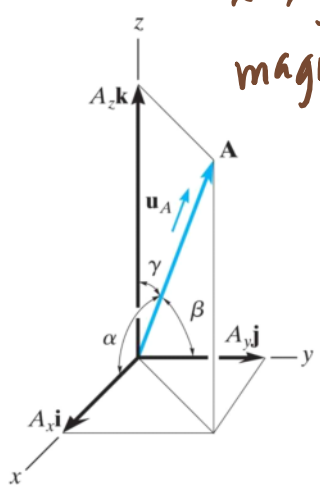
Magnitude of Cartesian vectors

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



x-, y-component form variables: A_x, A_y

magnitude and angular direction variables: A, θ



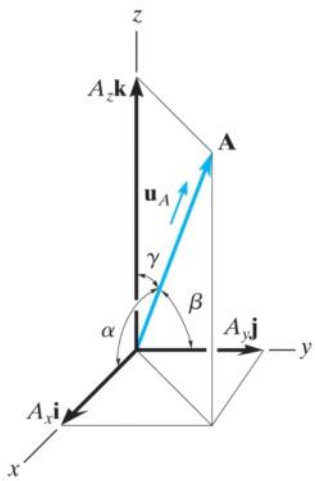
$$A_x = A\cos\theta \qquad A = \sqrt{A_x^2 + A_y^2}$$

$$A_y = A\sin\theta \qquad \theta = \tan^{-1}\left(\frac{A_y}{A_{A_x}}\right)$$

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:

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

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

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

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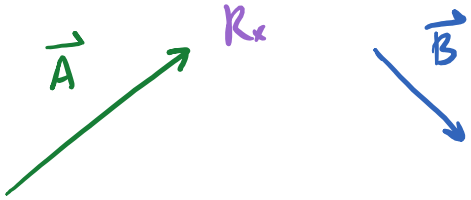
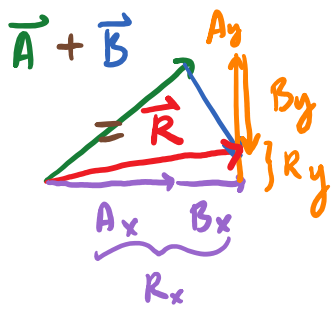
Addition of Cartesian vectors

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





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