Statics - TAM 210 & TAM 211

Lecture 2

January 19, 2018

Announcements

WA1 : now available, due Thurs

- Go through course website (policies, info, schedule)
  - See instructions to register for Mastering Engineering on info page
  - Must purchase ME Access Code (stand alone code, + eText, + hard copy)
- Register i>clicker (Compass2g)
- Grainger office hours start TODAY.
- MATLAB training sessions TBA (next 2 weeks)
- Take practice Quiz 0 on PrairieLearn (not graded)
- Upcoming deadlines:
- Friday (1/19)
  - Mastering Engineering Tutorial 2
- Sunday (1/21)
  - PrairieLearn HW0
- Tuesday (1/23)
  - PrairieLearn HW1

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Chapter 1: General Principles
Main goals and learning objectives

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

Numerical Calculations

Dimensional Homogeneity

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

Work problems in the units given unless otherwise instructed!

$$x = vt + \frac{1}{2}at^2$$

$$\text{length} = \frac{\text{length}}{\cancel{\text{time}}}\cancel{\text{time}} + \frac{\text{length}}{\cancel{\text{time}^2}}\cancel{\text{time}^2}$$

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

Dimensions

units: meter
feet
miles

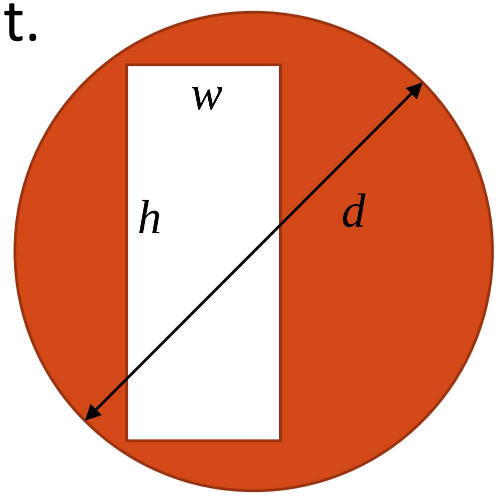
Numerical Calculations

Significant figures

Number of significant figures contained in any number determines 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, to maintain precision.

Example: Find area of circle with rectangular cut-out.

$$A = \frac{\pi d^2}{4} - wh$$



Given: d = 3.2 in., w = 1.413 in., and h = 2.7 in.

Solution: $A = \frac{\pi d^2}{4} - wh$

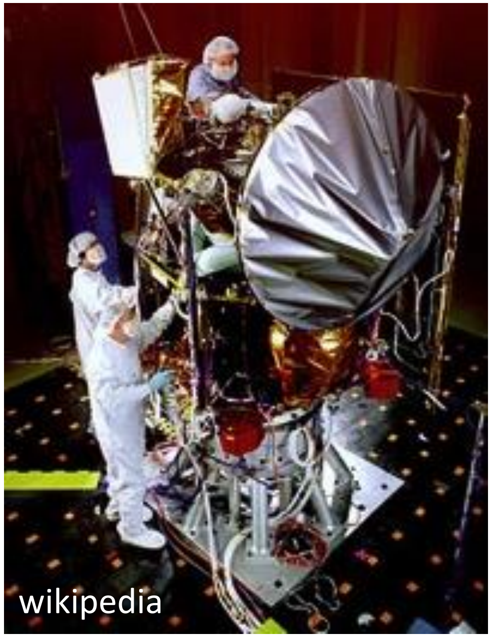
$$= \frac{\pi (3.2)^2}{4} - (1.413)(2.7)\ \text{in}^2$$

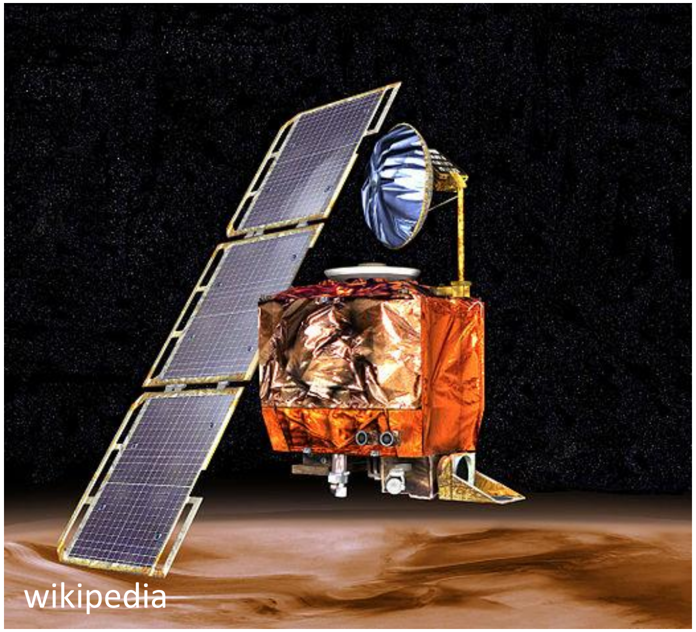
$$= 4.227\ \text{in}^2$$

$$\Longrightarrow \boxed{A = 4.23\ \text{in}^2}$$

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, plane ran out of fuel because pilot mistook liters for gallons!





Mars climate orbiter – $327.6 million

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!***

Chapter 2: Force Vectors

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	No special font A	Bold font or symbols (~ or ⇀) Ex: **A**, $\tilde{\mathbf{A}}$, $\vec{\mathbf{A}}$

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

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

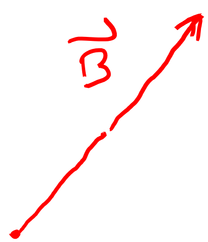
$\vec{B} = \alpha \vec{A}$

$\alpha = 2$

Given vector $\vec{A}$

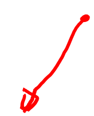
$\vec{A}$

$\vec{B}$



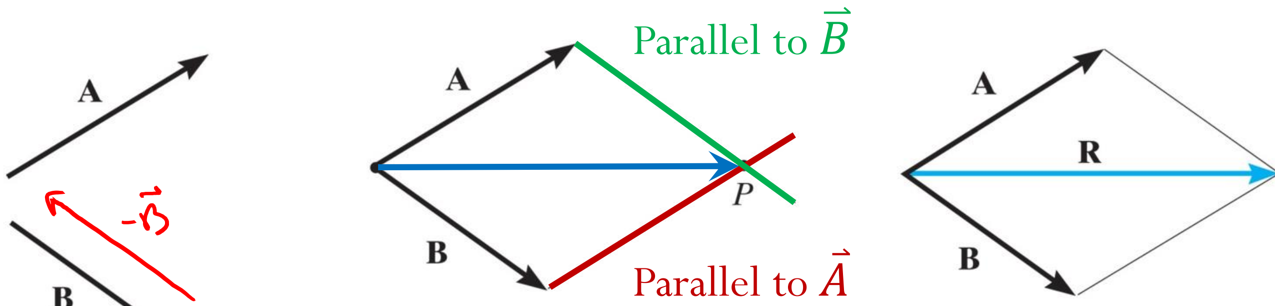
$\alpha = -1$

$\vec{B}$



Vector addition

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

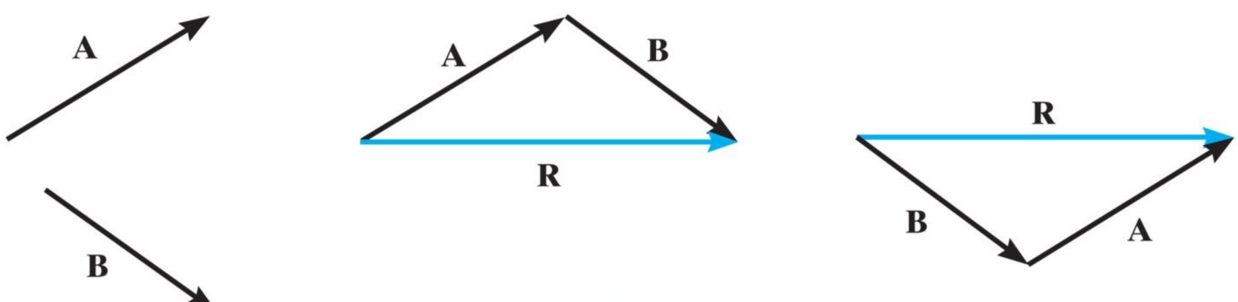


R = **A** + **B**

Parallelogram law

move "tails" together

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



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

Triangle rule

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

Triangle rule

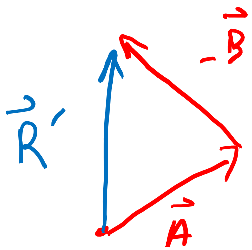
combine 'tip' to 'tail'

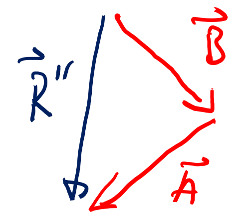
Associative law: $\boldsymbol{A} + (\boldsymbol{B} + \boldsymbol{C}) = (\boldsymbol{A} + \boldsymbol{B}) + \boldsymbol{C}$

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.





NOTE: $\vec{A} - \vec{B} \neq \vec{B} - \vec{A}$

$\vec{R}' \neq \vec{R}''$

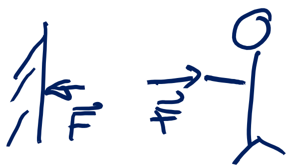
Scalar/Vector multiplication:

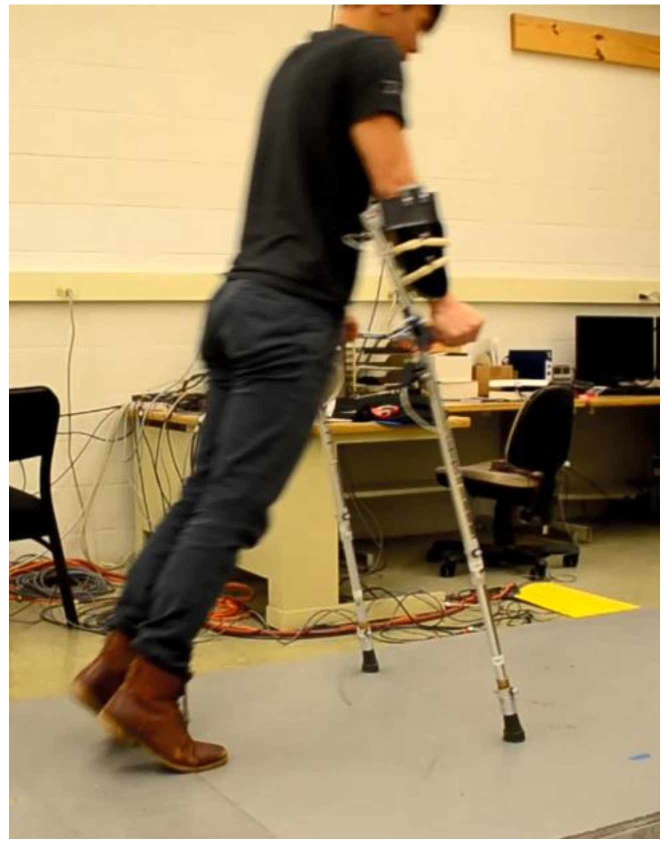
$$\alpha(\boldsymbol{A} + \boldsymbol{B}) = \alpha\vec{A} + \alpha\vec{B}$$

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

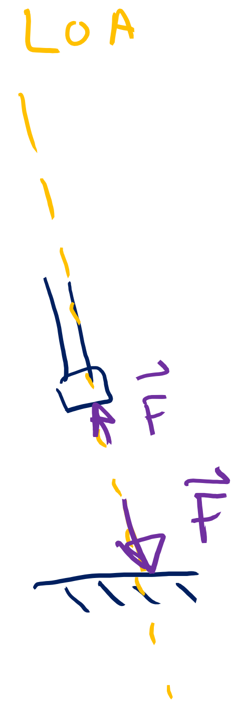
Force vectors

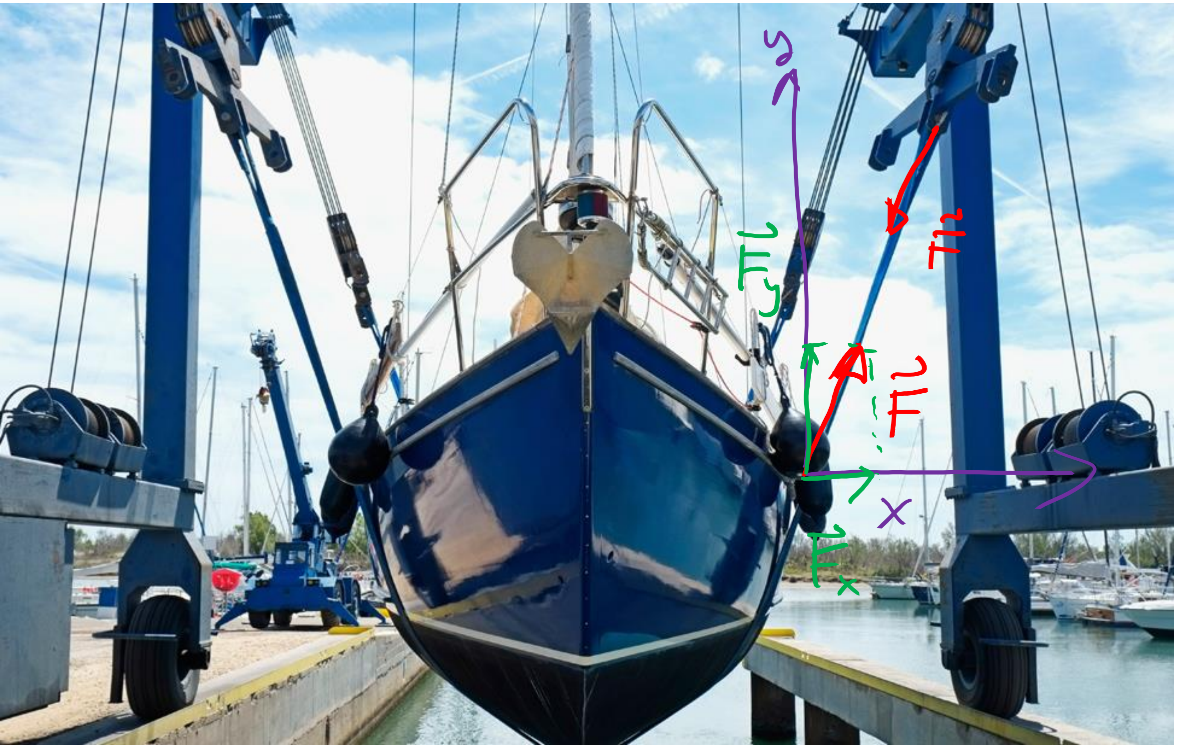
A force—the action of one body on another—can be treated as a vector, since forces obey all the rules that vectors do.





Human Dynamics & Controls Lab





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Generally asked to solve two types of problems.

1. Find the resultant force.

2. Resolve the force into components

Force on the boat

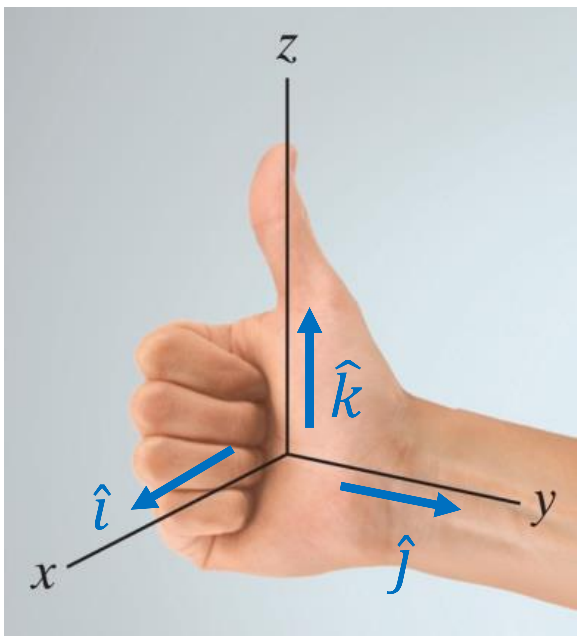
$$\vec{F} = \vec{F}_x + \vec{F}_y$$

Cartesian vectors

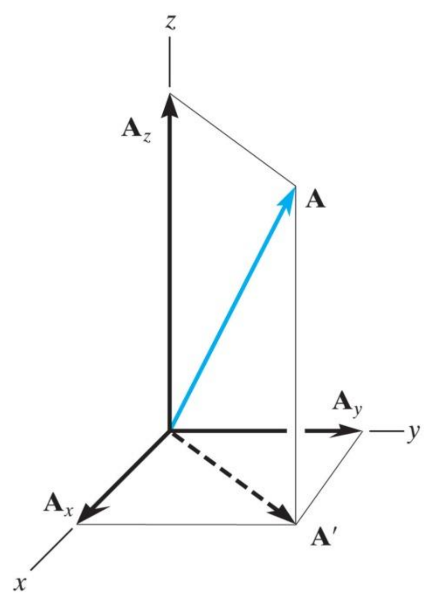
Rectangular coordinate system: formed by 3 mutually perpendicular axes, the x, y, z axes with unit vectors $\hat{\imath}, \hat{\jmath}, \hat{k}$ in these directions.

Note that we use the special notation “^” to identify *basis vectors* (instead of the “~” or “$\rightharpoonup$” notation)

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

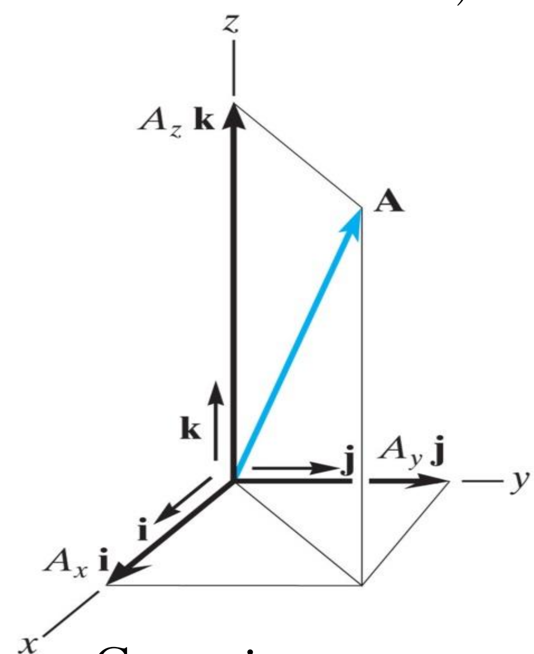


Right-handed coordinate system



Rectangular components of a vector

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



Cartesian vector representation

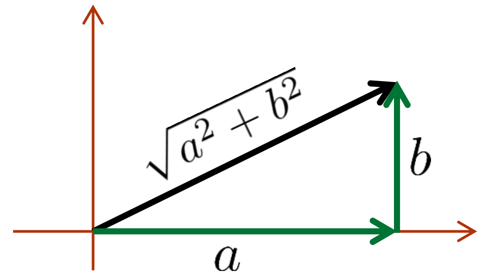
$\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k}$

$\vec{A}_x = A_x\,\hat{\imath}$ ← basis vector

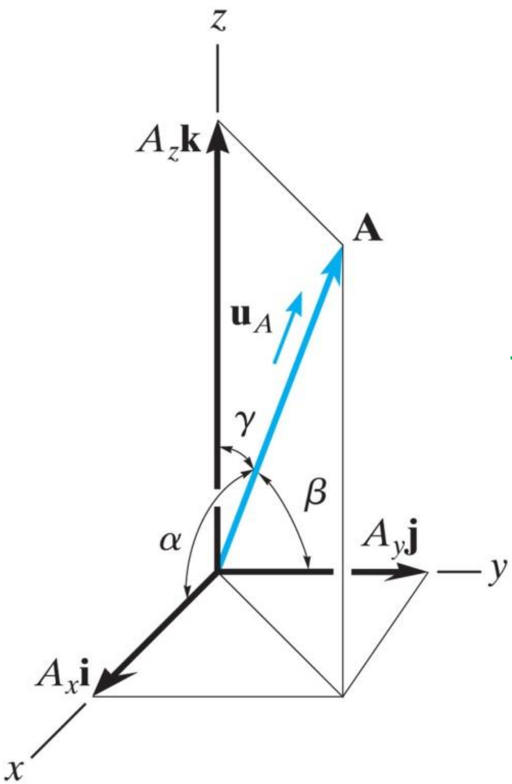
scalar

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**:

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

$$\vec{u}_A = \frac{\vec{A}_x}{|\vec{A}|}\hat{i} + \frac{\vec{A}_y}{|\vec{A}|}\hat{j} + \frac{\vec{A}_z}{|\vec{A}|}\hat{k}$$

A unit vector's magnitude is 1.

Direction cosines are the components of the unit vector: $\cos = \frac{Adj}{Hyp}$

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

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

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

Addition of Cartesian vectors

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