Statics - TAM 211

Lecture 2

September 12, 2018

Announcements

- Go through course website (policies, info, schedule, references)
- MATLAB training sessions TBA (next 2 weeks)
- Upcoming deadlines:
- Tuesday (Sept 18 – due by 11:59 pm)
  - PrairieLearn HW1
  - Take practice Quiz 0 on PrairieLearn (not graded)
  - If you have difficulty logging into PrairieLearn pleases post comment in Blackboard Discussion Board
- Quiz0 (Practice quiz)
  - Practice using PrairieLearn in quiz mode on your computer.
  - Not graded.
  - Should be available within 24 hours

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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!

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

$$[\text{length}] = \frac{[\text{length}]}{[\text{time}]}\cdot[\text{time}] + \frac{[\text{length}]}{[\text{time}^2]}[\text{time}^2]$$

$$[\text{length}] = [\text{length}] + [\text{length}] \checkmark$$

meters
km
feet
inches
miles

m/s

miles per $(\text{hour})^2$

$\underbrace{\qquad\qquad\qquad}_{\text{convert to same units}}$

meters or miles

Numerical Calculations

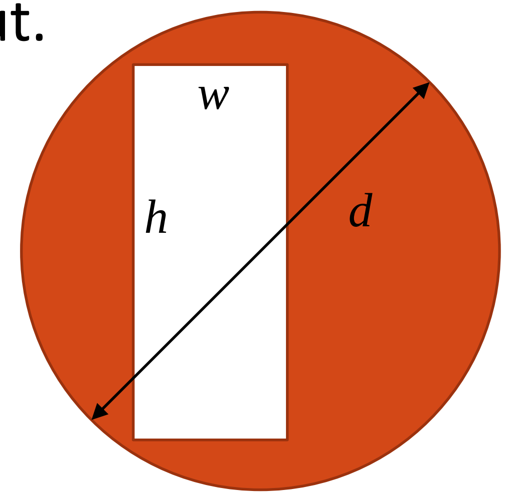
Significant figures

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.



A = 4.227 in
to 3 sign. fig.
$\Rightarrow \boxed{A = 4.23 \text{ in}}$

Examples:

0.5896 → 0.590

0.3762 → 0.376

≥?<5

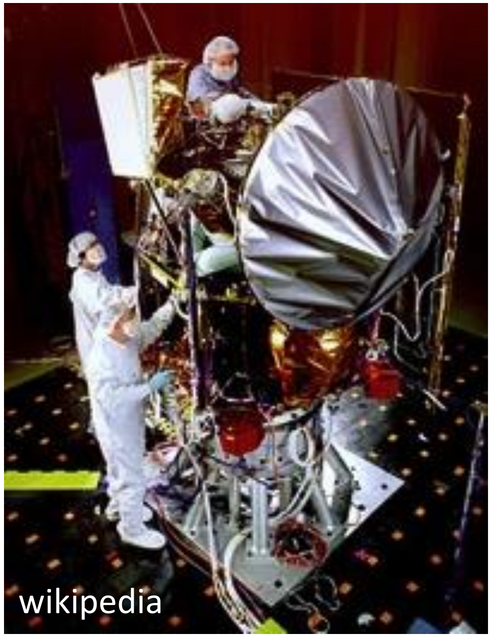
12.783 → 12.8

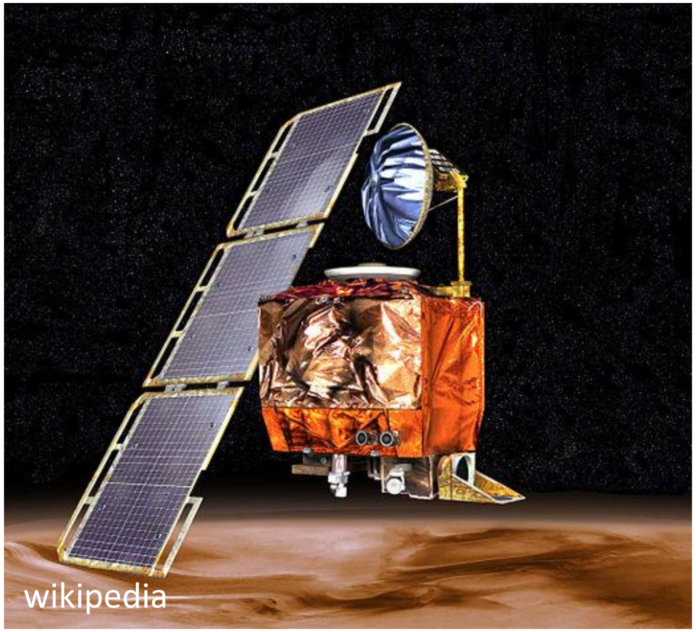
1,040,347.618947 → 1,040,000

Why so picky? Units matter…

- A national power company mixed up prices quoted in kilo-Watt-hour (kWh) and therms. → $1\,kWh = 1\,BTU = 26.3$ 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!

  $1\,gal \approx 3\,\ell \qquad 1\,\ell \approx 0.26\,gal$





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

? Do you know this term?

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
- + cross product
- Introduce the dot product and use it to find the angle between two vectors or the projection of one vector onto another

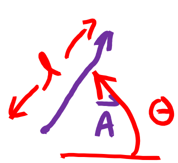
Scalars and vectors

	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: $\mathbf{A}$, $\widetilde{\mathbf{A}}$, $\overrightarrow{\mathbf{A}}$ Bold, tilda, half arrow

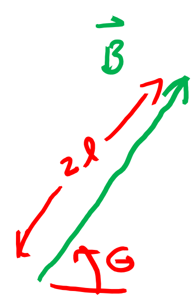
<u>Multiplication or division of a vector by a scalar</u>

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

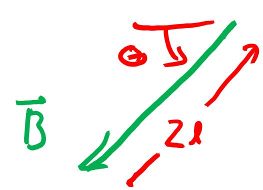
Given vector $\vec{A}$



If $\alpha = 2$, $\vec{B} = ?$

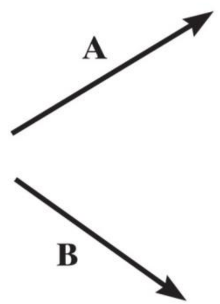


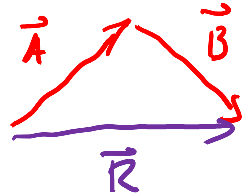
If $\alpha = -2$, $\vec{B} = ?$



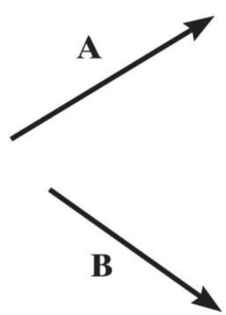
Vector addition

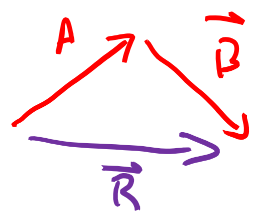
All vector quantities obey the parallelogram law of addition $\vec{\boldsymbol{R}} = \vec{\boldsymbol{A}} + \vec{\boldsymbol{B}}$

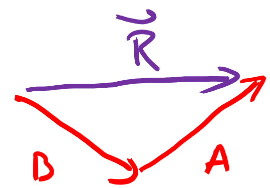




Commutative law: $\boldsymbol{R} = \boldsymbol{A} + \boldsymbol{B} = \boldsymbol{B} + \boldsymbol{A}$





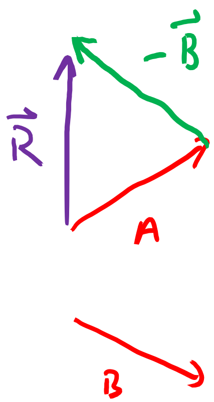


Associative law: $\boldsymbol{A} + (\boldsymbol{B} + \boldsymbol{C}) = (\boldsymbol{A} + \boldsymbol{B}) + \boldsymbol{C}$

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.



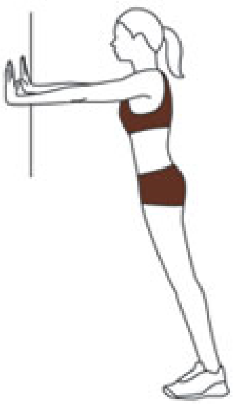
Scalar/Vector multiplication:

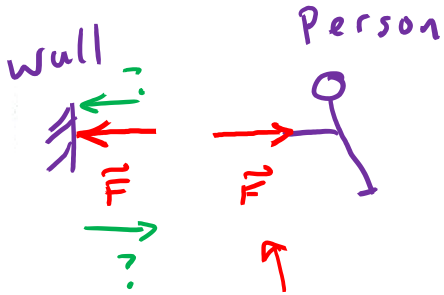
$$\alpha(\boldsymbol{A} + \boldsymbol{B}) = \alpha\vec{A} + \alpha\vec{B}$$

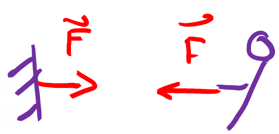
$$(\alpha + \beta)\boldsymbol{A} = \alpha\vec{A} + \beta\vec{A}$$

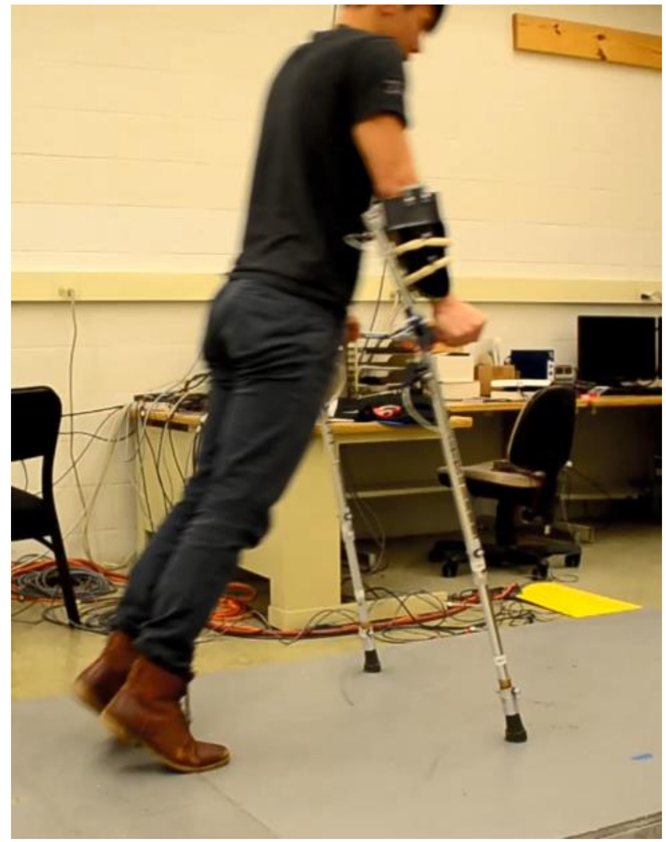
Force vectors

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

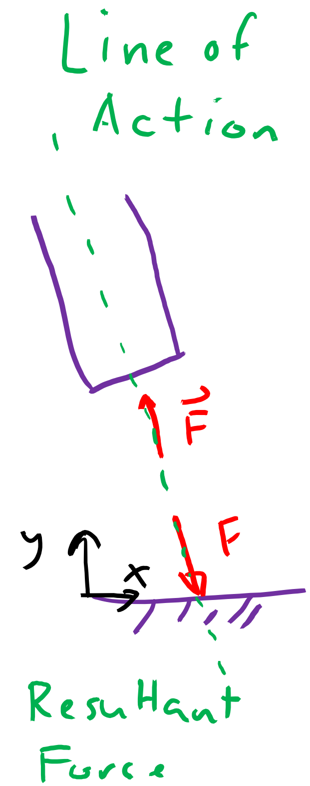


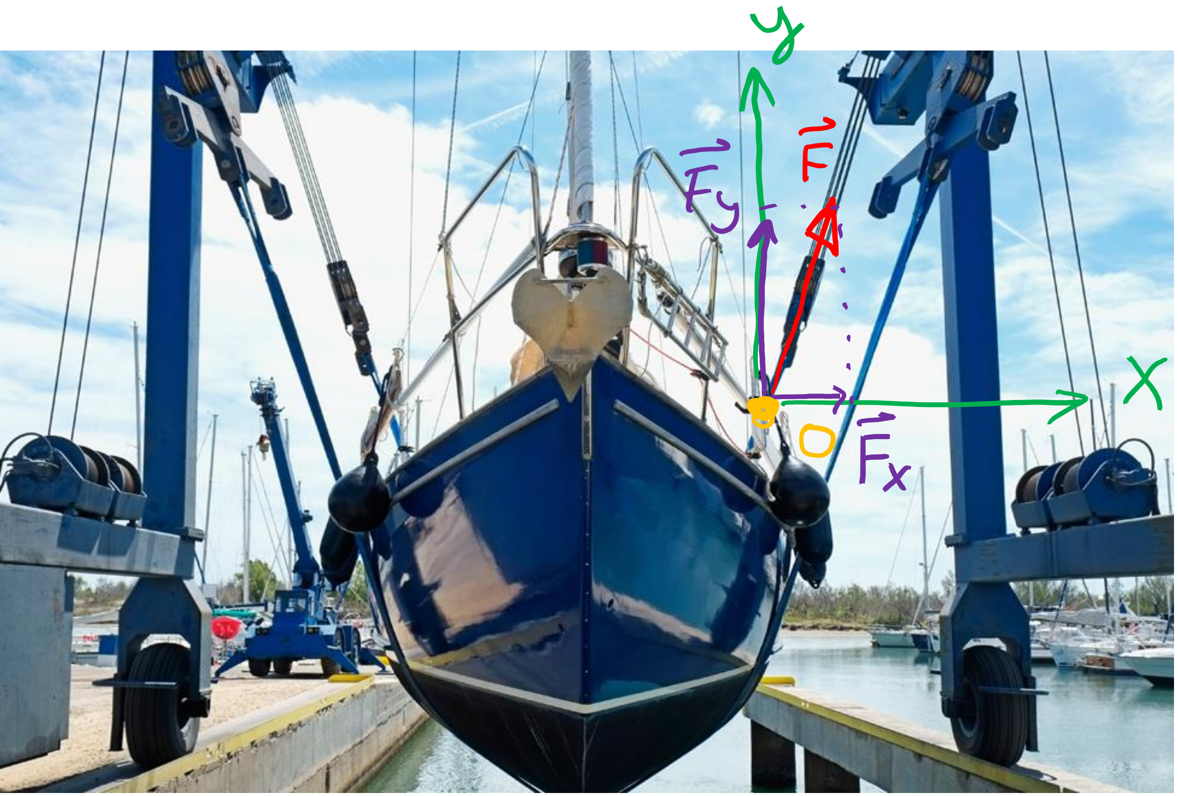






Human Dynamics & Controls Lab





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Generally asked to solve two types of problems.

1. Find the resultant force. $(\vec{F})$

2. Resolve the force into components

$\vec{F}_x$, $\vec{F}_y$

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

Force on boat (at one point O)

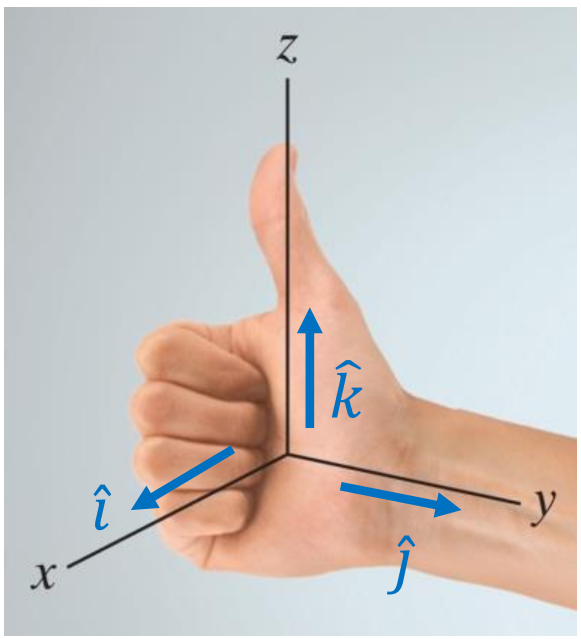
Cartesian vectors

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.

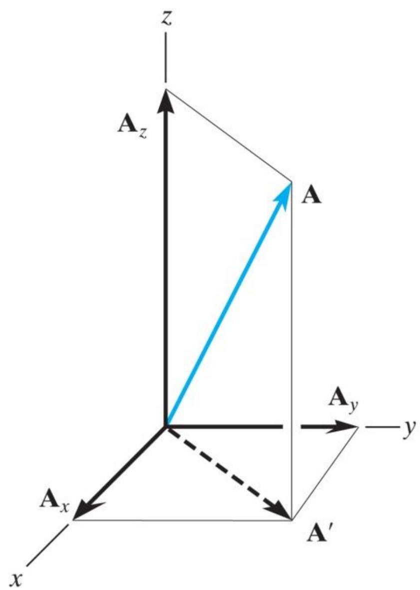
Note that we use the special notation "^" to identify *basis vectors* (instead of the "~" or "$\rightharpoonup$" notation)

hat ^

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



Right-handed coordinate system



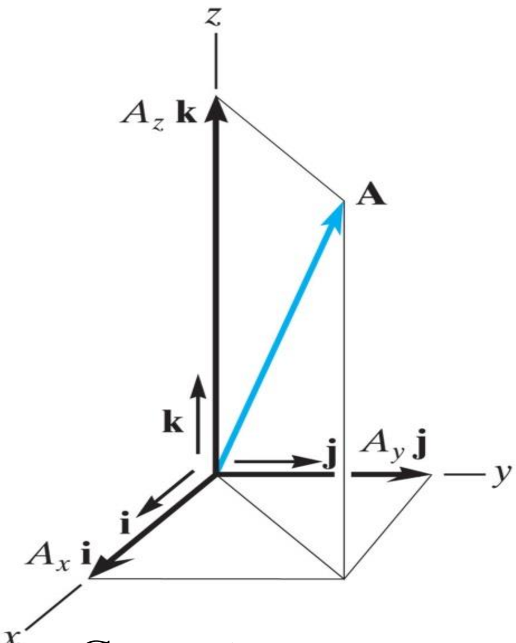
Rectangular components of a vector

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

$\vec{A}_x = A_x \hat{\imath}$

scalar

basis vector



Cartesian vector representation

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

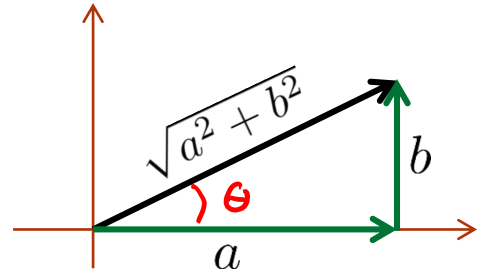
magnitude of $\vec{A}_x$

$= |\vec{A}_x|$

Magnitude of Cartesian vectors

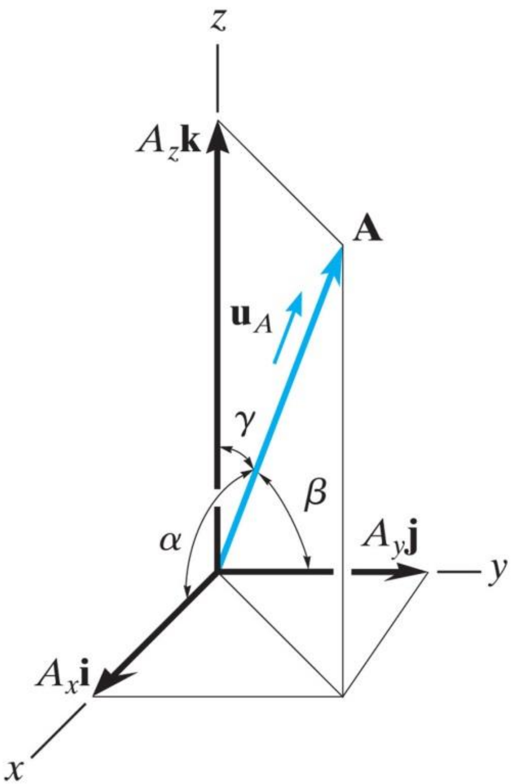
$$A = |\vec{A}| = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

for 3D vector



$\cos\theta = ? = \frac{\text{Adj}}{\text{Hyp}}$

Direction of Cartesian vectors



Expressing the direction using a **unit vector**: ← magnitude of 1

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

$$\vec{u}_A = \frac{A_x}{|\vec{A}|}\hat{i} + \frac{A_y}{|\vec{A}|}\hat{j} + \frac{A_z}{|\vec{A}|}\hat{k}$$

Direction cosines are the components of the unit vector:

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

$$\cos\beta = \frac{A_y}{|\vec{A}|}$$

$$\cos\gamma = \frac{A_z}{|\vec{A}|}$$

Addition of Cartesian vectors

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