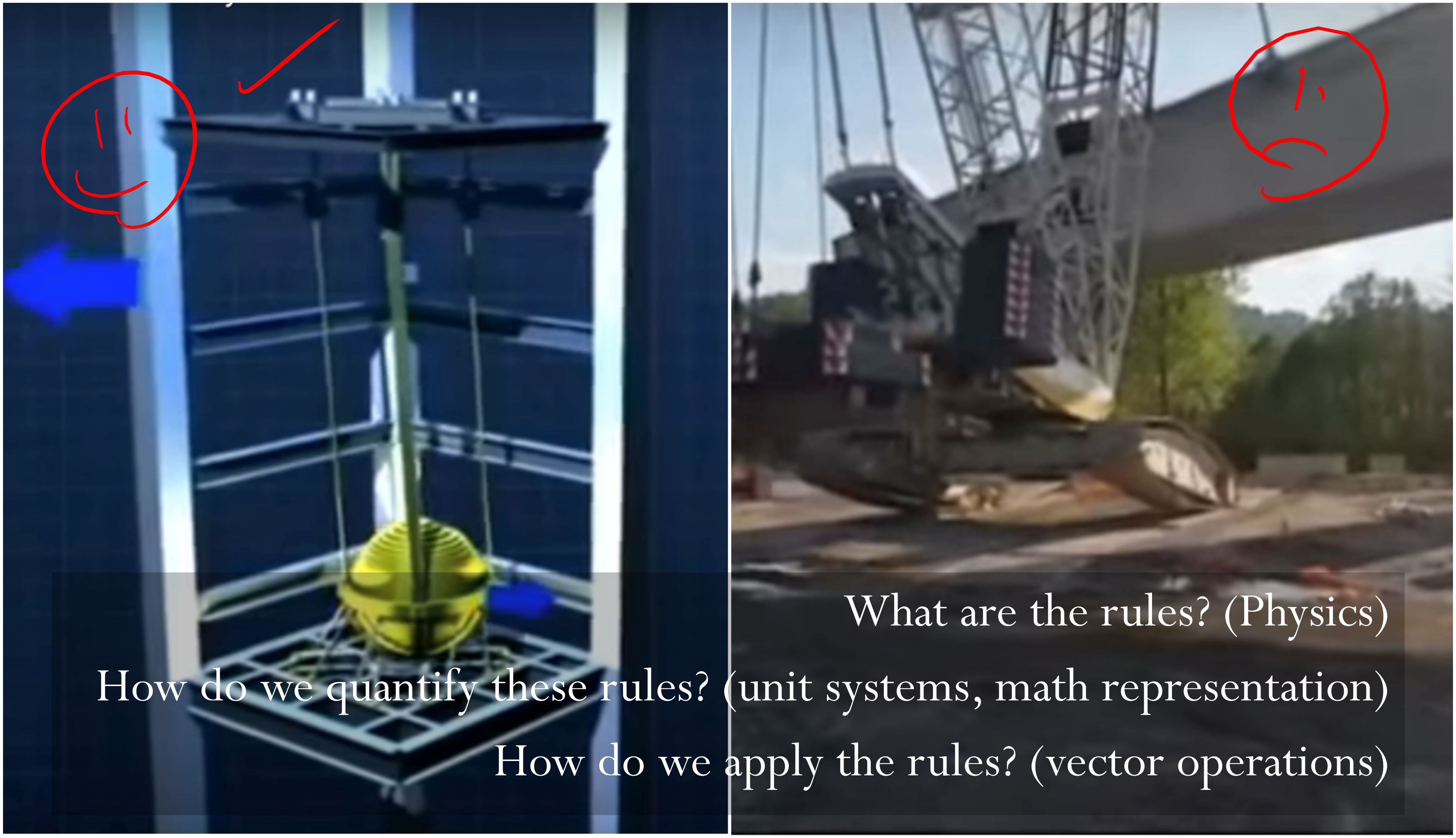
Announcements

- Concept Inventory Pre-test: starts today!
- Got i-Clicker?
- MATLAB clinic will be held in DCL L440 (first session at 5pm today)
- Remember to go through the course website
  - Office hours are posted (Schedule)
- Recommended reading: Hibbeler chapters 1-2

- Upcoming deadlines:
- Friday (9/1)
  - PrairieLearn HW0

From Last Time



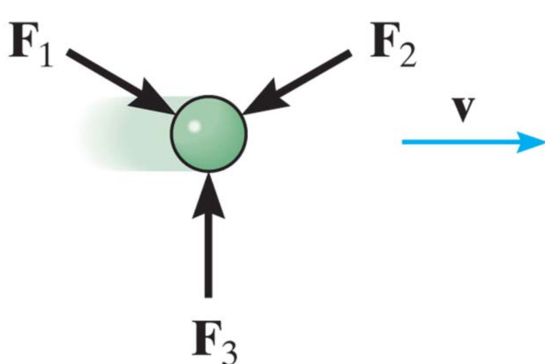
What are the rules? (Physics)

How do we quantify these rules? (unit systems, math representation)

How do we apply the rules? (vector operations)

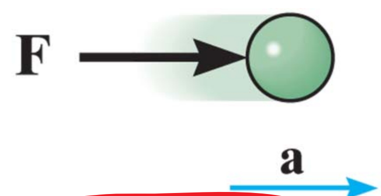
Newton’s laws of motion

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*: for statics

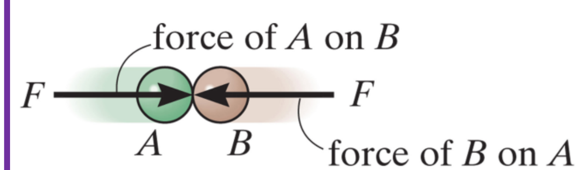
$$F = m\cancel{a}^{0}$$



$$\boxed{\Sigma \vec{F} = 0}$$

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


www.ashvegas.com

Which forces?

- gravity ✓ + "contact" for statics
- normal ✓
(- electwomag)
(- strong/weak)
- fiction ✓

⋮

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

m is mass

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

$$F = G\frac{m M_e}{r_e^2} = m\underbrace{\left(G\frac{M_e}{r_e^2}\right)}_{= g}$$

g: earth grav. constant

M_e is the mass of the earth

r_e is the distance between the earth's center and the particle near the surface (at sea level & latitude 45°)

g is the acceleration due to the gravity

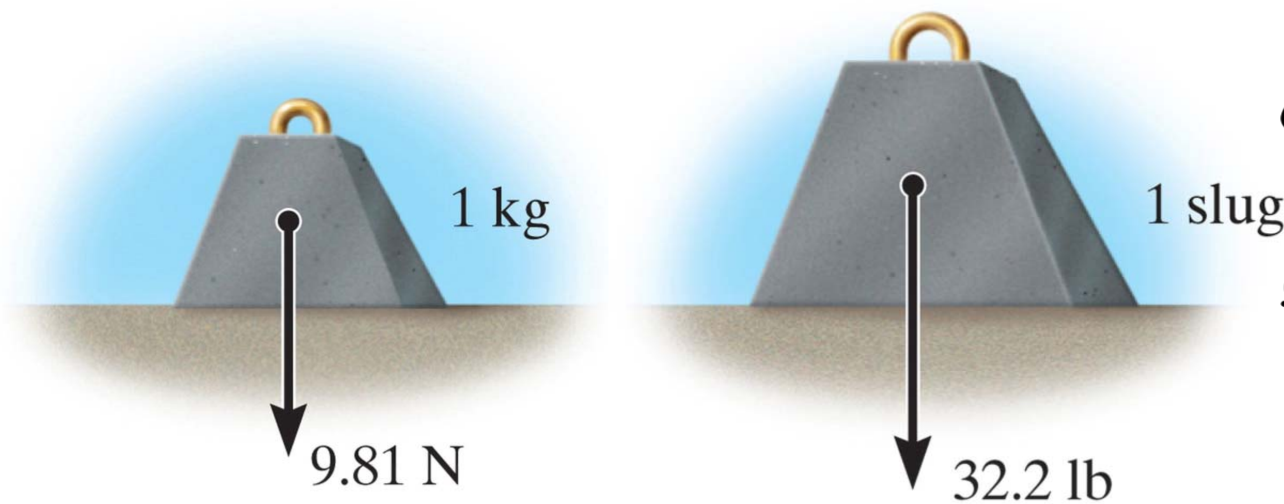
Figure: 01_PH003
The astronaut's weight is diminished, since she is far removed from the gravitational field of the earth.

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.



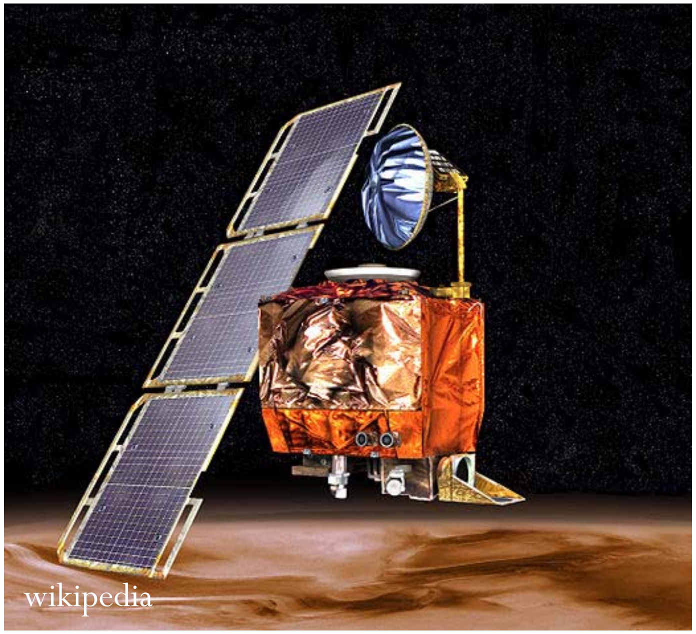
$$G = 66.73 \times 10^{-12} \frac{m^3}{kg \cdot s^2}$$

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

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

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

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!

Example: Find the units of *G* (the universal constant of gravitation).

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

$$[N] = [?]\frac{[kg][kg]}{[m]^2}$$

$$\Rightarrow \frac{[kg][m]}{[s]^2} = [?]\frac{[kg][kg]}{[m]^2}$$

$$\Rightarrow [?] = \frac{[\cancel{kg}][m][m]^2}{[s]^2[kg][\cancel{kg}]}$$

$\Rightarrow$ units of $G = \frac{m^3}{kg \cdot s^2}$ ✓

- same as slide 6

Numerical Calculations

Significant figures

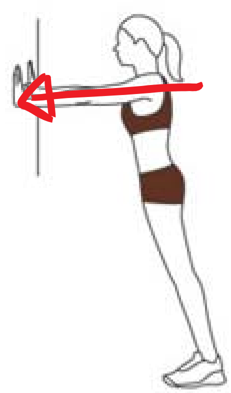
The number of significant figures contained in any number determines the accuracy of the number. Use 3 or > significant figures for final answers. For intermediate steps, use symbolic notation, store numbers in calculators or use more significant figures, in order to maintain precision.

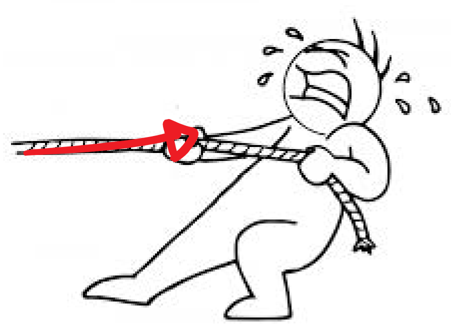
- Prairie Learn accepts 1% tolerance.

Eg. If $F = 2.18N$, 2.18 ± 0.0218 N range would be accepted, which requires at least 3 sig. fig.

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: $\mathbf{F}$, $\vec{F}$

$\vec{F} \neq ab$ $\quad\quad$ $\vec{F} = ab\vec{c}$

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

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

$\vec{A}$

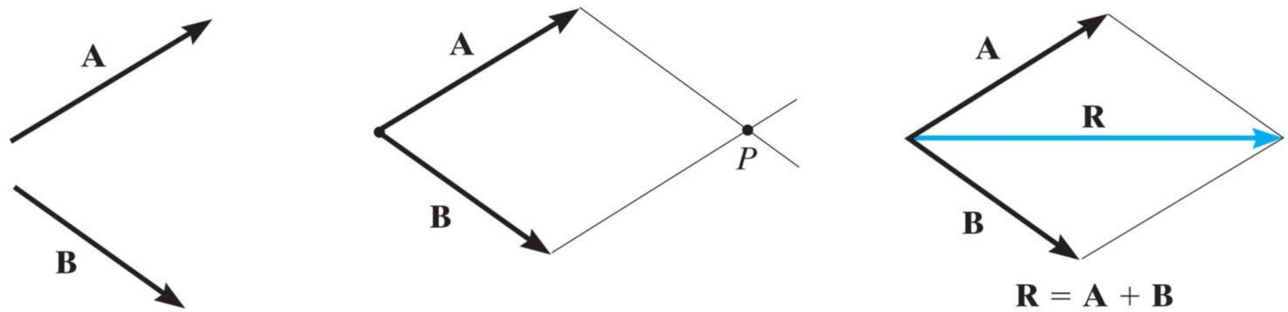
(magnitude doubles, keeps direction the same)

$-\vec{A}$

(reverse direction only)

Vector addition

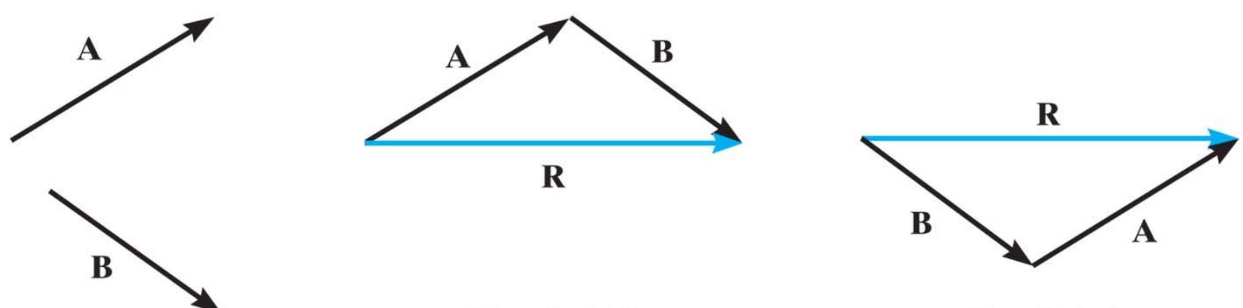
All vector quantities obey the parallelogram law of addition $\boldsymbol{R} = \boldsymbol{A} + \boldsymbol{B}$



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

Parallelogram law

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



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

Triangle rule

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

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:

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

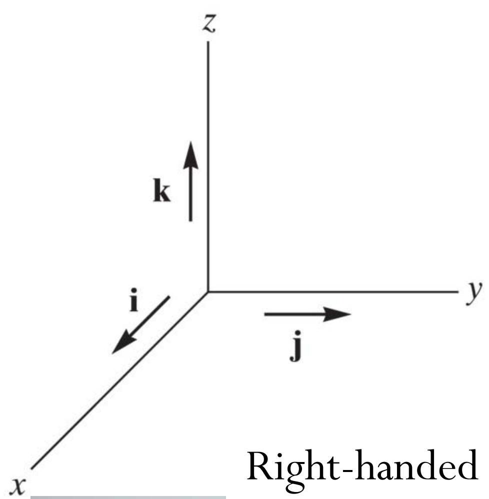
$$(\alpha + \beta)\boldsymbol{A} = \alpha\,\boldsymbol{A} + \beta\,\boldsymbol{A}$$

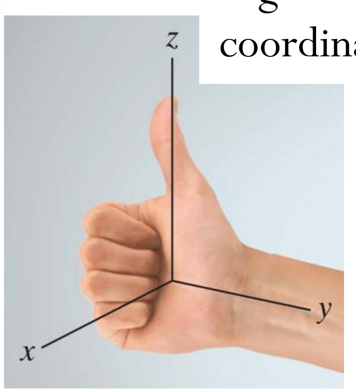
Cartesian vectors

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.

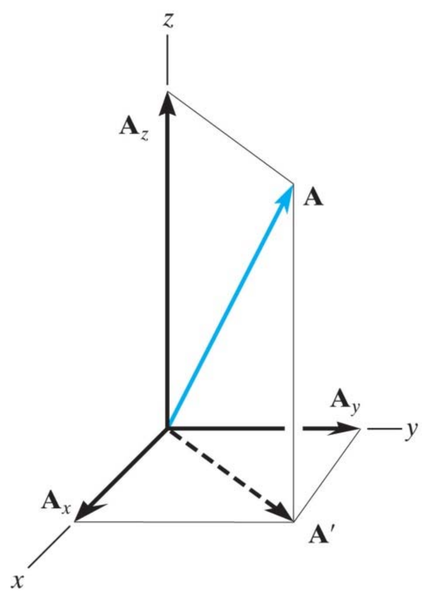
Note that we use the special notation "^" to identify *basis vectors* (instead of the "→" notation)

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

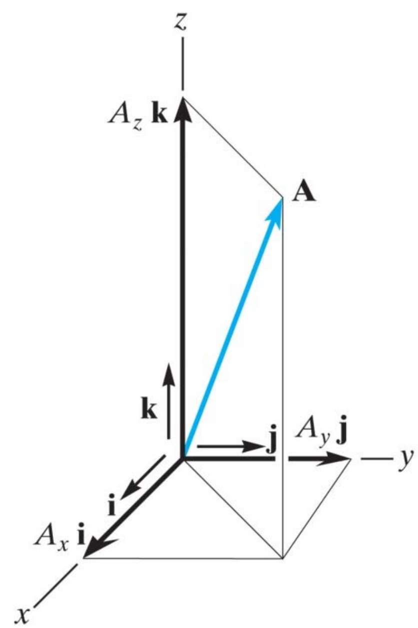




Right-handed coordinate system



Rectangular components of a vector



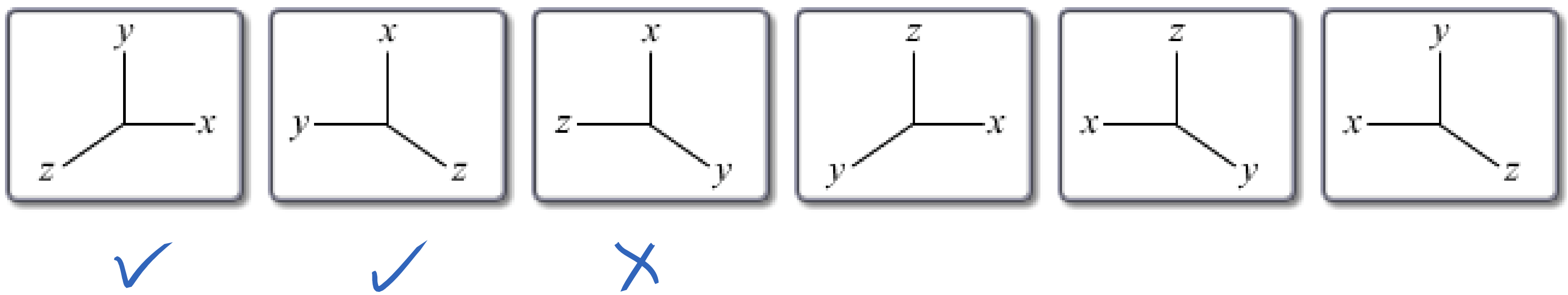
Cartesian vector representation

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

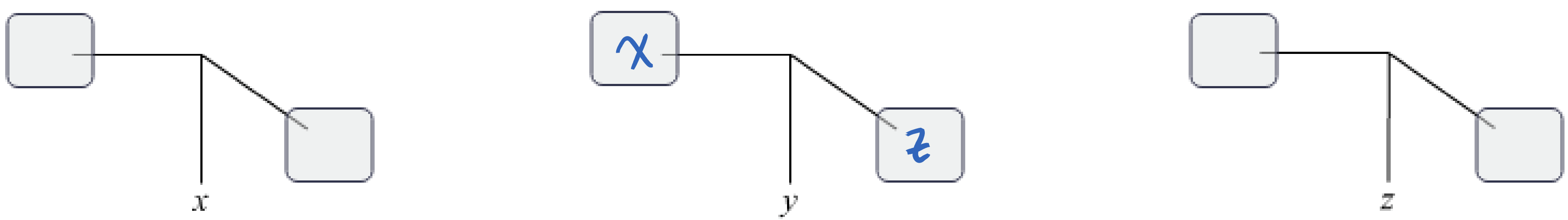
$\vec{A}_x = A_x\hat{i}$ $\quad \vec{A}_y = A_y\hat{j}$ $\quad \vec{A}_z = A_z\hat{k}$

Right-hand Rule

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

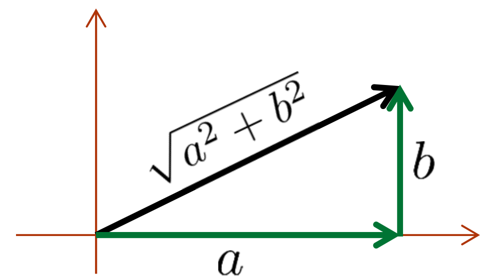


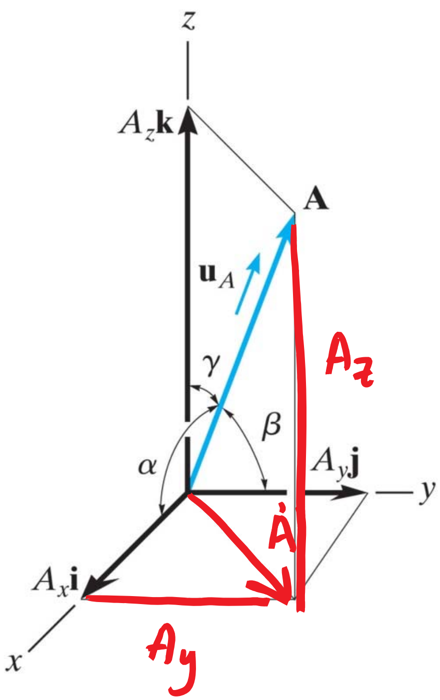
Label the missing coordinate axes in Cartesian coordinate system.



Magnitude of Cartesian vectors

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





$$A' = \sqrt{A_x^2 + A_y^2}$$

$$A = \sqrt{A'^2 + A_z^2}$$

$$= \sqrt{(A_x^2 + A_y^2) + A_z^2}$$

Direction of Cartesian vectors

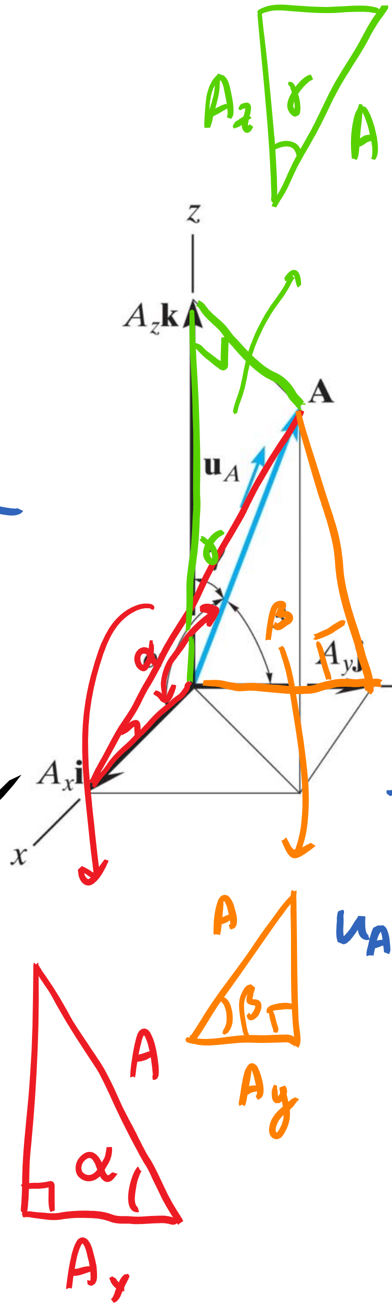
Expressing the direction using a unit vector:

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

$$u_A = \left(\frac{A_x}{A}\right)^2 + \left(\frac{A_y}{A}\right)^2 + \left(\frac{A_z}{A}\right)^2$$

$$= \frac{A_x^2 + A_y^2 + A_z^2}{A^2} = 1 \checkmark$$

(magnitude = 1)



Direction cosines are the components of the unit vector:

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

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

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

$$\hat{u}_A = \cos\alpha\,\hat{i} + \cos\beta\,\hat{j} + \cos\gamma\,\hat{k}$$

$$u_A = \cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$$

(magnitude = 1)