Theme 1
Introductory Material

Module T1M1:
The Predictable Universe

Vectors

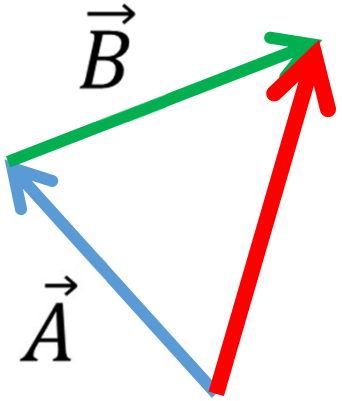
- Scalars
  - Answers a question like:
    - How hot?
    - How heavy?
    - How far can you throw the person sitting next to you?
- Vectors
  - Used when a number doesn't give enough info
    - Velocity $\vec{v} = 20\ m/s$ [north]

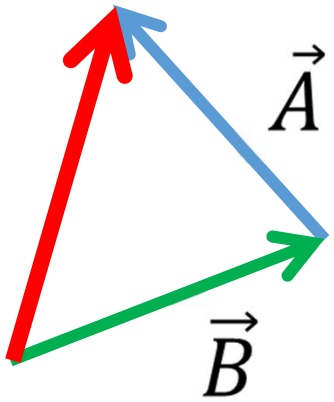
You will want to become comfortable with vector addition & subtraction, and in particular, working with vector components

Vector Addition

- When adding vectors, line them up ‘tip-to-tail’

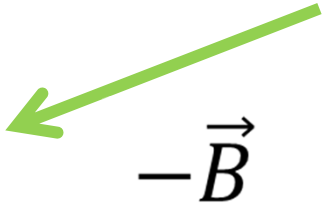
$$\vec{A}+\vec{B} = \vec{B}+\vec{A}$$



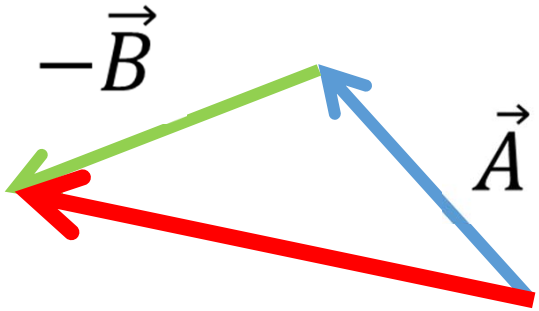


Vector Subtraction

- What about $\vec{A} - \vec{B}$?
  - Let's create a vector $-\vec{B}$
- Now we can simply add:

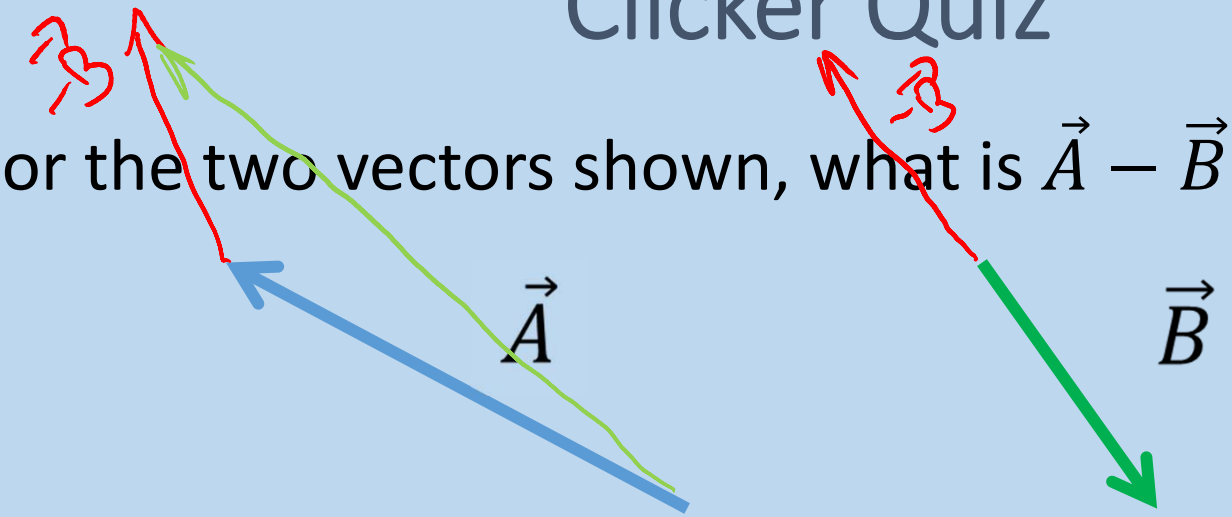


$$\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$$

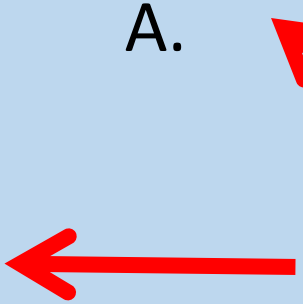


Clicker Quiz

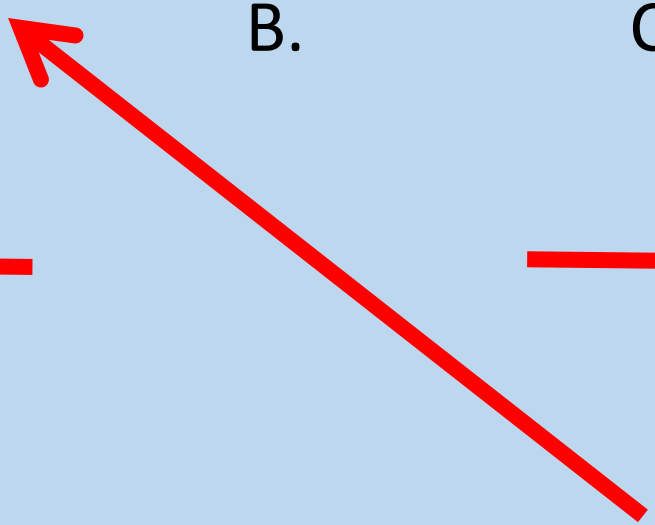
- For the two vectors shown, what is $\vec{A} - \vec{B}$



A.

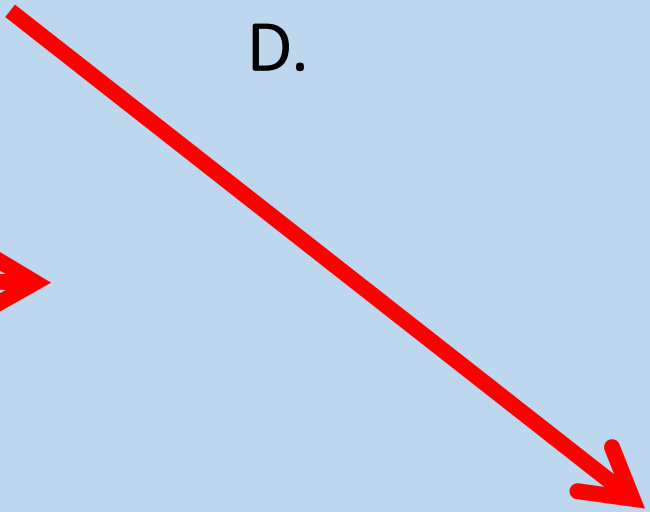


B.

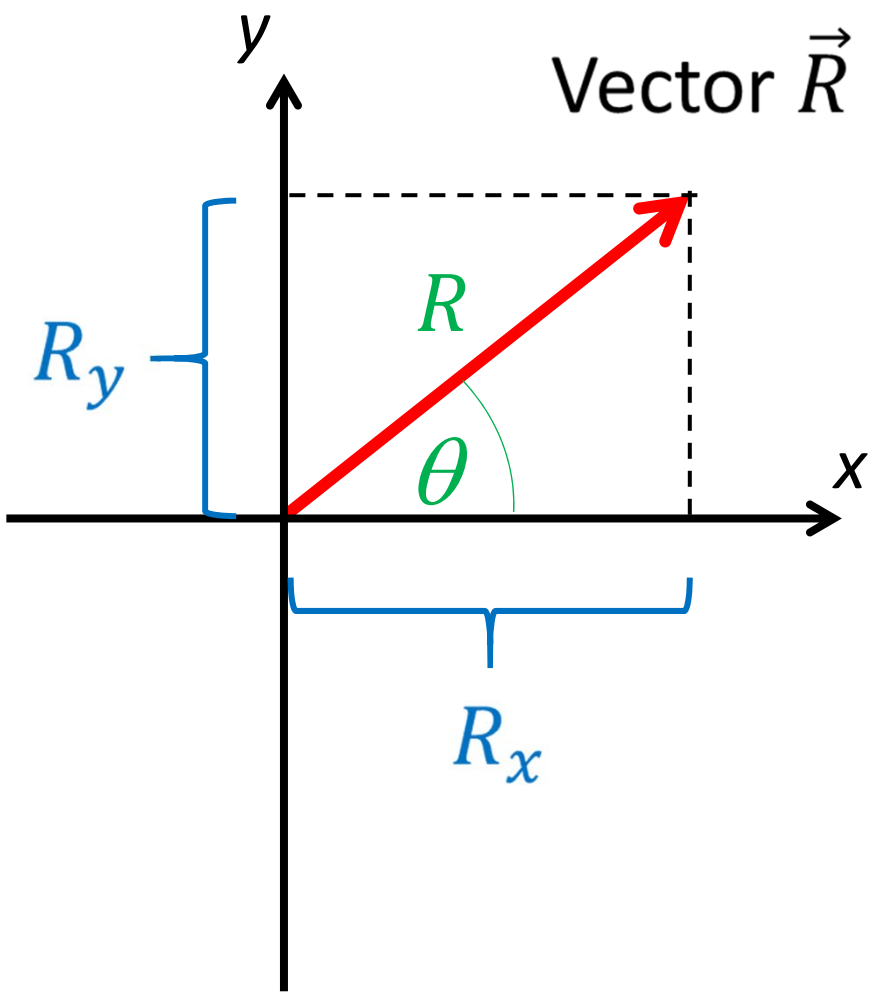


C.

D.



Vector Notation



1) $\vec{R} = (R, \theta)$

- $R = |\vec{R}|$ is the 'magnitude'
- θ is the direction, relative to the +x axis

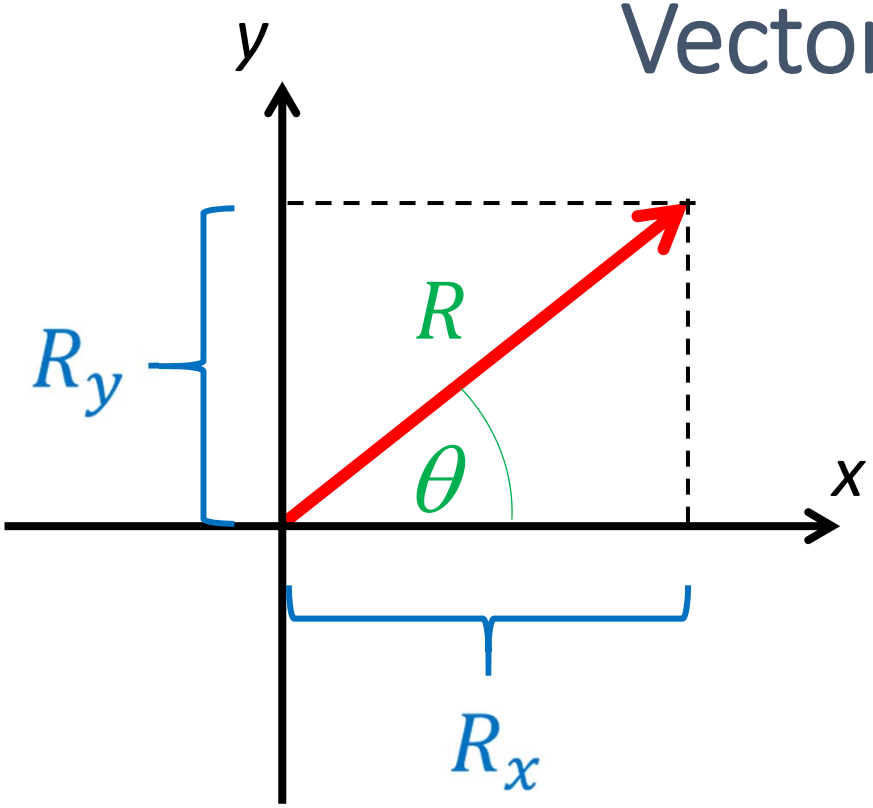
2. $\vec{R} = (R_x, R_y)$

- ***"vector components"***
- Sometimes also write

$$\vec{R} = R_x\hat{\imath} + R_y\hat{\jmath}$$

where $\hat{\imath}$ and $\hat{\jmath}$ indicate the +x and +y directions

Vector Notation



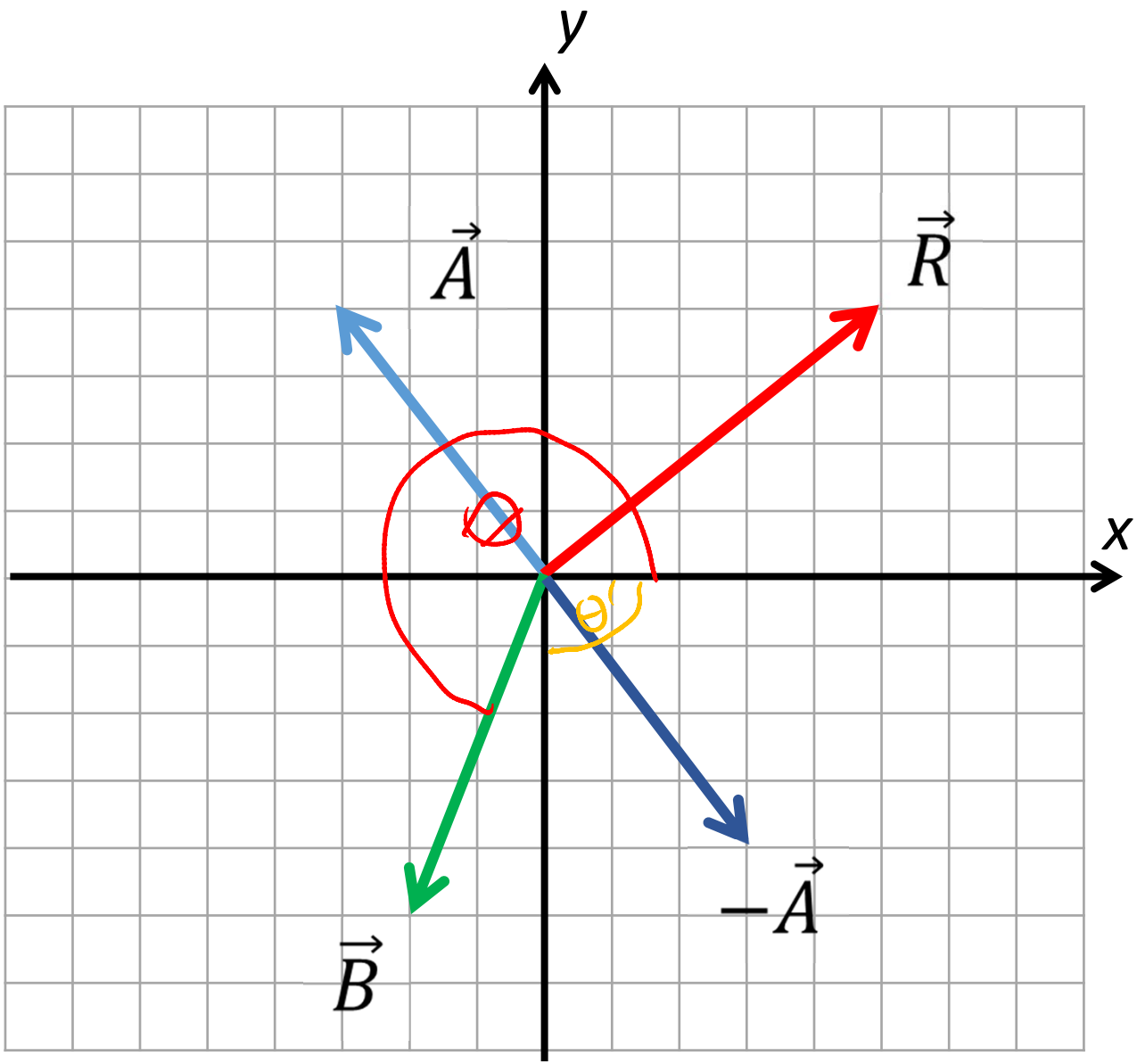
1. $(R, \theta) \rightarrow (R_x, R_y)$

- $R_x = R\cos(\theta)$
- $R_y = R\sin(\theta)$

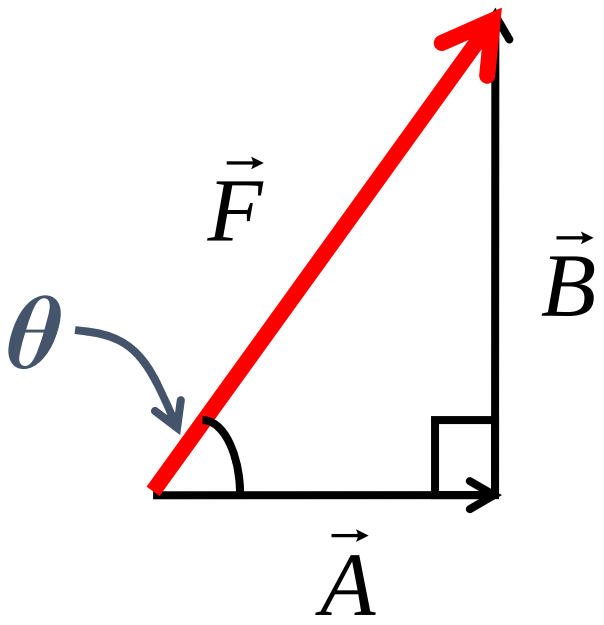
2. $(R_x, R_y) \rightarrow (R, \theta)$

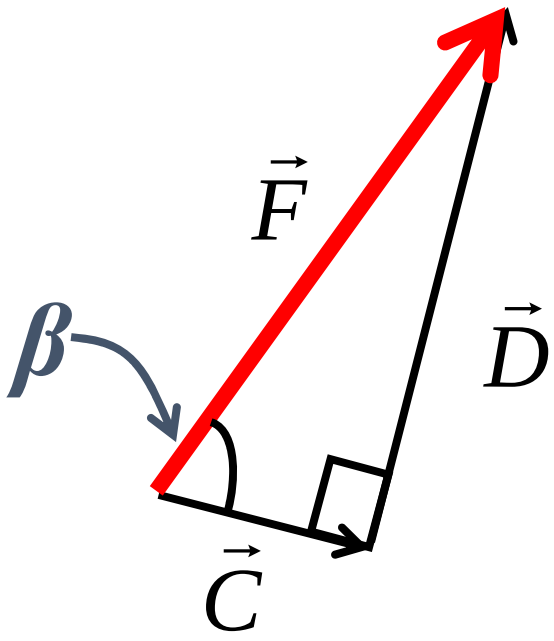
- $R = \sqrt{(R_x)^2 + (R_y)^2}$
- $\tan(\theta) = \frac{R_y}{R_x}$

Vector Notation



Vector Components





$$\vec{F} = \vec{A} + \vec{B}$$

$$\left|\vec{A}\right| = F\cos\theta$$

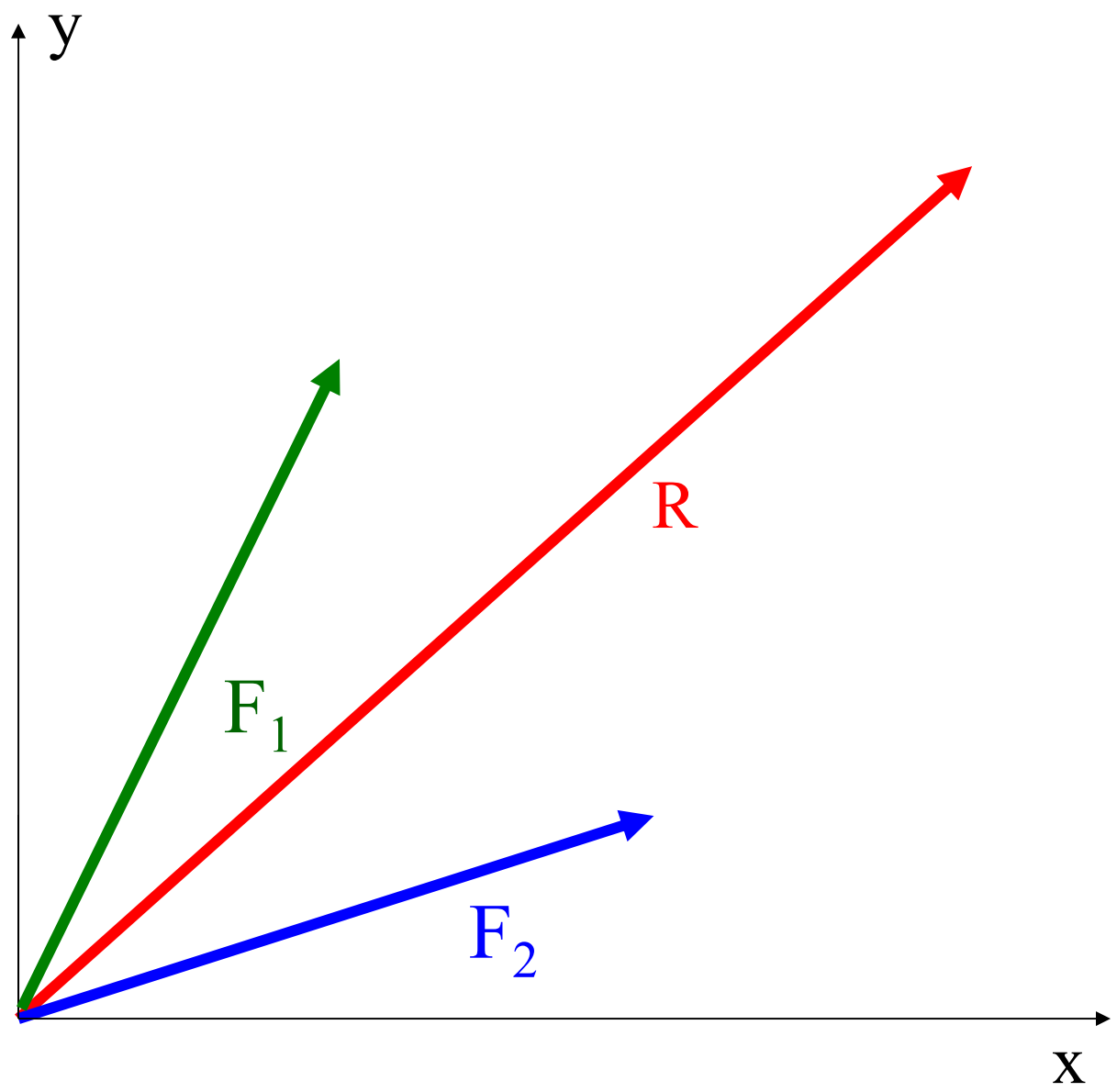
$$\left|\vec{B}\right| = F\sin\theta$$

$$\vec{F} = \vec{C} + \vec{D}$$

$$\left|\vec{C}\right| = F\cos\beta$$

$$\left|\vec{D}\right| = F\sin\beta$$

Adding two vectors using components



Adding two vectors using components

$$F_{2x} = F_2 \cos\alpha$$

$$F_{2y} = F_2 \sin\alpha$$

$$F_{1x} = F_1 \cos\beta$$

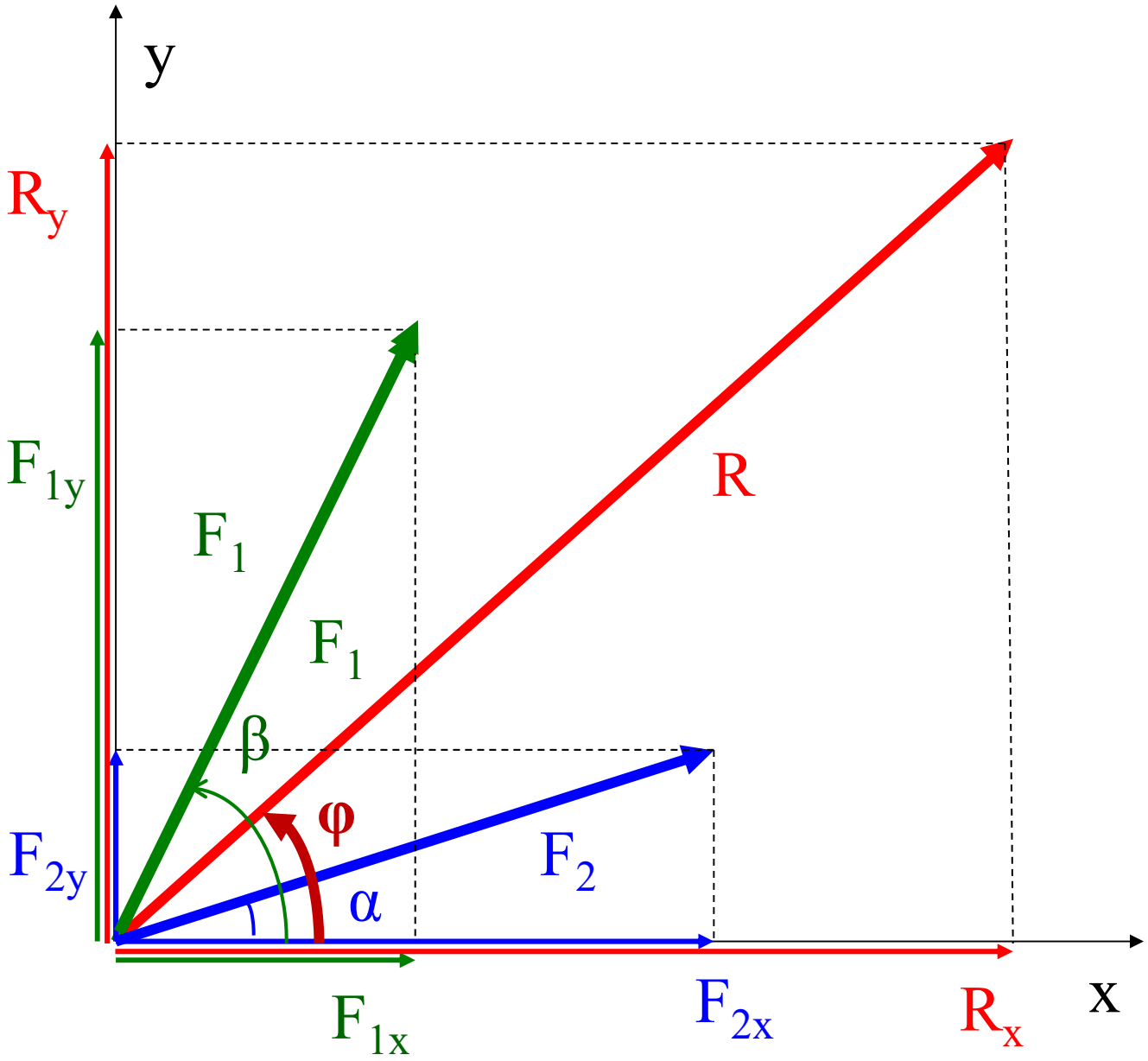
$$F_{1y} = F_1 \sin\beta$$

$$R_x = F_{1x} + F_{2x}$$

$$R_y = F_{1y} + F_{2y}$$

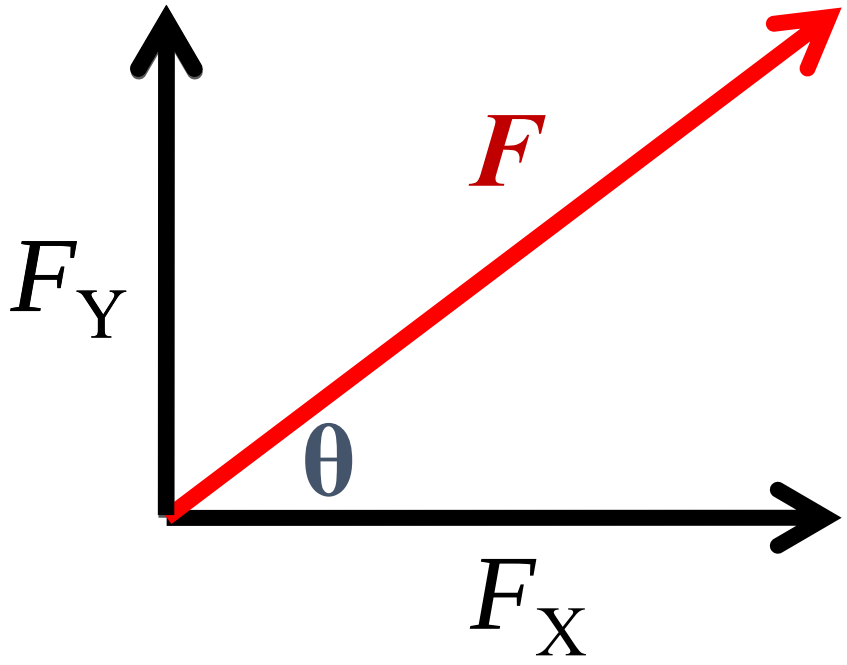
$$R = \sqrt{R_x^2 + R_y^2}$$

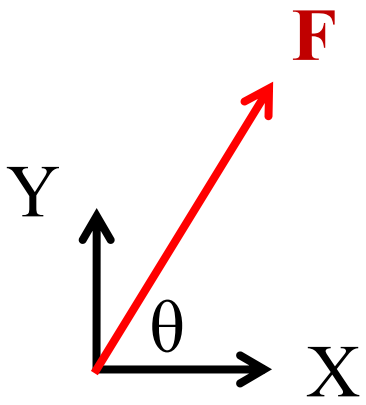
$$\tan\varphi = R_y / R_x$$



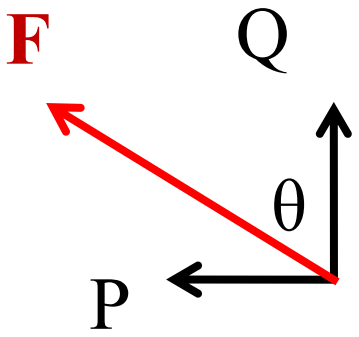
sin(θ) or cos(θ)?

SOH CAH TOA	PEN SWIPE
• **S**in = **O**pposite/**H**ypoteneuse • **C**os = **A**djacent/**H**ypoteneuse • **T**an = **O**pposite/**A**djacent	• Swipe over θ gives ‘cos’ • Swipe away from θ gives ‘sin’

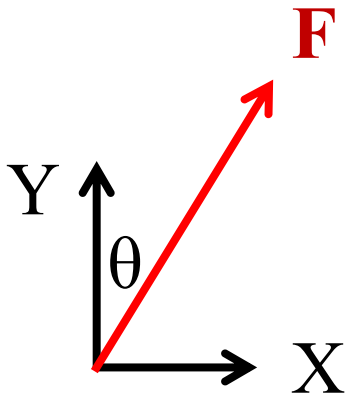




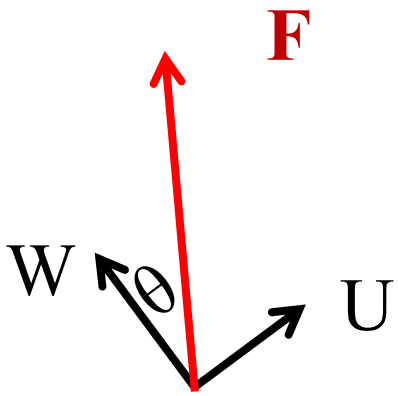
$F_X = F\cos(\theta)$



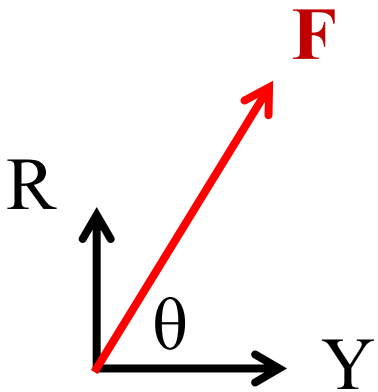
$F_Q = F\cos(\theta)$



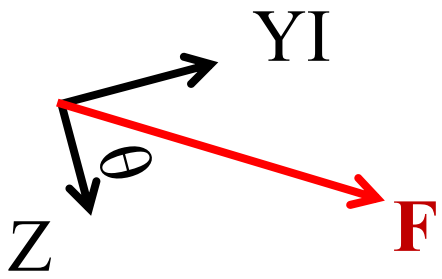
$F_Y = F\cos(\theta)$



$F_U = F\sin(\theta)$



$F_R = F\sin(\theta)$



$F_{YI} = F\sin(\theta)$

Theme 1
Introductory Material

Module T1M2:
Precision and Estimation

Learning Objectives

- Recognize that the presentation of a numerical quantity, using **significant figures** and **scientific notation**, reflects the accuracy of a measurement.
- Carry the appropriate significant figures through simple arithmetic calculations.
- Appreciate the importance of **estimating unknown quantities** as a means of understanding a system and predicting outcomes.
- Develop the skill of making an estimate and performing '**order of magnitude' approximations**.

Significant Figures

- When expressing a quantity, we want to communicate how precisely we know its value

- Example: My height is 16.705423 green fingers

- Is this a trustworthy statement?

- We usually count as ***"significant"*** all digits up to the first uncertain one
  - Based on how the measurement was made
  - Could be statistically determined (result of variations observed over successive measurements)

Significant Figures

- For a properly written quantity

  - 43.84
  - 27

  Non-zero digits are typically assumed to be significant

  - 5.0502
  - 2001

  Zeroes on the interior of a number are significant

  - 14.50
  - 270.

  Zeros on the right side of the number are typically significant

  - 0.013
  - 0.04710
  - 270

  The exception: sometimes zeros are used as placeholders, and are not significant.

How many sig figs?

Assuming these quantities have been properly expressed, how many significant figures does each have?

- 26.38 (4 *sig figs*),
- 27 (2 *sig figs*),
- 0.005**00** (3 *sig figs*),
- 0.03**0**4**0** (4 *sig figs*),
- 3.**0**88**0** (5 *sig figs*),
- 0.00418 (3 *sig figs*),
- 3.2088×10^6 (5 *sig figs*).

Sig Figs & Arithmetic

- When **adding/subtracting** quantities which have a specific number of significant figures

  the number of decimal places in our answer must match that of the least reliable measurement

- Examples:

a) 2.54 cm + 1.2 cm = ? = 3.7 cm (Not 3.74)

b) 7.432 cm + 2 cm = ? = 9 cm (Not 9.432)

- Don't forget to round!

c) 7.632 cm + 2 cm = ? = 10 cm (Not 9.632)

Sig Figs & Arithmetic

- When **multiplying/dividing** quantities which have a specific number of significant figures

  the number of significant figures in our answer must match that of the least reliable measurement

- Example:

a) $56.78\ \text{cm} \times 2.45\ \text{cm} = ?$

$= 139\ \text{cm}^2$ (Not $139.111\ \text{cm}^2$)

b) $813.2\ \text{m} \div 35\ \text{s} = ?$

$= 23\ \text{m/s}$ (Not $23.234\ \text{m/s}$)

Sig Figs & Scientific Notation

- What about this one?

a) $8132\ m \div 35\ s = ?$

$= 232\ m/s\ ?$

$= 230\ m/s\ ?$

Use Scientific Notation: $8132\ m \div 35\ s = 2.3 \times 10^2\ m/s$

Clicker Quiz

- How many significant figures should be written in the sum of:

14.65 g +9.023 g + 850.0078 g + 26540.4390 + 0.80 g?

A. 3
B. 4
C. 5
D. 6
E. 7