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 $v = 20\ m/s$ [north]

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

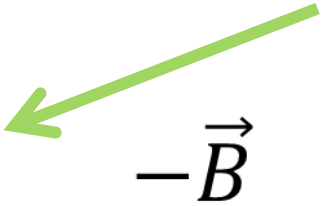
Vector Addition

- When adding vectors, line them up 'tip-to-tail'

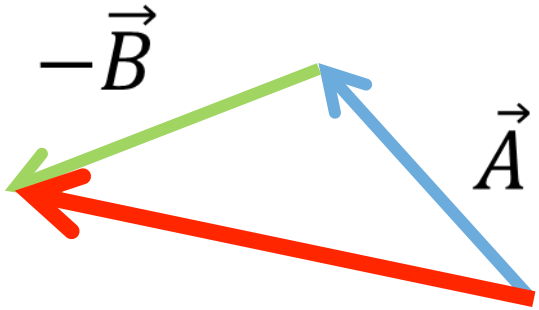
$$\vec{A}+\vec{B} = \vec{B}+\vec{A}$$

Vector Subtraction

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

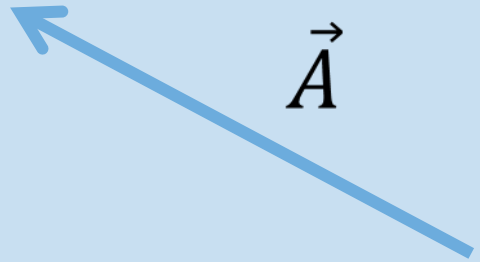


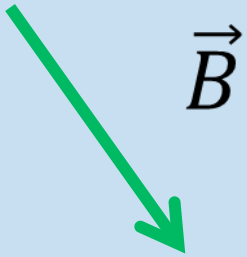
$$\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$$



Clicker Quiz

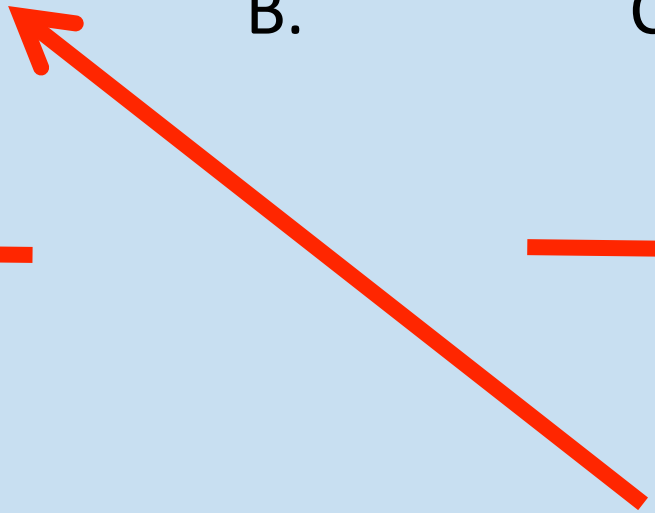
- For the two vectors shown, what is $\vec{A} + \vec{B}$





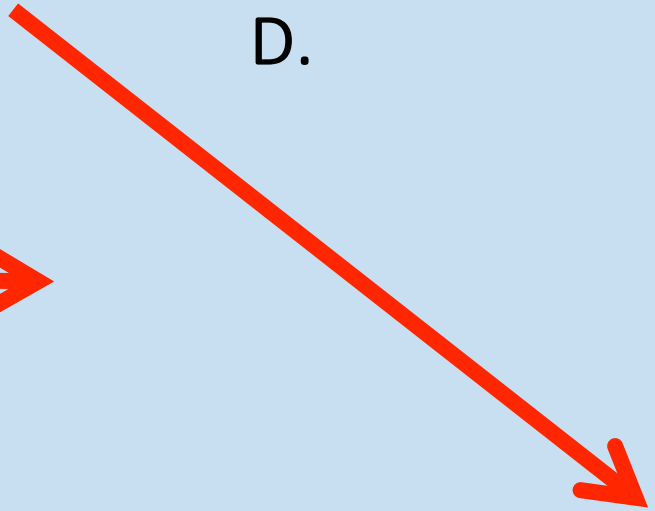
A.

B.



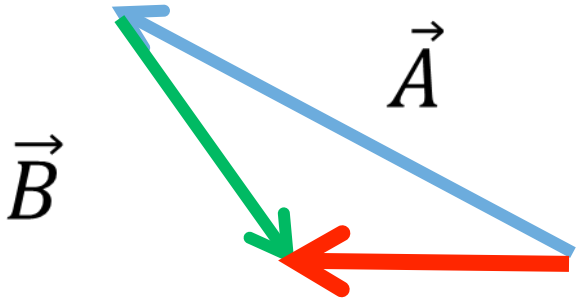
C.

D.



Clicker Quiz

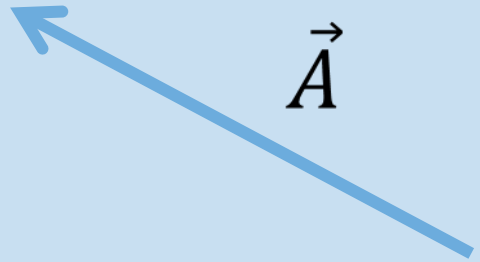
- For the two vectors shown, what is $\vec{A} + \vec{B}$

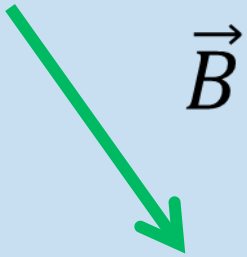


A. Is the answer

Clicker Quiz

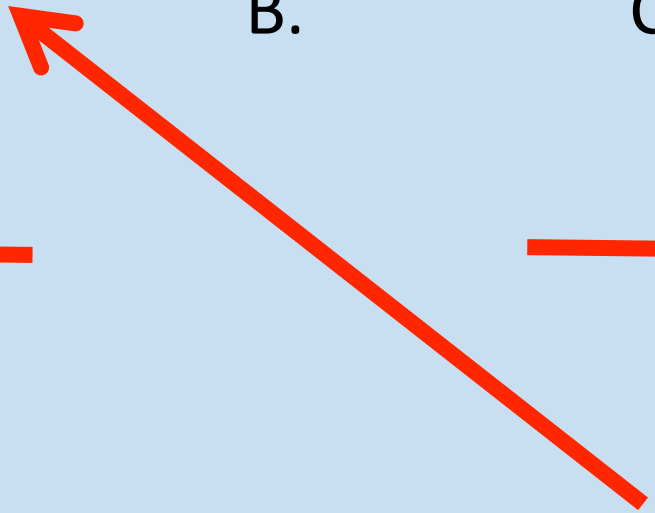
- For the two vectors shown, what is $\vec{A} - \vec{B}$





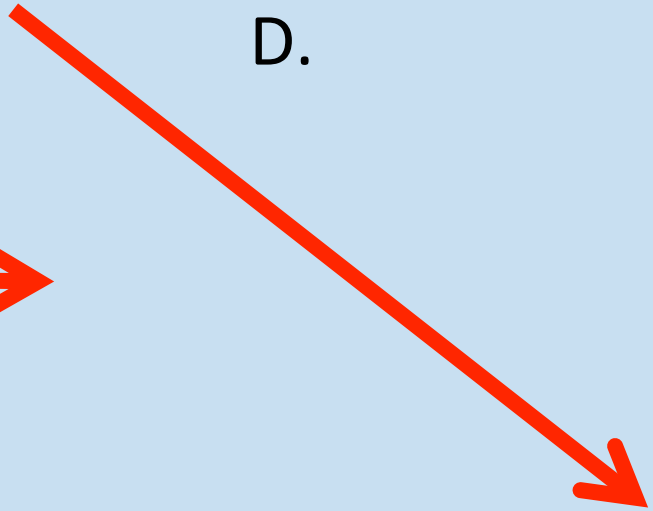
A.

B.



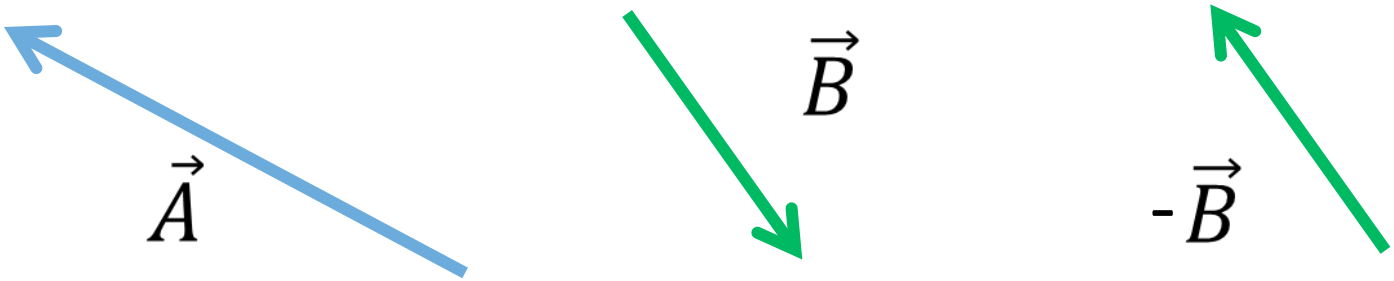
C.

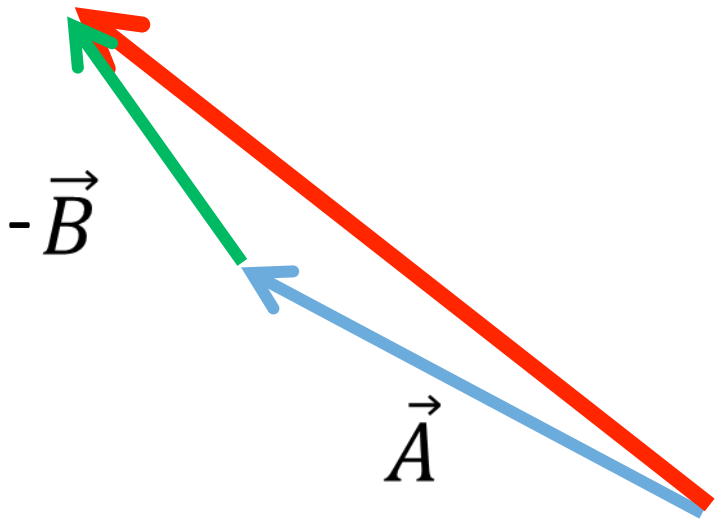
D.



Clicker Quiz

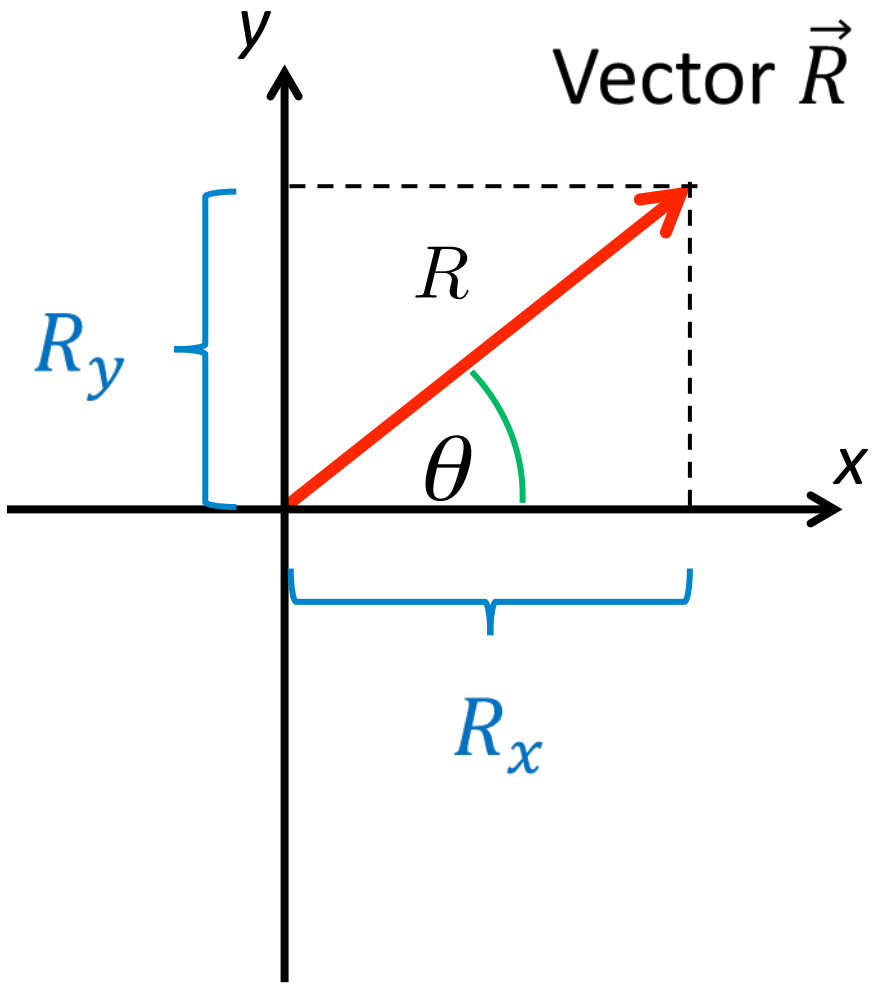
- For the two vectors shown, what is $\vec{A} - \vec{B}$





B. is the answer

Vector Notation



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

$R = |R|$ is the 'magnitude'

θ is the direction, relative to the $+x$ axis

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

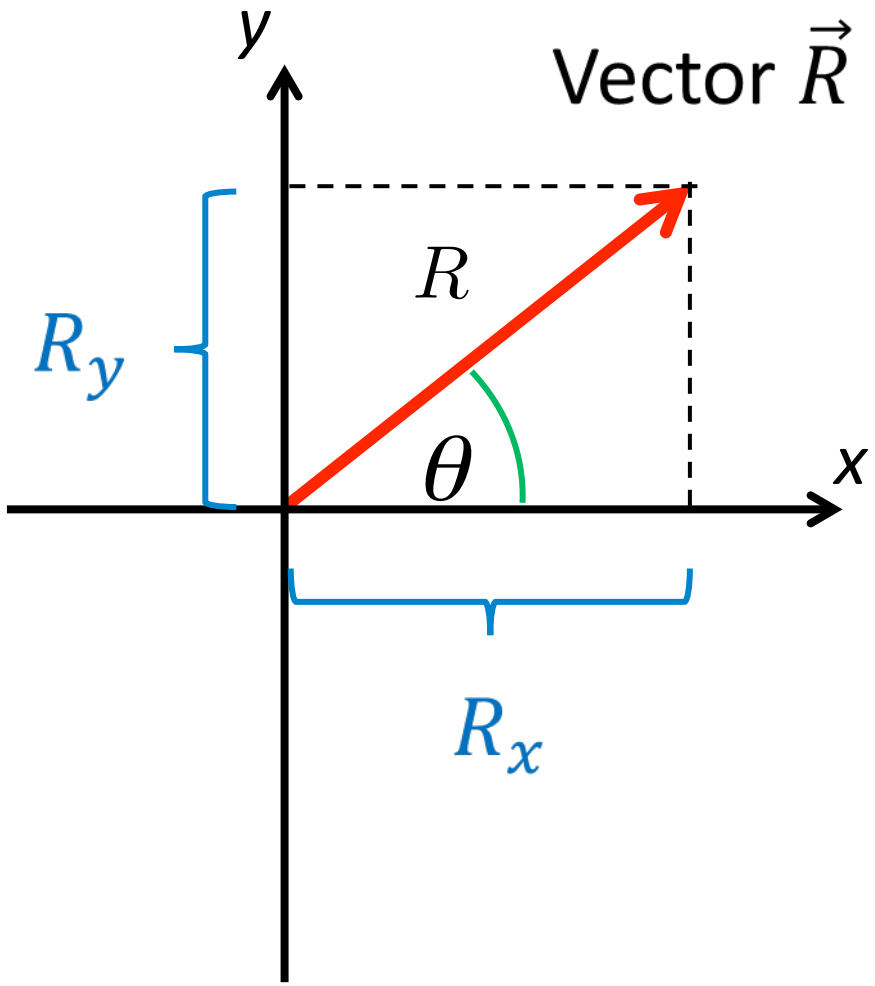
"vector components"

Sometimes also write:

$\vec{R} = R_x\hat{i} + R_y\hat{j}$

where $\hat{i}$ and $\hat{j}$ indicate the $+x$ and $+y$ directions

Vector Notation



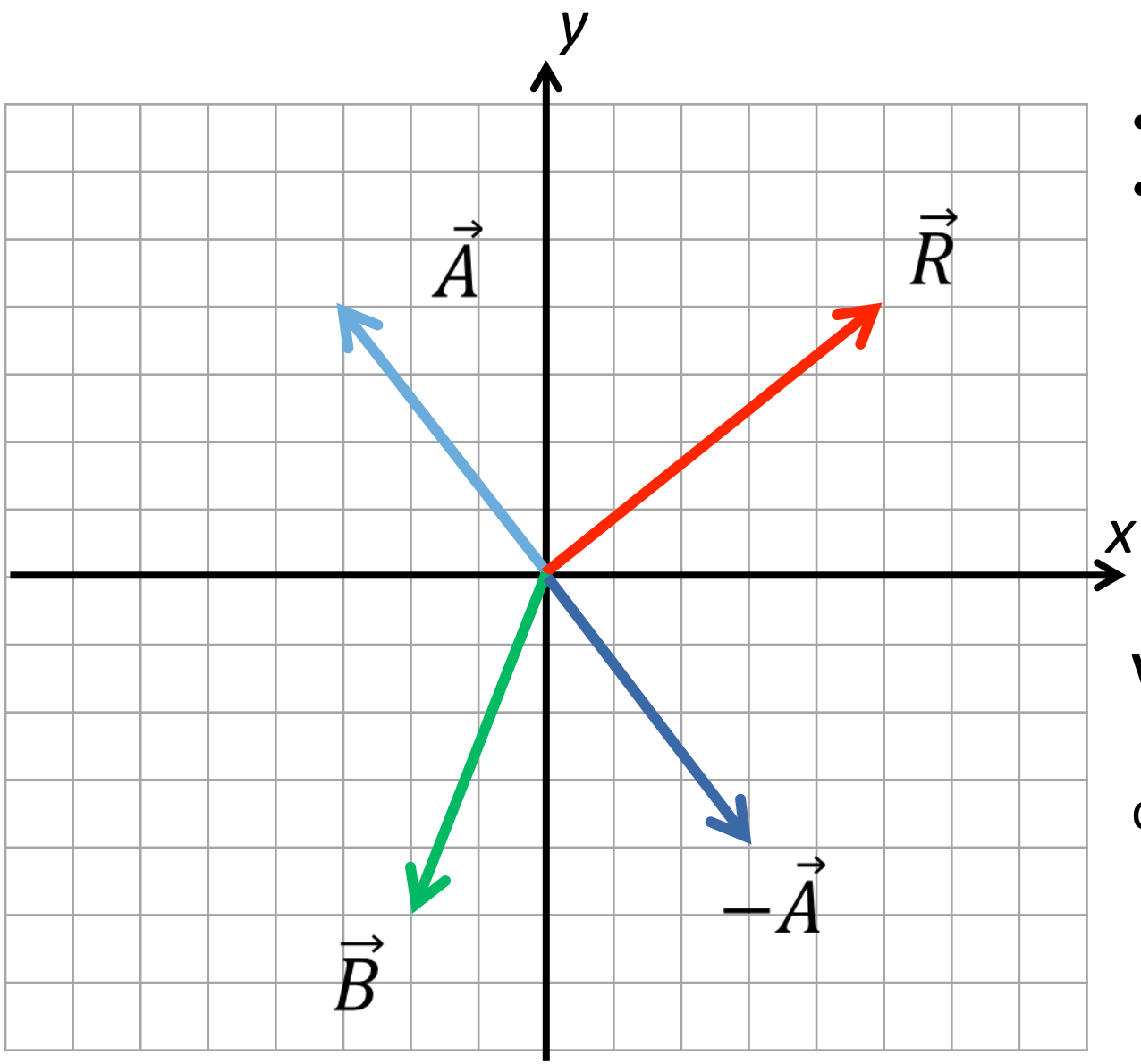
1) $(R, \theta) \rightarrow (R_x, R_y)$

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

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

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

Vector Notation



- degrees vs. radians
- +ve vs –ve angles:
  (0 to 360) or
  (-180 to 180)

Vector B:

atan(-5/-2) = 68.2°

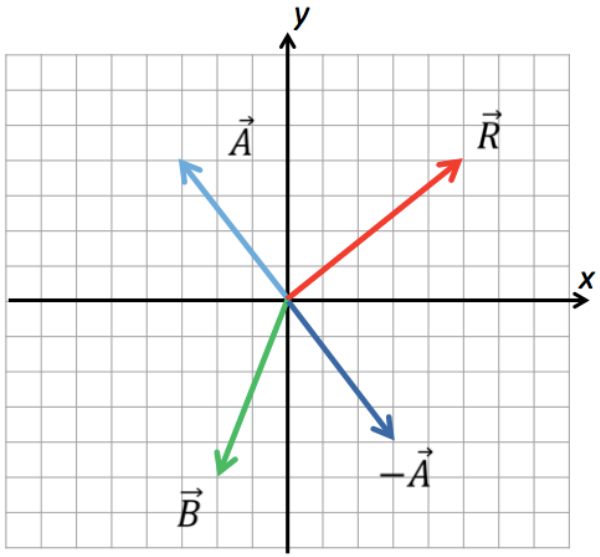
correct angle is:

68.2° + 180° = 248.2°

or

68.2° – 180° = -111.8°

Vector Notation: practice



See if you get the same answers as me:

(x,y), (r,theta)

Vector R:

(5,4), (6.4, 38.7^o [0.675 rad])

Vector A:

(-3,4), (5, 126.9^o [2.21 rad])

Vector B:

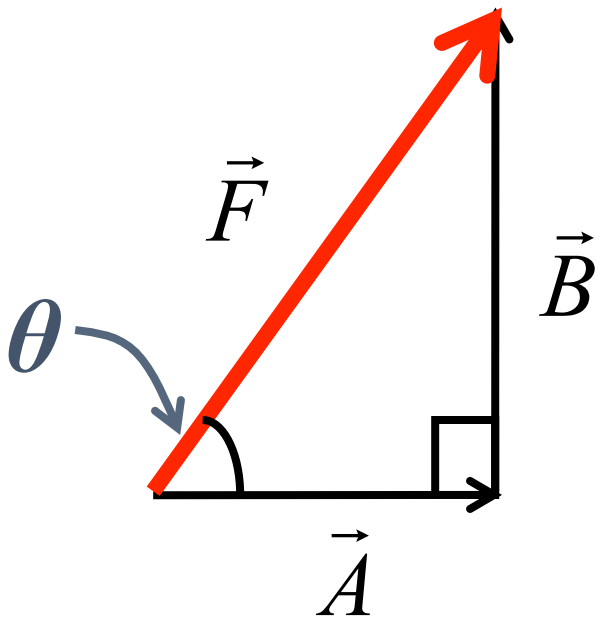
(-2,-5), (5.39, -111.8^o [-1.95 rad])

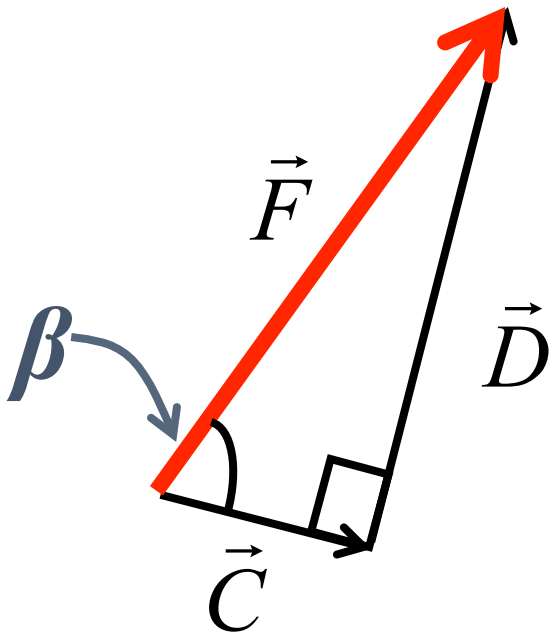
Vector -A:

(3,-4), (5, -53.1^o [-0.93 rad])

(same magnitude as A, but different by 180^o)

Vector Components





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

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

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

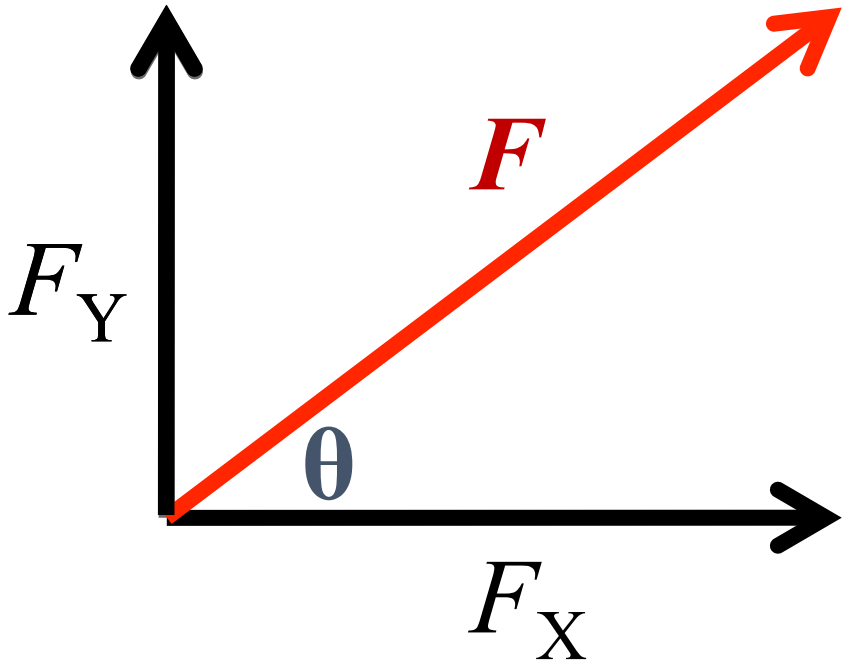
$$\vec{F} = \vec{C} + \vec{D}$$

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

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

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’



Adding two vectors using components

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

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

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

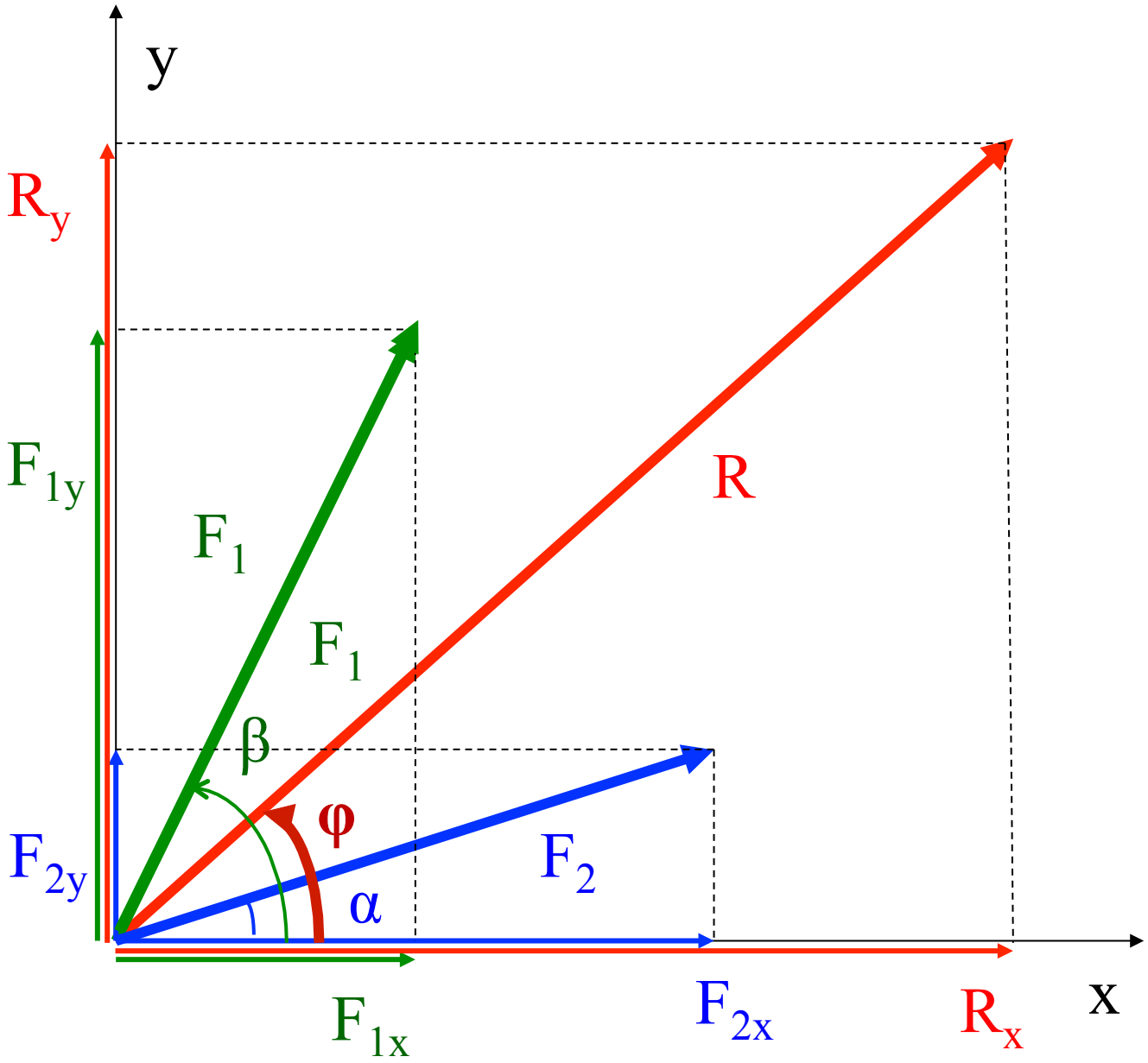
$$F_{1y} = F_1 \sin\beta$$

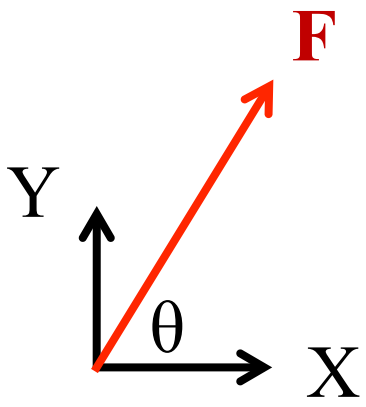
$$R_x = F_{1x} + F_{2x}$$

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

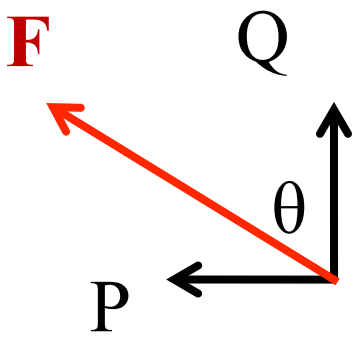
$$R = \sqrt{R_x^2 + R_y^2}$$

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

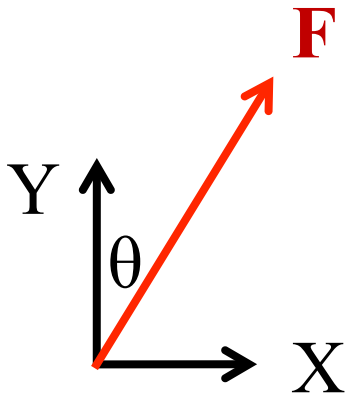




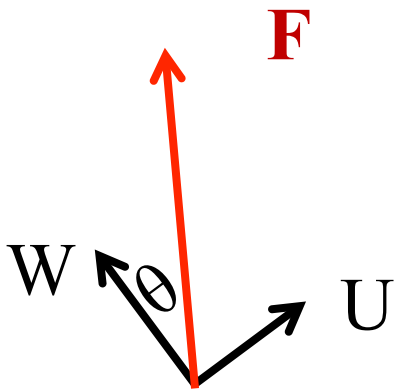
$F_X = F\cos(\theta)$



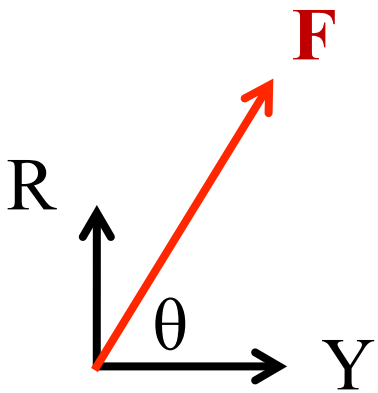
$F_Q = F\cos(\theta)$



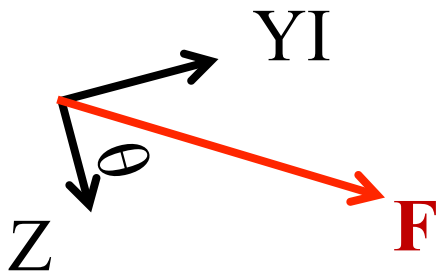
$F_Y = F\cos(\theta)$



$F_U = F\sin(\theta)$



$F_R = F\sin(\theta)$



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

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 TP-sheets

- 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 cm × 2.45 cm = ?

= 139 cm^2 (Not 139.111 cm^2)

b) 813.2 m ÷ 35 s = ?

= 23 m/s (Not 23.234 m/s)

Sig Figs & Scientific Notation

- What about this one?

a) 8132 m ÷ 35 s = ?

= 232 m/s ?

= 230 m/s ?

Use Scientific Notation: 8132 m ÷ 35 s = 2.3×10^2 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

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

Least reliable, therefore 2 decimal places:

Answer: E 27414.92

Clicker Quiz

- A parking lot is 134.3 m long and 37.66 m wide. The parking lot area is

A. $5.05774\times10^3\ m^2$
B. $5.0577\times10^3\ m^2$
C. $5.058\times10^3\ m^2$
D. $5.06\times10^3\ m^2$
E. $5.1\times10^3\ m^2$

Clicker Quiz

- A parking lot is 134.3 m long and 37.66 m wide. The parking lot area is

A. 5.05774×10^3 m^2
B. 5.0577×10^3 m^2
C. 5.058×10^3 m^2
D. 5.06×10^3 m^2
E. 5.1×10^3 m^2

Answer is C:

134.3 m x 37.66 m
= 5057.738 m^2

But should use 4 sig figs:

5058 m^2,
or 5.058x10^3 m^2