# *Chapter 1*

# ***Introduction and Mathematical Concepts***

## 1.1 *The Nature of Physics*

Physics has developed out of the efforts of men and women to explain our physical environment.

Physics encompasses a remarkable variety of phenomena:

planetary orbits
radio and TV waves
magnetism
lasers

***many more!***

# 1.1 *The Nature of Physics*

Physics predicts how nature will behave in one situation based on the results of experimental data obtained in another situation.

Newton's Laws $\rightarrow$ Rocketry

Maxwell's Equations $\rightarrow$ Telecommunications

## *1.2 Units*

Physics experiments involve the measurement of a variety of quantities.

These measurements should be accurate and reproducible.

The first step in ensuring accuracy and reproducibility is defining the units in which the measurements are made.

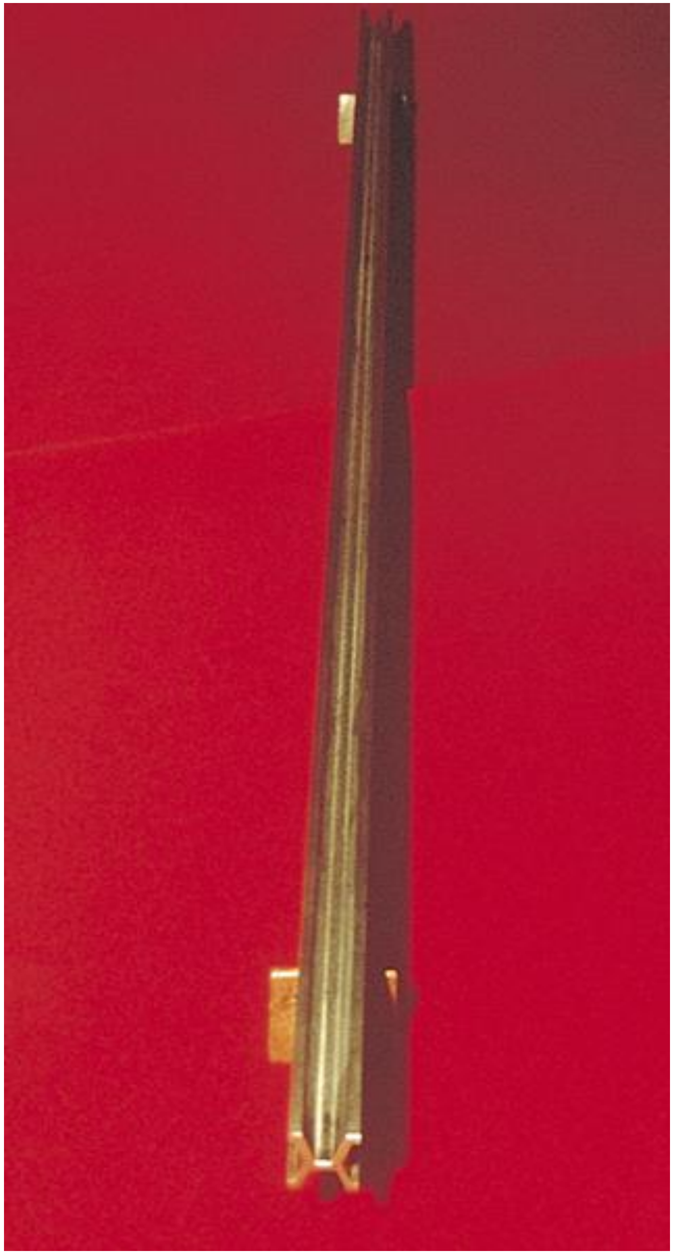
# *SI units*

*meter* (m): unit of length

*kilogram* (kg): unit of mass

*second* (s): unit of time

# 1.2 Units



## 1.2 Units

## 1.2 Units

**Table 1.1** **Units of Measurement**

| | System | | |
|---|---|---|---|
| | SI | CGS | BE |
| Length | Meter (m) | Centimeter (cm) | Foot (ft) |
| Mass | Kilogram (kg) | Gram (g) | Slug (sl) |
| Time | Second (s) | Second (s) | Second (s) |

The units for length, mass, and time (as well as a few others), are regarded as *base* SI units.

These units are used in combination to define additional units for other important physical quantities such as force and energy.

# THE CONVERSION OF UNITS

1 ft = 0.3048 m

1 mi = 1.609 km

1 hp = 746 W

1 liter = $10^{-3}$ $m^3$

***Example 1*** **The World's Highest Waterfall**

The highest waterfall in the world is Angel Falls in Venezuela, with a total drop of 979.0 m. Express this drop in feet.

Since 3.281 feet = 1 meter, it follows that

(3.281 feet)/(1 meter) = 1

$$\text{Length} = (979.0\text{ meters})\left(\frac{3.281\text{ feet}}{1\text{ meter}}\right) = 3212\text{ feet}$$

# 1.3 The Role of Units in Problem Solving

**Table 1.2 Standard Prefixes Used to Denote Multiples of Ten**

| Prefix | Symbol | Factor[a] |
|---|---|---|
| tera | T | $10^{12}$ |
| giga[b] | G | $10^{9}$ |
| mega | M | $10^{6}$ |
| kilo | k | $10^{3}$ |
| hecto | h | $10^{2}$ |
| deka | da | $10^{1}$ |
| deci | d | $10^{-1}$ |
| centi | c | $10^{-2}$ |
| milli | m | $10^{-3}$ |
| micro | $\mu$ | $10^{-6}$ |
| nano | n | $10^{-9}$ |
| pico | p | $10^{-12}$ |
| femto | f | $10^{-15}$ |

[a]Appendix A contains a discussion of powers of ten and scientific notation.
[b]Pronounced jig′a.

## *1.3 The Role of Units in Problem Solving*

### Reasoning Strategy: Converting Between Units

1. In all calculations, write down the units explicitly.

2. Treat all units as algebraic quantities. When identical units are divided, they are eliminated algebraically.

3. Use the conversion factors located on the page facing the inside cover. Be guided by the fact that multiplying or dividing an equation by a factor of 1 does not alter the equation.

**_Example 2_ Interstate Speed Limit**

Express the speed limit of 65 miles/hour in terms of meters/second.

Use 5280 feet = 1 mile and 3600 seconds = 1 hour and
3.281 feet = 1 meter.

$$\text{Speed} = \left(65\,\frac{\text{miles}}{\text{hour}}\right)(1)(1) = \left(65\,\frac{\text{miles}}{\text{hour}}\right)\left(\frac{5280\text{ feet}}{\text{mile}}\right)\left(\frac{1\text{ hour}}{3600\text{ s}}\right) = 95\,\frac{\text{feet}}{\text{second}}$$

$$\text{Speed} = \left(95\,\frac{\text{feet}}{\text{second}}\right)(1) = \left(95\,\frac{\text{feet}}{\text{second}}\right)\left(\frac{1\text{ meter}}{3.281\text{ feet}}\right) = 29\,\frac{\text{meters}}{\text{second}}$$

# DIMENSIONAL ANALYSIS

[L] = length    [M] = mass    [T] = time

Is the following equation dimensionally correct?

$$x = \tfrac{1}{2} v t^2$$

$$[\mathrm{L}] = \left[\frac{\mathrm{L}}{\mathrm{T}}\right][\mathrm{T}]^2 = [\mathrm{L}][\mathrm{T}]$$

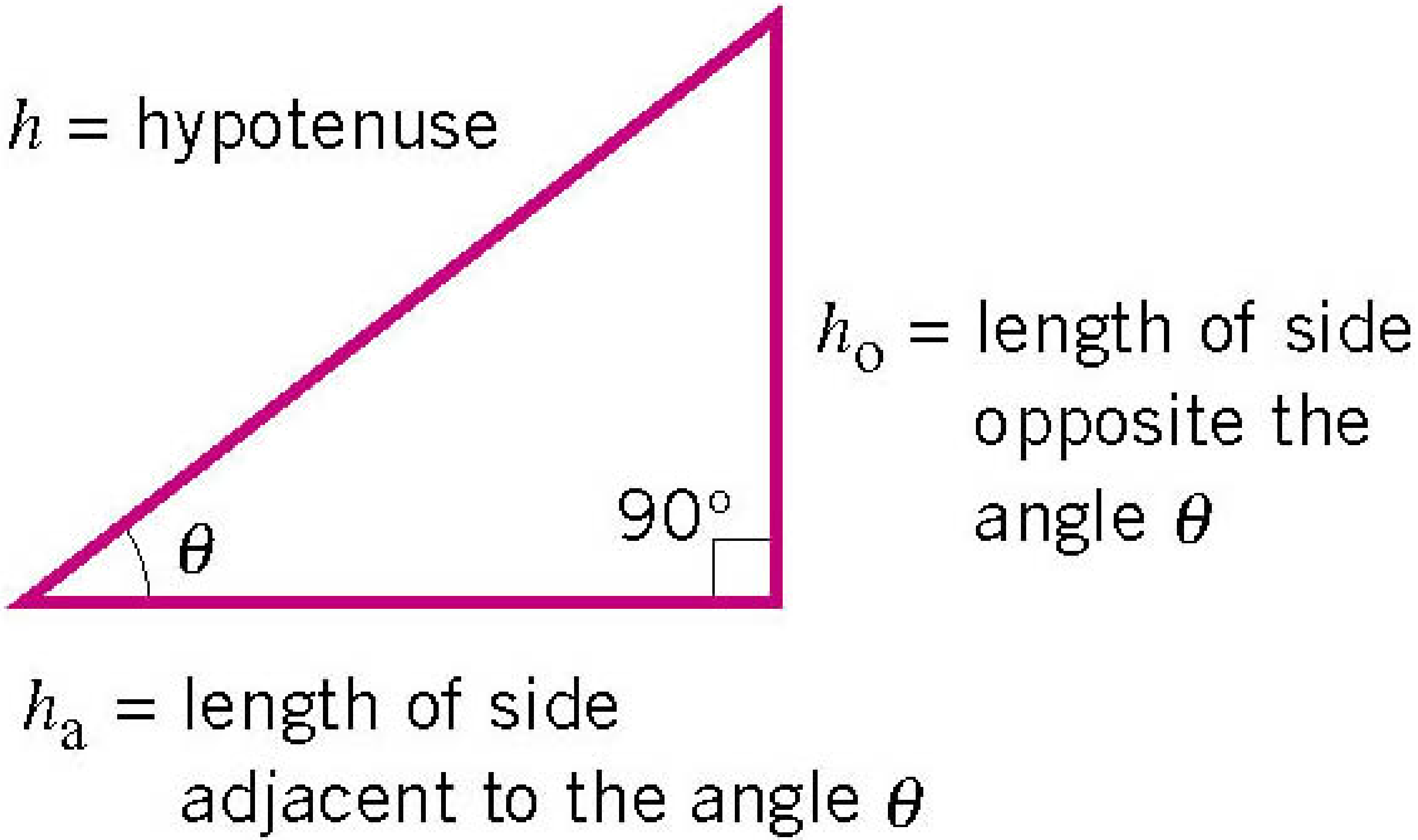
## 1.3 The Role of Units in Problem Solving

Is the following equation dimensionally correct?

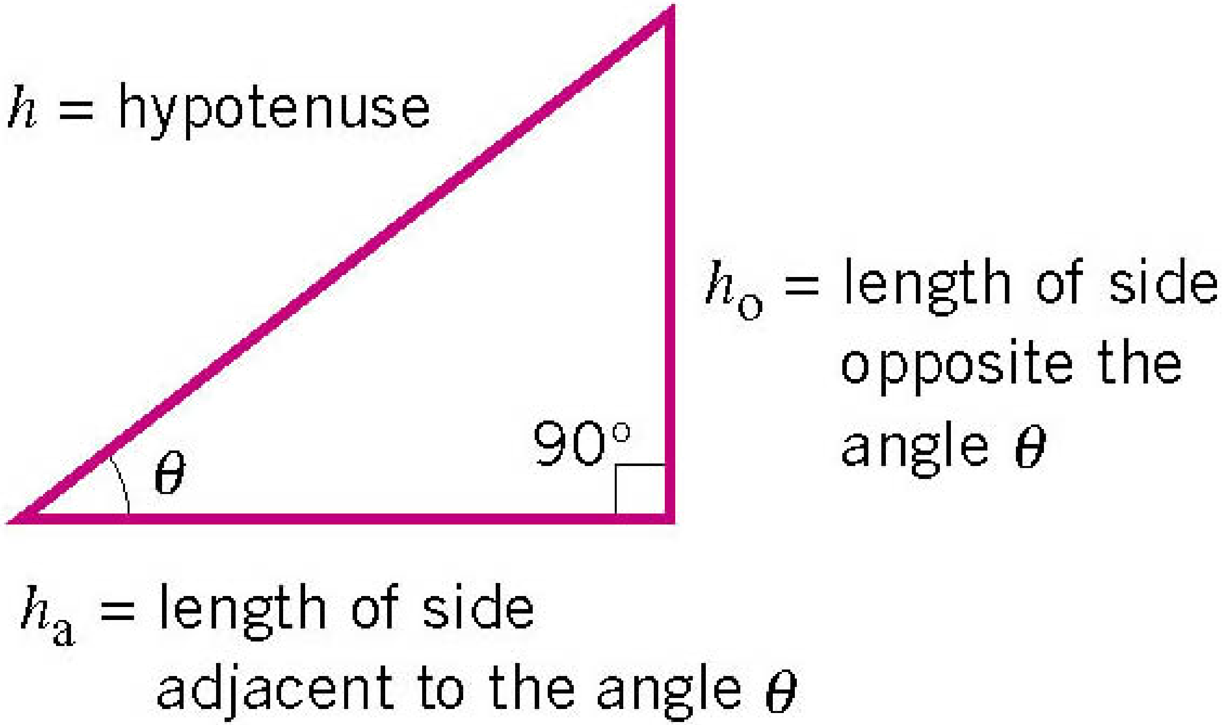
$$x = vt$$

$$[\mathrm{L}] = \left[\frac{\mathrm{L}}{\mathrm{T}}\right][\mathrm{T}] = [\mathrm{L}]$$

# 1.4 Trigonometry



# 1.4 Trigonometry

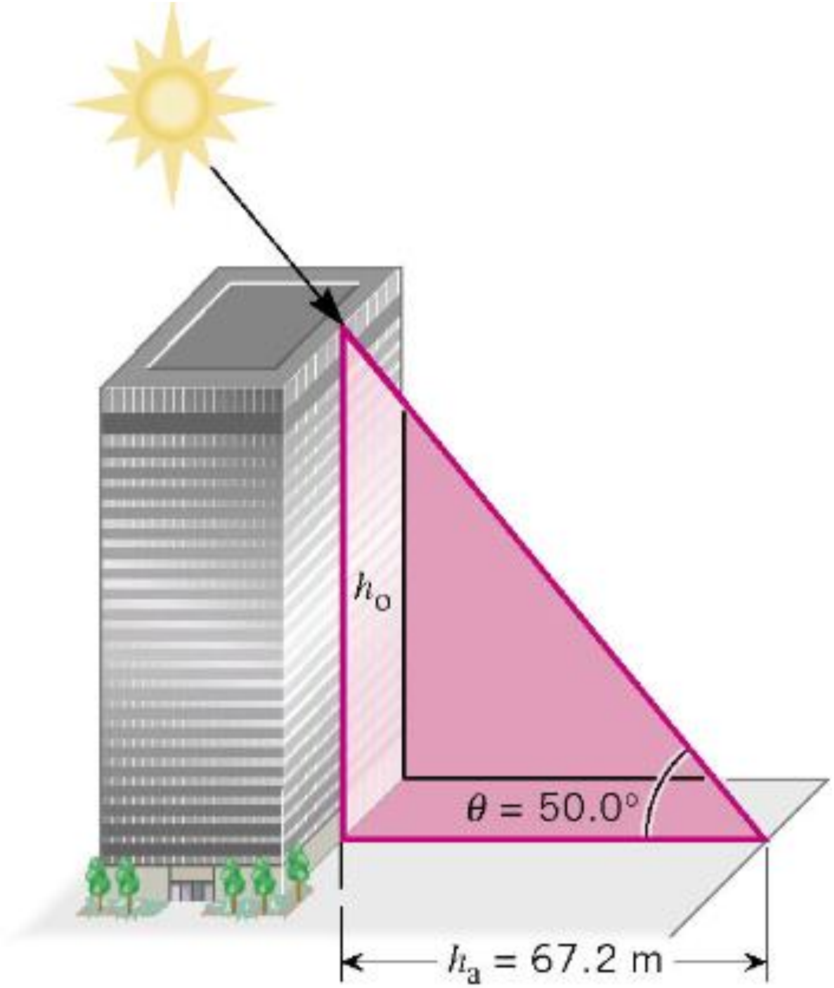



$$\sin\theta = \frac{h_o}{h}$$

$$\cos\theta = \frac{h_a}{h}$$

$$\tan\theta = \frac{h_o}{h_a}$$

# 1.4 Trigonometry

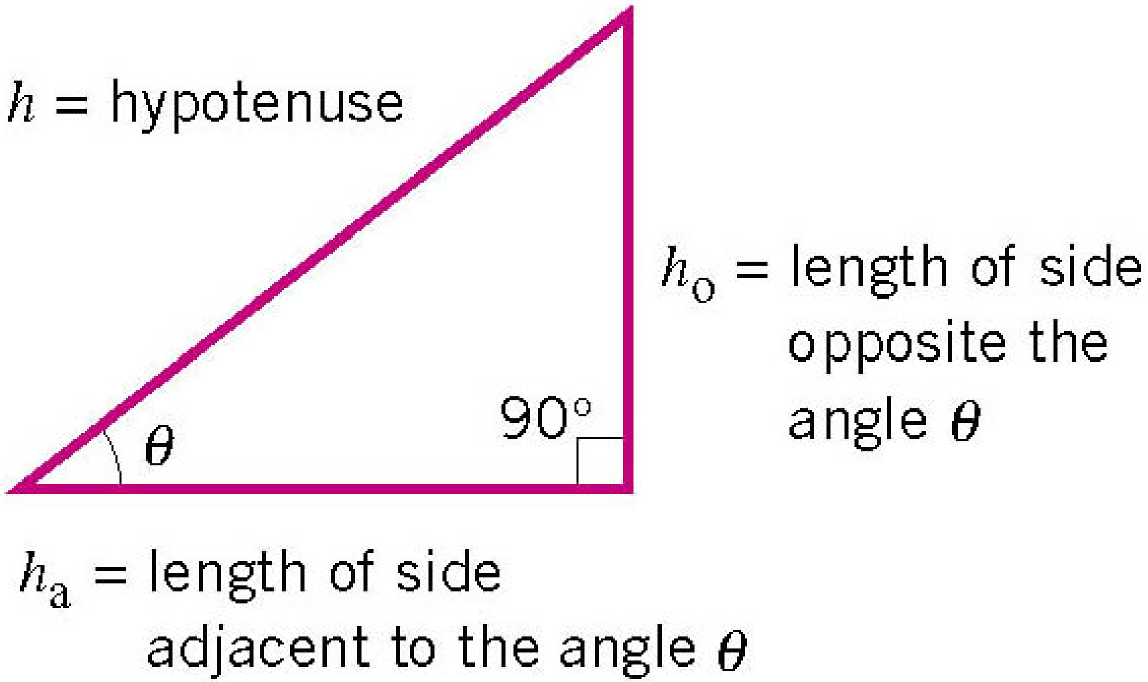



$$\tan\theta = \frac{h_o}{h_a}$$

$$\tan 50.0^\circ = \frac{h_o}{67.2\text{m}}$$

$$h_o = \tan 50.0^\circ\left(67.2\text{m}\right) = 80.1\text{m}$$

# 1.4 Trigonometry

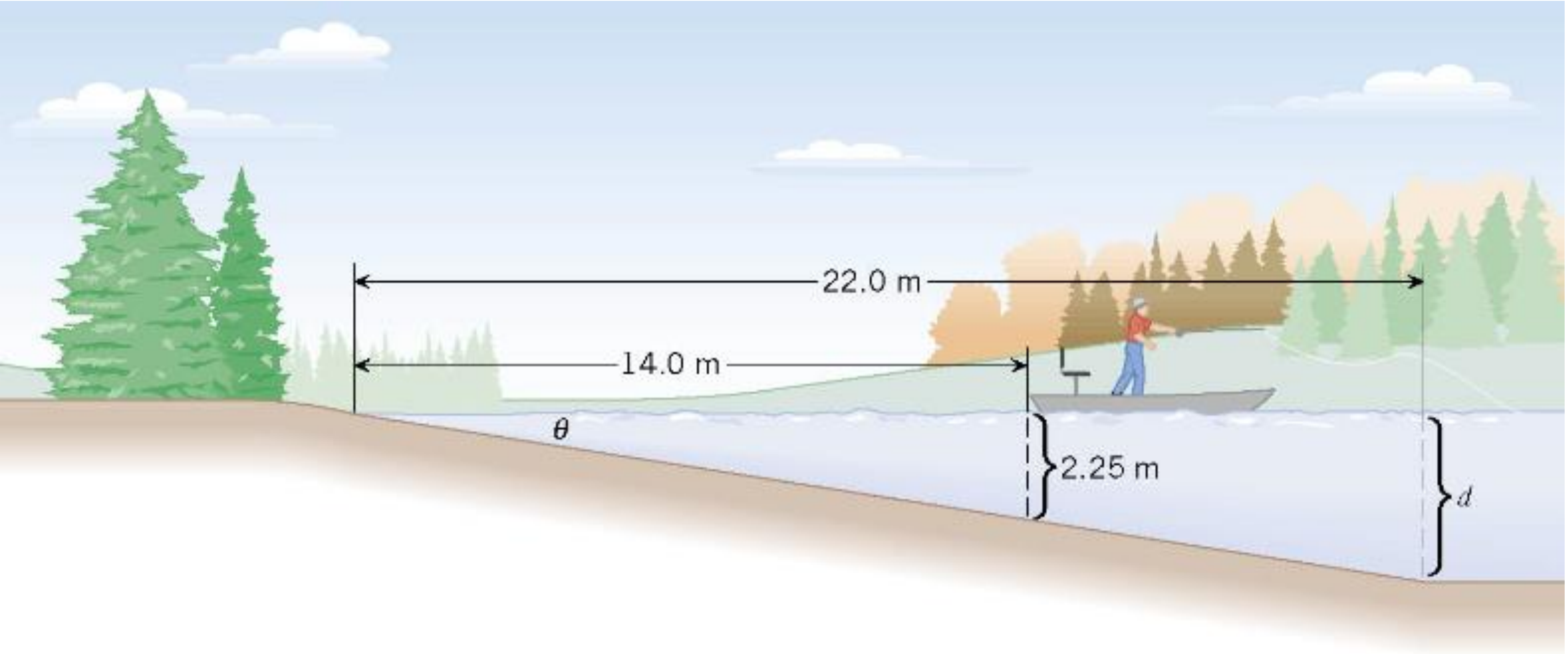



$$\theta = \sin^{-1}\left(\frac{h_o}{h}\right)$$

$$\theta = \cos^{-1}\left(\frac{h_a}{h}\right)$$

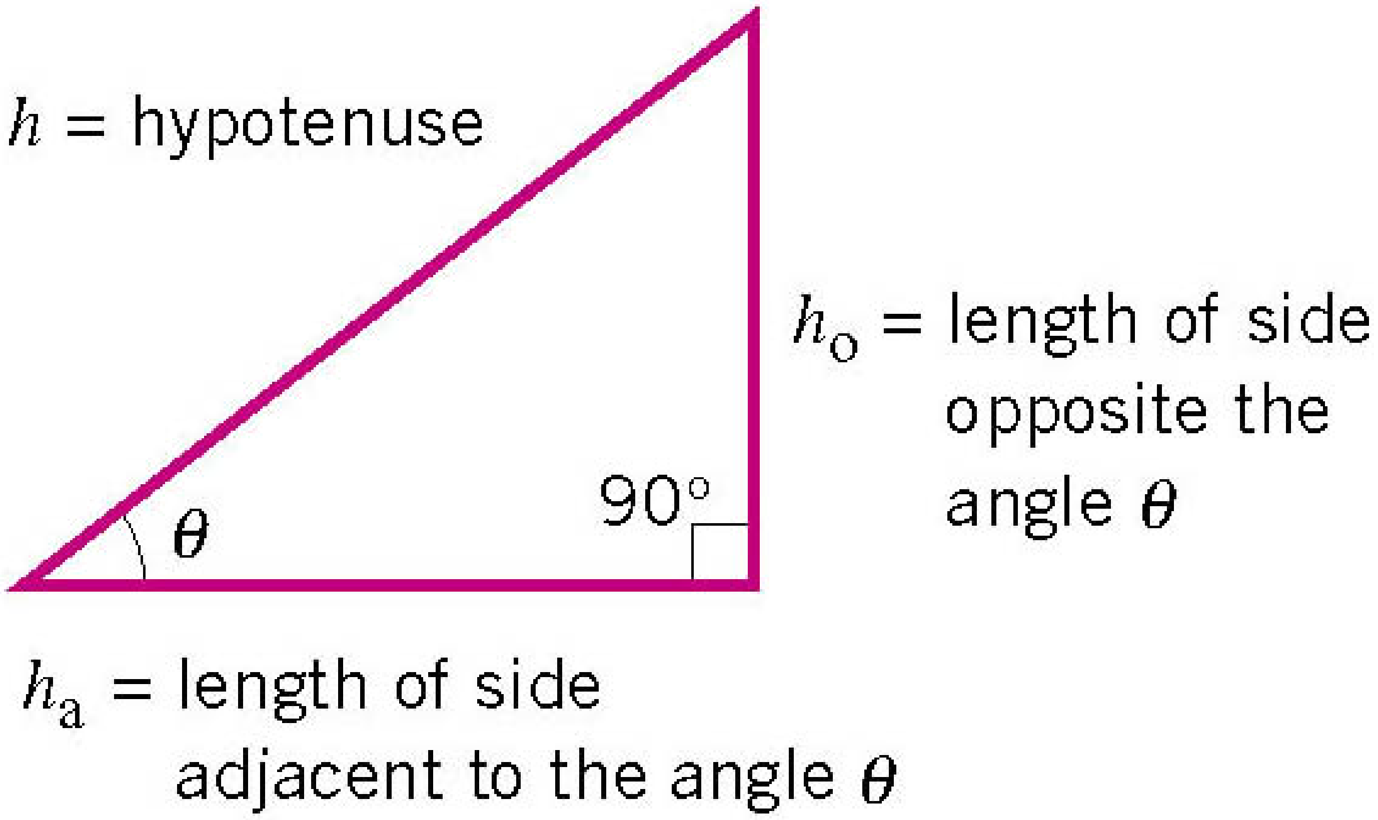
$$\theta = \tan^{-1}\left(\frac{h_o}{h_a}\right)$$

# 1.4 Trigonometry




$$\theta = \tan^{-1}\left(\frac{h_o}{h_a}\right) \qquad \theta = \tan^{-1}\left(\frac{2.25\text{m}}{14.0\text{m}}\right) = 9.13^\circ$$

Pythagorean theorem: $$h^2 = h_o^2 + h_a^2$$



## 1.5 Scalars and Vectors

A *scalar* quantity is one that can be described by a single number:

temperature, speed, mass

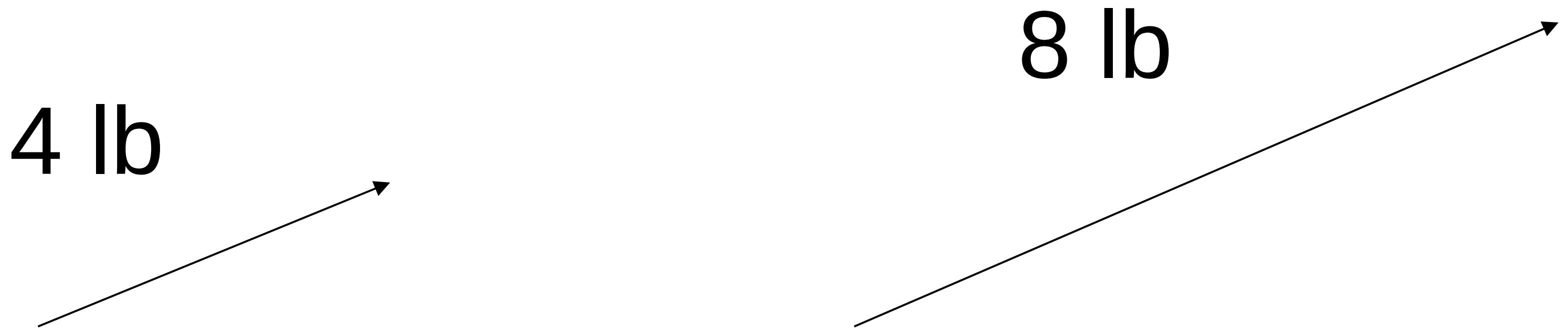
A *vector* quantity deals inherently with both magnitude and direction:

velocity, force, displacement

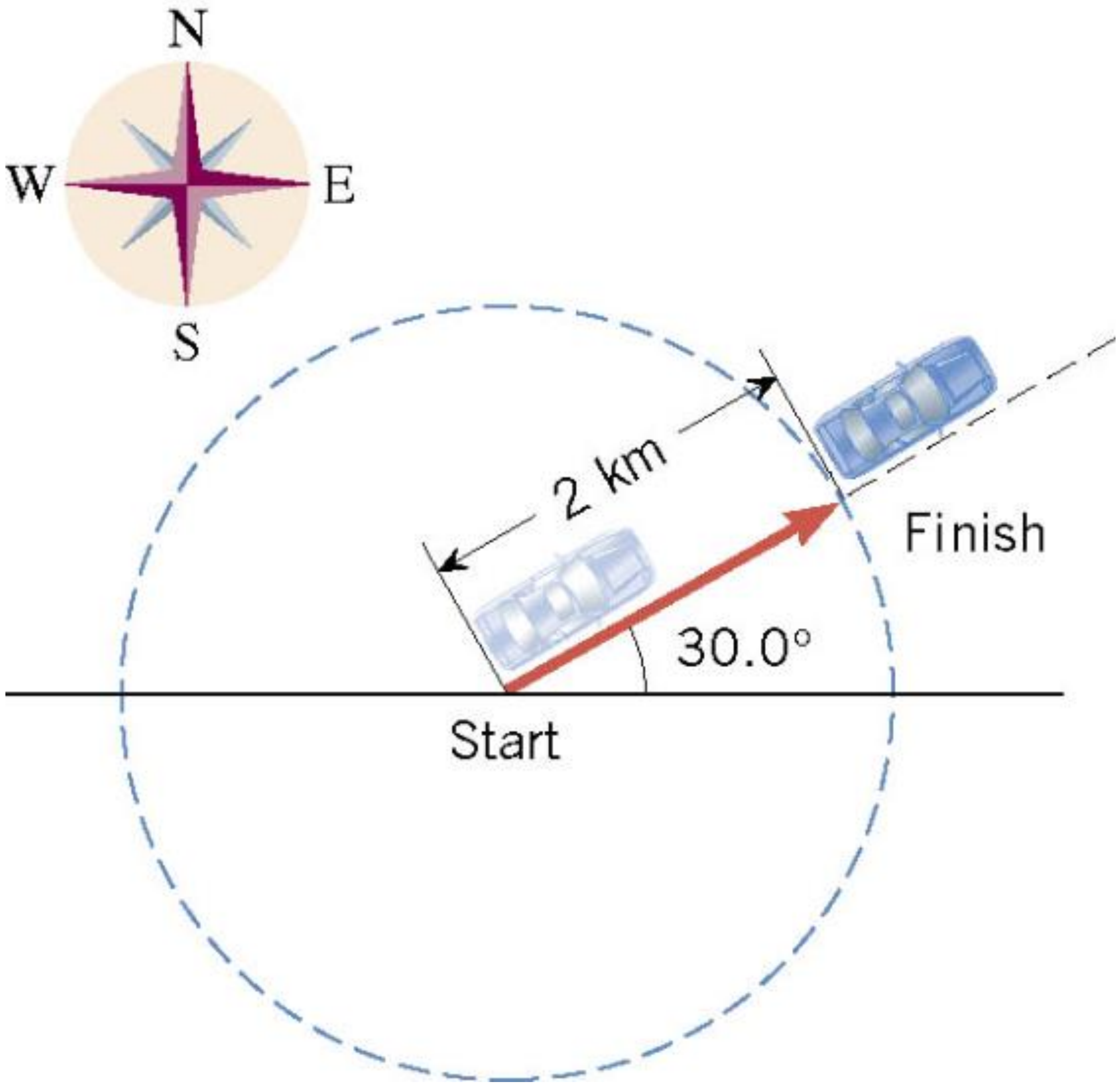
## 1.5 Scalars and Vectors

Arrows are used to represent vectors. The direction of the arrow gives the direction of the vector.

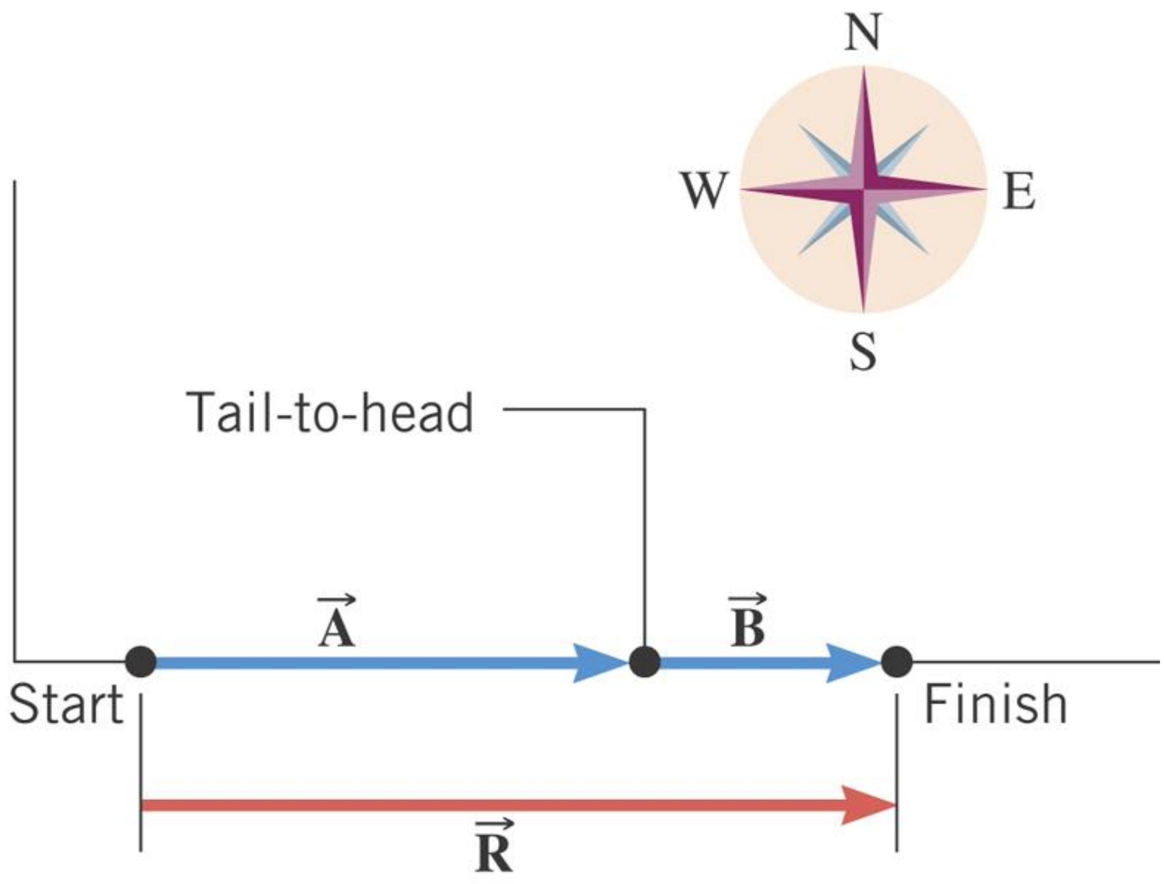
By convention, the length of a vector arrow is proportional to the magnitude of the vector.



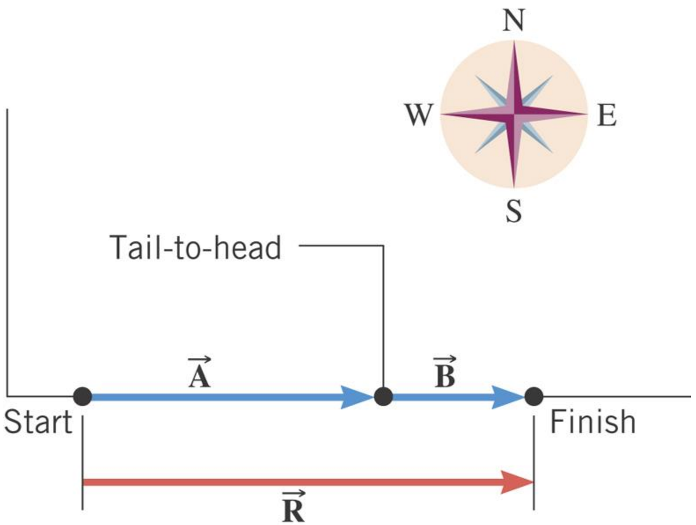
# 1.5 Scalars and Vectors

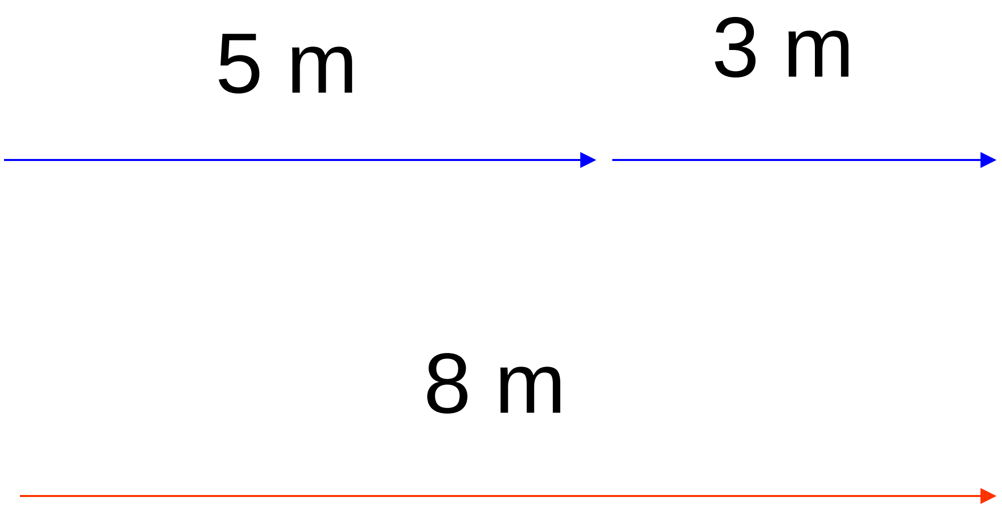


Often it is necessary to add one vector to another.



# 1.6 Vector Addition and Subtraction



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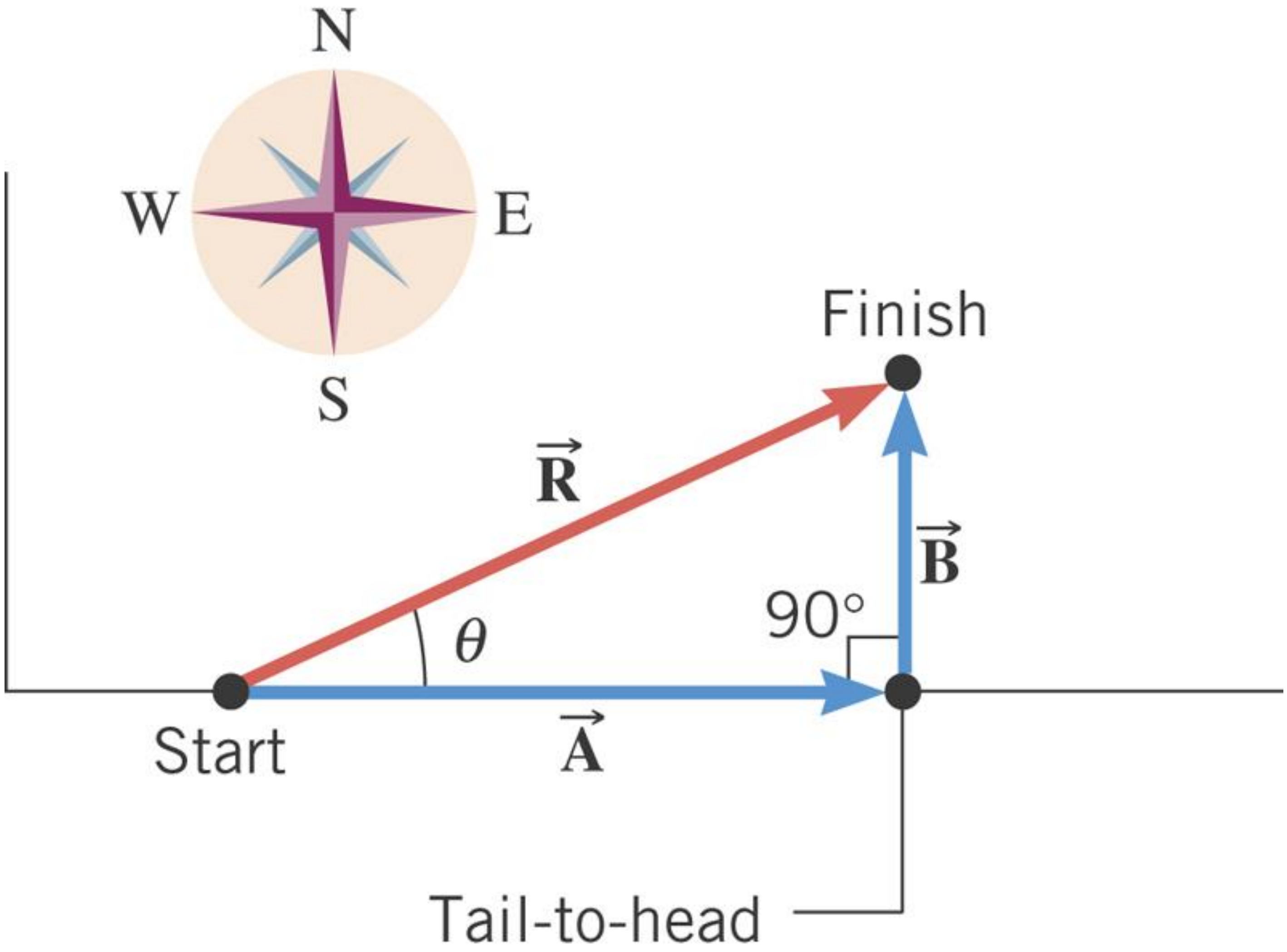
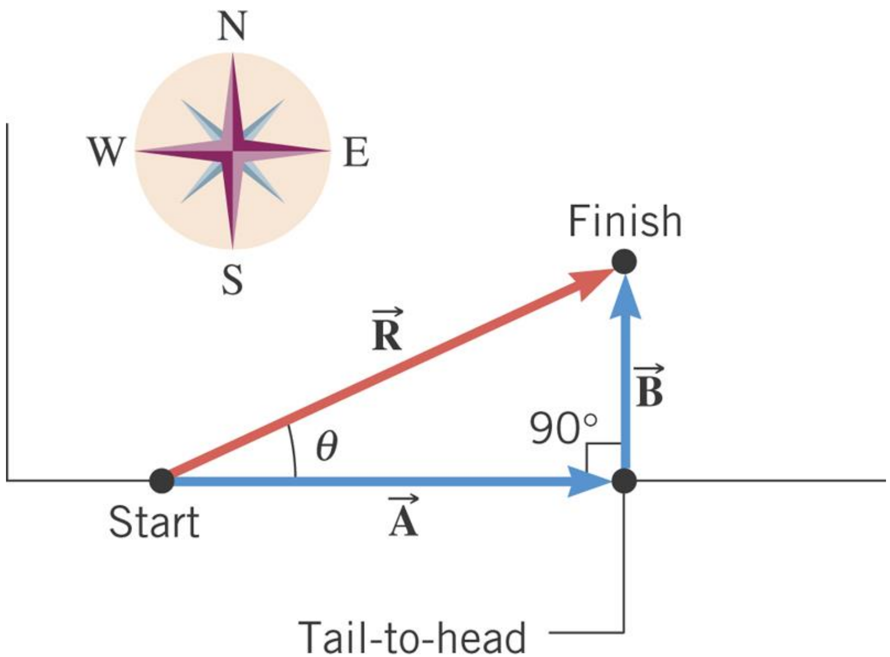
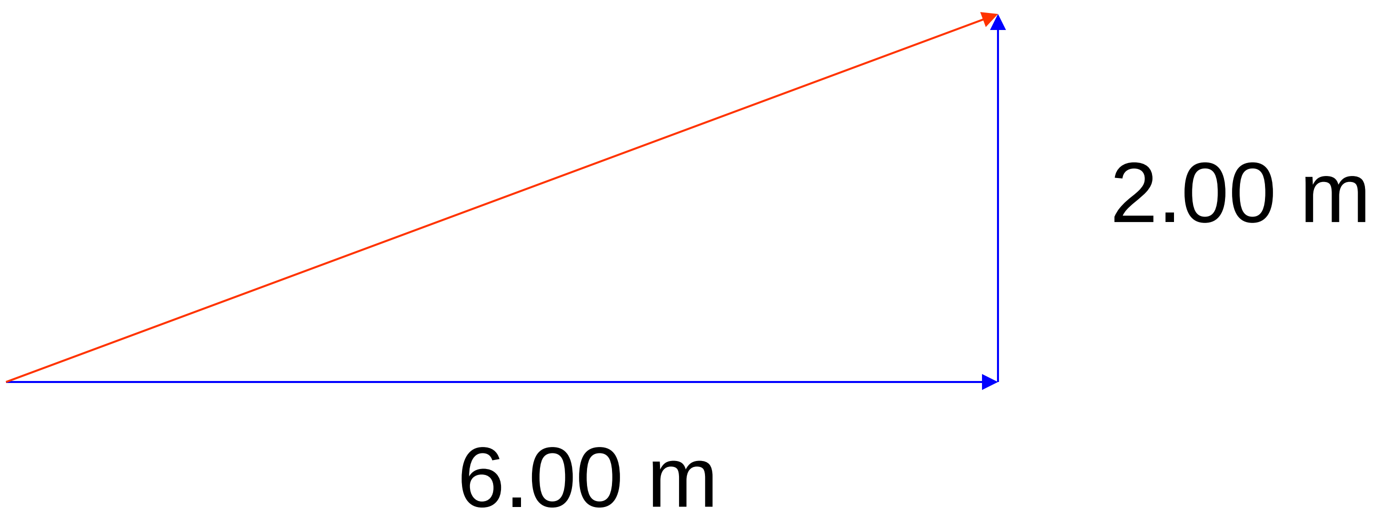


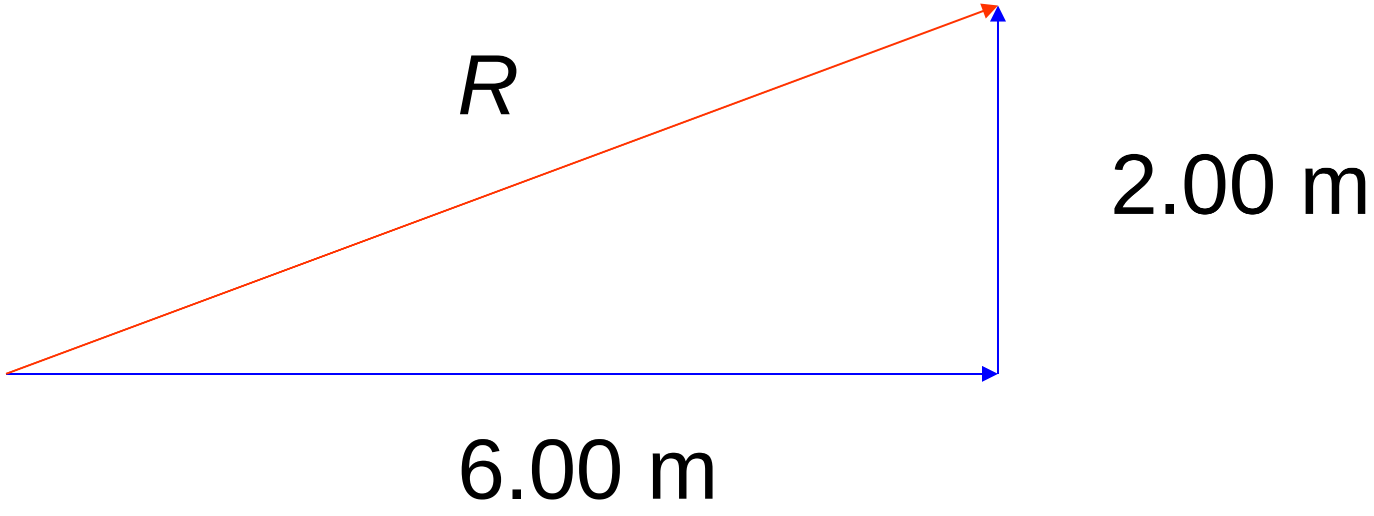
## 1.6 Vector Addition and Subtraction



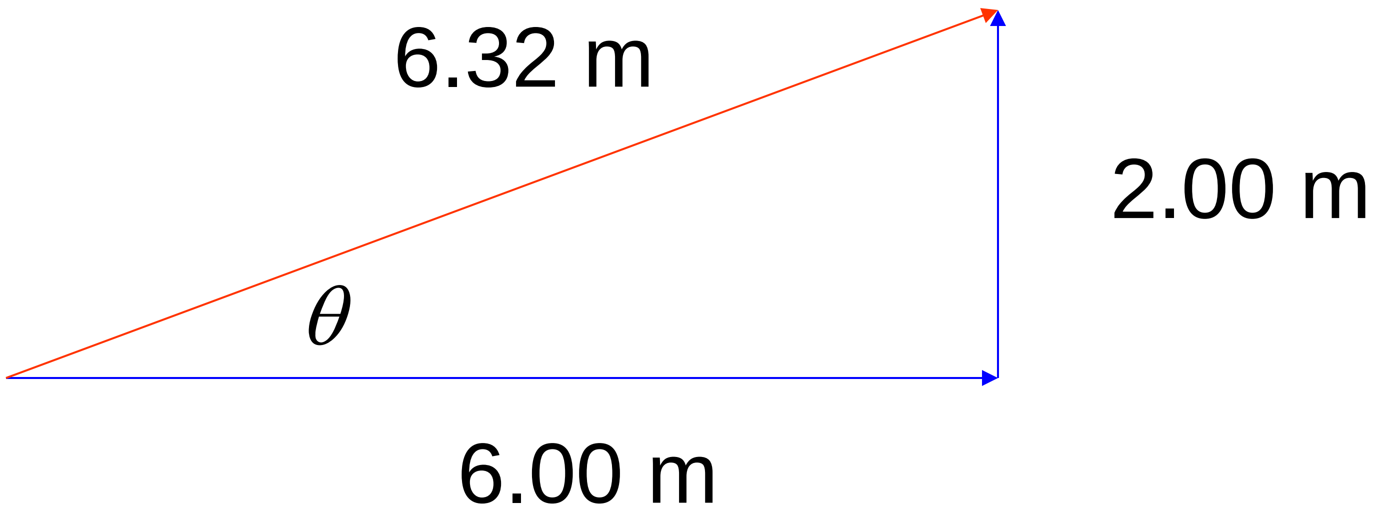
$$R^2 = (2.00\,\mathrm{m})^2 + (6.00\,\mathrm{m})^2$$

$$R = \sqrt{(2.00\,\mathrm{m})^2 + (6.00\,\mathrm{m})^2} = 6.32\mathrm{m}$$

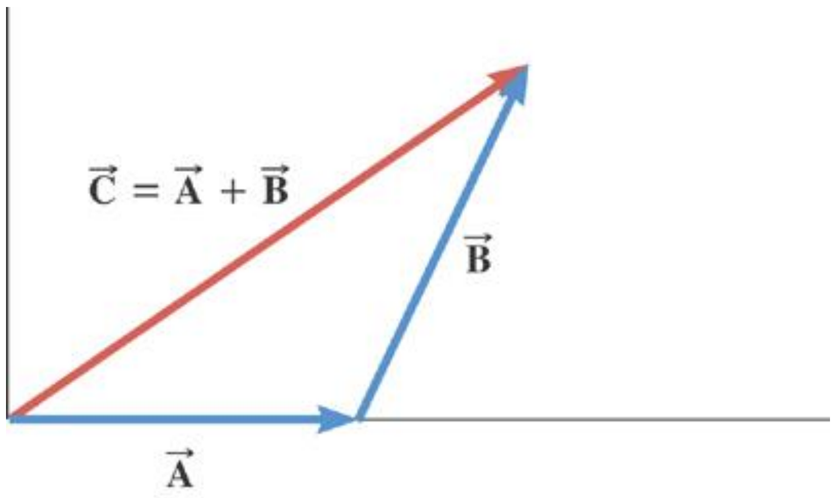


$$\tan\theta = 2.00/6.00$$

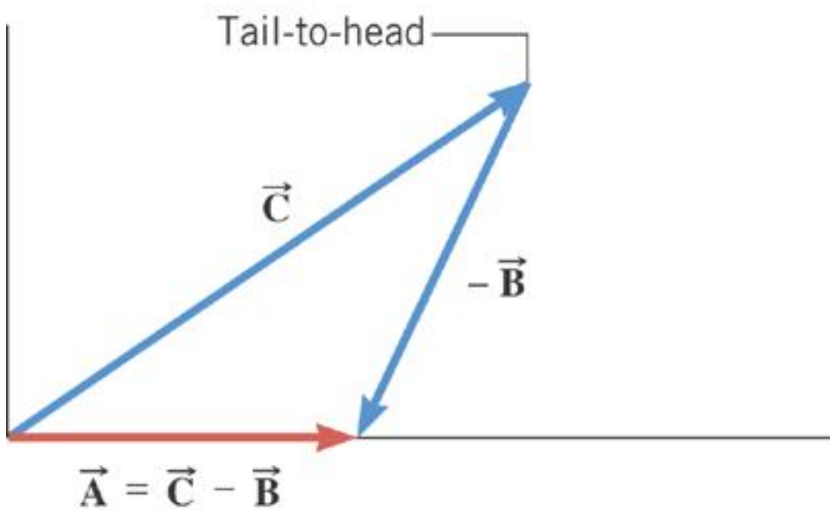
$$\theta = \tan^{-1}\left(2.00/6.00\right) = 18.4^{\circ}$$



# 1.6 Vector Addition and Subtraction



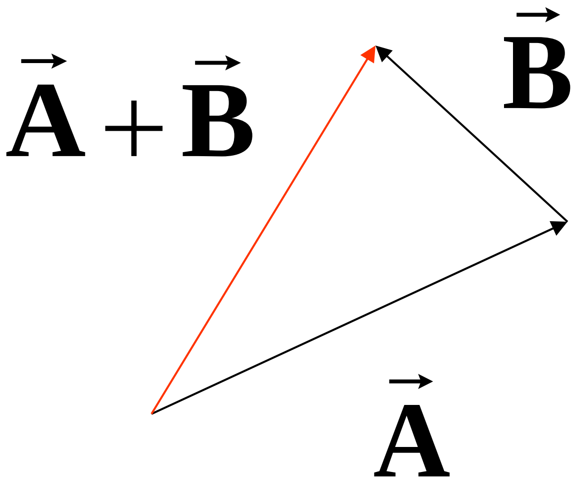
(a)

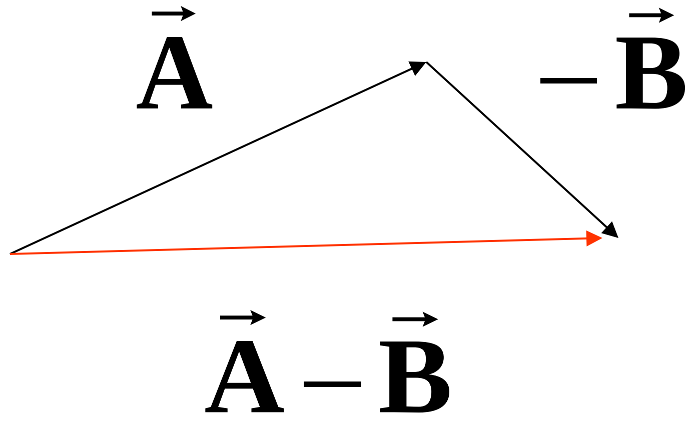


(b)

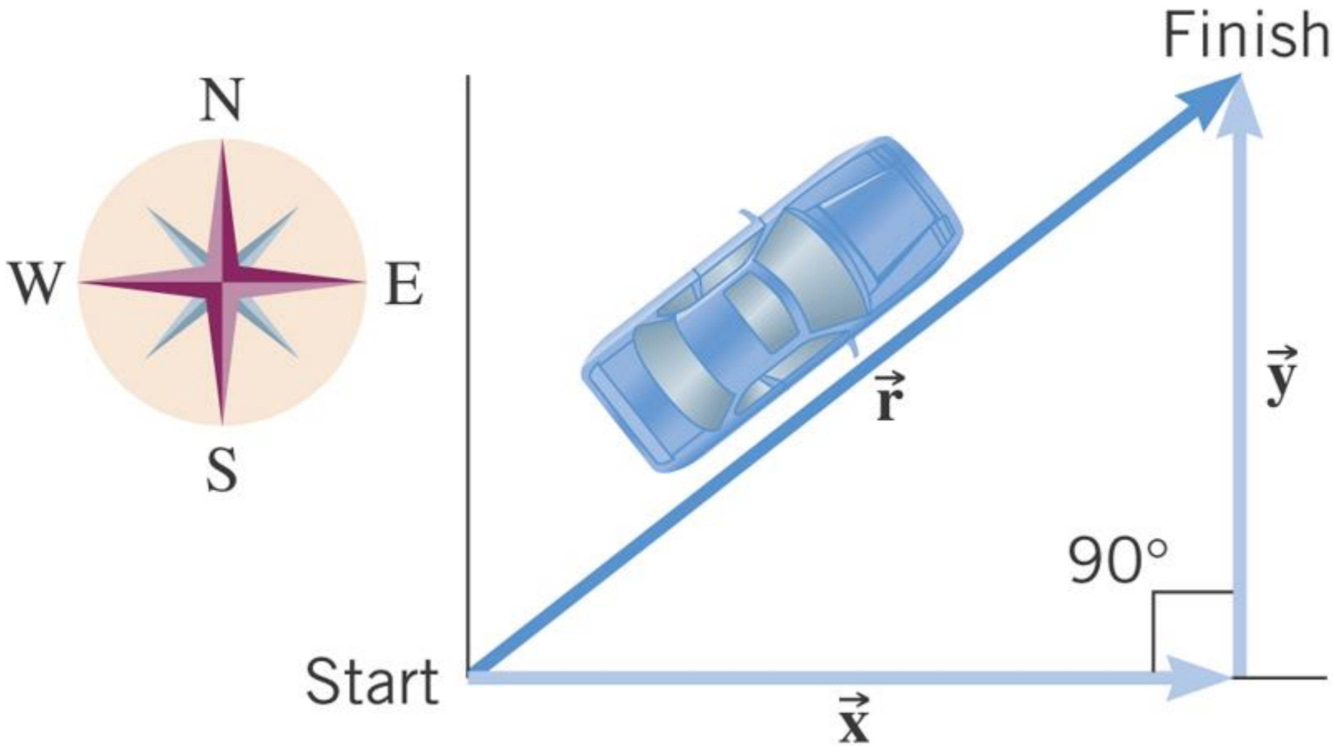
*When a vector is multiplied by -1, the magnitude of the vector remains the same, but the direction of the vector is reversed.*

## 1.6 Vector Addition and Subtraction



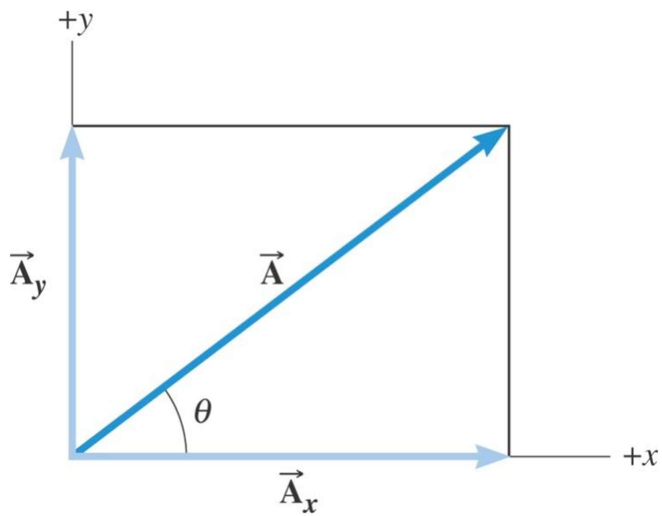



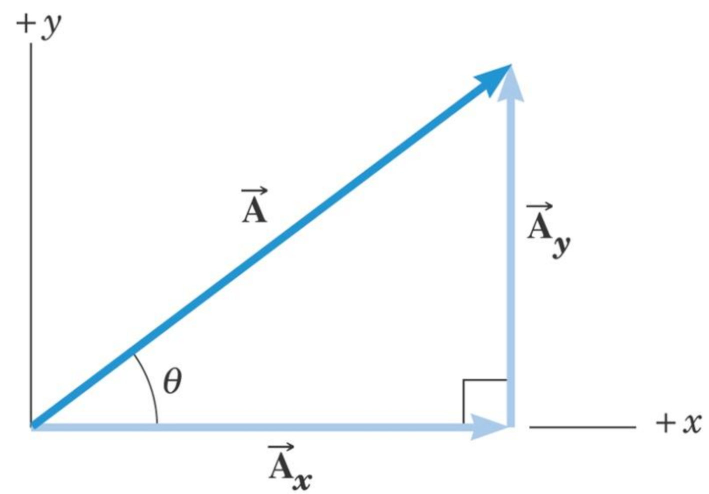
# 1.7 The Components of a Vector




$\vec{\mathbf{x}}$ and $\vec{\mathbf{y}}$ are called the *x* vector component and the *y* vector component of $\vec{\mathbf{r}}$.

## 1.7 The Components of a Vector

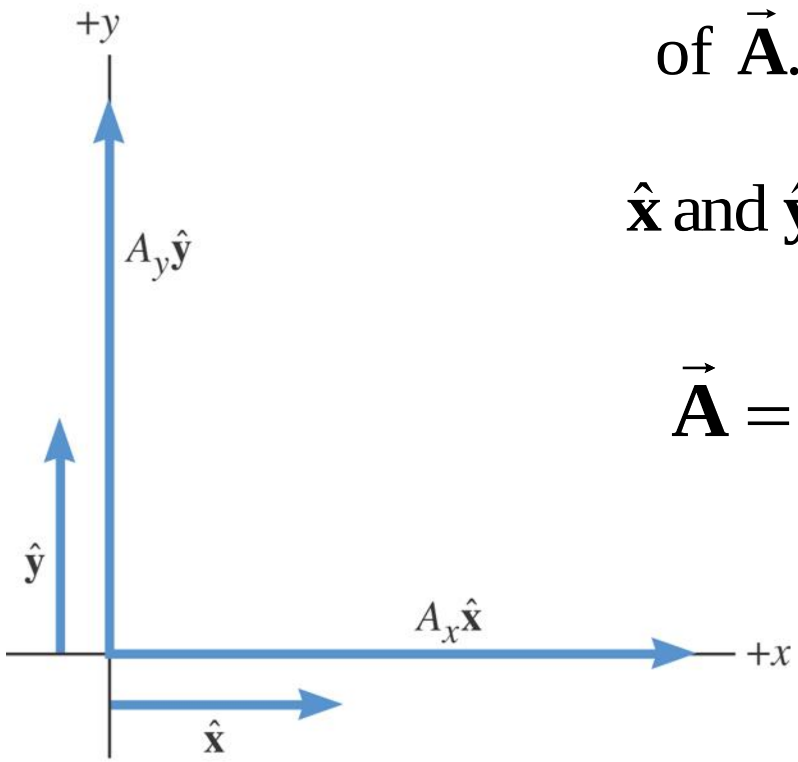



The vector components of $\vec{\mathbf{A}}$ are two perpendicular vectors $\vec{\mathbf{A}}_x$ and $\vec{\mathbf{A}}_y$ that are parallel to the $x$ and $y$ axes, and add together vectorially so that $\vec{\mathbf{A}} = \vec{\mathbf{A}}_x + \vec{\mathbf{A}}_y$.

# 1.7 The Components of a Vector

It is often easier to work with the **scalar components** rather than the vector components.



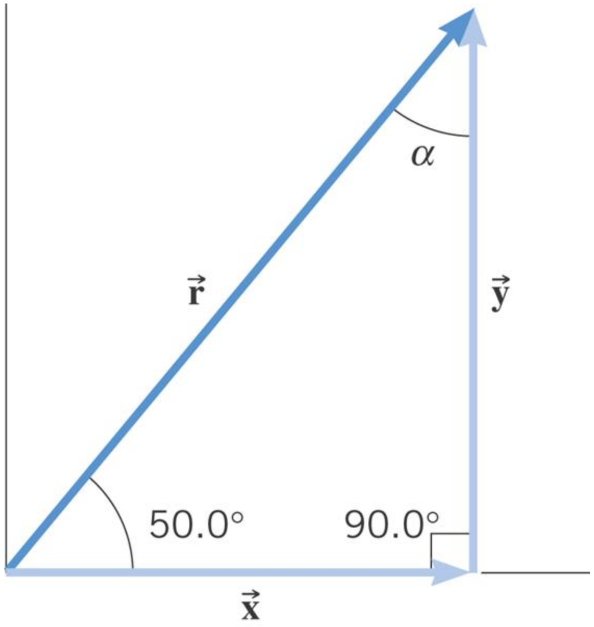

$A_x$ and $A_y$ are the scalar components of $\vec{\mathbf{A}}$.

$\hat{\mathbf{x}}$ and $\hat{\mathbf{y}}$ are unit vectors with magnitude 1.

$$\vec{\mathbf{A}} = A_x\hat{\mathbf{x}} + A_y\hat{\mathbf{y}}$$

## Example

A displacement vector has a magnitude of 175 m and points at an angle of 50.0 degrees relative to the *x* axis. Find the *x* and *y* components of this vector.




$$\sin\theta = y/r$$

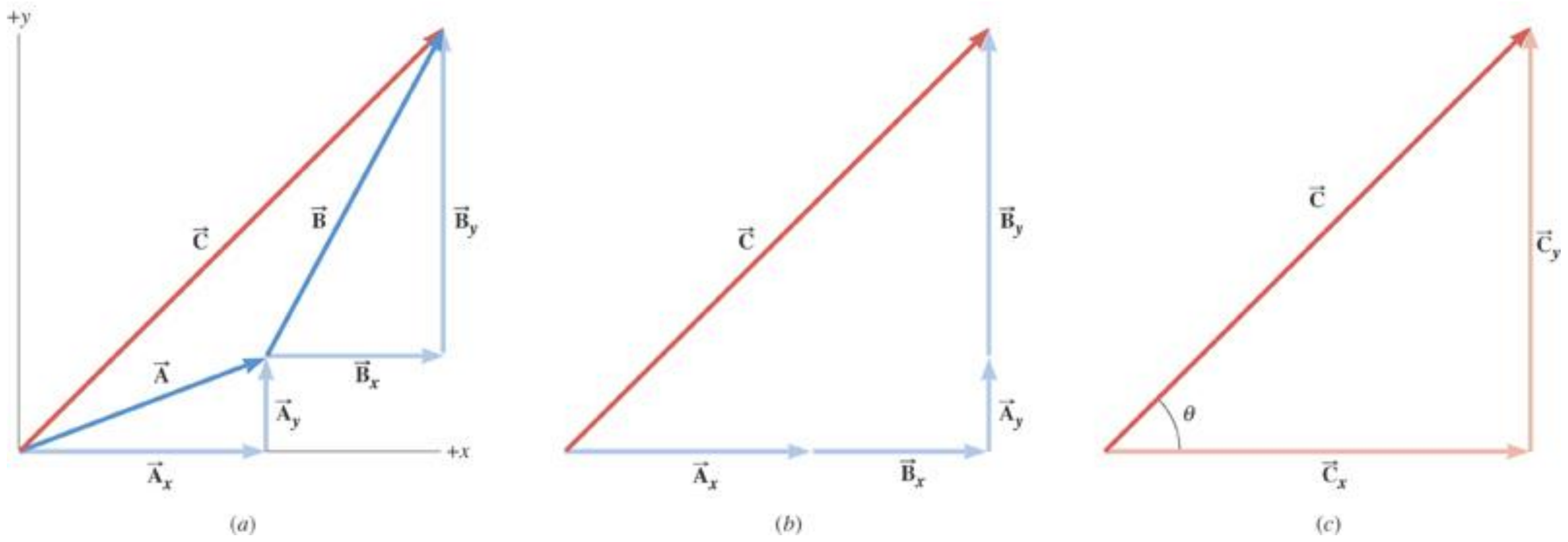
$$y = r\sin\theta = (175\,\text{m})(\sin 50.0^\circ) = 134\,\text{m}$$

$$\cos\theta = x/r$$

$$x = r\cos\theta = (175\,\text{m})(\cos 50.0^\circ) = 112\,\text{m}$$

$$\vec{\mathbf{r}} = (112\,\text{m})\hat{\mathbf{x}} + (134\,\text{m})\hat{\mathbf{y}}$$

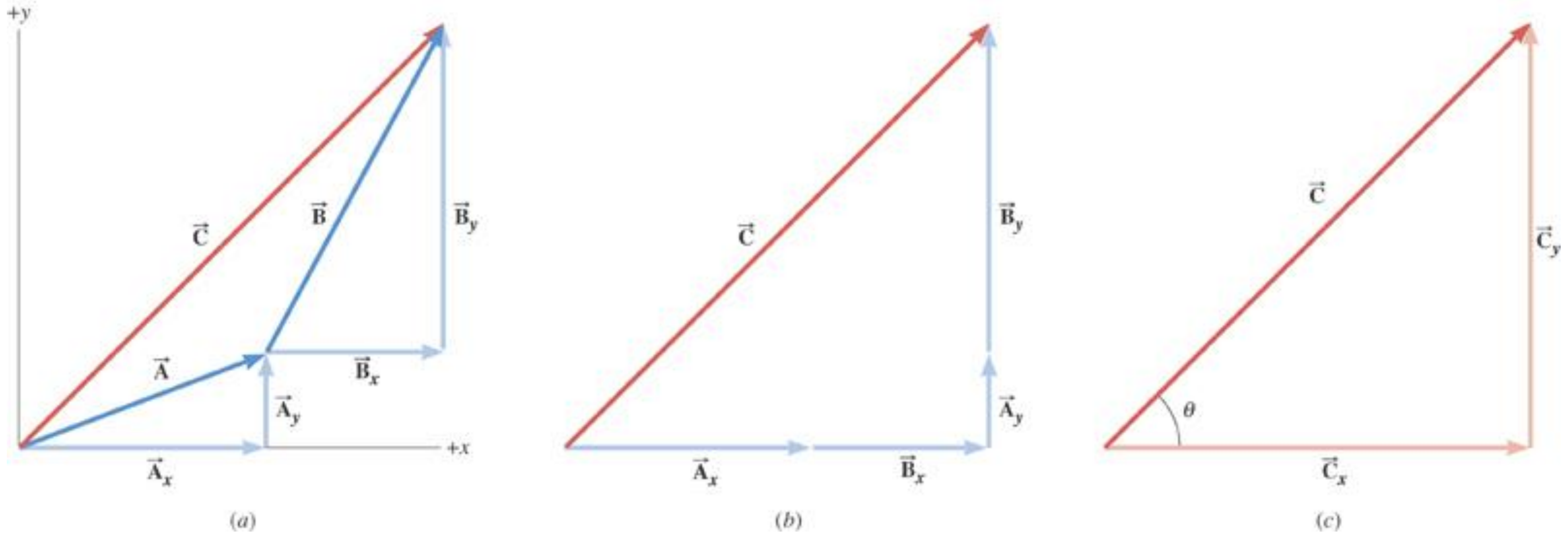
# 1.8 Addition of Vectors by Means of Components




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

$$\vec{\mathbf{A}} = A_x\hat{\mathbf{x}} + A_y\hat{\mathbf{y}} \qquad \vec{\mathbf{B}} = B_x\hat{\mathbf{x}} + B_y\hat{\mathbf{y}}$$

# 1.8 Addition of Vectors by Means of Components




$$\vec{\mathbf{C}} = A_x\hat{\mathbf{x}} + A_y\hat{\mathbf{y}} + B_x\hat{\mathbf{x}} + B_y\hat{\mathbf{y}}$$

$$= \left(A_x + B_x\right)\hat{\mathbf{x}} + \left(A_y + B_y\right)\hat{\mathbf{y}}$$

$$C_x = A_x + B_x \qquad C_y = A_y + B_y$$