

Chapter 1

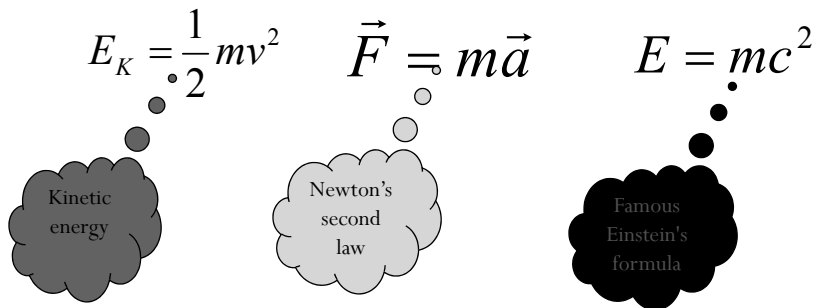
Introduction and Mathematical Concepts

1.1 The Nature of Physics

- Physics has developed out of the efforts of men and women to explain our physical environment.
- Physics predicts how nature will behave in one situation based on the results of experimental data obtained in another situation.

LAWS OF PHYSICS

LAWS OF PHYSICS ARE EXPRESSED IN
MATHEMATICAL FORM,



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.

Standards of Fundamental Quantities

- Standardized systems
 - Agreed upon by some authority, usually a governmental body
- SI – Système International
 - Agreed to in 1960 by an international committee
 - Main system used in this text

Fundamental Quantities and Their Units

Quantity	SI Unit
Length	meter
Mass	kilogram
Time	second
Temperature	Kelvin
Electric Current	Ampere

1.2 Units

Quantities Used in Mechanics

- In mechanics, three fundamental quantities are used:
 - Length
 - Mass
 - Time
- All other quantities in mechanics can be expressed in terms of the three fundamental quantities.

1.2 Units

SI units

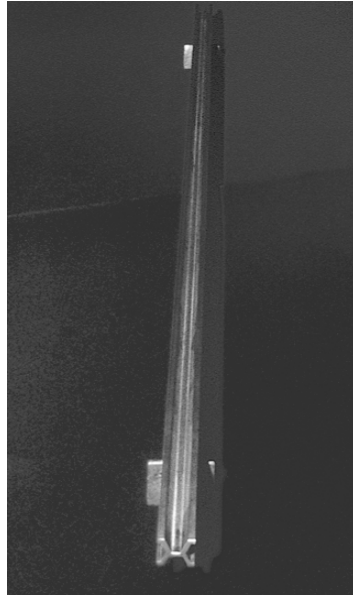
meter (m): unit of length

kilogram (kg): unit of mass

second (s): unit of time

1.2 Units

Standard platinum-iridium meter bar



1.2 Units

Standard platinum-iridium Kilogram



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)

Prefixes

- Prefixes correspond to powers of 10.
- Each prefix has a specific name.
- Each prefix has a specific abbreviation.
- The prefixes can be used with any basic units.
- They are multipliers of the basic unit.
- Examples:
 - $1 \text{ mm} = 10^{-3} \text{ m}$
 - $1 \text{ mg} = 10^{-3} \text{ g}$

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	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

^aAppendix A contains a discussion of powers of ten and scientific notation.

^bPronounced jig'a.

Fundamental and Derived Units

- Derived quantities can be expressed as a mathematical combination of fundamental quantities.
- Examples:
 - Area
 - A product of two lengths
 - Speed
 - A ratio of a length to a time interval
 - Density
 - A ratio of mass to volume

1.3 The Role of Units in Problem Solving

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

$$(3.281 \text{ feet}) / (1 \text{ meter}) = 1$$

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

1.3 The Role of Units in Problem Solving

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 guided by the fact that multiplying or dividing an equation by a factor of 1 does not alter the equation.

1.3 The Role of Units in Problem Solving

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.

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

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

1.3 The Role of Units in Problem Solving

DIMENSIONAL ANALYSIS

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

Is the following equation dimensionally correct?

$$x = \frac{1}{2} vt^2$$
$$[L] = \left[\frac{\text{L}}{\text{T}}\right][\text{T}]^2 = [\text{L}][\text{T}]$$

1.3 The Role of Units in Problem Solving

Is the following equation dimensionally correct?

$$x = vt$$
$$[\text{L}] = \left[\frac{\text{L}}{\text{T}} \right] [\text{T}] = [\text{L}]$$

Example

The period of a pendulum T is measured in units of time. Is the formula for the period correct?

$$T = 2\pi \sqrt{\frac{l}{g}}$$

The question is: Is the above equation dimensionally correct?

2π is dimensionless

l is length $[l] = \text{L}$

g is acceleration $[g] = \text{LT}^{-2}$

$$\left[\sqrt{\frac{l}{g}} \right] = \text{T}$$

Rounding

- Last retained digit is increased by 1 if the last digit dropped is greater than 5.

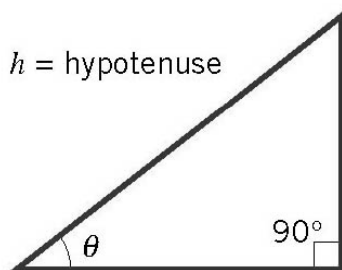
e.g: 1.346 becomes 1.35

- Last retained digit remains as it is if the last digit dropped is less than 5.

e.g: 1.343 becomes 1.34

- Saving rounding until the final result will help eliminate accumulation of errors.

1.4 Trigonometry



h = hypotenuse

h_o = length of side
opposite the
angle θ

h_a = length of side
adjacent to the angle θ

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

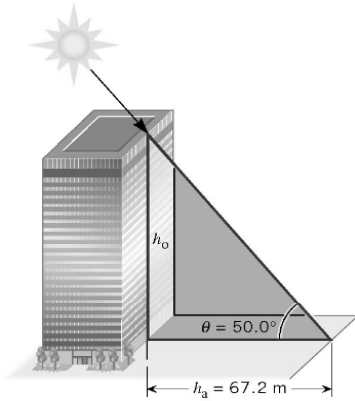
$$\cos \theta = \frac{h_a}{h}$$

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

Example

On a sunny day, a tall building casts a shadow that is 67.2 m long. The angle b/w the sun's rays and the ground is $\theta=50^\circ$, as shown in the fig below.

Determine the height of the building.

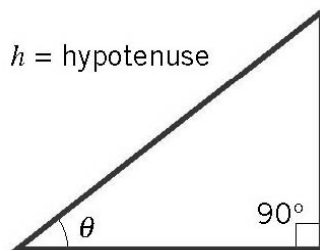


$$\tan \theta = \frac{h_o}{h_a}$$

$$\tan 50^\circ = \frac{h_o}{67.2\text{m}}$$

$$h_o = \tan 50^\circ (67.2\text{m}) = 80.0\text{m}$$

The concept of "inverse trigonometric functions"



h = hypotenuse

h_o = length of side opposite the angle θ

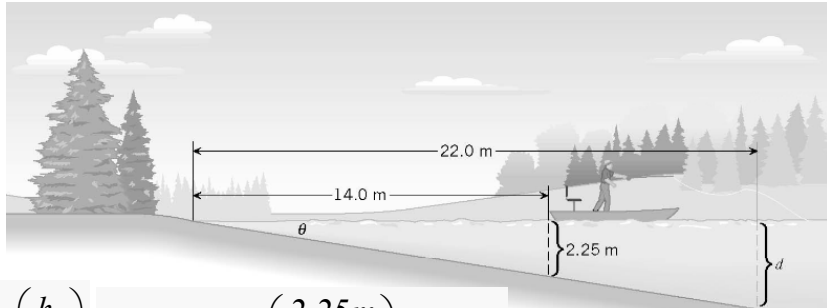
h_a = length of side adjacent to the angle θ

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

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

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

A lakefront drops gradually at an angle θ . To know how deep the lake at various distances from the shore. A lifeguard rows straight out from the shore a distance of 14m and drops a weighted fishing line. By measuring the length of the line, the lifeguard determines the depth to be 2.25m. (a) What is the value of θ ? (b) What would be the depth d of the lake at a distance of 22m from the shore?



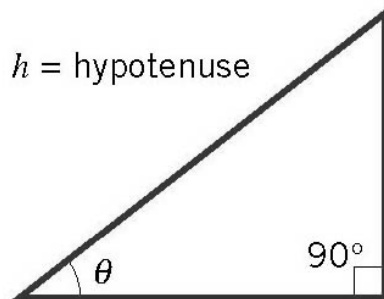
$$\theta = \tan^{-1}\left(\frac{h_o}{h_a}\right) \Rightarrow \theta = \tan^{-1}\left(\frac{2.25\text{m}}{14.0\text{m}}\right) = 9.13^\circ$$

$$\tan \theta = \frac{h_o}{h_a} \Rightarrow h_o = h_a \tan \theta \Rightarrow d = h_o = (22\text{m})(\tan 9.13^\circ) = 3.54\text{m}$$

1.4 Trigonometry

Pythagorean theorem:

$$h^2 = h_o^2 + h_a^2$$



h = hypotenuse

h_o = length of side
opposite the
angle θ

h_a = length of side
adjacent to the angle θ

1.5 Scalars and Vectors

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

temperature, speed, mass

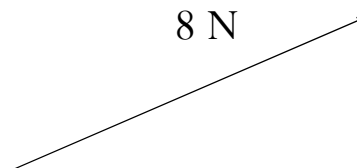
A *vector* quantity deals inherently with both magnitude and direction:

velocity, force, displacement

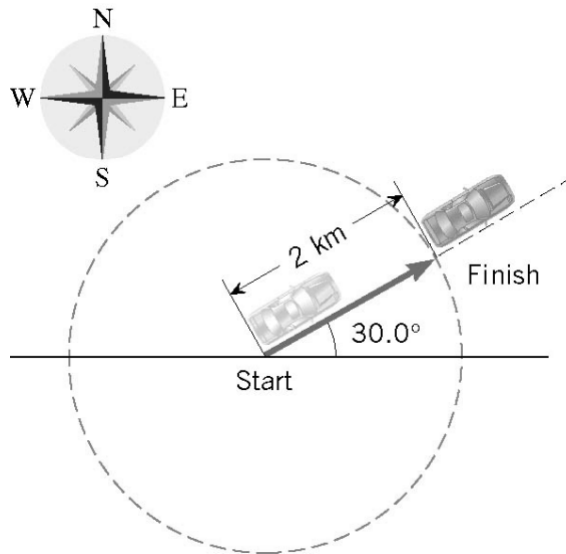
1.5 Scalars and Vectors

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

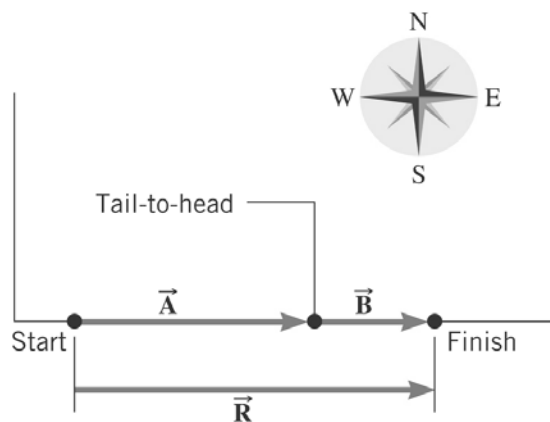


1.6 Vector Addition and Subtraction

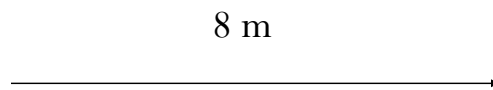
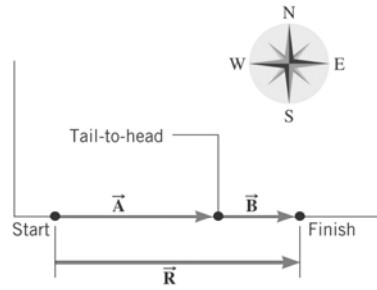
Often it is necessary to add one vector to another.

Vectors Addition:

Adding collinear vectors:



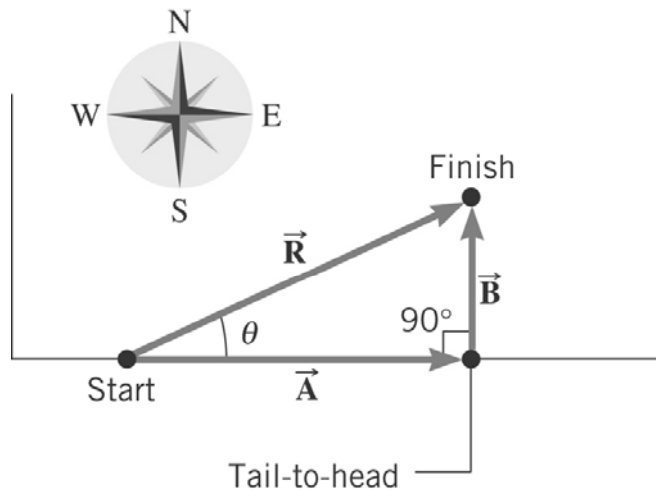
1.6 Vector Addition and Subtraction



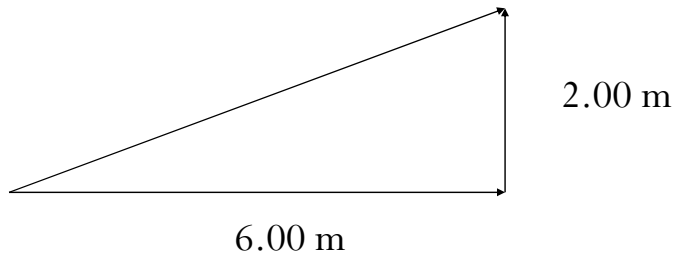
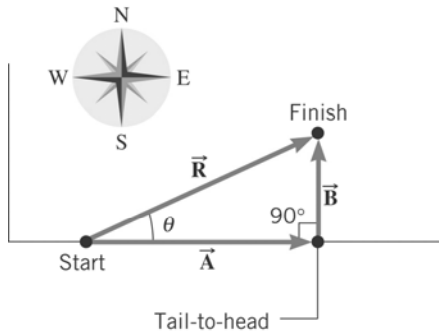
$$\vec{R} = \vec{A} + \vec{B}$$

Adding Non-Collinear Vectors

We use the tail-to-head fashion to find the resultant.



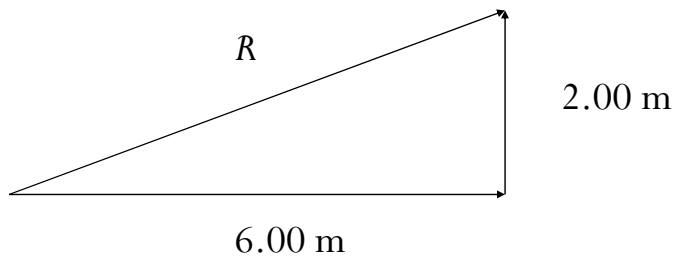
1.6 Vector Addition and Subtraction



Finding the magnitude of the resultant:

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

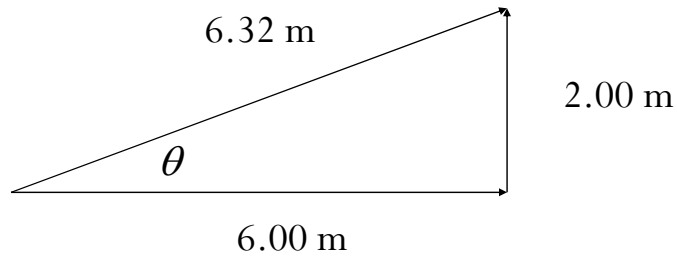
$$R = \sqrt{(2.00 \text{ m})^2 + (6.00 \text{ m})^2} = 6.32 \text{ m}$$



Finding the direction of the resultant:

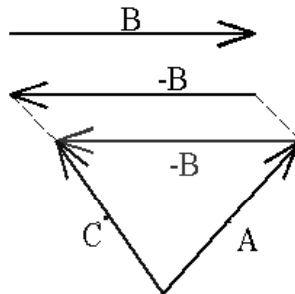
$$\tan \theta = 2.00/6.00$$

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

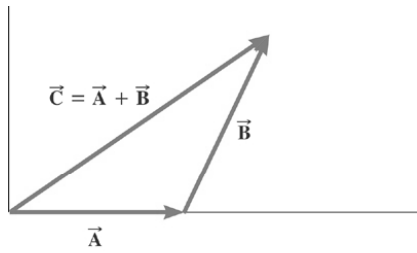


Subtracting two vectors

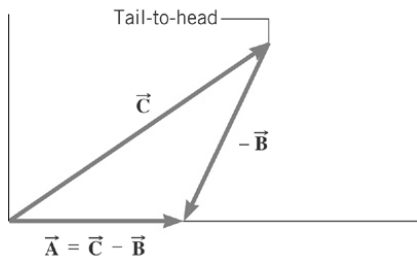
$$\mathbf{A} - \mathbf{B} = \mathbf{A} + (-\mathbf{B})$$



Vectors Subtraction:



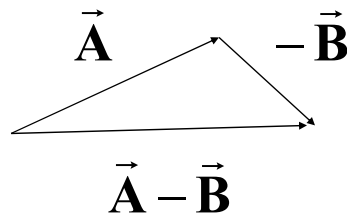
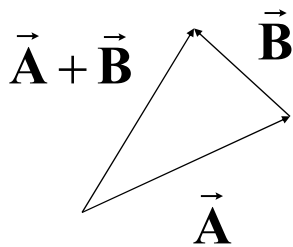
(a)



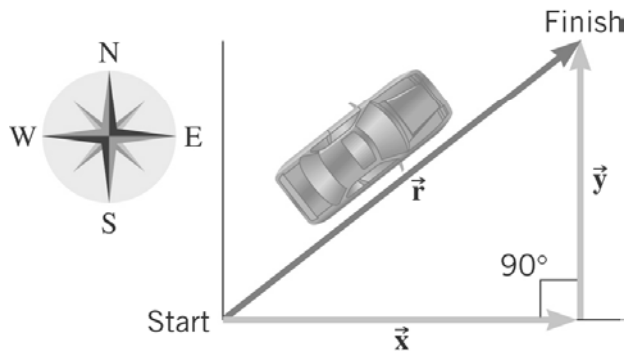
(b)

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

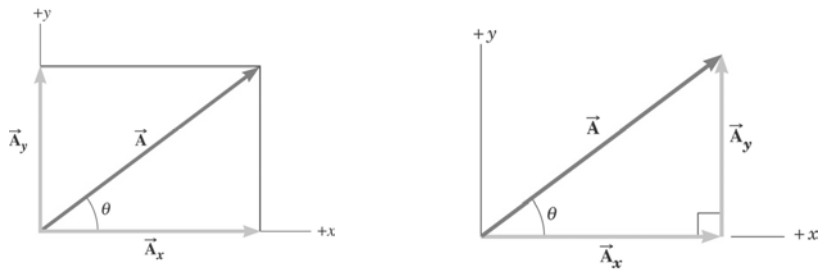


1.7 The Components of a Vector



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

1.7 The Components of a Vector



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

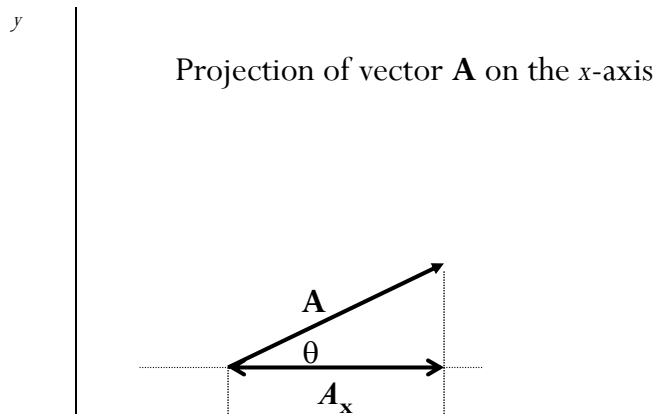
1.7 The Components of a Vector

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{A} .

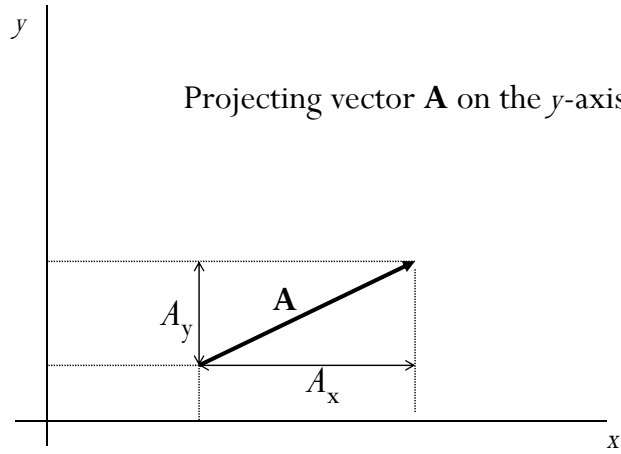
\hat{x} and \hat{y} are unit vectors with magnitude 1.

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



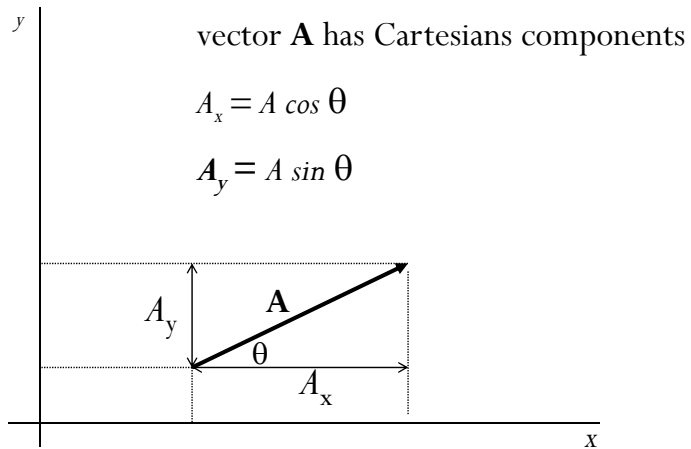
The x -component of vector \mathbf{A} is A_x

$$\mathbf{A}_x = A \cos \theta$$



The y -component of vector **A** is A_y

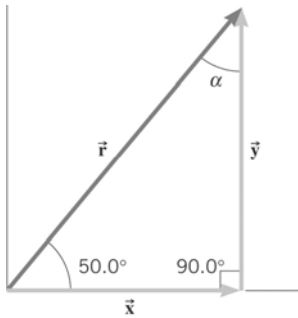
$$A_y = A \sin \theta$$



1.7 The Components of a Vector

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.



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

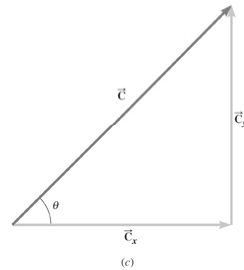
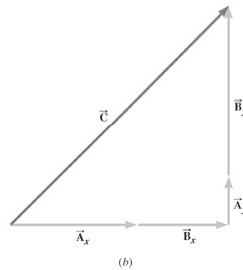
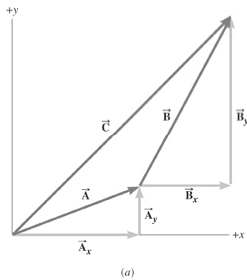
$$y = r \sin \theta = (175 \text{ m})(\sin 50.0^\circ) = 134 \text{ m}$$

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

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

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

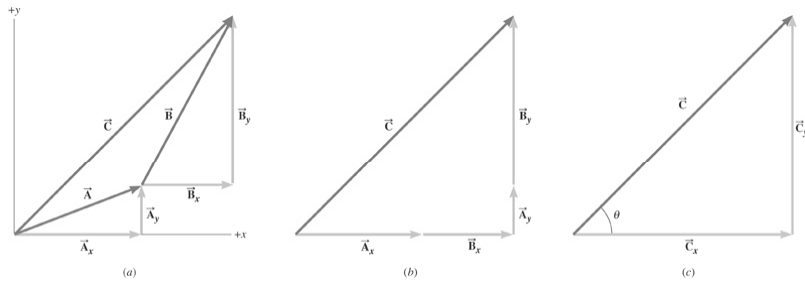
1.8 Addition of Vectors by Means of Components



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

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

1.8 Addition of Vectors by Means of Components



$$\begin{aligned}\vec{C} &= A_x \hat{x} + A_y \hat{y} + B_x \hat{x} + B_y \hat{y} \\ &= (A_x + B_x) \hat{x} + (A_y + B_y) \hat{y} \\ C_x &= A_x + B_x & C_y &= A_y + B_y\end{aligned}$$

The magnitude of \vec{C} is:

$$C = \sqrt{C_x^2 + C_y^2}$$

Product of a scalar by a vector

If m is a scalar and \mathbf{A} is a vector,

- Then $m\mathbf{A}$ is a vector

$$|m\mathbf{A}| = mA$$

