جـــامـعـة جـــدة
University of Jeddah

SCPH 101

Ch. 1

Units, Physical Quantities, and Vectors

Chapter 1

Chapter One
Units, Physical Quantities, and Vectors

- ***Standards and Units***
- ***Using and Converting Units***
- ***Vectors and Vector Addition***
- ***Component of Vectors***
- ***Unit Vectors***
- ***Products of Vectors***

Standards and Units

Measuring Things

- Measuring things can be by direct or indirect ways.

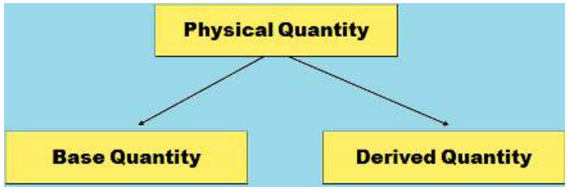
- Length

- Temperature

- Speed

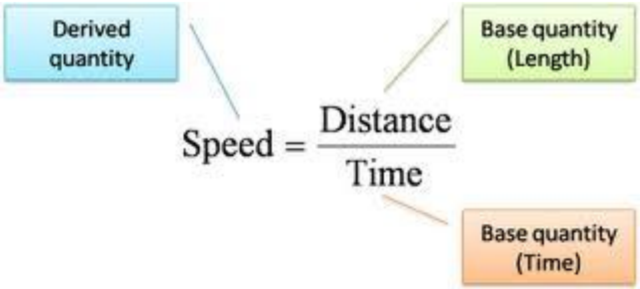
Standards and Units

- Physical Quantities Divided into two categories:



  - Basic Quantities.

  - Derived Quantities.



Standards and Units

Basic Quantities:

- Do not need other physical quantities to define them.
- Represented by one unit and without particular direction.
- Examples:

Unit symbol	Unit name	Basic physical quantities	
m	المتر	Length	الطول
s	الثانية	Time	الزمن
Kg	كيلو جرام	Mass	الكتلة
K	الكلفن	Temperature	درجة الحرارة
A	الأمبير	Electric Carnet	شدة التيار
C_d	الشمعة	Luminous Intensity	قوة الإضاءة

Standards and Units

Symbol	Multiple	Unit Name
K	10^3	Kilo
M	10^6	Mega
G	10^9	Giga
T	10^{12}	Tera
d	10^{-1}	Deci
c	10^{-2}	Centi
m	10^{-3}	Milli
μ	10^{-6}	Micro
n	10^{-9}	Nano
p	10^{-12}	Pico

Standards and Units

Derived Quantities:

- Expressed by more than one basic physical quantity.
- Examples:

Formula	Symbol	Derived physical quantities	
الطول × العرض	A	Area	المساحة
المسافة ÷ الزمن	υ	Velocity	السرعة
السرعة ÷ الزمن	a	Acceleration	التسارع
الكتلة ÷ الحجم	ρ	Density	الكثافة
الكتلة × التسارع	F	Force	القوة

Standards and Units

The International System of Units

- The units are a fundamental part of physical quantities to define it.

- Example:

$$m = 4 \ \ kg$$

Unit

Quantity Magnitude

Standards and Units

- There are several conventional systems of units:

  a) French system:

  centimeter-gram-second (cgs).

  b) Metric system:

  meter-kilogram-second (mks).

  c) British system:

  foot, slug and pound.

Standards and Units

- The metric system has been adopted in 1971 at the general conference of the measurements and weights in France (SI units).

Quantity	Unit Name	Unit Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg

Standards and Units

Length

The meter is the length of the path traveled by light in a vacuum during a time interval of 1/299 792 458 of a second.

Standards and Units

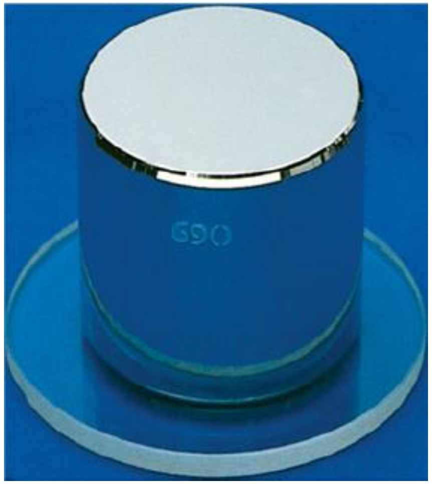
Time

One second is the time taken by 9 192 631 770 oscillations of the light (of a specified wavelength) emitted by a cesium-133 atom.

Standards and Units

Mass

The Standard Kilogram



Density

$$\rho = \frac{m}{V}$$

Using and Converting Units

Changing Units

$$\frac{1\ \text{min}}{60\ \text{s}} = 1 \quad \text{and} \quad \frac{60\ \text{s}}{1\ \text{min}} = 1.$$

$$2\ \text{min} = (2\ \text{min})(1) = (2\ \cancel{\text{min}})\left(\frac{60\ \text{s}}{1\ \cancel{\text{min}}}\right) = 120\ \text{s}.$$

Using and Converting Units

Example 1:

A car is traveling at 20 m/s. The speed of this car is equivalent to:

Solution:

(C)

(A) 23 km/h
(B) 56 km/h
(C) 72 km/h
(D) 97 km/h

Using and Converting Units

Example 2:

A cube of edge 47.5 mm, its volume is:

Solution:

(D)

(A) 43 m^3
(B) 0.473 m^3
(C) 47.3 m^3
(D) 1.072×10^{-4} m^3

Using and Converting Units

Example 3:

A train moves with a speed of 65 mile per hour. The speed in SI units is: (Hint: 1 mile = 1610 m)

Solution:

(B)

(A) 24
(B) 29
(C) 32
(D) 37

Vectors and Vector Addition

Vectors and Scalars

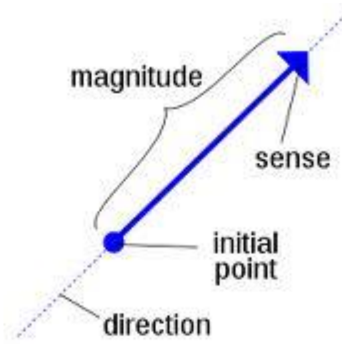
Scalars

- Have a magnitude only, such as:
    - Temperature.
    - Area.
    - Length.
- Specified by a number with a unit, (10°C) or (3m).
- Obey the rules of ordinary algebra.

Vectors and Vector Addition

Vectors

- Have both magnitude and direction, such as:
  - Displacement.
  - Velocity.
  - Acceleration.



- Specified by a number with a unit and direction,
  - (4 m) North.
  - (60 km/h) South.

- Obey the rules of vector algebra.

Vectors and Vector Addition

Example 4:

Which of the following quantities is not a vector quantity?

Solution:

(B)

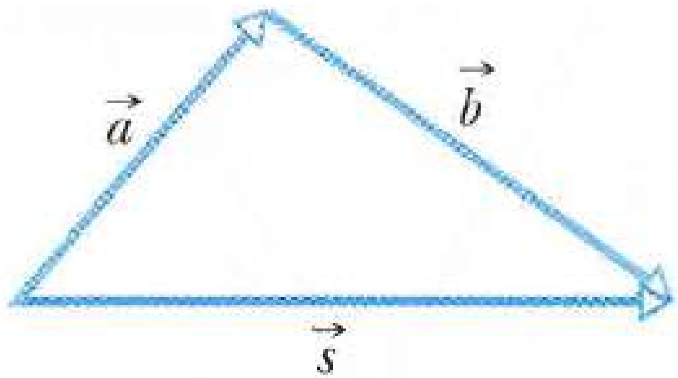
(A) Velocity
(B) Mass
(C) Acceleration
(D) Force

Vectors and Vector Addition

Adding Vectors Geometrically

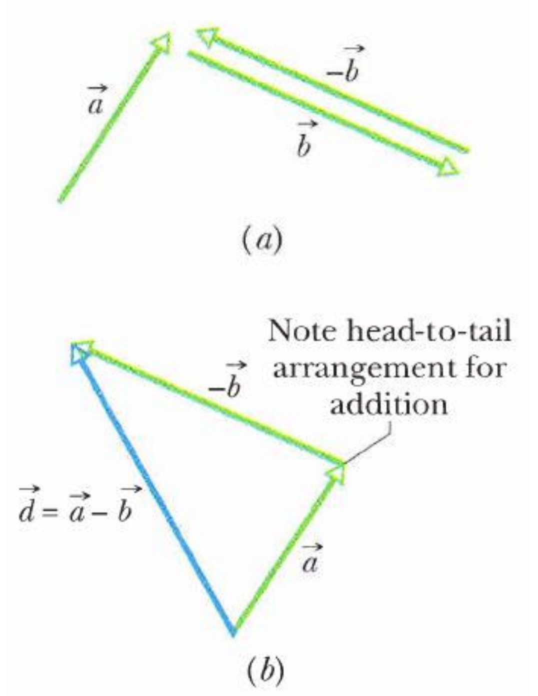
- Vectors added geometrically by drawing them to a common scale and placing them head to tail.

- Their vector sum can be represented by connecting the tail of the first to the head of the second.



Vectors and Vector Addition

- To subtract, reverse the direction of the second vector then add to the first.



- Vector addition is commutative and obeys the associative law.

$$\vec{a} + \vec{b} = \vec{b} + \vec{a}$$

$$(\vec{a} + \vec{b}) + \vec{c} = \vec{a} + (\vec{b} + \vec{c})$$

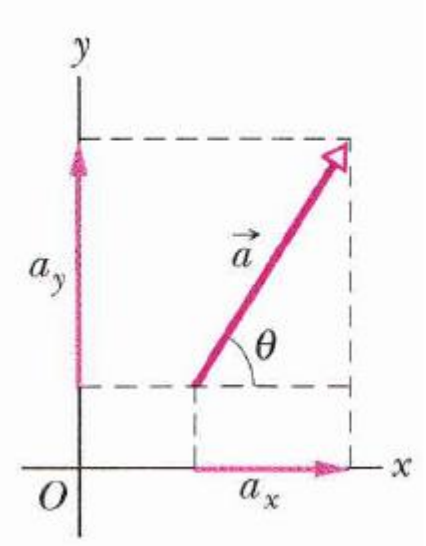
Component of Vectors

Components of Vectors

- Two dimensional vector has scalar components given by :

$$a_x = a\cos\theta$$

$$a_y = a\sin\theta,$$



- The magnitude and direction of the vector can be given as follows:

$$a = \sqrt{a_x^2 + a_y^2}$$

$$\tan\theta = \frac{a_y}{a_x}$$

Component of Vectors

Adding Vectors by Components

- To add vectors in component form, if

$$\vec{r} = \vec{a} + \vec{b},$$

Then

$$r_x = a_x + b_x$$
$$r_y = a_y + b_y$$
$$r_z = a_z + b_z.$$

Component of Vectors

Example 5:

The component of vector $\vec{A}$ are given as $A_x = 5.5\, m$ and $A_y = -5.3\, m$. The magnitude of vector $\vec{A}$ is:

Solution:

(C)

(A) 6.1 m
(B) 6.9 m
(C) 7.6 m
(D) 8.4 m

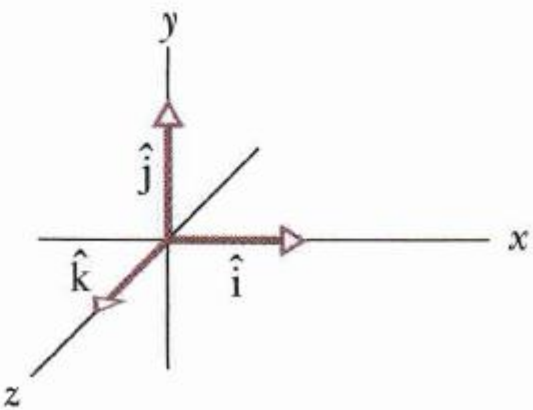
Unit Vectors

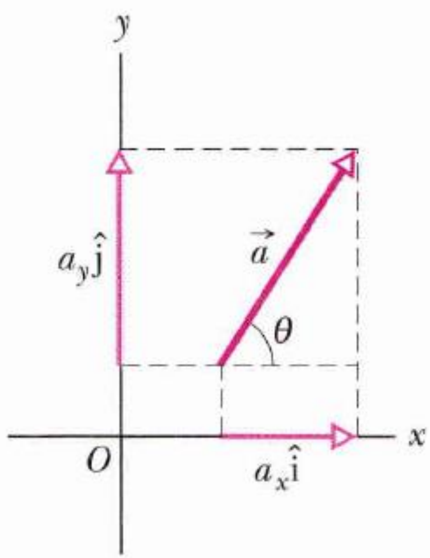
Unit Vectors

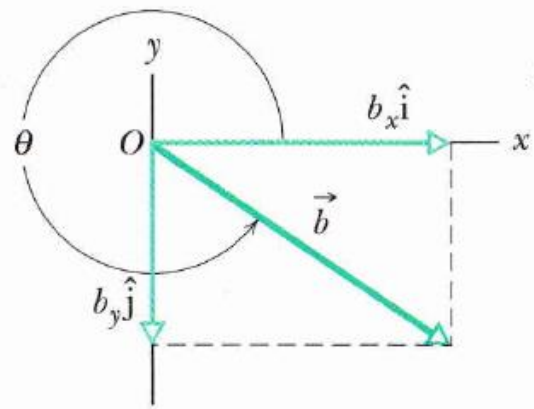
- Unit vectors have magnitude of unity and directed in the positive directions of the axes.

$$\vec{a} = a_x\hat{\mathrm{i}} + a_y\hat{\mathrm{j}}$$

$$\vec{b} = b_x\hat{\mathrm{i}} + b_y\hat{\mathrm{j}}.$$







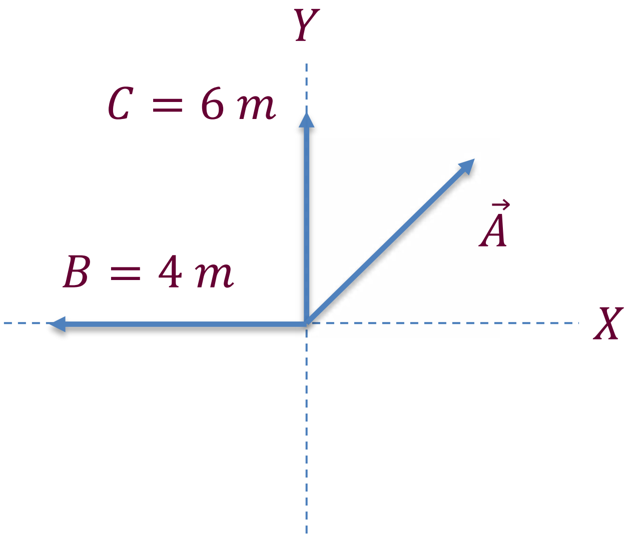
Unit Vectors

Example 6:

In figure, if $\vec{A} + \vec{B} - \vec{C} = 4\hat{\imath}$ then the vector $\vec{A}$ in unit vector notation is:

Solution:

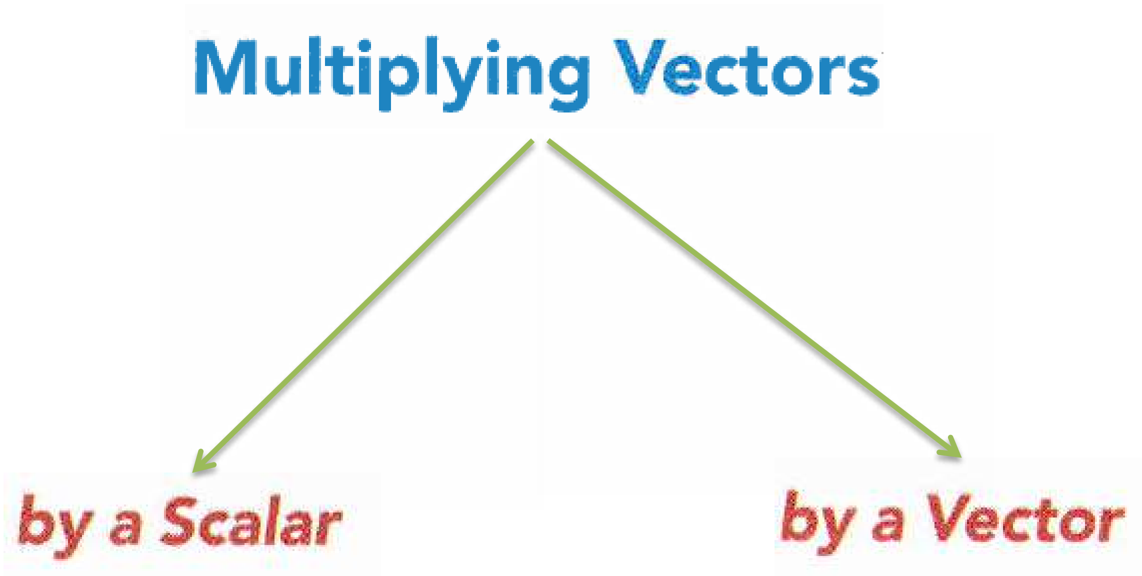
(C)



(A) $4\hat{\imath} + 2\hat{\jmath}$
(B) $9\hat{\imath} + 4\hat{\jmath}$
(C) $8\hat{\imath} + 6\hat{\jmath}$
(D) $5\hat{\imath} + 4\hat{\jmath}$

Products of Vectors

Multiplying Vectors



Products of Vectors

Multiplying Vector by a Scalar

- If we multiply a vector $\vec{a}$ by a scalar s, we get a new vector.
- Its magnitude is the product of the magnitude of $\vec{a}$ and the absolute value of s.

$$s\,\vec{a}$$

- Its direction is the direction of $\vec{a}$ if s is positive but the opposite direction if s is negative.
- To divide $\vec{a}$ by s, we multiply $\vec{a}$ by $1/s$.

$$1/s\,\vec{a}$$

Products of Vectors

Multiplying a Vector by a Vector

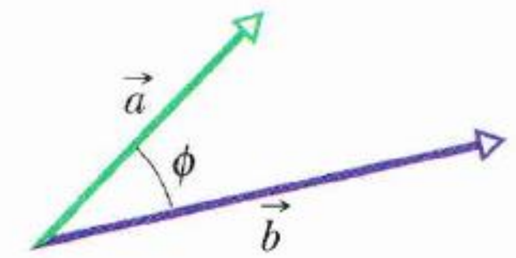
The Scalar Product

The Vector Product

Products of Vectors

The Scalar Product

$$\vec{a} \cdot \vec{b} = ab \cos \phi,$$



$$\vec{a} \cdot \vec{b} = \vec{b} \cdot \vec{a}$$

$$\vec{a} \cdot \vec{b} = (a_x\hat{\mathrm{i}} + a_y\hat{\mathrm{j}} + a_z\hat{\mathrm{k}}) \cdot (b_x\hat{\mathrm{i}} + b_y\hat{\mathrm{j}} + b_z\hat{\mathrm{k}}),$$

$$\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z.$$

Products of Vectors

Example 6:

Given $\vec{A} = \hat{\mathrm{i}} + 2\hat{\mathrm{j}} + 3\hat{\mathrm{k}}$, $\vec{\mathrm{B}} = 2\hat{\mathrm{i}} - 3\hat{\mathrm{j}} + 4\hat{\mathrm{k}}$, then $(\vec{A} \cdot \vec{B})$ is:

Solution:

(C)

(A) $3\hat{\mathrm{i}} + 4\hat{\mathrm{j}} - 5\hat{\mathrm{k}}$
(B) 40
(C) 8
(D) $\hat{\mathrm{i}} + \hat{\mathrm{j}} - 5\hat{\mathrm{k}}$

Products of Vectors

Example 7:

Given $\vec{A} = 2\hat{i} + \hat{j} + 3\hat{k}$, $\vec{B} = 2\hat{i} - 6\hat{j} + 7\hat{k}$, $\vec{C} = 2\hat{i} - \hat{j} + 4\hat{k}$ then the vector $\vec{D} = 2\vec{A} + \vec{B} - \vec{C}$ is:

Solution:

(D)

(A) $-\hat{i} - 2\hat{j} + 3\hat{k}$
(B) $3\hat{i} + 2\hat{j} - 5\hat{k}$
(C) $3.5\hat{i}$
(D) $4\hat{i} - 3\hat{j} + 9\hat{k}$

Products of Vectors

Example 8:

Refer to Example 7, the angle between the vector $\vec{A}$ and the positive z-axis is:

Solution:

(B)

(A) Zero
(B) 36.7^{o}
(C) 180^{o}
(D) 315^{o}

Products of Vectors

Example 9:

The result of $\hat{i} \cdot \hat{j}$ is:

Solution:

(A)

(A) Zero
$(B)\hat{i}$
(C) $\hat{k}$
(D) $\hat{j}$

Products of Vectors

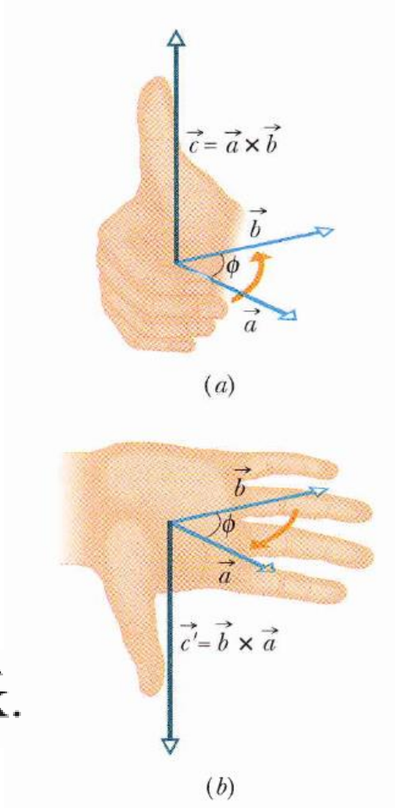
The Vector Product

$$c = ab \sin \phi,$$

$$\vec{b} \times \vec{a} = -(\vec{a} \times \vec{b}).$$

$$\vec{a} \times \vec{b} = (a_x\hat{\mathrm{i}} + a_y\hat{\mathrm{j}} + a_z\hat{\mathrm{k}}) \times (b_x\hat{\mathrm{i}} + b_y\hat{\mathrm{j}} + b_z\hat{\mathrm{k}}),$$

$$\vec{a} \times \vec{b} = (a_yb_z - b_ya_z)\hat{\mathrm{i}} + (a_zb_x - b_za_x)\hat{\mathrm{j}} + (a_xb_y - b_xa_y)\hat{\mathrm{k}}.$$



Products of Vectors

Example 10:

If $\vec{A}$ and $\vec{B}$ are vectors with magnitudes 5 and 4 respectively, and the magnitude of their cross product is 17.32, then the angle between $\vec{A}$ and $\vec{B}$ is:

Solution:

(C)

(A) 180^o
(B) 90^o
(C) 60^o
(D) 45^o

Products of Vectors

Example 11:

Given that $\vec{A} = \hat{\text{i}} + 2\hat{\text{j}} + 3\hat{\text{k}}$, $\vec{\text{B}} = 2\hat{\text{i}} - \hat{\text{j}} + 4\hat{\text{k}}$, then $(\vec{A} \times \vec{B})$ is:

Solution:

(A)

(A) $11\hat{\text{i}} + 2\hat{\text{j}} - 5\hat{\text{k}}$
(B) $-\hat{\text{i}} - 2 + 3\hat{\text{k}}$
(C) $3.5\hat{\text{i}}$
(D) $\hat{\text{i}} + 2\hat{\text{j}} - 5\hat{\text{k}}$

Products of Vectors

Example 12:

If $\vec{A} \times \vec{B} = 0$, the angle between the vectors $\vec{A}$ and $\vec{B}$ is:
(Hint: $\vec{A}$ and $\vec{B}$ are non-zero vectors)

Solution:

(D)

(A) 270^o
(B) 90^o
(C) 45^o
(D) Zero

Products of Vectors

Example 13:

The result of $(\hat{i} \times \hat{j}) \cdot \hat{j}$ is:

Solution:

(D)

(A) $\hat{i}$
(B) $\hat{j}$
(C) $\hat{k}$
(D) Zero

Products of Vectors

Example 14:

The result of $(\hat{i} \times \hat{j}) \times \hat{i}$ is:

Solution:

(B)

(A) Zero
(B) $\hat{j}$
(C) $\hat{k}$
(D) 1