CC140

1. Preliminaries

1.1.Physical Quantities and Units of Measurement

- ✓ A quantity is a definite or indefinite amount or size of something.

Examples

Thing	Amount	Type
Desire	Strong	Indefinite
Mass of box	Heavy	Indefinite
Mass of box	5 kg	Definite
Love	Deep	Indefinite
Height of a person	Tall	Indefinite
Height of a person	2 m	Definite

- ✓ A quantity could be: i) Non-physical quantities or

ii) A physical quantity

i) ***Non-physical quantities***: are not a concern in physics studies and experiments and cannot be measured. **E.g.** love, hate, fear and hope .

ii) ***A physical quantity:*** A physical quantity is a quantity that can be measured by defining its units of measurement or using a measuring instrument.

- always expressed in terms of a numerical value (magnitude) and a unit.

1.1.Physical Quantities and Units of Measurement

- **Physical quantity = (numerical value) unit**
- Have there own unit of measurement.
- Could be: Fundamental (*Basic*) and *Derived*

Basic physical quantity	Symbol for quantity	Basic unit	Symbol for unit
Length	l	metre	m
Mass	m	kilogram	kg
Time	t	second	s
Electric current	I	ampere	A
Temperature	T	kelvin	K
Amount of substance	n	mole	mol
Luminous intensity	I_v	candela	cd

Derived quantity	Unit	Symbol	
Area	square meter	m^2	m^2
Volume	cubic meter	m^3	m^3
Frequency	Hertz	Hz	s^{-1}
Density	kilogram per cubic metre	kgm^{-3}	kgm^{-3}
Force	Newton	N	$kgms^{-2}$
Work, energy	Joule	$J\ (Nm)$	kgm^2s^{-2}
Power	Watt	$W\ (J/s)$	kgm^2s^{-3}
Velocity (speed)	metre per second	ms^{-1}	ms^{-1}

Dimension and dimensional analysis

- Every physical quantity can be expressed in terms of some *powers* of the fundamental SI quantities which are called the *dimensions* of the physical quantity in question. The square brackets [ ] stand for "dimension of"
- In mechanics, a derived physical quantity x can be expressed as

$$[x] = [l]^a[m]^b[t]^c = L^aM^bT^c$$

1.1.Physical Quantities and Units of Measurement

E.g. $[V] = L^3$; $[F] = MLT^{-2}$; $[\rho] = ML^{-3}$; $[E] = ML^2T^{-2}$ etc.

- ✓ Fundamental quantities and their dimension are listed in table below

Base Quantity	Symbol for Dimension
Length	L
Mass	M
Time	T
Current	I
Thermodynamic temperature	Θ
Amount of substance	N
Luminous intensity	J

SI Prefixes and scientific notation

- ✓ The International System of Units (SI) is a decimal system in which units are divided or multiplied by 10 to give smaller or larger units.

1.1.Physical Quantities and Units of Measurement

Prefix	Symbol	Base Unit Multiplier	In Words	Exponential
yotta	Y	1,000,000,000,000,000,000,000,000	septillion	10^{24}
zetta	Z	1,000,000,000,000,000,000,000	sextillion	10^{21}
exa	E	1,000,000,000,000,000,000	quintillion	10^{18}
peta	P	1,000,000,000,000,000	quadrillion	10^{15}
tera	T	1,000,000,000,000	trillion	10^{12}
giga	G	1,000,000,000	billion	10^{9}
mega	M	1,000,000	million	10^{6}
kilo	k	1,000	thousand	10^{3}
hecto	h	100	hundred	10^{2}
deca	da	10	ten	10^{1}
(base unit)		1	one	10^{0}
deci	d	0.1	tenth	10^{-1}
centi	c	0.01	hundredth	10^{-2}
milli	m	0.001	thousandth	10^{-3}
micro	µ	0.000001	millionth	10^{-6}
nano	n	0.000000001	billionth	10^{-9}
pico	p	0.000000000001	trillionth	10^{-12}
femto	f	0.000000000000001	quadrillionth	10^{-15}
atto	a	0.000000000000000001	quintillionth	10^{-18}
zepto	z	0.000000000000000000001	sextillionth	10^{-21}
yocto	y	0.000000000000000000000001	septillionth	10^{-24}

Conversion of Units

- Measurements of physical quantities are expressed in terms of *units*, which are standardized values.
- To convert a quantity from one unit to another, multiply by conversions factors.

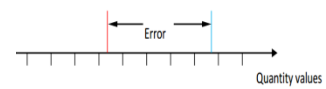
Quantity	From	To	Operation
Length	inch (in)	m	(inch) × 0.0254
	foot (ft)	m	(foot) × 0.3048
	mile (mi)	m	(mile) × 1609.34
Mass	pound (lb)	kg	(pound) × 0.4536
	metric ton (t)	kg	(ton) × 1000
	ounce	kg	(ounce) × 0.02835
Volume	liter (l)	m^3	(*liter*) × 0.001
	gallon (ga)	m^3	(gallon) × 0.00379
Temperature	fahrenheit (F)	K	$\{(\text{fahrenheit}) - 32\} \times \frac{5}{9} + 273.15$
	celcius (C)	K	(celcius) + 273.15

E.X: Honda Fit weighs about 2,500 lb. It is equivalent to 2500 x0.4536kg = 1134.0kg.

1.2. Uncertainty in Measurement and Significant Figures

- **Uncertainty and** Error **in measurement**
- Although the terms "error" and "uncertainty" are used interchangeably, they are a bit different.
- **Error** : is defined as the difference between an observed value and a true value.

$$Error = |observed\ value - true\ value|$$



- Measurement **errors** can arise from three possible origins: the *measuring device*, the *measurement procedure*, and the *measured quantity* itself.
- **Errors** can be divided into two types: *Systematic and Random errors.*
- ***Systematic errors*** arise from procedures, instruments, bias or ignorance.
- Systematic errors bias every measurement in the same direction, causing your measurement to consistently be higher or lower than the accepted value. **E.g.** The zero error of an ammeter is an example of systematic error
- ***Random errors*** are uncontrollable differences between measurements because of equipment, environment or other sources, no matter how well designed and calibrated the tools are.

1.2. Uncertainty in Measurement and Significant Figures

- Random errors are *unbiased* small variations that have both positive and negative values.
- Making multiple measurements and averaging can reduce the effect of random errors.
- Errors can also be classified as **absolute** and **relative:**
- **Absolute err**or is the difference between the measured value and the accepted value.

$$Absolute\ error = |measured\ value - accepted\ value|$$

- **Relative error** is a fractional error defined as:

$$Relative\ Error = \frac{Absolute\ error}{Accepted\ value}$$

- ***Percentage error*** is relative error expressed as a percentage:

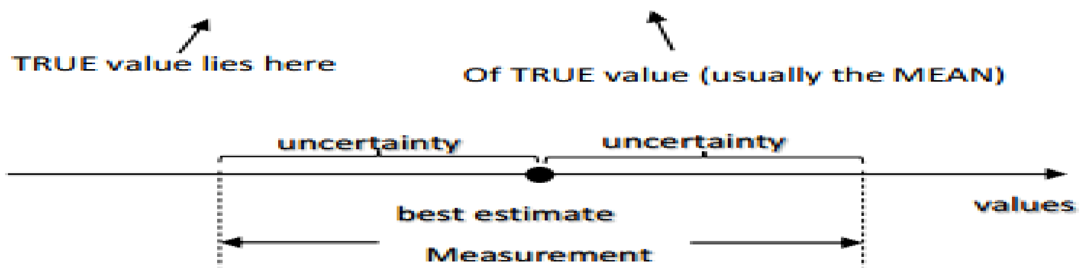
$$Percentage\ error = relative\ error \times 100\%$$

1.2. Uncertainty in Measurement and Significant Figures

Uncertainty

- Uncertainty is a quantification of the *doubt* about the measurement result.
- This quantification gives the range of values within which the true value is believed to lie with some level of confidence.
- Uncertainty is determined by statistical analysis of many values of measurement

$$measurement = (best\ estimate \pm uncertainty)\ unit\ of\ measurement$$



- The following general rules of thumb are often used to determine the uncertainty in a single measurement when using a scale or digital measuring device.

1.2. Uncertainty in Measurement and Significant Figures

- **<u>Uncertainty in a Scale Measuring Device</u> is equal to the smallest increment divided by 2.**

$$\boldsymbol{\sigma}_x = \frac{\text{smallest increment}}{\mathbf{2}}$$

. **E.g.** Meter Stick(Scale device)

$$\boldsymbol{\sigma}_{\mathbf{x}} = \frac{\mathbf{1}\boldsymbol{mm}}{\mathbf{2}} = \mathbf{0.5mm} = 0.05\text{cm}$$

- **<u>Uncertainty in a Digital Measuring Device</u>** is equal to the smallest increment.

$$\boldsymbol{\sigma}_{\mathbf{x}} = \text{smallest increment}$$

. **E.g.** Digital Balance (digital device)

5	.	7	5	1	3	kg

$$\boldsymbol{\sigma}_x = \mathbf{0.0001\ kg}$$

- In general, any measurement can be stated in the following preferred form:

1.2. Uncertainty in Measurement and Significant Figures

$$measurement = X_{best} \pm \sigma_x$$

x_{best} = best estimate of measurement

σ_x = uncertainty (error) in measurement

- **Rule For Stating Uncertainties** – Experimental uncertainties should be stated to 1- significant figure

Ex. $v = 31.25 \pm 0.034953$ m/s

$v = 31.25 \pm 0.03$ m/s (correct)

- **Percentage Uncertainty (Fractional Uncertainty)**– the uncertainty out of 100%

$$\%\sigma_x = \frac{\sigma_x}{X_{best}} \times 100\%$$

EX. $x = 47 \pm 2$ cm = $x = 47$ cm $\pm$ 4 % (By determining X_{best} & σ

1.2. Uncertainty in Measurement and Significant Figures

Significant Figures

- ✓ A significant figure is a meaningful or a reliably known digit in measurement.

A. <u>Rules for Determining Significant Figures in a Number</u>

1. All non-zero numbers are significant.
2. Zeros within a number are always significant.
3. Zeros that do nothing but set the decimal point are not significant. Both 0.000098 and 0.98 contain two significant figures.
4. Zeros that aren't needed to hold the decimal point are significant. For example; 4.00 has three significant figures.
5. Zeros that follow a number ***may*** be significant.

B. <u>Rule for Adding and Subtracting Significant Figures</u>

- ✓ When measurements are added or subtracted, the number of decimal places in the final answer should equal the smallest number of decimal places of any term.

<u>**Ex.**</u> 256.5895g+8.1g= 264.6895g= 264.7g (answer)

1.2. Uncertainty in Measurement and Significant Figures

C. <u>Rule for Multiplying/Dividing Significant Figures</u>

- ✓ When measurements are multiplied or divided, the number of significant figures in the final answer should be the same as the term with the lowest number of significant figures.

Ex. L_1=2.2 cm; L_2=38.2935 cm :

$$A=L_1L_2=84.126900000cm^2 = A=84\ cm^2 answer)$$

D. Stating a number in scientific notation removes all ambiguities with regard to how many significant figures a number has.

Order of magnitude

- ✓ The order of magnitude of a number is the value of the number rounded to the nearest power of ten (no significant figures)
- **Ex**: The number of molecules in a mole is of the order of 10^{23}, Planck's constant is of the order of 10^{-34}, The mean free path of a nitrogen molecule at room temperature and one atmosphere is 59 nm. The order of magnitude is 10^{-8}, The order of magnitude of 142 particles is 10^2. Since 142 in scientific notation is n1.42×10^2.

1.2. Uncertainty in Measurement and Significant Figure

Accuracy and Precision

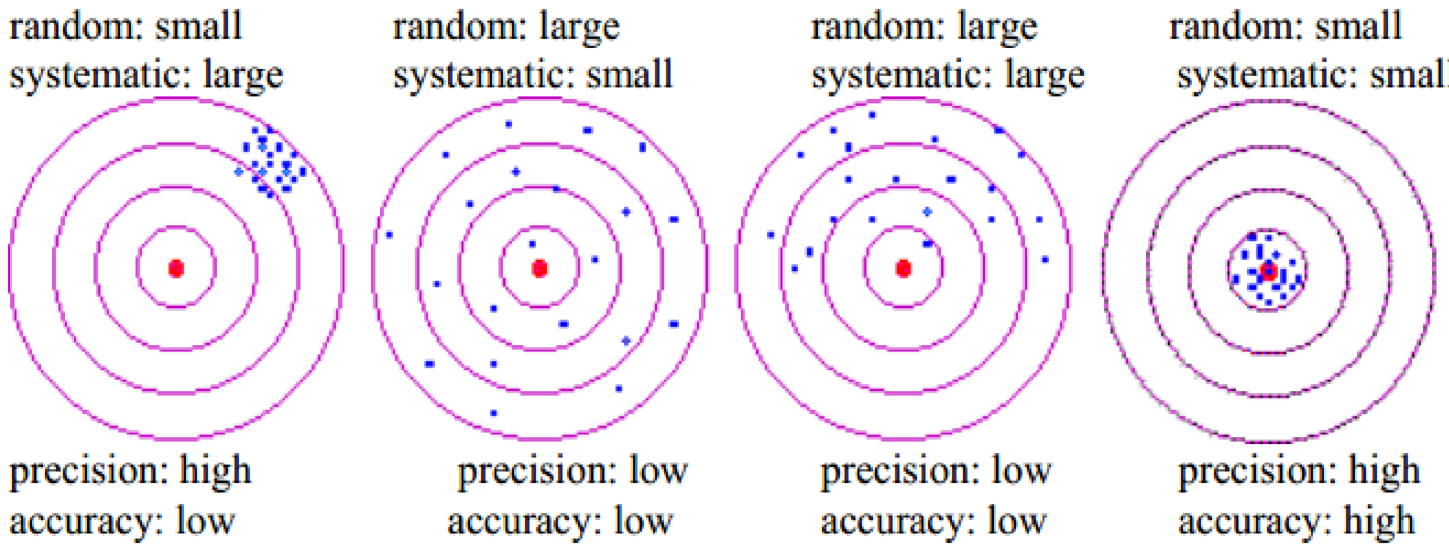
- ✓ The terms accuracy and precision are often mistakenly used interchangeably. In error analysis there is a clear distinction between the two.

Accuracy – an indication of how close a set of measurements is to the exact (true) value.

Precision – a measure of the closeness of a set of measurements. (sometimes it is used to specify the exactness of a measurement)

1.2. Uncertainty in Measurement and Significant Figures

- To get a better feeling for the difference between accuracy & precision and random & systematic errors, let's consider the following shooting-target analogy.
- The experiment is to shoot a set of rounds at a stationary target and analyze the results. The results are summarized below.



1.3. Vectors: Addition, Components, Magnitude and Direction

Vectors

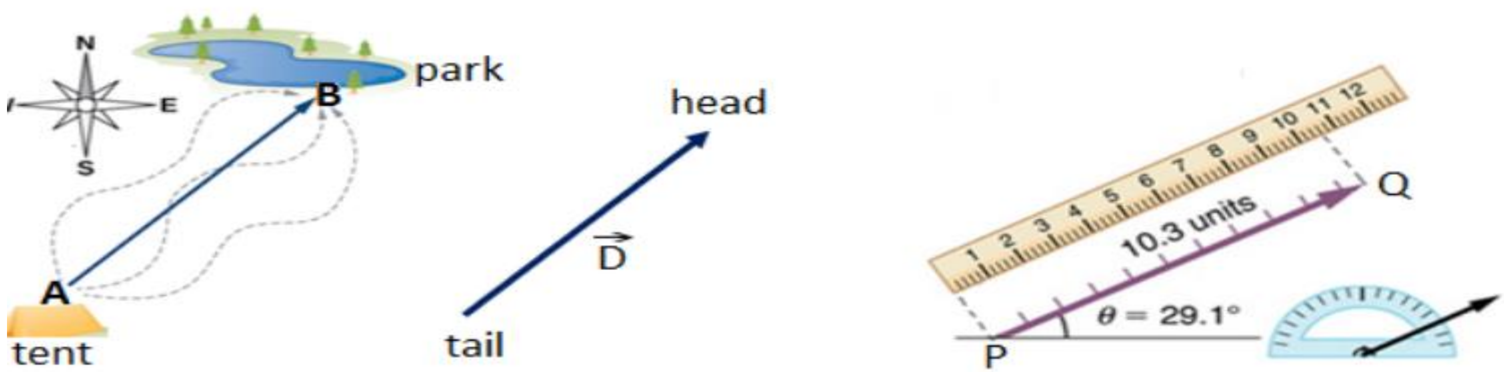
- ✓ Are expressed in terms of both magnitude (with a unit) and direction.
- ✓ Examples of vectors are force, velocity, acceleration, momentum, torque, electric and magnetic dipole moments, electric field, magnetic field etc.
- ✓ A physical quantity is a genuine vector if it adds to another vector according to the law of parallelogram
- ✓ Have magnitude and direction Vec.=Scalar +Direction
- ✓ Physical quantities such as length, volume, mass, density, temperature and time can be expressed in terms of magnitude or size alone (together with a unit). These are called **scalar** quantities.

1.3. Vectors: Addition, Components, Magnitude and Direction

Vector notation

- ✓ represented by Geometrically or analytically
- ✓ Geometrically represented by arrows in two or three dimensions.

<u>Ex</u>: Displacement from a tent to a unity park is 10.3km at an angle of 29.1^0 N/E



- ✓ Analytically represented or denoted by bold-face letter or a letter with an arrow above it.

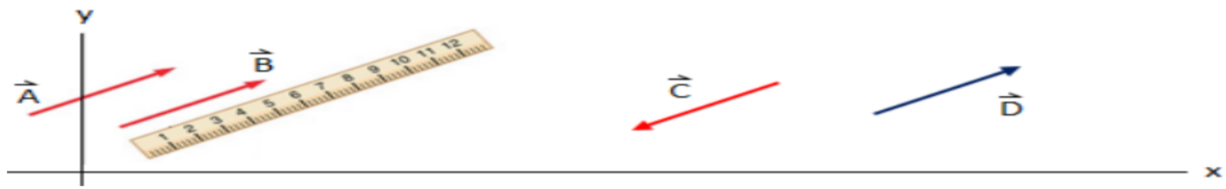
<u>Ex</u>: For a vector A: **A** or $\vec{A}$

1.3. Vectors: Addition, Components, Magnitude and Direction

Equality of Two Vectors

- ✓ Two vectors are equal if they have the same magnitude and direction.

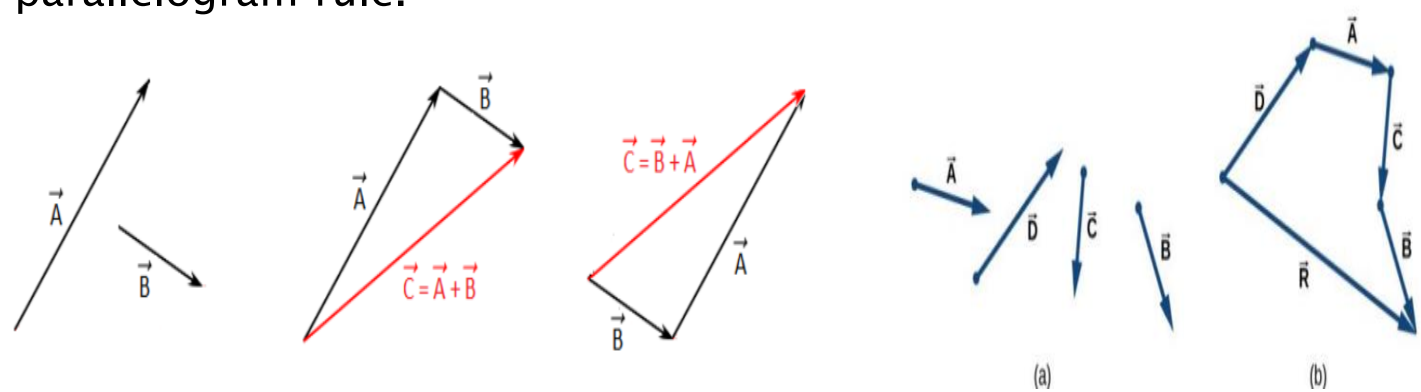
<u>Ex</u>: $\vec{A}$ and $\vec{B}$ but $\vec{C}$ and $\vec{D}$ are not equal.



Adding and Subtracting Vectors geometrically

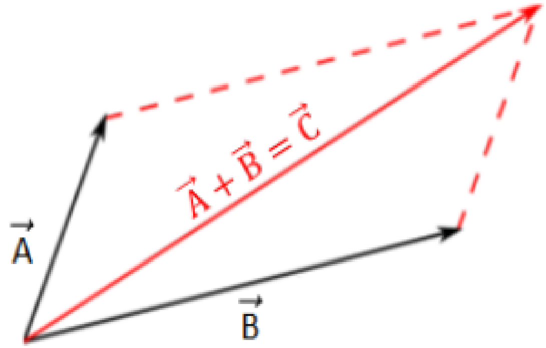
- ✓ Two vectors can be added geometrically using triangle rule, polygon rule or the parallelogram rule.

<u>Ex</u>:-



1.3. Vectors: Addition, Components, Magnitude and Direction

Ex -Parallelogram law



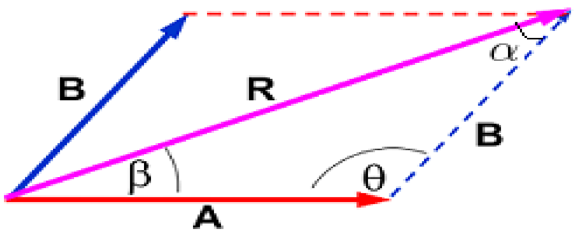
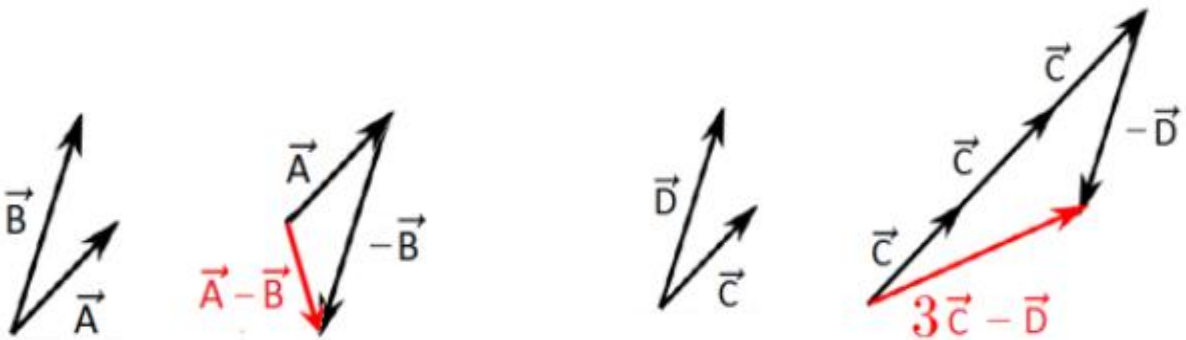


Figure 2. Parallelogram law of vector addition

- ✓ For subtraction of vectors, the only needed technique is reversing the direction of vector & add.

Ex:



1.3. Vectors: Addition, Components, Magnitude and Direction

Parallelogram law of vector addition

- ✓ *The parallelogram law* states that the resultant **R** of two vectors **A** and **B** is the **diagonal** of the **parallelogram** for which the two vectors **A** and **B** becomes adjacent sides.
- ✓ All three vectors **A**, **B** and **R** are concurrent as shown in Figure 2. All three vectors **A**, **B** and **R** are concurrent as shown in Figure 2 above.
- ✓ Applying cosine and sine laws for the triangle formed by the two vectors we find the magnitude and direction of $\overrightarrow{R}$

Cosine law and Sine Law

$$\text{Cosine law: } R = \sqrt{A^2 + B^2 - 2AB\cos\theta}$$

$$\text{Sine law: } \frac{\sin\theta}{R} = \frac{\sin\alpha}{A} = \frac{\sin\beta}{B}$$

1.3. Vectors: Addition, Components, Magnitude and Direction

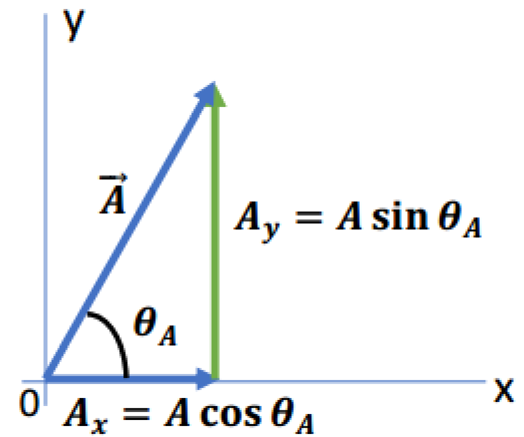
Components of a vector

- ✓ One way of finding the components of a vector uses the rectangular coordinate system as shown in Fig. below.
- ✓ The vector $\vec{A}$ can be expressed as the sum of two vectors, $\vec{A}x$ and $\vec{A}y$: $\vec{A} = \vec{A}x + \vec{A}y$

$Ax = A \cos \theta A, \quad Ay = A \sin \theta A$

- ✓ the magnitude and direction of any vector by the (inverse) equations:

$$A = \sqrt{A_x^2 + A_y^2} \qquad \theta_A = \tan^{-1}\left(\frac{A_y}{A_x}\right)$$

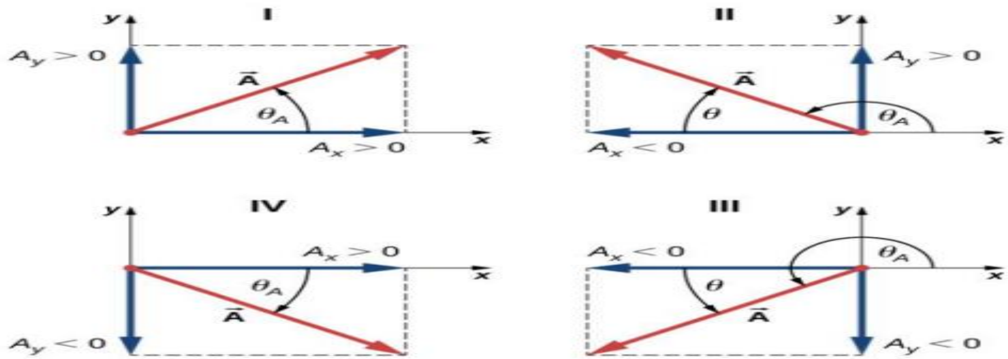


- For vectors in quadrants II and III, the direction angle of a vector is given by :

$\boldsymbol{\theta A = \theta + 180°}$ counterclockwise from the positive x-axis all possibilities are shown below.

1.3. Vectors: Addition, Components, Magnitude and Direction

- ✓ Generally, the components of a vector can be positive and negative scalar components.



- ✓ Similarly, any three dimensional vector A can be written as the sum of its *x, y and z* components.

$$\mathbf{A} = \mathbf{A}_x + \mathbf{A}_y + \mathbf{A}_z$$

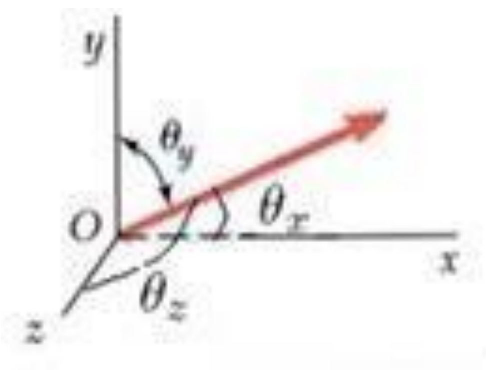
- ✓ And its magnitude becomes:

$$A = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

Direction of Cosines

- ✓ The direction angles that this ve ctor makes with the three axes, is given by the:

1.3. Vectors: Addition, Components, Magnitude and Direction



$$Cos\theta_x = \frac{A_x}{A} \quad \Rightarrow \quad \theta_x = \cos^{-1}\left(\frac{A_x}{A}\right)$$

$$Cos\theta_y = \frac{A_y}{A} \quad \Rightarrow \quad \theta_y = \cos^{-1}\left(\frac{A_y}{A}\right)$$

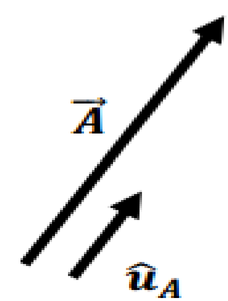
$$Cos\theta_z = \frac{A_z}{A} \quad \Rightarrow \quad \theta_z = \cos^{-1}\left(\frac{A_z}{A}\right)$$

Unit Vectors

- ✓ A unit vector, û is a vector of magnitude one. $|\hat{u}| = 1.$

A unit vector in the direction of any vector $\vec{A}$ is given by

$$\hat{u}_A = \frac{\vec{A}}{A}$$



1.3. Vectors: Addition, Components, Magnitude and Direction

- ✓ we can write any vector $\vec{A}$ in terms of its magnitude and parallel unit vector:

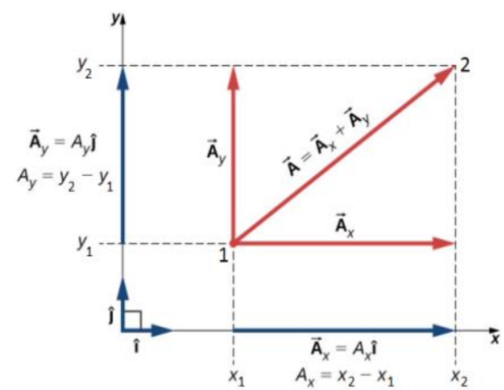
$$\vec{A} = \overbrace{A}^{\text{magnitude}}\underbrace{\hat{u}}_{\text{direction}}$$

Unit vectors of the rectangular xy-coordinate system

- ✓ In the rectangular xy coordinate system, unit vectors are defined in the directions of $+x$ and $+y$.
- ✓ The unit vector in the direction of $+x$ is denoted by $\hat{\imath}$
- ✓ the unit vector in the direction of $+y$ is denoted by $\hat{\jmath}$.
- ✓ the vector component in the x &y direction is described

as: $\vec{A}x = Ax\hat{\imath}$; $\vec{A}y = Ay\hat{\jmath}$

- ✓ Suppose $\vec{A}$ and $\vec{B}$ are any two vectors in the
- ✓ rectangular coordinate system given by:



1.3. Vectors: Addition, Components, Magnitude and Direction

$$\vec{A} = Ax\hat{\imath} + Ay\hat{\jmath} \qquad \text{and } \vec{B} = Bx\hat{\imath} + By\hat{\jmath}$$

- The sum or difference, $\vec{A} \pm \vec{B}$, is carried out component-by-component as shown below:

$$\vec{S} = \vec{A} + \vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath}) + (B_x\hat{\imath} + B_y\hat{\jmath}) = (A_x + B_x)\hat{\imath} + (A_y + B_y)\hat{\jmath}$$

$$\vec{D} = \vec{A} - \vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath}) - (B_x\hat{\imath} + B_y\hat{\jmath}) = (A_x - B_x)\hat{\imath} + (A_y - B_y)j$$

- The scalar multiple of a vector $\vec{A} = Ax\hat{\imath} + Ay\hat{\jmath}$ can also be found by multiplying each component of $\vec{A}$ by the given scalar. So, if $\vec{B} = \alpha\,\vec{A}$, then

$$\vec{B} = \alpha\,\vec{A} = \alpha(A_x\hat{\imath} + A_y\hat{\jmath}) = (\alpha A_x)\hat{\imath} + (\alpha A_y)\hat{\jmath} = B_x\hat{\imath} + B_y\hat{\jmath},$$

where $Bx = \alpha Ax$ and $By = \alpha Ay$

- The unit vectors can also be described in three dimension; X,Y and Z. Thus **A** can be expressed as:

$$\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k}$$

1.3. Vectors: Addition, Components, Magnitude and Direction

CHAPTER SUMMARY

- **Physical quantity** is the property of an object that can be quantified.
- **Measurement** is the act of comparing a physical quantity with its unit.
- **Basic quantities** are the quantities which cannot be expressed in terms of any other physical quantity. Example: length, mass and time.
- **Derived quantities** are quantities that can be expressed in terms of fundamental quantities. Example: area, volume, density.
- **Uncertainty** gives the range of possible values of the measure and, which covers the true value of the measure and thus uncertainty characterizes the spread of measurement results.

1.3. Vectors: Addition, Components, Magnitude and Direction

- A **scalar** is a quantity that is completely specified by a number and its unit. It has magnitude but no direction. Scalars obey the rules of ordinary algebra. Examples: mass, time, volume,
- A **vector** is a quantity that is specified by both a magnitude and direction in space.
- Vector **can be represented either by** Algebraic method **or** Geometric method.
- A single vector that is obtained by adding two or more vectors is called **resultant vector** and it is obtained using the following two methods

1.3. Vectors: Addition, Components, Magnitude and Direction

- Vectors can be added using the ways **Graphical method of vector addition** or **Parallelogram law of vector addition.**
- A unit vector is a vector that has magnitude of one and it is dimensionless and a sole purpose of unit vector is to point-that is, to specify a direction. It is usually denoted with a —hat.

Review Questions and Problems

1. How many significant figures do the following numbers have:
   a) 258 b) 0.2 c) 12 000 d) 0.084

. The dimensions of a rectangular block measured with least count of 0.002cm are $8mm \times 12mm \times 4mm$. Determine the maximum percentage error in the volume block.

. Three resistors connected in parallel with resistance value of $2\Omega \pm 0.04\Omega$, $4\Omega \pm 1.2\%$ and $4.8\Omega \pm 0.24\Omega$ respectively. Find the equivalent resistance and its range of values.

. A $1.2kg \pm 0.22kg$ ball is projected vertically from the table with a velocity of $4m/s \pm 0.08\%$. Determine the initial kinetic of the ball.

. Chaltu walks 4000feet in 40minutes. What speed is she walking at?

. A bulb is connected as a part of a circuit. The following data is collected in the laboratory.
Electric current= $6.4A \pm 0.04A$
Potential difference= 24.64 ± 0.2
Determine the resistance and express it percentage uncertainty.

1.3. Vectors: Addition, Components, Magnitude and Direction

. Which of the following measurement is most significant?

A. 8800cm

B. 8.8000cm

C. 0.0000880cm

D. 88.0000cm

:. How many significant figures do the following numbers have:

a) 258 b) 0.2 c) 12 000 d) 0.084

EXERCISE ON VECTORS

1. Vector $\vec{A}$ has magnitude of 8units and makes an angle of 45^0 with the positive x-axis. Vector $\vec{B}$ also has the same magnitude of 8units and directed along the negative x-axis. Find

   a. The magnitude and direction of $\vec{A} + \vec{B}$

   b. The magnitude and direction of $\vec{A} - \vec{B}$

1.3. Vectors: Addition, Components, Magnitude and Direction

2. Given the displacement vectors $\vec{A} = 3\hat{\imath} - 4\hat{\jmath} + 4\hat{k}$, $\vec{B} = 2\hat{\imath} + 3\hat{\jmath} - 7\hat{k}$. Find the magnitudes of the vectors a) $\vec{A}+\vec{B}$ b) $2\vec{A}-\vec{B}$
3. If $\vec{A} = 6\hat{\imath} - 8\hat{\jmath}$, $\vec{B} = -8\hat{\imath} + 3\hat{\jmath}$ and $\vec{C} = 26\hat{\imath} + 19\hat{\jmath}$. Find a and b Such that $a\vec{A} + b\vec{B} + \vec{C} = 0$
4. Find a unit vector in the direction of the resultant of vectors $\vec{A} = 2\hat{\imath} - 3\hat{\jmath} + \hat{k}$, $\vec{B} = \hat{\imath} + \hat{\jmath} + 2\hat{k}$ and $\vec{C} = 3\hat{\imath} - 2\hat{\imath} + 4\hat{k}$

THANKYOU ALEXANDER K. @HiLCoE 2023