PPP0101

PRINCIPLES OF PHYSICS

CHAPTER 1: PHYSICAL QUANTITIES & VECTORS

CONTENTS

LEARNING OUTCOME

- **Distinguish standard units and system of units.**
- **Use common metric prefixes**
- **Explain the advantage of and apply dimensional analysis and unit analysis.**
- **Determine the number of significant figures in a numerical value and report the proper number of significant figures after performing simple calculation.**
- **Distinguish between scalars and vectors.**
- **Add and subtract vectors analytically.**

INTRODUCTION TO PHYSICS

Classic Physics

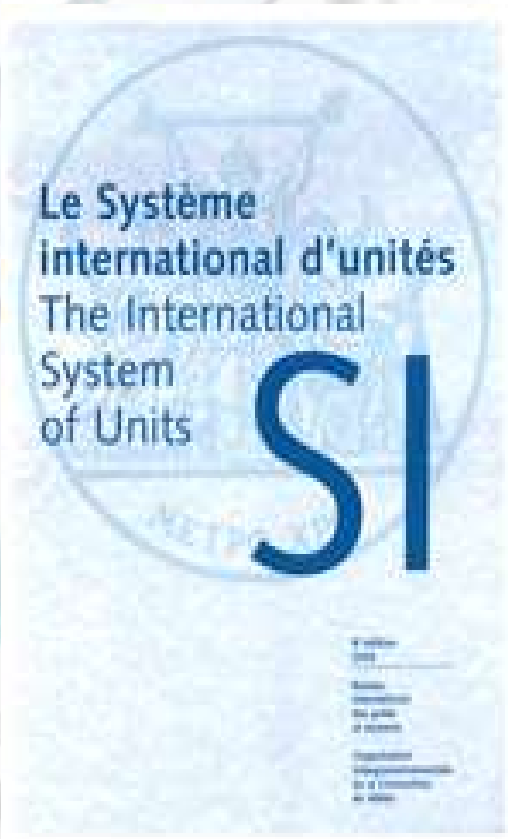
- Motion
- Fluids
- Heat
- Sound
- Light
- Electricity
- Magnetism

Modern Physics

- Relativity
- Atomic Structure
- Condensed Matter
- Nuclear Physics
- Elementary Particles
- Cosmology
- Astrophysics

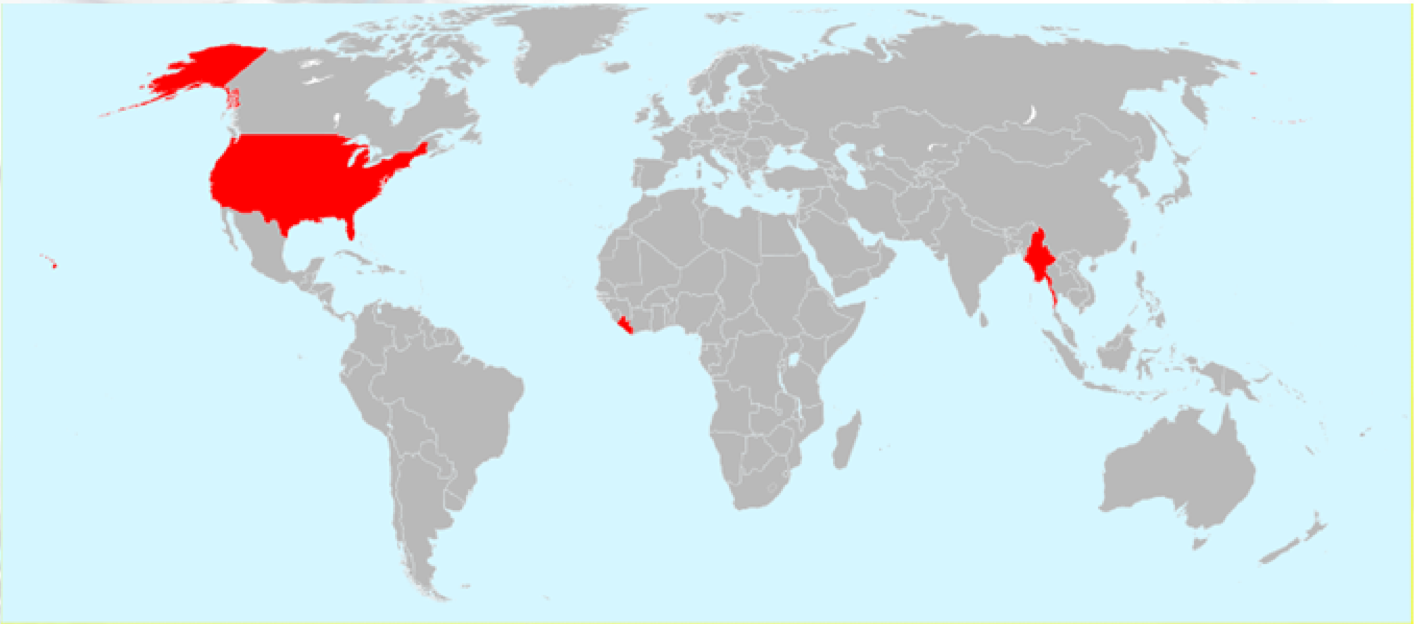
INTRODUCTION TO PHSYICS

QUANTITY



- SI units (***S***_ystème_ ***i***_nternational d'unités or international System of Units) is the modern form of the metric system._
- _It is the world's most widely used system of measurement, both in commerce and science_

QUANTITTY



- Three nations have not officially adopted the International System of Units as their primary or sole system of measurement: Burma, Liberia, and the United States.

QUANTITY

SI Units

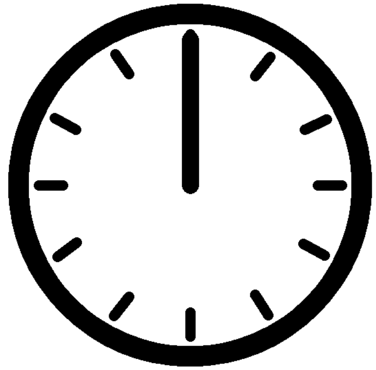
- Base quantities
  - Length
  - Mass
  - Time
  - Electric current
  - Temperature
  - Luminous Intensity
  - Amount of substance
- Derived quantities
  - Units that derived from base units.

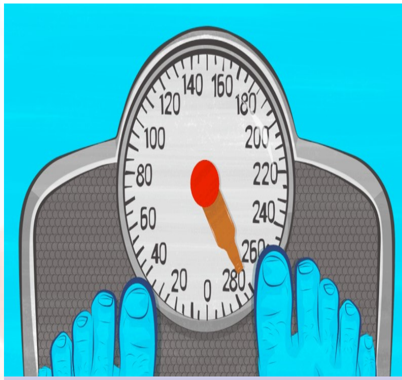
The physical quantities we shall encounter in our study of mechanics

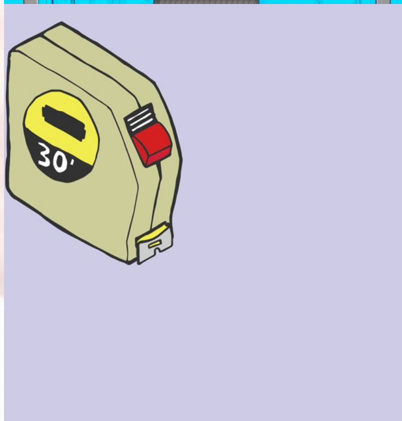
QUANTITY

Base Quantities

- **Length**
  - SI units : Meter
  - Symbol : m
- **Mass**
  - SI units : Kilogram
  - Symbol : Kg
- **Time**
  - SI units : Second
  - Symbol : s







QUANTITY

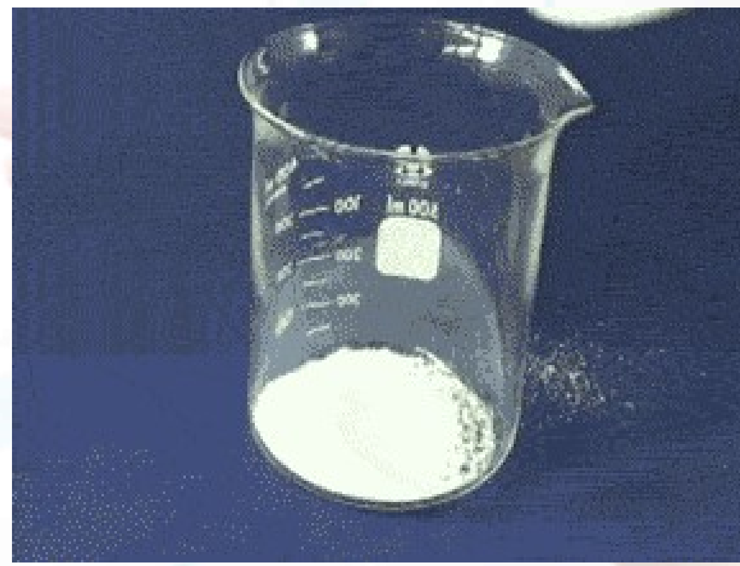
Base Quantities

- **Electric Current**
  - SI units : Ampere
  - Symbol : I
- **Temperature**
  - SI units : Kelvin
  - Symbol : K

QUANTITY

Base Quantities

- **Luminous Intensity**
  - SI units : Candela
  - Symbol : Cd
- ***Amount of substance***
  - SI units : mole
  - Symbol : mol



QUANTITY - SUMMARY

Physical Quantity	SI Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Temperature	Kelvin	K
Amount of substance	*Mole*	*mol*
Luminous intensity	*Candela*	*cd*

QUANTITY

- Derived Quantities
  - All other quantities can be defined in terms of these seven quantities and hence are referred to as **derived quantities.**
  - Derived quantities units can be written in terms of base units.
  - Example
    - **velocity** is the **rate** of **change of position**

$$\text{velocity} = \frac{\text{distance}}{\text{time}}$$

QUANTITY

- Example of derived Units

QUANTITY	UNIT	ABBREVIATION	IN TERMS OF BASE UNITS
Force	Newton	N	$kg\ ms^{-2}$
Energy & Work	Joule	J	$kg.m^{2}\ s^{-2}$
Power	Watt	W	$kg.m^{2}\ s^{-3}$
Pressure	Pascal	Pa	$kg/(m.s^{2})$
Electric Charge	Coulomb	C	A.s
Electric Potential	Volt	V	$kg.m^{2}/(A.s^{3})$
Electric Resistance	Ohm	Ω	$kg.m^{2}/(A^{2}.s^{3})$
Capacitance	Farad	F	$A^{2}.s^{4}/(kg.m^{2})$
Inductance	Henry	H	$kg.m^{2}/(s^{2}.A^{2})$
Magnetic Flux	Weber	Wb	$kg.m^{2}/(A.\ s^{2})$

STANDARD PREFIXES– Used to denote multiples of 10

$\#\#\#\#\#\# \times 10^n$

FACTOR	PREFIX	SYMBOL	FACTOR	PREFIX	SYMBOL
10^{18}	Exa	E	10^{-1}	deci	d
10^{15}	Peta	P	10^{-2}	Centi	c
10^{12}	Tera	T	10^{-3}	Milli	m
10^{9}	Giga	G	10^{-6}	Micro	μ
10^{6}	Mega	M	10^{-9}	Nano	n
10^{3}	Kilo	k	10^{-12}	Pico	p
10^{2}	Hecto	h	10^{-15}	Femto	f
10^{1}	deka	da	10^{-18}	Ato	a

STANDARD PREFIXES

- **Example**
  - 1.2×10^{-12} F = 1.2 pF
  - 2.9×10^{-6} Hz = 2.9 μHz.

Exercise:

convert the following to SI multiples of ten form.

- ❖6.9 Em = 6.9×10^{18} m
- ❖5.78 MKg = 5.78×10^{6}Kg
- ❖6.34 fmol =

UNIT CONVERSION

- Since any quantities such as length can be represented in difference prefixed, so it is important to know how to convert from one unit to another.
- How to convert
  - Convert 1 m to 1 km

Prefix	µ	m	c	d	base	da	h	k	M	G
Factor	-6	-3	-2	-1	0	1	2	3	6	9

Go to left

$$1m = 1\times10^{-3}\,km$$

UNIT CONVERSION

- How to convert
  - Convert 1 m^2 to 1 mm^2

Prefix	µ	m	c	d	base	da	h	k	M	G
Factor	-6	-3	-2	-1	0	1	2	3	6	9

$$1m = 1\times10^{3}\,mm$$

$$1m^{2} = \left(1\times10^{3}\right)^{2} mm^{2}$$

$$= 1\times10^{6}\,mm^{2}$$

UNIT CONVERSION

- How to convert
  - Convert 1 kg/m^3 to g/cm^3

$$1kg = 10^3 g$$

$$1m = 10^2 cm$$

$$1m^3 = \left(10^2\right)^3 cm^3$$

$$= 10^6 cm^3$$

$$\frac{1kg}{1m^3} = \frac{10^3 g}{10^6 cm^3}$$

$$= 0.001 gcm^{-3}$$

$$= 1 \times 10^{-3} gcm^{-3}$$

UNIT CONVERSION

- **Exercise**

Converting the following values from one unit to another:

- ❖0.75 hour = ???min
- ❖2 m^2 = ???cm^2
- ❖ 200 mm^3 = ???m^3
- ❖1.7 g/cm^3 = ???kg/m^3
- ❖1.5 cm/s = ???m/s

UNIT CONVERSION

Exercise:

The height of Mt. Everest is 8850m, what is the elevation, in feet, of an elevation of the height of Mt. Everest ?
Given:
1 ft = 12 in
1 in = 2.5400 cm

UNIT CONVERSION

Solutions:

$$1in = 2.54cm$$

$$1in = 0.0254m$$

$$1m = \frac{1}{0.0254}in$$

$$= 39in$$

$$8850m = 8850 \times 39in$$

$$= 345150in$$

$$1\,ft = 12in$$

$$1in = \frac{1}{12}\,ft$$

$$= 0.083\,ft$$

$$345150in = 345150 \times 0.083\,ft$$

$$= 28647.45\,ft$$

$$= 2.9 \times 10^4\,ft$$

EXAMPLES ON STANDARD PREFIXES AND UNIT CONVERSION

Convert the following to SI units:

(i) 9.12 μs   (ii) 3.42 Mm

(iii) 44 cm / ms   (iv) 80 km / hour

EXAMPLES ON STANDARD PREFIXES AND UNIT CONVERSION

a) Change the following value 5 μm^3/hour to unit m^3/s .

b) The area of a land is 500 km^2. Express this area in mi^2. Given 1 mi = 1.6 km .

EXAMPLES ON STANDARD PREFIXES AND UNIT CONVERSION

Low-pressure sodium lamps produce a virtually monochromatic light averaging a 0.0000005893 *m* wavelength. Convert the value of the wavelength to its scientific notation.

EXAMPLES ON STANDARD PREFIXES AND UNIT CONVERSION

A certain fuel-efficient hybrid car gets gasoline mileage of 55 mpg (miles per gallon). Given 1 gallon = 3.788 liters, 1 miles = 1.609 km.

(a) If you are driving this car in Europe and want to compare its mileage with that of other European cars, express this mileage in km/L (L = liter).

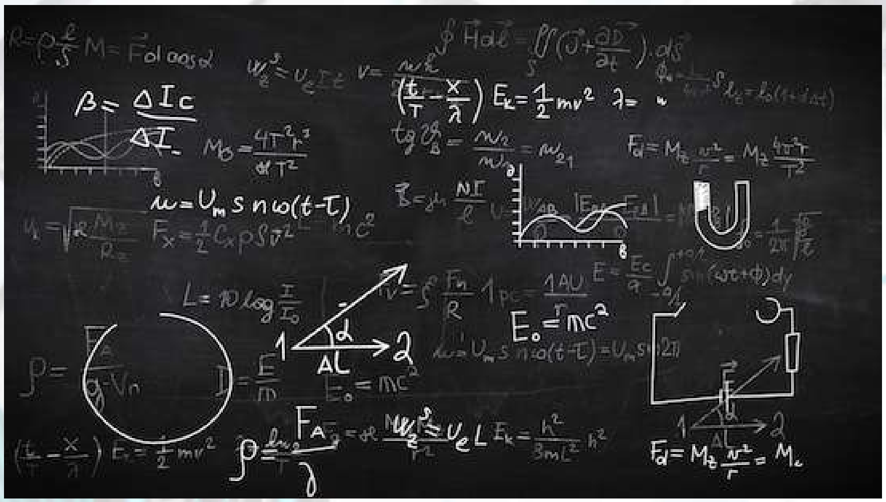
(b) If this car's gas tank holds 45 L, calculate the number of tanks of gas you will use to drive 1700 km.

DIMENSION

- Assumes that you are doing an experiment on what is the factor that cause a love between a guy and girl.
- You realize that the cause of love is cause by "love force", F_Ω
- This "love force", F_Ω is depends on several variable such as running speed, and distance.
- What is the unit of this "love force" variable ?

$$F_\Omega = -2\frac{v}{R}$$

DIMENSION



- When doing physics problems, you'll often be required to determine the numerical value and the units of a variable in an equation.
- The numerical value usually isn't too difficult to get, but for a novice, the same can't be said for the units.
- Therefore dimension analysis is taken in place to determine the units of a variable

DIMENSION

- Dimension is used to refer to the **physical nature of a quantity** and the **type of unit used to specify it.**
- Many physical quantities can be expressed in terms of a **combination of fundamental dimensions** such as

Length (L) | **Time (T)** | **Mass (M)**

Electric Current (A) | **Temperature (θ)**

DIMENSION

- Dimensional analysis can be used to:
    - **Check whether an equation is dimensionally correct**
        - Does an equation has the same dimension (unit) on both sides ?
    - **Derive an equation**
    - **Find out dimension or units of derived quantities.**

** dimensionally correct does not necessary mean the equation is correct.

DIMENSION

- Example of dimensional unit

QUANTITY	DIMENSION	SYMBOL
Mass	[mass]	M
Length	[length]	L
Time	[time]	T
Density	[mass] / $[\text{length}]^3$	ML^{-3}
Velocity	[length] / [time]	LT^{-1}
Acceleration	[velocity] / [time]	LT^{-2}
Force	[mass] × [acceleration]	MLT^{-2}
Work/ Power Energy	[force] × [distance]	ML^2T^{-2}
Power	[work] / [time]	ML^2T^{-3}

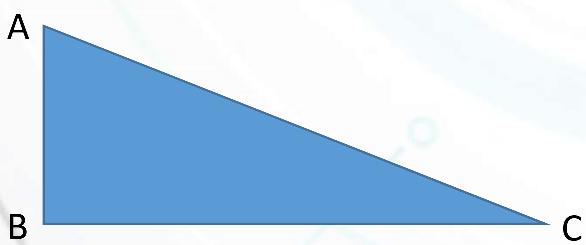
DIMENSION

Don't have Dimension !!!

- Caution !!!
  - Numerical value
  - Ratio between the same quantity
    - High of myself and high of twin tower

$$\begin{aligned}[\text{high ratio}] &= [\text{high of myself}]/[\text{high of Twin Tower}] \\ &= L/L \\ &= 1\end{aligned}$$

  - Angle, because it is a comparison between two position of length measurement.



$$\begin{aligned}\angle ABC &= \frac{AB}{AC} \\ &= \frac{L}{L} \\ &= 1\end{aligned}$$

DIMENSION

- Known constant:

❑ ln, log, π

Don't have Dimension !!!

** but some of the constant had a dimension

- Modulus Young
- Gravitational Acceleration

DIMENSION

- **Example**

Verify the following equation is dimensionally correct.

Left Hand Side
s is a length

$$s = ut + \frac{1}{2}at^2$$

$$[s] = [L]$$

RIGHT Hand Side
First Term
ut is a **velocity x time**

Second Term
½ at^2 is a
numeric x acceleration x time

$$[ut] = [LT^{-1}][T]$$
$$= L$$

$$[\frac{1}{2}at] = [LT^{-2}][T^2]$$
$$= L$$

Each side had the same dimension. Therefore, this equation is dimensionally correct.

DIMENSION

- **Example**

The smallest meaningful measure of length is called the "Planck length" and is defined in term of 3 fundamental constant in nature, the speed of light $c=3.00 \times 10^{8}$ m/s, the gravitational constant $G=6.67 \times 10^{-11}$ $m^3/kg.s^2$, and Planck's constant $h=6.63 \times 10^{-34}$ $kg.m^2/s$. The Planck length λ_p is given by the following combination of these three constants:

$$\lambda_p = \sqrt{\frac{Gh}{c^3}}$$

Show that the dimension of λ_p are length [L]

DIMENSION

- Solution: We rewrite the equation in term of dimension by referring the question

$$c = \frac{m}{s} = \left[\frac{L}{T}\right]$$

$$G = \frac{m^3}{kg \bullet s^2} = \left[\frac{L^3}{MT^2}\right]$$

$$h = \frac{kg \bullet m^2}{s} = \left[\frac{ML^2}{T}\right]$$

$$\begin{aligned}
\lambda_p &= \sqrt{\frac{G\ h}{c^3}} \\
&= \sqrt{\frac{\left[\frac{L^3}{M\ T^2}\right]\left[\frac{M\ L^2}{T}\right]}{\left[\frac{L}{T}\right]^3}} \\
&= \sqrt{\left[\frac{\frac{L^5}{T^3}}{\frac{L^3}{T^3}}\right]} \\
&= \sqrt{\left[\frac{L^5}{T^3}\right] \times \left[\frac{T^3}{L^3}\right]} \\
&= \sqrt{\left[L^2\right]} \\
&= \left[L\right]
\end{aligned}$$

DIMENSION

- **Example**

Given that the time, *t* is influenced by

  - Length, *l*
  - Gravitational acceleration, *g* (9.80 m/s^2)of a simple pendulum experiment.

Derive the equation which relates the above quantities.

DIMENSION

- Solution
  - Step 1 :Assume that the equation is as following:

$$t \propto \mathrm{lg}$$

$$t = hlg$$

$$t = hl^{i}g^{j}$$

  - Step 2 : Convert the equation into dimensionally representation

$$t = hl^{i}g^{j}$$

$$[T] = [L^{i}L^{j}T^{-2j}]$$

$$[T] = [L^{i+j}T^{-2j}]$$

DIMENSION

- Solution
  - Step 3: Compare the power

$$T:$$

$$1 = -2j$$

$$j = -\frac{1}{2}$$

$$L:$$

$$0 = i + j$$

$$= i + \left(-\frac{1}{2}\right)$$

$$i = \frac{1}{2}$$

$$t = hl^{\frac{1}{2}}g^{-\frac{1}{2}}$$

$$= h\sqrt{\frac{l}{g}}$$

TUTORIAL QUESTION No.5

- Given that the time, *t* is influenced by length, *l*, and the velocity, *v* of a simple harmonic motion oscillator experiment. Derive the equation which relates the above quantities.

TUTORIAL QUESTION No.14

- The kinetic energy of a baseball is denoted by $m\dfrac{v^2}{2} = \dfrac{p^2}{2m}$

where *m* is the baseball's mass and *v* is its speed. This relation can be used to define *p*, the baseball's momentum. Use dimensional analysis to find the dimensions of momentum.

TUTORIAL QUESTION No.15

- Determine if the following equation is dimensionally correct:

$$P = a\sqrt{\rho g h}$$

Where,

P = pressure

ρ = density

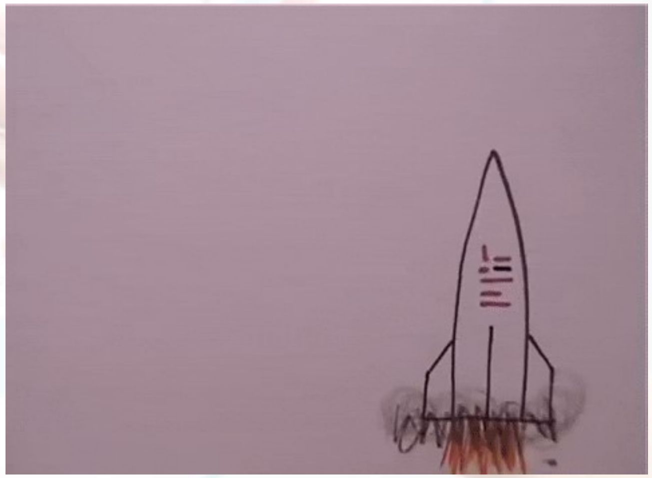
g = gravitational acceleration

h = height

a = dimensionless constant

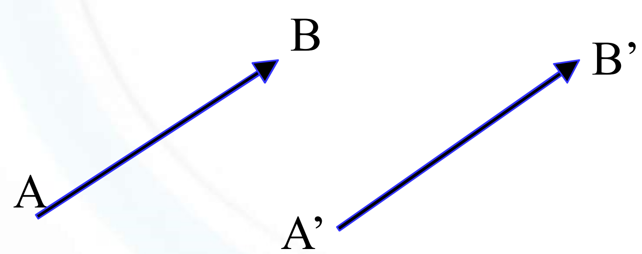
VECTOR

- Scalar Quantity
  - Magnitude
  - Length, time, temperature, mass, density, charge, volume ……
- Vector Quantity
  - Magnitude and Direction
  - Force, momentum, velocity, displacement and acceleration.

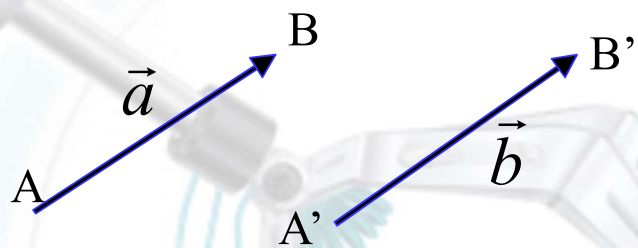


VECTOR

- In printed material , vectors are often represented by boldface type, such as ***F*** . When written by hand, the commonly used designations $\vec{F}$
- The **<u>magnitude</u>** of vector **a** is written as **a** or |a|



VECTOR

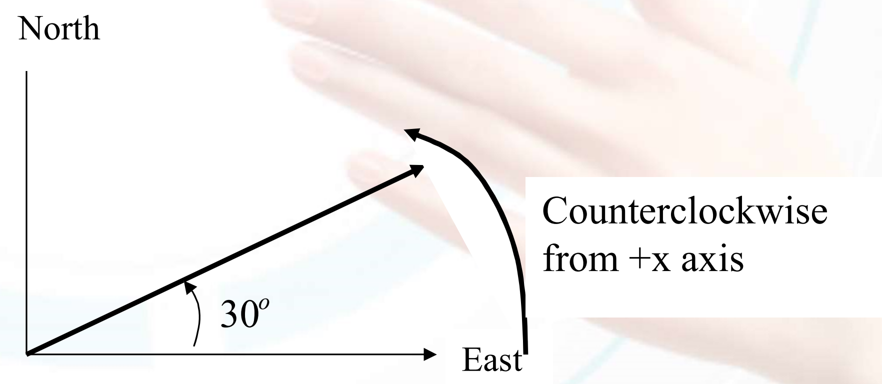


- Property:
  - Vector **AB** and **A’B’** are identical if:
    - Same direction
    - Same length
  - Two vectors **a** and **b** are equal only if:
    - $|a|=|b|$
    - Direction of **a** = direction of **b**

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

VECTOR

- How to draw a vector ?
  - Step 1 : Choose a scale
    - 1cm : 1km
  - Step 2: Choose the length of the arrow proportional to the magnitude of the vector
  - Step 3: ensure the direction
- Example
  - F=50N 30^o North of East

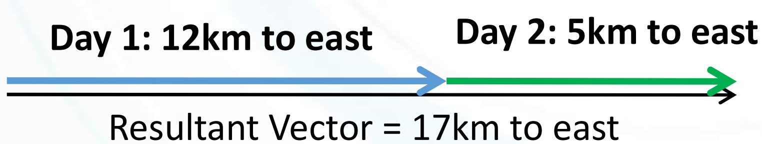


VECTOR

- Addition of Vector by drawing
  - Condition : 1 Dimension direction

Example

A student walks 12 km east one day and 5km east next day. What is the resultant vector ?

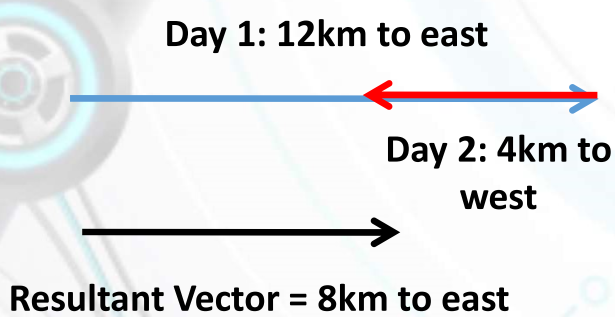


VECTOR

- Addition of Vector by drawing
    - Condition : 1 Dimension direction

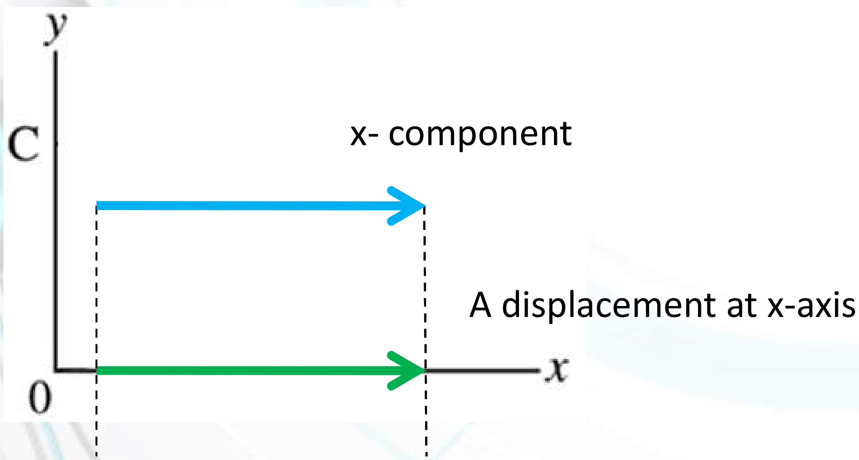
Example

Another Multimedia student walks 12km east one day and 4km west next day. What is the resultant vector?



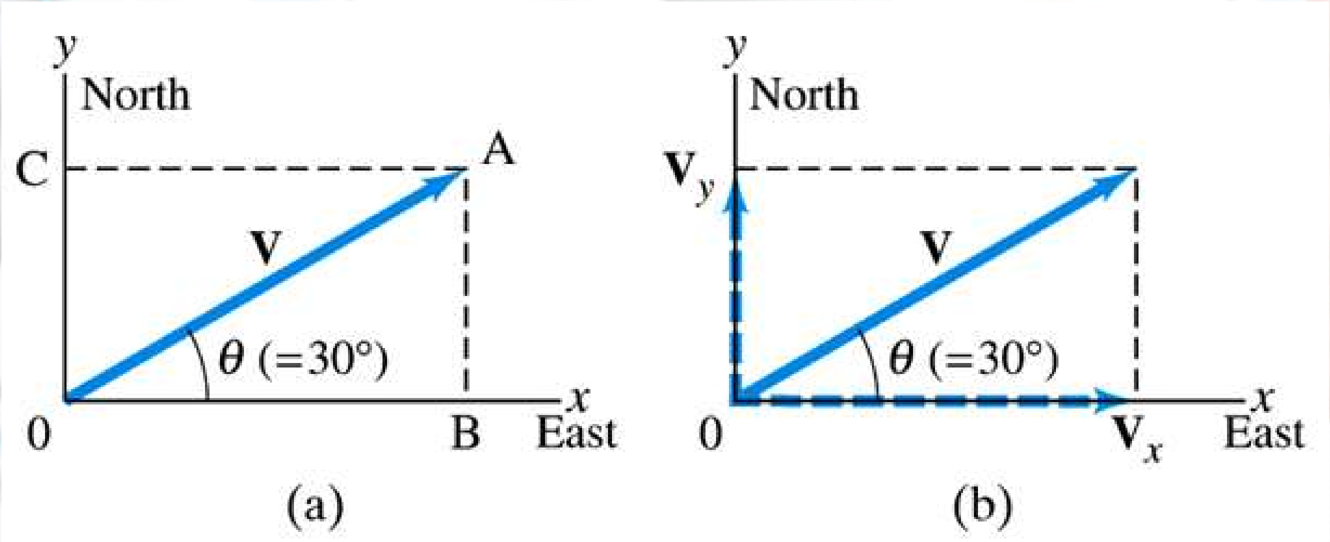
VECTOR

- A component of a vector-resolving
  - A component of a vector is its *effective value in a given direction.* For example, the x-component of a displacement is the displacement parallel to the x-axis caused by the given displacement.



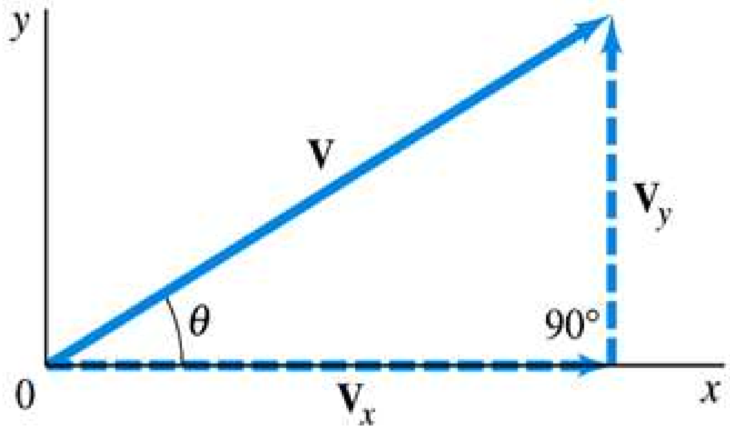
VECTOR

- A component of a vector-resolving
  - A vector in *two dimensions* may be resolved into *two component vectors acting along any two mutually perpendicular directions.*
  - The process of finding the components is known as *resolving the vector into its components*.



VECTOR

- A component of a vector-resolving



$$\sin\theta = \frac{V_y}{V}$$

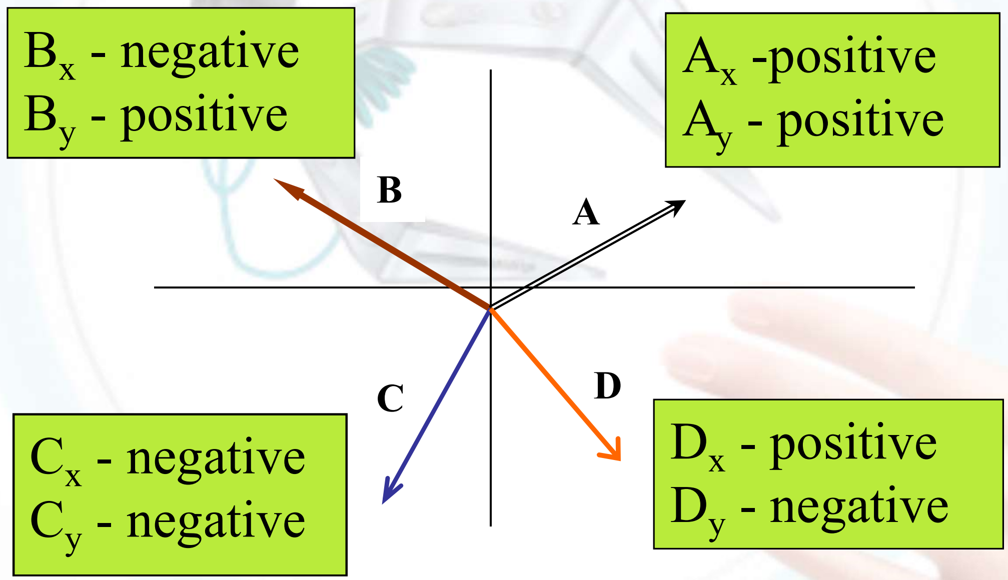
$$\cos\theta = \frac{V_x}{V}$$

$$\tan\theta = \frac{V_y}{V_x}$$

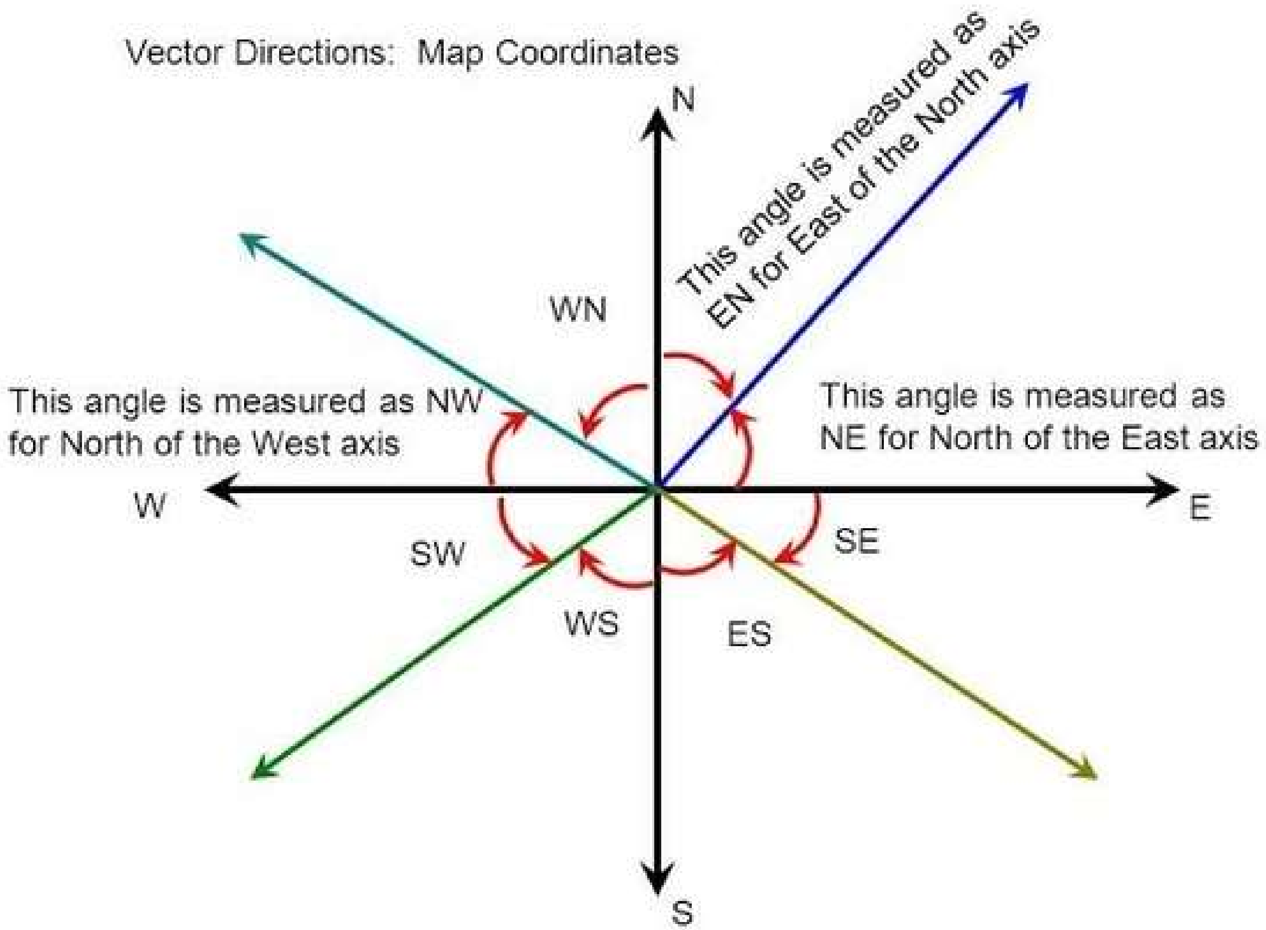
$$V^2 = V_x^2 + V_y^2$$

VECTOR

Component vector along x and y axes depend on the angle, θ.



VECTOR

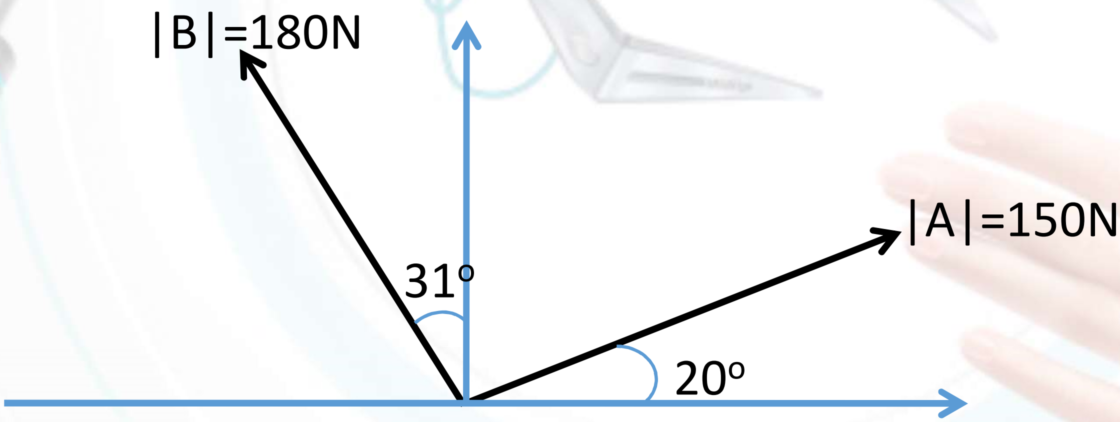


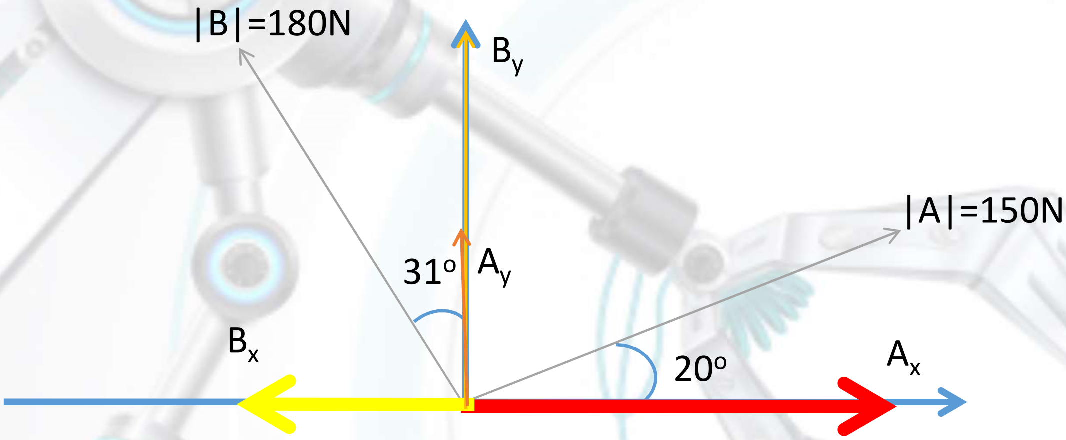
Vector Directions: Map Coordinates
N
This angle is measured as
EN for East of the North axis
WN
This angle is measured as NW
for North of the West axis
This angle is measured as
NE for North of the East axis
W
E
SW
SE
WS
ES
S

VECTOR

- Example

Obtain the resultant force.





As we know,

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

How to calculate R_x and R_y ?

$$\begin{aligned} R_x &= A_x + B_x \\ &= A\cos 20^o + B\cos(90+31)^o \\ &= 150\cos 20^o + 180\cos 121^o \\ &= 141 + (-93) \\ &= 48 \end{aligned}$$

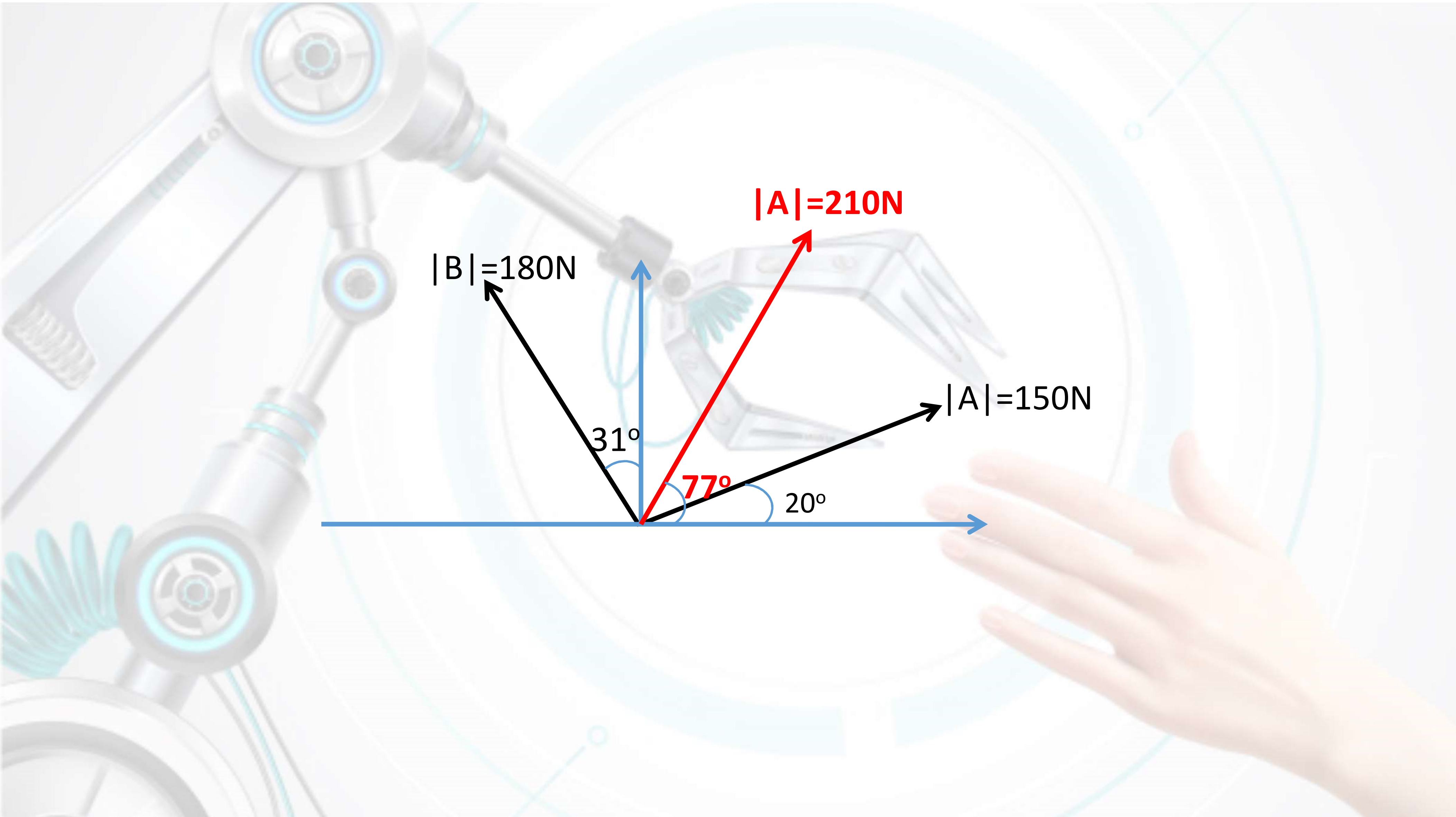
$$\begin{aligned} R_y &= A_y + B_y \\ &= A\sin 20^o + B\sin(90+31)^o \\ &= 150\sin 20^o + 180\sin 121^o \\ &= 51 + 154 \\ &= 205 \end{aligned}$$

How to calculate angle of the resultant vector ?

$$\begin{aligned} |R| &= \sqrt{R_x^2 + R_y^2} \\ &= \sqrt{(48)^2 + (205)^2} \\ &= 210N \end{aligned}$$

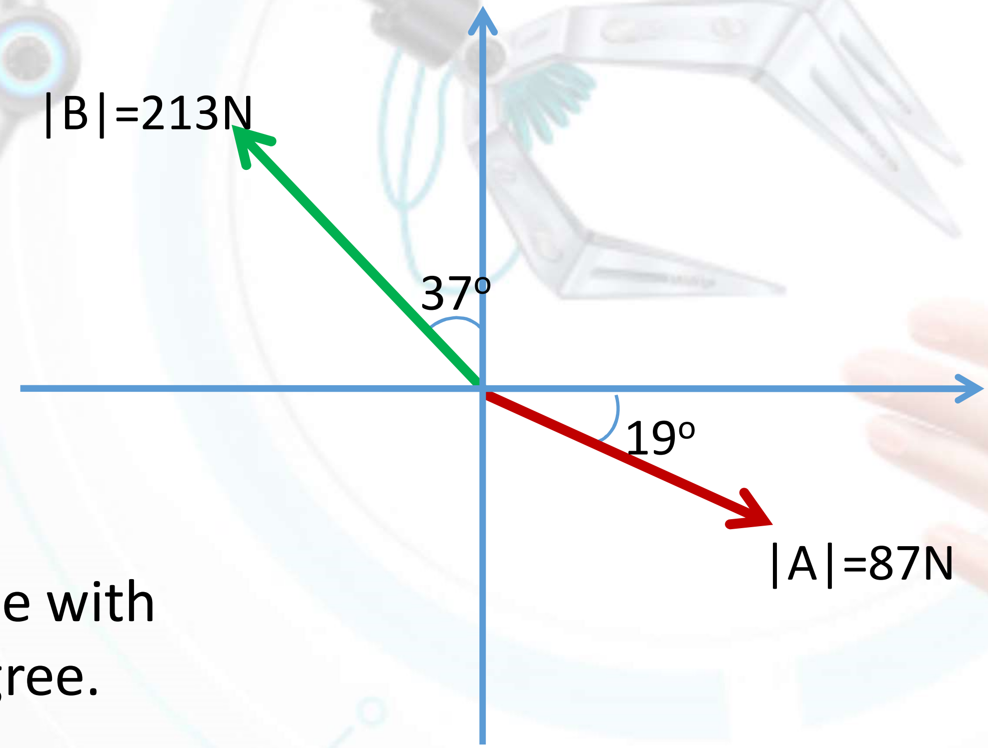
$$\begin{aligned} \tan\theta &= \frac{R_y}{R_x} \\ &= \frac{205}{48} \end{aligned}$$

$$\begin{aligned} \theta &= \tan^{-1}\left(\frac{205}{48}\right) \\ &= 77^o \end{aligned}$$


|A|=210N
|B|=180N
|A|=150N
31°
77°
20°

VECTOR

- Exercise



Obtain the resultant force with its vector degree.


THE
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