PHYSICAL QUANTITIES AND UNITS

Physical Quantity :-

- Any quantity which can be measured, all physical quantities consist of a numerical magnitude and a unit.

- Usually the quantities are represented by a letter, these letters can represent more than one quantity, in that case units provide the context as to what letter refers to :-

$V = 5\ ms^{-1} \longrightarrow$ velocity

$V = 7\ m^3 \longrightarrow$ volume

$V = 20\ V \longrightarrow$ voltage

Basic Quantities :-

- There are almost endless number of physical quantities, but there are only seven BASIC quantities and rest are known as DERIVED quantities.

- The SI units of these base quantities are known as 'SI base units'.

- Units of all derived quantities can be reduced to these SI base units.

- The SI base units is the only system of measurement that is officially used in almost every country around the world.

QUANTITY	SI BASE UNIT	SYMBOL
mass	kilogram	kg
Length	meter	m
time	second	s
current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol
intensity of Light	candela	cd

Derived Quantities :-

→ Are the quantities which are derived from the basic quantities, so derived units can be broken down to the SI base units.

→ How to reduce derived units to their SI base units :-

∴ To deduce the base units of any derived quantity, it is necessary to use the formula / defination of the quantity.

→ FORCE :- (Newton) (N)

$$F = ma$$

$$N = kg \frac{m}{s^2}$$

$$N = kgms^{-2}$$

∴ Therefore, the Newton (N) in SI base units is $kgms^{-2}$

ENERGY :- (Workdone) (Joules) (J)

$E = Fd$
$J = N\,m$
$J = kgms^{-2}\,m$
$J = kgm^2s^{-2}$

$E = \frac{1}{2}mv^2$
$J = kg\,(ms^{-1})^2$
$J = kgm^2s^{-2}$

$E = mgh$
$J = kg\,ms^{-2}\,m$
$J = kgm^2s^{-2}$

∴ Therefore, the Joule (J) in SI base units is kgm^2s^{-2}

PRESSURE :- (Pascal) (Pa)

$P = \frac{F}{A}$
$Pa = \frac{N}{m^2}$
$Pa = \frac{kgms^2}{m^2}$
$Pa = kgm^{-1}s^2$

$P = \rho gh$
$Pa = kgm^{-3}\,ms^{-2}\,m$
$Pa = kgm^{-1}s^{-2}$

∴ Therefore, the Pascal (Pa) in SI base units is $kgm^{-1}s^{-2}$

VOLTAGE :- (Volts) (V)

$V = \frac{E}{Q}$
$V = \frac{J}{C}$
$V = \frac{kgm^2s^{-2}}{As} \Rightarrow V = kgm^2s^{-3}A^{-1}$

$Q = It$
$Q = As \rightarrow$ base units of charge

∴ Therefore, the volts (V) in SI base units is $kgm^2s^{-3}A^{-1}$

Homogeneity of Physical Equations :-

All formulas and equations in physics are homogenous means that unit on the both sides of equation are same.

ENERGY

SI units :- Joule

SI base units :- kgm^2s^{-2}

$$E = mc^2$$

$$kgm^2s^{-2} = kg\,(ms^{-1})^2$$

$$kgm^2s^{-2} = kgm^2s^{-2}$$

∴ Thus units on both sides of equation are same, which shows the homogenity of the equation.

e.g $v = \sqrt{\dfrac{(\gamma P)}{\rho}}$ where, $v \rightarrow$ speed

$P \rightarrow$ pressure

$\rho \rightarrow$ density.

Show that γ has no units :-

Sol

$v \rightarrow ms^{-1}$

$\gamma \rightarrow$?

$P \rightarrow kgm^{-1}s^{-2}$

$\rho \rightarrow kgm^{-3}$

$$ms^{-1} = \sqrt{\frac{(\gamma)\,(kgm^{-1}s^{-2})}{kgm^{-3}}}$$

∴ square both sides

$$m^2s^{-2} = \frac{(\gamma)\,(kgm^{-1}s^{-2})}{kgm^{-3}}$$

$$m^2s^{-2} = (\gamma)\,(m^2s^{-2})$$

$$\gamma = \frac{m^2s^{-2}}{m^2s^{-2}} = 1$$

$$\boxed{\gamma = 1 \Rightarrow \text{no units}}$$

Prefixes :-

We use prefixes to deal with very large and very small magnitudes.

PREFIX	SYMBOL	VALUE
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}

(For very big values)

PREFIX	SYMBOL	VALUE
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

(For very small values)

Conversions :-

∴ Prefix to Standard unit [Multiplication]

$$20\ Gm \longrightarrow 20 \times 10^{9} \longrightarrow 2.0 \times 10^{10}\ m$$

$$15\ \mu m \longrightarrow 15 \times 10^{-6} \longrightarrow 1.5 \times 10^{-5}\ m$$

∴ Standard unit to Prefix [Division]

$$500\ m \xrightarrow{km} \frac{500}{10^3} = 0.5\ km$$

$$0.005\ m \xrightarrow{\mu m} \frac{0.005}{10^{-6}} = 5.0 \times 10^{3}\ \mu m$$

Scalar and Vector Quantities :

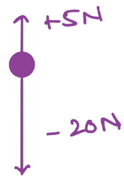
➡ A scalar is a quantity which only has a magnitude.

distance , speed , time , mass , energy , temperature

➡ A vector is a quantity which has both a magnitude and a direction.

displacement , velocity , acceleration , force , weight , momentum , electric field strength , gravitational field strength

➡ direction of vectors is represented by a sign (+ve or -ve)



∴ Remember quantities that can be written with a -ve sign are usually vector quantities.

Combining Vectors (Addition & Subtraction)

➡ Vectors can be represented by an arrow, where the arrowhead indicates the direction of vector and its length refers to magnitude.

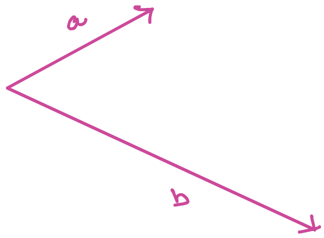
➡ We have two methods which can be used for combining the vectors.

1) Parallelogram method
2) Triangle method

Parallelogram Method :-

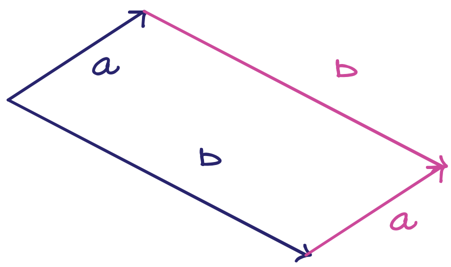
Step 1 :-

Link the vectors tail to tail



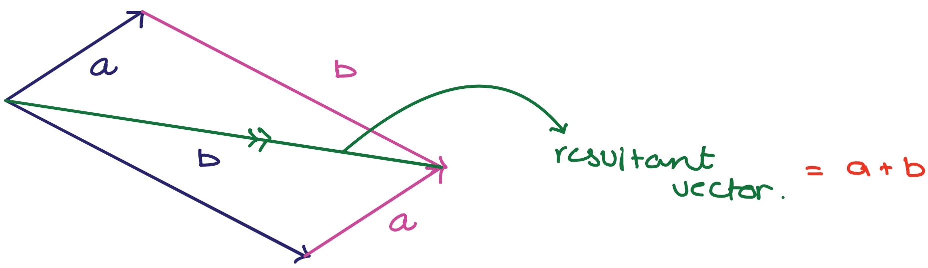
Step 2 :-

Complete the resulting parallelogram by drawing same vectors on opposite side.



Step 3 :-

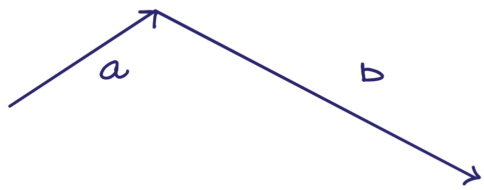
Draw the diagonal from the point where initially vector tail were joining, this diagonal represents the resultant vector.



Triangle Method :-

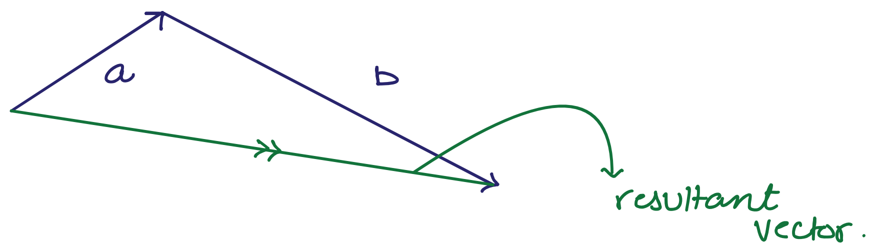
Step 1 :-

Link the vectors head to tail



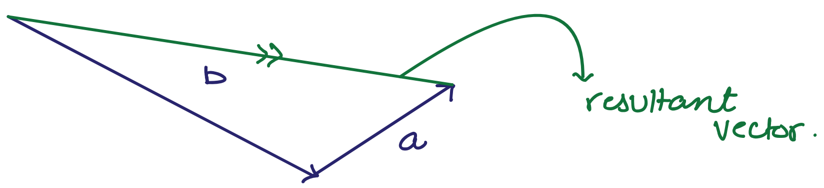
Step 2 :-

Draw the line from tail of first vector to the head of second vector , this line represents you the resultant vector .



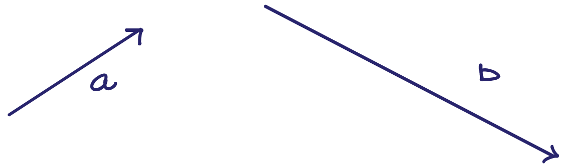
= a + b

∴ it won't matter which vector is drawn first , in both cases your resultant vector will be same.



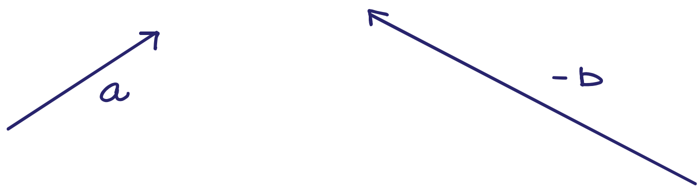
= a + b

Vector Subtraction :-

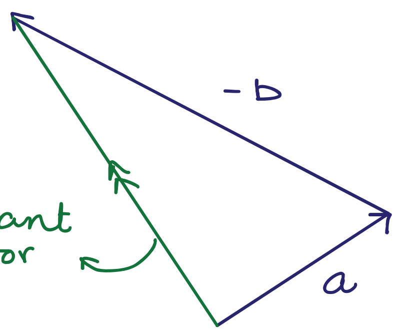


➡ to subtract vectors we will just change the direction of the vector we want to subtract and will use triangle or parallelogram method.

$= a - b$



∴ using triangle method

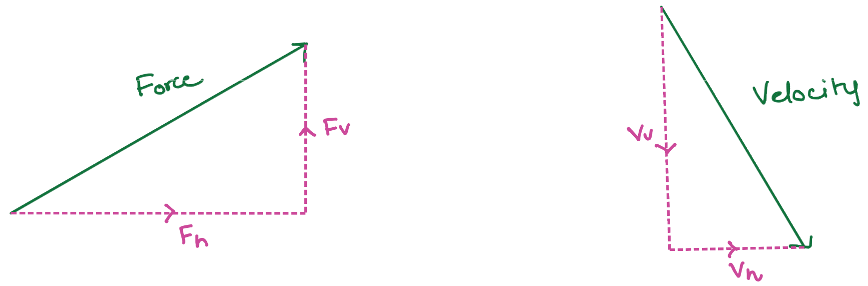


$a - b$ = resultant vector

Vectors at an Angle :- [Resolving Vectors]

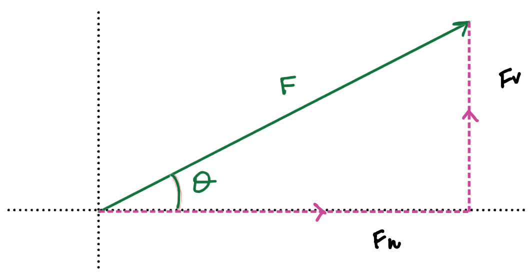
→ if the vector is acting at an angle, we can't make direct calculations using it, thus to make it useable the vectors are resolved into components. Every vector can be broken down to its two components :-

1) verticle component (v)
2) horizontal component (h)



∴ to mark the verticle and horizontal components we always start from the tail of vector and move towards its head, using only verticle and horizontal paths. (Basically you'll form a right angle triangle)

→ Calculation of verticle and horizontal components.



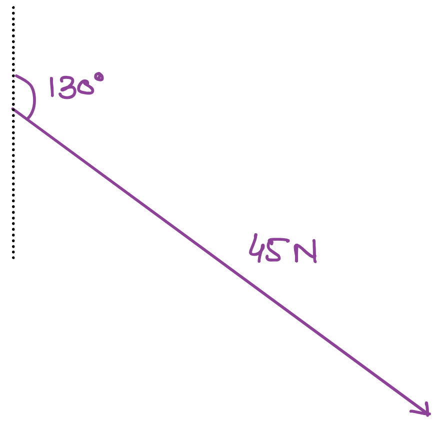
∴ Use trignometric ratios to find F_h & F_v.

The side which shares the angle (θ) is given by cos θ
The side opposite to angle (θ) is given by sin θ

$$F_h = F\cos\theta$$

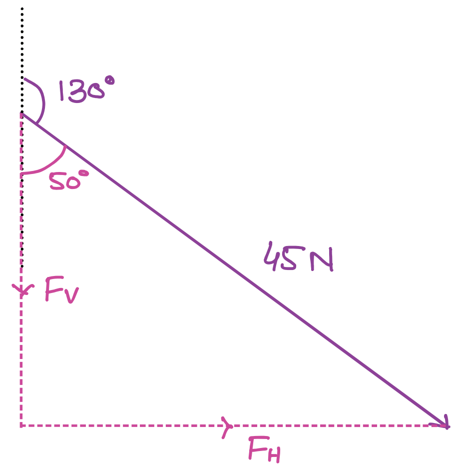
$$F_v = F\sin\theta$$

QUESTION



Calculate the verticle and horizontal components of the given force?

ANSWER



∴ in this Fv is sharing the angle so cos θ will be used for it.

$F_v = F\cos\theta$

$F_v = 45\cos(50)$

$F_v = 28.93$ N

$F_v \approx 28.9$ N

$F_h = F\sin\theta$

$F_h = 45\sin(50)$

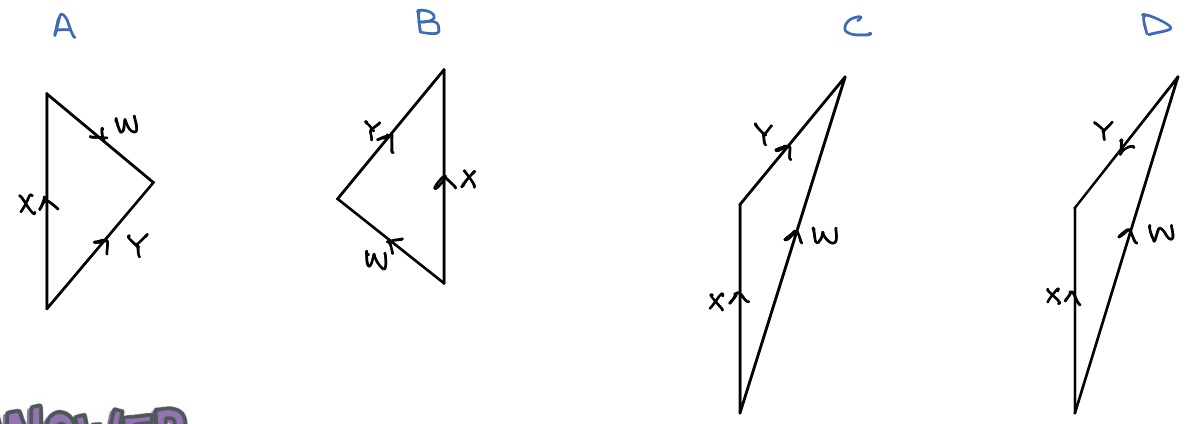
$F_h = 34.47$ N

$F_h \approx 34.5$ N

QUESTION

An airplane can fly at a velocity X when moving through still air. When flying in wind the airplane's velocity relative to the ground is Y.

Which vector diagram shows the magnitude and direction of the wind velocity W?



ANSWER

Velocity in still air = X

Velocity of wind = W

Velocity in presence of wind = Y

∴ You need to realize that which vector out of these three is resultant vector.

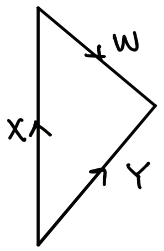
⇒ Remember, in the presence of wind, the velocity of airplane changes so, it is the final (resultant) velocity.

- The resultant in this case is Y

$(Y = X + W)$

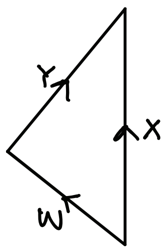
- Using triangle method, just see which option satisfies ($Y = X + W$)

A



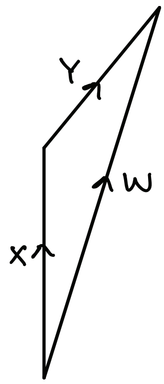
$Y = X + W$

B



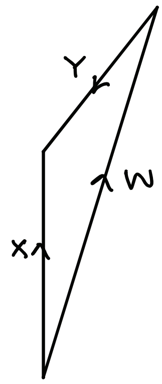
$Y = -W + X$

C



$Y = -X + W$

D



$Y = -W + X$

$\therefore$ Answer $\Rightarrow$ option A