CHAPTER 01

General Physics

Rules for Counting Significant Figures

***Rule* 1** All non-zero digits are significant. For example, 126.28 has five significant figures.

***Rule* 2** The zeros appearing between two non-zero digits are significant. For example, 6.025 has four significant figures.

***Rule* 3** Trailing zeros after decimal places are significant. Measurement $l = 6.400$ cm has four significant figures.

Let us take an example in its support.

Measurement	Accuracy	*l* lies between (in cm)	Significant figures	Remarks
$l = 6.4$ cm	0.1 cm	6.3-6.5	Two	
$l = 6.40$ cm	0.01 cm	6.39-6.41	Three	closer
$l = 6.400$ cm	0.001 cm	6.399-6.401	Four	more closer

Thus, the significant figures depend on the accuracy of measurement. More the number of significant figures, more accurate is the measurement.

***Rule* 4** The powers of ten are not counted as significant figures.

For example, 1.4×10^{-7} has only two significant figures 1 and 4.

***Rule* 5** If a measurement is less than one, then all zeros occurring to the left of last non-zero digit are not significant. For example, 0.0042 has two significant figures 4 and 2.

***Rule* 6** Change in units of measurement of a quantity does not change the number of significant figures. Suppose a measurement was done using mm scale and we get $l = 72$ mm (two significant figures).

We can write this measurement in other units also (without changing the number of significant figures) :

$$\begin{aligned} &7.2 \text{ cm} &&\rightarrow \text{Two significant figures} \\ &0.072 \text{ m} &&\rightarrow \text{Two significant figures} \\ &0.000072 \text{ km} &&\rightarrow \text{Two significant figures} \\ &7.2 \times 10^{7} \text{ nm} &&\rightarrow \text{Two significant figures} \end{aligned}$$

***Rule* 7** The terminal or trailing zeros in a number without a decimal point are not significant. This also sometimes arises due to change of unit.

For example, 264 m = 26400 cm = 264000 mm

All have only three significant figures 2, 6 and 4.

Zeros at the end of a number are significant only, if they are behind a decimal point as in Rule 3. Otherwise, it is impossible to tell if they are significant.

For example, in the number 8200, it is not clear, if the zeros are significant or not. The number of significant digits in 8200 is at least two, but could be three or four.
To avoid uncertainty, use scientific notation to place significant zeros behind a decimal point

8.200×10^3 has four significant digits

8.20×10^3 has three significant digits

8.2×10^3 has two significant digits

Therefore, if it is not expressed in scientific notations, then write least number of significant digits. Hence, in the number 8200, take significant digits as two.
***Rule* 8** Exact measurements have infinite number of significant figures. For example,

10 bananas in a basket

46 students in a class

Speed of light in vacuum = 299,792,458 m/s (exact)

$$\pi = \frac{22}{7} \text{ (exact)}$$

All these measurements have infinite number of significant figures.

Rounding off a Digit

Following are the rules for rounding off a measurement

***Rule* 1** If the number lying to the right of cut off digit is less than 5, then the cut off digit is retained as such. However, if it is more than 5, then the cut off digit is increased by 1.

For example, $x = 6.24$ is rounded off to 6.2 to two significant digits and $x = 5.328$ is rounded off to 5.33 to three significant digits.

***Rule* 2** If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit is increased by 1.

For example, $x = 14.252$ is rounded off to $x = 14.3$ to three significant digits.

***Rule* 3** If the digit to be dropped is simply 5 or 5 followed by zeros, then the preceding digit is left unchanged if it is even.
For example, $x = 6.250$ or $x = 6.25$ becomes $x = 6.2$ after rounding off to two significant digits.

***Rule* 4** If the digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is raised by one if it is odd.
For example, $x = 6.350$ or $x = 6.35$ becomes $x = 6.4$ after rounding off to two significant digits.

Algebraic Operations with Significant Figures

Addition or Subtraction

Suppose in the measured values to be added or subtracted, the least number of digits after the decimal is n. Then, in the sum or difference, the number of significant digits after the decimal should also be n.

For example $1.2 + 3.45 + 6.789 = 11.439 \approx 11.4$

Here, the least number of significant digits after the decimal is one. Hence, the result will be 11.4 (when rounded off to smallest number of decimal places).

Multiplication or Division

Suppose in the measured values to be multiplied or divided, the least number of significant digits be n. Then, in the product or quotient, the number of significant digits should also be n.

For example $1.2 \times 36.72 = 44.064 \approx 44$

The least number of significant digits in the measured values are two. Hence, the result when rounded off to two significant digits will be 44. Therefore, the answer is 44.

Error Analysis

- **Least count**

Instrument	Its least count
mm scale	1 mm
Vernier callipers	0.1 mm
Screw gauge	0.01 mm
Stop watch	0.1 s
Temperature thermometer	1°C

- **True value**

  Usually the mean value a_m is taken as the true value. So,

$$a_m = \frac{a_1 + a_2 + \ldots + a_n}{n}$$

- **Absolute error**

$$\Delta a_1 = a_m - a_1$$
$$\Delta a_2 = a_m - a_2$$
$$\ldots \quad \ldots \quad \ldots$$
$$\Delta a_n = a_m - a_n$$

  Absolute error may be positive or negative.

- **Mean absolute error**

$$\Delta a_{\text{mean}} = \frac{|\Delta a_1| + |\Delta a_2| + \ldots + |\Delta a_n|}{n}$$

  The final result of measurement can be written as, $a = a_m \pm \Delta a_{\text{mean}}$.

- **Relative (or fractional) and percentage error**

$$\text{Relative error} = \frac{\Delta a_{\text{mean}}}{a_m}$$

$$\text{Percentage error} = \frac{\Delta a_{\text{mean}}}{a_m} \times 100$$

- **Error in sum or difference**

Let $x = a \pm b$

Then, $\Delta x = \pm (\Delta a + \Delta b)$

- **Error in product**

Let $x = ab$

Then, $\frac{\Delta x}{x} = \pm \left(\frac{\Delta a}{a} + \frac{\Delta b}{b} \right)$

- **Error in division**

Let $x = \frac{a}{b}$

Then, $\frac{\Delta x}{x} = \pm \left(\frac{\Delta a}{a} + \frac{\Delta b}{b} \right)$

- **Error in quantity raised to some power**

Let $x = \frac{a^n}{b^m}$

Then, $\frac{\Delta x}{x} = \pm \left(n \frac{\Delta a}{a} + m \frac{\Delta b}{b} \right)$

Experiments

1. Vernier Callipers

(i) $\text{VC} = \text{LC} = \frac{1 \text{ MSD}}{n} = \frac{\text{smallest division on main scale}}{\text{number of divisions on vernier scale}} = 1 \text{ MSD} - 1 \text{ VSD}$

(ii) In ordinary vernier callipers, 1 MSD = 1 mm and $n = 10$

$\therefore$ $\text{VC or LC} = \frac{1}{10} \text{ mm} = 0.01 \text{ cm}$

(iii) Total reading = $(N + n \times \text{VC})$ (N = main scale reading)

(iv) Zero correction = – Zero error

(v) Zero error is algebraically subtracted while the zero correction is algebraically added.

(vi) If zero of vernier scale lies to the right of zero of main scale, the error is positive. The actual length in this case is less than observed length.

(vii) If zero of vernier scale lies to the left of zero of main scale, the error is negative and the actual length is more than the observed length.

(viii) Positive zero error = $(N + x \times \text{VC})$

(ix) In negative zero error, suppose 8th vernier scale division coincides with the main scale division, then

Negative zero error = – [0.00 + 8 × VC] = – [0.00 + 8 × 0.01cm] = – 0.08 cm

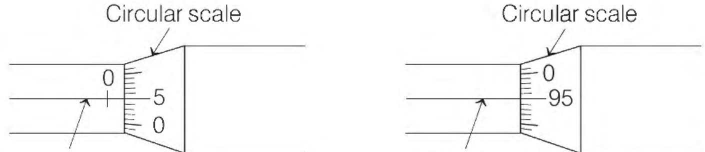
2. Screw Gauge

$$\text{Least count} = \frac{\text{pitch}}{\text{number of divisions on circular scale}}$$

Total reading = $N + n \times$ LC

If the zero of the circular scale advances beyond the reference line, the zero error is negative and zero correction is positive. If it is left behind the reference line, the zero error is positive and zero correction is negative.

For example, if zero of circular scale advances beyond the reference line by 5 divisions, zero correction = + 5 × (LC) and if the zero of circular scale is left behind the reference line by 5 divisions, zero correction = – 5 × (LC).



(a) Positive zero error (b) Negative zero error

Note *In negative zero error, 95th divisions of the circular scale is coinciding with the reference line. Hence, there are 5 divisions between zero mark on the circular scale and the reference line.*

3. Speed of Sound using Resonance Tube

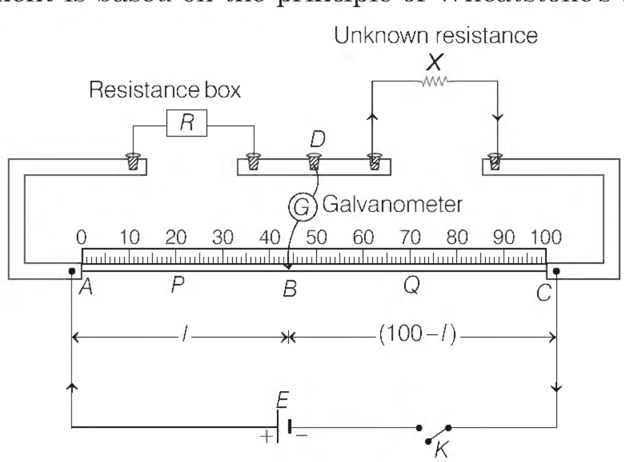
(i) Result is independent of end correction

(ii) $v = 2f(l_2 - l_1)$, where f = frequency of tuning fork,
l_1 = first resonance length and l_2 = second resonance length.

(iii) End correction, $e = \dfrac{l_2 - 3l_1}{2}$

4. Meter Bridge Experiment

Meter bridge experiment is based on the principle of Wheatstone's bridge.



When current through galvanometer is zero or bridge is balanced, then

$$\frac{P}{Q} = \frac{R}{X}$$

$$\therefore \qquad X = R\left(\frac{Q}{P}\right) = \left(\frac{100 - l}{l}\right) R$$

End Corrections

In meter bridge, some extra length (under the metallic strips) comes at points A and C. Therefore, some additional length (α and β) should be included at the ends.

Here, α and β are called the end corrections. Hence, in place of l, we use $l + \alpha$ and in place of $100 - l$, we use $100 - l + \beta$.

To find α and β, use known resistors R_1 and R_2 in place of R and X and suppose we get null point length equal to l_1. Then,

$$\frac{R_1}{R_2} = \frac{l_1 + \alpha}{100 - l_1 + \beta} \qquad \text{...(i)}$$

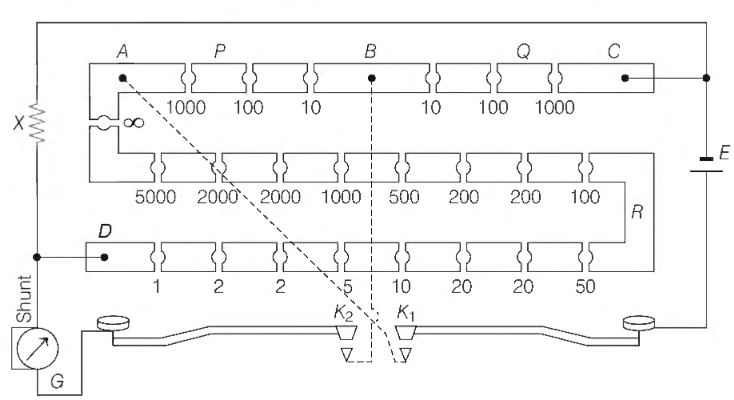
Now, we interchange the positions of R_1 and R_2 and suppose the new null point length is l_2. Then,

$$\frac{R_2}{R_1} = \frac{l_2 + \alpha}{100 - l_2 + \beta} \qquad \text{...(ii)}$$

Solving Eqs. (i) and (ii), we can find α and β.

5. Post Office Box

Post office box also works on the principle of Wheatstone's bridge.



In a Wheatstone's bridge circuit, if $\frac{P}{Q} = \frac{R}{X}$, then the bridge is balanced. So, unknown resistance $X = \frac{Q}{P} R$.

P and Q are set in arms AB and BC, where we can have $10\,\Omega$, $100\,\Omega$ or $1000\,\Omega$ resistances to set any ratio $\frac{Q}{P}$.

These arms are called ratio arms, initially we take $Q = 10\,\Omega$ and $P = 10\,\Omega$ to set $\frac{Q}{P} = 1$.

The unknown resistance (X) is connected between C and D and battery is connected across A and C.

Now, put resistance in part A to D such that the bridge gets balanced.

For this, keep on increasing the resistance with $1\,\Omega$ interval, check the deflection in galvanometer by first pressing key K_1, then galvanometer key K_2.

Suppose at $R = 4\,\Omega$, we get deflection towards left and at $R = 5\,\Omega$, we get deflection towards right.

Then, we can say that for balanced condition, R should lies between $4\,\Omega$ to $5\,\Omega$.

Now,
$$X = \frac{Q}{P} R = \frac{10}{10} R$$
$$= R = 4\,\Omega \text{ to } 5\,\Omega$$

To get closer value of X, in the second observation, let us choose $\frac{Q}{P} = \frac{1}{10}$, i.e. $\left(\frac{P = 100}{Q = 10}\right)$

Suppose now at $R = 42\,\Omega$, we get deflection towards left and at $R = 43\,\Omega$, deflection is towards right.

So, $R \in (42, 43)$.

Now, $X = \frac{Q}{P} R = \frac{10}{100} R = \frac{1}{10} R$, where $R \in (42, 43\,\Omega)$.

Now, to get further closer value, take $\frac{Q}{P} = \frac{1}{100}$ and so on.

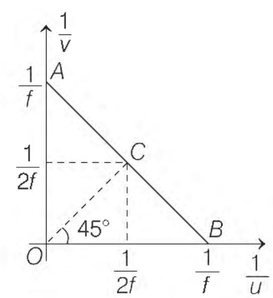
The observation table is shown below

Resistance in the ratio arms		**Resistance in arm** *AD* (*R*) (ohm)	**Direction of deflection**	**Unknown resistance** $X = \frac{Q}{P} \times R$ (ohm)
AB (*P*) (ohm)	*BC* (*Q*) (ohm)			
10	10	4	Left	4 to 5
		5	Right	
100	10	40	Left (large)	(4.2 to 4.3)
		50	Right (large)	
		42	Left	
		43	Right	
1000	10	420	Left	4.25
		424	Left	
		425	No deflection	
		426	Right	

So, the correct value of X is $4.25\,\Omega$.

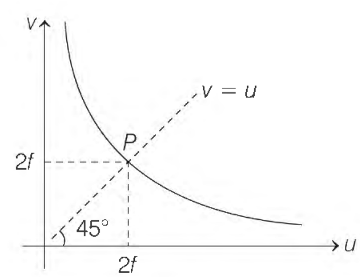
6. Focal Length of Concave Mirror

(i) $\frac{1}{v}$ ***versus*** $\frac{1}{u}$ **graph**



The coordinates of point C are $\left(\frac{1}{2f}, \frac{1}{2f}\right)$. The focal length of the concave mirror can be calculated by measuring the coordinates of either of the points A, B or C.

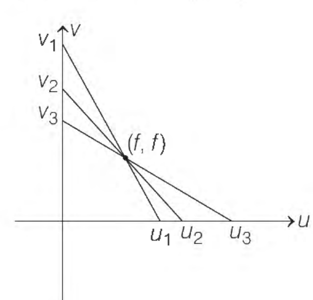
(ii) ***v versus u*** **graph**



From u-v data, plot v *versus* u curve and draw a line bisecting the axis. Find the intersection point and equate them to $(2f, 2f)$.

(iii) **By joining v_n and u_n**

All lines intersect at a common point (f, f).

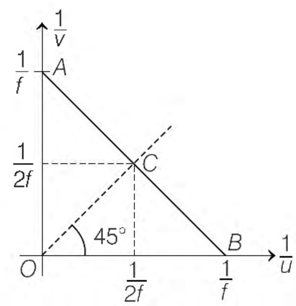


Find common intersection point and equate it to (f, f).

7. Focal Length of Convex Lens

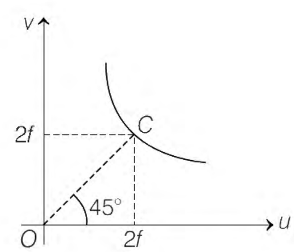
(i) $\frac{1}{v}$ ***versus*** $\frac{1}{u}$ **graph**

The focal length of convex lens can be calculated by measuring the coordinates of either of the points A, B or C.



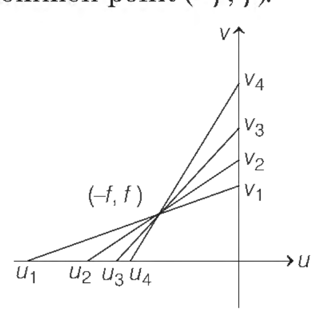
(ii) ***v versus u*** **graph**

By measuring the coordinates of point C, whose coordinates are $(2f, 2f)$, we can calculate the focal length of the lens.



(iii) **By joining v_n and u_n**

All lines intersect at a common point $(-f, f)$.



Find common intersection point and equate it to $(-f, f)$.

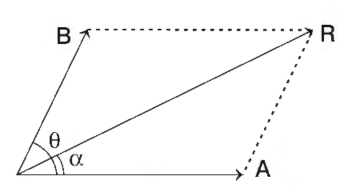
Note *All graphs are for real images.*

Physical quantities having the same dimensions

Physical Quantities or Combination of Physical Quantities	Dimensions
Angle, strain, $\sin\theta$, π, e^x	$[M^0 L^0 T^0]$
Work, energy, torque, Rhc	$[ML^2 T^{-2}]$
Time, $\frac{L}{R}$, CR, $\sqrt{LC}$	$[M^0 L^0 T]$
Frequency, ω, $\frac{R}{L}$, $\frac{1}{CR}$, $\frac{1}{\sqrt{LC}}$, velocity gradient, decay constant, activity of a radioactive substance	$[M^0 L^0 T^{-1}]$
Pressure, stress, modulus of elasticity, energy density (energy per unit volume), $\varepsilon_0 E^2$, $\frac{B^2}{\mu_0}$	$[ML^{-1} T^{-2}]$
Angular impulse, angular momentum, Planck's constant	$[ML^2 T^{-1}]$
Linear momentum, linear impulse	$[MLT^{-1}]$
Wavelength, radius of gyration, light year	$[M^0 LT^0]$
Velocity, $\frac{1}{\sqrt{\varepsilon_0\mu_0}}$, $\sqrt{\frac{GM}{R}}$, $\frac{E}{B}$	$[M^0 LT^{-1}]$

Vectors

- $R = |\mathbf{A} + \mathbf{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta} = |\mathbf{R}|$
- Angle of **R** from **A** towards **B** is given by, $\tan\alpha = \dfrac{B\sin\theta}{A + B\cos\theta}$



- If $|\mathbf{B}| = |\mathbf{A}| = A$(say), then $R = 2A\cos\dfrac{\theta}{2}$ and **R** passes along the bisector line of **A** and **B**.

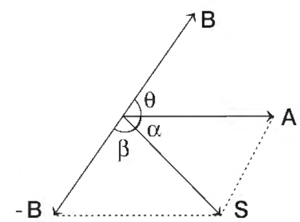
  In this case, if

$$\begin{aligned} \theta &= 0^\circ, & R &= 2A \\ \theta &= 60^\circ, & R &= \sqrt{3}\,A \\ \theta &= 90^\circ, & R &= \sqrt{2}\,A \\ \theta &= 120^\circ, & R &= A \\ \text{and} \quad \theta &= 180^\circ, & R &= 0 \end{aligned}$$

- $S = |\mathbf{A} - \mathbf{B}| = \sqrt{A^2 + B^2 - 2AB\cos\theta} = |\mathbf{S}|$

  Here, θ is the angle between **A** and **B**, not the angle between **A** and $-$**B**.

- Angle of **S** from **A** towards $-$**B** is given by, $\tan\alpha = \dfrac{B\sin\theta}{A - B\cos\theta}$



or angle of **S** from $-$**B** towards **A** is given by

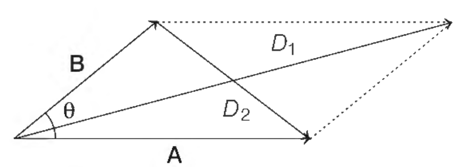
$$\tan\beta = \frac{A\sin\theta}{B - A\cos\theta}$$

- If $|\mathbf{B}| = |\mathbf{A}| = A$ (say), then $S = 2A\sin\dfrac{\theta}{2}$ and **S** passes through the bisector line of **A** and $-$**B**.

In this case, if

	$\theta = 0°$,	$S = 0$
	$\theta = 60°$,	$S = A$
	$\theta = 90°$,	$S = \sqrt{2}\,A$
	$\theta = 120°$,	$S = \sqrt{3}\,A$
and	$\theta = 180°$,	$S = 2A$

- In the figure shown,



$$\text{diagonal, } D_1 = |\mathbf{A} + \mathbf{B} \text{ or } \mathbf{R}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$

$$\text{diagonal, } D_2 = |\mathbf{A} - \mathbf{B} \text{ or } \mathbf{S}| = \sqrt{A^2 + B^2 - 2AB\cos\theta}$$

$$D_1 = D_2 = \sqrt{A^2 + B^2}, \text{ if } \theta = 90°$$

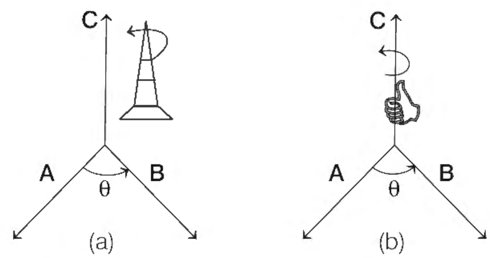
- $\mathbf{A}\cdot\mathbf{B} = AB\cos\theta$. Here, A and B are always positive as these are the magnitudes of **A** and **B**. Hence,

$$0° \le \theta < 90°, \quad \text{if } \mathbf{A}\cdot\mathbf{B} \text{ is positive}$$

$$90° < \theta \le 180°, \quad \text{if } \mathbf{A}\cdot\mathbf{B} \text{ is negative.}$$

$$\text{and } \theta = 90°, \quad \text{if } \mathbf{A}\cdot\mathbf{B} \text{ is zero.}$$

- $|\mathbf{A}\times\mathbf{B}| = AB\sin\theta$
- $\mathbf{A}\times\mathbf{B} = -\,\mathbf{B}\times\mathbf{A}$
- **Direction of Vector Cross Product** When $\mathbf{C} = \mathbf{A}\times\mathbf{B}$, then the direction of **C** is at right angles to the plane containing the vectors **A** and **B**. The direction of **C** is determined by the right hand screw rule and right hand thumb rule.



(a) **Right Hand Screw Rule** Rotate a right handed screw from first vector (**A**) towards second vector (**B**) through the smaller angle between them. The direction in which the right handed screw moves gives the direction of vector (**C**).

(b) **Right Hand Thumb Rule** Curl the fingers of your right hand from **A** to **B** through the smaller angle between them. Then, the direction of the erect thumb will point in the direction of $\mathbf{A} \times \mathbf{B}$ or **C**.

- **Direction Cosines of a Vector** If any vector **A** subtend angles α, β and γ with x-axis, y-axis and z-axis respectively and its components along these axes are A_x, A_y and A_z, then

$$\cos\alpha = \frac{A_x}{A}, \quad \cos\beta = \frac{A_y}{A}, \quad \cos\gamma = \frac{A_z}{A}$$

and
$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$$

Here, $\cos\alpha$, $\cos\beta$ and $\cos\gamma$ are called the direction cosines of **A** along x, y and z-axis.

- If we have to prove two vectors mutually perpendicular, then show their dot product equal to zero.
- To prove two vectors mutually parallel or antiparallel, we have two methods :

First Show their cross product equal to zero.

Second Show that the ratio of coefficients of $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$ and $\hat{\mathbf{k}}$ of two vectors is constant. If this constant is positive, vectors are parallel and if this constant is negative, vectors are antiparallel.

- **Angle between two vectors** In some cases, angle between two vectors can be obtained just by observation as given in following table :

A	B	θ between A and B
$2\hat{i}$	$6\hat{i}$	0°
$3\hat{j}$	$-5\hat{j}$	180°
$2\hat{i}$	$3\hat{j} - 4\hat{k}$	90°
$6\hat{i}$	$2\hat{i} + 2\hat{j}$	45°
$8\hat{i}$	$-4\hat{i} + 4\hat{j}$	135°

In general, angle between **A** and **B** can be obtained by the following relation,

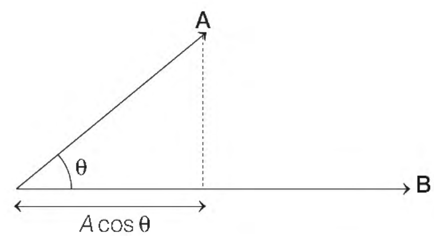
$$\theta = \cos^{-1}\left(\frac{\mathbf{A}\cdot\mathbf{B}}{AB}\right)$$

It is not always, $\sin^{-1}\left\{\frac{|\mathbf{A}\times\mathbf{B}|}{AB}\right\}$

Let's Practice Explain the reason why θ is not always given by the following relation?

$$\theta = \sin^{-1}\left\{\frac{|\mathbf{A} \times \mathbf{B}|}{AB}\right\}$$

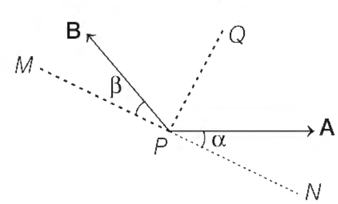
- Component of **A** along **B** $= A\cos\theta = \dfrac{\mathbf{A}\cdot\mathbf{B}}{B}$



Similarly, component of **B** along **A** $= B\cos\theta = \dfrac{\mathbf{A}\cdot\mathbf{B}}{A}$

Component of **A** along **B** = component of **B** along **A**, if $|\mathbf{A}| = |\mathbf{B}|$ or $A = B$. Otherwise they are not equal.

- If resultant of n vectors is zero, of which $(n-1)$ vectors are known and only one vector is unknown, then this last unknown vector is equal and opposite to the resultant of $(n-1)$ known vectors.
- Vector sum of n vectors of same magnitudes is always zero if angle between two successive vectors is always $\left(\dfrac{360}{n}\right)^\circ$.
- If resultant of **A** and **B** is along PQ, then components of **A** and **B** perpendicular to PQ or along MN should be equal and opposite.



$\Rightarrow$ $$A\cos\alpha = B\cos\beta$$

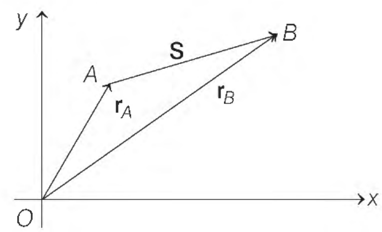
and the resultant along PQ is, $$R = A\sin\alpha + B\sin\beta$$

- A unit vector perpendicular to both **A** and **B**

$$\hat{\mathbf{C}} = \pm\frac{\mathbf{A}\times\mathbf{B}}{|\mathbf{A}\times\mathbf{B}|}$$

- $\hat{\mathbf{i}}\cdot\hat{\mathbf{i}} = \hat{\mathbf{j}}\cdot\hat{\mathbf{j}} = \hat{\mathbf{k}}\cdot\hat{\mathbf{k}} = 1,\ \hat{\mathbf{i}}\cdot\hat{\mathbf{j}} = \hat{\mathbf{j}}\cdot\hat{\mathbf{k}} = \hat{\mathbf{i}}\cdot\hat{\mathbf{k}} = 0$
- If coordinates of point A are (x_1, y_1, z_1) and coordinates of point B are (x_2, y_2, z_2), then

$\mathbf{r}_A$ = position vector of $A = x_1\hat{\mathbf{i}} + y_1\hat{\mathbf{j}} + z_1\hat{\mathbf{k}}$

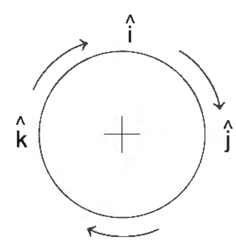


$$\mathbf{r}_B = x_2\,\hat{\mathbf{i}} + y_2\,\hat{\mathbf{j}} + z_2\,\hat{\mathbf{k}}$$

$$\mathbf{S} = \mathbf{r}_B - \mathbf{r}_A = (x_2 - x_1)\,\hat{\mathbf{i}} + (y_2 - y_1)\,\hat{\mathbf{j}} + (z_2 - z_1)\,\hat{\mathbf{k}}$$

= displacement vector from A to B

- $\hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}}$, $\hat{\mathbf{j}} \times \hat{\mathbf{k}} = \hat{\mathbf{i}}$, $\hat{\mathbf{k}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}}$, $\hat{\mathbf{i}} \times \hat{\mathbf{k}} = -\hat{\mathbf{j}}$, $\hat{\mathbf{k}} \times \hat{\mathbf{j}} = -\hat{\mathbf{i}}$
  $\hat{\mathbf{j}} \times \hat{\mathbf{i}} = -\hat{\mathbf{k}}$, $\hat{\mathbf{i}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}} \times \hat{\mathbf{k}} =$ a null vector



- If vectors are given in terms of $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$ and $\hat{\mathbf{k}}$,
  let $\mathbf{A} = a_1\hat{\mathbf{i}} + a_2\hat{\mathbf{j}} + a_3\hat{\mathbf{k}}$ and $\mathbf{B} = b_1\hat{\mathbf{i}} + b_2\hat{\mathbf{j}} + b_3\hat{\mathbf{k}}$, then

  (i) $|\mathbf{A}| = A = \sqrt{a_1^2 + a_2^2 + a_3^2}$ and $|\mathbf{B}| = B = \sqrt{b_1^2 + b_2^2 + b_3^2}$

  (ii) $\mathbf{A} + \mathbf{B} = (a_1 + b_1)\hat{\mathbf{i}} + (a_2 + b_2)\hat{\mathbf{j}} + (a_3 + b_3)\,\hat{\mathbf{k}}$

  (iii) $\mathbf{A} - \mathbf{B} = (a_1 - b_1)\,\hat{\mathbf{i}} + (a_2 - b_2)\,\hat{\mathbf{j}} + (a_3 - b_3)\,\hat{\mathbf{k}}$

  (iv) $\mathbf{A} \cdot \mathbf{B} = a_1 b_1 + a_2 b_2 + a_3 b_3$

  (v) $|\mathbf{A} \times \mathbf{B}| = \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix} = (a_2 b_3 - b_2 a_3)\,\hat{\mathbf{i}} + (b_1 a_3 - b_3 a_1)\,\hat{\mathbf{j}} + (a_1 b_2 - b_1 a_2)\,\hat{\mathbf{k}}$

  (vi) Component of **A** along **B**

  $$= A\cos\theta = \frac{\mathbf{A} \cdot \mathbf{B}}{B} = \frac{a_1 b_1 + a_2 b_2 + a_3 b_3}{\sqrt{b_1^2 + b_2^2 + b_3^2}}$$

  (vii) Unit vector parallel to **A**

  $$= \hat{\mathbf{A}} = \frac{\mathbf{A}}{A} = \frac{a_1\hat{\mathbf{i}} + a_2\,\hat{\mathbf{j}} + a_3\,\hat{\mathbf{k}}}{\sqrt{a_1^2 + a_2^2 + a_3^2}}$$

(viii) Angle between $\mathbf{A}$ and $\mathbf{B}$,

$$\theta = \cos^{-1}\left(\frac{\mathbf{A} \cdot \mathbf{B}}{AB}\right)$$

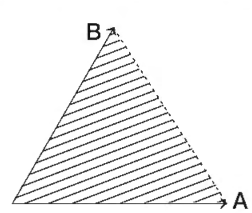
$$\therefore \qquad \theta = \cos^{-1}\left(\frac{a_1 b_1 + a_2 b_2 + a_3 b_3}{\sqrt{a_1^2 + a_2^2 + a_3^2} \times \sqrt{b_1^2 + b_2^2 + b_3^2}}\right)$$

- $(\mathbf{A} + \mathbf{B})$ is perpendicular to $(\mathbf{A} - \mathbf{B})$, if $A = B$.
- $(\mathbf{A} \times \mathbf{B})$ is perpendicular to both $\mathbf{A}$ and $\mathbf{B}$ separately, or it is perpendicular to the plane formed by $\mathbf{A}$ and $\mathbf{B}$.
- $\hat{\mathbf{i}} \times \hat{\mathbf{j}}$ should always be in the direction of $\hat{\mathbf{k}}$.
- Pressure is a scalar quantity, not a vector quantity. It has magnitude but no direction sense associated with it. Pressure acts in all directions at a point inside a fluid.
- Surface tension is scalar quantity because it has no specific direction. Current is also a scalar quantity.
- Stress and moment of inertia are tensor quantities.
- To qualify as a vector, a physical quantity must not only possess magnitude and direction but must also satisfy the parallelogram law of vector addition.

  For example, the finite rotation of a rigid body about a given axis has magnitude (the angle of rotation) and also direction (the direction of the axis) but it is not a vector quantity.

  This is so far the simple reason that the two finite rotations of the body do not add up in accordance with the law of vector addition.

  However, if the rotation be small or infinitesimal, it may be regarded as a vector quantity.
- Area can behave either as a scalar or a vector and how it behaves depends on circumstances.
- Area (vector), dipole moment and current density are defined as vectors with specific direction.
- The area of triangle bounded by vectors $\mathbf{A}$ and $\mathbf{B}$ is $\frac{1}{2} |\mathbf{A} \times \mathbf{B}|$.



- Area of parallelogram bounded by vectors $\mathbf{A}$ and $\mathbf{B}$ is $|\mathbf{A} \times \mathbf{B}|$.