PHYSICS

Kinematics_Part 1

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Chapter Description

- **Aims**
  - Student need to understand and can solve any problems related with kinematics
- **Expected Outcomes**
  1) Able to understand the concept of vector and kinematics.
  2) Able to resolve vectors on *x* and *y* axis and calculate the resultant force.
  3) Able to solve problems in kinematics and vector operation.
- **References**

  - Cutnell, J. D. and Johnson, K. W., 2010. Physics, 8th edition, Wiley, Asia.
  - Young, H. D. and Freedman, R. A., 2006. University Physics with Modern Physics. 12th edition, Pearson, San Francisco.
  - Giancoli, D. C., 2009. Physics for scientists and engineers: with modern Physics. Pearson Prentice Hall, United States of America.
  - Halliday, D. and Resnick, R., 2008. Fundamentals of Physics Extended. 8th edition. Wiley International Student Edition, Asia.

Content

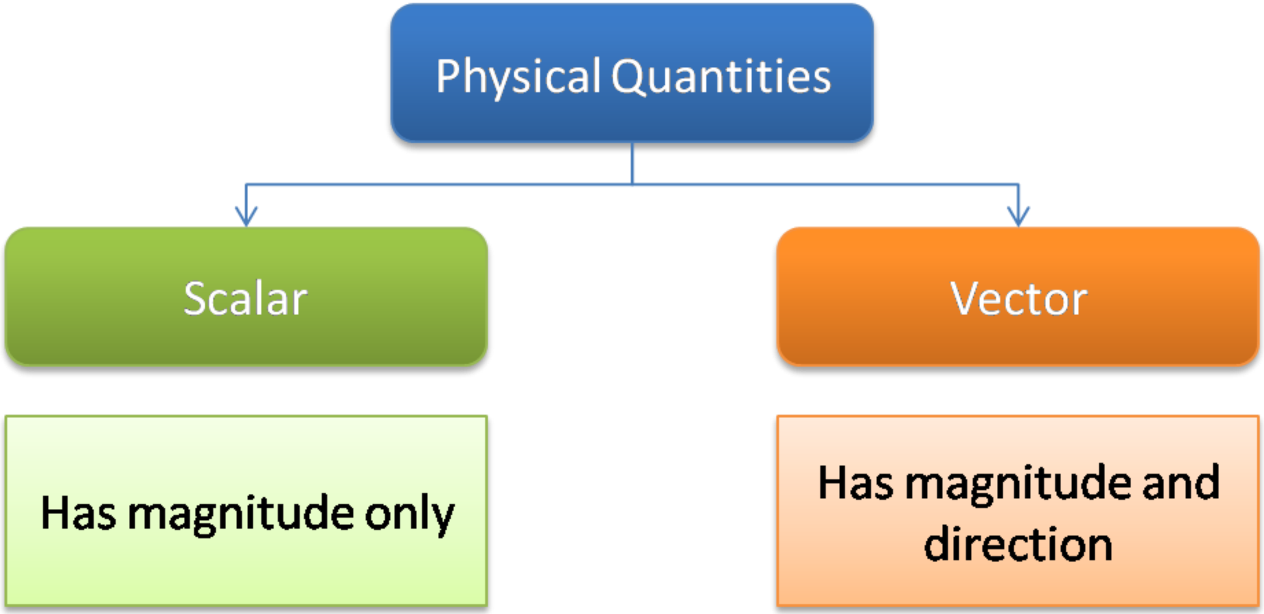
2.1 Vector and Scalar

2.2 Displacement, position, velocity, speed and acceleration

2.3 Instantaneous velocity ad speed.

Vector & Scalar

- Vector & Scalar Quantity



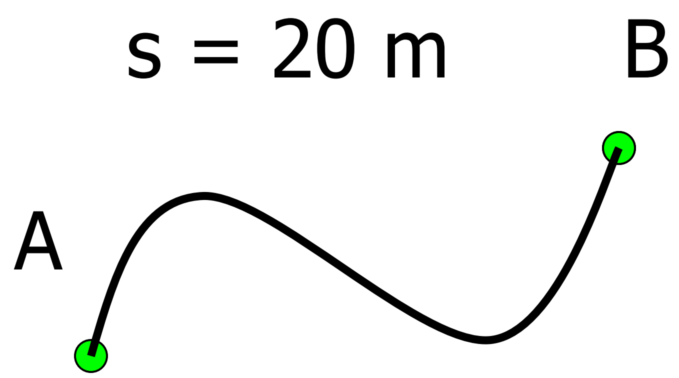
Scalar Quantity	Vector Quantity
Example: distance. mass, speed, time, temperature and volume	Example: displacement, velocity, acceleration, force, momentum, magnetic field

Example 1

- Which of the following quantities is a scalar quantity ?
  (a) Velocity
  (b) Displacement
  (c) Speed
  (d) Force
- Which of the following shows a group of vector quantities ?
  (a) Acceleration, speed , length
  (b) Acceleration, area, volume
  (c) Acceleration, temperature, momentum
  (d) Acceleration, displacement, velocity

Distance: A Scalar Quantity

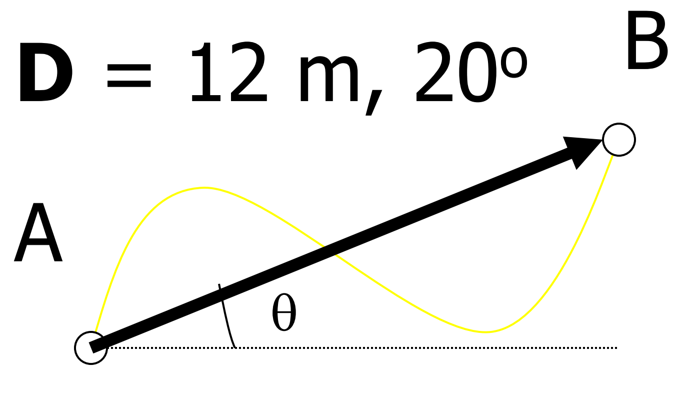
- Is a actual path between two point.
- Has a magnitude only
- For example: 20 km, 100 seconds



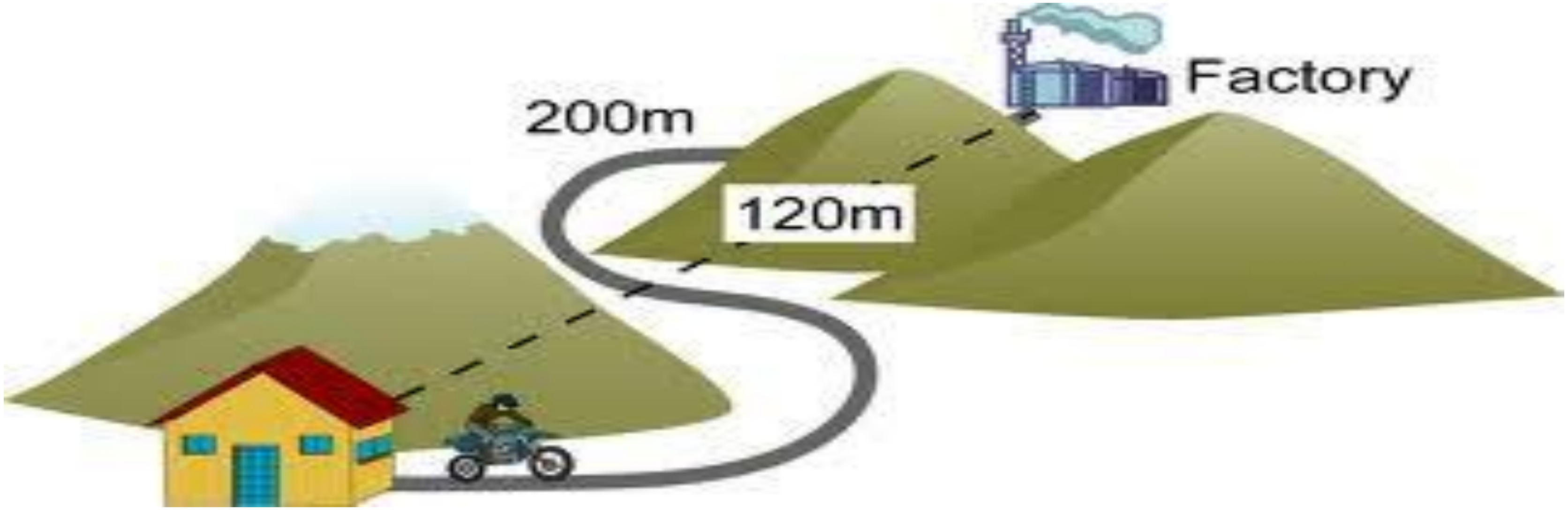
Displacement: A Vector Quantity

- Is a shortest path between two point in specified direction.
- Has a magnitude and direction
- For example: 10 m (to the right), 12 m (20^o)

$\mathbf{D}$ = 12 m, 20^o



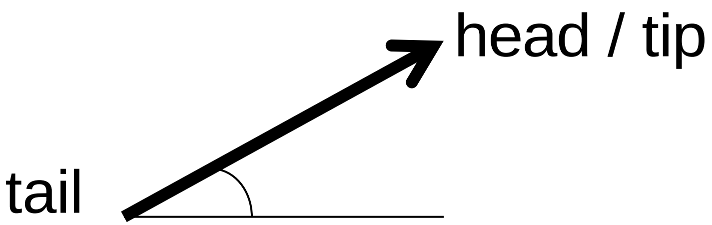
Example 2



- Find the total distance travels by Chua?
- Determine the displacement made by Chua?
- Find the distance and displacement if Chua from house go to factory and back again?

Vector Notation

- Vector quantity is represented by an **arrow.**



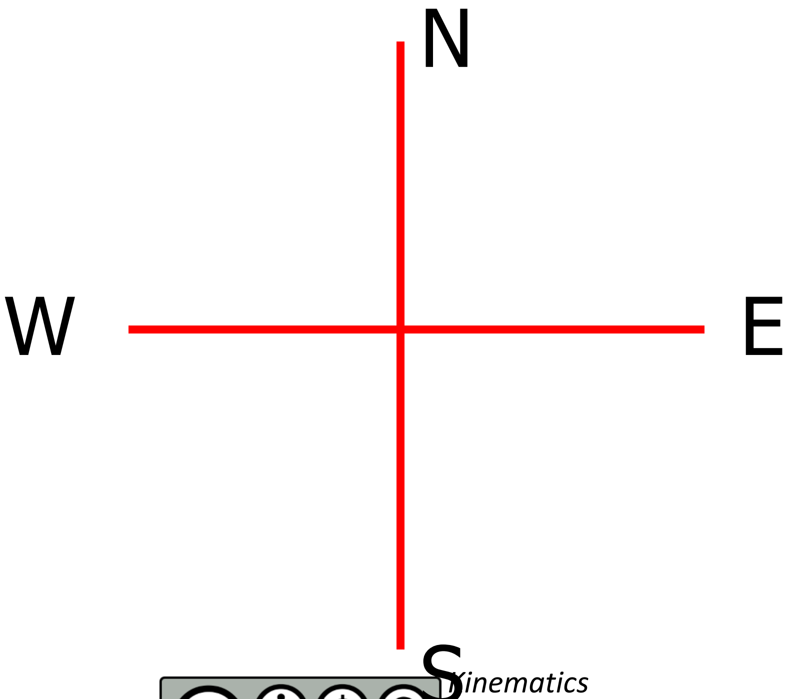
- The magnitude is represented by length of an arrow.
- The direction is represented by an arrowhead.

Vector Notation

- The vector is always write in a boldface type (**B**) or $\vec{B}$ with a tiny arrow above the symbol
- The magnitude of the vector will be write using an italic letter (*B*) or absolute value/modulus | **B** |
    - Magnitude has a unit
    - Magnitude is always positive number

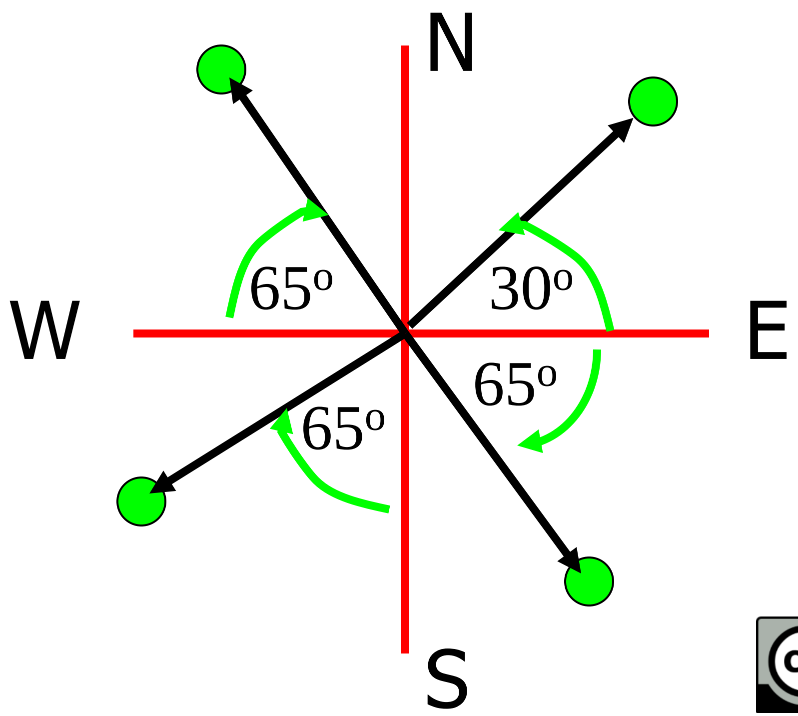
Identifying Direction

- The direction can be identified by using a
  - South
  - West
  - East
  - North



Example 3

- Write the displacement (vector quantity) by using a direction of South, West, North and East



Length = 12 m

12 m, 30^o N of E

12 m, 65^o N of W

12 m, 65^o W of S

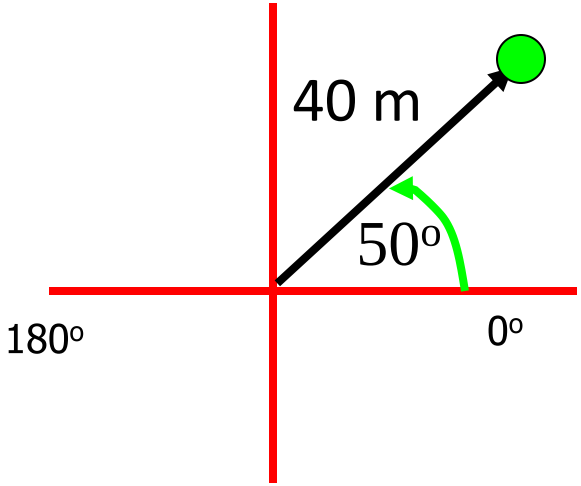
12 m, 65^o S of E

Vector and Polar Coordinates

- The vector is also can express in polar coordinates (R,θ).
- R is represented by magnitude.
- θ is represented by direction.

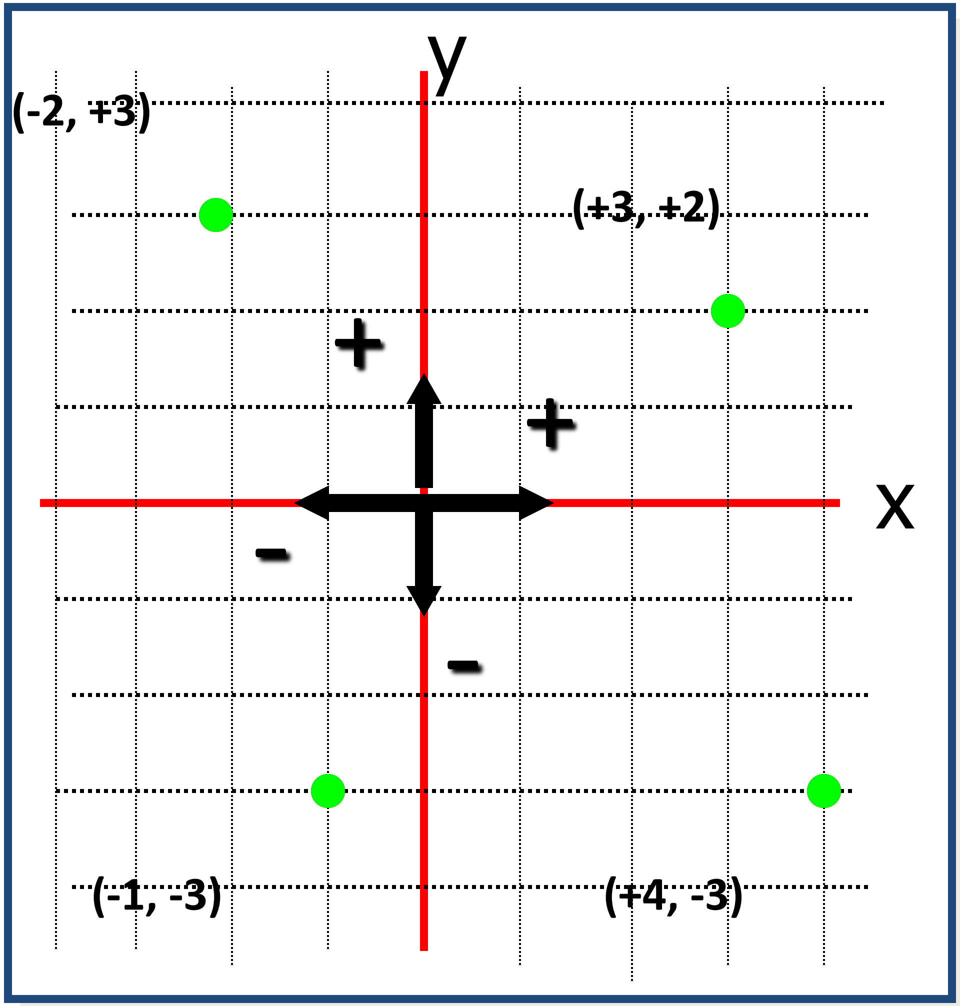
Example 4

- Determine the polar coordinates at first quadrant as shown in figure below.



$(R, \theta) = 40\text{ m}, 50^{o}$

Rectangular Coordinates



- The direction will be refer to *x* and *y* axis (positive or negative)

Addition of Vector

- The direction must be consider when do a vector addition.
- Vectors only can be add if it comes from the same physical quantity
- Using two methods:
    - i) Graphical Methods - Use scale to sketch a vector
    - ii) Algebraic Methods - More convenient (algebraic)

Graphical Method

1) Select a suitable scale.
2) Draw the first vector with the correct length and direction by refer the coordinate system. Follow the scale that already set up.
3) Then, draw the second vector with the correct length and direction by placing its tail at the head of first arrow.

Graphical Method

4) Draw the resultant vector from the origin/tail of first vector to the head of final vector.
5) Determine the length (convert the length by using a scale to get the actual value) and direction (angle) of resultant vector

Vector Addition & Subtraction

Graphical Method

- If you have more than two vectors, just repeat the same method until all the vectors are included.
- The resultant vector is still draw from the origin/tail of first vector to the head of final vector.

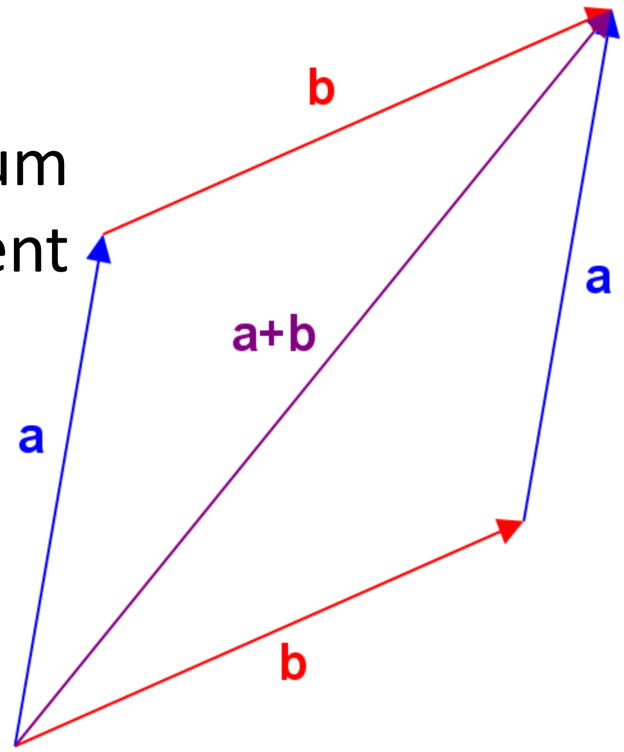
Vector Addition & Subtraction

Law of Addition

- **Commutative Law of Addition**

  - This law states that the sum (addition) of two vectors is independent of the vectors order.

$$\vec{\mathbf{A}} + \vec{\mathbf{B}} = \vec{\mathbf{B}} + \vec{\mathbf{A}}$$



Vector Addition & Subtraction

Law of Addition

- **Associative Law of Addition**

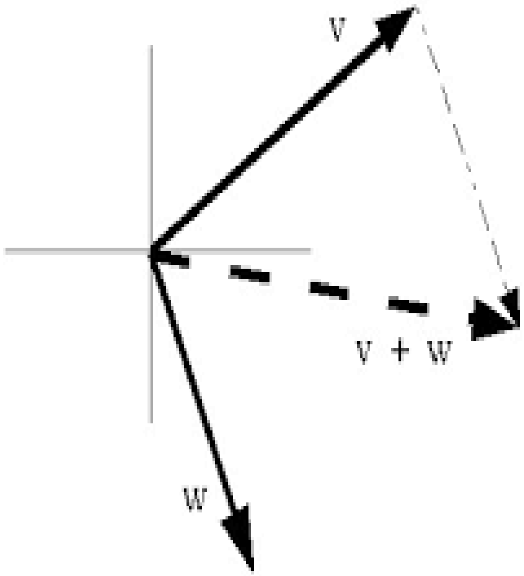
  - This law states that the sum (addition) of three or more vectors is independent of the way the vectors are grouping.

$$\vec{\mathbf{A}} + \left(\vec{\mathbf{B}} + \vec{\mathbf{C}}\right) = \left(\vec{\mathbf{A}} + \vec{\mathbf{B}}\right) + \vec{\mathbf{C}}$$

Vector Addition & Subtraction

Parallelogram Method

- Is a another method to add vector graphically.
- The two vector are drawn from the same point or the tail of second vector is placed at the tail of first vector.



Equal & Unequal Vector

- Two vectors are equal vectors if they have same magnitude and direction.
- For example, **A =** 6 N, North; **B =** 6 N, North; **C =** 10 N, North. So,

A = **B** ; **A** ≠ **C**

Negative Vector

- Is a vector that have a resultant vector of zero when we add it with original vector.

$$\vec{\mathbf{A}} + \left(-\vec{\mathbf{A}} \right) = 0$$

- The negative vector has a same magnitude but opposite direction

$$\vec{\mathbf{A}} \neq -\vec{\mathbf{A}}$$

Vector Addition & Subtraction

Substraction of Vector

- May used the method of commutative law of addition.
- So, from the subtraction operation;

$$\vec{\mathbf{A}} - \vec{\mathbf{B}}$$

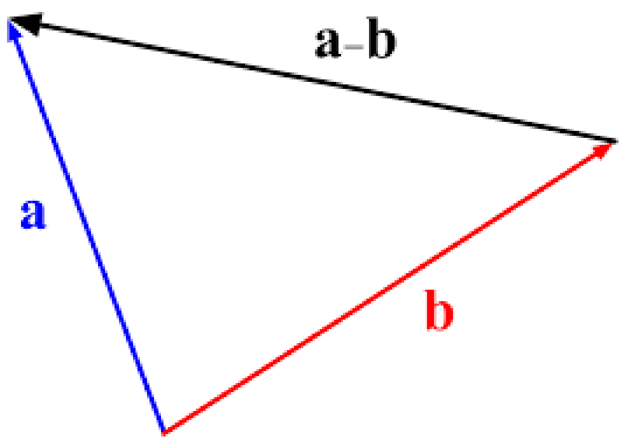
change it to the addition operation.

$$\vec{\mathbf{A}} + \left(-\vec{\mathbf{B}}\right)$$

Vector Addition & Subtraction

Substraction of Vector

- Another method to solve the subtraction of vector
- The two vector are drawn from the same point or the tail of second vector is placed at the tail of first vector.
- Then, the resultant vector is drawn from the head of second vector to the head of first vector.



$$\vec{\mathbf{A}} + \left(-\vec{\mathbf{B}}\right) = \vec{\mathbf{C}}$$

Example 5

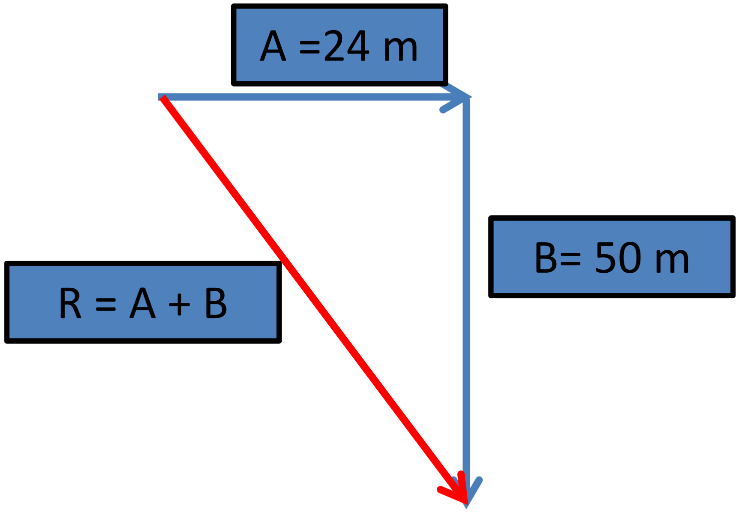
- Given that **A**=24 m, E; **B**=50 m, S. Find the resultant vector of

  (i) **A** + **B**

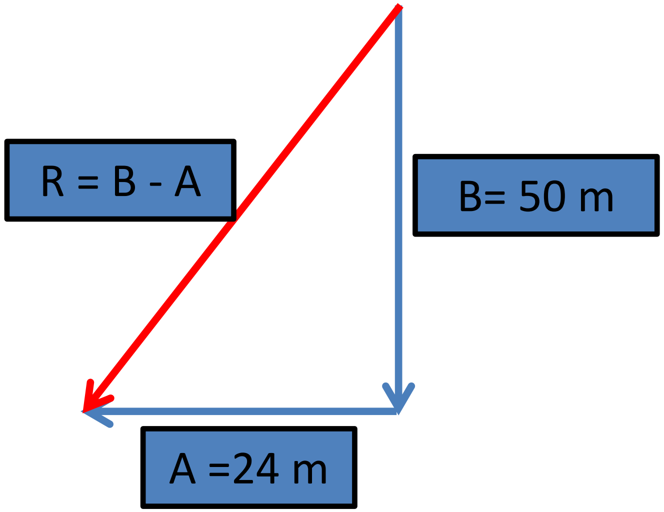
  (ii) **B** – **A**

(a) (A + B)

Scale: 10 m = 1 cm

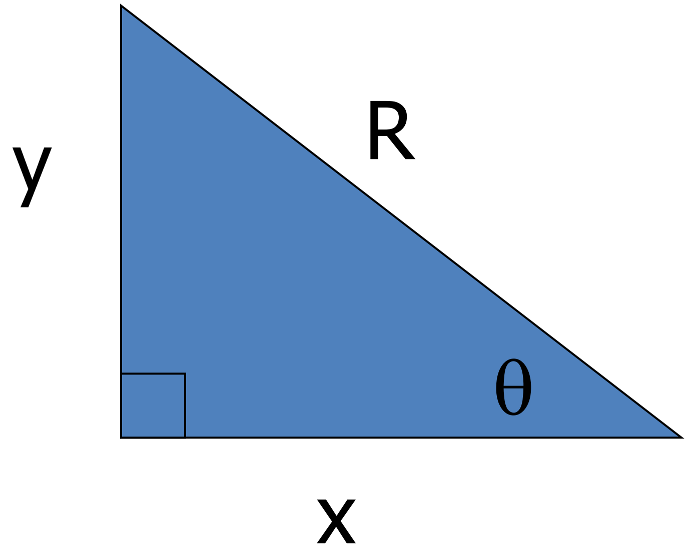


(b) (B - A)



Trigonometry Review

- Formula for trigonometry



$$\sin\theta = \frac{y}{R}$$

$$\cos\theta = \frac{x}{R}$$

$$\tan\theta = \frac{y}{x}$$

Example 5

- Determine the height of a tower if it casts a shadow 200 m long at angle of 60^o.

$$\tan 60^0 = \frac{opp}{adj} = \frac{h}{200 \text{ m}}$$

$$h = 346.41 \text{m}$$

Components of a Vector

- The result of resolving the vector is called as a vector components.
- When the vector is resolved, the vector components can be lying in *x* and *y* axis.
- In other words, it will be resolved into *x*-component and *y*-component.

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

Components of a Vector

- The vector along *x*-component can be write as a

$$\overrightarrow{A_x} = \overrightarrow{A} \cos\theta$$

- The vector along *y*-component can be write as a

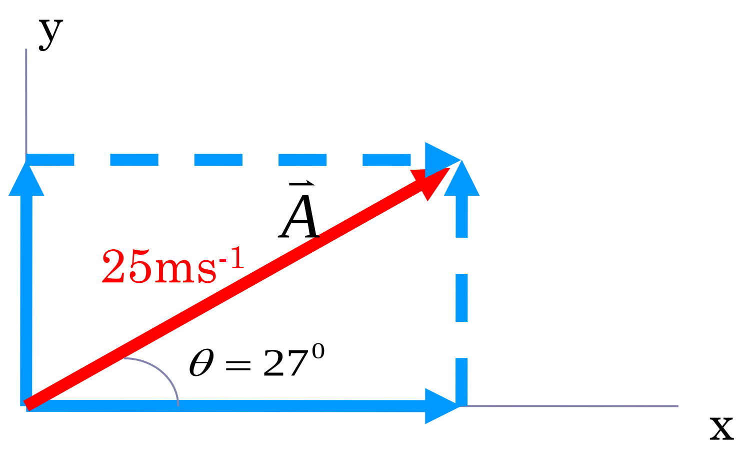
$$\overrightarrow{A}_y = \overrightarrow{A} \sin\theta$$

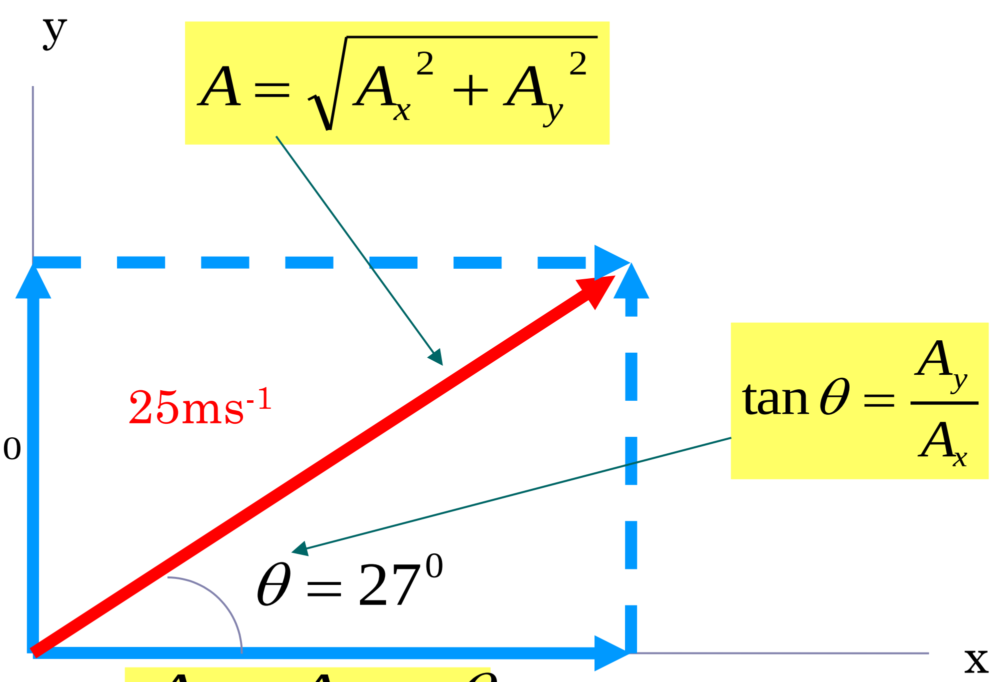
- The magnitude and direction of **A** in terms of component are:-

$$A = \sqrt{A_x^2 + A_y^2} \quad \text{and} \quad \theta = \tan^{-1}\frac{A_y}{A_x}$$

Example 6

- Calculate the components of vector as shown below.





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

$$\tan\theta = \frac{A_y}{A_x}$$

$$A_y = A\sin\theta = 25\sin 27^0$$
$= 11\ \text{ms}^{-1}$

$$A_x = A\cos\theta = 25\cos 27^0$$
$= 22\ \text{ms}^{-1}$

$\theta = 27^0$

Example 7

- From the police station, policeman drives 22.0 km to the north. Then, he drives for 47.0km in a direction 60.0^{o} south of east. Determine the displacement of the policeman.

1. Resolve the vectors into its component.
2. Sum the vectors that having same component.

Vector (Displacement)	x- component (x-axis)	y- component (y-axis)
$\mathbf{D_1}$ = 22 km	$\mathbf{D_{1x}}$ = 22 cos 90° = 0 km	$\mathbf{D_{1y}}$ = 22 sin 90° = 22 km
$\mathbf{D_2}$ = 47 km	$\mathbf{D_{2x}}$ = 47 cos 60° = 23.5 km	$\mathbf{D_{2y}}$ = - 47 sin 60° = - 40.703 km
ΣDisplacement	$\Sigma\mathbf{D}_x$ = 23.5 km	$\Sigma\mathbf{D}_y$ = -18.703 km

3. Find the resultant vector and its direction

Total displacement:

$$R = \sqrt{(23.5\text{ km})^2 + (-18.703\text{ km})^2}$$

$$= 30.034\text{ km}$$

Direction:

$$\theta = \tan^{-1}\left(\frac{-18.703}{23.5}\right) = -38.556°$$

Unit Vector

- Is a vector without unit and has a magnitude of 1.
- The “hat” (^) is used for unit vector.
- Unit vector $\hat{\boldsymbol{i}}, \hat{\boldsymbol{j}}, \hat{\boldsymbol{k}}$ will represent the vector along *x*, *y* and *z*.
- For example;

$$\vec{A}_x = A_x \hat{i}$$

$$\vec{A}_y = A_y \hat{j}$$

$$\vec{A}_z = A_z \hat{k}$$

Vector Addition & Subtraction

Algebraic Method

- Vector **A** can be write in its components;

$$\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k}$$

- The addition or subtraction using algebraic method; the vector must be form in vector unit.

Example 8

- Given two vectors, **B** and **C**. Find the its resultant vector.

$$\vec{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k}$$

$$\vec{C} = C_x\hat{i} + C_y\hat{j} + C_z\hat{k}$$

$$\vec{R} = \left(B_x + C_x\right)\hat{i} + \left(B_y + C_y\right)\hat{j} + \left(B_z + C_z\right)\hat{k}$$

$$\vec{R} = R_x\hat{i} + R_y\hat{j} + R_z\hat{k}$$

Vector Multiplication

- **Scalar** or **dot** product
  - useful where a scalar result is wanted from the product of two vectors.

- **Vector** or **cross** product
  - useful where a vector result is wanted from the product of two vectors.

Vector Multiplication

Scalar or dot product

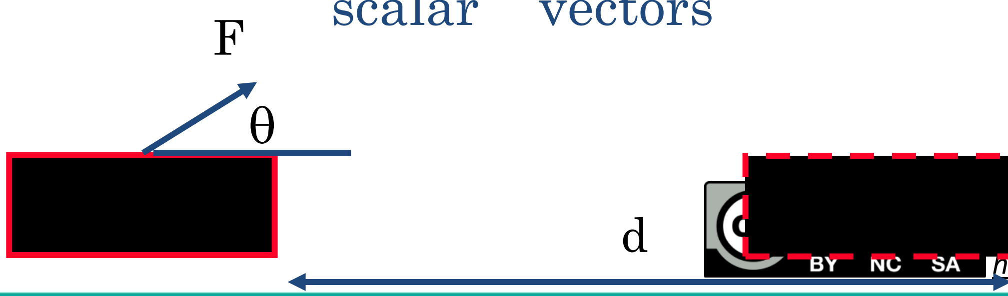
- Denoted by

$$\mathbf{a} \bullet \mathbf{b} = |\mathbf{a}|\ |\mathbf{b}| \cos \theta$$

- Example

$$\text{Work} = \mathbf{F} \bullet \mathbf{d} = Fd \cos q$$

scalar   vectors



Vector Multiplication

<u>Properties of scalar or dot product</u>

- Properties
  - **b.c** = **c.b**
  - **b.b =** b^2
  - **b.c =** 0 where **b** and **c** orthogonal
  - **b.c =** ab where **b** and **c** parallel

Thus i.i = 1, i.j = 0 (Cartesian unit vector)

Vector Multiplication

Properties of scalar or dot product

- Dot product of two vectors.

$$\mathbf{b} = b_x\hat{i} + b_y\hat{j} + b_z\hat{k}$$

$$\mathbf{c} = c_x\hat{i} + c_y\hat{j} + c_z\hat{k}$$

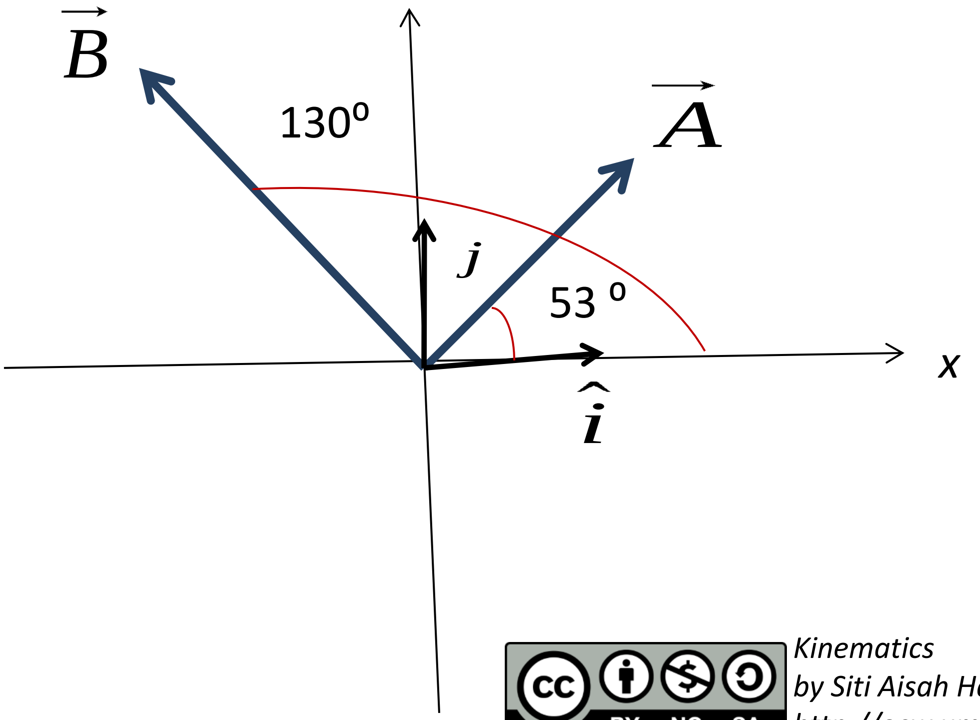
$$\mathbf{b.c} = b_x c_x + b_y c_y + b_z c_z$$

- Angle between ***b*** and ***c***

$$\cos\theta = \frac{\mathbf{b}\,.\,\mathbf{c}}{|b||c|}$$

Example 9

- Determine the dot product of vector **B** and **C.** Given magnitude of *B* = 4 and *C* = 5.



answer

$$\mathbf{b.c} = |b||c| \cos \theta$$
$$= (4)(5)\cos 77$$
$$= 4.5$$

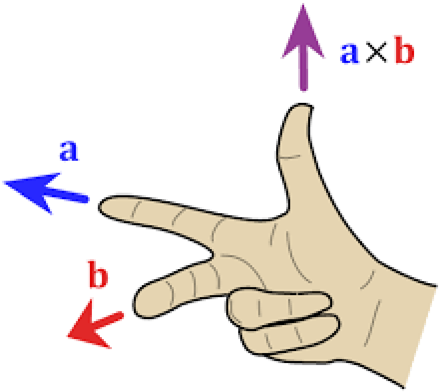
Vector Multiplication

Vector or cross product

- Denoted by

$$\mathbf{a} \times \mathbf{b} = |\mathbf{a}|\ |\mathbf{b}| \sin\theta$$

- This product has a direction, the direction can be determined by using right hand rule.



Vector Multiplication

Properties of vector or cross product

- Properties

$$\hat{i} \times \hat{j} = \hat{k}$$

$$\hat{j} \times \hat{k} = \hat{i}$$

$$\hat{k} \times \hat{i} = \hat{j}$$

- Cross product of two vectors.

$$\vec{A} \times \vec{B} = (A_y B_z - A_z B_y)\hat{i} + (A_z B_x - A_x B_z)j + (A_x B_y - A_y B_x)k$$

Position, Displacement, Velocity & Acceleration

Position

- Is a location that measure from reference point.

Displacement

- Is a change in position during certain time.

Position, Displacement, Velocity & Acceleration

Speed

- Speed is how far an object travel in time interval.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time Interval}}$$

Velocity

- Velocity signify both the magnitude of how fast the object moving and the direction in which it is moving

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time Interval}} \qquad v_{x,avg} \equiv \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t}$$

Position, Displacement, Velocity & Acceleration

Acceleration

- Is a changing of velocity.

$$a_{x,avg} \equiv \frac{\Delta v_x}{\Delta t} = \frac{v_{xf} - v_{xi}}{t_f - t_i}$$

Example 10

- The MRT train accelerates from rest to 90 km/h in 5.0 s. What is the magnitude of its average acceleration?

$$90\text{ km/h} = 90\text{ km/h} \times \left(\frac{1000\text{ m}}{1\text{ km}}\right) \times \left(\frac{1\text{ h}}{3600\text{ s}}\right) = 25\text{ m/s}$$

$$\bar{a} = \frac{\Delta v}{\Delta t}$$

$$= \frac{25\text{ m/s} - 0}{5.0\text{ s} - 0}$$

$$= 5\text{ m/s}^2$$

Position, Displacement, Velocity & Acceleration

Instantaneous Velocity

- Is a velocity at a certain time/specific time

Instantaneous Speed

- Is a magnitude of the instantaneous velocity

Instantaneous Acceleration

- Is a acceleration at a certain time/specific time

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