BUF1113 BASIC PHYSICS

KINEMATICS PART I

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Chapter Description

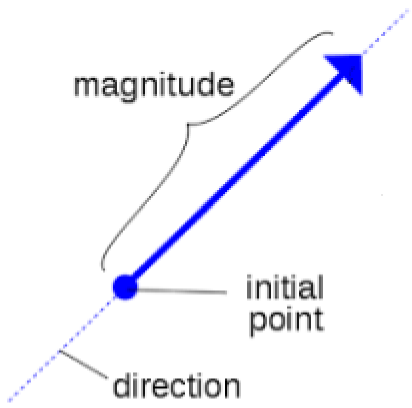
- Aims
  - Student should understand and solve the problems in kinematics.
- Expected Outcomes
  - Understand the concept of vector and kinematics.
  - Solve problem in free fall and projectile motion
  - Solve problems in kinematics.

- References
  - Giancoli, D.C. Physics for Scientists and Engineers: with Modern Physics (4th Edition). Pearson Prentice Hall, 2013
  - Paul E. Tippens, Physics 7th Edition. Mc Graw Hill, 2013
  - Physics for scientists and engineers / Raymond A. Serway, John W. Jewett, Australia : Cengage Learning, 2014

CONTENT

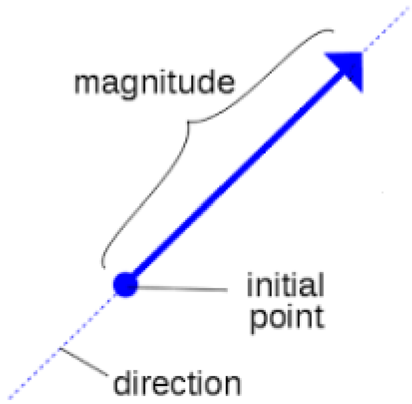
2.1 Vector and Scalar Quantities

2.1 Vectors and Scalars Quantities



- A **vector quantity** has **magnitude** and **direction**.
- Examples of vector: displacement, velocity, force and momentum
- A **scalar** has only a **magnitude.**
- Examples of scalar: mass, time and temperature

2.1 Vectors and Scalars Quantities



- In a diagram, vector is represented by an arrow →
- The arrow is drawn in the direction of vector quantity its represent.
- The length of the arrow is proportional to the magnitude of the vector quantity.

2.1 Vectors and Scalars Quantities

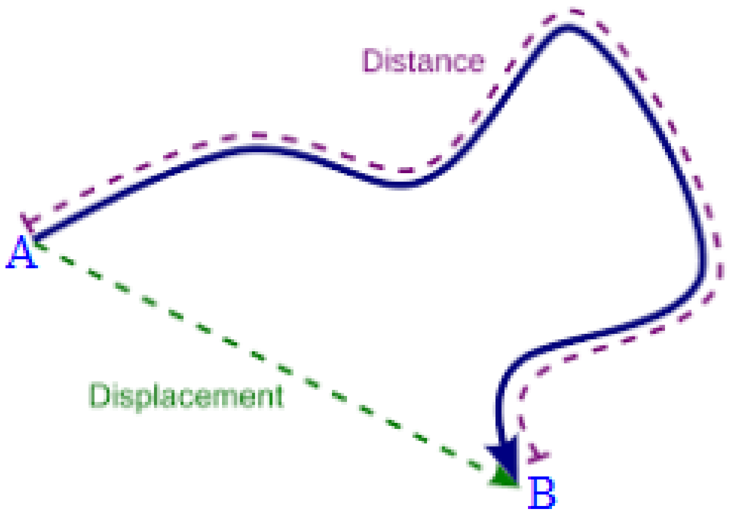
- The vector is represented in a boldface type, with a tiny arrow. E.g. : $\vec{A}$

- To write the magnitude of the vector, an italic letter will be used: *A* or $\left|\vec{\mathbf{A}}\right|$

2.1 Vectors and Scalars Quantities

- An object moves from point A to B represented by red line.
  - This is the ***distance*** (scalar quantity).

- The ***displacement*** (vector quantity) is shortest path from point A to B represented by solid line.
  - The displacement is independent of the path between the two points.



2.1 Vectors and Scalars Quantities

- Vector can be treated as an algebraic quantities, (it can be add, subtract & multiply) the vectors.

- To apply addition or subtraction of the vectors, the directions must be considered.

- Vectors must have the same type of quantity and same units when apply mathematical operation.

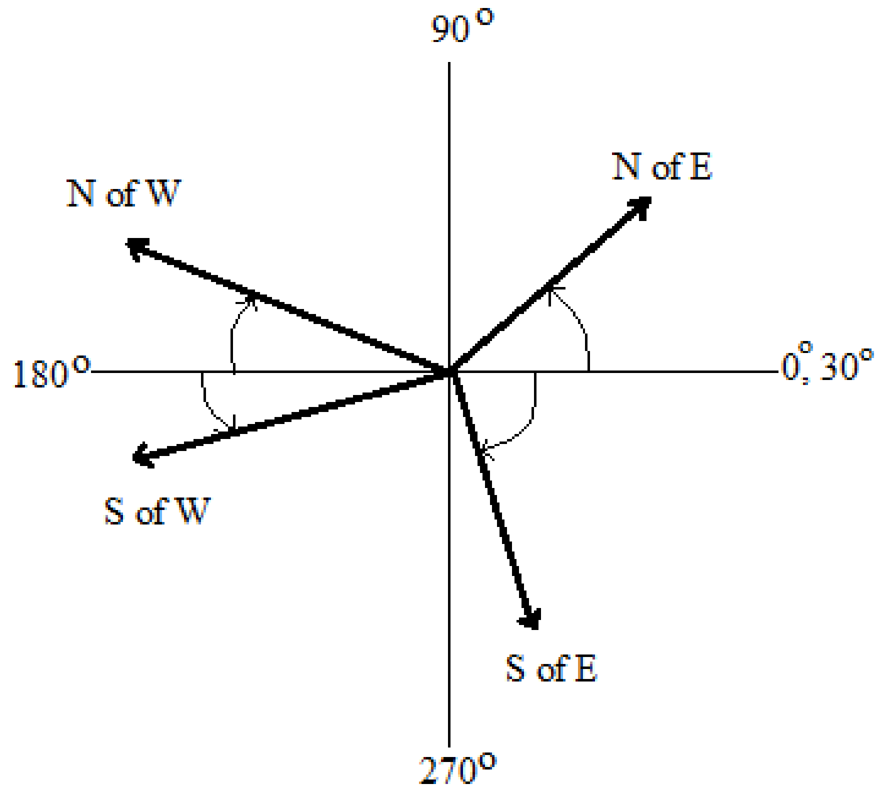
- 2 method of vector addition:
  i. **Graphical Method**
  ii. **Component's Method** ~ more convenient

2.1 Vectors and Scalars Quantities

- The direction of the vector may be given by reference to conventional North, South, East & West direction.
  - e.g.: 20 m, W and 40 m, 30° North of East

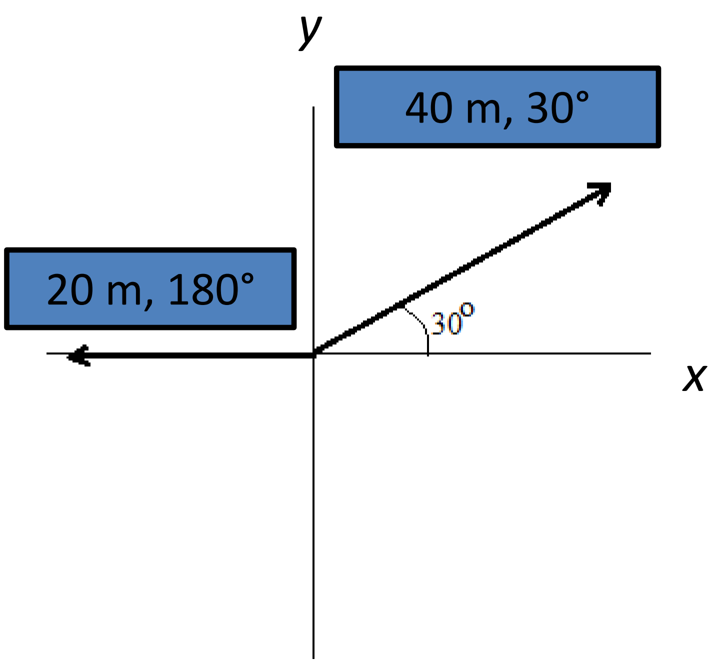
N of E – the angle is formed by rotating a line northward from east direction

2.1 Vectors and Scalars Quantities

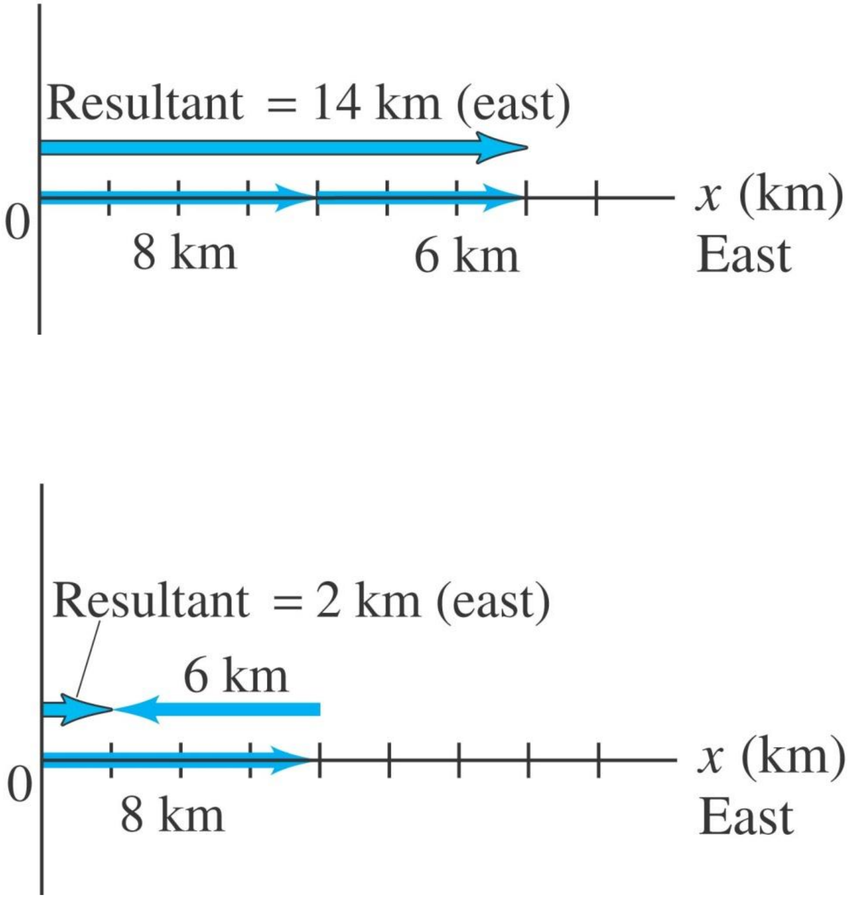


2.1 Vectors and Scalars Quantities

- Another method to determine direction by making reference to perpendicular line or axes
    - *x* and *y* axes



2.1 Vectors and Scalars Quantities

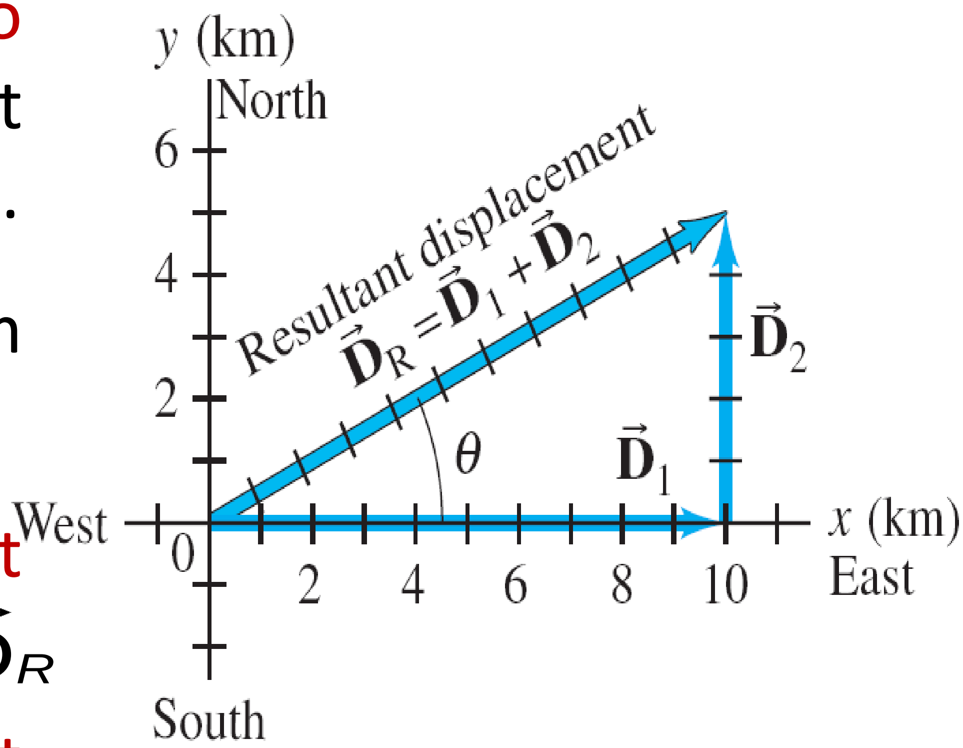


- For vectors in one dimension, you can simply apply direct *addition and subtraction.*
- You need to consider the signs, as the figure indicates.

Images from Giancoli, D.C. Physics for Scientists and Engineers: with Modern Physics (4th Edition

2.1 Vectors and Scalars Quantities

- If the vector is in two dimensions, you cannot simply use direct calculation.
- For e.g.: Ali walks 10 km east and then 5 km north
- The resultant displacement is drawn by arrow labeled $\vec{D}_R$
- The length of the resultant vector represent its magnitude.



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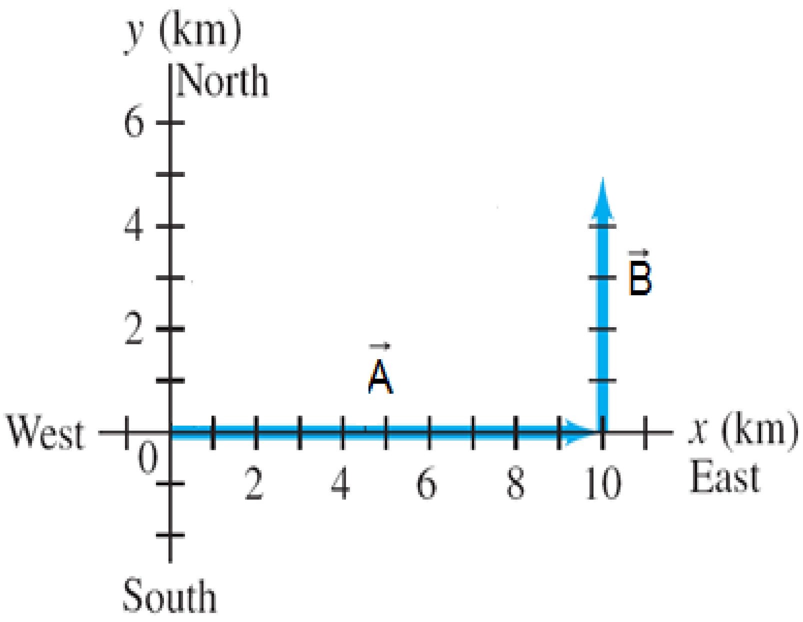
2.1 Vectors and Scalars Quantities

The rules are follow:

1. Draw the first vector $\vec{A}$ (with correct length and direction) with respect to a coordinate system.
2. Next, draw the second vector $\vec{B}$ (with correct length and direction) by putting the tail of the second vector at the tip of the first vector.



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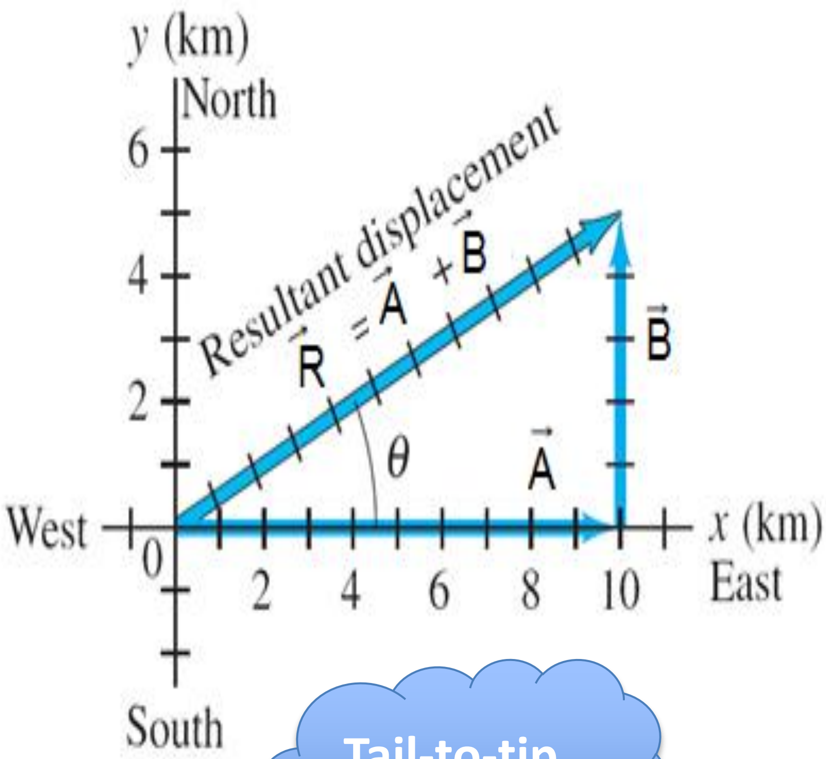
2.1 Vectors and Scalars Quantities

3. The resultant vector is drawn from the tail of $\vec{A}$ to the tip of $\vec{B}$
4. Calculate the length of the resultant vector and its angle
   - Use the scale factor to get the actual magnitude or
   - Obtained using the theorem of Pythagoras :

$$D_R = \sqrt{D_1^2 + D_2^2}$$



Tail-to-tip method

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2.1 Vectors and Scalars Quantities

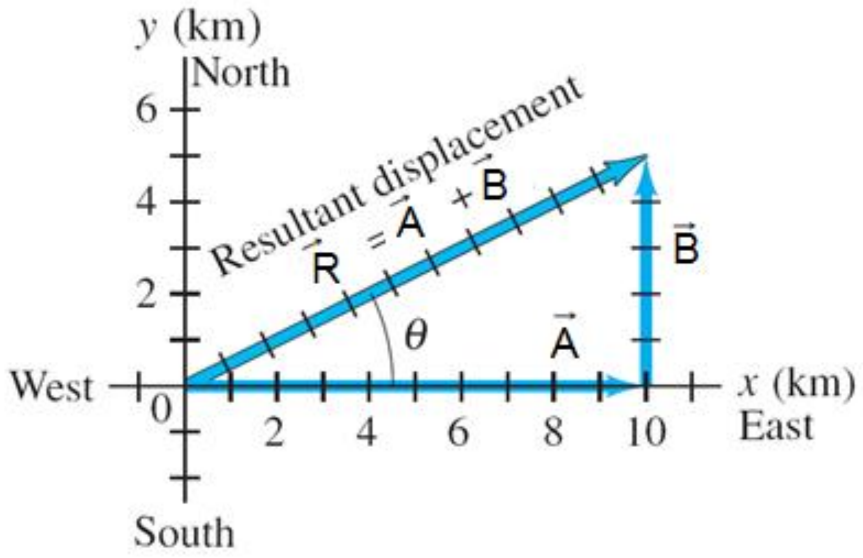
Example 1

Ali walks 10 km to east and continue his walks 5 km north. Find the total displacement of his walks.

2.1 Vectors and Scalars Quantities

Example 1: Answer

Scale:
1 km = 1 cm



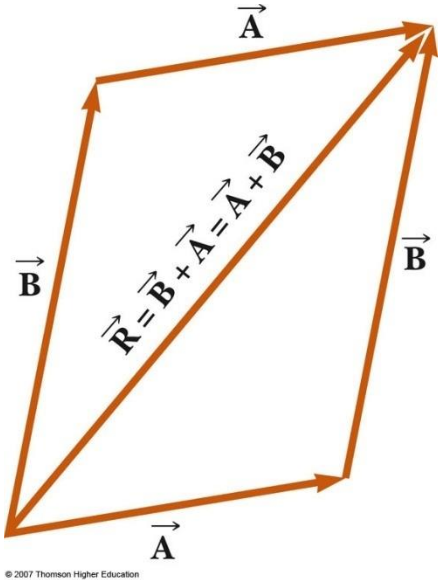
Resultant Displacement, R = 11.2 km, 26.6°

2.1 Vectors and Scalars Quantities

- The resultant is not affected by the order in which the vector are added.

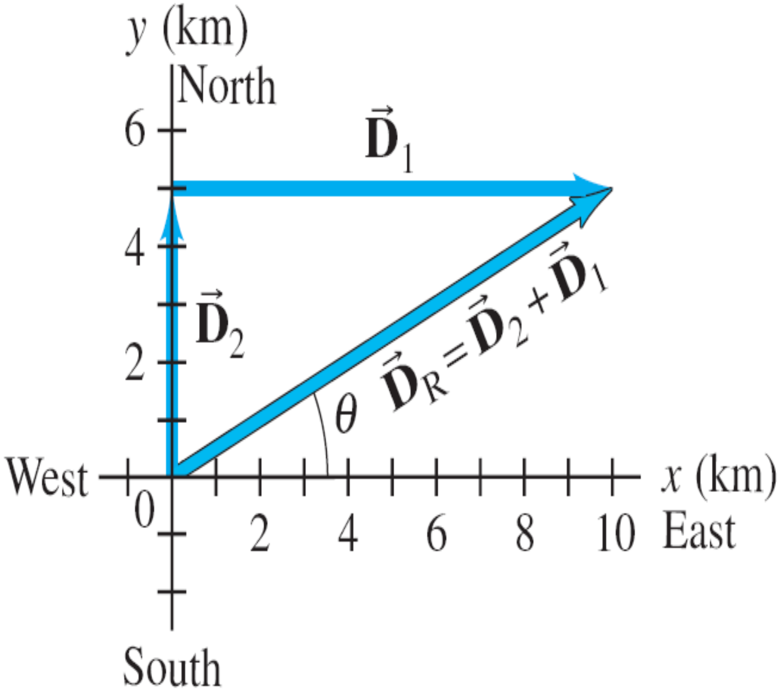
- This is the ***commutative law of additions***:

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



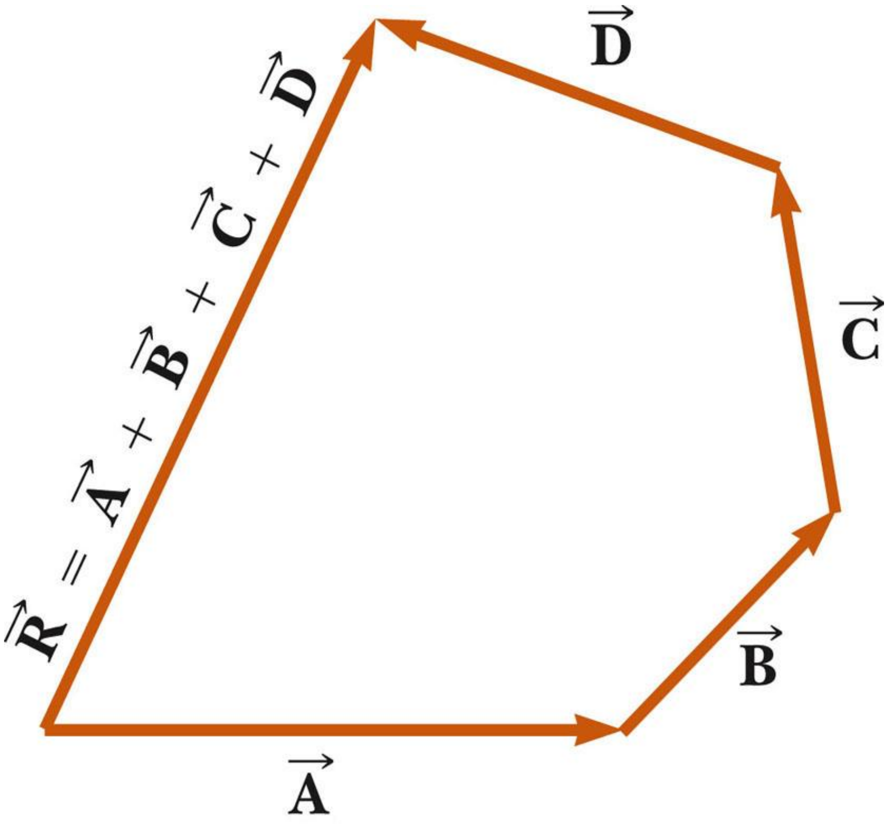
2.1 Vectors and Scalars Quantities

- For e.g., displacement of 5 km north, then 10 km east.
  - Give the same resultant of 11.2 km and angle θ=27° as before.



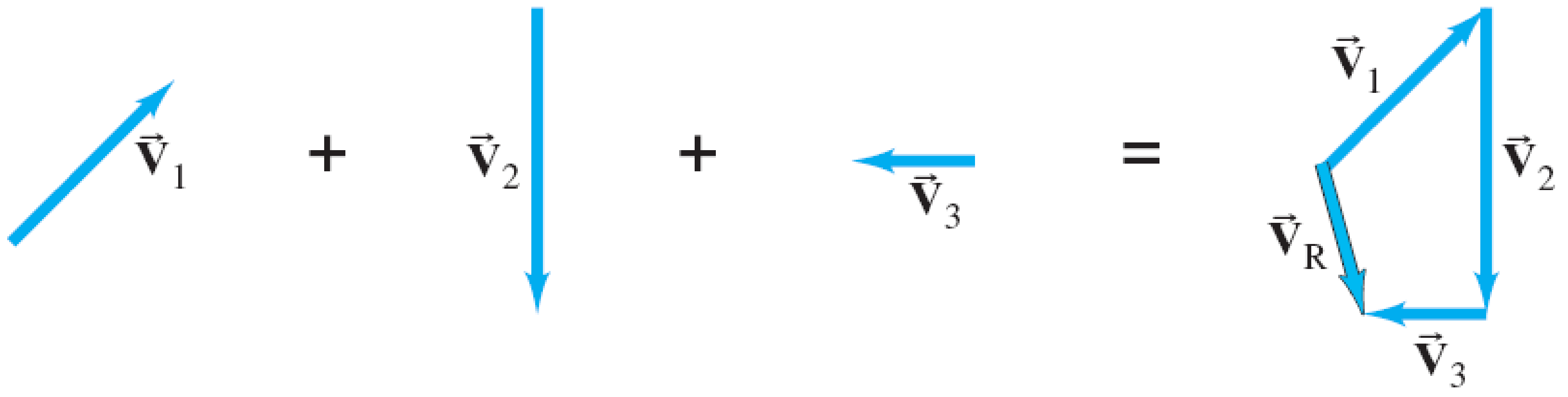
2.1 Vectors and Scalars Quantities

- To add more vectors, draw the vector continuously until all are included.
- The resultant is drawn from the origin of the first vector to the end of the last vector



2.1 Vectors and Scalars Quantities

Not at right angles vector can also be added by using the tail-to-tip method (poligon method).



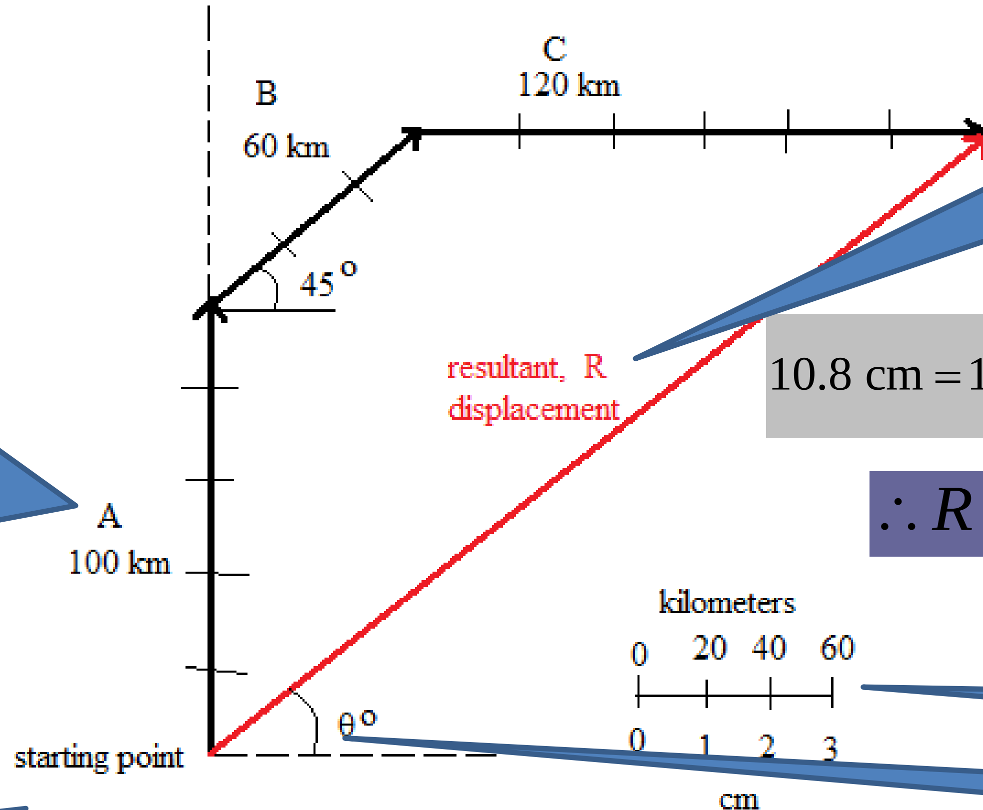
Example 2:

A ship sailing 100 km to north on Monday of a weekly trip, 60 km northeast on Tuesday, and 120 km due to east on the Wednesday. Find the resultant displacement of the ship by the graphical method.

Example 2: Answer

4. Resultant vector drawn using tail to tip method & measure

3. Draw each vector in proportion to magnitude



$$10.8\text{ cm} = 10.8\text{ cm} \times \frac{20\text{ km}}{1\text{ cm}} = 216\text{ km}$$

$$\therefore R = 216\text{ km}, 41^\circ$$

1.Scale

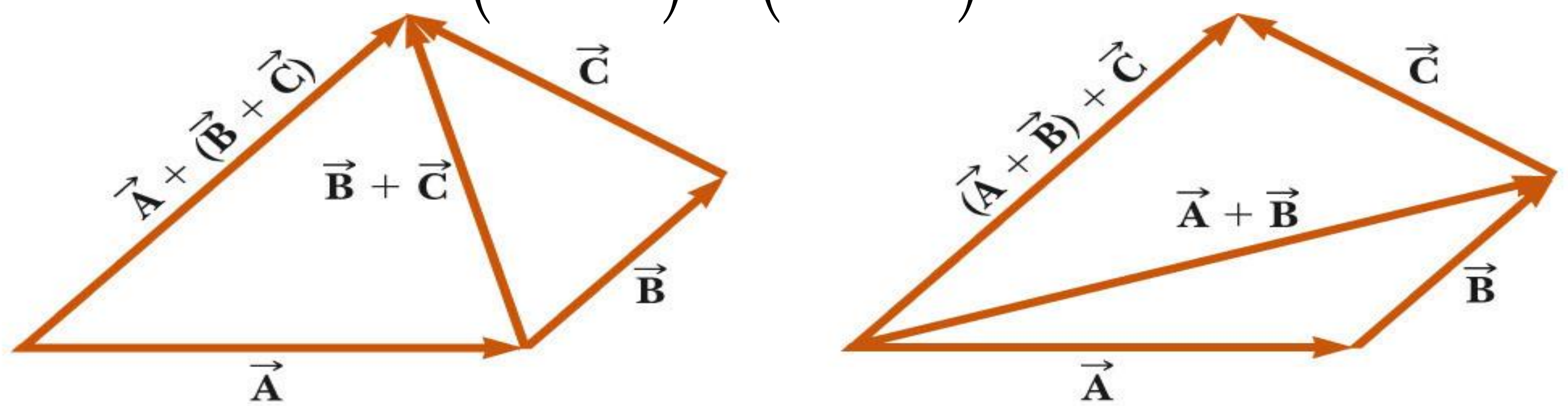
2. Set the starting point

5. Measure θ

2.1 Vectors and Scalars Quantities

- The summation of many vectors is independent of which the individual vectors are grouped.
- This is known as the ***Associative Property of Addition***

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



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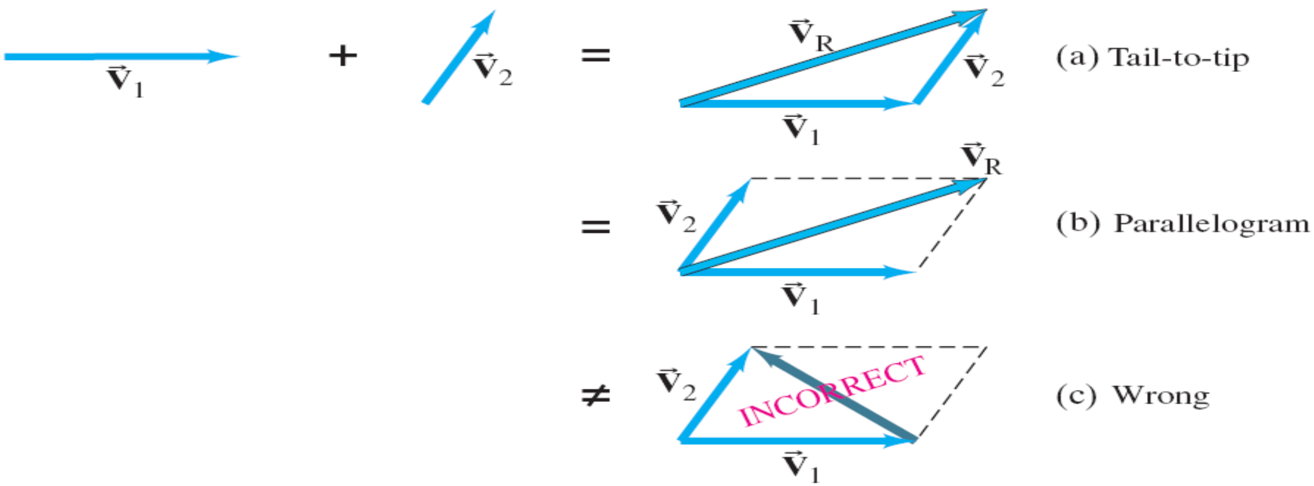
2.1 Vectors and Scalars Quantities

- Another way to do vector graphically is the parallelogram method.

- In this method , both vectors are drawn from the origin (both tails is at a the same origin).



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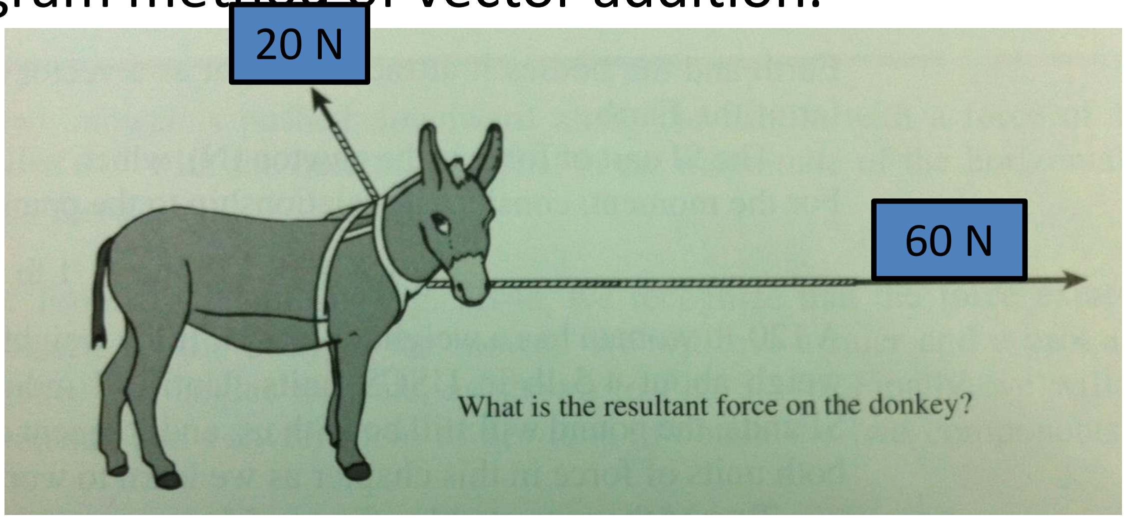
2.1 Vectors and Scalars Quantities

Example 3

Determine the resultant force on the donkey if the angle between the two ropes is 120°.One end is pulled with a force of 60 N, and the other with a force of 20 N. Use the parallelogram method of vector addition.



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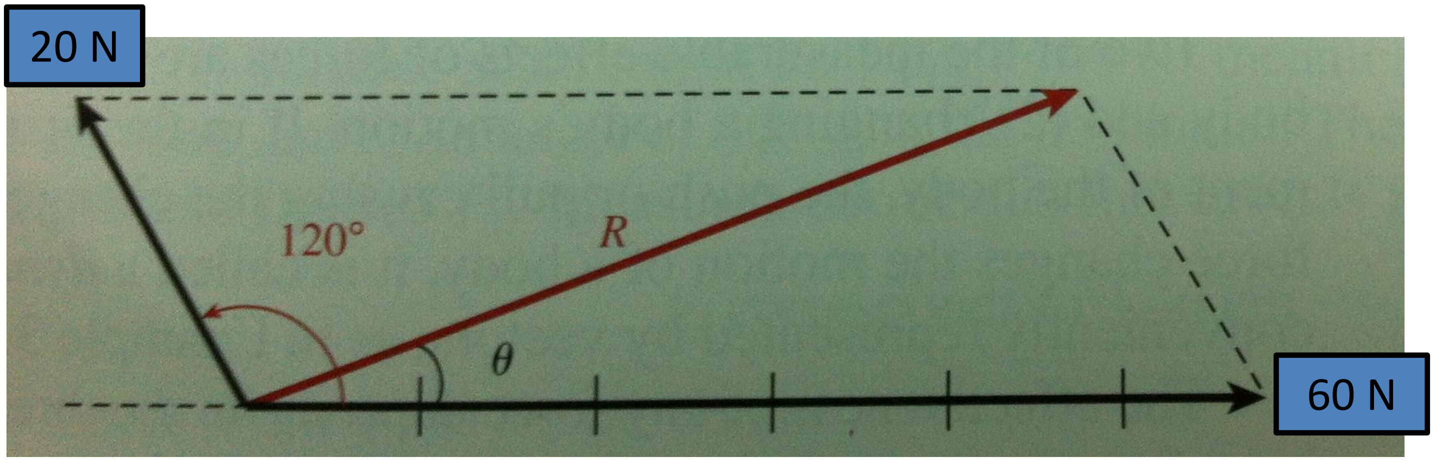
2.1 Vectors and Scalars Quantities

Example 3: Answer

Scale:

1 N = 1 cm



Resultant?

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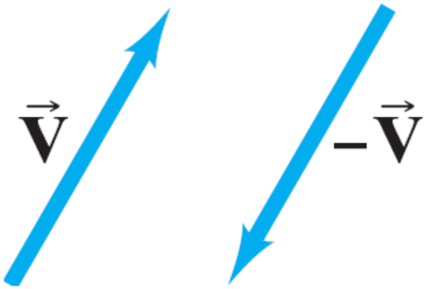
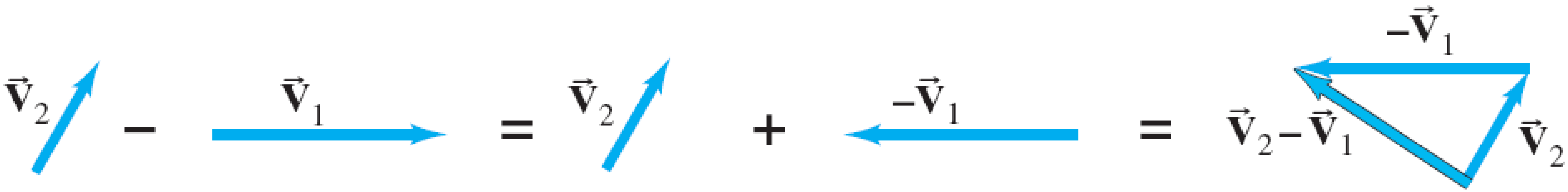
2.1 Vectors and Scalars Quantities



To subtract vectors,

- Use the negative of a vector, (same magnitude but opposite direction).

Then, add the negative vector using tail-to-tip method.



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2.1 Vectors and Scalars Quantities

- Thus, the subtraction between two vectors, is defined as:

$$\vec{V}_2 - \vec{V}_1 = \vec{V}_2 + (-\vec{V}_1)$$

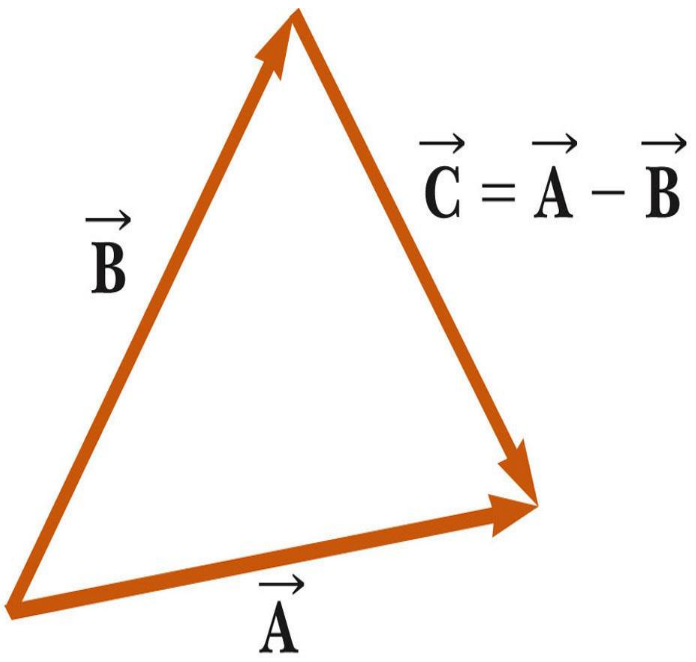
- Hence, you can apply for addition of vectors (using tail-to-tip).

2.1 Vectors and Scalars Quantities

- Another method to solve the vector subtraction is to find the vector that, added to the second vector gives you the first vector

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

- The resultant vector is drawn from the tip of the second to the tip of the first.



2.1 Vectors and Scalars Quantities

Example 4

Given that **A**=24 m, E; **B**=50 m, S. Find the magnitude and direction of

(a) (**A** + **B**)

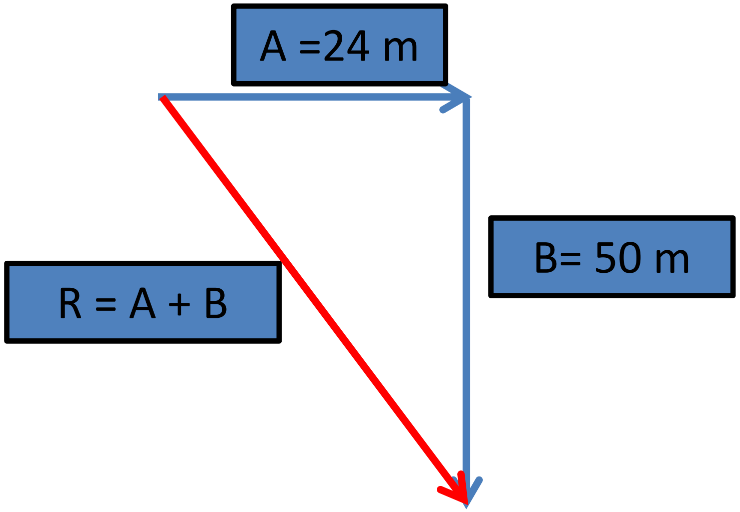
(b) (**B** – **A**)

2.1 Vectors and Scalars Quantities

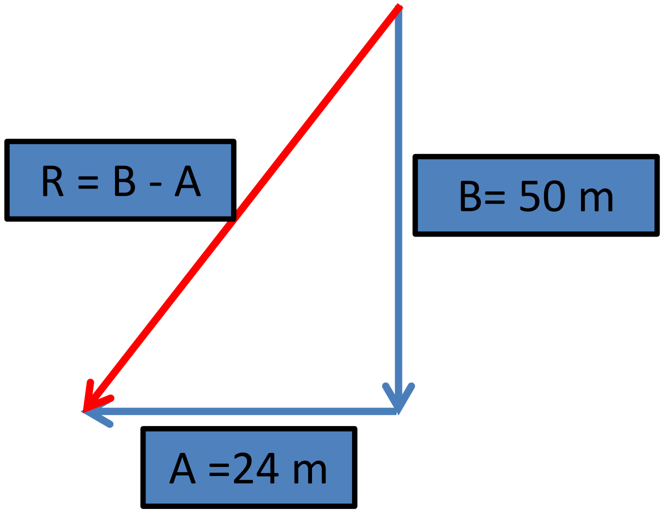
Example 4: Answer

(a) (A + B)

Scale: 10 m = 1 cm



(b) (B - A)



Kinematics Part I
by Mazni bt. Mustafa
http://ocw.ump.edu.my/course/view.php?id=464

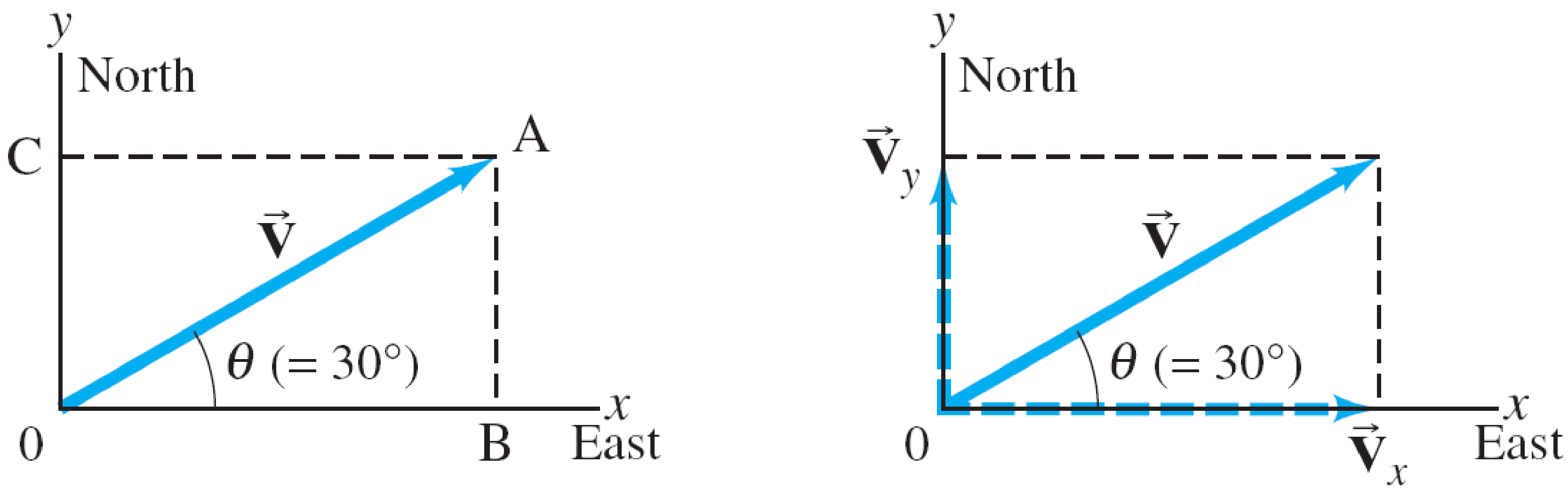
2.1 Vectors and Scalars Quantities

- Vector can be stated as the total of two vectors which is vector components.

- Commonly the vector components are perpendicular to each other. (such as x and y axis).

- To find the vector components is known as the resolving the vector.

2.1 Vectors and Scalars Quantities



- Generally, vector component is represented by dashed-arrow
- v_x and v_y, are the magnitude of vector component
- Vector v can be find by the parallelogram method of adding vector. $\vec{V}_x + \vec{V}_y = \vec{V}$

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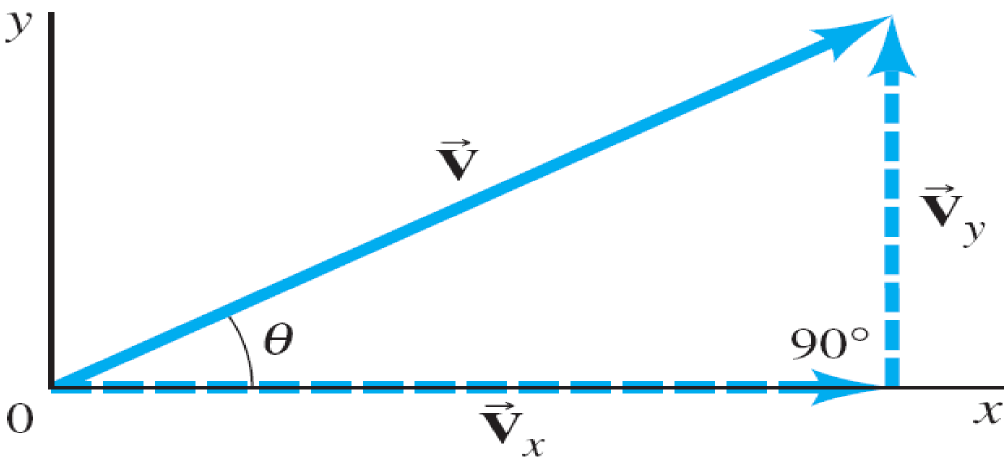
2.1 Vectors and Scalars Quantities



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

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

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

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

Vector component can be found using trigonometric functions.

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2.1 Vectors and Scalars Quantities

- Use the trigonometric function, to find:
- The *x*-component of a vector (along *x*-axis):

$$v_x = v\cos\theta$$

- The *y*-component of a vector (along the *y*-axis):

$$v_y = v\sin\theta$$

- Use θ (angle) that vector make with the positive *x*- axis, measured counterclockwise.
  - If not, use trigonometry.

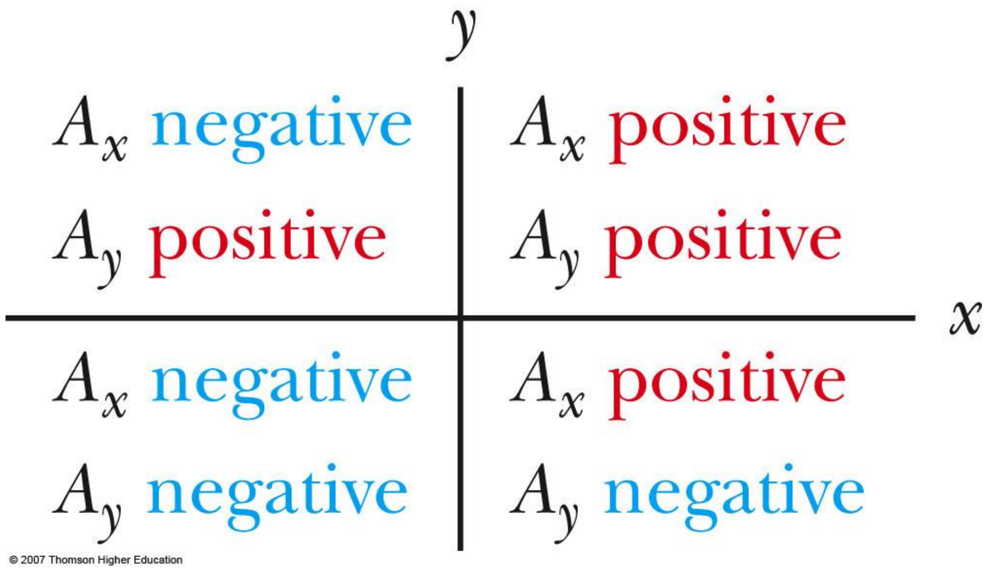
2.1 Vectors and Scalars Quantities

- The magnitude and direction of vector *v* can be found using

$$v = \sqrt{v_x^2 + v_y^2} \quad \text{and} \quad \theta = \tan^{-1}\frac{v_y}{v_x}$$

2.1 Vectors and Scalars Quantities

- The vector components can be positive or negative depend on the located quadrant as shown:

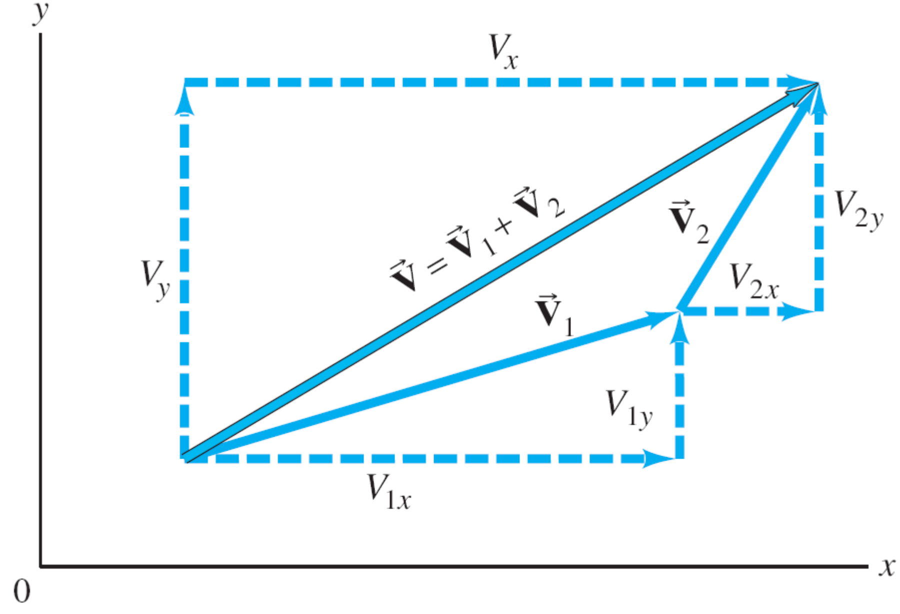


2.1 Vectors and Scalars Quantities

- The addition of any two vector, (in component) $\vec{V} = \vec{V}_1 + \vec{V}_2$ implies that:

$$V_x = V_{1x} + V_{2x}$$

$$V_y = V_{1y} + V_{2y}$$



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2.1 Vectors and Scalars Quantities

Step to add vector by components:

1. Select the *x* and *y* axes.
2. Resolve vector into *x* and *y* components using trigonometry sines and cosines.
3. Add the *x* and *y* components.
4. Find the resultant vector and direction of the vector by:

$$V = \sqrt{V_x^2 + V_y^2}$$

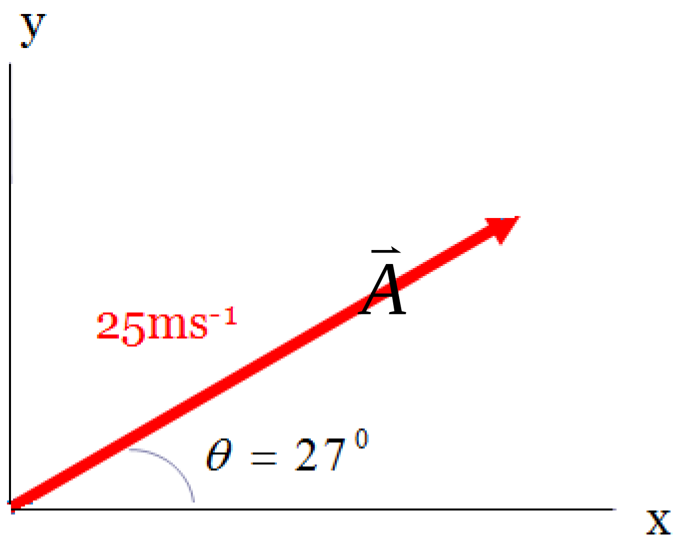
and

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

2.1 Vectors and Scalars Quantities

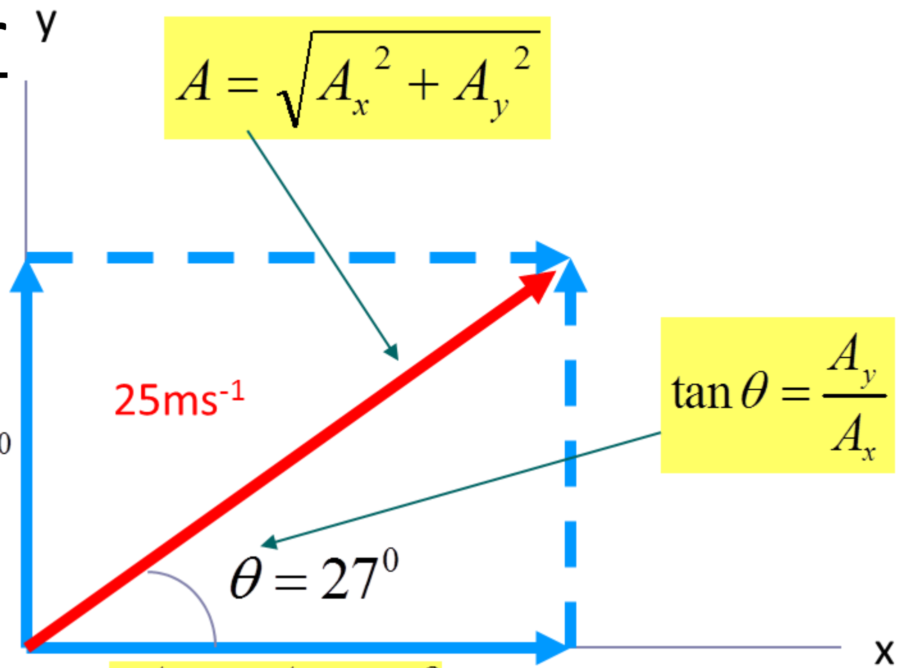
Example 5:

Resolve vector $\vec{A}$



2.1 Vectors and Scalars Quantities

Example 5: answer



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

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

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

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

2.1 Vectors and Scalars Quantities

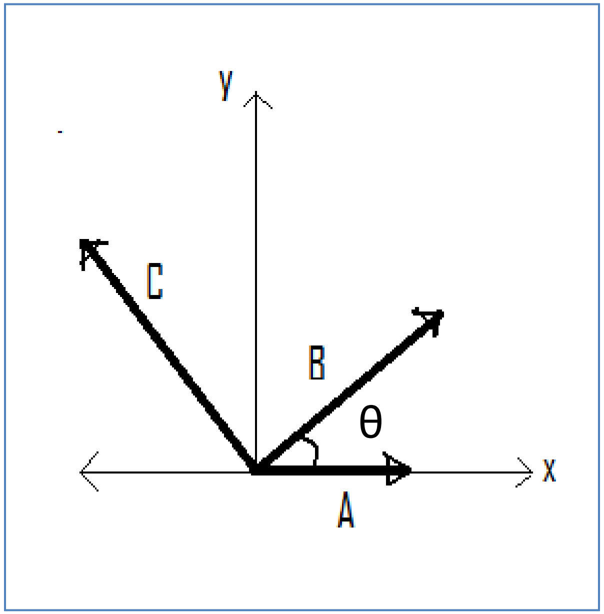
Example 6

The three vectors shown have magnitudes A = 3 N, B = 4 N and C = 10 N and angle θ =30°. Find the

(a) vector component of $\vec{A}$

(b) vector component of $\vec{B}$

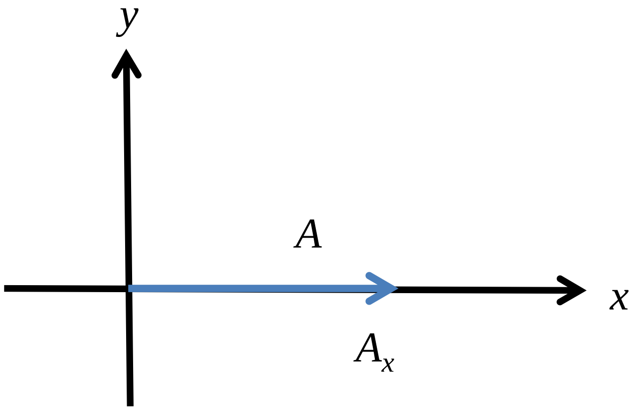
(c) vector component of $\vec{C}$



2.1 Vectors and Scalars Quantities

Example 6: Answer

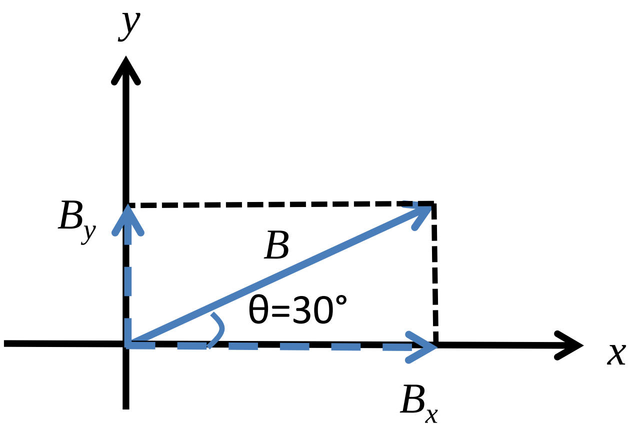
(a)



$$A_x = 3\ \text{N}\ \cos 0^\circ = 3\ \text{N}$$

$$A_y = 3N \sin 0^\circ = 0$$

(b)



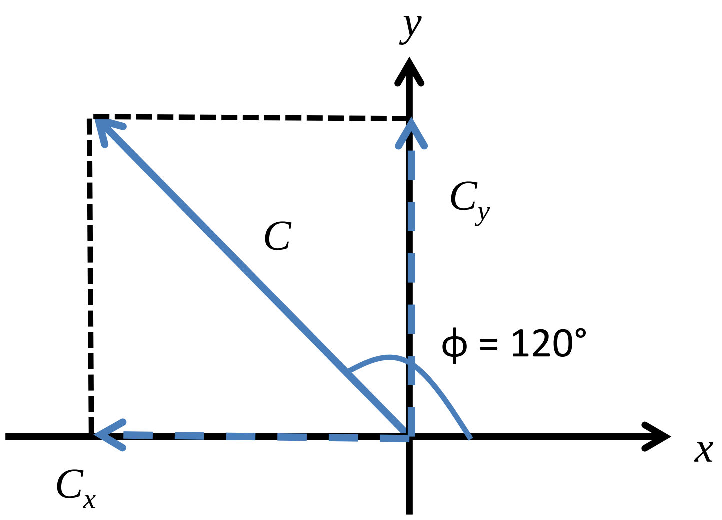
$$B_x = 4\ \text{N}\ \cos 30^\circ = 3.5\ \text{N}$$

$$B_y = 4\ \text{N}\ \sin 30^\circ = 2.0\ \text{N}$$

2.1 Vectors and Scalars Quantities

Example 5: Answer

(c)



$$C_x = 10\text{ N }\cos 120^\circ = -5\text{ N}$$

$$C_y = 10\text{ N }\sin 120^\circ = 8.7\text{ N}$$

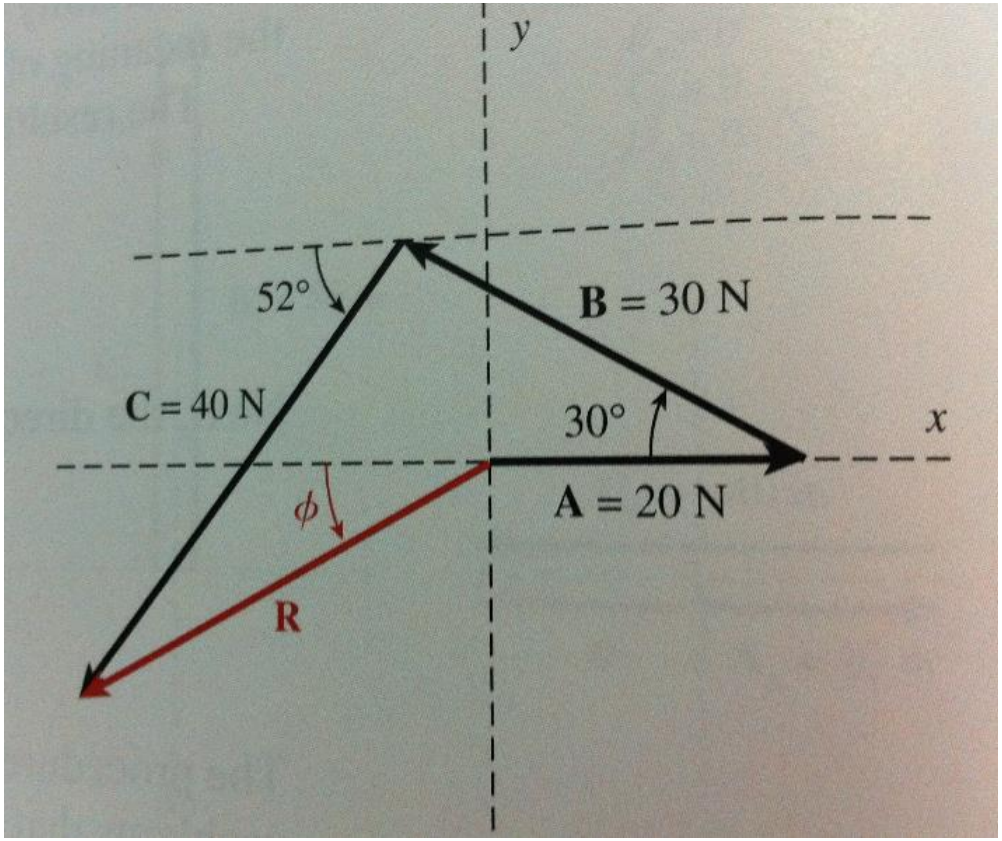
2.1 Vectors and Scalars Quantities

Example 6

The three cords are tied to a pole, and the following forces are exerted. A = 20 N, East; B = 30 N, 30° North of West; and C = 40 N, 52° South of West.

Find the resultant force using the component method.

Example 6: Answer



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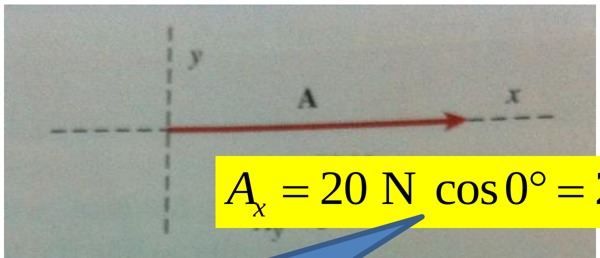
2.1 Vectors and Scalars Quantities

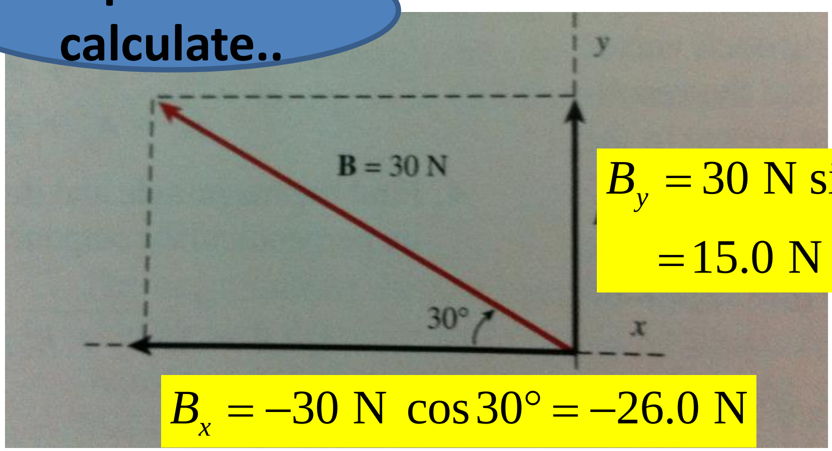
Example 6: Answer

Step 1: Resolve each components



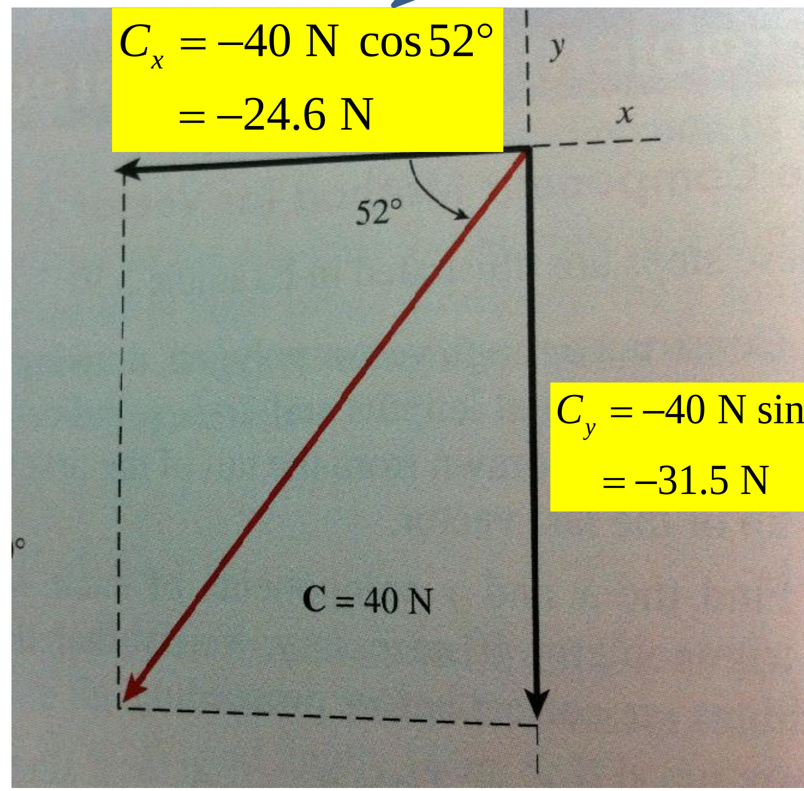
$$A_x = 20 \text{ N } \cos 0° = 20 \text{ N}$$

Step 2: ..and calculate..



$$B_y = 30 \text{ N } \sin 30° = 15.0 \text{ N}$$

$$B_x = -30 \text{ N } \cos 30° = -26.0 \text{ N}$$



$$C_x = -40 \text{ N } \cos 52° = -24.6 \text{ N}$$

$$C_y = -40 \text{ N } \sin 52° = -31.5 \text{ N}$$

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2.1 Vectors and Scalars Quantities

Example 6: Answer

Step 3: Add components in each direction

Force	x - component	y - component
A	$A_x = 20\text{ N } \cos 0° = 20\text{ N}$	$A_x = 20\text{ N} \sin 0° = 0$
B	$B_x = -30\text{ N } \cos 30° = -26.0\text{ N}$	$B_y = 30\text{ N} \sin 30° = 15.0\text{ N}$
C	$C_x = 40\text{ N } \cos 52° = -24.6\text{ N}$	$C_y = 40\text{ N} \sin 52° = -31.5\text{ N}$
∑F	$\sum F_x$ = - 30.6 N	$\sum F_y$ = - 16.5 N

2.1 Vectors and Scalars Quantities

Example 6: Answer

Step 4: Calculate the resultant and direction using Pythagoras theorem

Resultant force:

$$R = \sqrt{(-30.6\ \text{N})^2 + (-16.5\ \text{N})^2}$$

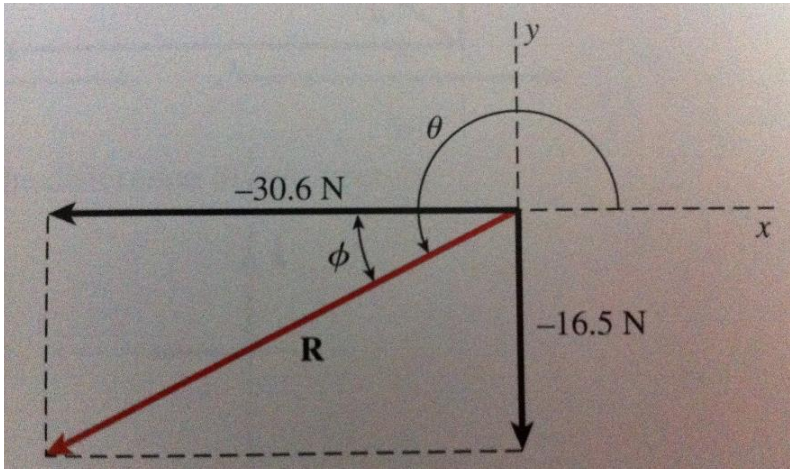
$$= 34.8\ \text{N}$$

Direction:

$$\theta = \tan^{-1}\left(\frac{-16.5}{-30.6}\right) = 28.33^\circ$$

$$= 180^\circ + 28.33^\circ$$

$$= 208.33^\circ$$



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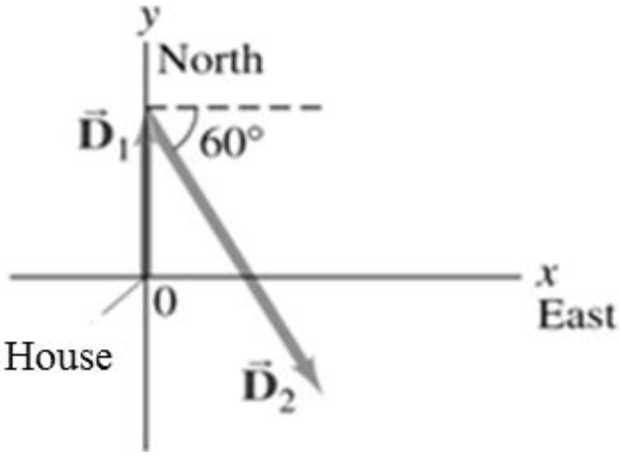
2.1 Vectors and Scalars Quantities

Example 7

Sara leaves her house and ride 22 km with motorcycle in a north direction. After a while, she then ride another 60º south of east for distance 47 km. Determine her displacement from the house?



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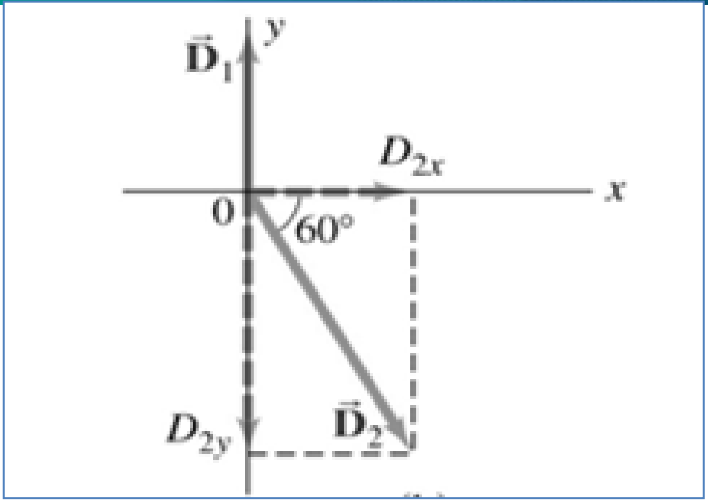
2.1 Vectors and Scalars Quantities

Example 7: Answer



Force	x - component	y - component
D_1	0	$D_{1y} = 22 \text{ km } \sin 90° = 22 \text{ km}$
D_2	$D_{2x} = 47 \text{ km } \cos 60° = 23.5 \text{ km}$	$D_{2y} = -47 \text{ km } \sin 60° = -40.7 \text{ km}$
∑D	$\sum D_x$ = - 23.5 km	$\sum D_y$ = - 18.7 km

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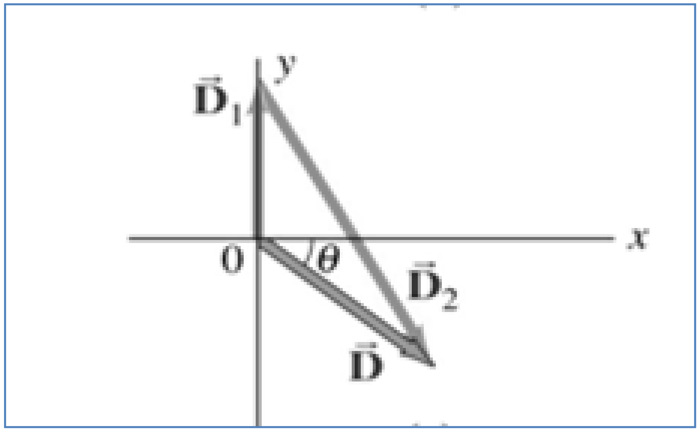
Example 7: Answer

Total displacement:

$$R = \sqrt{(23.5\text{ km})^2 + (-18.7\text{ km})^2}$$
$$= 30.0\text{ km}$$



Direction:

$$\theta = \tan^{-1}\left(\frac{-18.7}{23.5}\right) = -38.5°$$

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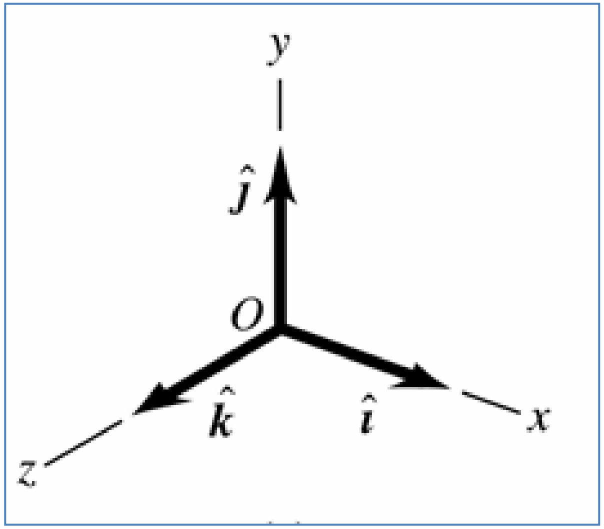
2.1 Vectors and Scalars Quantities

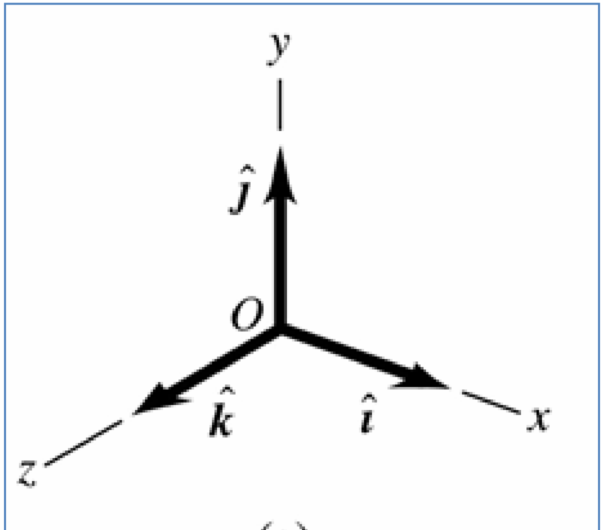
- A unit vector is a vector:
  - Has a magnitude of 1
  - No units.
  - To describe a direction in space.
  - In an x, y, z coordinate, unit vector are called i, j, k with "hat" (^) symbol.



2.1 Vectors and Scalars Quantities

- The relationship between unit vector and components is:

$$\vec{A}_x = A_x\,\hat{i}$$
$$\vec{A}_y = A_y\,\hat{j}$$
$$\vec{A}_z = A_z\hat{k}$$



(a)

- Component vector can be write as:

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

2.1 Vectors and Scalars Quantities

- The vector sum of the two vectors $\vec{A}$ and $\vec{B}$ can be expressed (in term of vector unit):

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

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

$$\vec{R} = \left(A_x + B_x\right)\hat{i} + \left(A_y + B_y\right)\hat{j} + \left(A_z + B_z\right)\hat{k}$$

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

2.1 Vectors and Scalars Quantities

<u>Example 8</u>

Determine an expression of summation of two vectors $\vec{A}$ and $\vec{B}$ in the *x*-*y* plane. Given

$$\vec{A} = \left(2.0\hat{i} + 2.0\,\hat{j}\right)\ \text{m} \quad \text{and} \quad \vec{B} = \left(2.0\hat{i} - 4.0\,\hat{j}\right)\ \text{m}$$

Hence, find the resultant displacement.

2.1 Vectors and Scalars Quantities

Example 8: Answer

$$\vec{R} = \vec{A} + \vec{B}$$
$$= \left(2.0\hat{i} + 2.0\hat{j}\right)\text{ m} + \left(2.0\hat{i} - 4.0\hat{j}\right)\text{ m}$$
$$= \left[\left(2.0+2.0\right)\hat{i} + \left(2.0-4.0\right)\hat{j}\right]\text{m}$$
$$= \left(4.0\hat{i} - 2.0\hat{j}\right)\text{ m}$$

Unit Vector expression

$$R = \sqrt{\left(4.0\text{ m}\right)^2 + \left(-2.0\text{ m}\right)^2} = 4.5\text{ m}$$

$$\theta = \tan^{-1}\left(\frac{-2}{4}\right) = -26.5° \text{ or } 333.5°$$

2.1 Vectors and Scalars Quantities

Multiplication between 2 vectors:

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

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

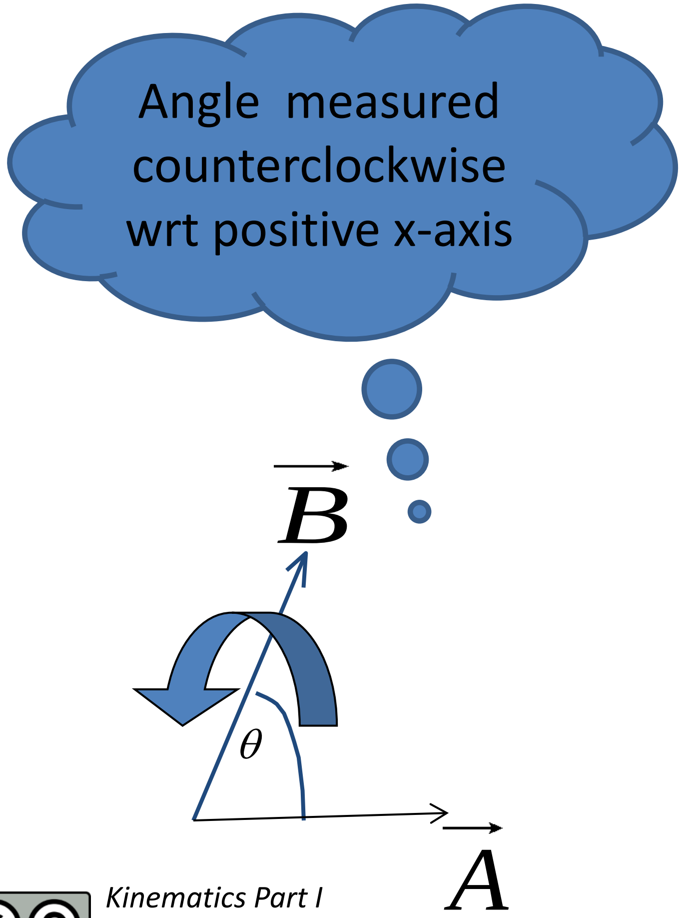
2.1 Vectors and Scalars Quantities

- The scalar or **dot product** is denoted by $\vec{A} \bullet \vec{B}$
- Although $\vec{A}$ and $\vec{B}$ are vectors, the quantity $\vec{A} \bullet \vec{B}$ are scalar.

2.1 Vectors and Scalars Quantities

- We define $\vec{A} \bullet \vec{B}$ to be the magnitude of $\vec{A}$ multiplied by the component of $\vec{B}$ in the direction of $\vec{A}$. Expressed as:

$$\vec{A} \bullet \vec{B} = AB\cos\theta = \left|\vec{A}\right|\left|\vec{B}\right|\cos\theta$$



- The scalar product may be positive (when 0< ϑ <90^o), negative (90 ^{o} < ϑ <180^o) and zero (ϑ = 90^o)

2.1 Vectors and Scalars Quantities

- Because of these properties of scalar product…

$$\hat{i}\bullet\hat{i} = j\bullet j = k\bullet k = (1)(1)\cos 0^\circ = 1$$

$$\hat{i}\bullet j = \hat{i}\bullet k = j\bullet k = (1)(1)\cos 90^\circ = 0$$

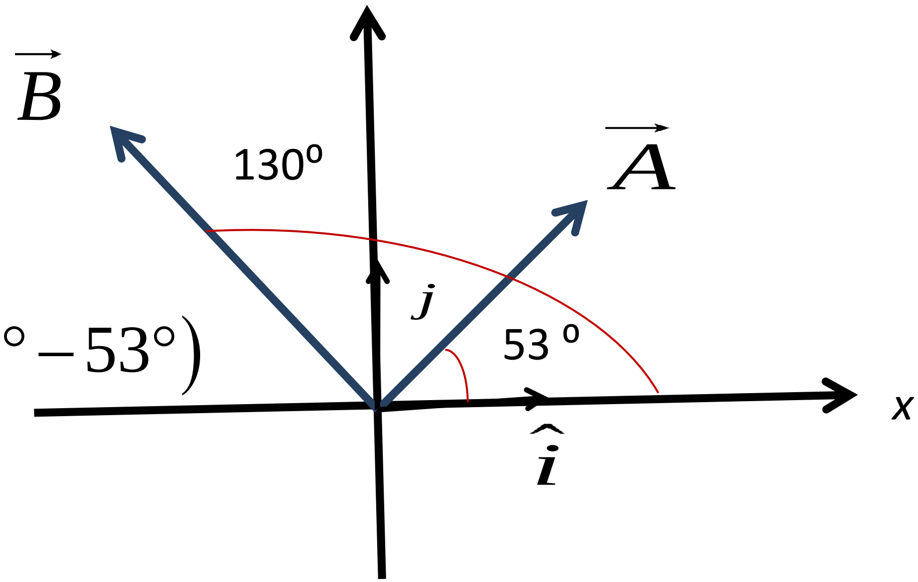
- …we can expressed scalar product in term of component:

$$\vec{A}\bullet\vec{B} = A_x B_x + A_y B_y + A_z B_z$$

- i.e. the scalar product of two vectors is the sum of the products of their respective components.

Example 11

Determine the scalar product of two vectors in figure shown. The magnitudes of vector *A* = 4.00 N and *B* = 5.00 N.



Answer:

$$\vec{A}\times\vec{B} = AB\cos\theta$$
$$= (4.00\text{ N})(5.00\text{ N})\cos(130° - 53°)$$
$$= 4.5\text{ N}$$

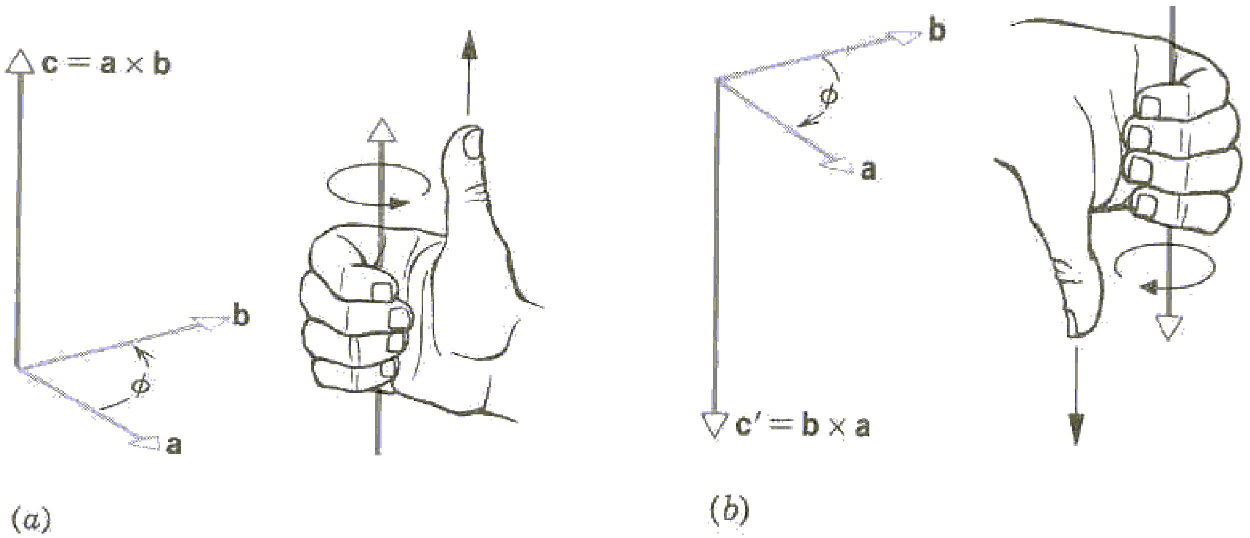
2.1 Vectors and Scalars Quantities

- The vector product,
  - also known as **cross product** is represented by $\vec{A} \times \vec{B}$
  - is defined as a **vector quantity** with a **direction perpendicular to this plane** (*perpendicular to both* $\vec{A}$ *and* $\vec{B}$)…
  - and a **magnitude** :

$$\vec{A} \times \vec{B} = AB \sin\theta$$

2.1 Vectors and Scalars Quantities

- Direction? Use Right Hand Rule



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2.1 Vectors and Scalars Quantities

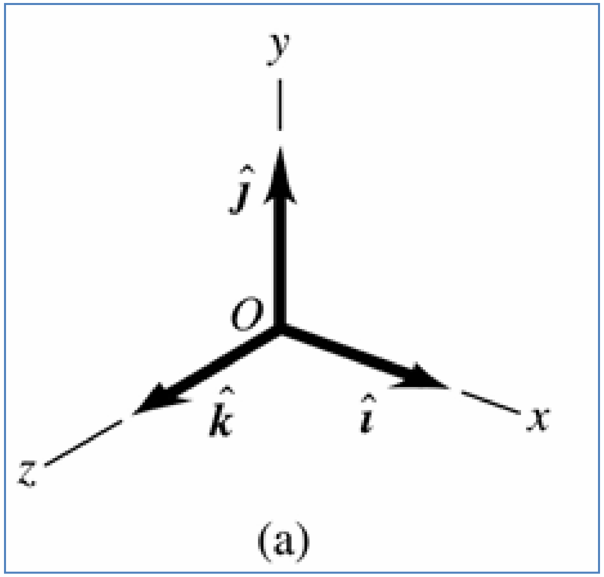
- To find the **cross product**, we can use these properties:

$$\hat{i}\times\hat{i} = j\times j = k\times k = 0$$

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

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

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



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

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

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

- Hence: $\vec{A}\times\vec{B} = (A_yB_z - A_zB_y)\hat{i} + (A_zB_x - A_xB_z)j + (A_xB_y - A_yB_x)k$

2.1 Vectors and Scalars Quantities

$$\text{If } a = a_1 i + a_2 j + a_3 k \quad \text{and} \quad b = b_1 i + b_2 j + b_3 k$$

$$a \times b = \begin{vmatrix} i & j & k \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix}$$

$$= i \begin{vmatrix} a_2 & a_3 \\ b_2 & b_3 \end{vmatrix} - j \begin{vmatrix} a_1 & a_3 \\ b_1 & b_3 \end{vmatrix} + k \begin{vmatrix} a_1 & a_2 \\ b_1 & b_2 \end{vmatrix}$$

2.1 Vectors and Scalars Quantities

Example 12

Vector $\vec{A}$ has magnitude 6 units and is in direction of the +*x*-axis. Vector $\vec{B}$ has magnitude 4 units and lie in the *xy*-plane, making an angle 30° with the +*x*-axis. Find the vector product $\vec{A} \times \vec{B}$.

Answer:

$$A \bullet B = AB\sin\theta = (6 \text{ unit})(4 \text{ unit})\sin(30°) = 12 \text{ unit}$$