Units of Measurements

Units are an **essential part** of any measurement.

eg. Gas in the USA is sold by the gallon but in Europe it is sold by the liter (1 gal ~ 4 l).

Types of units:

English / US (inch, foot, yard, mile, pound, pint, quart, gallon)

Metric (meter, kilogram, liter)

* The metric system uses standard prefixes representing **multiples of 10** and is much simpler to use.

eg. kilo = 1000, mega = 1,000,000, giga = 1,000,000,000
milli = 1/1,000, micro = 1/1,000,000, nano = 1/ 1,000,000,000

Example: 1 kilometer = 1000 meters, kilogram = 1000 grams
1 milliliter = 1/1,000 liter = 0.001 liters

Compare with: 1 mile = 5,280 feet = 63,360 inches

Scientific Notation (Appendix B)

Physics deals with a vast range of scale sizes from atoms and molecules (billionth of a meter) to every day phenomena (m, km) to stellar and galactic dimensions (trillions of km).

Scientific notation (power of 10) allows us to represent these numbers in a simple and concise way.

eg. $100 = 10 \times 10 = 10^2$ $1{,}000 = 10^3$ $100{,}000 = 10^5$ etc.

$1/1{,}000 = 10^{-3}$ $1/100{,}000 = 10^{-5}$ etc.

Examples:

1. Distance from the Earth to the Sun …

   D = 150,000,000 km

   or **$D = 15 \times 10^7$ km** (or $D = 1.5 \times 10^8$ km)

2. Red color in rainbow has a wavelength…

   ? = 0.0000007 m

   or **$? = 0.7 \times 10^{-6}$ m** (or ? = 7.0×10^{-7} m)

Table B.1 Examples of Scientific Notation

Positive powers of ten			
5 460	= 5.46 times 1 thousand	=	5.46×10^{3}
23 400	= 23.4 times 10 thousand	=	2.34×10^{4}
6 700 000	= 6.7 times 1 million	=	6.7×10^{6}
9 400 000 000	= 9.4 times 1 billion	=	9.4×10^{9}
5 980 000 000 000 000 000 000 000		=	5.98×10^{24}
(MASS EARTH IN kg)			

Negative powers of ten (fractions)			
0.62	= 6.2 times one-tenth	=	6.2×10^{-1}
0.0523	= 5.23 times one-hundredth	=	5.23×10^{-2}
0.0082	= 8.2 times one-thousandth	=	8.2×10^{-3}
0.000 0024	= 2.4 times one-millionth	=	2.4×10^{-6}
0.000 000 0079	= 7.9 times one-billionth	=	7.9×10^{-9}
0.000 000 000 000 000 000 16		=	1.6×10^{-19}
(CHARGE ON ELECTRON)			

Multiplying Powers of 10:

Rule: **Add** together powers of 10

Example: Jet flying at speed of sound for one hour…

D = speed x time = (300 m/s) x (3,600 s)

2 + 3 = 5

$D = (3 \times 10^2) \times (3.6 \times 10^3) = 10.8 \times 10^5$ m

Dividing Powers of 10:

Rule: **Subtract** denominator power from numerator power.

Example: Car travelling 60 km in 30 min…

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{60{,}000 \text{ m}}{30 \times 60 \text{ s}} = \frac{6 \times 10^4 \text{ m}}{18 \times 10^2 \text{ s}}$$

4 - 2 = 2

$$\text{Speed} = \frac{1}{3} \times 10^2 \text{ m/s} = 0.33 \times 10^2 \text{ m/s} = 33 \text{ m/s}$$

Examples of Metric Units

Length: meter (m) 1 km = 1000 m (~ 0.6 miles)

1 light- year = 9.46×10^{15} m

Mass: kilogram (kg) 1 kg = 1000g (~ 2.2 lbs)

Mass of Earth = 5.98×10^{24} kg

Volume: liter (*l*) 1 *l* = 1000 m*l* (1 gal = 3.786 *l*)

Energy: Joules (J) or **N.m** (1 calorie = 4.2 J)

Temperature: Kelvin (K) "Absolute zero" 0K = -273°C

Force: Newtons (N) (1 lb = 4.448 N)

Pressure: Pascal (Pa) or **N / m^2**

Atmospheric Pressure = 1×10^5 Pa (=14.78 lb/in^2)

Useful values:

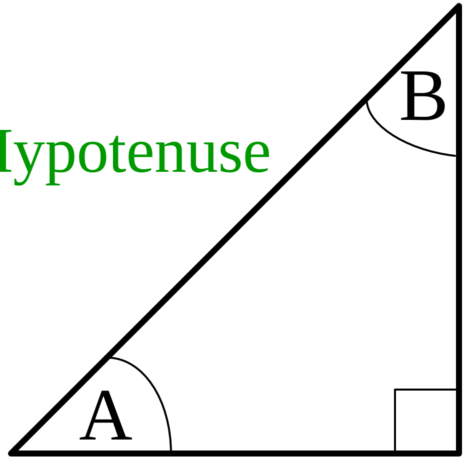
Speed of light ~ 3.0×10^8 m/s

Acceleration due to gravity = 9.81 m/s^2 (approx 10 m/s^2)

Electron charge = 1.6×10^{-19} C (Coulombs)

Basic Trigonometry:

Right Angle Triangle



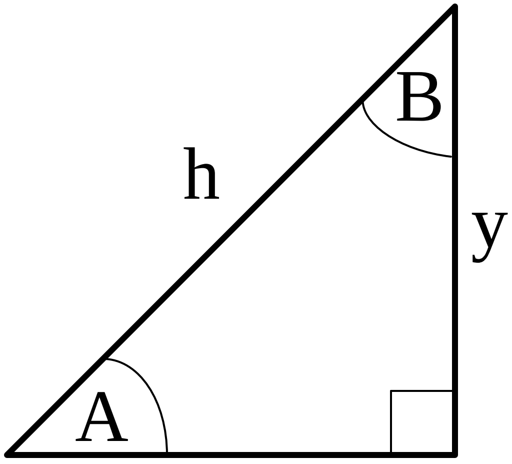
$$\sin A = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\tan A = \frac{\text{opposite}}{\text{adjacent}}$$

$$\cos A = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\angle A + \angle B + 90° = 180°$$

or $\angle A + \angle B = 90°$



$$\sin A = \frac{\text{y}}{\text{h}}$$

$$\tan A = \frac{\text{y}}{\text{x}}$$

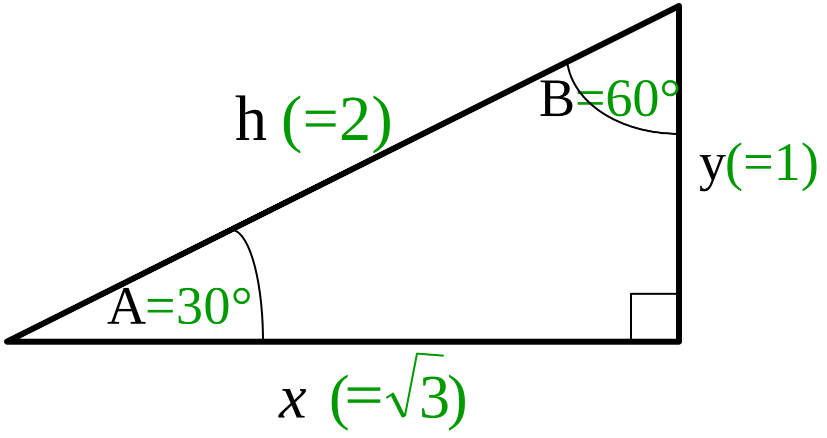
$$\cos A = \frac{\text{x}}{\text{h}}$$

$$h = \sqrt{x^2 + y^2}$$

$\sin A = \frac{y}{h}$ and $\cos B = \frac{y}{h}$

so $\sin A = \cos B$ and vice versa

Example



$$\sin 30^\circ = \frac{1}{2}$$

$$\cos 30^\circ = \frac{\sqrt{3}}{2}$$

$$\tan 30^\circ = \frac{1}{\sqrt{3}}$$

Triangle components:

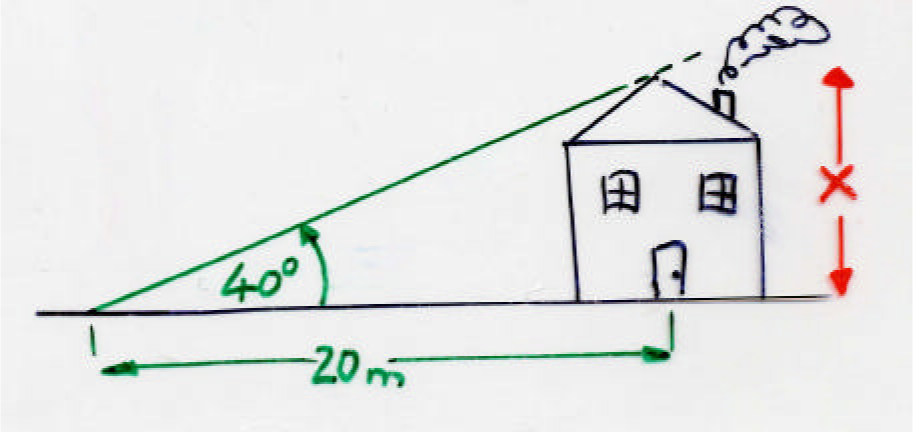
$$\sin A = \frac{y}{\mathrm{h}} \quad \text{or} \quad y = \mathrm{h}.\sin A$$

$$\cos A = \frac{x}{\mathrm{h}} \qquad x = \mathrm{h}.\cos A$$

$$\tan A = \frac{y}{\mathrm{x}} \qquad y = \mathrm{x}.\tan A$$

Resolving a right angle triangle into its horizontal (x) and vertical (y) **components** can be **very helpful** in solving problems of motion as well as static trigonometry.

Example: Calculate the height of your house…



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

$$x = y.\tan A$$

$$= 20\text{m} . \tan 40^\circ$$

$$= 20 \text{ x } 0.84 = 16.8 \text{ m} \quad \text{high}$$

Scalars and Vectors

Scalar: Measure of quantity or size sometimes called "magnitude".

Examples: Length, volume, mass, temperature, speed…

Vectors: Many measurements in physics require a knowledge of the magnitude and direction of quantity. These are termed **vector quantities.**

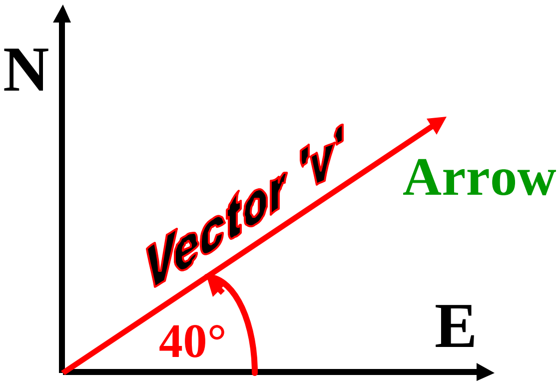
Examples: Velocity, acceleration, force, electric field…

Direction is an essential feature of a vector quantity.

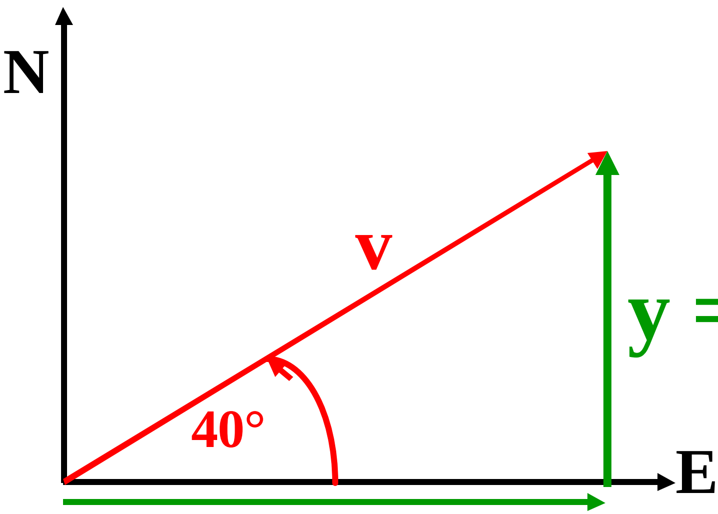
Example: Flying at 1000 km/hr due North is quite different to the same speed due East!

Vectors require 2 pieces of information **MAGNITUDE** and **DIRECTION.**

How to Represent a Vector:



- Represents its magnitude by its length.
- Represents its direction by its angle.

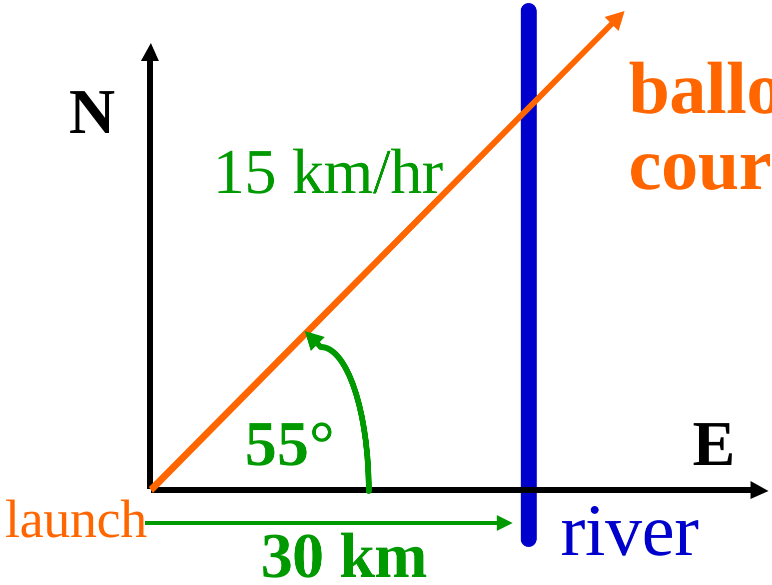


$$y = v \, . \, \sin 40°$$

$$x = v \, . \, \cos 40°$$

We have resolved the vector motion into 2 "orthogonal components".

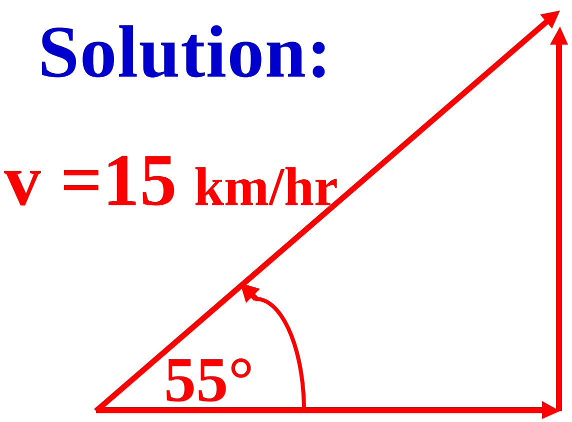
Example:



Questions:

1. How fast is the balloon moving eastward?
2. How long before the balloon crosses the river?

Solution:



$V_N = v \sin(55°)$

$V_E = v \cos(55°)$

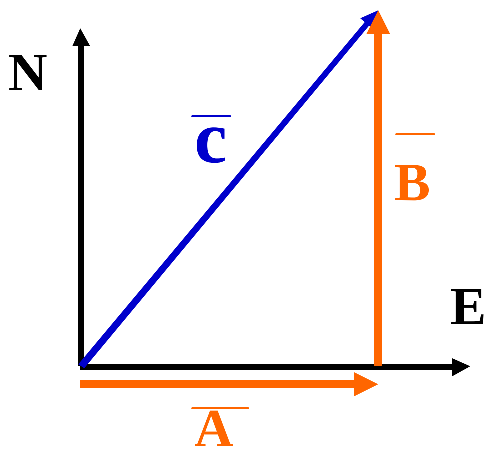
$V_E = v \cos(55°) = 15 \times 0.5736 = 8.6$ km/hr

As river is 30 km due E; the balloon will reach it in: 30/8.6 = 3.49 hrs.

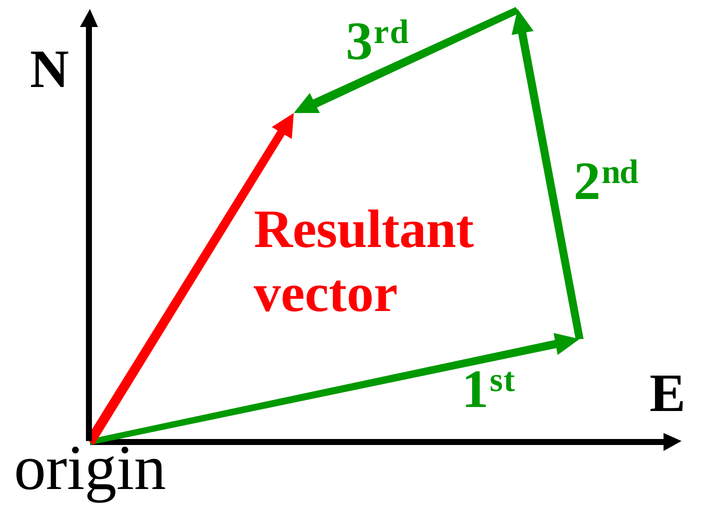
Note: can also use v_N to get distance traveled Northwards.

How to add vectors:

We are often interested in combining 2 (or more) vectors to solve a problem. e.g. **Flying in strong winds.**



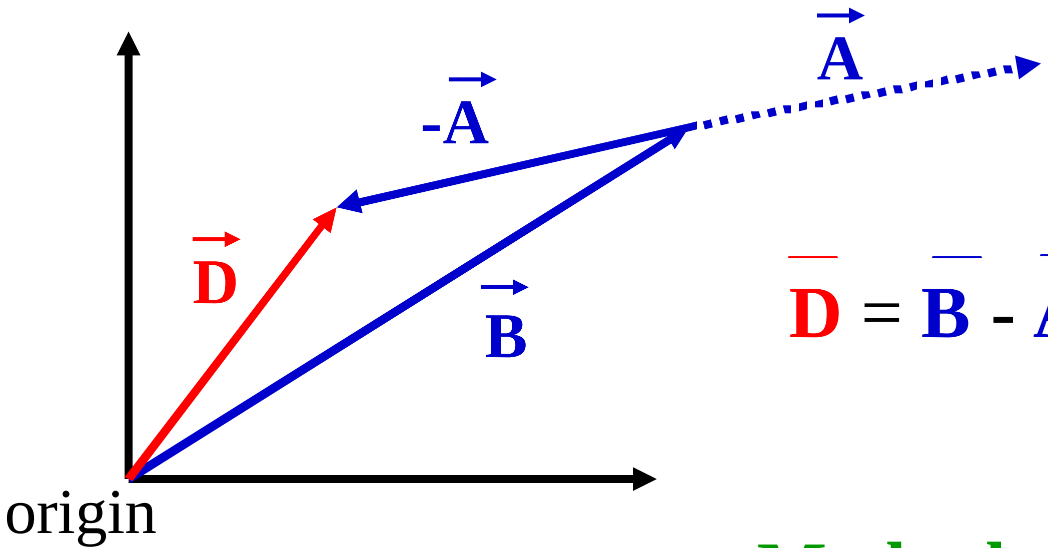
$$\overline{C} = \overline{A} + \overline{B}$$



Method: (graphical)

1. Draw 1st vector to scale and in appropriate direction,
2. Start 2nd vector at head of 1st vector and in appropriate direction.
3. Repeat for other vectors.
4. **Resultant** (sum) vector is found by drawing **vector from origin to head of last vector.**

Vector subtraction:



$\overline{\mathbf{D}} = \overline{\mathbf{B}} - \overline{\mathbf{A}}$

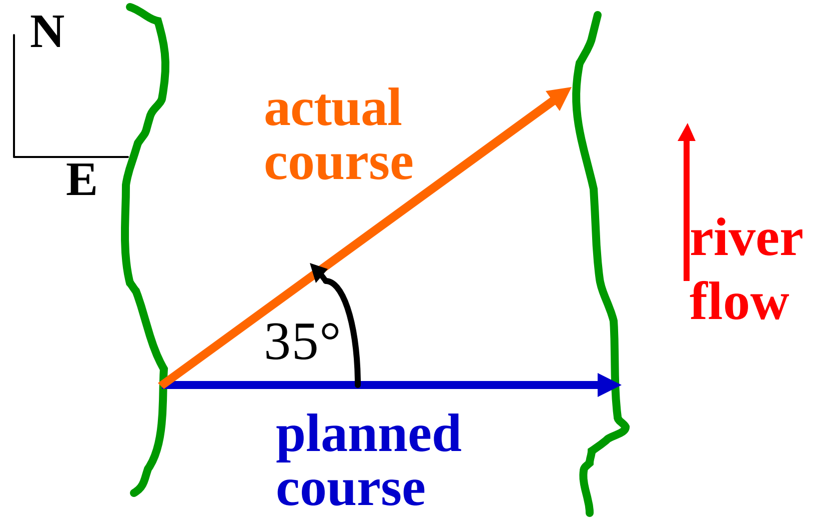
Method:

1. Draw $\overline{B}$ vector to scale and in positive direction.
2. Draw $\overline{A}$ vector from tip of $\overline{B}$ but in opposite direction to yield ($-\overline{A}$).
3. Resultant difference vector $\overline{D}$ is found by joining the origin to the tip of ($-\overline{A}$) vector.

Note: Alternate solution is given by finding the horizontal and vertical vector components and adding/subtracting as appropriate.

Example vector velocities:

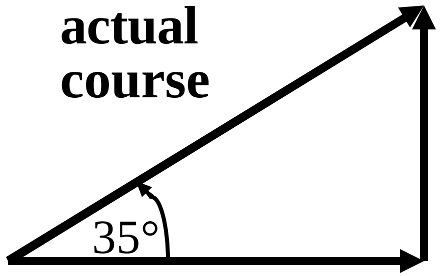
Boat crossing a river…



Question: How fast is the river flowing?

Boat speed $v_B = 7$ km/hr.

Solution:



$v_R = v_B \tan(35°)$ **= 7 x 0.7002 = 4.9 km/hr**

Answer: The river is flowing at **4.9 km/hr <u>Northwards</u>**.

Note: To cross the river on planned course, the boat needs to **aim upriver** at an angle of 35°. Aircraft always need to take account of wind to get to the right place!