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General Physics

Physical Quantities & Units
AS level

Marline Kurishingal

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Syllabus content

The table below shows which parts of the syllabus contain AS material and/or A2 material.

Section		AS	A2
I General Physics	1. Physical quantities and units	✓	✓
	2. Measurement techniques	✓	✓

Section I: General physics
Recommended prior knowledge Candidates should be aware of the nature of a physical measurement, in terms of a magnitude and a unit. They should have experience of making and recording such measurements in the laboratory.

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1. Physical quantities and units

Content	Learning outcomes
1.1 Physical quantities 1.2 SI Units 1.3 The Avogadro constant 1.4 Scalars and vectors	Candidates should be able to: *(a)* show an understanding that all physical quantities consist of a numerical magnitude and a unit *(b)* recall the following SI base quantities and their units: mass (kg), length (m), time (s), current (A), temperature (K), **amount of substance (mol)** *(c)* express derived units as products or quotients of the SI base units and use the named units listed in this syllabus as appropriate *(d)* use SI base units to check the homogeneity of physical equations *(e)* show an understanding of and use the conventions for labelling graph axes and table columns as set out in the ASE publication *Signs, Symbols and Systematics* (*The ASE Companion to 16–19 Science*, 2000) *(f)* use the following prefixes and their symbols to indicate decimal sub-multiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T) *(g)* make reasonable estimates of physical quantities included within the syllabus ***(h)* show an understanding that the Avogadro constant is the number of atoms in 0.012 kg of carbon-12** ***(i)* use molar quantities where one mole of any substance is the amount containing a number of particles equal to the Avogadro constant** *(j)* distinguish between scalar and vector quantities and give examples of each *(k)* add and subtract coplanar vectors *(l)* represent a vector as two perpendicular components.

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Physical Quantities

Quantitative versus qualitative

- Most observation in physics are quantitative
- Descriptive observations (or qualitative) are usually imprecise

<u>Qualitative Observations</u>

How do you measure artistic beauty?

<u>Quantitative Observations</u>

What can be measured with the instruments on an aeroplane?

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Physical Quantities

- A physical quantity is one that can be measured and consists of a magnitude and unit.

SI units are used in Scientific works

Measuring length

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Physical Quantities

Are classified into two types:

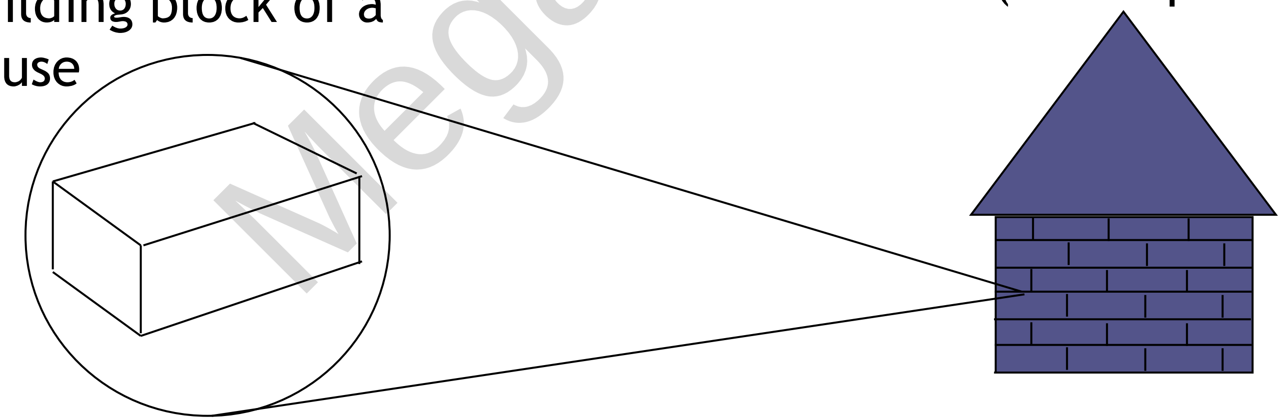
- Base quantities
- Derived quantities

Base quantity

For example : is like the brick – the basic building block of a house

Derived quantity

For example : is like the house that was build up from a collection of bricks (basic quantity)



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Definitions :-

- Base quantities are the quantities on the basis of which other quantities are expressed.

- The quantities that are expressed in terms of base quantities are called derived quantities

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SI Units for Base Quantity

- **SI Units** – International System of Units

Base Quantities	Name of Unit	Symbol of Unit
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol

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Derived quantity & equations

- A derived quantity has an equation which links to other quantities.
- It enables us to express a derived unit in terms of base-unit equivalent.

Example: $F = ma$; Newton = kg m s^{-2}

$P = F/A$; Pascal = kg m s^{-2}/m^2 = kg m^{-1} s^{-2}

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Some derived units

Derived quantity	Base equivalent units	Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s or $m\ s^{-1}$
acceleration	meter per second squared	m/s/s or $m\ s^{-2}$
density	kilogram per cubic meter	$kg\ m^{-3}$
amount concentration	mole per cubic meter	$mol\ m^{-3}$
force	$kg\ m\ s^{-2}$	Newton
work/energy	$kg\ m^2\ s^{-2}$	Joule
power	$kg\ m^2\ s^{-3}$	Watt
pressure	$kg\ m^{-1}\ s^{-2}$	Pascal
frequency	s^{-1}	Hertz

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SI Units

1. Equation: area = length × width

In terms of base units: Units of area = m × m = m^2

2. Equation: volume = length × width × height

In terms of base units: Units of volume = m × m × m = m^3

3. Equation: density = mass ÷ volume

In terms of base units: Units of density = kg m^{-3}

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SI Units

- Work out the derived quantities for:

1. Equation: speed = $\frac{\text{distance}}{\text{time}}$

In terms of base units: Units of speed = ms^{-1}

2. Equation: acceleration = $\frac{\text{velocity}}{\text{time}}$

In terms of base units: Units of acceleration = ms^{-2}

3. Equation: force = mass × acceleration

In terms of base units: Units of force = kg ms^{-2}

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SI Units

- Work out the derived quantities for:

1. Equation: $\text{Pressure} = \frac{\text{Force}}{\text{Area}}$

In terms of base units: Units of pressure = $Kgm^{-1} s^{-2}$

2. Equation: Work = Force × Displacement

In terms of base units: Units of work = $Kgm^{2}s^{-2}$

3. Equation: $\text{Power} = \frac{\text{Work done}}{\text{Time}}$

In terms of units: Units of power = $Kgm^{2}s^{-3}$

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SI Units - Fill in…

Derived Quantity	Relation with Base and Derived Quantities	Unit	Special Name
Momentum			
Electric Charge			
Potential Difference			
Resistance			

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For you to know…

Physical quantity	Defined as	Unit	Special name
density	mass (kg) ÷ volume (m^3)	$kg\ m^{-3}$	
momentum	mass (kg) × velocity ($m\ s^{-1}$)	$kg\ m\ s^{-1}$	
force	mass (kg) × acceleration ($m\ s^{-2}$)	$kg\ m\ s^{-2}$	newton (N)
pressure	force ($kg\ m\ s^{-2}$ or N) ÷ area (m^2)	$kg\ m^{-1}\ s^{-2}$ ($N\ m^{-2}$)	pascal (Pa)
work (energy)	force ($kg\ m\ s^{-2}$ or N) × distance (m)	$kg\ m^2\ s^{-2}$ (N m)	joule (J)
power	work ($kg\ m^2\ s^{-2}$ or J) ÷ time (s)	$kg\ m^2\ s^{-3}$ ($J\ s^{-1}$)	watt (W)
electrical charge	current (A) × time (s)	A s	coulomb (C)
potential difference	energy ($kg\ m^2\ s^{-2}$ or J) ÷ charge (A s or C)	$kg\ m^2\ A^{-1}\ s^{-3}$ ($J\ C^{-1}$)	volt (V)
resistance	potential difference ($kg\ m^2\ A^{-1}\ s^{-3}$ or V) ÷ current (A)	$kg\ m^2\ A^{-2}\ s^{-3}$ ($V\ A^{-1}$)	ohm (Ω)

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Reference Link – Physical quantities

- http://thinkzone.wlonk.com/Units/PhysQuantities.htm

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KEY CONCEPTS

1. A **physical quantity** is a quantity that can be measured and consists of a numerical magnitude and a unit.
2. The physical quantities can be classified into **base quantities** and **derived quantities**.
3. There are seven base quantities: length, mass, time, current, temperature, amount of substance and luminous intensity.
4. The SI units for length, mass, time, temperature and amount of substance, electric current are metre, kilogram, second, kelvin, mole and ampere respectively.

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Homogeneity of an equation

- **An equation is homogeneous if quantities on BOTH sides of the equation has the same unit.**
- **E.g. $s = ut + \frac{1}{2} at^2$**
- **LHS : unit of s = m**
- **RHS : unit of ut = $ms^{-1} \times s = m$**
- **unit of $at^2 = ms^{-2} \times s^2 = m$**
- **Unit on LHS = unit on RHS**
- **Hence equation is homogeneous**

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Non-homogeneous

- $P = \rho g h^2$
- LHS ; unit of P = $Nm^{-2} = kgm^{-1}s^{-2}$
- RHS : unit of $\rho g h^2 = kgm^{-3}(ms^{-2})(m^2) = kgs^{-2}$
- **Unit on LHS ≠ unit on RHS**
- **Hence equation is not homogeneous**

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Homogeneity of an equation

- **Note: numbers has no unit**
- **some constants have no unit.**
- **e.g. π,**

- **A homogeneous eqn may not be physically correct but a physically correct eqn is definitely homogeneous**

- **E.g. $s = 2ut + at^2$** (homogenous but not correct)
- **$F = ma$** (homogeneous and correct)

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Magnitude

- **Prefix : magnitudes of physical quantity range from very large to very small.**
- **E.g. mass of sun is 10^{30} kg and mass of electron is 10^{-31} kg.**
- **Hence, prefix is used to describe these magnitudes.**

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Significant number

- **Magnitudes of physical quantities are often quoted in terms of significant number.**
- **Can you tell how many sig. fig. in these numbers?**
- **103, 100.0 , 0.030, 0.4004, 200**
- **If you multiply 2.3 and 1.45, how many sf should you quote?**
- **3.19, 3.335 , 3.48**
- **3.312, 3.335, 3.358**

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The rules for identifying significant figures

- The rules for identifying significant figures when writing or interpreting numbers are as follows:-

- All non-zero digits are considered significant. For example, 91 has two significant figures (9 and 1), while 123.45 has five significant figures (1, 2, 3, 4 and 5).
- Zeros appearing anywhere between two non-zero digits are significant. Example: 101.1203 has seven significant figures: 1, 0, 1, 1, 2, 0 and 3.
- Leading zeros are not significant. For example, 0.00052 has two significant figures: 5 and 2.

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The rules for identifying significant figures (cont)

- Trailing zeros in a number containing a decimal point are significant. For example, 12.2300 has six significant figures: 1, 2, 2, 3, 0 and 0. The number 0.000122300 still has only six significant figures (the zeros before the 1 are not significant). In addition, 120.00 has five significant figures since it has three trailing zeros.

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- **Often you will be asked to estimate some magnitudes of physical quantities around you.**

- **E.g. estimate the height of the ceiling, volume of an apple, mass of an apple, diameter of a strand of hair,**

Reference link :

http://www.xtremepapers.com/revision/a-level/physics/measurement.php

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Estimates of physical quantities

- When making an estimate, it is only reasonable to give the figure to 1 or at most 2 significant figures since an estimate is not very precise.

Physical Quantity	Reasonable Estimate
Mass of 3 cans (330 ml) of Pepsi	1 kg
Mass of a medium-sized car	1000 kg
Length of a football field	100 m
Reaction **time** of a young man	0.2 s

- Occasionally, students are asked to estimate the area under a graph. The usual method of counting squares within the enclosed area is used.

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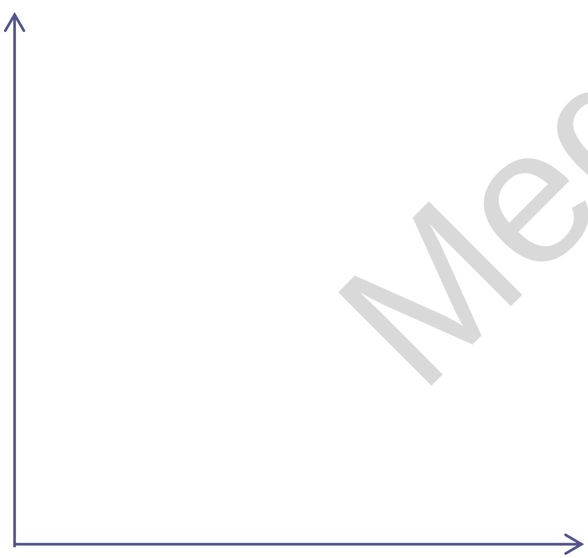
Convention for labelling tables and graphs

t/s	v/ms⁻¹
0	2.5
1.0	4.0
2.0	5.5

- The symbol / unit is indicated at the italics as indicated in the data column left.
- Then fill in the data with pure numbers.
- Then plot the graph after labelling x axis and y axis



[Illustration with sample graph on left]

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Prefixes

- For very large or very small numbers, we can use standard prefixes with the base units.
- The main prefixes that you need to know are shown in the table. (next slide)

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Prefixes

- Prefixes simplify the writing of very large or very small quantities

Prefix	Abbreviation	Power
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}
Tera	?	??

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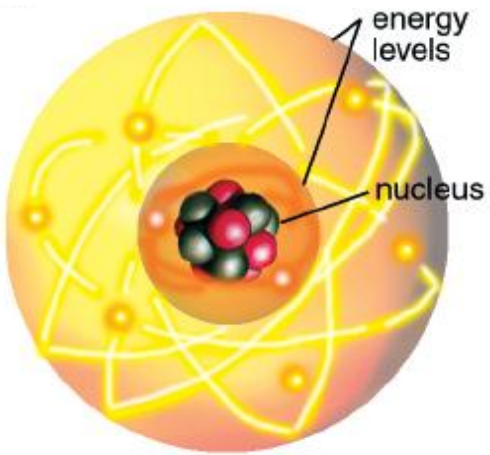
Prefixes

- Alternative writing method
- Using standard form
- $N \times 10^n$ where $1 \leq N < 10$ and n is an integer

This galaxy is about 2.5×10^6 light years from the Earth.



The diameter of this atom is about 1×10^{-10} m.

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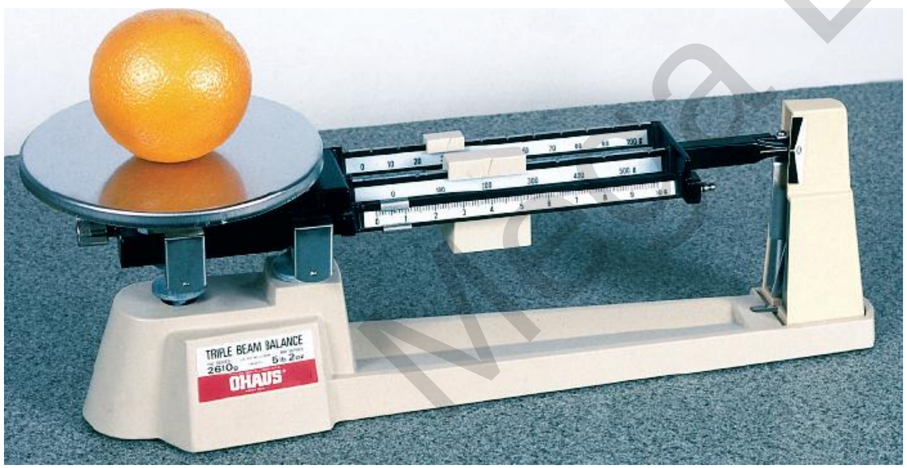
Scalars and Vectors

- **Scalar quantities** are quantities that have magnitude only. Two examples are shown below:

Measuring Mass



Measuring Temperature

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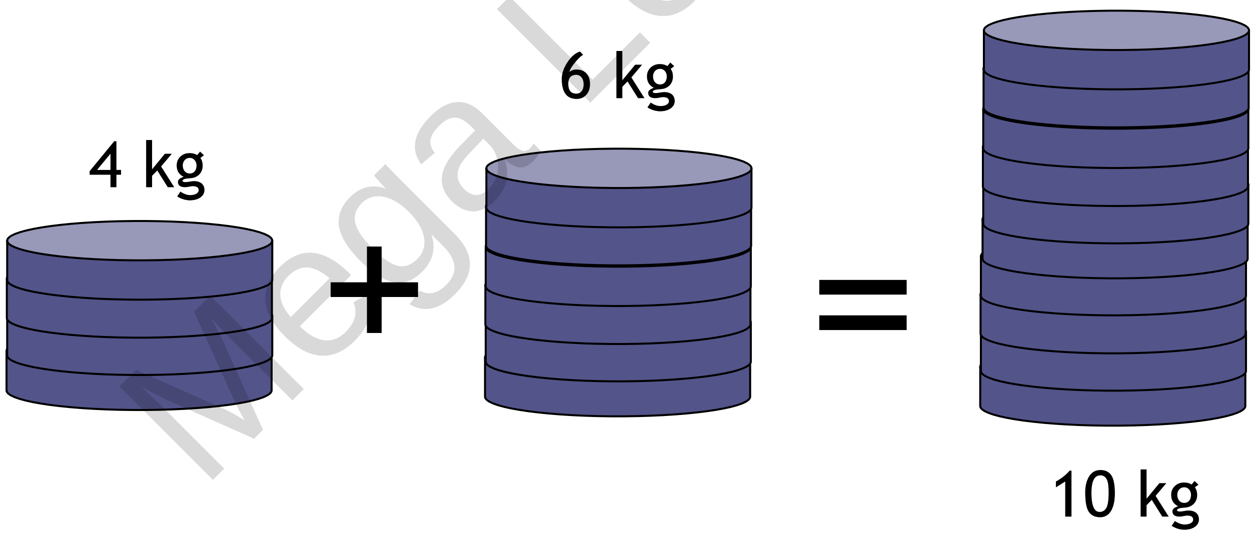
Scalars and Vectors

- **Scalar quantities** are added or subtracted by using simple arithmetic.

  Example: 4 kg plus 6 kg gives the answer 10 kg



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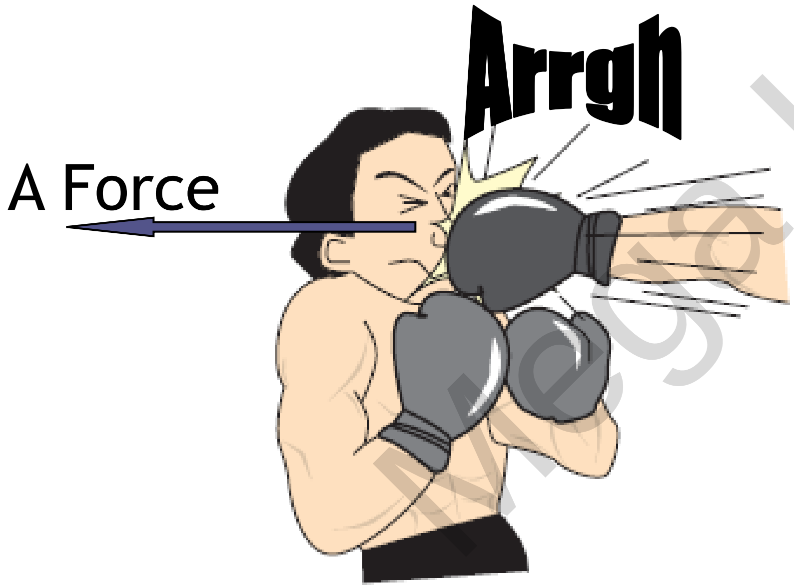
Scalars and Vectors

- **Vector quantities** are quantities that have both magnitude and direction



Magnitude = 100 N

Direction = Left

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Scalars and Vectors

- Examples of scalars and vectors

Scalars	Vectors
distance	displacement
speed	velocity
mass	weight
time	acceleration
pressure	force
energy	momentum
volume	
density	

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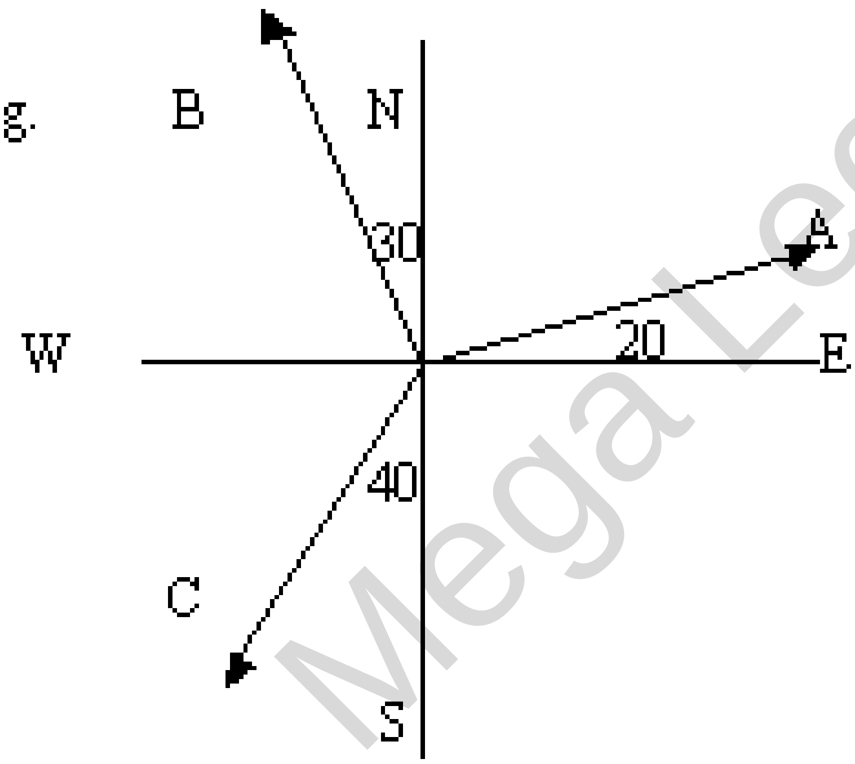
Direction of vector

e.g.



Vector A – E 20^0 N or
N 70^0 E

Vector B – N 30^0 W or
W 60^0 N

Vector C -

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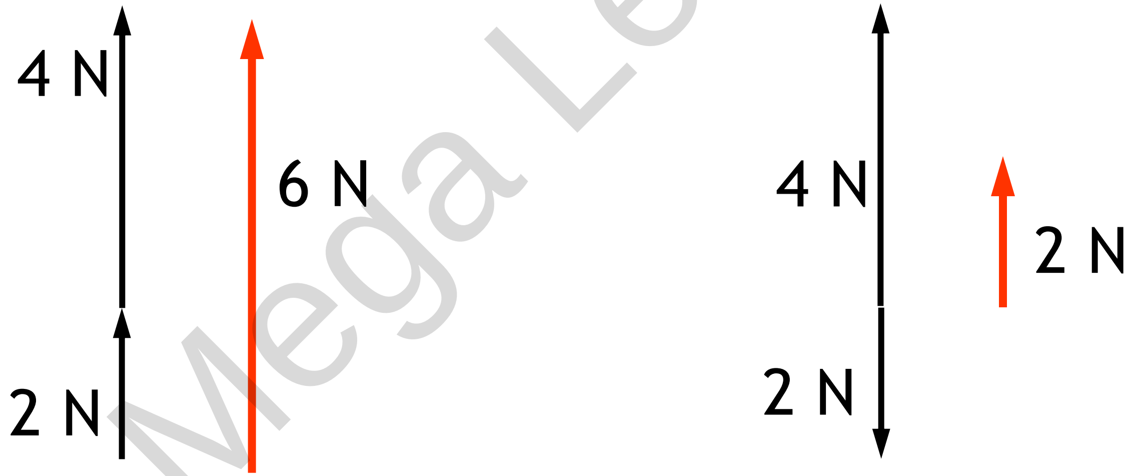
Scalars and Vectors

Adding/Subtracting Vectors using Graphical Method

- Parallel vectors can be added arithmetically



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Scalars and Vectors

Adding Vectors using Graphical Method

- Non-parallel vectors are added by graphical means using the parallelogram law
  - Vectors can be represented graphically by arrows

$$5.0 \text{ cm} \equiv 20.0 \text{ N}$$

Direction = right

  - The length of the arrow represents the magnitude of the vector
  - The direction of the arrow represents the direction of the vector
  - The magnitude and direction of the resultant vector can be found using an accurate scale drawing

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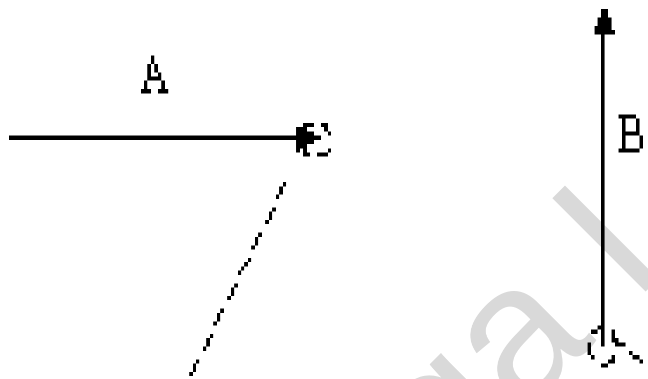
Vector addition

(a) Drawing method

E.g. Below are two vectors A and B.



What will be the result of adding them up? The resultant vector is the one that you get when you add two or more vectors together. It is a single vector that has the same effect as all the others put together.

Let's describe the result as C.

So $C = A + B$

You will connect the two vectors in this manner. The tail of B connects to the head of A

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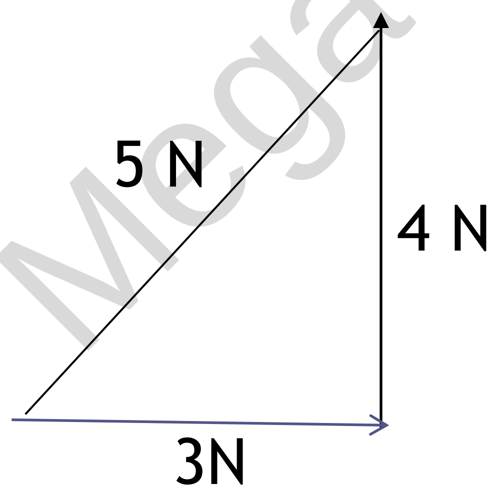
Vector operation

- **Vector problem must be solved vectorically unlike scalar quantity.**
- **E.g. 3 N + 4 N = 5 N**



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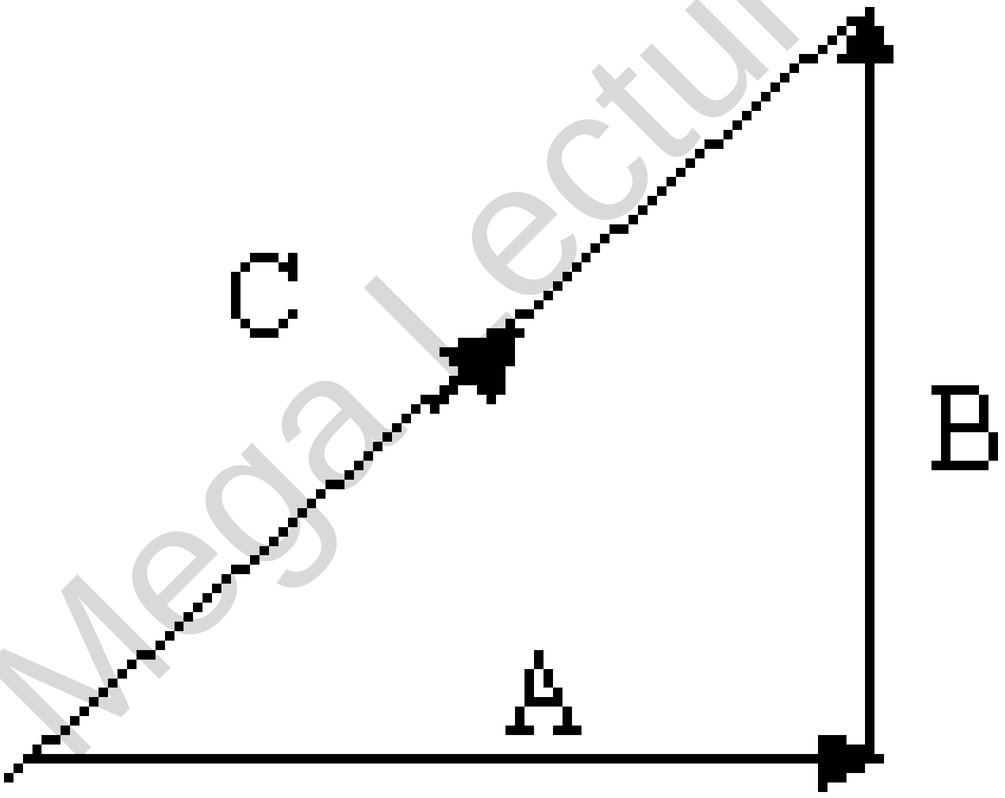
Addition using drawing method



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Reference link : Vector addition

- http://www.physicsclassroom.com/class/vectors/u3l1b.cfm

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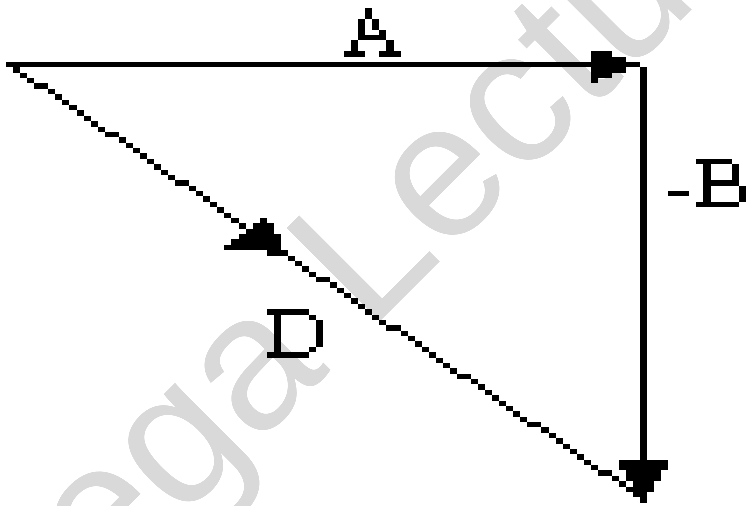
Subtraction using drawing method

- if D = A – B



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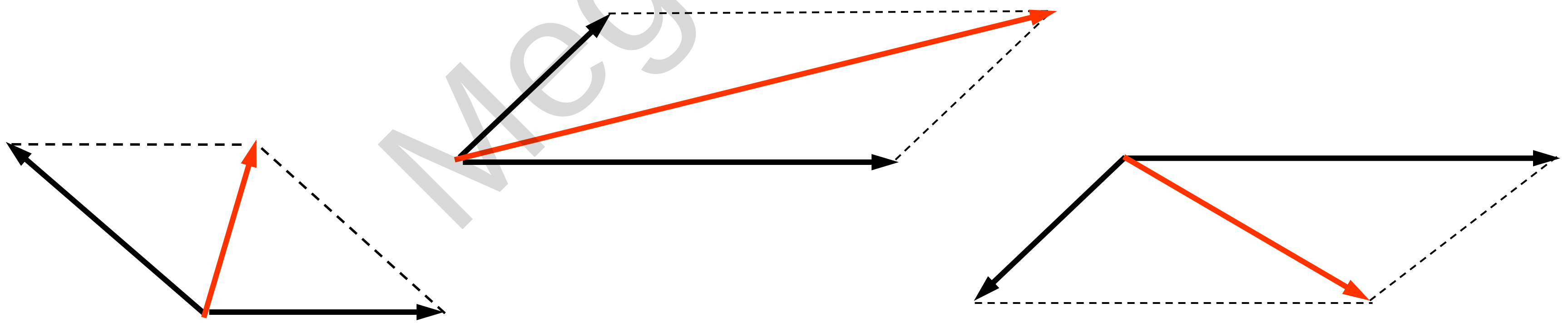
Scalars and Vectors

- The **parallelogram law of vector addition** states that if two vectors acting at a point are represented by the sides of a parallelogram drawn from that point, their resultant is represented by the diagonal which passes through that point of the parallelogram



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Coplanar vectors

- When 3 or more vectors need to be added, the same principles apply, provided the vectors are all on the same plane i.e. coplanar
- To subtract 2 vectors, reverse the direction i.e. change the sign of the vector to be subtracted, and add

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Change in a Vector

Case 1

- If an object changes it's direction but not speed, then velocity vector will only change its direction but not magnitude.

Case 2

- If an object changes it's direction and also speed, vector will change its direction as well as magnitude. So the change in the vector would be final minus initial.

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Components of a Vector

- Any vector directed in two dimensions can be thought of as having an influence in two different directions. That is, it can be thought of as having two parts. Each part of a vector is known as a **component**.

- 2N + 4N = 6N (2N and 4N are the components of 6N)

- The components of a vector depict the influence of that vector in a given direction. The combined influence of the two components is equivalent to the influence of the single vector. The single vector could be replaced by the two components.

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Components of a Vector

- Any vector can be thought of as having two different components. The component of a single vector describes the influence of that vector in a given direction.

- $\vec{3N} + \vec{4N} = \vec{7N}$ ($\vec{3N}$ and $\vec{4N}$ are the components of $\vec{7N}$)

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Resolution of vectors

- **Resolving vectors into two perpendicular components**

- A vector can be broken down into **components**, which are perpendicular to each other, so that the vector sum of these two components, is equal to the original vector.

- Splitting a vector into two components is called **resolving** the vector. It is the reverse of using Pythagoras' theorem to add two perpendicular vectors, and so adding the two components will give you the original vector.

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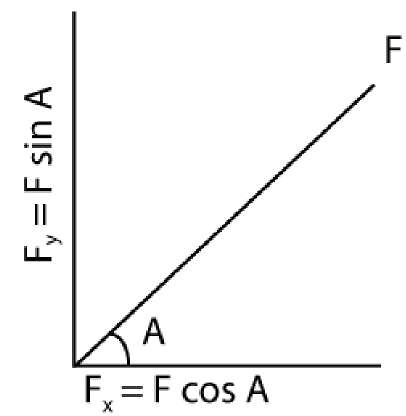
Resolution of vectors

- **Resolving vectors into two perpendicular components**

- Resolving a vector requires some simple trigonometry. In the diagram, the vector to be resolved is the force, F for angle A;

- the horizontal component of F : $F_x = F \cos A$
- the vertical component of F : $F_y = F \sin A$



Note that the two components do not have to be horizontal and vertical. The angle can be changed to any required direction, and both components will still be perpendicular to each other

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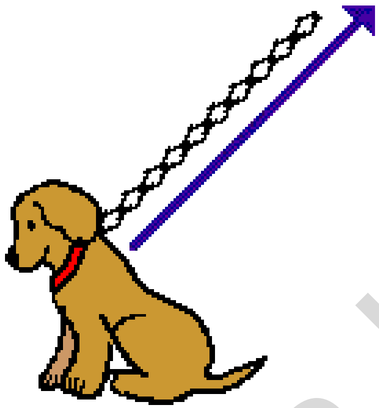
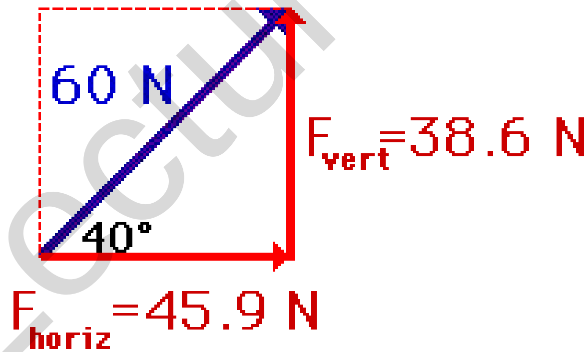
Resolution of vectors

- **Resolving vectors into two perpendicular components**





$$\sin 40° = \frac{F_{vert}}{60\ N} \qquad \cos 40° = \frac{F_{horiz}}{60\ N}$$

$$F_{vert} = 60\ N \times \sin 40° \qquad F_{horiz} = 60\ N \times \cos 40°$$

$$F_{vert} = 38.6\ N \qquad F_{horiz} = 45.9\ N$$

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In short…

- Vectors addition and subtraction can be performed using diagram method or the resolve and recombine method

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Reference links – Vector Resolution

- http://www.physicsclassroom.com/class/vectors/u3l1d.cfm
- http://www.physicsclassroom.com/class/vectors/U3l1e.cfm

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KEY CONCEPTS

1. Scalar quantities are quantities that only have magnitudes
2. Vector quantities are quantities that have both magnitude and direction
3. Parallel vectors can be added arithmetically
4. Non-parallel vectors are added by graphical means using the parallelogram law.
5. Vectors addition and subtraction can be performed using diagram method or the resolve and recombine method

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Youtube videos links with explanation on :
General Physics - Physical quantities

- http://www.youtube.com/watch?v=kuoQUv7bY2Y
- http://www.youtube.com/watch?v=Rmy85_EwLoY&feature=related

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