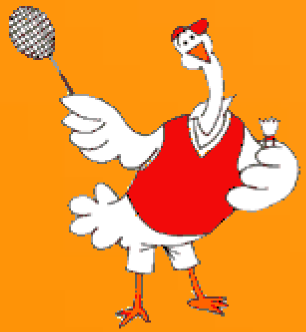
Chap 1
Physical quantities and units



Lim Wan Hong

2012

Lesson 1.1

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

Physical quantity

- Physical quantity – a property which is measurable. It has a magnitude and a unit.
- For instance, the temperature of a body is 32^{o}C. temperature is a physical quantity.

  Magnitude -32

  Unit - ^{o}C
- Non-physical quantity – not measurable, e.g. faith, love, hope, currency

6 base quantities

Base quantities		Base units	
name	symbol	Name	Symbol
length	l	metre	m
mass	m	kilograms	kg
time	t	second	s
temperature	T, θ	kelvin	K
electrical current	I	Ampere	A
amount of substance	n	mole	mol

Base & Derived quantities

- Base Quantities: Physical quantities that can not be derived from other quantities.

  E.g. mass, temperature, time.

- Physical quantities that are derived from other quantities, defining by an equation.

  E.g. speed is a derived quantity which is defined as distance travelled/ time taken, where distance and time are base quantities.

SI base units of a derived quantity

- One must know the definition of a derived quantity or its relation with other quantities before deriving its units and expressing it in SI base units.
- Example 1, force F = mass m x acceleration a

$F = ma$ and $a = dv/dt$

$[a] = m\ s^{-1}/s = m\ s^{-2}$

$[m] = kg$

$[F] = kg\ m\ s^{-2}$

Derived units

- Example 2

pressure p is defined as force F acting normally per unit area A.

$p = F/ A$

$[p] = kg\ m\ s^{-2} / m^2$

$= kg\ m^{-1}\ s^{-2}$

Example 3

Given that intensity = energy transferred per unit time per unit area normal to the propagation of the energy.

[Energy] =[force] x [displacement]

$= \text{kg m s}^{-2} \text{ x m}$

$= \text{kg m}^2 \text{ s}^{-2}$

$$\frac{\text{Energy}}{\text{Time x area}}$$

$$= \frac{\text{kg m}^2 \text{ s}^{-2}}{\text{s x m}^2}$$

$$= \text{kg s}^{-3}$$

Lesson 1.2

Candidates should be able to:

- *(d)* use SI base units to check the homogeneity of physical equations

introduction

- $s = ut + \frac{1}{2} a t$, is it correct?

Let's check!

- $[s] = m$
- $[ut] = ms^{-1} \times s = m$
- $[at] = ms^{-2} \times s = ms^{-1}$

$s = ut + \frac{1}{2} a t^2$

homogeneity

- Homogeneity – consistency
- use SI base units to check the homogeneity of physical equations
- A = BC
- Check both sides of the equation if they have the same SI base units

- A = B +C +D
- Check each term of the equation if they have the same SI base units

Physically correct & dimensionally correct

- s= ut + ½ a t ,
- both physically & dimensionally incorrect
- s= ut + a t^2 ,
- physically incorrect but dimensionally correct because ½ is unitless and hence it cannot be detected
- s= ut + ½ a t^2
- both physically & dimensionally correct

Example 1

- Drag force F acting on a car traveling in the air is given by

$$F = \frac{1}{2} C_D A \rho v^2$$

, where C_D is the drag coefficient, A area of vehicle, ρ density and *v* speed of vehicle.

Show that C_D has no units.

Solution:

$$F = \frac{1}{2} C_D A \rho v^2$$

- LHS

  $[F] = \text{kg ms}^{-2}$

- RHS

  ½ has no unit

  $[A] = \text{m}^2$

  $[\rho] = \text{kg m}^{-3}$

  $[v^2] = \text{m}^2\,\text{s}^{-2}$

$[A\rho v^2] = \text{m}^2 \times \text{kg m}^{-3} \times \text{m}^2\,\text{s}^{-2}$
$= \text{kg m s}^{-2}$

Since $[F] = [A\rho v^2]$ without taking C_D into account, C_D has no units.

Example 2

- This is known as Bernoulli equation:

$$\frac{P}{\rho g}+\frac{v^2}{2g}+h=k$$

where *P* is pressure, ρ density, *g* acceleration due to gravity , *v* speed, *h* height and *k* is a constant which has the same dimension as *h*.

Check if this equation is homogenous.

solution

$$\frac{P}{\rho g} + \frac{v^2}{2g} + h = k$$

- $[\frac{P}{\rho g}]$ = kg m^{-1} s^{-2} / (kg m^{-3} x ms^{-2}) = m
- $[\frac{v^2}{2g}]$ = m^2 s^{-2} / (ms^{-2}) = m
- [h]=[k] =m
- Since each term has the same units, this equation is correct (dimensionally)

Lesson 2.3

Candidates should be able to:

- *(f)* use the following prefixes and their symbols to indicate decimal submultiples 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

Prefixes

Multiple	prefix	Symbol	multiple	prefix	symbol
10^{12}	Tera	T	10^{-1}	deci	d
10^{9}	Giga	G	10^{-2}	centi	c
10^{6}	Mega	M	10^{-3}	mili	m
10^{3}	kilo	k	10^{-6}	micro	μ
			10^{-9}	nano	n
			10^{-12}	pico	p

examples

- Hard disk – Giga byte (Gb)
- Dimension – nano metre (nm)
- Capacitance – pico farad (pF)
- Intensity of sound – decibel (dB)
- Mass of a boy – 80 kilograms (kg)

estimates of physical quantities

- Some estimates are logical

  E.g. mass of an apple,

  A wide range of estimates are accepted, 100g – 500 g

- While some need common sense or knowledge

  the mass of a person 40 – 100 kg

  the speed of an Olympiad 100-m sprinter, slightly less than 10 ms^{-1}

- Some estimates can be calculated

  E.g. the pressure at a point 10 metres deep in water

  $p = \rho\, hg = 1000 \times 10 \times 10 = 10^5$ Pa

Lesson 2.4

Candidates should be able to:

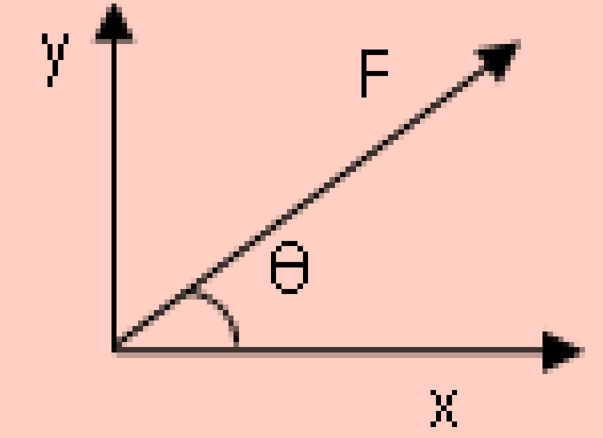
- *(j)* distinguish between scalar and vector quantities and give examples of each
- *(k)* add and subtract coplanar vectors
- *(l)* represent a vector as two perpendicular components.

Vector & Scalar quantities

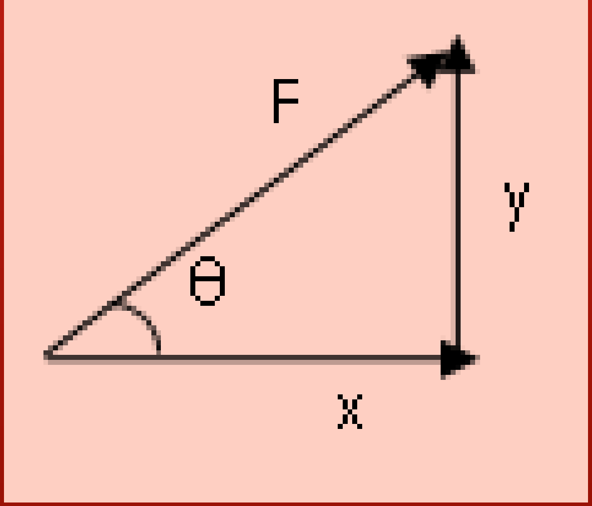
Vector quantities	Scalar quantities
Physical quantities that have the properties of magnitude and direction.	Physical quantities that have magnitude but do not have the property of direction.
Acceleration, force, momentum, electric field strength,	temperature, work, energy, pressure, power

Resolving a vector F into two perpendicular components X & Y

$Y = F \sin\theta$



$X = F \cos\theta$



$Y / F = \sin\theta$

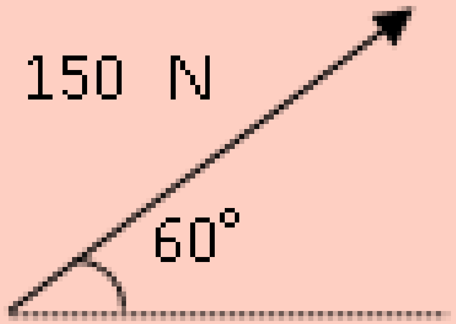
$Y = F \sin\theta$

$X / F = \cos\theta$

$X = F \cos\theta$

Example 1
resolve a force of 150 N into two perpendicular components

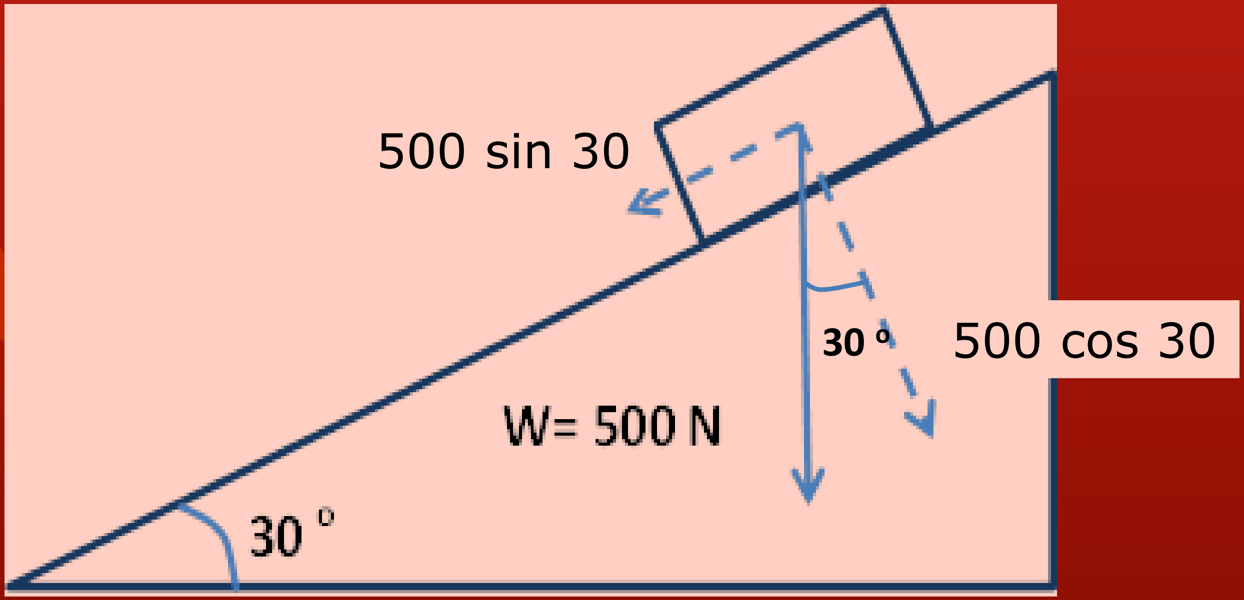
$Y = 150 \sin 60$



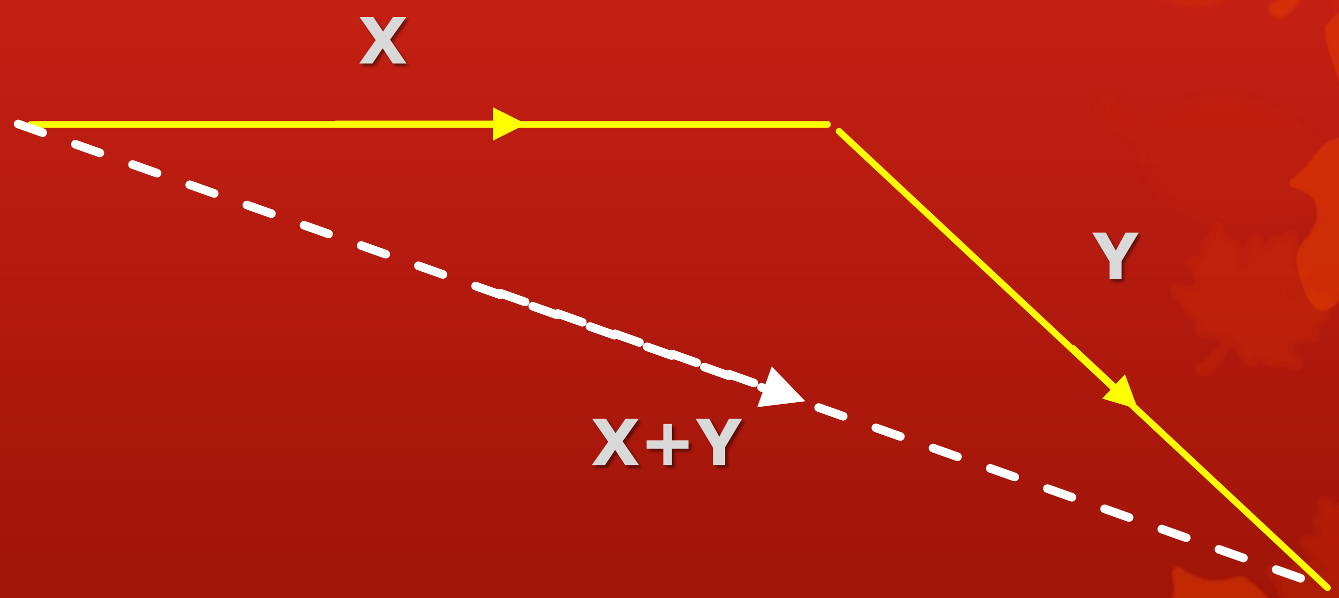
$X = 150 \cos 60$

Example 2

a mass of weight 500 N lies on a ramp. Determine the component of the weight down the slope and normal to the slope

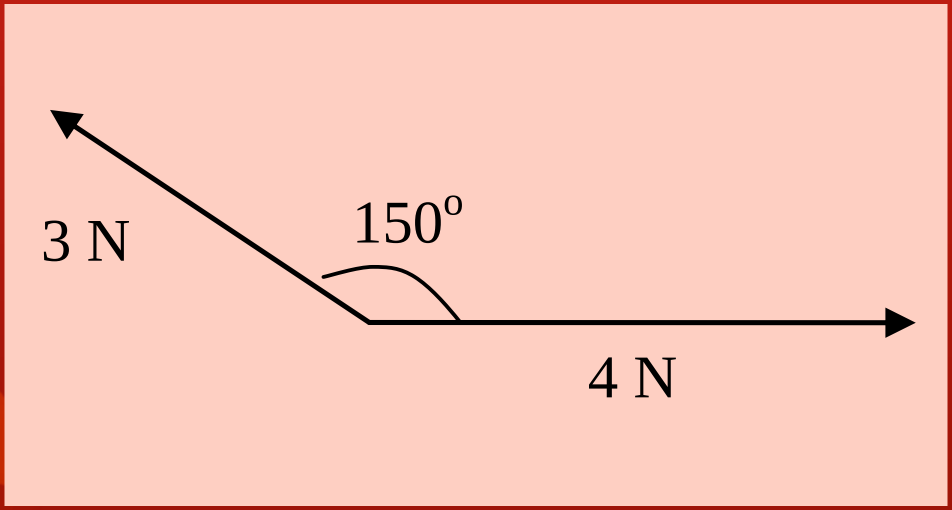


Vector addition



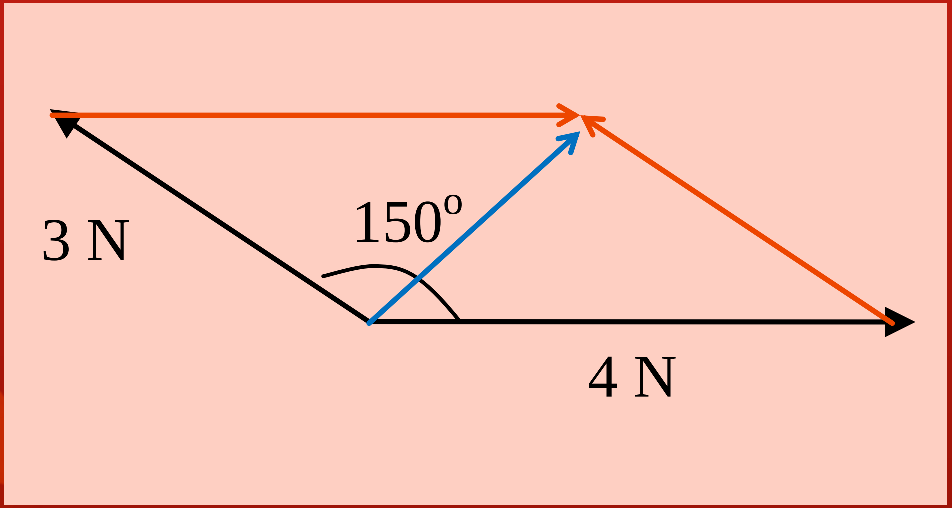
- Determine the resultant vector of two vectors that occur concurrently
- For instance, the resultant force on a boat which is pulled by two tugs

Vector addition



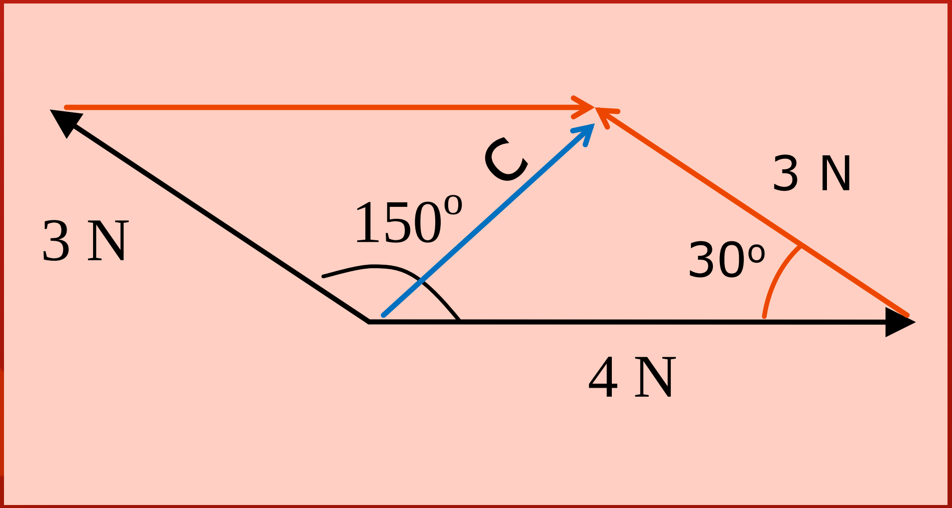
- Two methods
  - Draw to scale and measure the resultant vector by ruler and protractor
  - Cosine rule & sine rule

1. drawing



- Firstly, draw a parallelogram to scale e.g. 1cm: 1N
- Determine the resultant vector
- Measure the length of arrow and calculate the resultant force
- Measure its angle to horizontal with a protractor

2. Cosine rule and since rule



- Firstly, draw a parallelogram
- Determine the resultant vector
- $C^2=4^2+3^2 - 2(3)(4)\cos 30$

c =…………..

$$C^2 = 12^2 + 35^2 - 2(12)(35)\cos 135$$

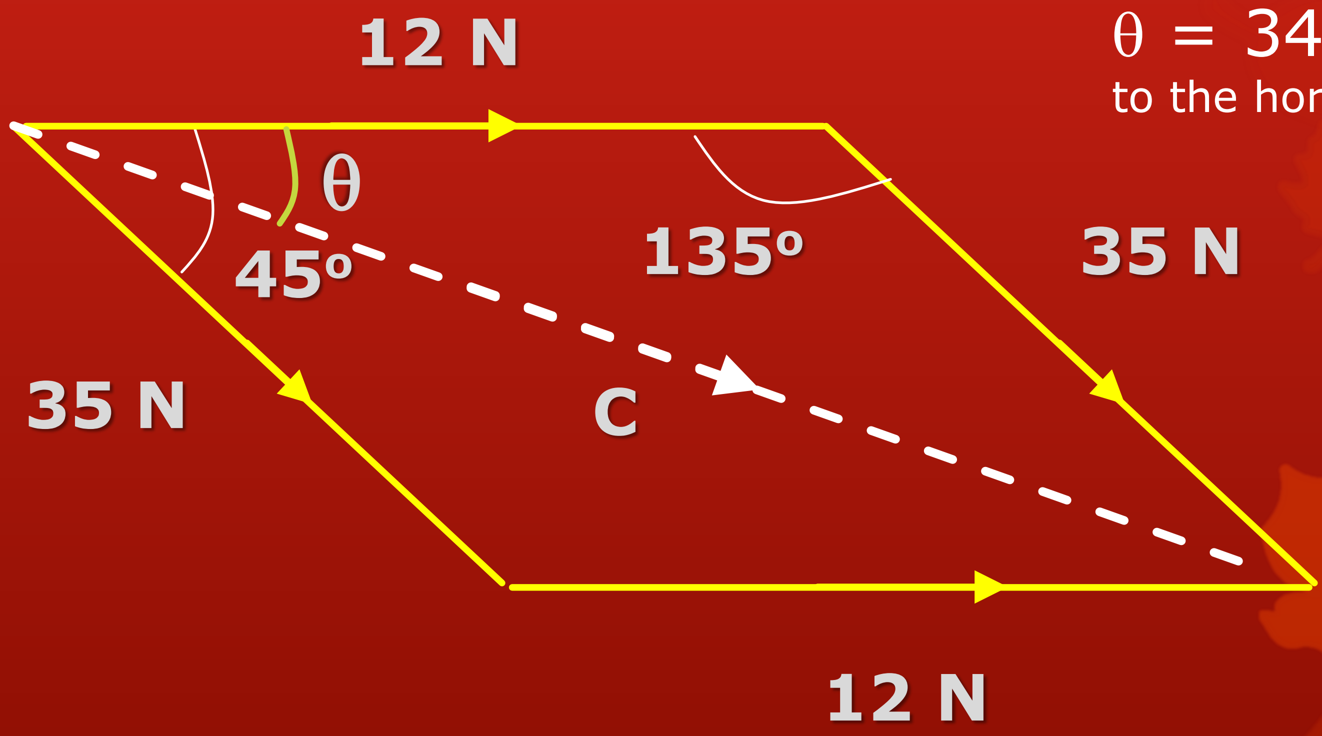
$$C = 44.3\text{ N}$$

Example 1

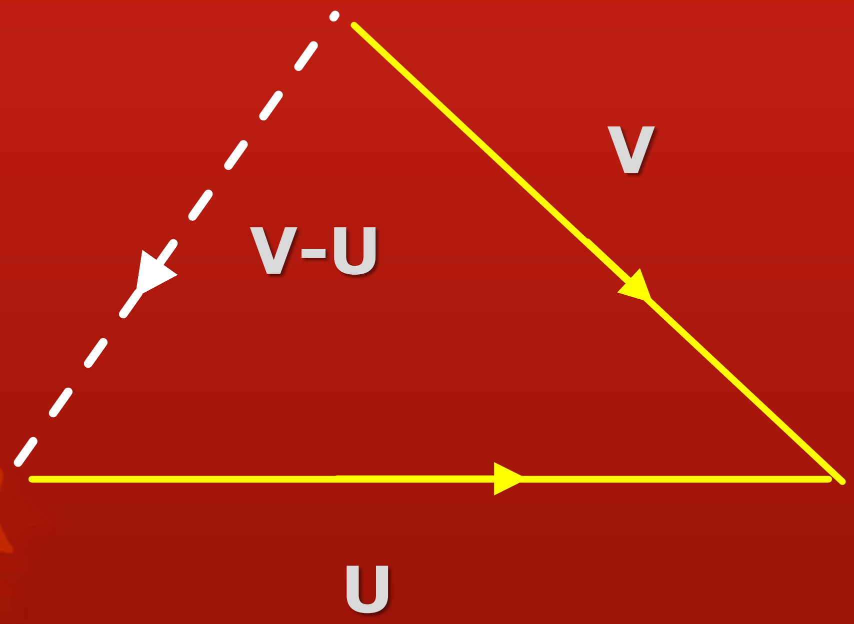
$$\frac{\sin 135}{44.3} = \frac{\sin\theta}{35}$$

$$\theta = 34^\circ$$

to the horizontal



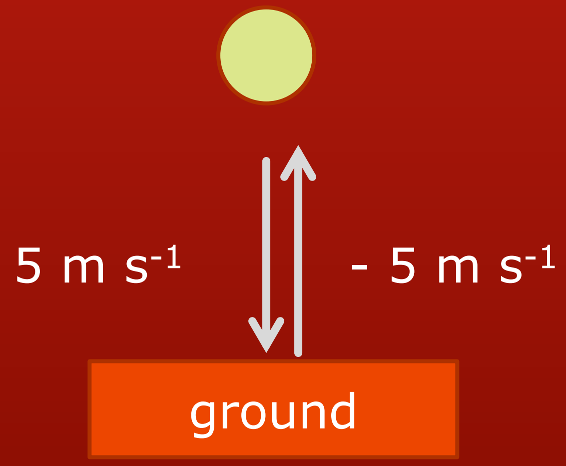
Vector subtraction



- Determine the change of a vector
- For instance the change in velocity **V-U** of a car
- **V-U = a** t
- The magnitude **V-U** of is equal to a x t
- The direction of **V-U** represents direction of acceleration as well as the direction of force that causes the change in velocity

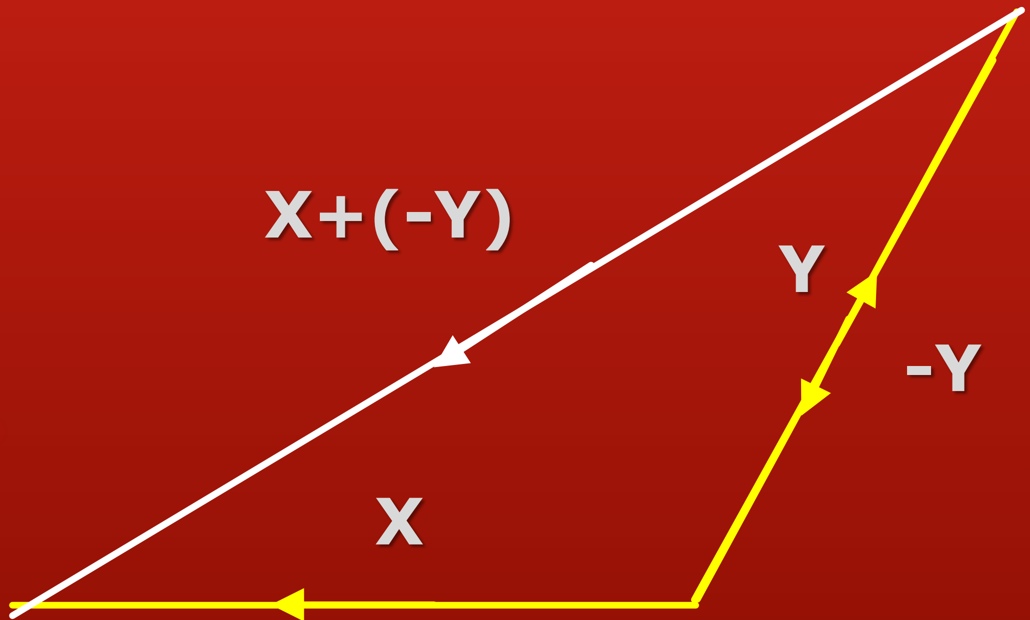
Change in velocity **V-U**

- A ball hits the ground with 5 m s^{-1} and rebounds with 5 m s^{-1} . Taking downwards as positive, determine the change in velocity.
- Answer = - 10 m s^{-1} (-ve means the force that causes the change acts upwards)



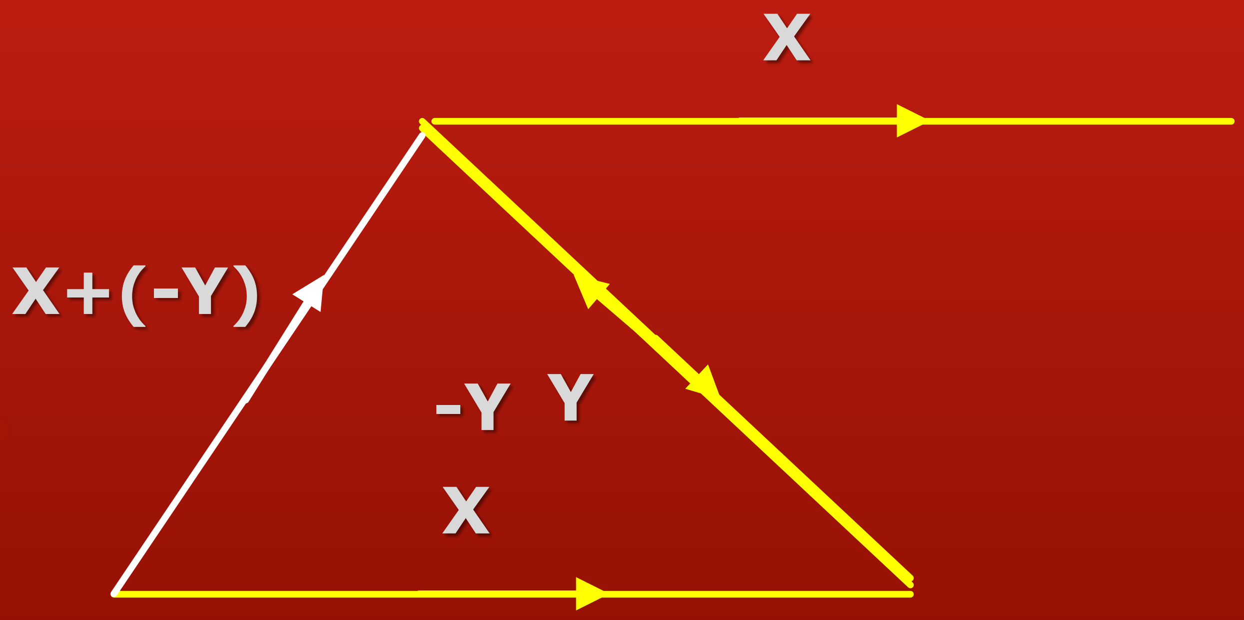
Example1

determine **X-Y**?



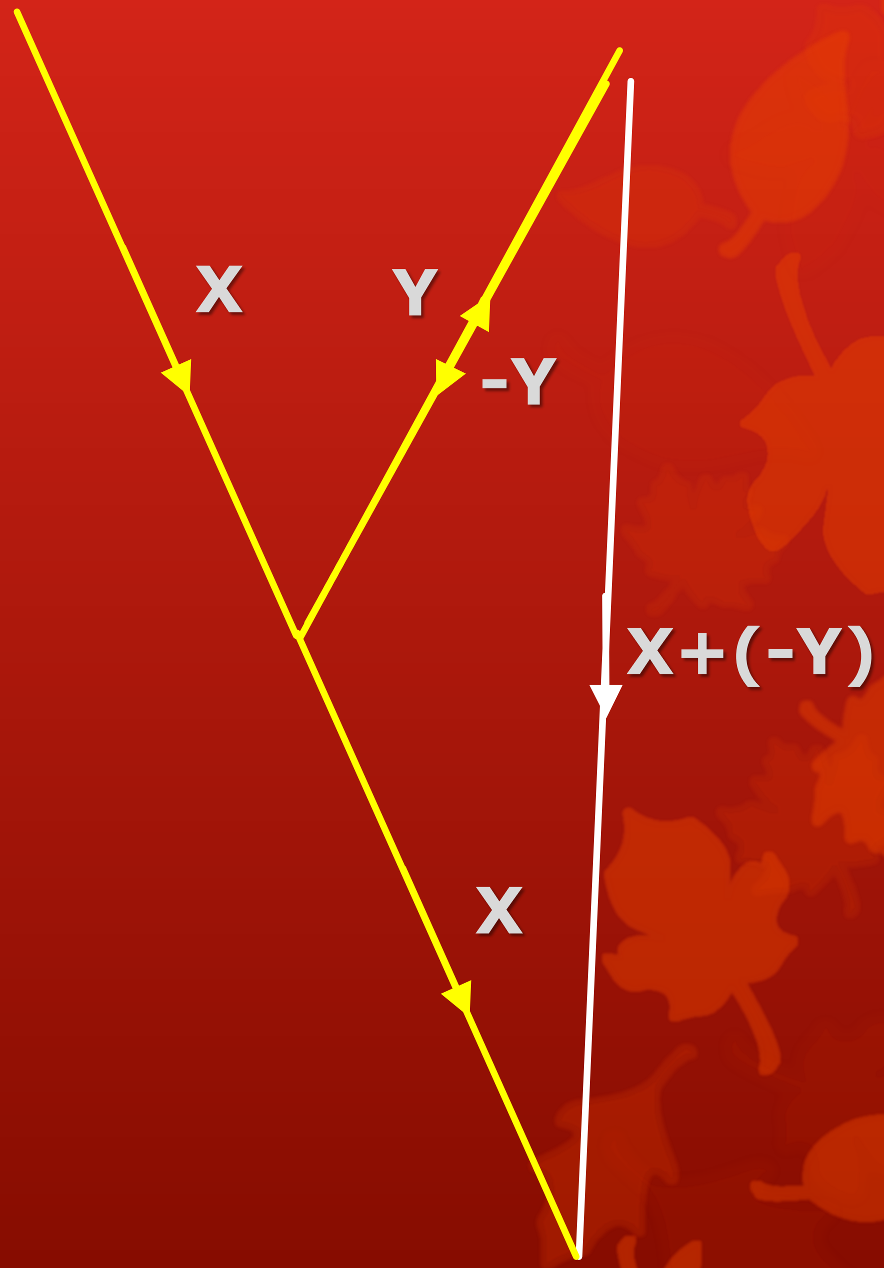
Example 2

determine **X-Y**

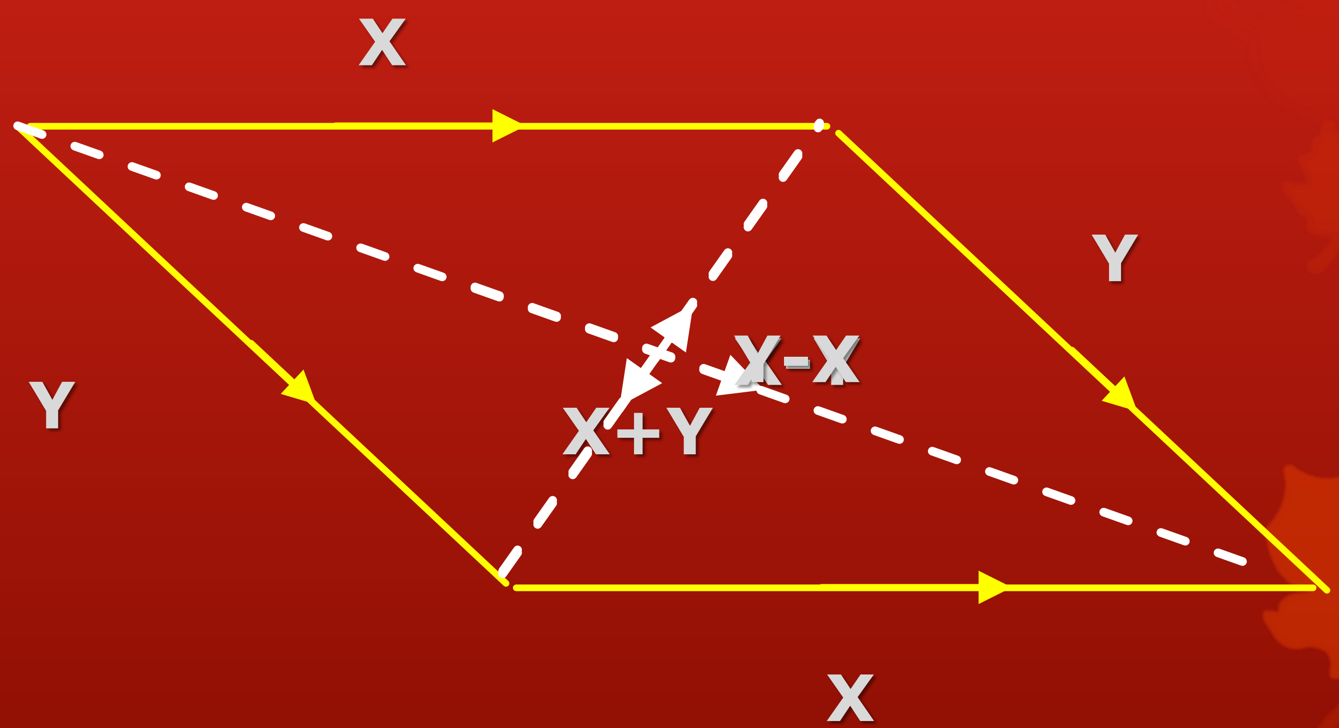


Example3

determine **X-Y**?



Other approach - parallelogram



Additional info

- Unified atomic mass constant *u* = 1.66x 10^{-27} kg
  - Mass of a nucleus of Uranium-235 = 235 u
- Elementary charge *e* = 1.6 x 10^{-19} C
  - Charge of a nucleus of Uranium, proton number 92= 92 *e*
- 1 Kilowatt-hour (Kwh) = 3.6 x 10^{6} J
- 1 atm= 1.01 x 10^{5} Pa

Any questions?

** The End **