LETS TALK PHYSICS

From many perspectives, we need to talk physics in the language of mathematics!

Physics has been narrating the non-fictional stories of the universe from the beginning of time. In fact, if you take time to read them, you can make splendiferous friends!

You're not human if physics can't get you thinking!

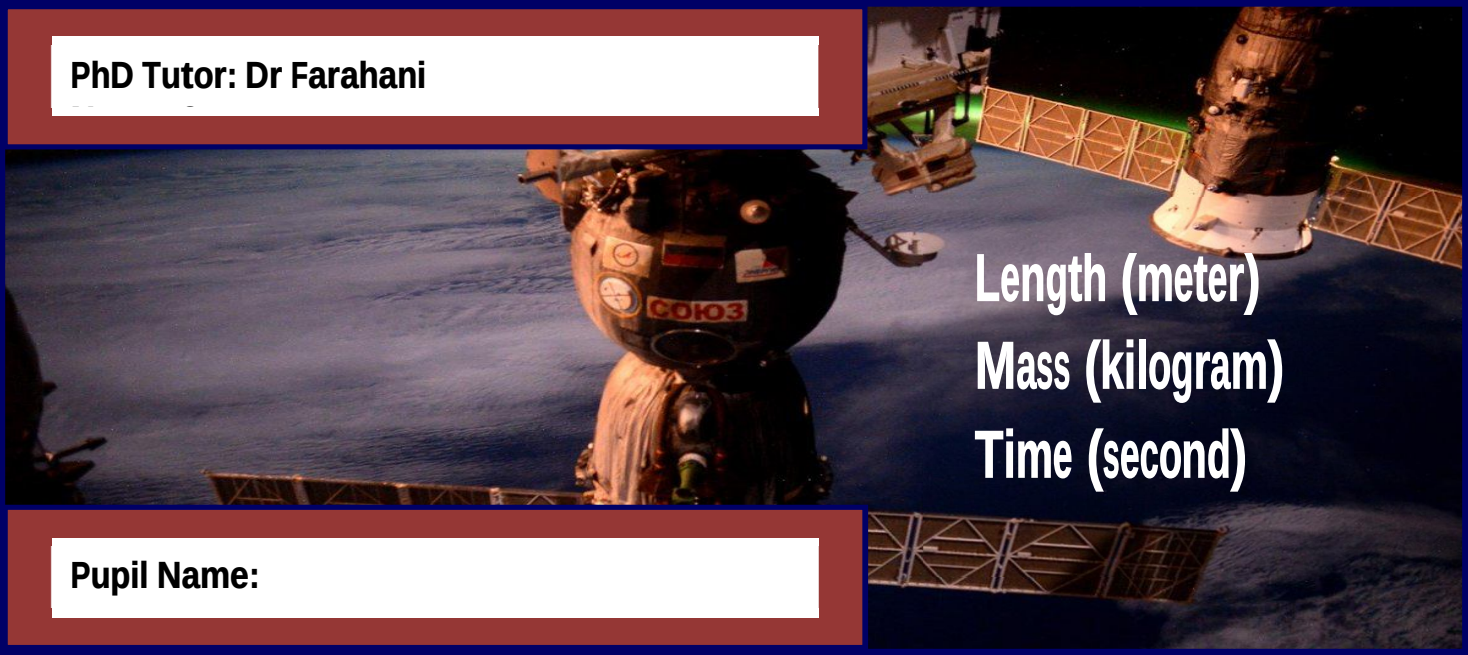
What we hope ever to do with ease, we must first learn to do with diligence.
Samuel Johnson

Researchers in Schools

Mechanics

Key Stage 4 Programme – Autumn 2016

PhD Tutor: Dr Farahani



Pupil Name:

Timetable and Assignment Submission

Timetable – Tutorials

Tutorial	Date	Time	Location
1 (Launch Trip)			
2			
3			
4			
5			
6			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after 4.00pm on **Wednesday 6th April 2016**	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Assignment Submission – Virtual Learning Environment

VLE username	
VLE password	

Please remember the following key details…

- You are able log into the VLE either through the link on our website (**www.thebrilliantclub.org**) or going directly to the VLE site at (**vle.thebrilliantclub.org**).
- When you submit your final assignment, please remember that you need to do so through the **'My Activities'** tab and not as an attachment to a message.

The Brilliant Club Year 12 Programme – Spring 2016 – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at first year undergraduate level
2:1	60-69	Performing to a good standard at first year undergraduate level
2:2	50-59	Performing to an excellent standard at current key stage
3rd	40-49	Performing to a good standard at current key stage
Working towards a pass	0-39	Performing below a good standard at current key stage
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of PhD Tutor	Dr Farahani		
Title of Assignment	Mechanics		
Name of Pupil			
Name of School	Nether Stowe School		
ORIGINAL MARK / 100		**FINAL MARK / 100**	
DEDUCTED MARKS		**FINAL GRADE**	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Learning Feedback Comment 1 - *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 2 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 3 – *Enter Key Learning Priority Here*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Resilience Comment	
How you showed learning resilience during the course *Enter feedback here*	**How you could build learning resilience in the future** *Enter feedback here*

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Course Rationale

I was born in Chichester in South-East England and grew up in a nearby village. My older sister and I enjoyed an ordinary family life. Like many children I dreamt of going into space but never really considered it a possibility. Now a lifelong fascination with flying, years of training as a pilot and then an astronaut, and some luck, has turned that dream into reality.

Tim Peake

Mechanics is holding the four pillars of Physics

Physics is a mathematical science. Without mathematical knowledge, physical knowledge cannot flourish. The underlying concepts and principles of physics have a mathematical or geometrical basis. To understand physics, we need to acknowledge and remind ourselves of the things we encounter and activities we do on a daily basis. From getting up in the morning in a reversed quarter-of-a-somersault fashion to stopping on the pavement watching the cars whizzing by and even sometimes seeing the international space station passing across the sky in its orbit around our planet.

The science that can explain these experiences is ***Physics*** and the branch which they all fall into is called ***Mechanics***. Throughout the course of this project, you will study a variety of just these physical concepts and their associated mathematical basis that would form the foundational knowledge necessary for the understanding of the world around us in the future. In whichever way we lay emphasis upon the conceptual nature of physics, we will do as such carefully and persistently to its mathematical aspect.

The subjects of Mechanics that is introduced in this course are essential not just to physics but to nearly all engineering subjects too encompassing the study, design and manufacturing of devices, machines, systems of either small, medium or large scale. The fields of interest, to name but a few, include, electrical engineering, mechanical engineering, materials engineering, aerospace engineering (aeronautical and astronautical engineering), civil engineering and architecture.

We start this course by the introduction and understanding of some mathematical tools which are extremely important throughout the course. We link this into different types of physical quantities. Mechanics as a field is divided into two subfields of Kinematics and Dynamics, and so is this course book. The subject starts on with kinematics and will link up with Dynamics in the following tutorials. The fundamentals of Mechanics will be studied and put into context to gain a broader vision of the subject and its practicality in real life. Each tutorial of the course will progress from an introduction into a set of questions, activities and discussions.

During this course, we are also planning to establish a scientific approach towards viewing and achieving things in connection to an ordinary way of an individual without a background in physics.

The final assignment is designed for purposeful research, independent learning of scientific information, and writing about them.

The ultimate goal of the course is to create self-confidence towards approaching problems, engaging with them and generating ideas for further understanding. This would involve promoting of independent learning, research and citation (referencing), critical thinking and team work. The use of key words and phrases, and efficient use of resources including your ***teacher*** is emphasised from the outset and throughout.

Mark Scheme

Key Skill	1st	2.2
Comprehension	☐ The materials proposed to read have been well understood and the summary within the words specified represent an excellent summary of the manuscripts.	☐ From the materials proposed to read, sections selected are important, nonetheless, weakly put across the aim of the work.
Illustration	☐ Illustrations have been presented for necessary ideas or analogies, features of which well-defined, and by which the idea has been understandably conveyed.	☐ Illustrations include the key features and their relationships are fairly well described.
Methodological sequence	☐ Explanations well fit into a scientific agenda with well-adopted logical sequence.	☐ Arguments are understandable, nonetheless, lacks a regular pattern collectively.
Numerical and analytical clarity	☐ Necessary formulae and equations have been all introduced before any requested numerical substitution. All correct units appear in front of physical values.	☐ Correct answers have been arrived at; however, the approach appears to be infirm.
Evidencing and Communication	☐ Any argument chosen or direct answers to questions were all supported by evidence or references and well communicated by both normal and scientific writing.	☐ The use of key words were adequate in respective arguments or responses, however, there were lack of evidence and clarity in communication.

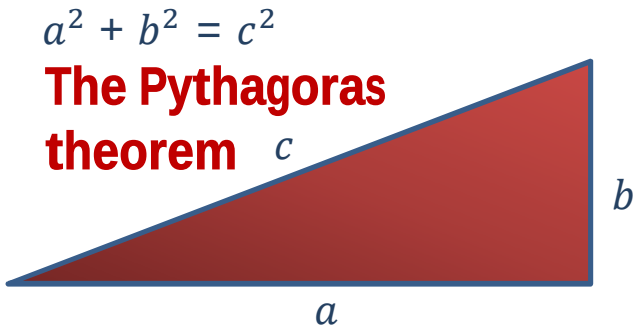
Glossary of Keywords

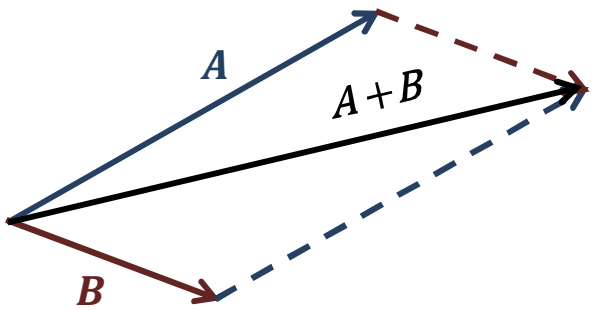
Word	Definition	In a sentence...
Magnitude	Size	The magnitude of a physical quantity comes as number
Direction	Where something is pointing to	The direction of our journey is south-west
Vector	An arrow whose length from the tail to the head is the magnitude of the vector	A vector can be resolved into its components
Scalar Quantity	Physical quantities that only have magnitude and no direction	Speed, mass, distance, time, energy, and power are all scalar quantities
Vector Quantity	Physical quantities that have both magnitude and direction	Velocity, acceleration, force, and momentum are examples of vector quantities
Vector Resolution	Projecting a vector onto the axes of a reference frame	In two dimensions, a vector has two components
Resultant Vector	The result of two or more vectors combined	The resultant vector can also be determined by vector resolution
Trigonometry	The branch of mathematics dealing with the relations of the sides and angles of triangles using the relevant functions of angles	Trigonometry is the tool for vector resolution
X-Component	The component or shadow of a vector on the x-axis	The x-component of a vector is normally the horizontal component
Y-Component	The component or shadow of a vector on the y-axis	The y-component of a vector is normally the vertical component
Parameter	A constant in an equation that can be different (varies) in other similar equations	In Hook's law, *k* is a parameter
Gradient	Slope	The higher the gradient of a slide, the harder to climb it
Intercept	The point at which a line intersects a coordinate axis, for example, the x-axis or y-axis	In a typical equation of a straight line, the intercept is where the line intersects the y-axis
Distance	The extent of space between two points, objects, or places	The distance over which I have to walk from home to school is 300 m
Displacement	Change in position	My displacement from home to school is 220m
Stationary	Not moving	In the traffic jam, at one time we were stationary for 15 minutes
Speed	The rate at which someone or something moves	The speed of the Thomson's Gazelle can reach 50 miles an hour

Velocity	The speed of something in a given direction	The velocity of the cruise was 25 miles per hour north-east
Acceleration	The rate of change of velocity	I saw the acceleration of that car because it was going faster and faster every second
Instantaneous	Relating to an instant in time	The average velocity of an object over a period of time is not the same as its instantaneous velocity at every part of the journey if the velocity of the object is changing
Mass	The amount of matter or stuff in a physical body	Kg is the unit of mass. 1 kg gold is very expensive because that amount of gold is a lot of gold
Inertia	Resistance to motion	If no outside force is acted on a body at rest, the body will stay at rest because of its inertia. Or even if the body is in straight-line motion, its inertia will keep it in straight-line motion with the same velocity if no outside force is acted on it
Force	A push or pull upon an object	Forces are experienced by objects because of their interaction with another object or their surroundings
Gravity	Natural attraction between physical bodies	The gravity on the moon is less than the gravity on Earth
Gravitational Acceleration	The acceleration of an object caused by the gravitational force (the force of gravity) acting on the object	The gravitational acceleration near the surface of the Earth is 9.81 m/s^2
Force of Friction	A force created when two object are moving or trying to move across each other with contact	The force of friction can impede the motion of an object
Coefficient of Friction	A parameter that relates the force of friction between two objects with the normal force between them	The coefficient of friction is always between 0 and 1
Terminal Velocity	A constant velocity that a free-falling object reaches when the resistance of the medium stops its acceleration	A typical skydiver in a spread-eagle position will reach terminal velocity after about 12 seconds, during which time he will have fallen around 450 m
Inclined Surface	A ramp	An object on an inclined surface can slide down because of the gravitational force acting on it
Kinetic Energy	The energy that an object has due to its motion	The higher the speed of an object, the higher its kinetic energy
Momentum	Mass in motion	The higher the speed of an object, the higher its momentum so the harder to stop it
Gravitational Potential Energy	The energy an object gains by being at height above the Earth's surface	The higher an object above the ground, the higher its gravitational potential energy

Free-Fall	Downward motion under the gravitational force only	A parachute jumper is in a free-fall until she opens her parachute
Conservation of Energy	Energy can neither be created nor destroyed	Because of conservation of energy, the total energy of any isolated system remains constant
Mechanical Energy	The sum of kinetic energy and potential energy	Mechanical energy is the energy associated with the speed and position of an object
Conservation of Momentum	The total momentum of a system remains constant if no outside force is acted on the system	In a system composed of objects, so long as no external forces are acting on the objects within the system, the total momentum of the system stays the same in any explosions and collisions
Elastic Collision	A collision in which the total kinetic energy of the colliding objects stays the same before and after the collision	In elastic collisions, the conservation of momentum can be used in conjunction with the conservation of kinetic energy
Inelastic Collision	A collision in which the total kinetic energy of the objects is not conserved due to the action of internal friction	Two common inelastic collisions are when two object collide and stick together, or when explosions occur
Equilibrium	A condition in which the forces acting on an object cancel each other out or are balanced	A chandelier hanging from the roof is in equilibrium
Impact Force	A force acting on an object for a short period of time when objects collide	The impact force changes the momentum of the colliding objects
Impulse	The change of momentum of an object when the object is acted upon by an impact force	If an object undergoes a high change of momentum after a collision, it means that the impulse the object experienced was high
One Dimensional	Having or relating to a single dimension	A one dimensional event is an event that involves moving or developing along a straight line
Two Dimensional	Having or relating to two dimensions	A two dimensional event is an event that happens or lies on a plane

Tutorial 1 – Physical Quantities, Vectors, and Graphs





The parallelogram method

Today's Key Question(s):

- What are scalar and vector quantities?
- Do we add and subtract vectors differently to the way do with scalars?
- Why algebra is an excellent way of formulating physics?

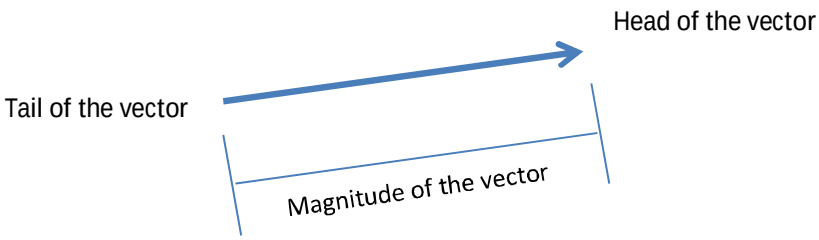
What is the Purpose of Tutorial 1?

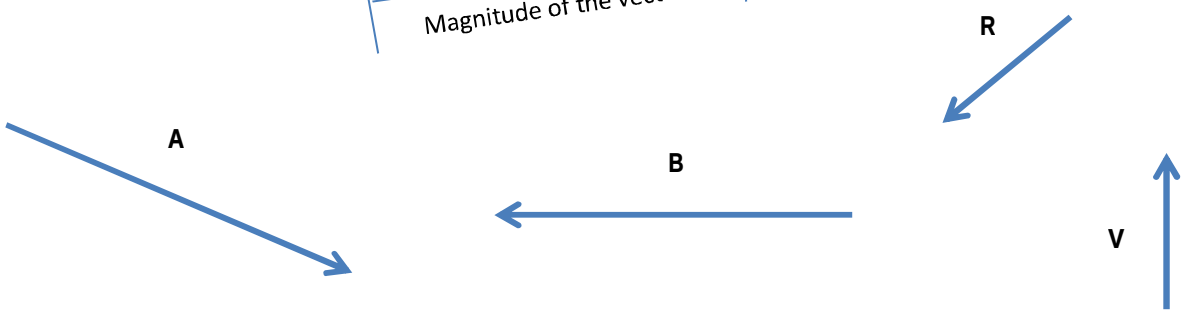
- To be competent in using mathematical tools to your understanding and in your solutions.
- To be able to distinguish between physical quantities.
- To be competent in using trigonometric functions for vector resolution.
- To gain a better insight into the components of a vector when drawn on a graph.

Activity 1 – What is a Vector? In what Way is it Different from a Scalar?

A scalar or a scalar quantity is a quantity that only has a magnitude or size – it is denoted by a letter or symbol.

A vector or a vector quantity is a quantity that has a magnitude (size) and a direction – it is denoted by a bold letter or symbol. The mathematical tool to show a vector is an arrow:





Fill in the blanks using the given words or phrases - each option can be used more than once or never.

Scalar starting point vector direction velocity force length faster stronger slower weaker

The mass of an object is a ..... quantity. The..... exerted on an object is a ..... quantity.

The tail of a vector shows the ..... and the head shows the..... of the vector.

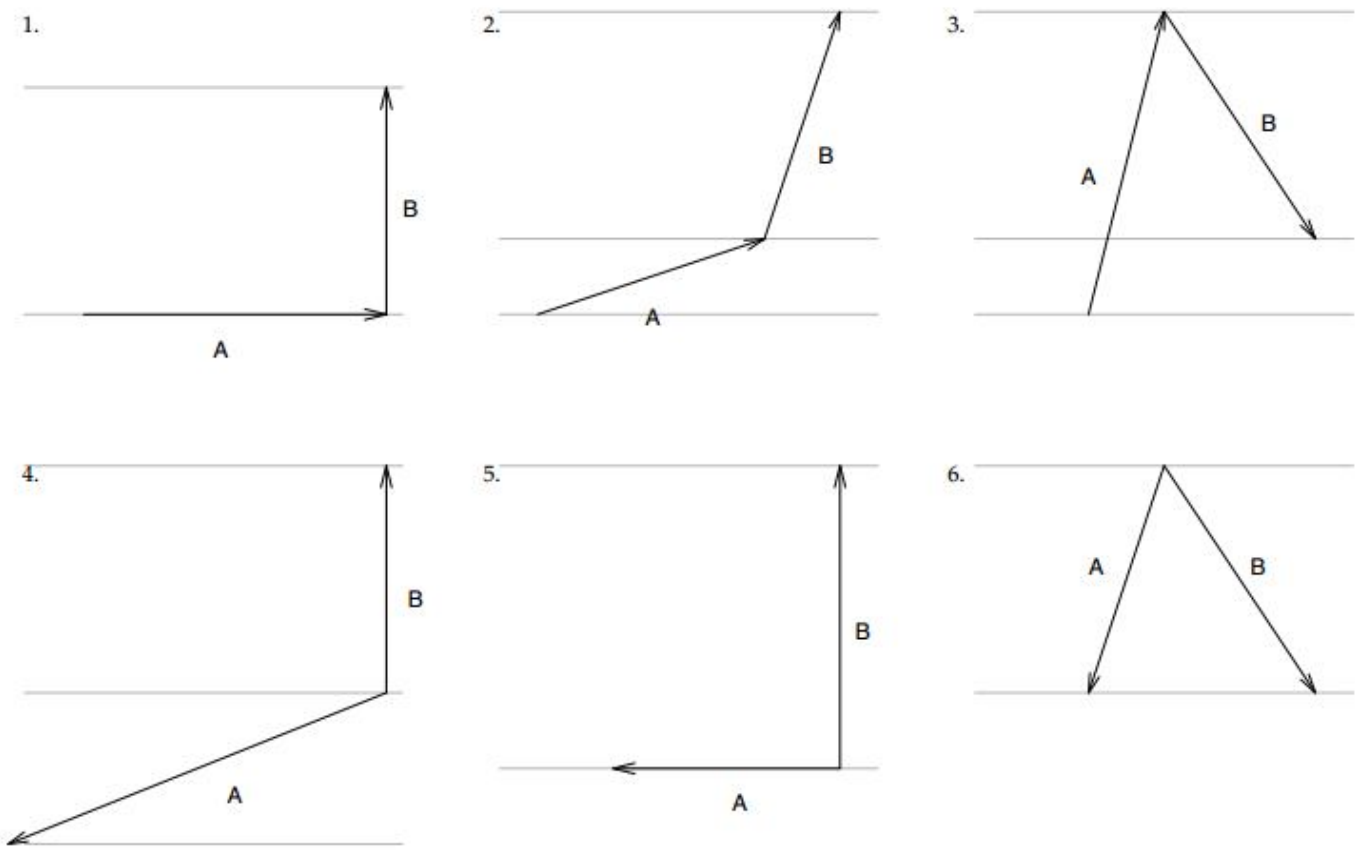
The ..... of a vector shows the magnitude of the vector. Therefore, the longer the force vector, the ..... is the acting force.

A vehicle with a shorter ..... vector compared to other vehicles, moves ..... compared to them.

Graphical addition and subtraction of vectors

Do not rotate or stretch the vectors, only feel free to translate (move) them!

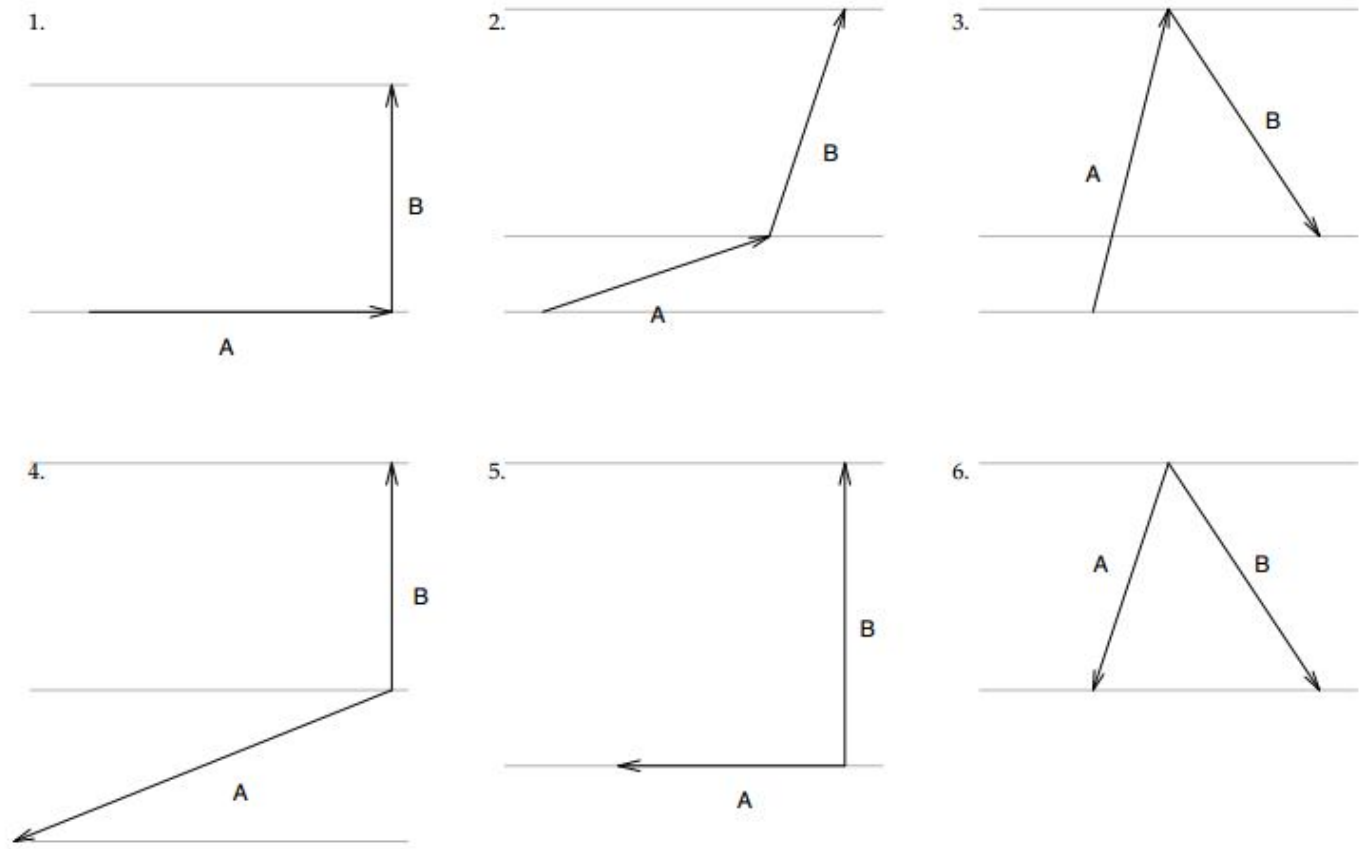
The head-to-tail method ***The parallelogram method***



A + B = ? ***B + A = ?***

Draw another arbitrary vector and perform the following:

A + B + C = ?



A – B = ? ***B – A = ?***

Draw another arbitrary vector and perform the following:

A – B + C = ?

Because ***A*** + ***B*** = ***B*** + ***A***, we say that addition is commutative. Can you think of any other operation that is commutative?

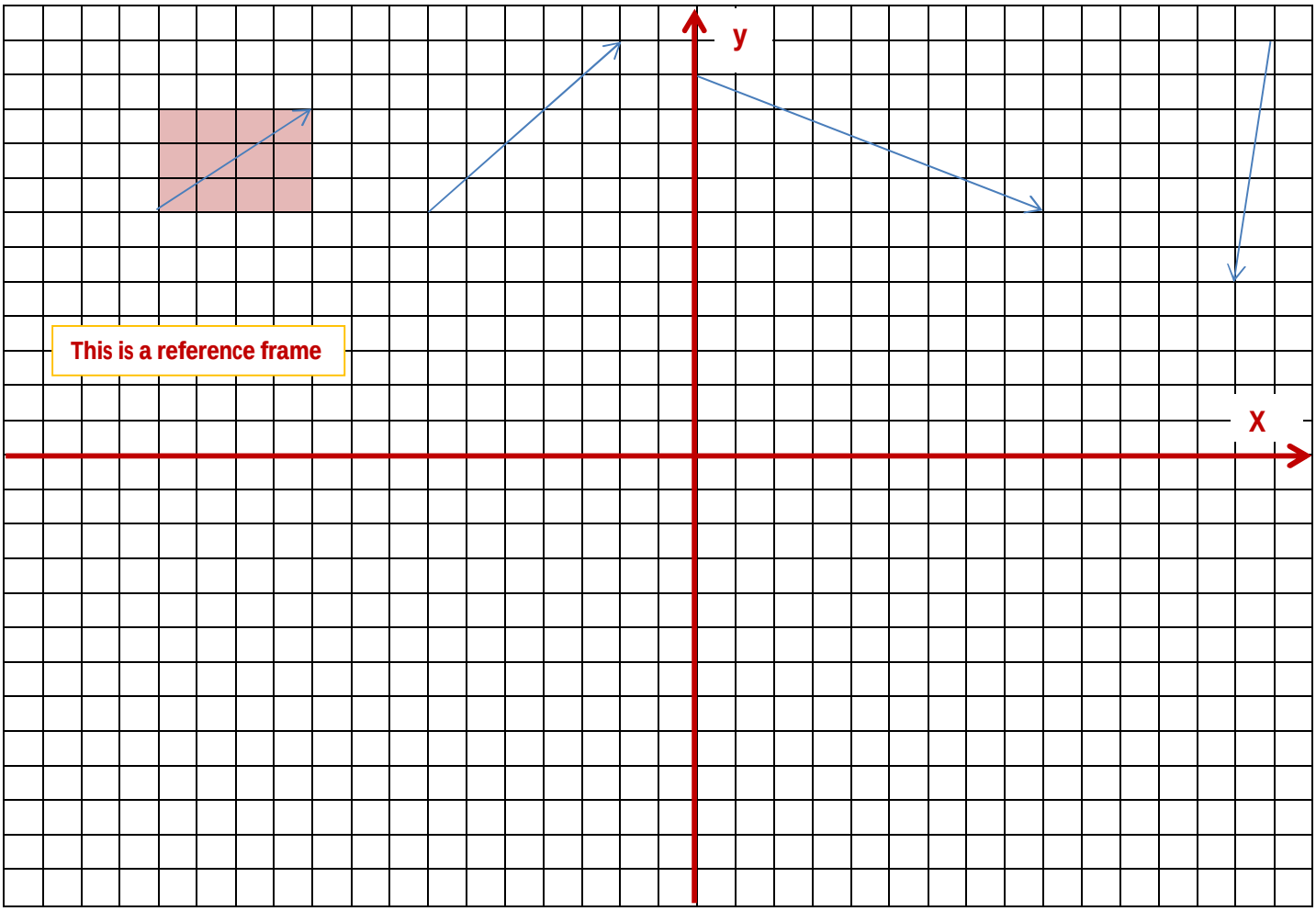
True or false?

- If a vector quantity is multiplied by the number *n*, the resulting quantity is a scalar and *n* times larger.
- If a vector quantity is multiplied by the number *n*, the resulting quantity is a vector in the same direction and *n* times longer.
- If a vector quantity is multiplied by the number *n*, the resulting quantity is a vector in the same direction with the same magnitude.
- If the number *n* is negative, the direction of the vector stays the same.
- If the number *n* is negative, the direction of the vector changes 180° or the vector is flipped.

Exercise
Draw an arbitrary vector, then multiply it by both the numbers 3 and -3 and show the resulting vector.
Make sure you write down the algebraic equation as well as the graphical expression.

Activity 2 – Components of a Vector

In physics and mathematics, most of the times we need to break down our vector into its components! It is called ***vector resolution***. To be able to do so we need a _____. Perform the practice in the grid below.



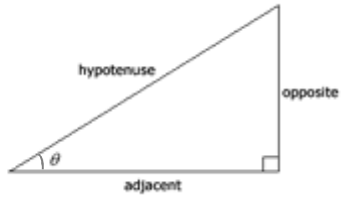
The y-component ÷ the x-component gives the slope of the vector – this is very important, you must remember this!

Trigonometric functions

Trigonometric function are described as the ratios of a right-angle triangle as follows:

$$\sin\theta = \frac{\text{opp}}{\text{hyp}} \qquad \cos\theta = \frac{\text{adj}}{\text{hyp}} \qquad \tan\theta = \frac{\text{opp}}{\text{adj}}$$

$$\csc\theta = \frac{\text{hyp}}{\text{opp}} \qquad \sec\theta = \frac{\text{hyp}}{\text{adj}} \qquad \cot\theta = \frac{\text{adj}}{\text{opp}}$$



Exercise

Label the horizontal dimension x and the vertical dimension y. Now, re-letter the equations above.

	Sin	***Cos***	***Tan***	***Cot***
0°	**0**	**1**	**0**	∞
30°	**1/2**	$\sqrt{3}/2$	$\sqrt{3}/3$	$\sqrt{3}$
45°	$\sqrt{2}/2$	$\sqrt{2}/2$	**1**	**1**
60°	$\sqrt{3}/2$	**1/2**	$\sqrt{3}$	$\sqrt{3}/3$
90°	**1**	**0**	∞	**0**

Spot four important facts about the table above.

.....

.....

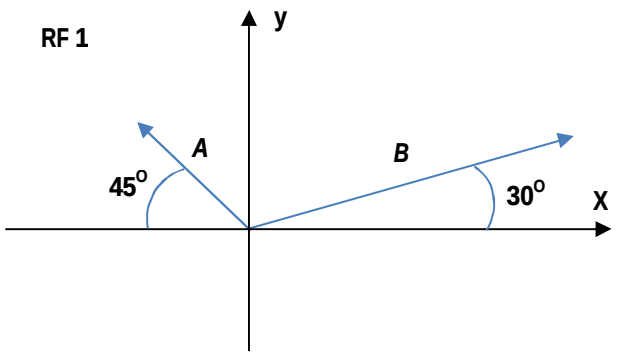
.....

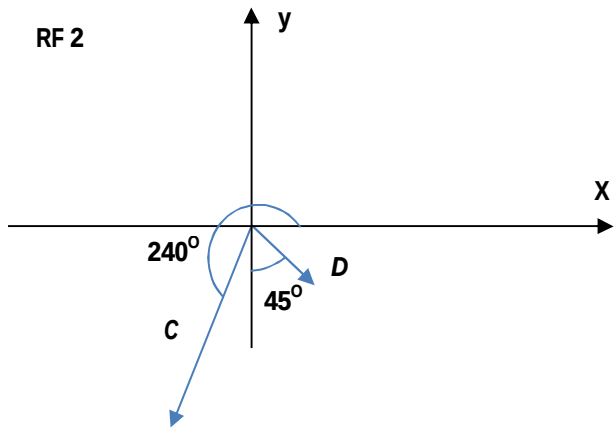
.....

Resolution of vectors using trigonometry

Every vector can be resolved using the trigonometric functions and a reference frame.

Do this activity! *Calculation of vectors using components*
Resolve the vectors below using your trigonometric knowledge and fill in table 1.1.





A = 2 cm, B = 4 cm, C = 3 cm, D = 1 cm.

Table 1.1

Component	A_x	A_y	B_x	B_y	C_x	C_y	D_x	D_y
Trigonometric function								

Now, by adding the vectors, find the *magnitude* and *direction* of the resultant vector in each RF by filling in table 1.2. Remember that for the direction you can ***go graphical***!

Table 1.2

	RF 1	**RF 2**
x-component of the resultant		
y-component of the resultant		
Magnitude of the resultant		
Which way is it pointing to?		

Notes or exercise

.....

.....

.....

.....

.....

.....

Activity 3 – Algebra

In algebra, numbers and phrases are represented by letters and symbols.
In mathematics, you have performed many arithmetic operations using the symbols +, -, ×, ÷. In physics you meet many other useful operations and symbols which you can see in table 1.3.

Table 1.3

Symbol	Meaning	Example
=	Equal to	5 m/s × 3 s = 15 m
∝	Is proportional to	In a spring: Force (F) ∝ x (extension)
<	Is less than	The mass of food a child eats < the mass of food an adult eats
<<	Is very much less than	The diameter of a football << the diameter of the earth
>	Is greater than	The volume of a gallon > the volume of a toothpaste tube
>>	Is very much greater than	The diameter of the earth >> the diameter of a football
≈	Is approximately equal to	5.8 ≈ 6
~	Is the same order of magnitude as	The diameter of the sun ~ 10^6 km

Short, multiple-choice, completion questions, and rearranging equations

What is an equation?
……

What is the subject of an equation?
……

Can you change or rearrange an equation to make any variable or quantity in that equation the subject of the equation?

……

Subtracting is the opposite of …… and adding is the opposite of ……

Dividing is the opposite of …… multiplying and multiplying is the …… dividing.

Taking the square root is the …… squaring and squaring is the …… taking the square root.

Taking the cube root is the opposite of …… and ……

Taking the forth root is the opposite of ……

Whatever you do to one side of an equation (if you add a thing, subtract a thing, multiply a thing, divide a thing, square it, cube it, take the square root, take the cube root, etc.), you …… do the exact same operation to the other side of the equation!

If $\frac{a}{b} = \frac{c}{d}$, ***which of the following is correct?***

$$ab = cd \qquad ac = bd \qquad ad = bc$$

Use the commutative law of multiplication and express the answer in a different outlook. ……

If $a = bc$, ***which of the following is correct?***

$$b = \frac{a}{c} \qquad a = \frac{b}{c} \qquad c = ab \qquad c = \frac{a}{b}$$

Test the above two question by substituting numbers for letters. ……

So using the information above as a general rule, if

$$sand = \frac{brick}{pebble}$$

then which of the following is correct?

$$sand = brick \times pebble \qquad brick = \frac{pebble}{sand} \qquad brick = sand \times pebble$$

The information above is very important and are the steps that you will need to take for changing the subject of any equation.

- *<u>Rearrange</u> equation,* $\frac{a}{b} = \frac{c}{d}$*, to make* d *the subject.*

- *Rearrange the kinetic energy equation,* $KE = \frac{1}{2}mv^2$*, to make* v *the subject.*

- *Rearrange the distance-average speed-time equation,* average speed = distance/time,

to make distance the subject.

to make time the subject.

- *Rearrange the equation for the force in a spring,* $F = kx$*,*

to make k *the subject.*

to make x *the subject.*

- *Rearrange the equation,* $v^2 = u^2 + 2as$*,*

to make s *the subject.*

to make u *the subject.*

Homework 1 – Baseline Test

- **Describe what a one-dimensional problem is and what a two-dimensional problem is.**

- **Write the equation which converts degrees to radians. Then use it to calculate the following:**
  Make sure you use the Greek letter, π, when your answer is in radians.
  - **90° in radians.**
  - **$\pi/3$ in degrees.**
  - **270° in radians.**
  - **2π in degrees.**
  - **$3\pi/4$ in degrees.**

- **There are 360° in a circle. How many radians are there in a circle?**

- **In RF 1, find the resultant vector graphically using the parallelogram method and its magnitude using the cosine law.**

- **Choose 6 multiplying factors to memorise from the table below. If you don't know what a negative power (index) is, read about it and understand it before you carry on.**

Prefix	nano	micro	milli	centi	deci	kilo	mega	giga
Symbol	n	μ	m	c	d	k	M	G
Multiplying factor	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}	10^{9}

Apply your 6 symbol of choice to a unit. For example, I choose my unit to be second for which the symbol is s, and I write: 3 megasecond = 3 Ms = 3×10^{6} s or 1 megasecond = 1 Ms = 1×10^{6} s.

Do you now understand how we convert units when they have prefixes?
For instance, why 1 km = 1000 m or why 2 ms = 2/1000 s or why 10 μm = 10/1000000 m = 1/100000 m?

Graphs

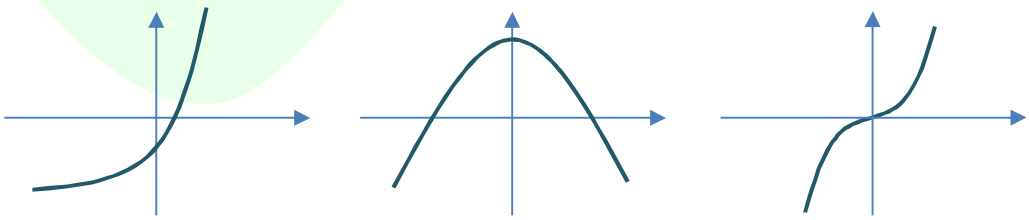
- **Find out what do we exactly mean by 'plotting a graph'.**

- **Write down the generic equation of a straight line.**
  - **What are the two main parameters in the equation of a straight line and what do they represent?**
  - **If there are few straight lines that are parallel to one other, which parameter should be the same in all of the equations?**
  - **If there are few straight lines that cross the y-axis at the same point, which parameter should be the same in all of the equations?**

- **Calculate the gradient of a straight line that crosses the points *A*(3,2) and *B*(5,3).**

- **Write down the equation of a straight line with gradient 2 that crosses point *C*(2,4); what is the intercept of the line?**

- **If the plotted line is not straight but curved, how can we graphically work out how the slope of the curve is changing - explain it in the graphs below. Remember that we always monitor changes moving from left to right in any graph!**



Tutorial 2 – Kinematics: One Direction

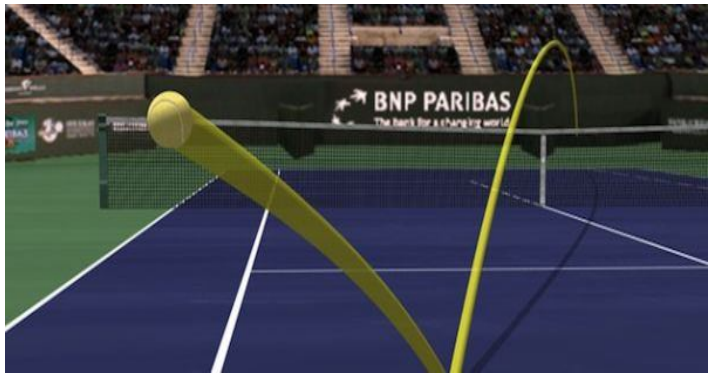


Figure 1. The focus is just to see that a body or an object is moving in a particular pattern, e.g., left, right, up, down, etc. For the time being, we don't want to know what makes them move – this is kinematics, the language of motion!

Kinematics is a branch of mechanics that describes the motion of objects without considering their masses or the forces that cause the motion.

In kinematics: NO MASS, NO FORCE

Today's Key Question(s):

- What physical quantities are used in kinematics?
- What is the difference between distance and displacement?
- What is the difference between speed and velocity?
- To recognise relationships between physical quantities.
- How do you describe acceleration and deceleration?

What is the Purpose of Tutorial 2?

- To understand why we should have different types of physical quantities.
- To learn how to marry mathematics with physics.
- To appreciate zero and negative numbers also as real numbers and that physics uses them just like positive numbers.
- To be able to formulate motion in at least one dimension.
- Improve on interpreting data-graphs in physics.

Activity 1 – Distance, Displacement, and Speed

Distance and displacement are two physical quantities that may seem to mean the same thing; however, they have separate definitions.

Distance is a ..... quantity that refers to .....

Displacement is a ..... quantity that refers to .....

Exercise
Draw an arbitrary path taken by a moving object or person that clearly shows that the distance covered by the object is different to the displacement of it – use the space below.

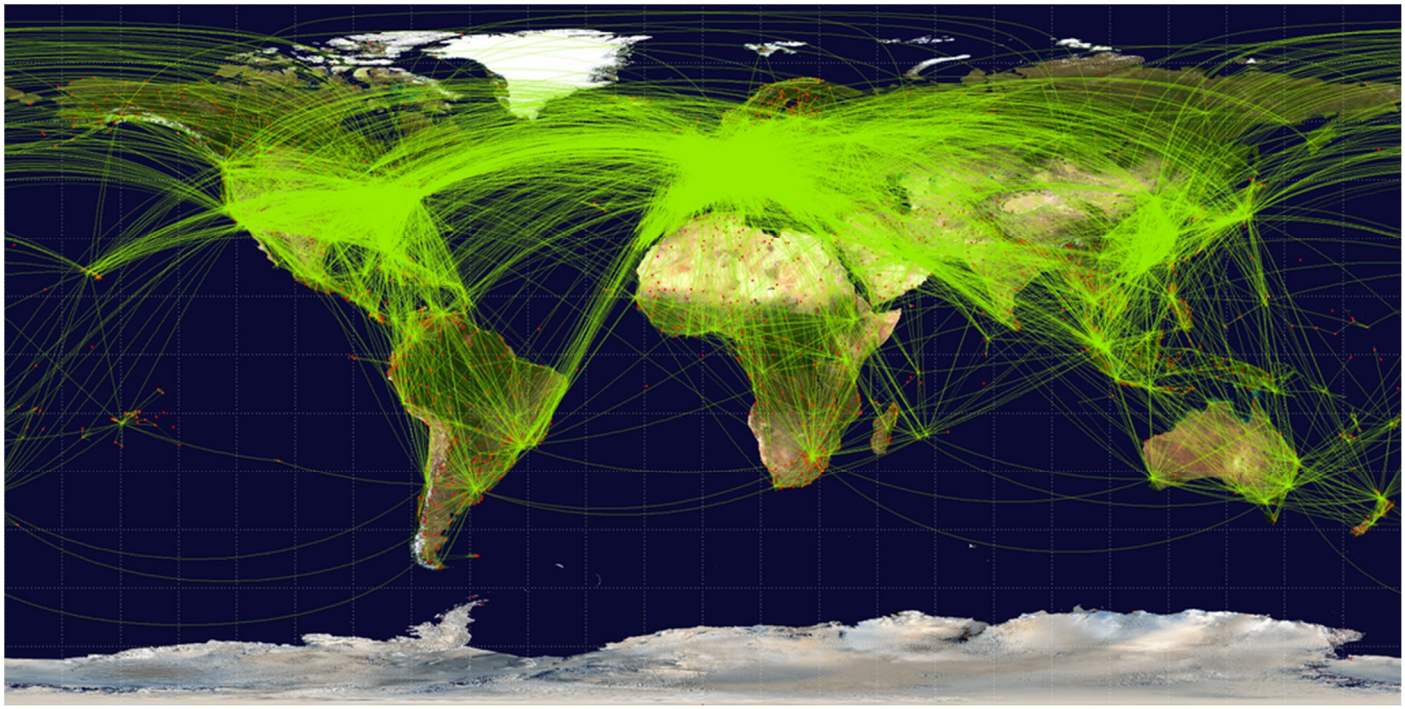


Figure 2.1. The map of scheduled airline traffic in 2009. It is clear that the distance each airplane travels from the start to the end of each route is not the same as the displacement of the airplane from the start to the end of that route. Displacement is always a vector that connects the start of a journey to the end of it. Can you now visualise how distance and displacement are two separate quantities?

Think, pair, and share

What is not different between distance and displacement, in other words, what do these two quantities have in common?

.....

Speed

Speed is a ..... quantity that refers to .....

The unit of speed in the SI or metric system of units is .....

Define speed using its units. Then use it to write down an equation for speed. .....

Mention few other units of speed. .....

Few facts

If you are moving towards a lake with a speed of 10 km/h, at some point you need to change your direction because if you don't, you will fall into it!

When you move east, it is definitely different to when you move west because you get to two different locations!

Mention few more examples which indicate why the direction of motion is very important. And note down what the combination of *speed and direction of motion* is called.

.....

.....

.....

.....

Always remember this as a general rule: if the velocity of an object in a certain direction is v, with having the same ..... in the exact opposite direction, its velocity will be $-v$.

Before moving onto your exercise, remember from now on, when you're doing physics you need to watch the units and be able to convert them if you need to!

Exercise

Write down the equation for average speed – both in words and algebraic form (Δ is a Greek symbol which means change of).

For a cheetah that travels 100 m in 4 s, work out its speed.

Work out what distance a Ferrari can travel with a speed of 200 km/h both over 25 min and over 1hr?

How long it would take to travel a distance of 2800 m at this speed in minutes?

The monorail at Buffer's Theme Park takes people from the visitor centre to the main park and back again. It travels at the same speed on the outward and return journeys. The monorails velocity on the outward journey is 12 m/s. what is its velocity on the return journey?

A car on a motorway travels a distance in 7 min at a speed of 18 m/s. A bus takes 15 min to travel twice the distance.

a) *Calculate the distance and the speed of the bus.*
b) *If the bus and the car start a race, what will be the distance between them in 5 min? Which one is ahead?*

Fill in the blanks

An object moving at a steady or constant ..... travels ..... distance every second.

An object moving at a steady or constant ..... takes the same ..... To travel same .....

Tick in front of the correct statement,

If vehicle A and vehicle B travel at the same speed, they will travel the same distance in the same time.
If we double the speed of vehicle B, the distance it travels doubles/halves for the same amount of time.
If we triple the speed of vehicle A, the time it takes for it to travel the same distance is thrice as much/a third as much.

Activity 2 – Speed and the Distance-Time Graph

Why do we use graphs in physics? We use graphs because they summarise an event in a simple plot. The subject we have studied is about the distances we travel, the speed we are at when travelling those distances, and the time it takes us to do the travel.

Why do we use a distance-time graph?

.....

.....

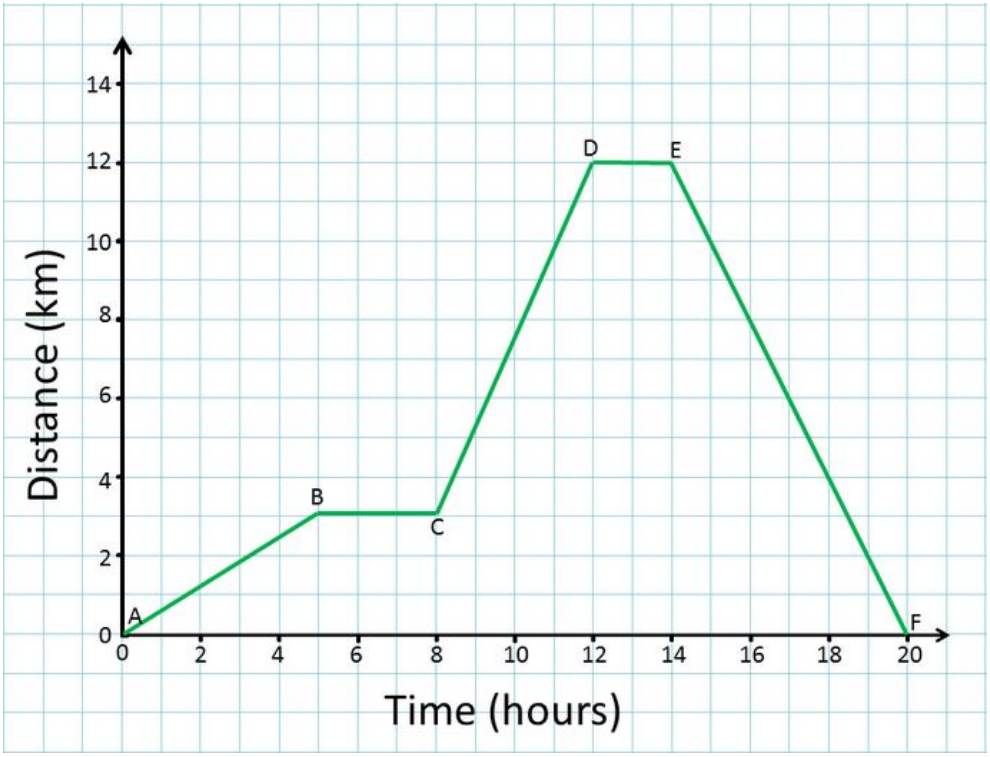


Figure 2.2. The distance-time graph of a certain journey.

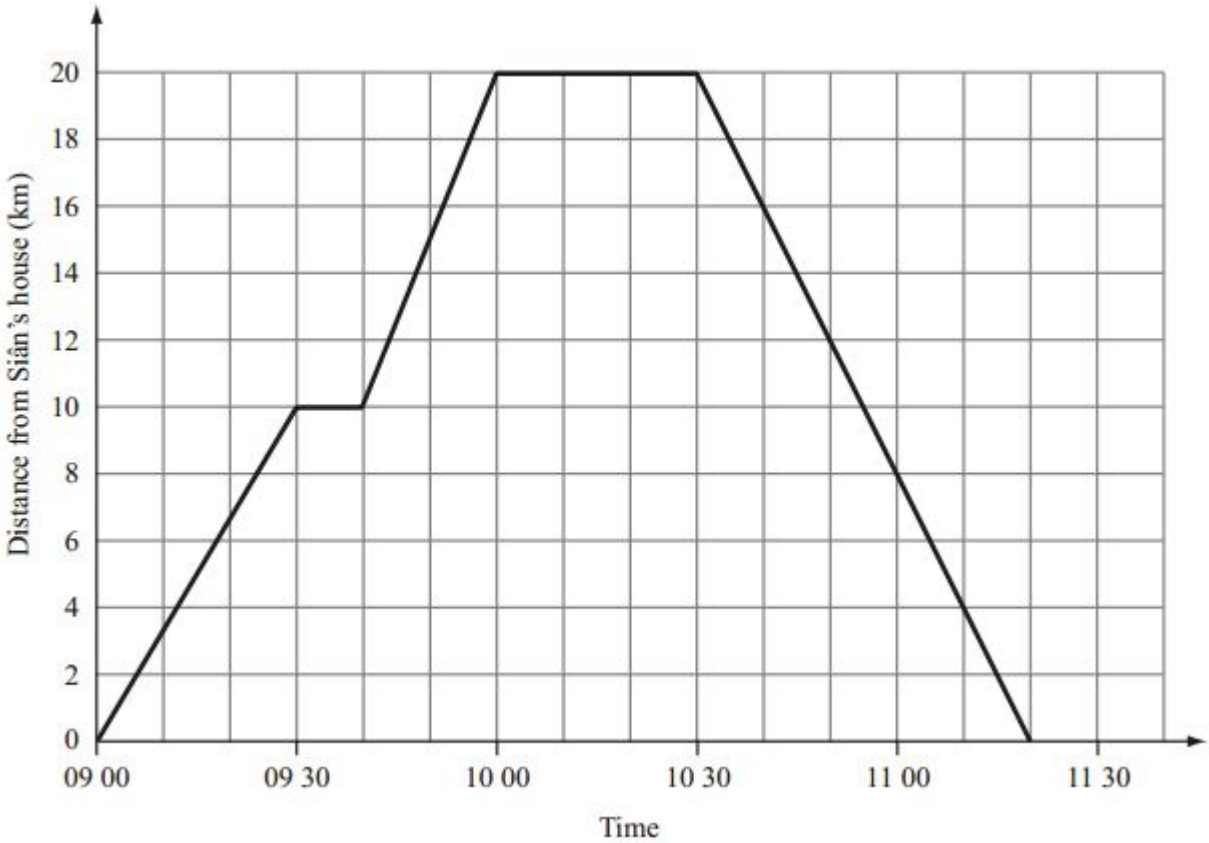
Think, pair, and share

In Fig. 2.2, identify the separate sections of the plot and label them. State what is different between those sections.

Compare the equation for average speed with a fact in tutorial 1. Activity 2 and explain how you can determine the average speed and velocity in a distance-time graph. Now determine the average speed and velocity in each section of the journey.

The steeper the line on a distance-time graph of a moving object, the greater is its .....

Below is Sian's journey from home to library and back home. **Exercise**



a) How far is the library from Sian's house?
b) How far is she from her house at 9:30?
c) At what time did she arrive at the library?
d) How long did she spend at the library?
e) When did she leave the library for home?
f) At what time did she arrive back home?
g) What was Sian's top speed during the whole journey? When and how long was it?
h) Write down Sian's velocity on each segment of her journey.

Activity 3 – Acceleration and the Velocity-Time Graph

The velocity of an object is its *speed* in a given *direction*.
If the velocity of an object changes, we say that the object is accelerating.
In which ways would the velocity of an object change?

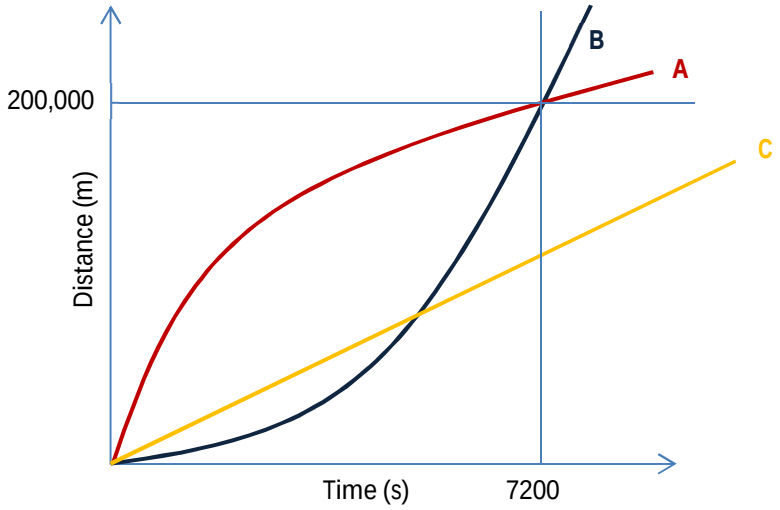
.....

So, acceleration is the rate of change of velocity. In other words, acceleration is the change of velocity per second.

Compare the journeys of vehicle A, B, and C in the distance-time graph below in terms of distance, time, and velocity.
Outline as many ideas as possible.

In curved lines, the tangent at every point is

the line to look at for the slope at that point.



Make use of your knowledge of calculating the average velocity and write down an equation to calculate acceleration.

.....

Introduce the quantities involved and their units. What is the unit of acceleration?

.....

.....

Whenever acceleration has a negative value, we say the object is decelerating meaning that it is slowing down.

Fill in the blanks with the choices given.

greater speed accelerating slope acceleration lower shallower steady steeper velocity decelerating

The slope or gradient of the line on a velocity-time graph represents .....

The ..... the slope of the line of a v-t graph, the ..... the acceleration.

If the line on a v-t graph is horizontal, the ..... is zero, which means that the body is moving at a ..... speed.

If the slope of a line on a v-t graph is negative, the object is .....

Exercise

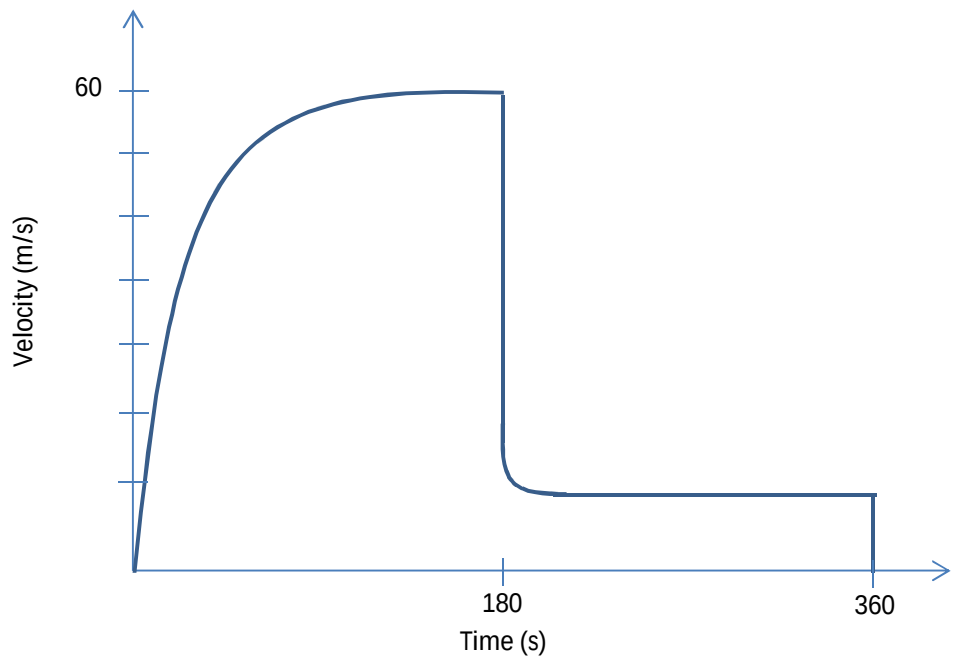


Figure 2.3. The change of velocity of a sky-diver after jumping from an air plane until landing on the ground. After falling for some time, she opened her parachute.

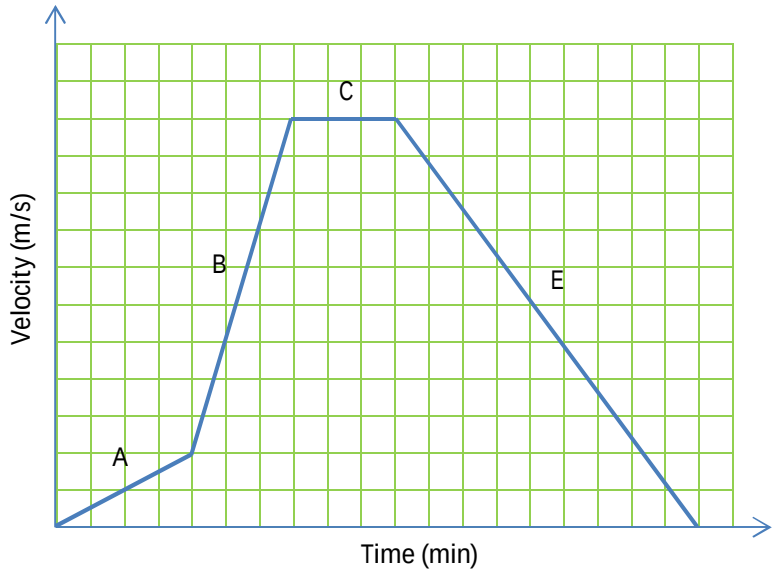
a) What happened at the 180th and 360th second after the sky-diver jumped out of the aeroplane?
b) There was an increase in air resistance on the sky-diver as her speed increased.
Explain how the graph shows this.
c) Two sections of the graph show where the air resistance was equal and opposite to the sky-diver's weight. Which sections are they?
d) Use the graph to estimate how far the sky-diver fell between 180 s and 360 s. Explain why this can only be an estimate figure.

The area under the line on a velocity-time graph gives the distance travelled in a given time. **Exercise**

The bigger the area, the ..... the distance travelled.

At constant acceleration, the average velocity is calculated as,

$$v_{av} = \frac{v_i + v_f}{2}$$



The velocity-time graph of a test drive is shown above.

a) Calculate the acceleration between 240 s and 420 s of the journey.

b) Calculate the total distance the car travels.

c) Complete the sentences below (in terms of acceleration):

The car is ..... on part A of the journey. The car is ..... on part B of the journey.

The car is ..... on part C of the journey. The car is ..... on part D of the journey.

d) Put the four parts of the journey in order of acceleration. .....

e) How can you tell that the acceleration of the car on each part is constant?

.....

f) Calculate the average velocity along the journey. Put them in order of magnitude and compare with part d.

g) At which part of the journey the brakes are applied?

h) At which part of the journey the gradient is negative? How does this translate to the car's acceleration?

.....

.....

Algebraic relationships between distance, velocity, and acceleration

We know the equation for acceleration is,

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

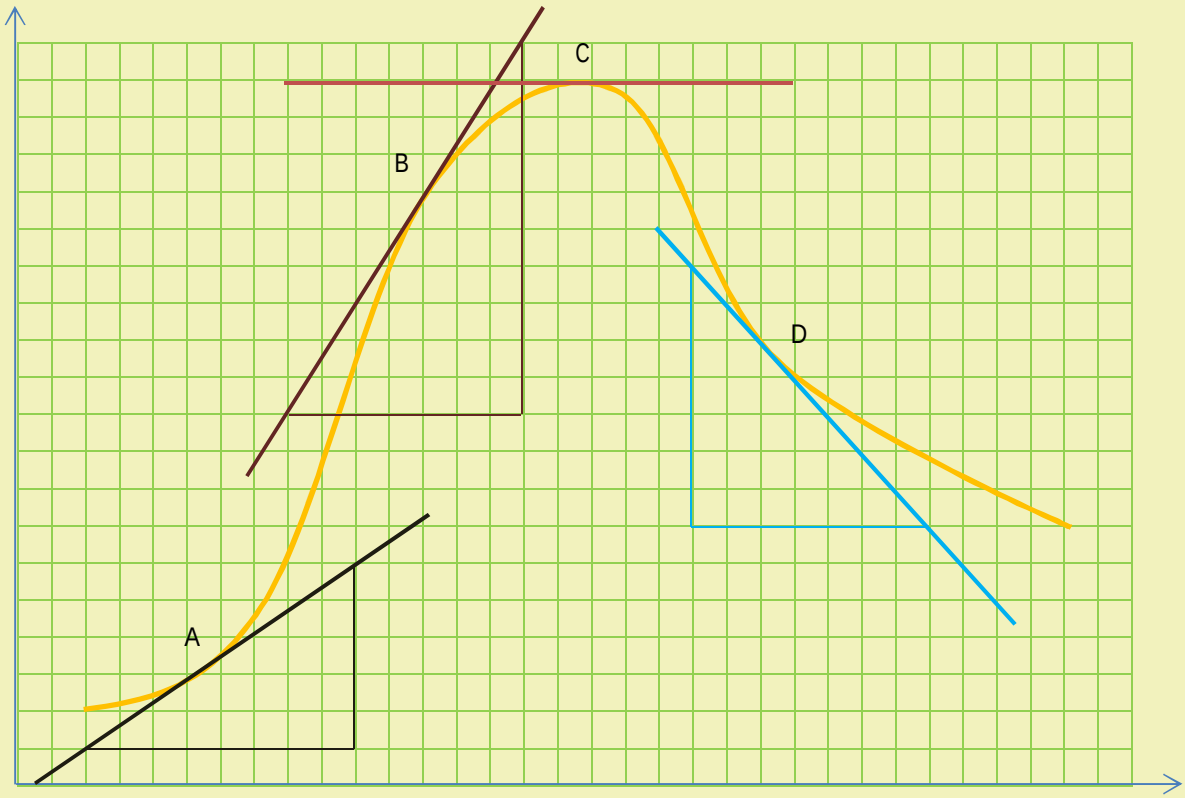
We know the equation for average velocity is,

$$v_{av} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

With constant acceleration, the average velocity is,

$$v_{av} = \frac{v_f + v_i}{2}$$

How to <u>determine</u> the gradient or slope at any point on a curved line.



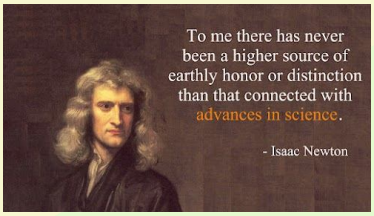
Find out the slope at points specified in the graph. Put the slopes in order of magnitude.

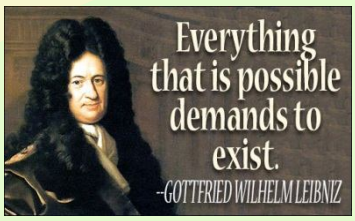
Make comments.

Today's Homework is:

From the list of selected prominent physicists below, choose one and write about their education and their significant discoveries and contributions to physics and science – describe in 500 words; do include a photo of the scientist and a quote which you deem significant.

- *Isaac Newton*
- *James Clerk Maxwell*
- *Ernest Rutherford*
- *Marie Curie*
- *Galileo Galilei*
- *Michael Faraday*
- *Gottfried Wilhelm Leibniz*





- **<u>Define</u> *instantaneous velocity* and <u>compare</u> it to *average velocity. Which graph(s) in this chapter can be associated with instantaneous velocity?***
- **<u>Research</u> the concept of *relative motion*. Give three quantitative examples of relative motion.**
- **Now that you know the equation for speed, explain how speed cameras measure the speed of a vehicle as it passes by.**
- **Rearrange the equation for acceleration to make v_f the subject.**
- **<u>Generate</u> an equation that relates initial and final velocity to acceleration and distance travelled.**
- **In each of the pictures below, depict the instantaneous velocity at three separate points along the trajectories.**

- **The velocity of a car increased from 12 m/s to 34 m/s in 9 s without change of direction. Calculate,**
  - **Its change of velocity**
  - **Its acceleration**
- **A car accelerates from rest to the speed of 35 m/s. What is its acceleration?**
- **An egg is dropped from the top of Eiffel tower and hits the ground in 8 at a speed of 80 m/s.**
  - **Find the eggs acceleration.**
  - **How long did it take for the egg to reach 40 m/s?**
- **A motorcycle accelerates at 2 m/s^2. After 4 s it reaches a speed of 26 m/s. <u>How fast</u> was it going before it started to accelerate?**
- **<u>Show</u> that speed is directly proportional to distance and inversely proportional to time. <u>Denote</u> the proportionalities mathematically.**

Tutorial 3 – Dynamics

In 1589 the Italian scientist Galileo Galilei thought of an experiment to drop two spheres of different masses from the Leaning Tower of Pisa to demonstrate that it would take the same time for both to reach the ground. He had predicted that all objects free-fall with equal acceleration independent of their masses. He was the first scientist to challenge and disprove Aristotle's theory of gravity which states that an object falls at a speed relative to its mass. Later, the law of gravity was formulated by Isaac Newton.

Figure 3.1. Tower of Pisa in Italy.

In Dynamics, we are concerned with the motion of objects under the action of *force*. We are going to find out how kinematic quantities like distance, speed or velocity, and acceleration of an object are related to the force acted on the object. The reason why we do it is because it is force that moves an object over a distance; it is the force that gives an object its velocity; and it is the force that gives the object its acceleration.

Today's Key Question(s):

- Who formulated the relation between force and acceleration?
- Does the mass of an object play any role in its motion?
- What is the difference between mass and weight?
- What is meant by the inertia of an object?
- What forces are naturally and normally opposing forces to the motion of an object?

What is the Purpose of Tutorial 3?

- Application of Newton's first, second, and third law of motion.
- To be introduced to the force of gravity (gravitational force).
- To understand the use of force diagrams in analysing motion.

Activity 1 – Force and Acceleration

A force is a push or pull upon an object resulting from the object's interaction with another object or its surroundings. Force is a vector quantity because:

.....

Use your answer above and answer this: If there are forces acting on an object, does it mean that the object will necessarily move?

……

……

Newton's laws of motion

Newton's First Law

An object will remain at rest or in uniform motion in a straight line (constant velocity) unless acted upon by an external force.

Newton's Second Law

The resultant force acting on an object is proportional to its acceleration – the proportionality factor is the object's mass:
The unit of force is newton or N.

$$\boldsymbol{F} = m\boldsymbol{a}$$

It is obvious from the equation that the resultant force on the object and its acceleration are always in the same direction.

Newton's Third Law

For every action, there is an equal and opposite reaction.
This means that when an object exerts a force on a second object, the second object exerts an equal and opposite force on the second object.

Definition of inertia: a property of matter by which it continues in its existing state of rest or uniform motion in a straight line, unless that state is changed by an external force.

Based on the definition of inertia, which one of Newton's laws can be called 'the law of inertia'?

……

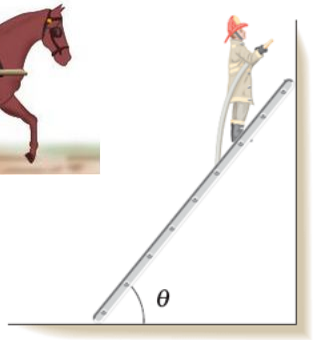
Which one of Newton's laws can be called 'the law of acceleration'?

……

Which one of Newton's laws can be called 'the law of equal interaction'?

……

Application of Newton's third law:



Fill in the blanks with the choices given. They can be used more than once or never.

Inversely acceleration greater mass directly upward downward steady weight resultant force velocity decelerating same opposite decreases accelerates decelerates positive negative speeding up slowing down earth centre

A ..... is needed to change the ..... of an object.

The ..... is a measure of an objects inertia. The inertia of an object is a measure of the difficulty of changing the object's .....

The acceleration of an object is always in the same direction as the .....

The velocity of an object ..... (i.e., it .....) if the resultant force is in the ..... direction as the velocity. In this case, you say that the acceleration is ..... because it is in the ..... direction as its velocity.

The velocity of an object ..... (i.e., it .....) if the resultant force is in the ..... direction as the velocity. In this case, you say that the acceleration is ..... because it is in the ..... direction to its velocity.

..... is a form of force. Its direction is ..... and towards the ..... of the earth.

This is the equation that relates the gravitational force (W) to the gravitational field strength (g):

$$W = mg$$

Compare this equation to Newton's second law and state what kind of quantity is g? ..... Now, conclude what is the unit of g? .....

The acceleration of an object is ..... Proportional to the ..... and ..... proportional to the mass of the object.

Planet	Radius (m)	Mass (kg)	g (m/s^2)
Mercury	2.43×10^6	3.2×10^{23}	3.61
Venus	6.073×10^6	4.88×10^{24}	8.83
Mars	3.38×10^6	6.42×10^{23}	3.75
Jupiter	6.98×10^7	1.901×10^{27}	26.0
Saturn	5.82×10^7	5.68×10^{26}	11.2
Uranus	2.35×10^7	8.68×10^{25}	10.5
Neptune	2.27×10^7	1.03×10^{26}	13.3
Pluto	1.15×10^6	1.2×10^{22}	0.61

What would you <u>conclude</u> from the data given in the table above?

.....

.....

The higher the gravitational acceleration of a celestial body, the ..... the objects weight on that body.

Activity 2 – Problems on Kinematics and Newton's Second Law

In this section, we solve problems that combine kinematic quantities with Newton's second law of motion.

In most physics problems, what is meant by commands such as 'calculate' or 'determine' is to do your working out in the order represented below.

Necessary

(Diagram) equation – substitution – answer – units (evaluation); and to remember: **(diagram) – ESAU – (evaluation)**

Complete performance

Calculate the resultant force on an object of mass 6 kg when it has an acceleration of 4 m/s^2.

Calculate the acceleration of an object of mass 5.0 kg acted on by a resultant force of 30 N.

A car and a trailer have a combined mass of 1400 kg.

a) Calculate the force needed to accelerate the car and the trailer at 2.0 m/s.
b) The mass of the trailer is 400 kg. Determine:
   i. The force of the tow bar on the trailer.
   ii. The resultant force on the car.

Definition of *stopping distance*

Stopping distance is the shortest distance a vehicle can safely stop in, and it is in two parts:

1. **Thinking distance**: the distance travelled by the vehicle during the time it takes the driver to react (during reaction time).
   So, thinking distance = $v \times t$; t is the reaction time.
2. **Braking distance**: the distance travelled by the vehicle during the time the braking force acts.

Now, what do you expect the **stopping distance** to be?

.....

Continue applying the method mentioned above in the questions that follow.

Use the equation for acceleration and derive two equations: one that calculates the braking distance, and one that calculates deceleration. After wards, formulate the stopping distance.

A constant force is used to accelerate a trolley from rest. The force gave the trolley an acceleration of 0.8 m/s^2. Then, a mass of 600 g was fixed onto the trolley which caused the acceleration to reduce by 0.15 m/s^2.

a) Explain why the acceleration decreased after putting the object on the trolley.
b) Now explain what is meant by the inertia of an object.
c) Determine the mass of the trolley.

Describe Fig. 3.2.

.....

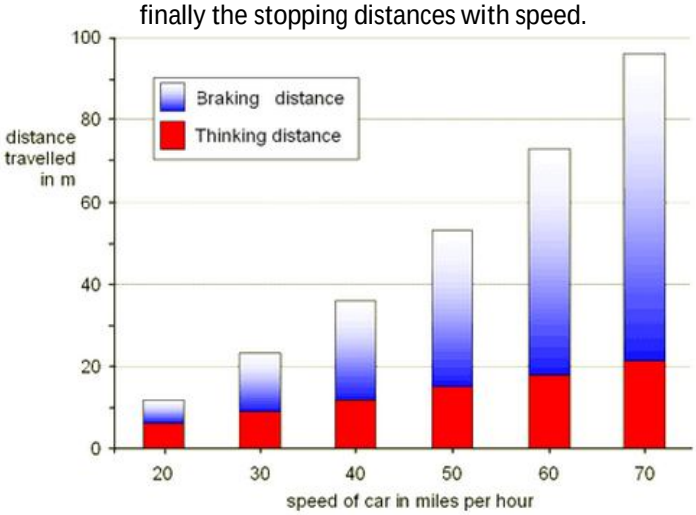
.....

.....

.....

.....

Figure 3.2. variation of thinking, braking, and finally the stopping distances with speed.



Circle the correct answer in the following statements.

- The road surface affects the *braking distance/thinking distance*.
- Poorly maintained brakes affect the *braking distance/thinking distance*.
- The tiredness of the driver affects the *braking distance/thinking distance*.
- Having the same reaction time, higher speeds result in *shorter/longer* thinking distances.
- Having the same reaction time, when the speed of a car is doubled, the thinking distance *doubles/more than doubles*.
- Having the same reaction time, when the speed of a car is doubled, the braking distance *doubles/more than doubles*.

Demonstrate your last two answers.

Is this claim valid that 'braking distance is proportional to the square of the speed'? Yes/No
Use the chart is Fig. 3.2 to examine your response.

A vehicle of mass 2000 kg moving at 42 m/s decelerates and stops in a distance of 65 m.

- Calculate the deceleration of the vehicle.
- Estimate the braking force on the vehicle.

In the last point, why is the question assuming that your answer is an estimation?

.....

.....

Activity 3 – Force Diagrams: Modelling and Idealisation of a Mechanical System

Have you wondered that when you step on a scale what you read is not really your weight – it is your mass because it is in kg. You can calculate your weight by using Newton's second law:

$$f = ma$$

Your weight is the gravitational force acting on you with the gravitational acceleration of g. Therefore, applying Newton's second law to weight, we have:

$$W = mg$$

Because weight is a force, it is a vector quantity so it has a direction. The direction of weight is always downward which means it is toward the centre of the earth. So, in diagrams, always draw the vector of weight pointing down.

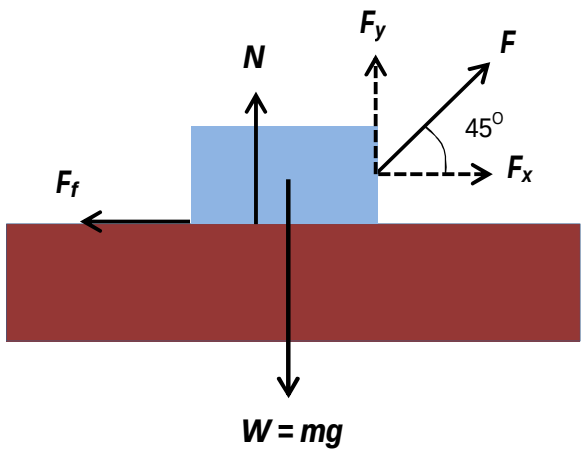
In Dynamics, there are two important forces which are present all the time – name them below and give an example of each separately and in combination through diagrams. State what is their effect on motion commonly.

……. …….

In the picture below, both contests start from rest (they were just holding the ropes and not moving). In which of the events there is motion when the contest starts, and in which direction? Explain why.

……

When analysing problems in force diagrams, always resolve your forces, i.e., project them onto x- and y-axes.



Specifying the resultant forces on x and y as below:

:

$$F_x^R = F_x - F_f$$

$$F_y^R = F_y + N - W$$

If the forces are balanced in both horizontal (x) and vertical (y) axes, we have:

$$F_x^R = F_x - F_f = 0 \rightarrow F_x = F_f$$

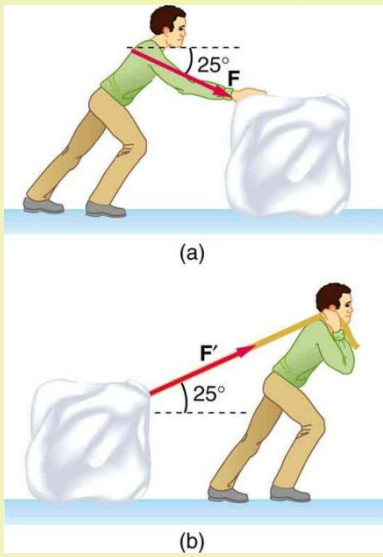
$$F_y^R = F_y + N - W = 0 \rightarrow F_y + N = W$$

If the forces are unbalanced in both horizontal (x) and vertical (y) axes, we have:

$$F_x^R = F_x - F_f = ma_x \rightarrow F_x - F_f = ma_x$$

$$F_y^R = F_y + N - W = ma_y \rightarrow F_y + N - W = ma_y$$

In picture (a) the cube can only move horizontally. The man is exerting a force of F = 80 N on the ice cube. Calculate the acceleration of the ice cube assuming there is no friction between the ice cube and the ground.



Calculate the acceleration if there is a friction force of F_f = 20 N between the ice cube and the ground.

Can you <u>differentiate</u> between the two forces in picture (a) and (b)? <u>Elaborate</u>.

Think, pair, and share

Fill in the blank using one of these words: acceleration speed deceleration

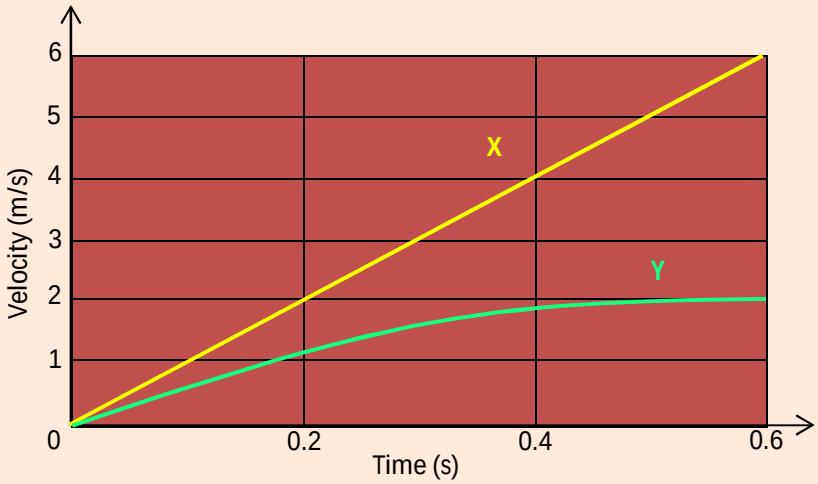
The greater the braking force on a car, the greater the ..... of the car.

Circle which two factors increase the thinking distance? tiredness alcohol brakes tyres road surface weather speed load

Circle the correct answer in an event where a student is pushing a box towards the door.

- The force of the box on the student is *towards/away from* the door.
- The force of friction of the student on the floor is *towards/away from* the door.

The figure below shows the velocity-time graph for a metal object X dropped in air and a similar object Y dropped in a tank of water.



a) What does graph X tell you about object X's velocity and acceleration?

.....

.....

b) What does graph Y tell you about object Y's acceleration?

.....

.....

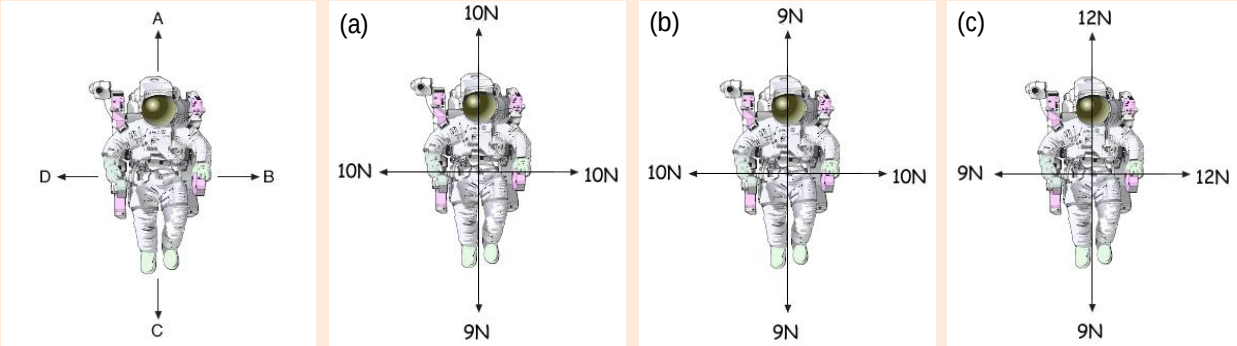
.....

c) Draw the force diagram for both of them and demonstrate why object Y reaches a constant velocity?

What is the phrase associated with the constant velocity that objects reach in such cases when medium resistance counter acts an object's acceleration?

.....

The drawing shows an astronaut in space with a mass of 100 kg. The four small jets attached to his suit produce forces on the astronaut in the direction A, B, C, and D.



(a) According to the size and direction of the forces, in which direction will the astronaut move? Will he accelerate? If yes, determine the acceleration and the resultant force on the astronaut (*now & forever:* ***both magnitude and direction***)?

(b) What happens to the astronaut when the jets produce these four forces? Will he accelerate? If yes, determine the acceleration and the resultant force on the astronaut.

(c) What happens to the astronaut when the jets produce these four forces? Will he accelerate? If yes, determine the acceleration and the resultant force on the astronaut.

The weight of an object of mass 100 kg on the moon is 160 N.

a) Calculate the gravitational field strength on the moon. b) Calculate the weight of the object on the earth's surface.

If you push on a wall with horizontal force of 25 N to the right, what force will the wall exert on you? .....

What happens to an object moving at a constant velocity if the resultant force on it becomes zero? .....

When will a resultant force cause deceleration? .....

What happens to the acceleration of an object if the resultant force on it increases? .....

Porsche 918 Spyder with a kerb mass of 1,650 kg can accelerate from 0 to 60 mph in only 2.3 s. What is its acceleration and driving force?

Today's Homework is:

Read and comprehend. You will be asked questions from the passage below at the beginning of the next tutorial.
You will also be asked to put questions to one another. Before you start, make sure you look up and understand the definition of The science Process Skills.

The Science Process Skills

Introduction

One of the most important and pervasive goals of schooling is to teach students to think. All school subjects should share in accomplishing this overall goal. Science contributes its unique skills, with its emphasis on hypothesizing, manipulating the physical world and reasoning from data.

The ***scientific method***, ***scientific thinking*** and ***critical thinking*** have been terms used at various times to describe these science skills. Today the term "**science process skills**" is commonly used. Popularized by the curriculum project, Science - A Process Approach (SAPA), these skills are defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behaviour of scientists. SAPA grouped process skills into two types-basic and integrated. The basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. These skills are listed and described below.

Basic Science Process Skills

Observing Qualities - using the senses to gather information about an object or event. Example: Describing a pencil as yellow.

Measuring Quantities - using standard and nonstandard measures or estimates to describe the dimensions of an object or event. Example: Using a meter stick to measure the length of a table in centimetres.

Sorting or Classifying - grouping or ordering objects or events into categories based on properties or criteria. Example: Placing all rocks having certain grain size or hardness into one group.

Inferring - making an "educated guess" about an object or event based on previously gathered data or information. Example: Saying that the person who used a pencil made a lot of mistakes because the eraser was well worn.

Predicting - stating the outcome of a future event based on a pattern of evidence. Example: Predicting the height of a plant in two weeks' time based on a graph of its growth during the previous four weeks.

Experimenting - finding out whether our prediction is true. Make a plan, perform, and explain the process and the results. Example: did the object in Kelly's hand go on the same trajectory as I had predicted?

Communicating - using words or graphic symbols to describe an action, object or event. Example: Describing the change in height of a plant over time in writing or through a graph.

Integrated Science Process Skills

Controlling Variables - being able to identify variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable. Example: Realizing through past experiences that amount of light and water need to be controlled when testing to see how the addition of organic matter affects the growth of beans.

Defining operationally - stating how to measure a variable in an experiment. Example: Stating that bean growth will be measured in centimetres per week.

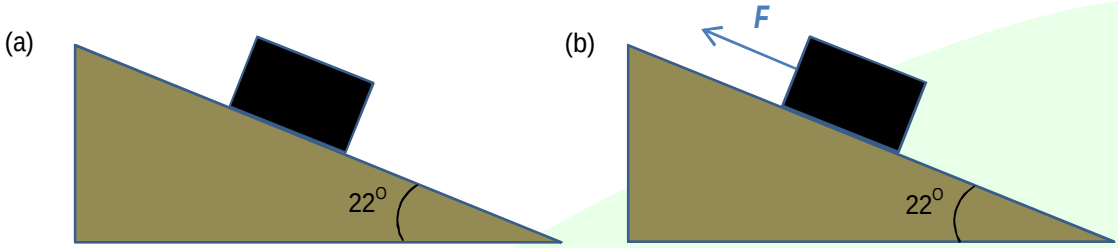
Formulating Hypotheses - stating the expected outcome of an experiment. Example: The greater the amount of organic matter added to the soil, the greater the bean growth.

Interpreting Data - organizing data and drawing conclusions from them. Example: Recording data from the experiment on bean growth in a data table and forming a conclusion which relates trends in the data to variables.

Experimenting - being able to conduct an experiment, including asking an appropriate question, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing a "fair" experiment, conducting the experiment, and interpreting the results of the experiment. Example: The entire process of conducting the experiment on the effect of organic matter on the growth of bean plants.

Formulating Models - creating a mental or physical model of a process or event. Examples: The model of how the processes of evaporation and condensation interrelate in the water cycle.

- **<u>Identify</u> and <u>resolve</u> the forces acting on a box on an inclined surface (a ramp). Draw the force diagram and resolution in two different motions:**
  - **a) When the box is moving downward because of its weight!**
  - **b) When the box is moving upward because of the application of a force!**

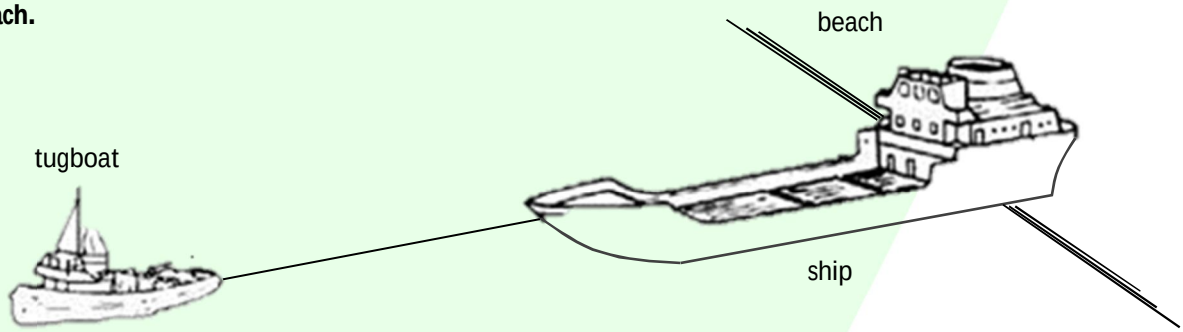


  - **a) If the mass of the box is 5000 g and the force of friction is 15 N, calculate the acceleration to decimal places (both magnitude and direction).**
  - **b) Work out the acceleration if:**
    - **i. *F* = 40 N.**
    - **ii. *F* = 8 N.**

- **Draw a line-graph that shows the change in the frictional force of an object from rest to motion versus the applied force. Describe the graph.**

- **Prove Newton's first law using the kinematic equation for acceleration.**

- **A ship was blown onto the beach in a storm. While the weather became calmer, a tugboat started to pull the ship off the beach.**



  - **a) The tugboat pulls the ship with a force of 25,000 N.**
    - **i. But the ship doesn't move because of the frictional force acting on it. Which of the following is correct about the frictional force acting on the ship?**

      $F_f = 0 \quad 0 < F_f < 25{,}000\ \text{N} \quad F_f = 25{,}000\ \text{N} \quad F_f > 25{,}000\ \text{N}$
    - **ii. Draw a vector on the picture to represent the frictional force acting on the ship.**
  - **b) When the tide is higher, the tugboat pulls the ship again with a steady force of 25,000 N and the ship begins to move. Once the ship is off the beach, the tugboat continues the pull the ship with the same force of 25,000 N while a frictional force of water is now acting on the ship.**
    - **i. At first, the speed of the ship increases. Which of the following describes the frictional force acting on the ship while its speed is increasing?**

      $F_f = 0 \quad 0 < F_f < 25{,}000\ \text{N} \quad F_f = 25{,}000\ \text{N} \quad F_f > 25{,}000\ \text{N}$
    - **ii. After a short while, the ship reaches a steady state. The tugboat continues to pull with a force of 25,000 N. which of the following describes the frictional force acting on the ship while it is going at a steady state?**

      $F_f = 0 \quad 0 < F_f < 25{,}000\ \text{N} \quad F_f = 25{,}000\ \text{N} \quad F_f > 25{,}000\ \text{N}$
    - **iii. The ship is towed to the north-west. What is the direction of the frictional force acting on the ship?**

- **Design a multiple-part question which asks for identification and analysis of forces acting in a cyclist-bicycle system, both at rest and in motion. *For your design, consider different aspects of motion, namely, magnitude and direction of both kinematic and dynamic quantities.***

Choose one of the following tasks,

- **Create a mind-map of the key concepts you have learnt so far and write three lines about each of them (feel free to go above three lines) – choose the map in the format that best suits your thoughts).**
- **Name and frame the key physical quantities that you have learnt so far with three lines about each of them (feel free to go above three lines) – choose the frame in the format that best suits your thoughts).**

Tutorial 4 – Formulation of the Conservation of Energy and Momentum

Figure 4.1. Every moving object has kinetic energy and momentum. If you are moving then you have them. If you move down a hill, the force of gravity gives you acceleration which makes you move faster giving you more kinetic energy and momentum. As you are speeding up, at one point you feel unable to control yourself and that is when we say your momentum takes over and keeps you moving but this time on the floor rolling! The pictures above show exactly that! It shows a British tradition called 'Cheese Rolling'. It is an annual competition held on the spring bank holiday at Cooper's Hill in the vicinity of Gloucester.

Kinetic energy is the energy that a moving object has.
Momentum is a measure of how difficult it is to stop a moving object, or the tendency of a moving object to continue moving.
If an object is stationary, both its kinetic energy and momentum are

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Today's Key Question(s):

- What is the kinetic energy of an object dependent on?
- What is the gravitational potential energy of an object dependent on?
- What is the momentum of an object dependent on?
- What is the mathematical relationship between kinetic energy and momentum?

What is the Purpose of Tutorial 4?

- To understand the concept of conservation of energy.
- To understand the concept of conservation of momentum.
- To be able to apply conservation of energy and conservation of momentum to physical problems.

Activity 1 – Introduction of Key Concepts and Methodologies

Any object that moves has an energy called kinetic energy and momentum due to its motion.

$$\text{KE} = \frac{1}{2}mv^2$$

$$\boldsymbol{p} = m\boldsymbol{v}$$

Any object that is elevated has an energy called gravitational potential energy.

Interpret the equation for the gravitational potential energy (GPE) below considering the airplane's motion.

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$$\text{GPE} = mgh$$

***Conservation*: The principle by which the total value of a physical quantity remains unchanged unless it is subject to an external influence.**

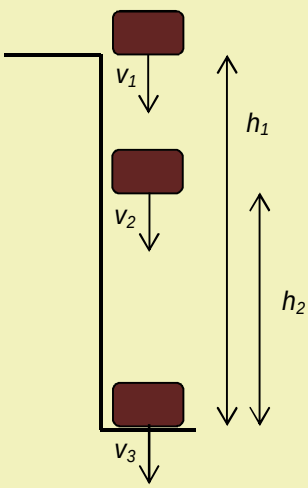
When there is only the gravitational force present, the conservation of energy can be expressed as the conservation of *mechanical energy* as follows:

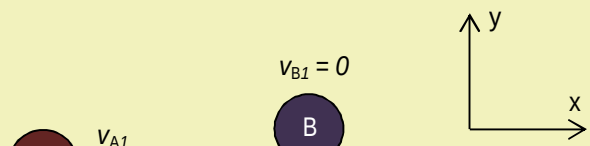
$$\text{KE}_i + \text{GPE}_i = \text{KE}_f + \text{GPE}_f$$

Conservation of momentum (momentum is a vector quantity) is mathematically expressed as follows:

$$\boldsymbol{p}_i = \boldsymbol{p}_f \rightarrow \begin{cases} p_{ix} = p_{fx} & \text{For the x-component:} \\ p_{iy} = p_{fy} & \text{For the y-component:} \end{cases}$$

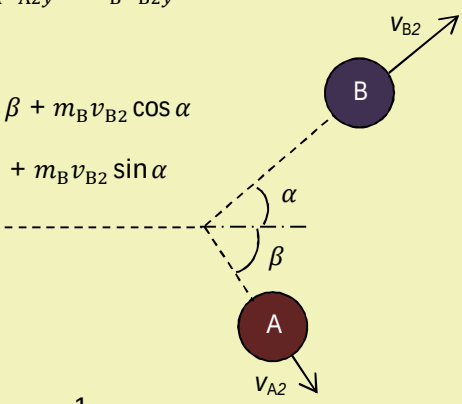
Momentum is conserved in any collision, explosion, firing shots, or jet propulsion provided that no external forces are acting on the objects involved in the event.





$$\begin{cases} m_A v_{A1x} + m_B v_{B1x} = m_A v_{A2x} + m_B v_{B2x} \\ m_A v_{A1y} + m_B v_{B1y} = m_A v_{A2y} + m_B v_{B2y} \end{cases}$$

$$\begin{cases} m_A v_{A1} + 0 = m_A v_{A2} \cos\beta + m_B v_{B2} \cos\alpha \\ 0 + 0 = -m_A v_{A2} \sin\beta + m_B v_{B2} \sin\alpha \end{cases}$$



$$\frac{1}{2}mv_1^2 + mgh_1 = \frac{1}{2}mv_2^2 + mgh_2 = \frac{1}{2}mv_3^2 + mgh_3$$

$$\frac{1}{2}m_A v_{A1}^2 + 0 = \frac{1}{2}m_A v_{A2}^2 + \frac{1}{2}m_B v_{B2}^2$$

Activity 2 – Identify and Analyse Physical Phenomena

Think, pair, and share

Explore the Energy Skate Park simulation. Identify the laws of physics, compare and contrast their application through the variation of relevant physical quantities.

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We are going to take the methodology expressed earlier to a more professional level.
This method must be obeyed over any physical problem.

Previously:

Necessary

(Diagram) Equation – Substitution – Answer – Units (Evaluation); and to remember: **(Diagram) – ESAU – (Evaluation)**

Complete performance

Now: It's **DICE**. *It demonstrates the whole thinking process.*

Diagram – Identify – Calculate – Evaluate

Note that this is an encompassing method in which Calculate means ESAU all together. **Identify** means identify the physical quantities, conditions, and laws of physics involved in the question (examples of laws are Newton's laws or laws of conservation).

A 2000 kg truck moving at a velocity of 18.0 m/s on a level road collides with a stationary vehicle of mass 1200 kg. The velocity of the truck is reduced to 10.0 m/s as a result of the collision.

a) Calculate the momentum of the truck:
   i. Before the collision.
   ii. After the collision.
b) For the 1200 kg vehicle after the collision, calculate:
   i. The momentum.
   ii. The velocity.

Conservation of momentum **Exercise**

A 1000kg rail wagon moving at velocity of 5.0 m/s on a level track collides with a stationary 1500 kg wagon. The two wagons *move together* after the collision.

a) Calculate the momentum of the 1000 kg wagon before the collision.
b) Show that the two wagons move at a velocity of 2.0 m/s after the collision.

Activity 3 – Equilibrium

Equilibrium is a state or condition in which an object is stationary. This does **not** mean that there are no forces acting on the object but it means that however many or however great the acting forces are, the resultant force is zero.

You are expected to identify a law in physics which is in correlation with equilibrium – what is it?

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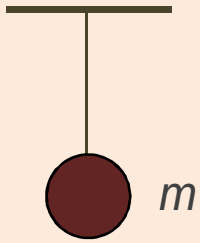
Think, pair, and share

Perform the exercises below. Remember DICE!

Most often, questions about equilibrium are already presented with a diagram. However, remember to label any diagram at all times, whether the diagram is given in the question or is your own!

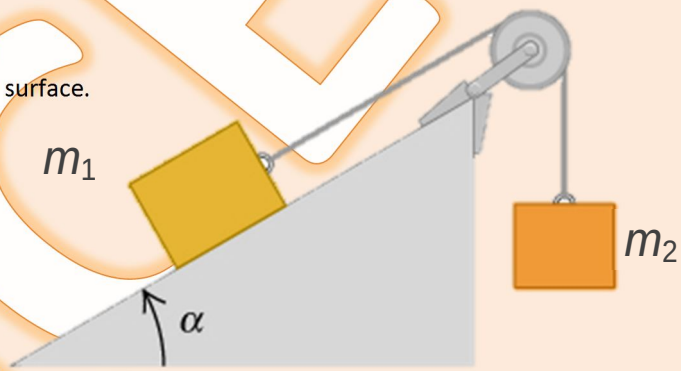
The object in the figure on the right is hanging on a rope and is stationary.

a) What can you say about the forces acting on it?
b) If the tension along the rope is T = 80 N, find the mass of the object.



The inclined surface on the right is attached to the ground and $m_1 = 3m_2$. Assume that there is no friction between m_1 and the surface.

a) If the weights are accelerated at 1.5 m/s^2, find the angle of the incline and the direction of motion.
b) At which angle of incline the system will be at equilibrium?



The Tiffany light shade on the right is in equilibrium. The suspension chains are equally spaced and each make a 30° angle with respect to the surface normal. If the hanging shade itself is 12 kg, calculate the tension along each of the suspension chains.

DICE

Today's Homework is:

Read, comprehend, and answer the following questions.

The question of weight

Weight is something we are all familiar with and take very much for granted. You now understand that it is about the force of gravity acting on a mass. In the past, this realisation had a big impact on science. Sir Isaac Newton attempted to explain why the Earth didn't fall apart as it spun on its own axis. Many people thought the Earth can't be spinning because it would fall apart if it was. Newton worked out that the force of gravity was easily strong enough to stop the Earth falling apart. Newton suggested a way the Earth's spinning motion could be tested: dropping an object from the top a very tall tower.

The commonly accepted theory was that the object would fall to Earth behind the tower. Newton said that as the top of the tower was travelling much faster than the surface of the Earth, it would fall in front of the tower. Unfortunately, there was not a tower tall enough to test the prediction!

Newton even worked out that gravity would eventually take the object to the centre of the Earth if it were able to go through the Earth. Robert Hooke pointed out an error in Newton's thinking and suggested it would follow an ellipse around the centre of the Earth.

Newton worked on this idea and many years later Edmund Halley used Newton's calculations to work out when a comet would return to be seen from the Earth. Halley died aged 85, some 16 years before his prediction about the comet was proved to be correct.

Use this passage to help you to answer these questions.

a) The observation that the Earth did not fall apart as it rotated produced which hypothesis from Newton?
b) What was the prediction that was made from this hypothesis?
c) What was the unscientific expectation for the object falling from the tower?
d) What was the technology that was missing to test this prediction?

Theories are there to be tested. Newton's theories about motion needed to be tested.

e) What was Halley's prediction that had been based on Newton's theories?
f) Did Halley's prediction support Newton's theory? How do you know?

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FLIPPED LEARNING

The work you have been asked to do below is for the purpose of acquiring good knowledge in your individual learning space across the subject in question on which the next tutorial (Tutorial 5) is based. Therefore, you explore the subject matter individually. In Tutorial 5, you will have your group space to apply what you have learnt to new problems that will be given to you by your teacher. You are expected to engage creativity and generate an interactive learning environment in your group and with your teacher – your teacher will be dynamic and flexible in guiding you in your discussions and solutions.

The concepts that you are going to be applying in Tutorial 5 are embedded in the activities below:

- **Research what is the frictional force proportional to, and state the proportionality constant. Then introduce the equation for calculating frictional force.**

- **Consider the inclined surface question in Tutorial 3/Homework/second page. Solve the question again but this time there is friction between m_1 and the surface with a coefficient of friction $\mu = 0.2$.**

- **<u>Designing questions</u>.**
  Make sure when you design your question, you write the relevant equations down for the calculation of the quantities involved and describe whatever equation you derive and your working out.
  a) ***Elastic collisions*: Design a question that involves the collision of two objects and requires both the conservation of momentum and conservation of kinetic energy to determine the kinematic and dynamic quantities involved in the problem in the two conditions below:**
     i. **A collision of two objects that results in a one-dimensional motion.**
     ii. **A collision of two objects that results in a two-dimensional motion.**
  b) ***Inelastic collisions*: Design a question that requires only the conservation of momentum to determine the kinematic and dynamic quantities involved in the problem in the two conditions below:**
     i. **Two moving objects collide and stick together after the collision.**
     ii. **A gun firing a bullet.**

- **Research and gain understanding of the concept of Impact Force and Impulse.**
  a) **Design a question, give the solution with explanation.**
  b) **Present a graph which shows the change in the impact force on an object versus the time of the impact.**

Resources

http://www.iop.org

http://www.nuffieldfoundation.org

https://blossoms.mit.edu

http://sciencenotes.org

http://www.physicsclassroom.com

http://www.cpalms.org

http://www.mathcentre.ac.uk

http://www.physics247.com

http://www.real-world-physics-problems.com

Tutorial 5 – Cognitive Thinking through Peer Interaction and Teacher Challenge

In this tutorial, students apply the concepts and ideas learnt outside of classroom to new and challenging problems inside the classroom given by the teacher. They use their collective knowledge and skills as a team to tackle the questions. Teacher sets challenges and facilitates discussion – your teacher is still a valuable resource, but ultimately you should do the work!

Today's Key Question(s):

- How well were you able to perform the tasks that were set out to you?
- How well do you understand the concepts and ideas that were involved in the problems?
- Any questions?

What is the Purpose of Tutorial 5?

- To promote independent learning.
- To agreeably blend independent learning with interactive learning.
- To make way for further opportunities of independent and team working.
- To enhance their subject knowledge and enthusiasm.

Activity – Problems and Questions will be set for Students to Solve.

Final Assignment:

The Scientific Method

Give answers to the questions below:

- What is science?
- Present an example of a scientific research.
- Define the term 'Phenomenon'.
- Describe the terms 'Observation' and 'Measurement'. Give an example of both.
- What is the information acquired from measurements called?
- When we say our data is reproducible, what do we mean by that? Give an example of reproducible data.
- When can you say that your data is reliable?
- When will you be able to use the data as evidence? Give an example of an experiment after which the data were used as evidence, and one example of an experiment after which the data could not be used as evidence.
- How can evidence be used by a scientist? Give an example.
- Define the term 'Hypothesis'.
- Name 8 prominent figures in the history of science or philosophy that proposed ideas - believable by people and other scientists or philosophers at their times - about:
  i. The universe or our solar system.
  ii. Force and motion.

Questions

- **A 1000 kg rail wagon moving at a velocity of 5.0 m/s on a level track collides with a stationary 1500 kg wagon. The two wagons move together after the Collision.**
  a) Calculate the momentum of the 1000 kg wagon before the collision.
  b) Show that the two wagons move at a velocity of 2.0 m/s after the collision.
- **A 30kg skater and a 40 kg skater standing in the middle of an ice rink push each other away. Complete and answer the following sentences and questions (use the words below if relevant).**

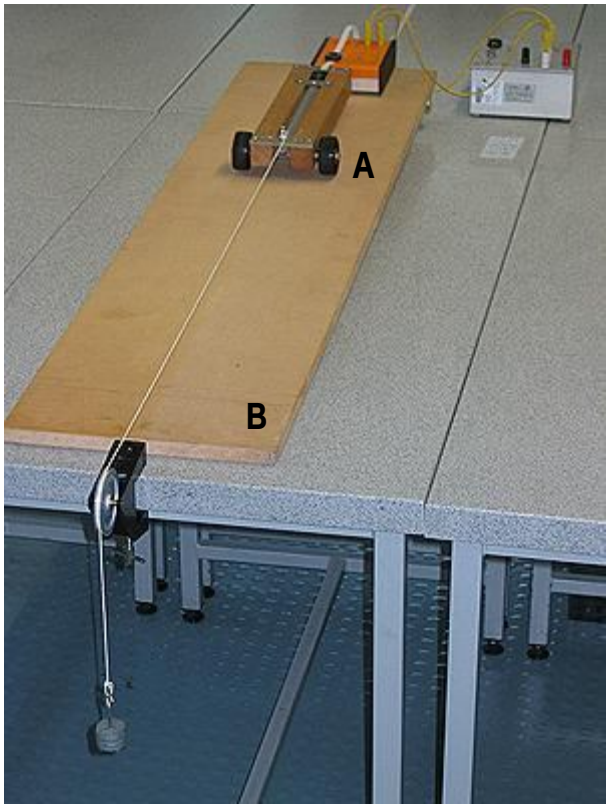
  Force Momentum Velocity

  a) They move apart with equal and opposite .....
  b) The 30 kg skater moves away with a bigger ..... than the other skater.
  c) They push each other with equal and opposite .....
  d) The 30 kg skater moves away at 2.0 m/s. Calculate:
     i. Her momentum.
     ii. The velocity of the other skater.
- **Answer the closed questions below.**
  a) If you push on a wall with a horizontal force of 15 N to the right, what force will the wall exert on you?
  b) What happens to an object moving at a constant speed if the resultant force on it is zero?
  c) When will a resultant force cause deceleration?
  d) What happens to an acceleration of an object as the resultant force on it increases?
  e) What is the effect of the speed of a vehicle on its stopping distance?
  f) What is terminal velocity?
  g) What is the decrease in gravitational potential energy when an object of mass 6 kg is lowered a distance of 9m?
  h) What is the kinetic energy of a car of mass 1200 kg travelling at 30 m/s?
  i) What is the unit of momentum?
  j) Why is a gymnast less likely to injure herself if she lands on a thick foam mat than if she lands on a hard floor?
- **A car of mass 1500 kg is moving at a speed of 30 m/s on a horizontal road when the driver applies the brakes and the car stops 12 s later.**
  a) Calculate the initial momentum of the car before the brakes are applied.
  b) Calculate the braking force.
  c) Describe how the momentum of the car changes when the brakes are applied.

d) Discuss the effect on the motion of the car if the brakes had been applied with much greater force.

- **A student investigated how the pulling force on a trolley affected the acceleration of the trolley between two points. The apparatus is shown in the figure below.**

The trolley was held at position **A** and weights were suspended by a hook. The trolley was then released and the time taken to travel between **A** and **B** was recorded. The test was repeated using weights with different values.



a) List the factors that should remain constant (the control variables) during the investigation.

b) The results of the investigation were recorded in the table below.

F (N)	100	200	300	400	500
a (m/s^2)	0.25	0.50	0.65	1.00	1.25

Plot a graph of the results.

c) Identify which one of the results is anomalous and suggest a reason for this anomalous result.

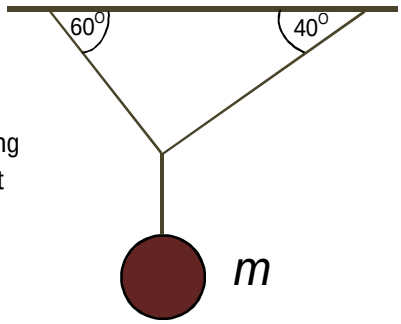
d) The student predicted that if the force was doubled, the acceleration would also be doubled. Describe how the graph can be used to confirm his prediction.

e) A stopwatch was used to measure the time taken for the trolley to travel between points A and B. Another student suggested that light gates attached to a data logger would improve the investigation. Give two advantages of using light gates and a data logger to measure the acceleration.

- **Two ropes are connected to a steel cable that supports a hanging weight.**

a) Draw a free-body diagram showing all of the forces acting at The knot that connects the two ropes to the steel cable. Based on your force diagram, which of the two ropes will have the greater tension?

b) If the maximum tension either rope can sustain without breaking is 5000 N, determine the maximum value of the hanging weight that these ropes can safely support. You can ignore the weight of the ropes and the steel cable.



- **Optional question.**
Give values to the man-standing-on-the-ladder problem you drew the force diagram earlier and find the force of friction between the ladder and the ground.

- **A man jumps out of his boat onto a stepping stone. He would naturally have to push his boat backward to gain speed or motion.**

If the mass of his boat and himself are 90 and 80 kg, respectively, and the boat gains a speed of 20 m/s after the push, determine the velocity of the man. Assume that there is no friction between the water and the boat, and the boat remains motionless.

Tutorial 6 – Feedback

What is the Purpose of Tutorial 6?

- Reflect on skills learned on the programme with a view to encouraging resilience
- Receive feedback on final assignment

What are the key questions?

- What strengths have I demonstrated in my work and what areas of development are there left for me to address?
- What steps do I need to take to improve my academic output?

Activity 1 – Marking your own

Using the mark scheme, identify three things you did well and three things you could improve.

What went well?

1.

2.

3.

What could be improved?

1.

2.

3.

Activity 2 – Responding to feedback

Read through your feedback sheet and highlight on your assignment where you received positive feedback (one colour) and areas for improvement (different colour). You might find it helpful to annotate this with a brief comment or two.

Activity 3 – Looking Forwards: Think, Pair Share

1. Think about how you can use this feedback in your future school work.
2. Talk to your partner about how you both plan to make changes to your school work in the future as result of this feedback
3. Share your ideas as a group.

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

A marker in your assignment: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].

Bibliography: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

Websites – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

Books – Author, date published, title of book (in italics), pages where the information came from.

E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

Articles – Author, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), date of the article.

E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', *Guardian*, 10 July 2014.

Appendix 2 – Using the VLE

VLE username	
VLE password	

Please remember the following key details…

- You are able log into the VLE either through the link on our website (**www.thebrilliantclub.org**) or going directly to the VLE site at (**vle.thebrilliantclub.org**).
- Please update your profile with your full name and email address- this will allow you to retrieve forgotten passwords or usernames
- If you forget your log-in details you can request them to be emailed to you by clicking the link on the VLE home page. (If you are still having problems you can email: **schools@thebrilliantclub.org**)

What is the VLE?

The VLE is a virtual learning environment for all pupils on the Scholars Programme it is used for:

- messaging your tutor
- submitting homework
- submitting your final assignment
- accessing resources for your tutorials
- finding out more information about university and careers

How should I use the VLE?

The VLE is a professional academic environment in which pupils are able to message their PhD Tutor. Here are a few things to consider:

- Ensure you keep a professional tone in the messages you send to your tutors.
- Ensure you always reply to your tutors in a timely manner.
- Thank your tutor for the effort they are putting in to give you your feedback etc.
- Submit all homework to your tutor on time.

IMPORTANT: Final assignment

- When you submit your final assignment, please remember that you need to do so through the **'My Activities'** tab and not as an attachment to a message.

Appendix 3 – University Applications Guidance

For course choices and careers information:	www.brightknowledge.org.uk
For information and statistics on universities and course:	www.unistats.direct.gov.uk
For comprehensive information on universities, including rankings:	www.thecompleteuniversityguide.co.uk

PLEASE NOTE – The Scholars Programme is designed to support the university applications process at your school. The work you complete for the programme should add to your schoolwork rather than detract from it. Please be aware of deadlines and try to manage your workload appropriately. If you are worried about the Scholars Programme interfering with your schoolwork then please speak to your teacher.