Progression - Engineering

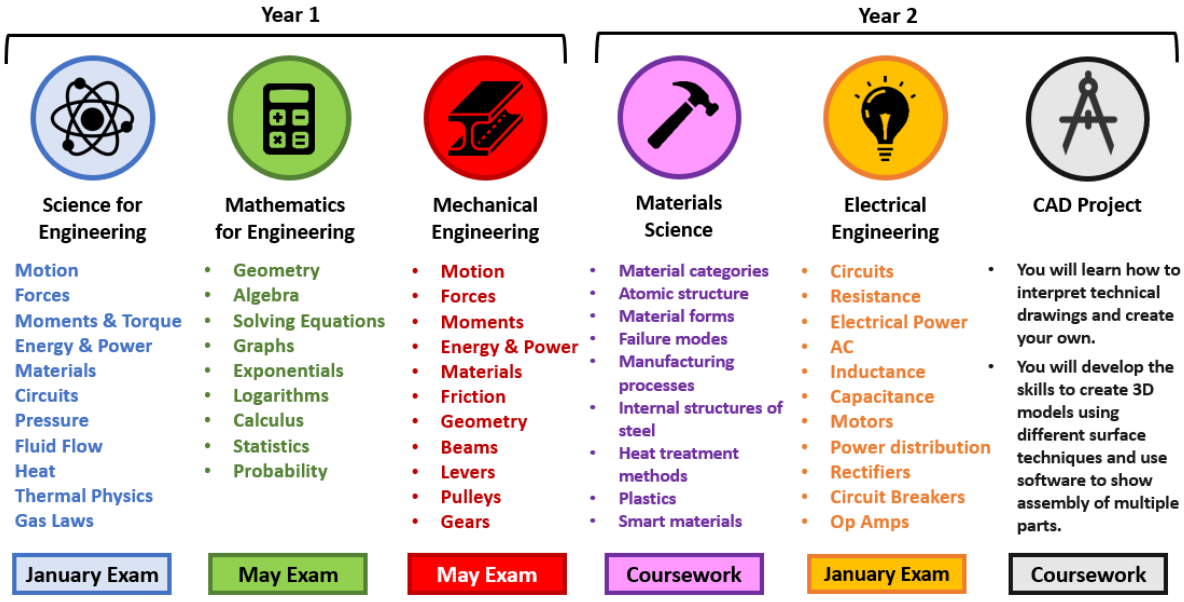
Contents:

- **What is Engineering? What will you study? How do we support you at Worcester Sixth Form College?**
- **Introduction Video: https://youtu.be/ve8ofgnKP_M**
- **Bridging Tasks (to complete before September):**
  1. Engineering Essentials – Measurements and SI Units
  2. Mechanical Engineering Basics – Kinematics
  3. Electrical Engineering – Circuit Symbols and Electrical Current
  4. Materials Engineering Fundamentals – Density and F-x Graphs
  5. Definitions Crossword
  6. Memorising Prefixes Task
  7. Solutions
- **Getting ready for September**

What is Engineering? What will you study? How do we support you at WSFC?

What is Engineering? Engineers are fantastic problem solvers that use a combination of **maths** and **physics** to understand and investigate the world around them. There are many types of engineers including mechanical engineers, electrical engineers, CAD engineers and material engineers. Over two years, you will learn about the fundamental concepts in each of these disciplines and discover strategies that will enable you to solve a huge variety of problems.

What will we study? The course is split into 6 modules: **maths**, **science**, **mechanics**, **materials**, **electronics** and **CAD** (computer aided design). The first year of the course is assessed by 3 written examinations with a high degree of mathematical content. You will be expected to use a formula book to rearrange and solve equations in nearly every Engineering problem you are faced with. This course is designed to get you to **think** like an Engineer, and provide you with the advanced mathematical tools and strategies needed conquer any problem!



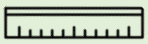
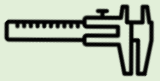
At the end of two years you will gain a *Cambridge Technical Extended Certificate in Engineering* – an A-level-equivalent that is highly regarded by employers and many universities. This will allow you to progress onto University Engineering degrees (with A-level Maths), onto Engineering foundation degrees (without A-level Maths) as well as onto some of the most competitive Engineering apprenticeships.

How do we support you? Here at Worcester Sixth Form College all our Engineering teachers are highly experienced. You will be provided with all the necessary resources you will need to flourish into a successful Engineering student. Every year our Engineering students achieve results that far exceed the nationwide average.

Introduction Video: https://youtu.be/ve8ofgnKP_M

1. Engineering Essentials - Measurements

Engineers deal with quantities, and so measuring instruments are needed to determine values for these quantities. **Do some research so you can fill in the gaps in table below**. The first row has been completed for you:

Quantity	Instrument Used To Measure Quantity?	
time	timer or stopwatch	
length	In the range mm → m? 	Smaller than a mm? 
mass	(hint: begins with the letter 'b'!) 	
current		Circuit Symbol? 
voltage		Circuit Symbol? 
resistance		
temperature		
atmospheric pressure		

SI Base Units

Engineers and scientists use an international system of units called SI Units. Throughout the Engineering course you will deal with dozens of different SI Units, however **there are just 7 fundamental units called SI Base Units**. Do some research so you can fill in the gaps in table below. The first row has been completed for you:

Physical Quantity	SI Base Unit	Symbol
time	second	s
length		
mass		
current		
temperature		
amount of substance		
luminous intensity		

2. Mechanical Engineering Basics - Kinematics

Mechanical Engineering is about using a scientific understanding of forces, energy and motion to create solutions to problems. In September you will start in familiar territory by looking at kinematics – the Physics of motion. In GCSE Physics you learned the following equation:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

In Engineering we will also use:

$$\text{velocity} = \frac{\text{change in displacement}}{\text{change in time}}$$

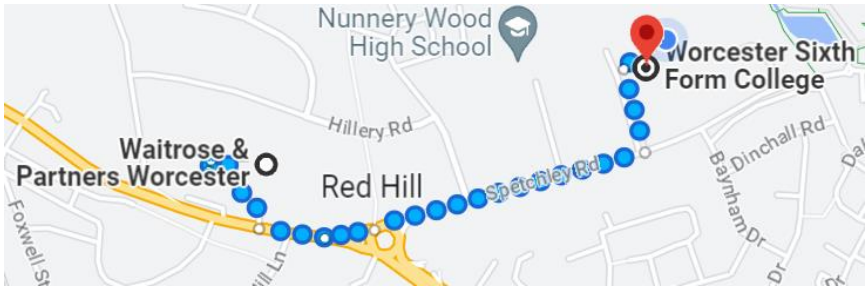
where velocity is defined as the "rate of change of displacement"

Question 1 A skydiver falls at terminal (constant) velocity for 30 seconds. During this time they travel 1950 metres.

Calculate the velocity of the skydiver . Give a suitable unit with your answer.

Question 2 The Boston Dynamics Spot robot can run 8 km in 90 minutes. Calculate Spot's velocity. Give your answer in metres per second.

Question 3 It takes 11 minutes to walk at a velocity of 1.5 metres per second from Waitrose to Worcester Sixth Form College. Calculate the distance in **(i)** metres **(ii)** kilometres



Acceleration is another quantity you are already familiar with:

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{change in time}}$$

where acceleration is defined as the "rate of change of velocity"

Question 4 A Lamborghini Aventador takes 2.8 seconds to accelerate from rest to a velocity of 28 m/s.

Calculate the acceleration.

Give a suitable unit with your answer.

Question 5 Upon launch, the Space X Dragon capsule has an acceleration of 4.5 m/s^2

(i) Calculate its velocity after 4 seconds.

(ii) How long would it take after launch to reach a velocity of 36 m/s ?

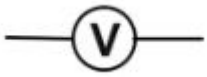
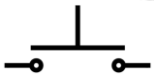
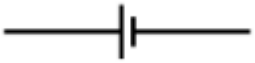
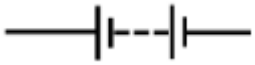
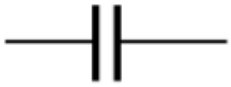
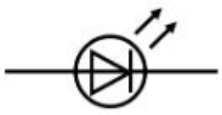
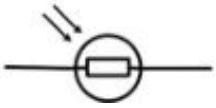
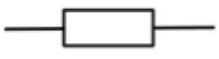
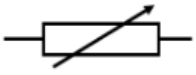
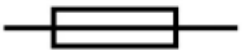
Mass is defined as "the property of a body which resists change in velocity"

(iii) Using the above definition, explain how the motion of the Space X Dragon would change as the mass of fuel stored in the rocket reduces.

3. Electrical Engineering Fundamentals - Circuit Symbols

Electrical Engineering requires you to be familiar with a range of circuit symbols. Many of these you will have encountered before at GCSE, others will be brand new to you.

Question 6 Research the following circuit symbols and complete the table:

Circuit Symbol	Name of Component?	Circuit Symbol	Name of Component?
			
			
			
			
			
			
			
			
			
			
			

Electrical Current

In GCSE Physics you used the following equation:

$$\text{charge} = \text{current} \times \text{time} \quad \text{or} \quad Q = It$$

where charge measured in coulombs, current measured in amps, and time is measured in **seconds**

This equation can be rearranged as:

$$\text{current} = \frac{\text{charge}}{\text{time}} \quad \text{or} \quad I = \frac{\Delta Q}{\Delta t}$$

where current is defined as the "rate of flow of charge"

Question 7

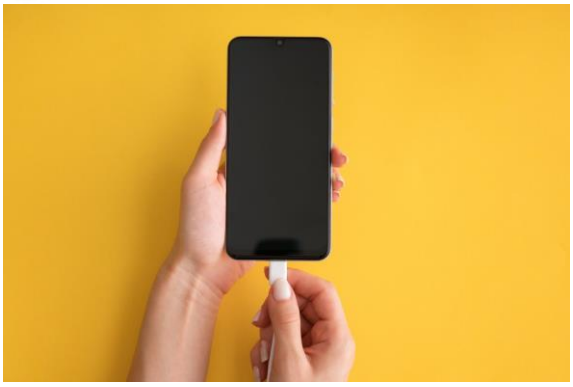
A Tesla charger can deliver a current of 300A to fast charge a battery in 30 minutes

Calculate the number of coulombs of charge transferred to the battery.

Question 8

It takes 2 hours to fully charge a phone using a USB charger. During this time 7200 coulombs of charge are transferred.

Calculate the current through the cable.



Question 9

Across the previous pages you have come across some familiar equations, but also some worded definitions for certain quantities. Match up each term with its correct definition.

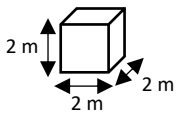
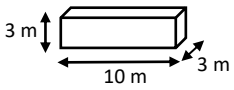
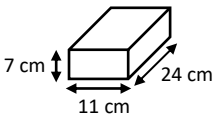
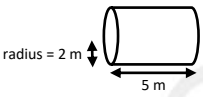
Velocity	**Rate of flow of charge**
Acceleration	**Rate of change of velocity**
Current	**Rate of change of displacement**
Mass	**The property of a body which resists change in velocity**

4. Materials Engineering Fundamentals – Density

The density of a material is defined as $\text{density} = \frac{\text{mass}}{\text{volume}}$ or $\rho = \frac{m}{V}$

where mass is measured in kg and volume is measured in m^3

Question 10 Fill in the table below. The first row has been completed for you.

	Sample Size	Volume (m^3)	Mass (kg)	Density (kg / m^3)
Steel		2 x 2 x 2 = 8	64,000 kg	$\frac{64,000}{8} = 8000$
Concrete			216,000 kg	
Brick		hint: convert to m before calculating volume.	2.77 kg	
Aluminium		hint: the volume of a cylinder is the area of the cross-section multiplied by its length.	170,000 kg	

Force vs. Extension

In GCSE Physics you will have tested springs to find out how force relates to extension. You were previously given the following equations:

force applied to a spring = spring constant × extension $F = kx$

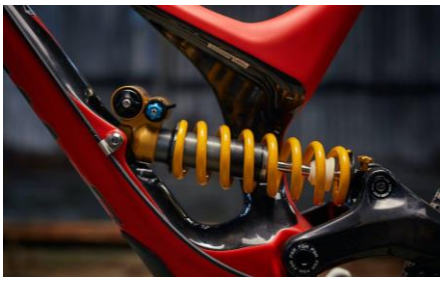
elastic potential energy = 0.5 × spring constant × extension² $E = \frac{1}{2}kx^2$

where x is the extension or compression (you may have used the symbol e for extension previously)

Question 11

A mountain bike suspension has a spring constant of 600 N/m

When the spring is compressed by 0.1 m calculate:



(i) the force exerted

(ii) the energy stored

Question 12

The spring in a retractable ballpoint pen has a spring constant of 150 N/m. When the pen is clicked the spring is compressed from 3 cm to 2 cm.

Calculate the force needed to click the pen.

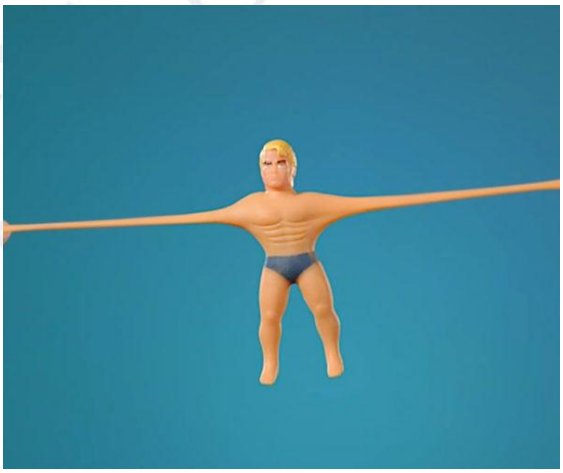
We can also use the equation F = kx for materials, not just springs. When dealing with materials it doesn't necessarily make sense to call k the 'spring' constant. Instead, we can call k the 'stiffness' of the material.

Rearranging gives $k = \frac{F}{x}$ meaning that **stiffness is defined as 'the ratio of force to extension"**.

Question 13

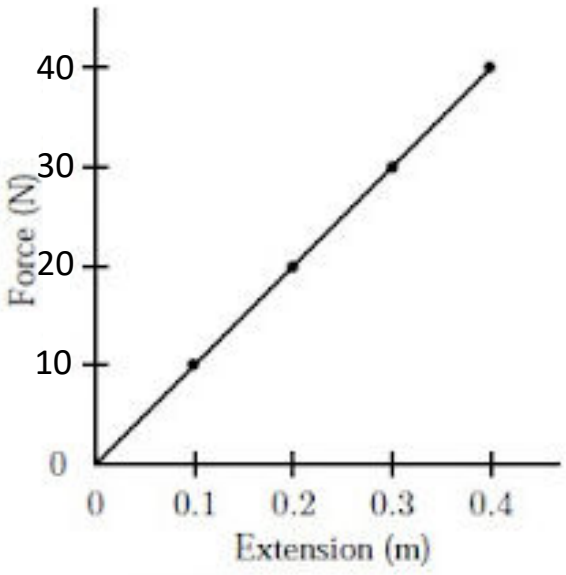
A force-extension graph is shown for Stretch Armstrong.

Use the graph to calculate:



(i) the stiffness

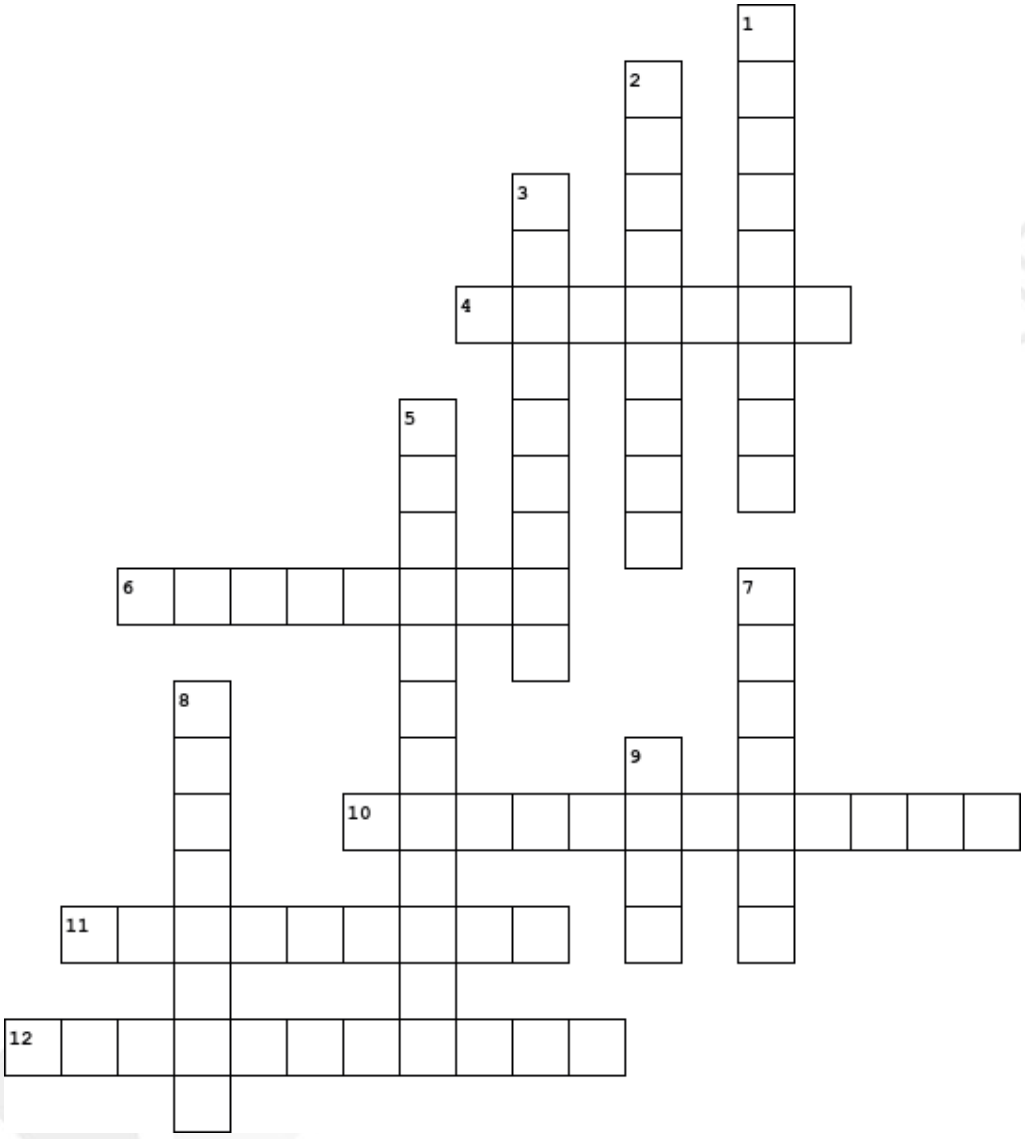
(ii) the energy stored



5. Definitions Crossword

When we dig deeper into Materials there will be lots of new terminology to describe and explain how materials behave. Follow the hyperlink to help you complete the following crossword:

https://www.ocr.org.uk/Images/253338-science-for-engineering.pdf **(scroll to the 11th page)**



Across

4. rate of flow of charge

6. the ability to resist surface abrasion and scratches

10. the ability to undergo plastic deformation in compression before failure

11. the ability of a material to plastically deform under tension without breaking (e.g. to be drawn into wires)

12. tendency for materials to break without undergoing any plastic deformation

Down

1. the ratio of force to extension

2. the ability to withstand repeated stress cycling

3. a measure of the amount of energy stored in a material before failure

5. rate of change of velocity

7. mass divided by volume

8. rate of change of displacement

9. property of a body that resists change in velocity

6. Memorising Prefixes

Engineering deals with very big numbers as well as very small ones. Prefixes are an easy way to express numbers of different sizes without loads and loads of zeros!

The width of this page is about 20 centimeters, it wouldn't necessarily occur to you to describe the width of the page in metres, since a metre is much bigger than the page.

The word 'centi' is called a prefix and it has a mathematical meaning:

20cm = 0.20m so centi must mean x 0.01 or $x10^{-2}$

There are lots of other prexifes, allowing us to use SI units for huge numbers as well as teeny weeny ones.

Prefix	Symbol	Meaning
pico	p	**$x\ 10^{-12}$**
nano	n	**$x\ 10^{-9}$**
micro	μ	**$x\ 10^{-6}$**
milli	m	**$x\ 10^{-3}$**
centi	c	**$x\ 10^{-2}$**
kilo	k	**$x\ 10^{3}$**
mega	M	**$x\ 10^{6}$**
giga	G	**$x\ 10^{9}$**
tera	T	**$x\ 10^{12}$**

It's essential to memorise these prefixes. Here's an example of a method you can use to lodge them into your long-term memory:

Step 1) Find a word similar or related to the prefix – the weirder the better!!

Step 2) Visualise your link to the prefix, and find a way to include a visual reminder of the power of ten.

Example: Nano sounds like Nandos. You could visualise the Nando's logo and incorporate the -9 into the design. Alternatively, you could visualise going to Nandos and finding that the little flag in your burger has $x10^{-9}$ written on it – the choice is yours!

Come up with visual reminders for each of the prefixes – some of them are trickier than others and it *will* take some time to come up with some really good memorable ones!!

Draw or describe each of the prefixes in the boxes below:

Prefix	Meaning	Memorisation tactic (the weirder the better!)
pico, p	**x 10^{-12}**	
nano, n	**x 10^{-9}**	
micro, µ	**x 10^{-6}**	
milli, m	**x 10^{-3}**	

centi, c	**x 10^{-2}**	
kilo, k	**x 10^{3}**	
Mega, M	**x 10^{6}**	
Giga, G	**x 10^{9}**	

7. Solutions – Check your calculations!

Question 1 $\text{velocity} = \frac{1950}{30} = 65 \text{ m/s}$

Question 2 $\text{velocity} = \frac{8000}{90\times60} = 1.48 \text{ m/s}$

distance must be in metres

Note that before using **any** equation in Engineering you must **convert the time into seconds**.

Question 3 **(i)** $\text{distance} = \text{speed} \times \text{time} = 1.5 \times (11 \times 60) = 990 \text{ metres}$

(ii) 990 meters = 0.99 kilometers

Question 4 $\text{acceleration} = \frac{28}{2.8} = 10 \text{ m/s}^2$

Question 5 **(i)** $\text{velocity} = \text{acceleration} \times \text{time} = 4.5 \times 4 = 18 \text{ m/s}$

(ii) $\text{time} = \frac{\text{velocity}}{\text{acceleration}} = \frac{36}{4.5} = 8 \text{ seconds}$

(iii) As the mass decreases it becomes easier to change the velocity. So the acceleration would increase.

Question 7 $Q = It = 300 \times (30 \times 60) = 540{,}000$ coulombs (or C for short)

Question 8 $I = \frac{\Delta Q}{\Delta t} = \frac{7200}{2\times60\times60} = 1$ amp (or A for short)

Question 10 Concrete: volume = 3 x 3 x 10 = 90 m^3 density = $\frac{216000}{90} = 2400 \text{ kg/m}^3$

Brick: volume = 0.11 x 0.07 x 0.24 = 1.848 x 10^{-3} m^3 density = $\frac{2.77}{1.848\times10^{-3}} = 1498.9 \text{ kg/m}^3$

Aluminium: volume = πr^2 x length = $\pi x 2^2$ x 5 = 62.8 m^3 density = $\frac{170{,}000}{62.8} = 2705.6 \text{ kg/m}^3$

Question 11 **(i)** F = kx = 600 x 0.1 = 60 newtons (or N for short)

(ii) E = ½kx^2 = ½ 600 x 0.1^2 = 30 joules (or J for short)

Question 12 Extension, x = 3 cm – 2 cm = 1 cm = 0.01 m

F = kx = 150 x 0.01 = 1.5 newtons (or N for short)

Question 13 **(i)** stiffness, $k = \frac{F}{x} = \frac{40}{0.4} = 100 \text{ N/m}$

(ii) energy, E = ½kx^2 = ½ 100 x 0.4^2 = 8 joules (or J for short)

Getting ready for September

- Before September you need to have completed the 6 bridging tasks in this booklet.

- You will be provided with class workbooks for each Engineering unit you study, however **you will also need a folder** to keep yourself organised.

  Many students choose to use ring binders, however alternatively you may find a foolscape or document wallet is useful for keeping worksheets safe.

- You **do not** need to purchase a text book – we will provide you with bespoke workbooks that we write ourselves and have been rated as 'excellent' by our students.

- You will need a scientific calculator. For Engineering we recommend Casio calculators, the Casio Classwiz range is the most up to date and fx-991EX range specifically will help you when it comes to the more challenging aspects of the Mathematics for Engineering unit.

  If you are also studying A-level Mathematics **don't rush to make a purchase** – they will advise you on the most appropriate models for their course (and in previous years have been able to offer discount on the most expensive graphical models).

Interesting things to keep you busy!

Science on Social Media:

Science communication is essential in the modern world and all the big scientific companies, researchers and institutions have their own social media accounts. Here are some of our top tips to keep up to date with developing news or interesting stories:

Follow on Twitter:

Commander Chris Hadfield – former resident aboard the International Space Station
@cmdrhadfield

NASA's Voyager 2 – a satellite launched nearly 40 years ago that is now travelling beyond our solar system
@NSFVoyager2

Neil deGrasse Tyson – Director of the Hayden Planetarium in New York @neiltyson

The SETI Institute – The Search for Extra Terrestrial Intelligence, be the first to know what they find!
@setiinstitute

Phil Plait – tweets about astronomy and bad science @badastronomer

Institute of Physics – The leading scientific membership society for physics @PhysicsNews

Scientific America – Journal sharing discoveries and insights into science that develops the world @sciam

SN Students – Science news for students
@SNStudents

Find on Facebook:

National Geographic - since 1888, National Geographic has travelled the Earth, sharing its amazing stories in pictures and words.

Science News Magazine - Science covers important and emerging research in all fields of science.

BBC Science News - The latest BBC Science and Environment News: breaking news, analysis and debate on science and nature around the world.

Institute of Physics - The Institute of Physics is a leading scientific membership society working to advance physics for the benefit of all.

Chandra X-ray Observatory - NASA's Chandra X-ray Observatory is a telescope specially designed to detect X-ray emission from very hot regions of the Universe such as exploded stars, clusters of galaxies, and matter around black holes.

Interesting Engineering - Interesting Engineering is a cutting edge, leading community designed for all lovers of engineering, technology and science.