# Progression - Engineering

## Contents:

# 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 5 main areas: **mechanical & electrical engineering**, **coursework**, **CAD** (computer aided design), **materials science** and **programmable electronics**. The first year of the course features a written examination 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!

**Year 1**

**Principles of Engineering**

You will build on your GCSE Maths & Physics skills to solve problems in these contexts:

- Geometry
- Motion & Forces
- Friction
- Moments & Torque
- Energy & Power
- Momentum
- Materials
- Structural Beams
- DC & AC Circuits
- Op Amps & Logic Gates

**January Exam**

**Engineering in Practice**

- You will learn how to analyse products, create engineering CAD drawings and design circuit simulations.
- You will make a mechanical prototype using hand tools and create a prototype of an electronic circuit.
- You will evaluate your manufactured prototypes to see how successful they have been.

**Coursework**

**Year 2**

**Computer Aided Design (CAD)**

- You will learn how to create 3D models using CAD software.
- You will learn how to assemble and animate multiple parts.
- You will learn how to create 2D technical drawings.
- You will learn about simulations in 3D modelling.

**Coursework**

**Materials Science and Technology**

You will learn about metals, polymers, ceramics & composite materials in terms of:

- Material Properties
- Atomic Structure
- Material Forms
- Failure Mechanisms and Failure Prevention
- Manufacturing Processes
- Heat Treatment Methods
- Smart Materials
- Sustainable Practices

**January Exam**

**Programmable Electronics**

- You will learn about different types of programmable electronic devices and their applications.
- You will create models and prototypes to test how systems function.
- You will develop skills in assembly, testing, and programming to build working systems.

**Coursework**

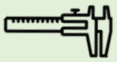
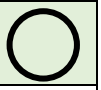
At the end of two years you will gain a *Cambridge Advanced National Extended Certificate in Engineering* – an A-level-equivalent that is highly regarded by employers and many universities. This will allow you to progress onto University Engineering degrees (with A-level Maths), onto Engineering foundation 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.

# 1. Engineering Essentials – Measurements, SI Units & Prefixes

In GCSE Physics you learned that quantities such as time, length and mass have standard units that work with equations. These units are called SI (Système International) units and they are used by Engineers and Scientists across the world.

Many quantities can be measured directly using a measuring instrument e.g. mass is measured using a balance. **Task 1: Complete the gaps in table below**, you may need to do some research.

| Quantity | Standard SI Unit? | Measuring Instrument Used To Measure Quantity? | |
|---|---|---|---|
| **time** | second | timer or stopwatch | |
| **length** | | In the range mm → m?  | Smaller than a mm?  |
| **mass** | kg | (hint: begins with the letter 'b'!)  | |
| **current** | | | Circuit Symbol?  |
| **voltage** | | | Circuit Symbol?  |
| **resistance** | | | Ω |

Engineers often work with extremely large and small numbers. Prefixes simplify these by avoiding long strings of zeros. For example, the width of this page is about 20 cm, where 'centi-' means $20 \times 10^{-2}$ meters. Knowing such prefixes is essential for the Engineering course.

| Prefix Name | 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 $10^{9}$** |

**Task 2: Use the information in the table to make 8 double-sided flashcards.**

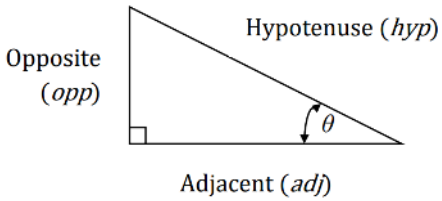
**Write the prefix name and symbol on the front, and the $\times 10^{value}$ on the back. Use the cards to test yourself on the prefixes until you've memorised them – you'll be tested on them in September.**

## 2. Mechanical Engineering Basics - Geometry

In GCSE Maths you've already learned about Pythagoras' Theorem ($a^2 + b^2 = c^2$) and Trigonometry (soh cah toa). You will be given an Engineering formula booklet with the following information:

**Trigonometry**

**Trigonometric Ratios**




$$\sin\theta = \frac{opp}{hyp}$$

$$\cos\theta = \frac{adj}{hyp}$$

$$\tan\theta = \frac{opp}{adj}$$

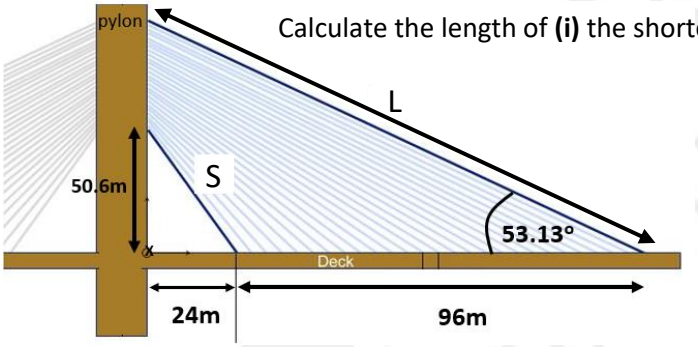
*Pythagoras' rule:* $hyp^2 = opp^2 + adj^2$

**USE A SCIENTIFIC CALCULATOR TO HELP YOU SOLVE THE FOLLOWING QUESTIONS.**

**YOU MUST SHOW YOUR FULL WORKING.**

**Question 1** A diagram of a suspension bridge is shown. Cables of different lengths connect the vertical pylon with the deck of the bridge.

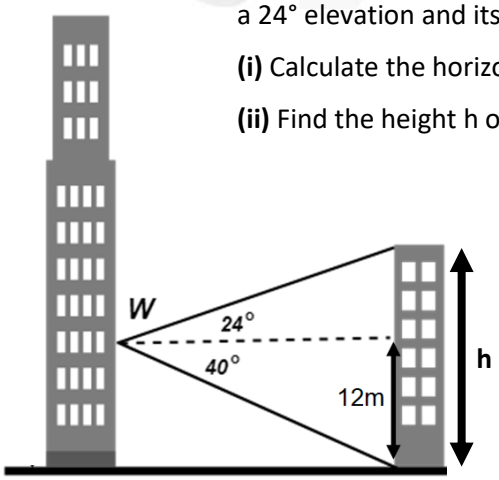
Calculate the length of **(i)** the shortest cable, S **(ii)** the longest cable, L.




**Question 2** An Engineer at a window 12m above ground observes the top of another building at a 24° elevation and its base at a 40° depression.

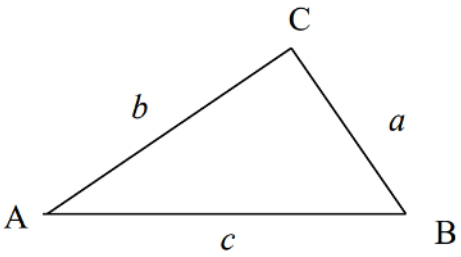
**(i)** Calculate the horizontal distance between the 2 buildings (the length of the dotted line in the diagram)

**(ii)** Find the height h of the second building.



Unlike Pythagoras and basic trigonometry, the Sine and Cosine rules apply to any triangle, not just right-angled ones. You will be given the following information in the Engineering formula book. The **uppercase letters represent angles**. The **lowercase letters represent sides**.

**Sine and Cosine rules**




Sine rule: $\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$

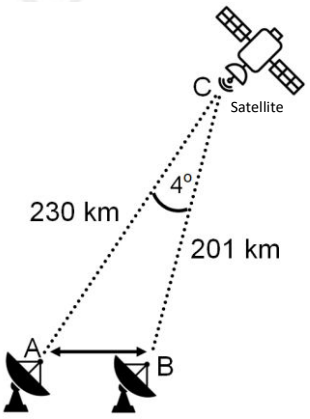
Cosine rule: $a^2 = b^2 + c^2 - 2bc\cos A$

$b^2 = a^2 + c^2 - 2ac\cos B$

$c^2 = b^2 + a^2 - 2ab\cos C$

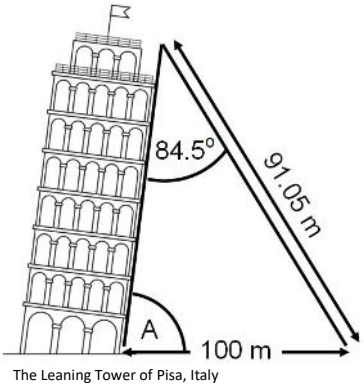
**Question 3**

Use the **cosine rule** to calculate the horizontal distance between the satellite dishes A and B.




**Question 4**

Use the **sine rule** to calculate the angle A.




The Leaning Tower of Pisa, Italy

# 3. Mechanical Engineering Basics - Kinematics

In GCSE Physics you learned that: $\text{speed} = \frac{\text{distance}}{\text{time}}$

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"

Speed and velocity are both measured in *metres per second*. At GCSE you'll have written this as m/s. Beyond GCSE we'll start to use the notation **ms$^{-1}$** to represent ***metres per second***. See if you can get used to this new way of writing units in the following questions.

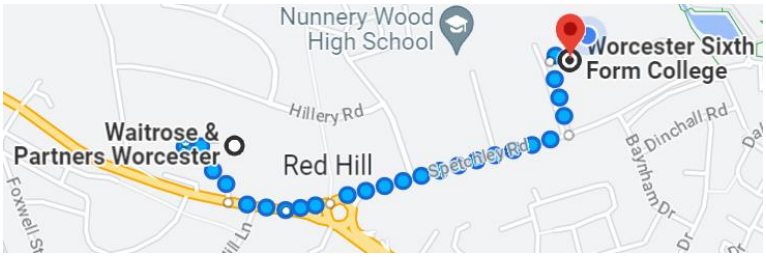
**Task 3:** Write the above equations, worded definition and unit on flash cards. On the reverse of each card write a question, e.g. "what is the definition of velocity?" so you can use the flash cards to test yourself and memorise these before your first lesson with us in September.

**Question 5** 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 6** The Boston Dynamics Spot robot can run 8 km in 90 minutes. Calculate Spot's velocity. Give your answer in metres per second (ms$^{-1}$)

**Question 7** It takes 11 minutes to walk at a velocity of 1.5 ms$^{-1}$ from Waitrose to Worcester Sixth Form College. Calculate the distance in **(i)** metres **(ii)** kilometres



Acceleration is calculated using: $\text{acceleration} = \frac{\text{change in velocity}}{\text{change in time}}$

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

The SI unit for **acceleration** is ***metres per second squared***. In Engineering we'll use the notation **$ms^{-2}$** (instead of $m/s^2$).

**Task 4:** Add the above equation, definition and unit to your growing pile of flash cards. Make these cards double sided with a question on the back so you can easily memorise them before September.

**Question 8**

A Lamborghini Aventador takes 2.8 seconds to accelerate from rest to a velocity of 28 $ms^{-1}$.

Calculate the acceleration.

Give the correct SI unit with your answer.

**Question 9**

Upon launch, a space rocket has an acceleration of 4.5 $ms^{-2}$

**(i)** Calculate its velocity 4 seconds after launch

**(ii)** How long would it take for the rocket to reach a velocity of 36 $ms^{-1}$ ?

**Question 10**

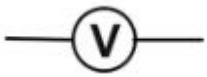
Fighter pilots can withstand accelerations of 9g for up to two seconds (where g = 9.81 $ms^{-2}$)

Calculate the change in velocity that the pilot would experience in this time.

## 4. 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.

**Task 5:** Research the following circuit symbols and complete the table:

| Circuit Symbol | Name of Component? | Circuit Symbol | Name of Component? |
|---|---|---|---|
|  | |  | |
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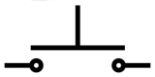
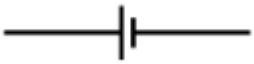
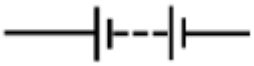
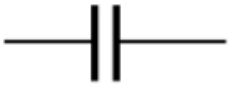
|  | |  | |
|  | |  | |
|  | |  | |
|  | |  | |
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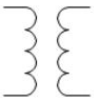
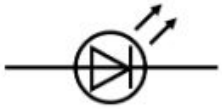
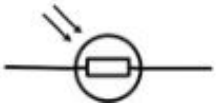
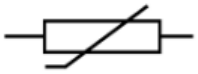
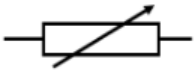
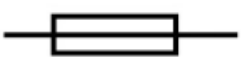
|  | |  | |
|  | |  | |
|  | |  | |
|  | |  | |

## Electrical Current

In GCSE Physics you used the following equation:

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

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

This equation can be rearranged as:

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

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

**Task 5:** Create some double-sided flash cards for the above equations, definition and units.

**Question 11**

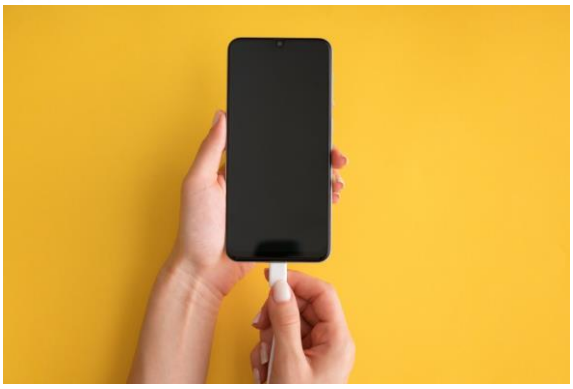
An electric car charger can deliver a current of 300A to fast charge a battery in 30 minutes

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

**Question 12**

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 13**

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** |

# 5. Solutions – Check your Calculations!

**Question 1** **(i)** Using Pythagoras: $S = \sqrt{50.6^2 + 24^2} = 56\text{m}$

**(ii)** Using trigonometry (soh cah toa): $\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} \rightarrow \cos 53.15^o = \frac{120}{L} \rightarrow L = \frac{120}{\cos 53.15} = 200\text{m}$

**Question 2** **(i)** Use trig. in bottom triangle: $\tan\theta = \frac{\text{opposite}}{\text{adjacent}} \rightarrow \tan 40^o = \frac{12}{\text{adj.}} \rightarrow \text{adjacent} = \frac{12}{\tan 40^o} = 14.3\text{m}$

**(ii)** Use trig. in top triangle: $\tan\theta = \frac{\text{opposite}}{\text{adjacent}} \rightarrow \tan 24^o = \frac{\text{opp.}}{14.3} \rightarrow 14.3 \times \tan 24^o = \text{opposite}$

$= 6.37\text{m}$

h = 12m + 6.37m = 18.4m (3 s.f.)

**Question 3** Using cosine rule: $c^2 = b^2 + a^2 - 2ab\cos C$

$c^2 = 201^2 + 230^2 - 2 \times 201 \times 230\cos 4^o$

$c^2 = 1066.2\ldots \rightarrow c = \sqrt{1066.2} = 32.7\text{ km (3s.f.)}$

**Question 4** Using sine rule: $\frac{\sin A}{a} = \frac{\sin B}{b}$

$\frac{\sin A}{91.05} = \frac{\sin 84.5^o}{100} \rightarrow \sin A = \frac{\sin 84.5^o}{100} \times 91.05 = 0.906\ldots \rightarrow A = \sin^{-1} 0.906 = 65^o$

**Question 5** $\text{velocity} = \frac{\text{change in displacement}}{\text{change in time}} = \frac{1950}{30} = 65\ \text{ms}^{-1}$

**Question 6** $\text{velocity} = \frac{\text{change in displacement}}{\text{change in time}} = \frac{8000}{90\times 60} = 1.48\ \text{ms}^{-1}$

distance must be in metres

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

**Question 7** **(i)** $\text{distance} = \text{speed} \times \text{time} = 1.5 \times (11 \times 60) = 990\text{ metres}$

**(ii)** 990 meters = 0.99 kilometers

**Question 8** $\text{acceleration} = \frac{\text{change in velocity}}{\text{change in time}} = \frac{28}{2.8} = 10\ \text{ms}^{-2}$

**Question 9** **(i)** $\text{velocity} = \text{acceleration} \times \text{time} = 4.5 \times 4 = 18\ \text{ms}^{-1}$

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

**Question 10** $\text{change in velocity} = \text{acceleration} \times \text{change in time} = (9 \times 9.81) \times 2 = 176.58\ \text{ms}^{-1}$

**Question 11** $\text{Q} = It = 300 \times (30 \times 60) = 540{,}000\text{ coulombs (or C for short)}$

**Question 12** $\text{I} = \frac{\Delta\text{Q}}{\Delta\text{t}} = \frac{7200}{2\times 60\times 60} = 1\text{ amp (or A for short)}$

**Question 13** velocity = rate of change of displacement

acceleration = rate of change of velocity

current = rate of flow of charge

## 6. Getting Ready for September – Tick List

- Complete Questions 1 – 13 ☐
- Use the solutions (page 10) to mark and correct your answers ☐
- Create double-sided flash cards for:
  - (i) the **8 prefixes** on page 3 ☐
  - (ii) **equations** for **v**, **a**, **Q** & **I** ☐
  - (iii) **definitions** for **v**, **a** & **I** ☐
  - (iv) SI units for **v**, **a**, **Q** & **I** ☐
- Use your flash cards to memorise the information ready for a test ☐
- Acquire a Scientific Calculator (**pre-2023 Casio Classzwiz** are best for Engineering) ☐

## 7. Extra Info for September

- In September you will have 4 Engineering lessons each week with a high degree of mathematical content. Expect to have 3-4 hours of homework to complete each week.
- The January Engineering exam is externally assessed and will count towards your final grade for the course.
- You **don't** need to buy a textbook – we'll provide you with a workbook for each Engineering unit that contains all of the information and class notes you need, plus the problems you will work through in lessons.
- You'll need a folder to stay organised. A ring binder, foolscape, or document wallet will help keep worksheets safe.
- You will need a scientific calculator. For Engineering we recommend **Casio** calculators. The now discontinued pre-2023 **models are best**. If possible, **avoid any new model with circular buttons**.

**These older models are great!**