

**A Level mechanics: the interface with aerospace,
automotive and mechanical engineering**

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A-Level Mechanics: The Interface with Aerospace, Automotive, and Mechanical Engineering

Dr Rohan Tittagala
Department of
Engineering and Mathematics

Who is an Engineer?



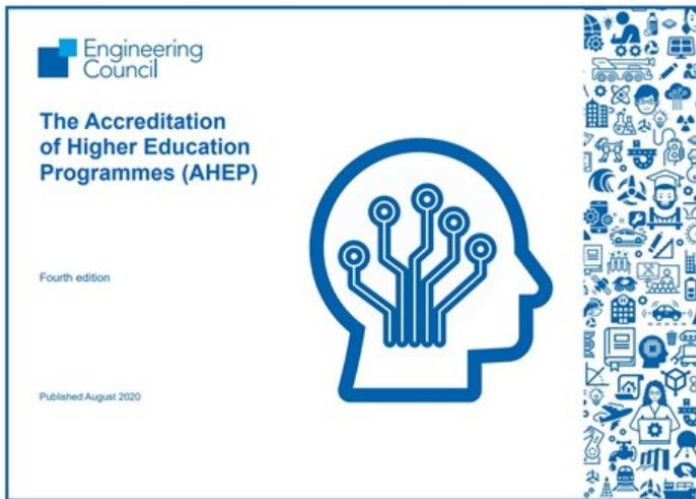
Please watch this Video (3 minutes only)

<https://youtu.be/ZZqU0pDfHjE>



Who is an Engineer?

What are the essential **competence** requirements to **professionally register** to practice engineering?



1. Science and Mathematics
2. Engineering analysis
3. Design and innovation
4. The Engineer and society
5. Engineering practice

The current focus is on:

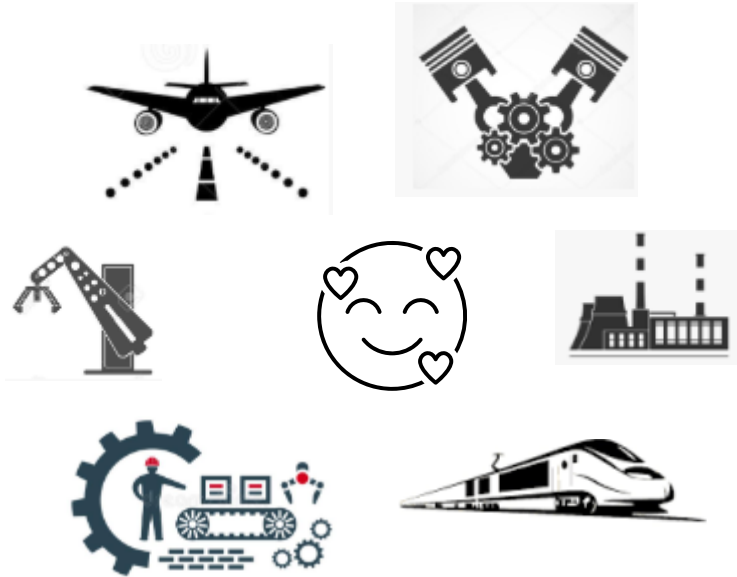
- Inclusive design and innovation
- Sustainability and ethics
- Equality, diversity, and inclusion
- Security and the mitigation of security risks



Core Subjects



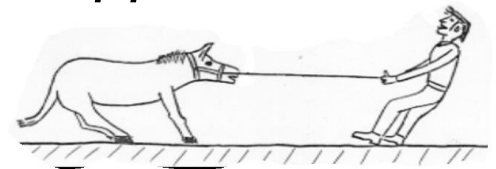
The Principles of Physics are at the heart of Aerospace, Automotive, and Mechanical Engineering.

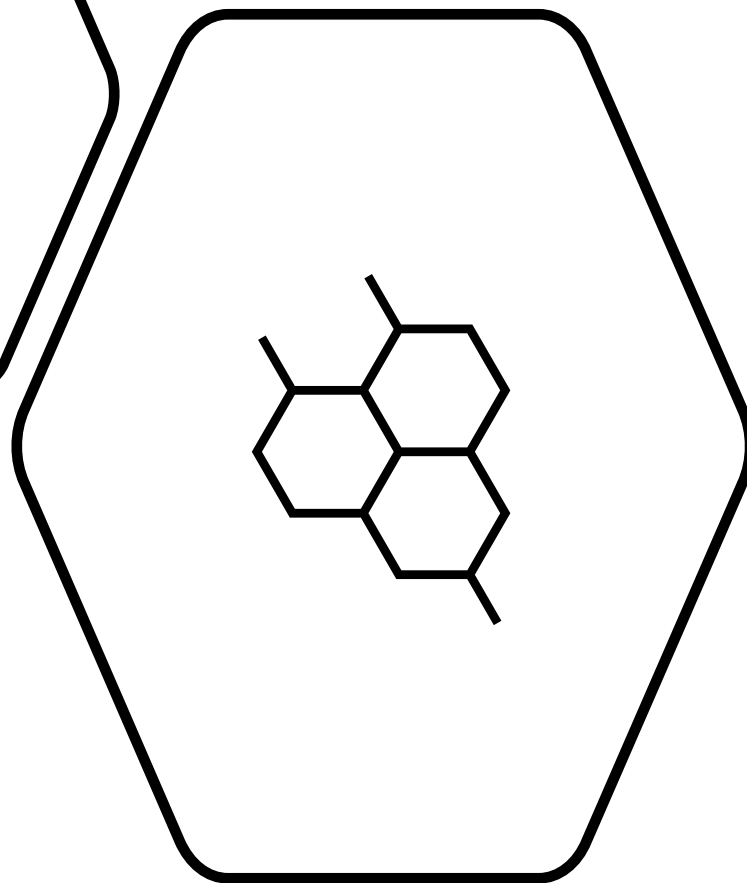
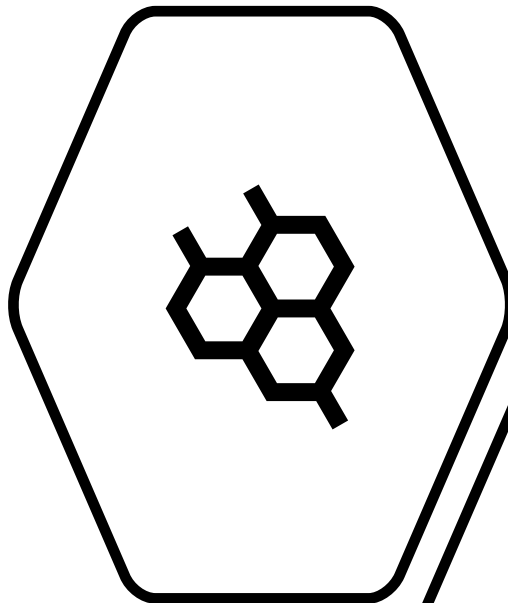
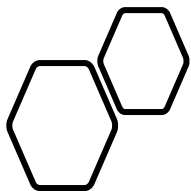


1. Mechanics of Solids
(Mechanics of Materials)
2. Dynamics
3. Thermodynamics
4. Fluid Mechanics

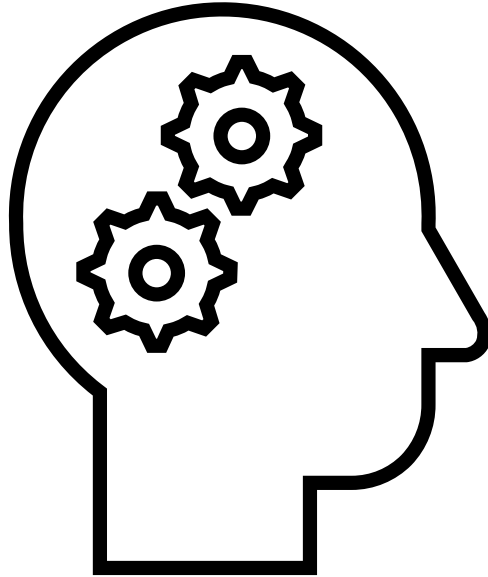
Newton's 3rd Law

"For every action, there is an equal and opposite reaction"





- **Chemistry** is very important too, for example, when studying Materials Engineering or Chemical Engineering.
- Good knowledge of chemistry makes a versatile engineer.



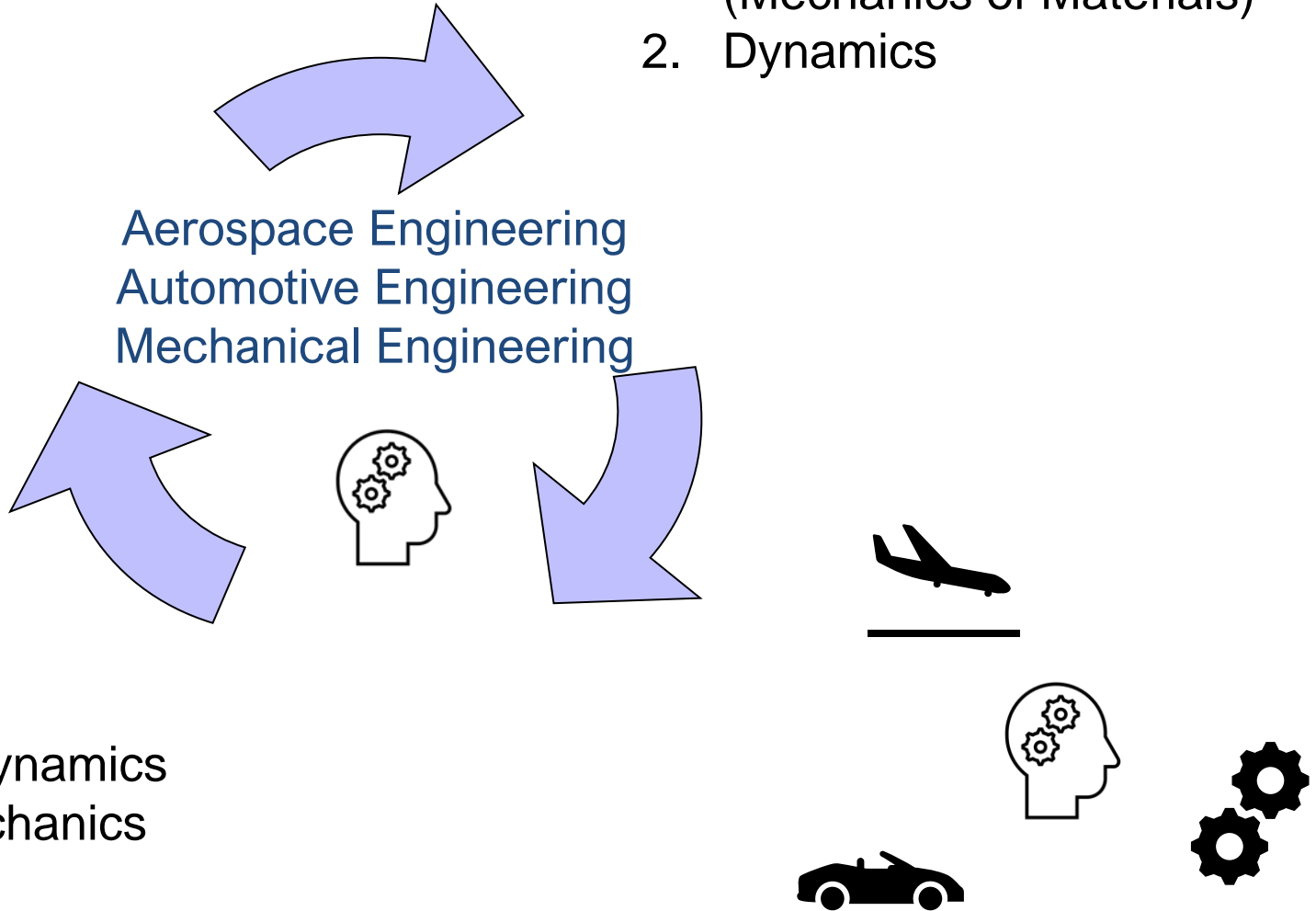
Why Mechanics?

Mechanics is the foundation of Aerospace, Automotive, and Mechanical Engineering

1. Mechanics of Solids
(Mechanics of Materials)
2. Dynamics

Aerospace Engineering
Automotive Engineering
Mechanical Engineering

3. Thermodynamics
4. Fluid Mechanics



Facilitating Subjects – Engineering Mathematics



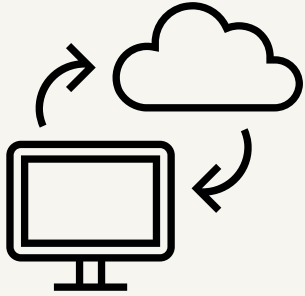
Maths provides a very useful toolkit to study Engineering

That is not to say students need to be brilliant at maths, but if they are good at maths and like maths, it certainly helps to 'fix' engineering.

What one needs is **a passion for maths**, a reasonable working knowledge in maths, a lot of **imagination**, and an **inquisitive mind** about how maths can be used in different engineering applications.



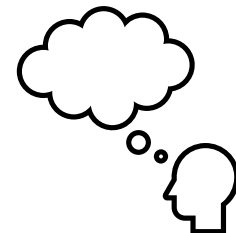
Engineering has now moved into the digital era, and in later years of study, there is a lot of **simulation and modelling**.



As the present generation of students is “digital wizards”, they are likely to enjoy engineering studies more and more as they master the **skills** to handle engineering software, and gradually move away from complex maths

. if that is the way they like their engineering to be.

Manufacturing, Rail, Maritime,
Automobile, Aerospace, Biomedical,
Renewable Energy





However, to make the most of future opportunities, students will still need a good early **foundation knowledge** of core mathematics and engineering principles.

The study of '**mechanics**' within Maths and Physics is a major part of this base knowledge.

The transition from A-Levels to university early engineering studies is an exciting stage of an engineering student's development. This needs to be carefully managed. In later years it is in their own hands to make that journey happen!

What really is Mechanics



It could mean different things to different people?



In Engineering, we mainly talk about two main types of Mechanics:

- Mechanics of Solids
- Mechanics of Fluids

Possible Definitions?

Mechanics of Solids

- Mechanics is the area of study in physics and mathematics that examines how forces affect a body and its motion. It deals with the movement of physical objects and the relationship between force, mass, and motion. Mechanics studies include stationary objects, where the forces acting over them are in equilibrium.
- Mechanics is that branch of Physics dealing with the study of behaviour of bodies and their motion when subjected to forces, and the subsequent effects of the bodies on their environment.

Possible Definitions?

Mechanics of Solids

- Mechanics is the area of study in physics and mathematics that examines how **forces** affect a body and its **motion**. It deals with the movement of physical objects and the relationship between **force**, **mass**, and **motion**. Mechanics studies include stationary objects, where the forces acting over them are in **equilibrium**.
- Mechanics is that branch of Physics dealing with the study of **behaviour of bodies** and their **motion** when subjected to **forces**, and the subsequent effects of the bodies on their environment.

The key name associated with Engineering Mechanics is,

Sir Issac Newton
1642 - 1727



- Newtonian Mechanics
- Classical Mechanics

Deals with macroscopic bodies

Newton's 1st Law

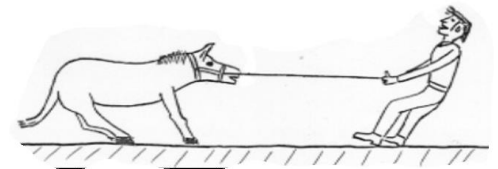
“Every object persists in a state of rest or uniform motion in a straight line unless it is compelled to change that state by force impressed on it”

Newton's 2nd Law

“The resultant force on an object is equal to the rate of change of momentum (mV)”

Newton's 3rd Law

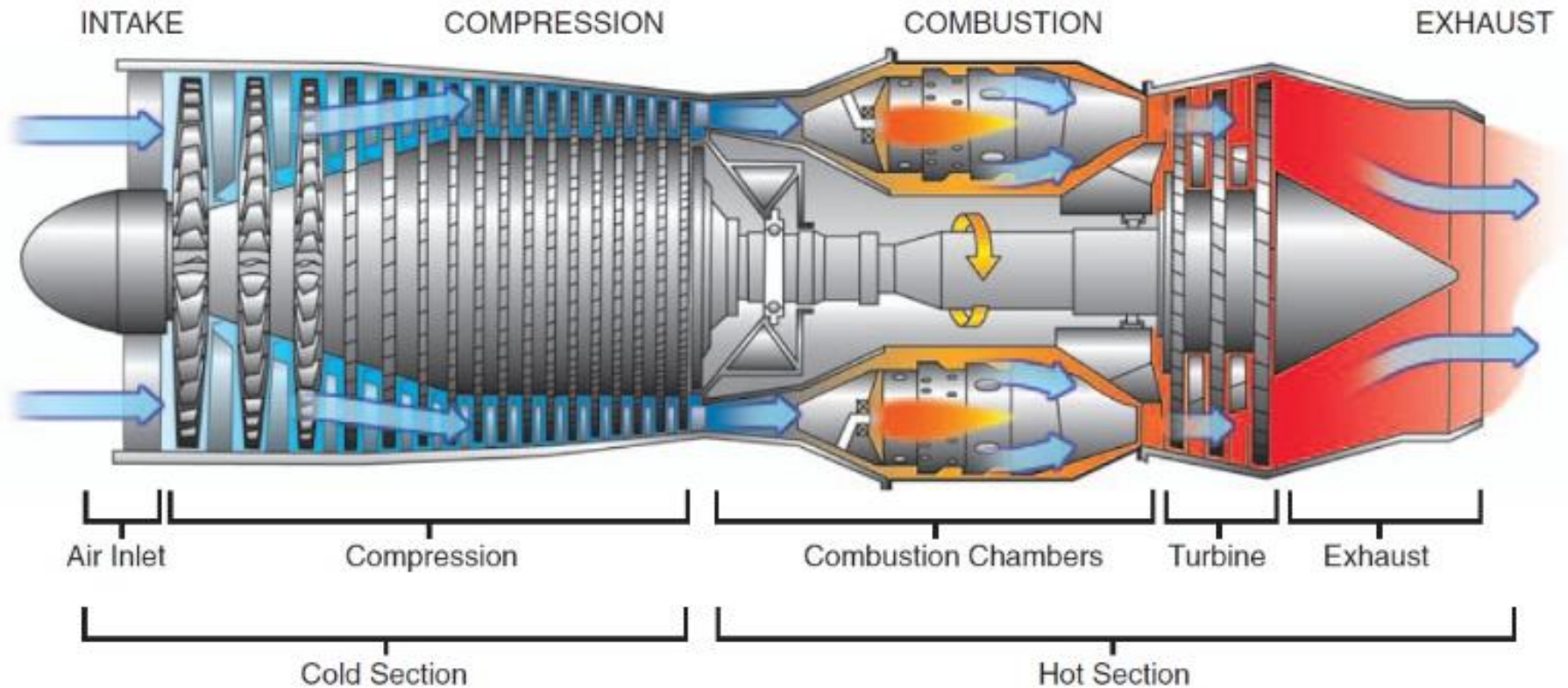
“For every action, there is an equal and opposite reaction”



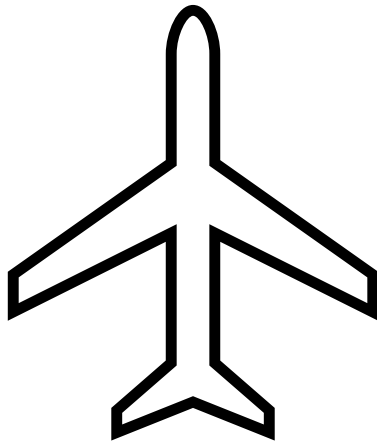
..... a bit of mathematics

What is this? Which company makes these?

Components of a gas turbine engine



Four sections: intake, compression, combustion, and exhaust

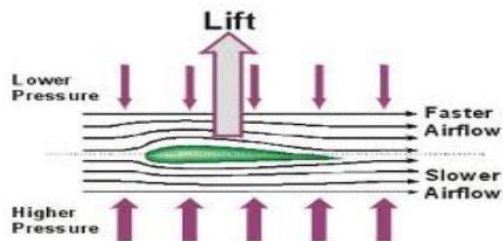


How does the aircraft fly?
Fluid Mechanics principles!

It has to accelerate along the runway, take off at high speed, gain height, gather speed, cruise at high altitude, overcome turbulent weather, decelerate, descend, and land **safely**.

$$p + \frac{1}{2} \rho v^2 = \text{Constant}$$

Bernoulli's principle



Pressure + $\frac{1}{2}$ density x (speed)² is constant

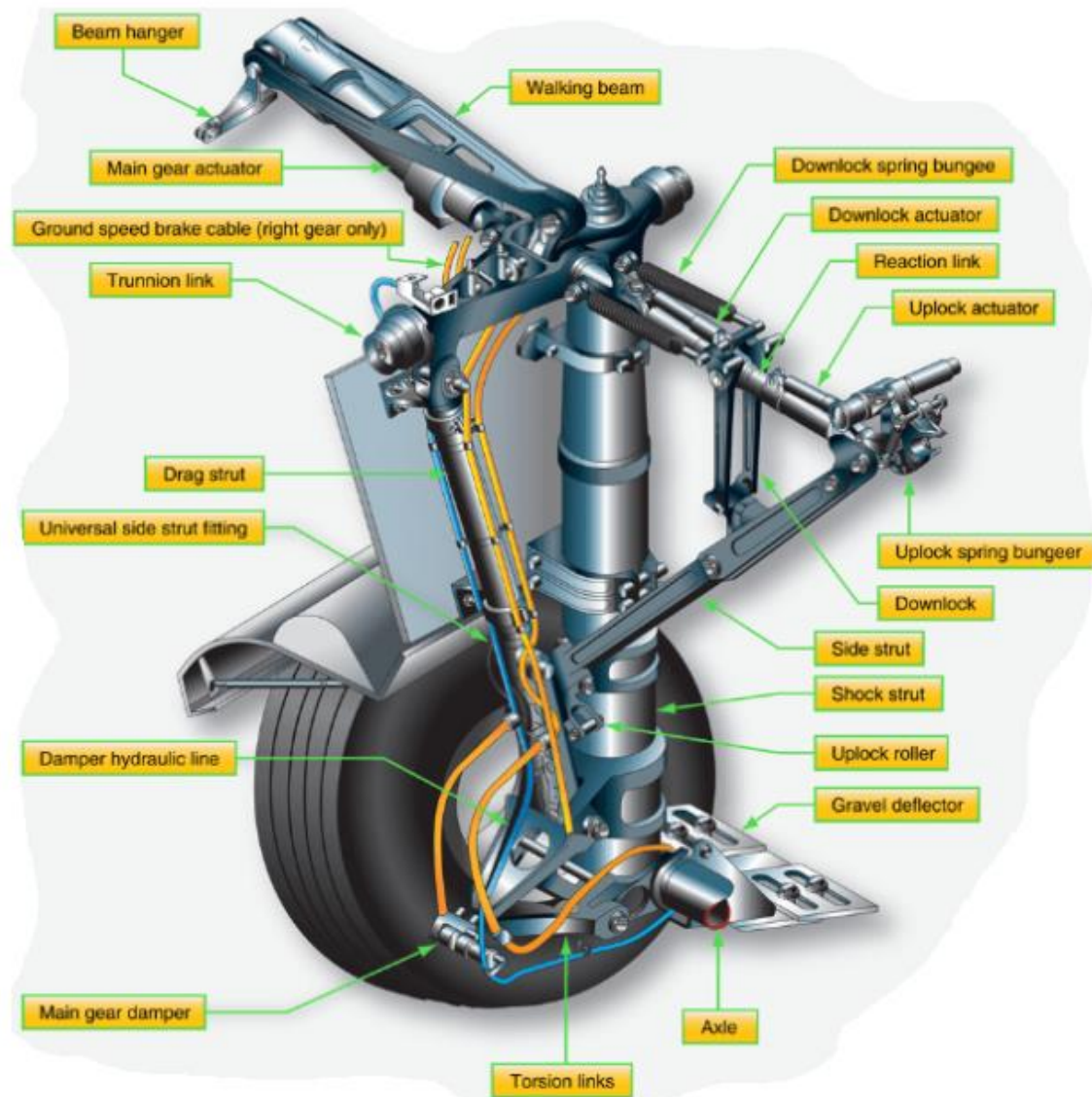
Apart from the Aerodynamics, how does the aircraft land smoothly and safely?

The landing gear on an Airbus A380. Photo: arpingstone via Wikimedia



The primary function of the landing gear is to absorb the force of landing and, of course, prevent the fuselage from hitting the ground. This force absorption happens in several ways.

Firstly, the main landing gear strut has a shock absorption system, using compressible fluids. Secondly, the landing force is spread over a number of wheels.



Let's look at a familiar example.
The Automotive shock absorber.

Types of Vibration Signature with Automotive Applications



Wave Form

Application

Suspensions

All signals formed from this,
i.e. Fourier Analysis

Rotary nature of engine
means this is of the form
of engine vibration/noise

Road surface
Flow noise

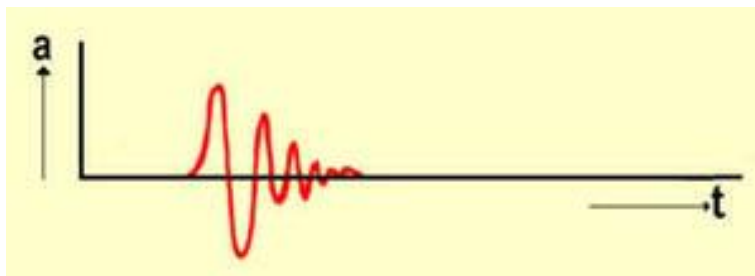
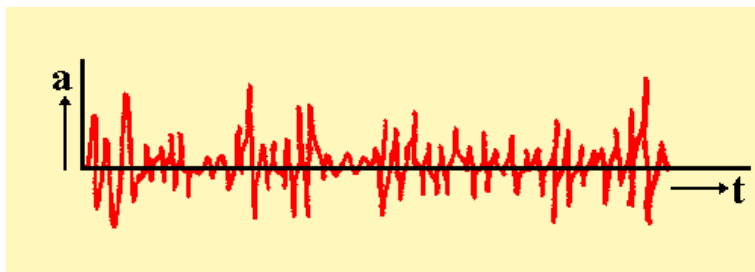
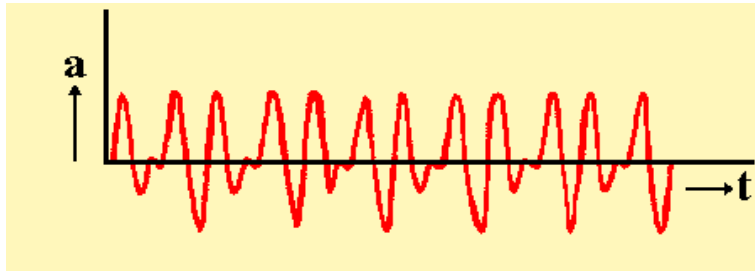
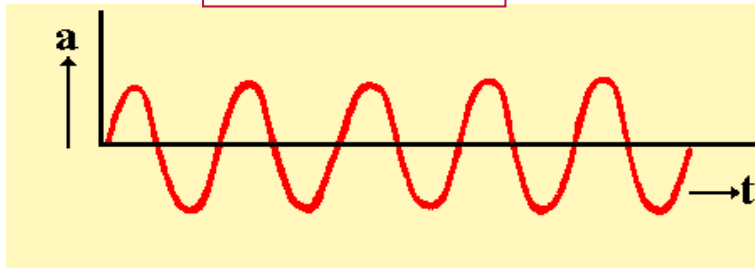
Door slam
Pot hole

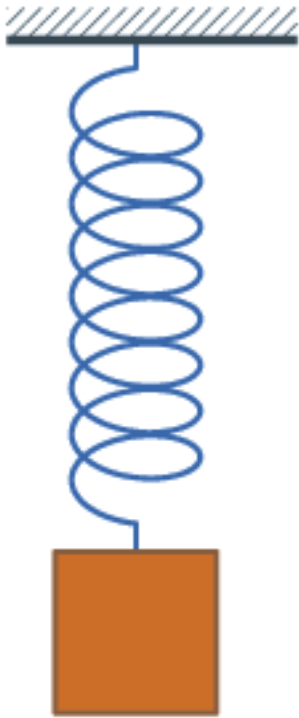
Harmonic

Periodic

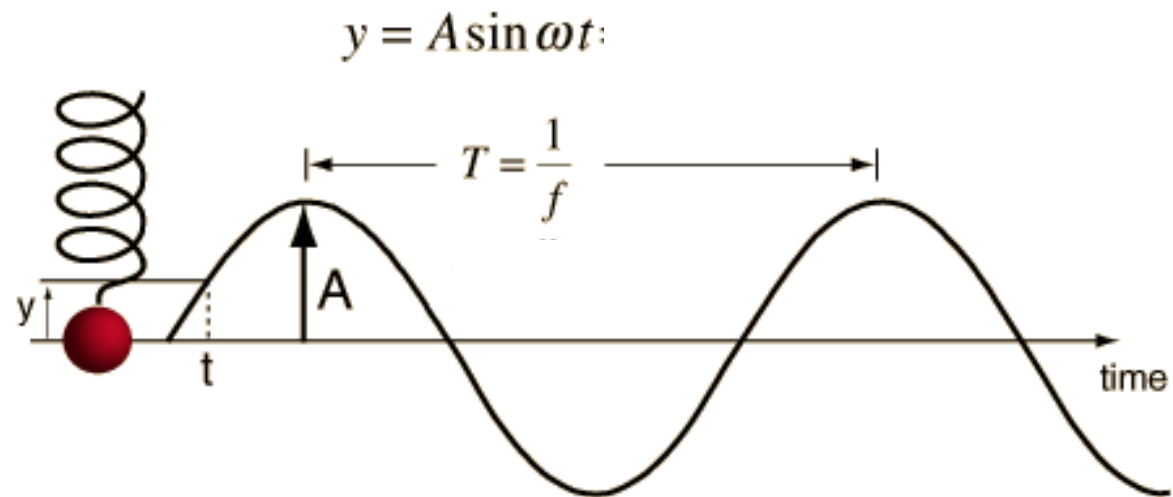
Random

Transient



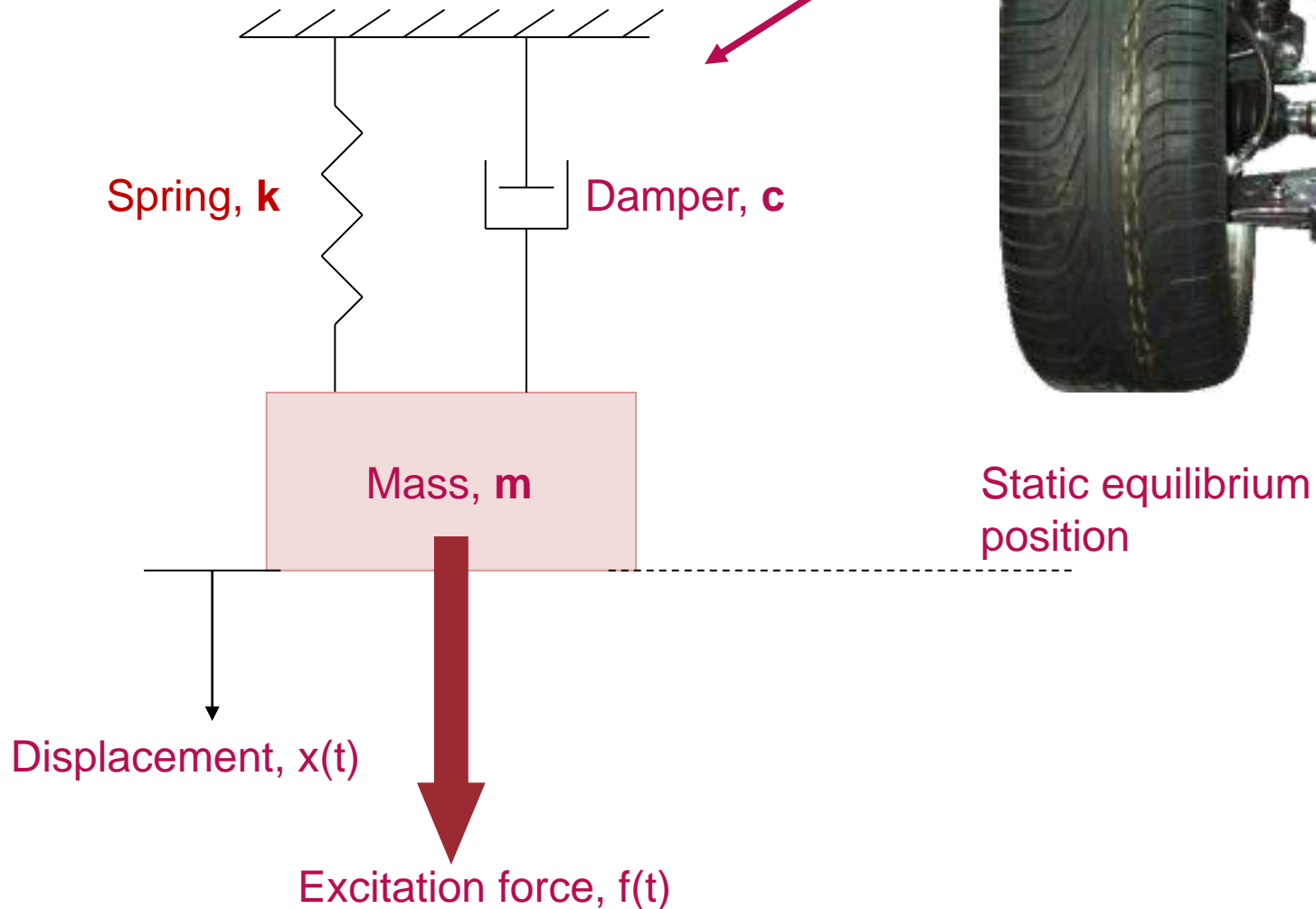


Un-damped Mass on Spring - SHM

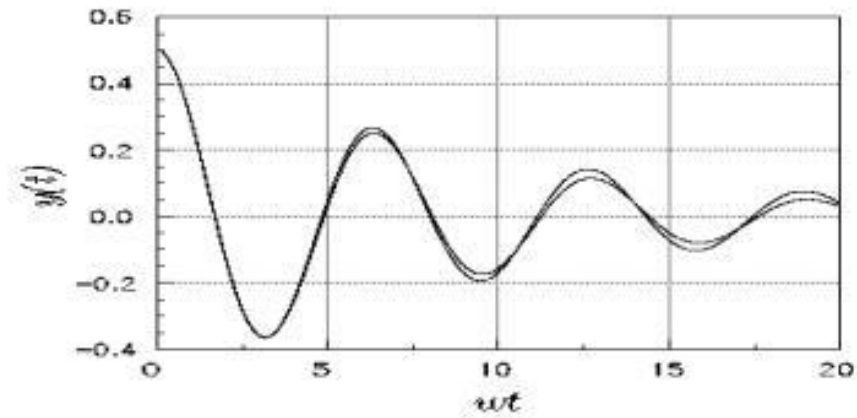
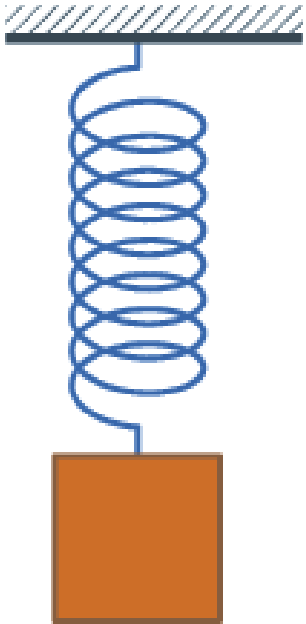


Basic Concepts / Terminology

Idealised elements of a Vibrating System
"Lumped Parameter System"



Damped Mass on Spring - SHM



Damping takes energy out of the system allowing the mass to decay to rest.

Let's look at another exciting example of Mechanics in action!

All kinds of Mechanics, and engineering knowledge and skills, will come into play here.

Remember - **Safety first** is always an underlying theme in Engineering.

Conservation of energy

$$\Delta E_p = mg\Delta h \quad E_k = \frac{1}{2}mv^2$$



Circular motion

$$\omega = \frac{v}{r} = 2\pi f \quad a = \frac{v^2}{r} = \omega^2 r \quad F = \frac{mv^2}{r} = m\omega^2 r$$

The formal study of Mechanics begins with GCSE Physics

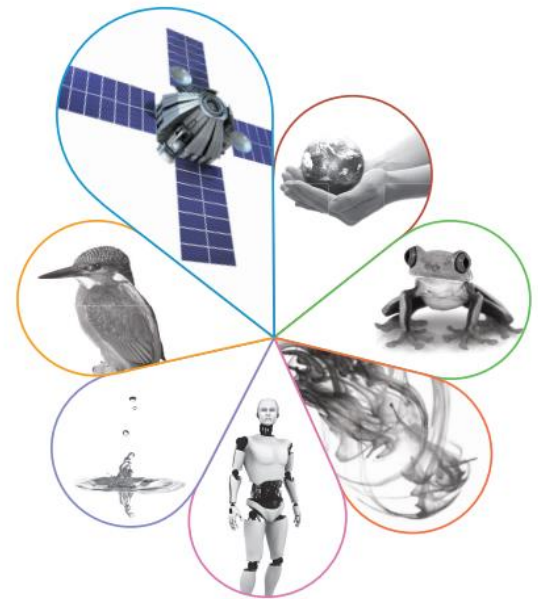
GCSE PHYSICS

(8463)

Specification

For teaching from September 2016 onwards
For exams in 2018 onwards

Version 1.1 30 September 2019



2.1 Subject content

1. Energy (page 17)
2. Electricity (page 23)
3. Particle model of matter (page 32)
4. Atomic structure (page 36)
5. Forces (page 43)
6. Waves (page 59)
7. Magnetism and electromagnetism (page 67)
8. Space physics (physics only) (page 72)

4.1 Energy

4.1.1 Energy changes in a system, and the ways energy is stored before and after such changes

4.1.1.1 Energy stores and systems

4.1.1.2 Changes in energy

Kinetic Energy $E_k = \frac{1}{2} m v^2$

Elastic Potential Energy Gravitational Potential Energy

$$E_e = \frac{1}{2} k e^2 \quad E_p = m g h$$

4.1.1.3 Energy changes in systems

4.1.1.4 Power

$$P = \frac{E}{t} \quad P = \frac{W}{t}$$

4.1.2 Conservation and dissipation of energy

4.1.2.1 Energy transfers in a system

4.1.2.2 Efficiency

4.5 Forces

4.5.1 Forces and their interactions

4.5.1.1 Scalar and vector quantities

4.5.1.2 Contact and non-contact forces

4.5.1.3 Gravity $W = m g$

4.5.1.4 Resultant forces

4.5.2 Work done and energy transfer $W = F s$

4.5.3 Forces and elasticity

Force Elastic potential energy

$$F = k e \quad E_e = \frac{1}{2} k e^2$$

4.5.4 Moments, levers, and gears

Moment of a force $M = F d$

4.5.5 Pressure and pressure differences in fluids

4.5.5.1 Pressure in a fluid

$$p = \frac{F}{A} \quad p = h \rho g$$

4.5.6 Forces and motion

4.5.6.1 Describing motion along a line

$$s = v t \quad a = \frac{\Delta v}{t} \quad v^2 - u^2 = 2 a s$$

4.5.6.2 Forces, accelerations, and Newton's Laws of motion

$$F = m a$$

4.5.6.3 Forces and braking

4.5.7 Momentum

$$p = m v$$

4.5.7.1 Momentum is a property of moving objects

4.5.7.2 Conservation of momentum

4.5.7.3 Changes in momentum

$$F = \frac{m \Delta v}{\Delta t}$$

AS AND A-LEVEL PHYSICS

AS (7407)
A-level (7408)

Specifications

For teaching from September 2015 onwards
For AS exams in May/June 2016 onwards
For A-level exams in May/June 2017 onwards

Version 1.3 June 2017



The study of
Mechanics
topics continue
in A-Level
Physics

.1 Subject content

Core content

Measurements and their errors (page 10)

Particles and radiation (page 12)

Waves (page 17)

Mechanics and materials (page 21)

Electricity (page 27)

Further mechanics and thermal physics
(A-level only) (page 30)

Fields and their consequences (A-level only)
(page 34)

Nuclear physics (A-level only) (page 41)

Options

9 Astrophysics (A-level only)

10 Medical physics (A-level only)

11 Engineering physics (A-level only)

12 Turning points in physics
(page 58)

13 Electronics (A-level only)

3.4 Mechanics and materials

3.4.1 Force, energy, and momentum

3.4.1.1 Scalars and vectors

3.4.1.2 Moments

3.4.1.3 Motion along a straight line

$$v = \frac{\Delta s}{\Delta t} \quad a = \frac{\Delta v}{\Delta t} \quad v = u + at$$
$$s = \left(\frac{u+v}{2}\right)t$$
$$s = ut + \frac{at^2}{2}$$
$$v^2 = u^2 + 2as$$

3.4.1.4 Projectile motion

3.4.1.5 Newton's laws of motion

3.4.1.6 Momentum

Force	Impulse
$F = \frac{\Delta(mv)}{\Delta t}$	$F\Delta t = \Delta(mv)$

3.4.1.7 Work, energy, and power

$$P = \frac{\Delta W}{\Delta t} = Fv$$

3.4.1.8 Conservation of energy

$$\Delta E_p = mg\Delta h \quad E_k = \frac{1}{2}mv^2$$

3.4.2 Materials

3.4.2.1 Bulk properties of solids

Density $\rho = \frac{m}{V}$

Hooke's law, elastic limit

Tensile strain and tensile stress

Elastic strain energy, breaking stress

3.4.2.2 The Young modulus

$$\text{Young modulus} = \frac{\text{tensile stress}}{\text{tensile strain}}$$

3.6 Further mechanics

3.6.1 Periodic motion

3.6.1.1 Circular motion

$$\omega = \frac{v}{r} = 2\pi f \quad a = \frac{v^2}{r} = \omega^2 r \quad F = \frac{mv^2}{r} = m\omega^2 r$$

3.6.1.2 Simple harmonic motion (SHM)

3.11 Engineering physics

3.11.1 Rotational dynamics

3.11.1.1 Concept of moment of inertia

$$I = \sum mr^2$$

3.11.1.2 Rotational kinetic energy

$$E_k = \frac{1}{2}I\omega^2$$

3.11.1.3 Rotational motion

$$\omega_2 = \omega_1 + \alpha t, \theta = \left(\frac{\omega_1 + \omega_2}{2}\right)t$$

$$\theta = \omega_1 t + \frac{\alpha t^2}{2}, \omega_2^2 = \omega_1^2 + 2\alpha\theta$$

3.11.1.4 Torque and angular acceleration

$$T = Fr \quad T = I\alpha$$

3.11.1.5 Angular momentum

$$\text{angular momentum} = I\omega$$

3.11.1.6 Work and power e

$$W = T\theta; P = T\omega$$

Let's look at A-Level Maths



A-LEVEL MATHEMATICS (7357)

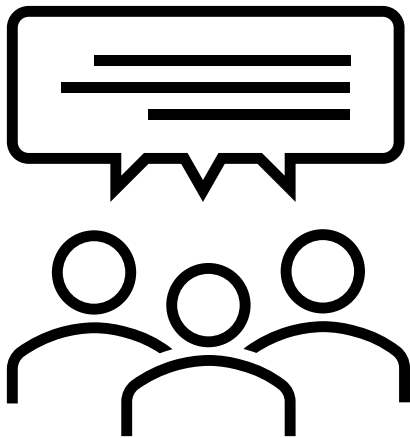
Specification
For teaching from September 2017 onwards
For exams in 2018 onwards

Version 1.3 31 January 2018

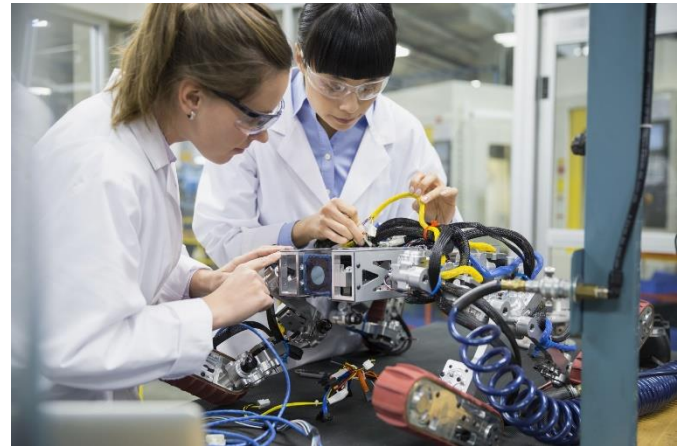
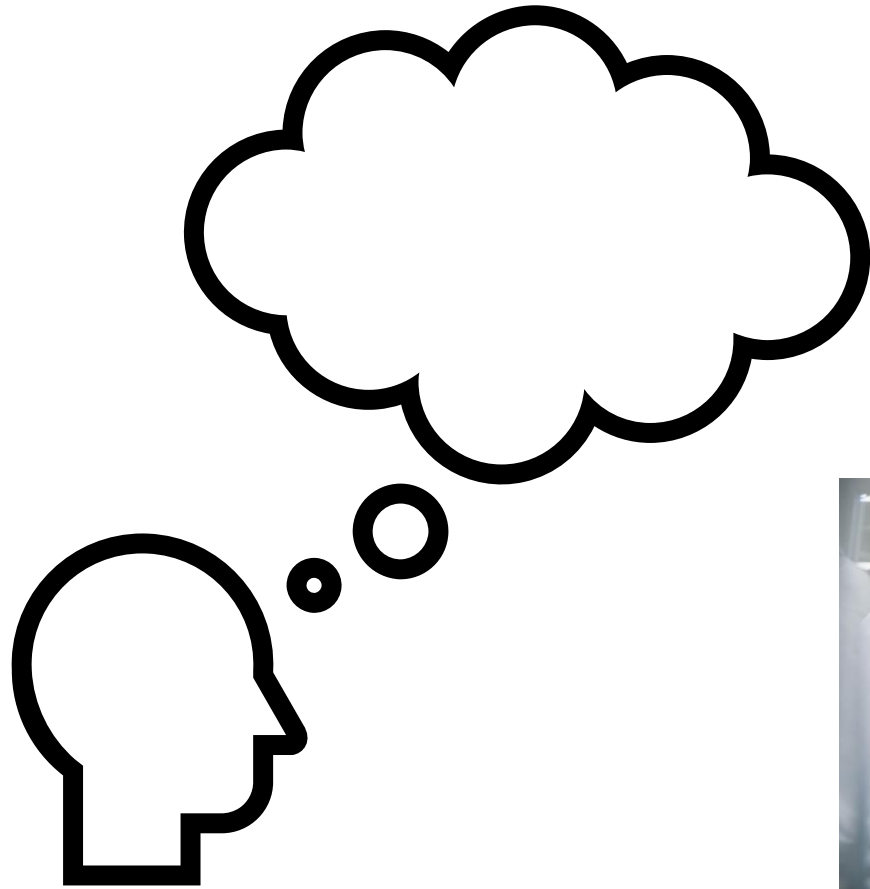


2.1 Subject content

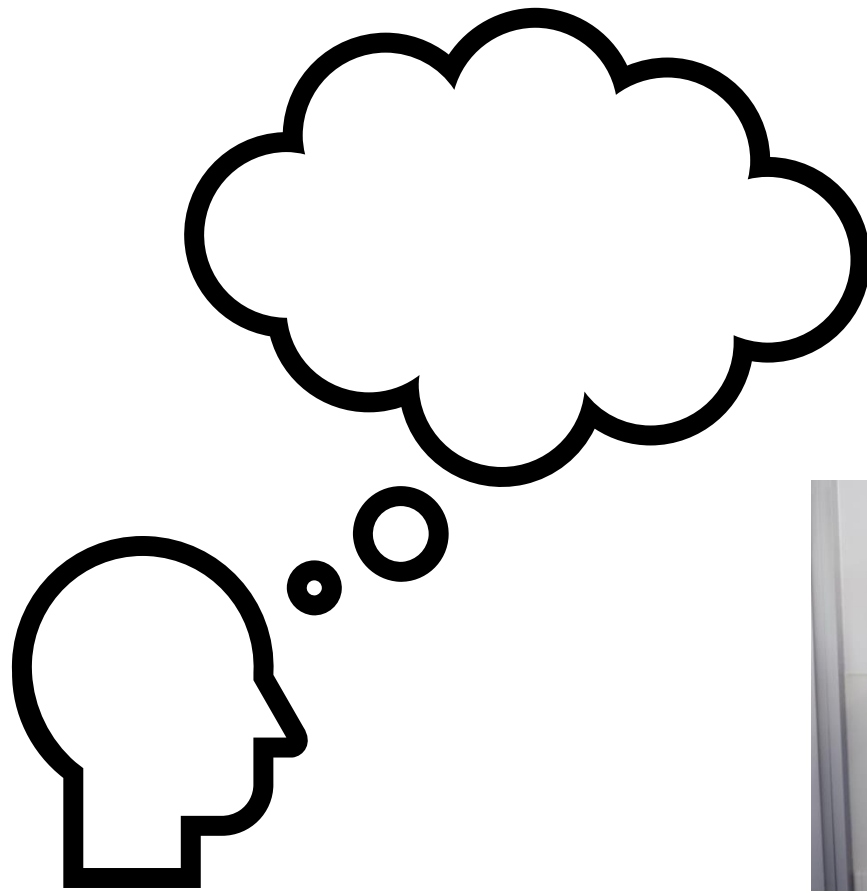
- [OT1: Mathematical argument, language and proof](#)
- [OT2: Mathematical problem solving \(page 11\)](#)
- [OT3: Mathematical modelling \(page 12\)](#)
- [A: Proof \(page 12\)](#)
- [B: Algebra and functions \(page 13\)](#)
- [C: Coordinate geometry in the \(\$x\$, \$y\$ \) plane \(page 14\)](#)
- [D: Sequences and series \(page 15\)](#)
- [E: Trigonometry \(page 16\)](#)
- [F: Exponentials and logarithms \(page 17\)](#)
- [G: Differentiation \(page 18\)](#)
- [H: Integration \(page 19\)](#)
- [I: Numerical methods \(page 20\)](#)
- [J: Vectors \(page 20\)](#)
- [K: Statistical sampling \(page 21\)](#)
- [L: Data presentation and interpretation \(page 21\)](#)
- [M: Probability \(page 22\)](#)
- [N: Statistical distributions \(page 23\)](#)
- [O: Statistical hypothesis testing \(page 23\)](#)
- [P: Quantities and units in mechanics \(page 24\)](#)
- [Q: Kinematics \(page 24\)](#)
- [R: Forces and Newton's laws \(page 24\)](#)
- [S: Moments \(page 25\)](#)



Question Time!

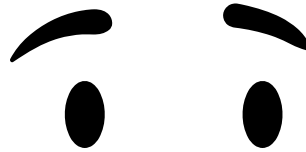


Are women good at Engineering?



Are men good at Nursing?

What am I good at?

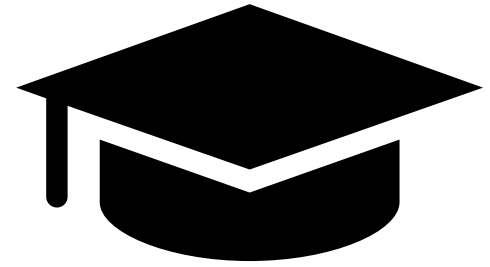
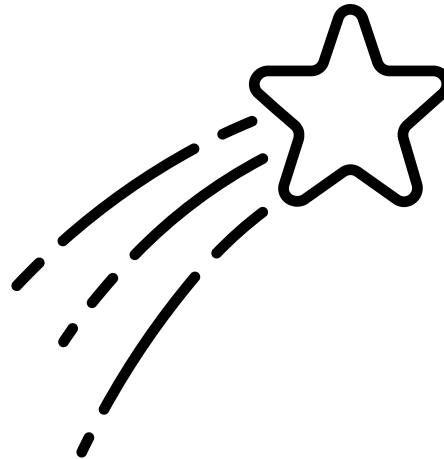


A person with dark hair and a beard is seen from the side, looking at a large computer monitor. The monitor displays a bright blue sky with white clouds. The person is wearing a dark shirt. The text "MATHS & ENGINEERING" is overlaid on the image in a bold, sans-serif font. "MATHS &" is in white, and "ENGINEERING" is in a vibrant green color.

MATHS & ENGINEERING

*Sheffield Hallam
University*

*Our Aerospace,
Automotive, and
Mechanical Engineering
MEng and BEng
Degrees have been
recently
re-accredited by the
Institution of Mechanical
Engineers for another 5
years up to 2025-2026*



**IMPROVING
THE WORLD
THROUGH
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**MECHANICAL
ENGINEERS**

Thank you!