Engineering focus module: Aeronautical engineering

30 hours indicative time

One or more examples of aeronautical engineering must be used to develop an understanding of the scope and nature of this profession.

Some examples include: design and construction of recreational aircraft, general aviation aircraft, military aircraft, space craft, agricultural aircraft, helicopters and home-built aircraft.

Outcomes

A student:

H1.1 describes the scope of engineering and critically analyses current innovations

H1.2 differentiates between the properties and structure of materials and justifies the selection of materials in engineering applications

H2.2 analyses and synthesises engineering applications in specific fields and reports on the importance of these to society

H3.1 demonstrates proficiency in the use of mathematical, scientific and graphical methods to analyse and solve problems of engineering practice

H3.2 uses appropriate written, oral and presentation skills in the preparation of detailed engineering reports

H3.3 develops and uses specialised techniques in the application of graphics as a communication tool

H4.1 investigates the extent of technological change in engineering

H4.3 applies understanding of social, environmental and cultural implications of technological change in engineering to the analysis of specific engineering problems

H5.2 selects and uses appropriate management and planning skills related to engineering

H6.1 demonstrates skills in research, and problem-solving related to engineering

Peter Tran

1. Scope of the profession	
Students learn about:	*Notes:*
▪ nature and scope of the aeronautical engineering profession	▪
▪ current projects and innovations	▪
▪ health and safety issues	▪
▪ training for the profession	▪
▪ career prospects	▪
▪ unique technologies in the profession	▪
▪ legal and ethical implications	▪
▪ engineers as managers	▪
▪ relations with the community	▪

Students learn to:	*Notes:*
▪ define the responsibilities of the aeronautical engineer	▪

Peter Tran

▪ describe the nature and range of the work of aeronautical engineers	▪
▪ examine projects and innovations from within the aeronautical profession	▪
▪ analyse the training and career prospects within aeronautical engineering	▪

2. Historical and societal influences	
Students learn about:	*Notes:*
▪ historical developments in aeronautical engineering	▪ aeronautical engineering first come into reference with birds and human flight. ▪ Apparatus of wings and feature of planes
▪ the effects of aeronautical innovation on people's lives and living standards	▪
▪ environmental implications of flight	▪

Students learn to:	*Notes:*
▪ research the history of flight in Australia and understand the way it has impacted on people's lives	▪ A
▪ examine safety issues related to flight and flying	▪

3. Engineering mechanics and hydraulics	
Students learn about:	*Notes:*
▪ fundamental flight mechanics relationship between lift, thrust, weight and drag lift to drag ratio effect of angle of attack	▪ In planes design engineers focus on **4 main forces** ➔ Lift, drag, weight and thrust. – **Lift (L)** is the **upwards force** that holds the plane in the air. It needs to be equal to the weight force, where the ailerons achieve most of its flight. – **Weight (W)** **rce due to gravity**, pulling the plane down. **D)** force that acts to **oppose the motion.** In most aircraft in motion, the drag is **air resistance**, which is used to **slow** the plane **t (T)** rces that allows the aircraft to **push in the desired direction**. It is created by the **engines,** and **propeller**, dragging air which s drag. ation of these forces allows for a straight and constant level flight **(equilibrium).**

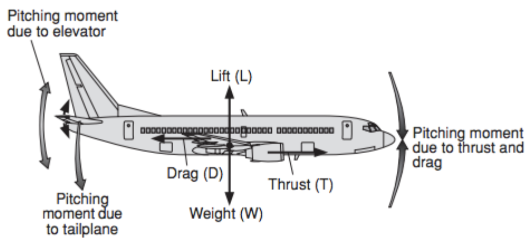

Figure 3.1 Forces and moments on a plane

- **Flight Dynamics.** If the 4 forces are manipulated and **not in equilibrium (usually caused by the surface controls)**, then they will experience a **moment**.
  - **Pitching ➔ Elevators**
    This is used to determine the **angle of attack** and **direction of the nose (either moving up or down).** Pitching involves the horizontal stabiliser (Elevators) that **move up to induce drag and hence reduce lift, causing the nose it point upwards and conversely**.

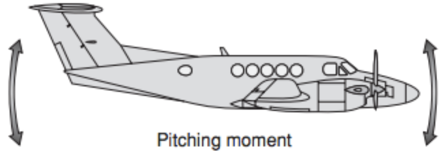

Figure 3.2 Pitching moment

  - **Rolling ➔ Ailerons**
    This is used to determine the **direction** and **change the aircraft position** (left or right). Rolling involves the wing's ailerons, that have **opposites motions on each side**, to allow for a lift on one wings and a reduce lift on the other causing a roll. **Useful for making Banks**.

Figure 3.3 Rolling moment

  - **Yawing ➔ Rudder**
    This used uses to **turn the aircraft to a left or right motion**. Yawing involves the vertical stabilisers (Rudders) which help deflect the plane. If the **rudders deflect left**, the **aircraft will yaw right forcing a right turn, and conversely**.

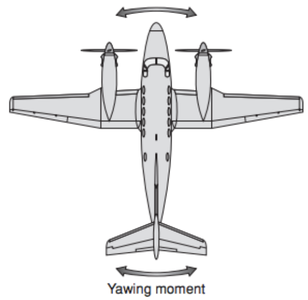

Figure 3.4 Yawing moment

- **Flight Surface Controls**. There are three mains deflectors that **help stabilise and control** the aircraft's motion.
  - **Elevators**
    Used to assist Pitching moments. They are located **horizontally at the back of the plane**, at the tailplane. They exists as a part fixed in a hinged, or be a whole horizontal elevators, at the tailplane (stabilisers). Elevators are useful to achieve an **ascend or a descend of a plane or making the right angle of attack**.
  - **Ailerons**

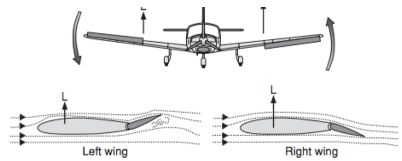

Figure 3.56 Ailerons allow the aircraft to turn or roll

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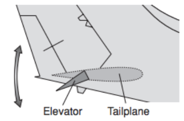
Used to assist Rolling moments. They are located horizontally at the plane's wings besides the flaps. They are used to create an imbalance in the forces, to create a rolling motion, where the ailerons on each side act oppositely. Ailerons are useful to achieve banking techniques, curving the plane and making a turn (by lifting one wings, and lowering the other).
– Rudders
Used to assist the Yawing moments. They are located as vertical stabilisers at the tailplane. They makes yawing and a left or right turn possible by deflect one side, to allow the aircraft to turn the opposite way. Rudders, are useful to making a turn.
– Flaps
Used to achieve (MORE INFORMATION)


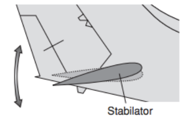
Figure 3.53 Hinged elevator


Figure 3.54 Stabilator or all moving tail
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▪ Bernoulli's principle and its application to
– venturi effect
– lift
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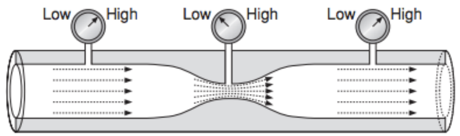
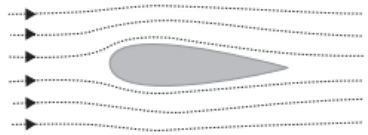
▪ Bernoulli's Principle in relations to
– Venturi Effect
States that in a fluid, the pressure to constant and to maintain a constant pressure in the aileron, it will induce lift. In relations to the venturi effect, when airflow flows through the glass hour pipe. At stage one all the airflow can flow normally, hence there is high pressure and a normal slow velocity. As in stage two, the pipe hole is smaller and hence, all the airflows must travel at the same direction, at the same time, means that the top and streamline must travel a longer distance to flow with the middle streamline, flowing at the normal slow velocity. This is through the venturi effect, that explain the Bernoulli's principle as the increase in velocity of the fluid due to its equilibrium in streamlines will create a low-pressure fluid.


Figure 3.12 Airflow through a venturi
– Lift
Bernoulli's Principle is used to explain lift in the wings of the plane.
In relations to the Venturi effect, as wind and air to colliding with the aerofoil shaped wings, they will create streamlines that that are massless air molecule flowing in the opposing direction. It is said through Bernoulli's principle that all the create streamlines are to simultaneously travel at the same time and velocity, hence the streamlines at the bottom travel unimpeded, whilst the top streamlines must curve and detour around the aerofoil wings. To hold Bernoulli's principle, they are required to travel at a faster velocity due to their increase in distance that they need to travel. This increase in velocity will decrease in pressure (Venturi Effect) creating a pressure difference. (Low pressure at top / High pressure at bottom). This change in air pressure, generates lift and hence, forms an upward motion.

– Aerofoil
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	The **shape of the wings is known as aerofoils.** – **Streamlines** Streamlining occurs when **succeeding molecules follow the same path** in a flow. ▪ **Pressures in Fluid (aircrafts)** – **Static Pressure** Static Pressure is caused by no motion in the fluid – **Dynamic Pressure** Dynamic Pressure is caused when there is an uneven pressure equilibrium. ▪
▪ bending stress – airframes	**Engines** • Originally, the **piston combustion engine** was used since the Wright Brothers. o These were similar to the engines cars used but with cooling systems o They originally had a poor power to weight ratio • Then came the **rotary piston engine** o This was an engine that was **lighter, more powerful and cheaper to produce**. o But they were very **difficult to fly** due to the gyroscopic effects of the pistons. • They're still used today, and they are usually lighter, simpler to maintain and cheap to obtain. o Which is good on small-scale/recreational aircraft. o They cannot fly very fast as these engines are not as powerful as others. o Easy to maintance and lighter
▪ propulsion systems including internal combustion engines jet including turbofan, ram and scram turboprop – rockets	▪ **Propulsion systems provide thrust for the aircraft**. Large amount of **air mass** is **heated up** to create **high pressure** and **high velocity** jets, which are **ejected at the rear**, to create **thrust** and **provide energy for the turbines**. ▪ **Turboprop engines** – A propeller located at the front collects and suck air into the inlet, consisting of a turbine and combustion chamber. The air is then compressed and forced in high speed streamlines, and are provided with fuel. This in turn heats up the air and drive the turbine

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shaft, which operates and spins the propeller (which in turn collects air and cycles). The remain hot gas is ejected to create thrust and drive the aircraft.
– Turboprops have little efficiency, as most of the energy is placed to spin to propeller. They may require a reduction gear, to slows the speed of the increasing turbine and reduce the wastage of power to loud noises.
– Turboprop engines are used for small, recreational aircraft.
▪ Turboprop engines
– Doesn’t have a propeller, instead incoming air is sucked into the inlet, consisting compressor and a combustion chamber. When air is forced into the compressor, layers of blades create a jump in air pressure and provide much higher pressure and velocity then normal streamlines. Witt this, fuel is induced to heat up the air, creating streams of hot air known as jets. Streams of jets are ejected and hence produces thrust.
(Analogy ➔ Depleting balloon, as when a release of the neck will create an imbalance pressure, causing high velocity air to ejects and propeller the balloon).
▪ Combustion engines

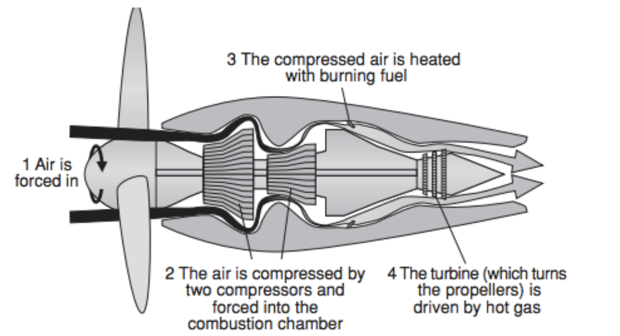

Figure 3.66 Turboprop engine

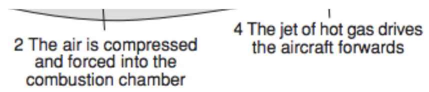

Figure 3.67 Turbojet engine
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▪ fluid mechanics
Pascal’s principle
hydrostatic and dynamic pressure
– applications to aircraft components and instruments
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▪ Pressure
– Hydrostatic Pressure (Static Pressure)
Pressure that is exerted equally through the fluid, like the force of gravity, where no external motion is applied.

$$P_S = \rho_S g h$$

– Dynamic Pressure
When extra pressure is present due to relative motion of the fluid

$$P_D = \frac{1}{2}\rho_D v$$

– Total Pressure

$$\text{Pressure}_{\text{Total}} = \text{Pressure}_{\text{Static}} + \text{Pressure}_{\text{Dynamic}}$$
$$P_T = \rho_S g h + \frac{1}{2}\rho_D v^2$$

▪ Pressure systems on are used on aircraft.
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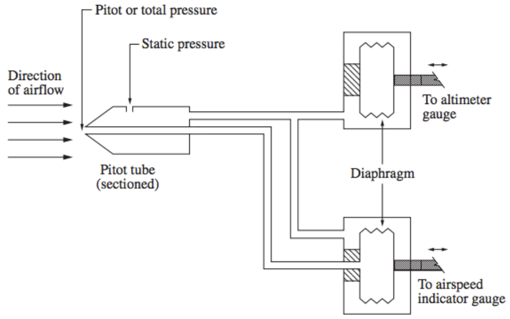
- **Applications** to aircraft components and instruments
  - **Pitot Tube**
    - Used to enable air to flow and measure its velocity, and pressures. Consisting of **two pipes**, one is fixed **perpendicular to air flow** to sense static pressure, whilst the **other is faced in the direction** of the flow to sense the total pressure.
    - Another CONCEPT THAT I HAVEN'T GRASPED
      In the pitot tube, there are fluid placed in the tubes to allow a height difference in both the tubes. This determines the velocity and the rate of the flow. However, due to wind and generate of cold condition, it may freeze the fluid, hence a heating pitot head it used.



  - **Airspeed Indicator**
    - Used to **measure the speed of the aircraft in the air.** It takes in account of the **total pressure and static pressure**. When **air enters to pitot tube,** into the **diaphragm**, the static pressure (already there) is accompanied with the dynamic pressure, produced by the incoming air. To measure the relative motion, the **static pressure line is introduced to nullify the static pressure from the total pressure**, enabling **only the dynamic pressure to contribute to the expansion and contraction of the diaphragm. This diaphragm is linked to a scale reading.**

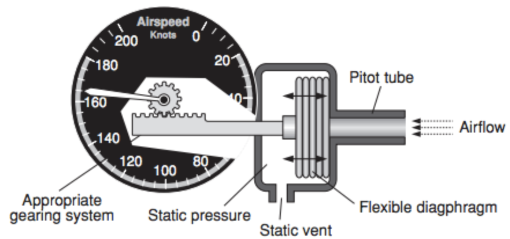


Figure 3.77 Airspeed indicator (ASI)

  - **Altimeter**
    - Used to **measure the height or altitude of the aircraft position**. Static pressure enters the pitot tube via a static vent, which is collected by the **Earth atmospheric pressure above sea level**. A **decrease in Earth's atmosphere, decreases the air molecule that is subjected onto the static pressure, and hence an increase in attitude.** This enables the diaphragm to **expands and contracts and the movement is indicated by a gear system on a scale (dial).**

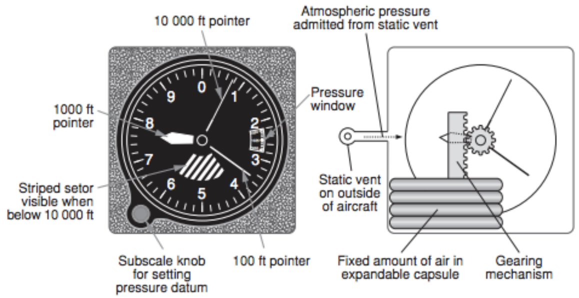


Figure 3.75 Altimeter

  - **Vertical Speed Indicators (NOT IMPORTANT)**
    - Used to measure the speed and rate of an ascend and decrease. Takes in account will static pressure.

Students learn to:	*Notes:*
▪ apply mathematical and graphical methods to solve flight-related problems	▪ Lift To Drag Ratio $$tan\theta = \frac{D}{L}$$ $$\frac{L}{D} = \frac{1}{tan\theta}$$
▪ outline Bernoulli's principle as applied to instrumentation and lift	▪
▪ investigate the nature and effect of bending stresses, applying appropriate mathematical methods	▪
▪ describe the operational principles and use of the stated propulsion systems used in the aircraft industry	▪

4. Engineering materials	
Students learn about:	*Notes:*

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- specialized testing of aircraft materials

dye penetrant
X-ray, gamma ray
magnetic particle
ultrasonic

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<table>
<tr><td>Non-Destructive Testing</td><td>Description</td><td>Other Notes</td></tr>
<tr><td>Visual Inspection</td><td>A magnifying glass is used to inspect the internal cracks formations and small flaws. Hot oil is poured in the structure and the movement of the oil will visualise if flaws.</td><td>Used repaired components</td></tr>
<tr><td>Dye Penetrant</td><td>The component is cleaned and then painted with penetrant fluid,</td><td>Used for components that many have external cracks due manufacturing fatigue.</td></tr>
<tr><td>X-ray</td><td>A X-ray scan is done on the component where the results can be displayed on a photographic film or a fluorescent screen</td><td>Used for small components, to detect Internal voids and subsurface cracks.</td></tr>
<tr><td>Gamma ray</td><td>Same as X-ray but with a high more dangerous EMR.</td><td></td></tr>
<tr><td>Magnetic Particle</td><td>The item become magnetised and the magnetic field lines that have discontinuity or accumulate due to the cracks, and defects provide the flaws.</td><td>Works well on magnetic materials like Steel and iron</td></tr>
<tr><td>Ultrasonic</td><td>A ultrasonic equipment is used as a vibration as, the reflection of each vibrations can be timed or the pulses of each interval, can help determine internal flaws</td><td>Used for any type of component. They are
Mainly used for small internal cracks.</td></tr>
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- aluminum and aluminum alloys used in aircraft including aluminum zinc, aluminum silicon magnesium, aluminum copper

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- Metals used mainly in **commercial airbus and aircrafts are heat-treated aluminium alloy**, whilst **military aircraft consist of titanium and stainless steel.**
- **Aluminium**
  - Aluminium is **ductile and malleable** and very **corrosive resistant**, hence is very **soft** and **lacks strength**.
- **Silicon**
  - As a non-metal material, Aluminium Silicon Alloy, **makes the alloy harder and not brittle**, **reducing it melt point** for easier casting.
- **Magnesium**
  - Aluminium Magnesium Alloy, **increase its tensile strength, hardness** and **weldabilit**y.
- **Zinc**
  - Aluminium Zinc Alloy, can be **heat-treated to increase stiffness** and **strength**, however **very brittle**.
- **Copper**
  - Aluminium Copper Alloy, **increases strength and hardness** as it ages, whilst **preventing crack formation** and is more **shock resistant.**

Cold Work ➔ Rolling bending drawing and pressing (Non Heat Treatment)

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▪ structure/property relationship and alloy applications changes in macrostructure and microstructure – changes in properties	▪
▪ heat treatment of applicable alloys	▪ Stabilising – When components are manufactured, that internal stress changed, hence stabilising process allows for the materials to relieve internal stress retaining its original strength and hardness. The component is heated to about 250 degrees for up to 5 hours before allowing it to slowly cool in the air. ▪ Annealing – The component is heated to about 360 degrees for an hour before it is air cooled. This process helps soften the aluminium alloy and improves corrosion resistant.
▪ thermosetting polymers structure/property relationships and their application manufacturing processes compression moulding hand lay-up vacuum lay-up – modifying materials for aircraft applications	▪
▪ composites – types including reinforced glass fibre, Kevlar, carbon fibre and Fibre Metal Laminate (FML) as used in aircraft construction	▪ ***Reinforce Glass Fibre*** – ***Reinforced Glass Fibre can either be tempered glass or laminated glass.*** ▪ ***Kevlar*** – ▪ ***Carbon Fibre*** – ***They have excellent strength to weight ratio, making them very strong, providing high stiffness. Having outstanding high temperature capabilities, they are extensively used in aerospace vehicle, as nozzles, re-entry vehicles, and jet turbines. For commercial airbus, they are used as aircraft brakes to withstand the friction of decelerating which causes high temperatures.*** ▪ ***Epoxy***

– structure/property relationships and their application in aircraft	– ***This is a matrix for carbon fibre providing high toughness at low cost (excellent mechanic properties).*** ▪ ***Fibre Metal Laminate (FML)*** – ***Different fibre metals are sandwiched with a core. In aircrafts, the cores are either, Honeycomb Core or Syntactic Core.***
▪ corrosioncommon corrosion mechanisms in aircraft structures – pit and crevice corrosion – stress corrosion/cracking – corrosion prevention in aircraft	▪ Pitting – Pitting is a form of corrosion that occurs when a material comes into contacts with acids, alkaline and chemical solution. It causes the metal to corrode into pit holes losing ductility and strength. Coating the surface or cleaning it with reduce pitting corrosion ▪ Crevice Corrosion – In crevice and inaccessible corner of metals, they lack oxygen compared to other parts. Hence they become anodic, losing gaining electrons and corroding. To prevent crevice corrosion on aircraft, the corners are vented and are drained, to allow for oxygen and remove electrolytic necessary for corrosion to occur. ▪ Stress Corrosion/Cracking – Metal under stress with corrode more often than unstressed metal. They have the ability to crack protective layer and hence make the surface vulnerable to corrosion and ultimately failure of the parts. ▪ Prevention of Corrosion – Aircraft parts can be protected from corrosion by coating the surface with a sacrificial anode or hot dipping in molten zinc. But, the most effective and simplest method is carefully cleaning all the parts of the aircraft. The skin of the aircraft, battery acids, floor and exhaust system should be thoroughly cleaned off.

Students learn to:	*Notes:*
▪ describe non-destructive tests used on aircraft materials and components	▪
▪ analyze structure, property relationship, uses and appropriateness of materials and	▪

processes used in aeronautical engineering applications	
▪ investigate the effects of heat treatment on the structure and properties of aluminum alloys	▪
▪ justify appropriate choices of polymers for their application and use in aircraft	▪
▪ describe the uses and application of composites used in aircraft construction	▪
▪ understand the mechanism of corrosion common to aircraft components and identify corrosion prevention techniques	▪

5. Engineering materials	
Students learn about:	*Notes:*
▪ freehand and technical drawing pictorial and scaled orthogonal drawings	▪
▪ Australian Standard (AS 1100)	▪

▪ developments – transition pieces	▪
▪ graphical mechanics – graphical solution to basic aerodynamic problems	▪
▪ computer graphics, computer aided drawing (CAD) – 3D applications	▪
▪ collaborative work practices	▪
▪ Engineering Report writing	▪

Students learn to:	*Notes:*
▪ produce dimensioned orthogonal component and scaled drawings applying appropriate Australian Standard (AS 1100)	▪
▪ construct the development of non-circular transition pieces	▪
▪ construct quality graphical solutions	▪

▪ use appropriate software to produce pictorial drawings	▪
▪ work with others and identify the benefits of working as a team	▪
▪ complete an Engineering Report on the aeronautical engineering profession with reference to the following aspects: – nature and range of the work of aeronautical engineers – engineers as managers – technologies unique to the profession – current projects and innovations – health and safety issues – ethics related to the profession and community career prospects – training for the professions – use of appropriate computer software and presentation technique	▪