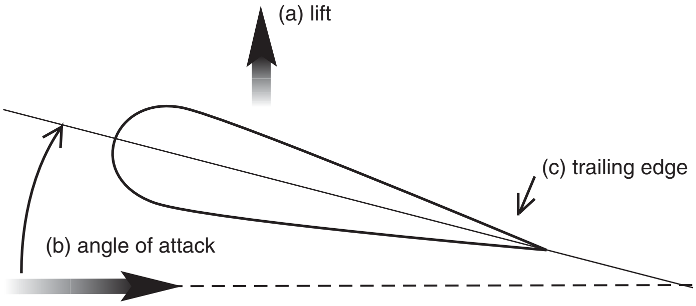
Unit 2 Detailed study 2: Investigations: aerospace

Chapter 17

Aerospace investigations

1. In fluids, the particles experience more freedom than in solids, they are bound together less tightly, and the spaces between them are larger. This is especially so in gases.
2. As the speed of a fluid increases, the pressure decreases. This is Bernoulli's principle in simple terms.
3. In the term $\frac{1}{2}\rho v^2$, ρ = density, measured in kg m^{-3}, and v = fluid speed, measured in m s^{-1}. Therefore the units of $\frac{1}{2}\rho v^2$ are kg m^{-3} × (m s^{-1})^2 = kg m^{-3} m^2 s^{-2} = kg m^{-1} s^{-2} . N is equivalent to kg m s^{-2}, so N m^{-2} is equivalent to kg m s^{-2} × m^{-2} or kg m^{-1} s^{-2} as above.
4. In the term ρgh, ρ = density, measured in kg m^{-3}, g = acceleration due to gravity, measured in m s^{-2}, and h = height, measured in m. Therefore the units of ρgh are kg m^{-3} × m s^{-2} × m = kg m^{-1} s^{-2}. N is equivalent to kg m s^{-2}, so N m^{-2} is equivalent to kg m s^{-2} × m^{-2} or kg m^{-1} s^{-2} as above.
5. The centre of pressure is the point on an aircraft's wing at which the lift forces are considered to be acting. The centre of gravity is the point on any object at which the weight force can be considered to be acting.
6. (a) ↑ 100 N, net force, accelerates up
   (b) → 100 N, decelerates
   (c) ↑ 200 N + ← 10 N, accelerates up and forwards
   (d) ↓ 200 N + ← 10 N, accelerates down and forwards
7. (a) Constant speed
   ∴ thrust = drag
   drag = 25 kN
   (b) F = 25 000 N
   v = 200 m s^{-1}
   $P = Fv$
   = 25 000 × 200
   = 5 000 000
   = 5.0×10^6 W
8. An aerofoil is curved on the top and flat on the bottom. It is shaped so that the air travelling over the top surface is sped up, reducing the air pressure below normal pressure. This results in an upwards force, known as the lift force, that acts from the region of normal air pressure below the aerofoil towards the region of lower pressure above the aerofoil.
9. $v_1 = 1.2$ m s^{-1} $\quad v_2 = ?$
   $A_1 = 0.45$ m^2 $\quad A_2 = 0.32$ m^2
   $$v_1A_1 = v_2A_2$$
   $$v_2 = \frac{v_1A_1}{A_2} = \frac{1.2 \times 0.45}{0.32} = 1.7 \text{ m s}^{-1}$$
10. $v_1 = 9.3$ cm s^{-1} $\quad v_2 = 13$ cm s^{-1}
   $A_1 = 61$ cm^2 $\quad A_2 = ?$
   $$v_1A_1 = v_2A_2$$
   $$A_2 = \frac{v_1A_1}{v_2} = \frac{9.3 \times 61}{13} = 44 \text{ cm}^2$$
11. $v_1 = 2.1$ m s^{-1} $\quad v_2 = ?$
   $d_1 = 0.15$ m $\quad d_2 = 0.45$ m
   $$v_1\frac{\pi d_1^2}{4} = v_2\frac{\pi d_2^2}{4}$$
   $$v_2 = \frac{v_1 d_1^2}{d_2^2} = \frac{2.1 \times 0.15^2}{0.45^2} = 0.23 \text{ m s}^{-1}$$
12. (a) $$v_1A_1 = v_2A_2$$
   $$\Rightarrow A_2 = \frac{v_1A_1}{v_2}$$
   but $v_2 = 2v_1$
   $$\Rightarrow A_2 = \frac{v_1A_1}{2v_1} = \frac{A_1}{2}$$
   The area is halved.
   (b) $$A_2 = \frac{A_1}{2}$$
   $$\pi r_2^2 = \frac{\pi r_1^2}{2}$$
   $$r_2 = \sqrt{\frac{r_1^2}{2}} = \frac{r_1}{\sqrt{2}}$$
   The radius would be reduced by a factor of $\frac{1}{\sqrt{2}}$ or 0.71.

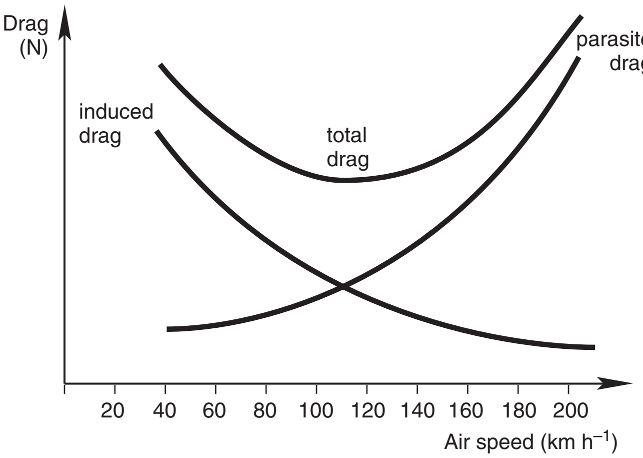
13.



14. As an aerofoil travels through the air, giving lift, it deflects the airflow downwards. This is downwash.

15. Wing-tip vortices are caused by the higher-pressure air under the wing flowing around the wingtip to the region of lower-pressure air on the top of the wing.

16. (a)



(b) Roughly 108 km h^{-1}

(c) A high lift-to-drag ratio means an aircraft experiences maximum lift and minimum drag. This corresponds to an optimum cruising speed for the aircraft and determines its maximum range and endurance.

(d) Stalling occurs at low airspeed due to an increase in drag. This corresponds to the left-hand region of the graph.

(e) In a stall, the airflow over the wing breaks down and becomes turbulent. Lift is lost and the aircraft could drop in an uncontrolled manner.

17. glide ratio = 9 : 1
loss of altitude = 1200 m

(a) $$\text{glide ratio} = \frac{\text{glide distance}}{\text{loss of altitude}}$$
$$\begin{aligned}\text{glide distance} &= \text{glide ratio} \times \text{loss of altitude}\\ &= 9 \times 1200\\ &= 10\,800 \text{ m (10.8 km)}\end{aligned}$$

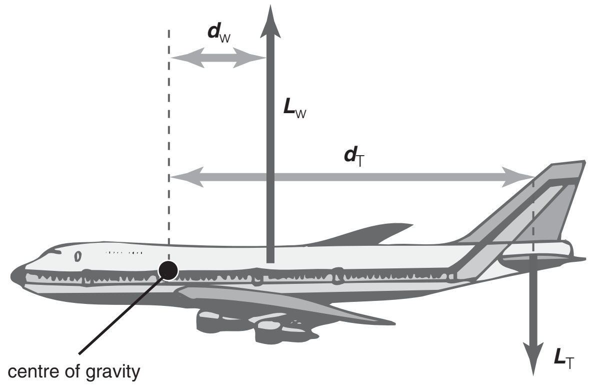
(b) lift-to-drag ratio = glide ratio
= 9 : 1

18. (a) $$\text{glide ratio} = \frac{\text{glide distance}}{\text{loss of altitude}} = \frac{12\,000}{800} = 15:1$$

(b) lift-to-drag ratio = glide ratio
= 15 : 1

19. The function of the tailplane in an aircraft is to provide an extra force that can be called into action when required to correct any out-of-balance of the aircraft.

20. (a) Taking torques about the centre of gravity,
$$\begin{aligned}\tau_{net} &= 0\\ \tau_{clockwise} &= \tau_{anticlockwise}\\ L_w \times d_w &= L_T \times d_T\\ 15\,000 \times 1.1 &= L_T \times 9.3\\ L_T &= \frac{15\,000 \times 1.1}{9.3}\\ &= 1.8 \times 10^3 \text{ N downwards}\end{aligned}$$



(b) The force that depends on the mass of the plane, the weight, mg, acts through the centre of gravity. When torques are taken about the centre of gravity, the torque due to the weight is zero.

21. The location of an aircraft's centre of gravity can be altered by repositioning the load it carries, for example, fuel, passengers and cargo. In this case, one or all of these would need to be shifted rearwards.

22. The longitudinal axis of an aircraft runs from the front end to the rear end through the centre of gravity. The vertical axis runs vertically downwards through the aircraft's body, through the centre of gravity. The lateral axis runs parallel with a line from wing tip to wing tip and also through the centre of gravity.

23.

Type of motion	**Axis about which motion occurs**	**Aircraft control surface responsible for motion**
yaw	vertical	**rudder**
pitch	**lateral**	elevators
roll	**longitudinal**	**ailerons**

24. $$v_1 A_1 = v_2 A_2$$
$$v_1 \frac{\pi d_1^2}{4} = v_2 \frac{\pi d_2^2}{4}$$
$$v_1 d_1^2 = 10 v_1 d_2^2$$
$$d_2^2 = \frac{d_1^2}{10}$$
$$d_2 = \frac{d_1}{\sqrt{10}}$$
Decrease in diameter by a factor of $\frac{1}{\sqrt{10}}$ or 0.32 increases air speed by a factor of 10.