Chapter 4 Basic Aerodynamics

4.1 Consider the incompressible flow of water through a divergent duct. The inlet velocity and area are 5 ft/s and 10 ft^2, respectively. If the exit area is four times the inlet area, calculate the water flow velocity at the exit.

4.2 In the above problem, calculate the pressure difference between the exit and the inlet. The density of water is 62.4 lb$_m$/ft^3.

4.3 Consider an airplane flying with a velocity of 60 m/s at a standard altitude of 3 km. At a point on the wing, the airflow velocity is 70 m/s. Calculate the pressure at this point. Assume incompressible flow.

4.4 An instrument used to measure the airspeed on many early low-speed airplanes, principally during 1919-1930, was the venturi tube. This simple device is a convergent-divergent duct. (The front section's cross-sectional area *A* decreases in the flow direction, and the back section's cross-sectional area increases in the flow direction. Somewhere in between the inlet and exit of the duct, there is a minimum area, called the throat.) Let A_1 and A_2 denote the inlet and throat areas, respectively. Let p_1 and p_2 be the pressures at the inlet and throat, respectively. The venturi tube is mounted at a specific location on the airplane (generally on the wing or near the front of the fuselage), where the inlet velocity V_1 is essentially the same as the freestream velocity, i.e., the velocity of the airplane through the air. With a knowledge of the area ratio A_1/A_2 (a fixed design feature) and a measurement of the pressure difference $p_1 - p_2$, the airplane's velocity can be determined. For example, assume $A_2/A_1 = 1/4$, and $p_1 - p_2 = 80$ lb/ft^2. If the airplane is flying at standard sea level, what is its velocity?

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4.5 Consider the flow of air through a convergent-divergent duct, such as the venturi described in Prob. 4.4. The inlet, throat, and exit areas are 3, 1.5, and 2 m^2, respectively. The inlet and exit pressures are 1.02×10^5 and 1.00×10^5 N/m^2, respectively. Calculate the flow velocity at the throat. Assume incompressible flow with standard sea-level density.

4.6 An airplane is flying at a velocity of 130 mi/h at a standard altitude of 5000 ft. At a point on the wing, the pressure is 1750.0 lb/ft^2. Calculate the velocity at that point, assuming incompressible flow.

Given:

$$v_1 = 130\frac{mi}{hr} \;\; ; \;\; h = 5000\,ft \;\; ; \;\; P_2 = 1750\,\frac{lb_f}{ft^2} \;\; ; \;\; v_2 = ?$$

Solution:

Use the pressure variation at gradient region 0-11 km, and use 2116.8 psf to P_0.

$$\frac{P_1}{P_0} = \left[\frac{T_0 + \lambda h}{T_0}\right]^{5.26}$$

$$P_1 = 1761.25\,psf$$

And now, the density variation at gradient region 0-11 km, and use 0.002377 slugs/ft^3 to ρ_0.

$$\frac{\rho_1}{\rho_0} = \left[\frac{T_0 + \lambda h_\rho}{T_0}\right]^{4.26}$$

$$\rho_1 = 2.05\times 10^{-3}\,\frac{slugs}{ft^3}$$

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Before proceeding to the Bernoulli's equation, we should convert the unit of velocity, v_1, from mi/hr to ft/s.

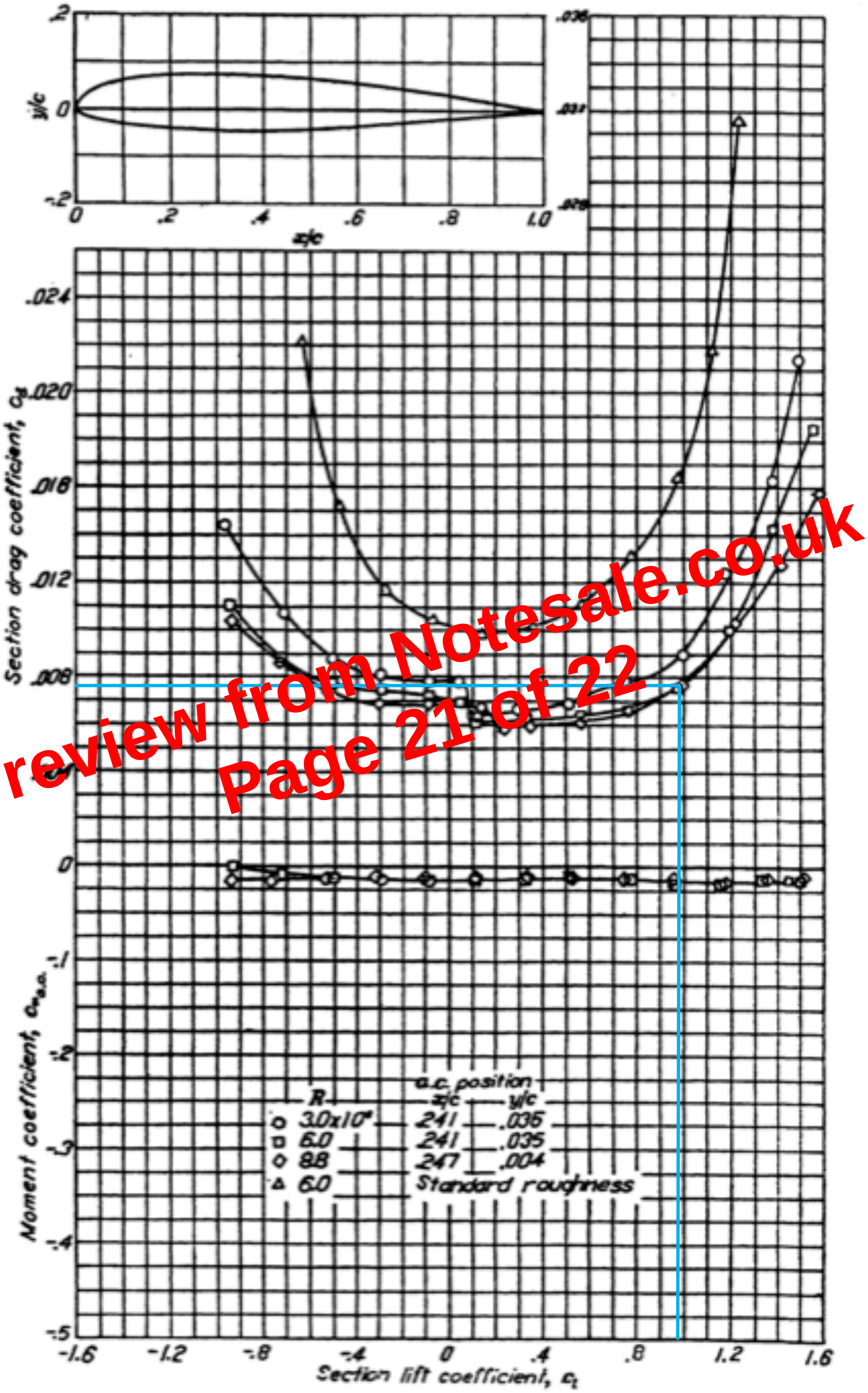
$$v_1 = 130\frac{mi}{hr}\times\left(\frac{88}{60}\right) = 190.67\,\frac{ft}{s}$$

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

Through derivation to get the value of velocity where the pressure is 1750 lb/ft^2,

$$v_2 = \sqrt{\frac{2(P_1 - P_2)}{\rho} + v_1^2}$$

$$\boldsymbol{v_2 = 217.58\,\frac{ft}{s}}$$ **←Answer**



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