Loughborough University

(08TTA003) FLUID MECHANICS
RESIT COURSEWORK

Where necessary assume:	density of air	=	1.225 kg/m^3
	density of water	=	10^3 kg/m^3
	density of mercury (Hg)	=	13.6 x 10^3 kg/m^3
	absolute viscosity of air	=	1.8 x 10^{-5} kg/ms
	absolute viscosity of water	=	1.8 x 10^{-3} kg/ms
	atmospheric pressure	=	1.013 x 10^5 N/m^2
	gravitational acceleration, g	=	9.81 m/s^2
	gas constant for air, R	=	287 J/kg K

1. Figure Q1 shows an open-topped tank filled to depth h with a salt-water solution of varying density. The solution is pure water of density ρ_w at the free surface, $z = h$, and is a saturated salt solution of density ρ_s at the bottom, $z = 0$. The density varies linearly with height. The walls of the tank are made of glass in order to view fluid motion in the tank.

   a) Determine an expression for the density ρ at any height z in the tank.

   b) Determine an expression for the pressure p at any height z in the tank.

   c) Determine an expression for the net force acting on unit width of the glass sides of the tank.

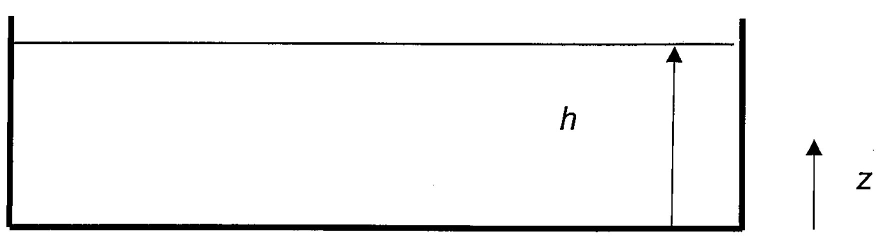

Figure Q1

2. In an aircraft, fuel of density 790 kg/m^3 is pumped from a tank to an engine through a 20 mm diameter delivery pipe. At the engine, the pipe ends in a nozzle of 10mm diameter which discharges a jet of fuel into a combustion chamber of the engine. The absolute static pressure in the combustion chamber is 2 MPa. The absolute static pressure in the delivery pipe immediately before the nozzle is 4.5 MPa. The fuel tank is pressurised to 1 bar (absolute) and the free surface of the fuel is 2m below the height of the nozzle.

a) Calculate the velocity of the jet of fuel into the combustion chamber.
b) Calculate the power required to pump the fuel from the tank to the engine.

c) If the fuel in the tank flows radially towards the delivery pipe that is mounted on a flat side wall of the tank, determine the velocity of the fuel in the tank a distance 25 cm from the pipe entrance.

3. Each cylinder of a 4-cylinder turbo-charged IC engine discharges into a pipe of diameter 20 mm at an average pressure of 1.8 bar and an average velocity of 44 m/s. The four separate pipes are joined together in a manifold into a single exhaust pipe of diameter 35 mm. The turbine of the turbo-charger is placed within the uniform exhaust pipe. The exhaust pipe discharges into atmosphere (pressure 1.1 bar) by way of a tailpipe which is bent to deflect the exhaust gas downwards by an angle of 60°, see Figure Q3.

a) Evaluate the power output of the turbine.

b) Evaluate the horizontal and vertical components of force of the exhaust gas upon the tailpipe bend.

(Assume the density of the exhaust gas is 0.48 kg/m^3 throughout.)

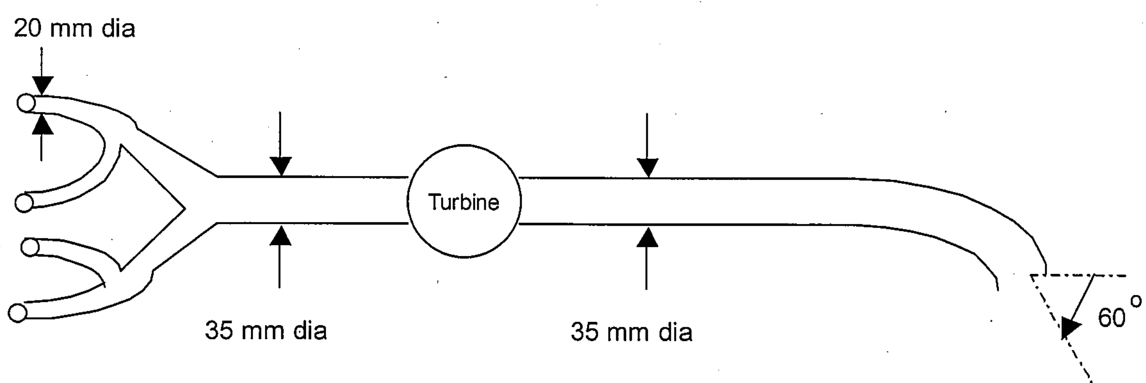

Figure Q3

4. A streamlined train is 150m long, 2.8m wide and with sides 2.5m high. It is moving at 144km/hr through air of density 1.225kg/m^3 and absolute viscosity 1.79x10^{-5} kg/ms. Assuming that the skin friction drag on sides and top equals that on one side of a flat plate 150m long and 8.5m wide, determine

a) The location of the boundary layer transition, if transition occurs at $R_x = 5 \times 10^5$

b) The boundary layer thickness at
   i) transition.
   ii) the rear of the train.

c) The shear stress at transition

d) The total skin friction drag.

Equations:

$$\frac{\delta}{x} = \sqrt{\frac{30}{R_x}} \qquad \frac{\delta}{\mathrm{x}} = \frac{0.38}{R_x^{0.2}}$$

$$c_{f_0} = \sqrt{\frac{8}{15R_x}} \qquad c_{f_0} = \frac{0.06}{R_x^{0.2}}$$

5. a) A sink of strength 20m^2/s is located at the origin and a uniform flow with a velocity of 3m/s from left to right is superimposed on the source flow. Determine:

   i) the streamfunction of the flow in polar and cartesian coordinates.

   ii) The location of the stagnation points.

b) The flow around a cylinder of radius R with circulation Γ is given by

$$\psi = U\left(\frac{R^2}{r} - r\right)\sin\theta - \frac{\Gamma}{2\pi}\ln(r)$$

For a cylinder of radius 0.3m, in a uniform flow of 3.5m/s and with a circulation of 2.4m^2/s calculate:

   i) the positions of the stagnation points.

   ii) the lift generated.

Assume ρ = 1.225kg/m^3 and use the following equations

$$v_t = -\frac{\partial\psi}{\partial r}, \quad \mathrm{v_r} = \frac{1}{r}\frac{\partial\psi}{\partial\theta}$$

velocity of the model and the pressure required in the tank for dynamic similarity.

At 6Km: speed of sound = 316.2m/s
$\mu = 1.595 \times 10^{-5}$kg/ms
$\rho = 0.66$kg/m^3

Carbon dioxide at 20^{0}C: speed of sound = 265.4m/s
$\mu = 1.47 \times 10^{-5}$kg/ms
gas constant = 187.8 J/KgK

b) Does the flow, whose velocity potential is given by $\varphi = a(x^2 - y^2)$, where *a* is a constant, satisfy the continuity equation?

c) Oil flows through a pipe of diameter 90mm at a rate of 400 litres per minute. Determine the head loss along 200m of the pipe.

Head loss: $h_L = f \dfrac{l}{d} \dfrac{V^2}{2g}$

Friction factors:	Laminar	$\dfrac{64}{R}$
	Turbulent	0.035

At transition *R*=2100

Take ρ=898 kg/m^3
μ=0.0574 kg/ms

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Hand – in date is 4.00p.m. on Friday 4th September 2009