Fluid Mechanics (ME 201)

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Tutorial 4 – Integral formulation of conservation equations

1. Water flows steadily through the 90^o reducing elbow shown in the diagram. At the inlet to the elbow, the absolute pressure is 220 kPa and cross-sectional area is 0.01 m^2. At the outlet, the cross-sectional area is 0.0025 m^2 and the velocity is 16 m/s. The elbow discharges to the atmosphere. Determine the force required to hold the elbow in place. Atmospheric pressure is 1.01bar. [R_x=1.03 kN and R_y=640 N]

2. The drag force of a bullet-shaped device may be measured using a wind tunnel, which is round with a diameter of 1 m, the pressure at section 1 is 1.5 kPa gage, the pressure at section 2 is 1.0 kPa gage, and air density is 1.0 kg/m^3. At the inlet, the velocity is uniform with a magnitude of 30 m/s. At the exit, the velocity varies linearly as shown in the sketch. Determine the drag force on the device and support vanes. Neglect viscous resistance at the wall, and assume pressure is uniform across sections 1 and 2. [304 N]

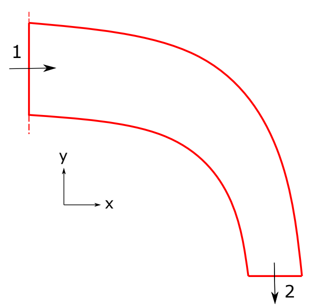

Figure for Problem 1

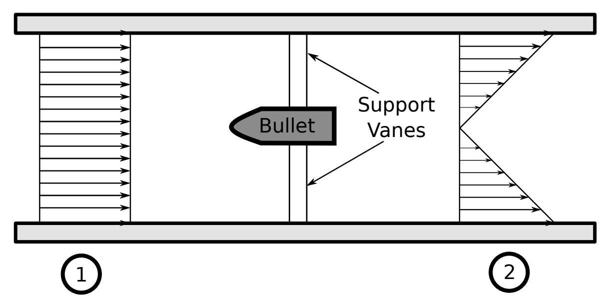

Figure for Problem 2

3. Air at 101 kPa (abs), 21^{o}C enters a compressor with negligible velocity and is discharged at 344 kPa (abs), 38^{o}C through a pipe with 0.09m^2 area. The flow rate is 9 kg/s. The power input to the compressor is 447 kW. Determine the rate of heat transfer. [-290.2 kW]

4. A static thrust stand is to be designed for testing a jet engine. The following conditions are known for a typical test: Intake air velocity = 200 m/s; exhaust gas velocity=500 m/s; intake cross-sectional area=1 m^2; intake static pressure is -22.5 kPa; intake static temperature is 268 K; exhaust static pressure is 0. Estimate the anchoring force required for the stand.
. [83.7 kN]

5. A compressible flow of air enters a jet engine of the aircraft with velocity, pressure and temperature of 200 m/s, -22.5 kPa and 268 K respectively. Area at the inlet is 1 m^2. The engine exhausts the gas at a velocity 500 m/s with the atmospheric pressure. Find the thrust force produced by the engine, assuming $R_{\text{air}} = 286.9\ J/kgK$, and $p_{\text{atm}} = 100\ kPa$. [82.5 kN]

6. Consider an incompressible fluid flow through a passage. At a particular section of area A and average velocity U, derive expressions for kinetic energy correction factor (α) and momentum correction factor (β). $\left[\alpha = \frac{1}{A}\int\left(\frac{u}{U}\right)^3 dA; \beta = \frac{1}{A}\int\left(\frac{u}{U}\right)^2 dA\right]$.

7. Air flows through a duct and a pitot-static tube measuring the velocity is attached to a differential gauge containing water. If the deflection of the gauge is 100 mm, calculate the air velocity, assuming density of air is 1.22 kg/m^3. [39.3 m/s]

8. Derive Bernouli's equation from the steady flow energy equation.

9. A light plane flies at 150 km/hr in standard air at an altitude of 1000 m. Determine the stagnation pressure at the leading edge of the wing. At a certain point close to the wing, the air speed relative to the wing is 60 m/s. Compute the pressure at this point. [90.6 kPa (abs); 88.6 kPa (abs)]

10. Consider flow of water between two flat plates that are 2 m apart. At the inlet, the flow enters with a uniform velocity of 1 m/s, and after 50 m from the inlet (section 2), the flow attains a parabolic velocity profile. Compute the kinetic energy correction coefficient at section 2. Calculate the pressure difference between inlet and section 2. What is the percentage of error produced while neglecting the correction factor?