ESO204A: Fluid Mechanics and Rate Processes
TUTORIAL 12 PROBLEMS

August-November 2017

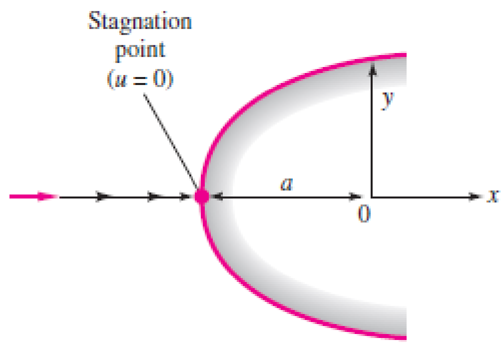
1. Review of Tutorial 11

2. A frictionless (inviscid), incompressible, steady flow field is given by

$$\mathbf{V} = 2xy\mathbf{i} - y^2\mathbf{j}$$

in arbitrary units. Let the density be $\rho_0 =$ constant and neglect gravity. Staring from the Euler equations, find an expression for the pressure gradient in the x direction.

3. According to potential theory (Chapter 8) for the flow approaching a rounded two-dimensional body, as in Fig. P4.31, the velocity approaching the stagnation point is given by the expression $u = U\left(1 - a^2/x^2\right)$, $v = 0$ where a is the nose radius and U is the velocity far upstream. Compute the position of greatest deceleration along this line.



P4.31

4. A two-dimensional incompressible flow field is defined by the velocity components

$$u = 2V\left(\frac{x}{L} - \frac{y}{L}\right) \qquad v = -2V\frac{y}{L}$$

where V and L are constants. Show that the stream function exists but not the velocity potential. Derive an expression for the stream function.

5. An incompressible stream function is given by $\psi = a\theta + br\sin\theta$. (a) Does this flow have a velocity potential? (b) If so, find it.

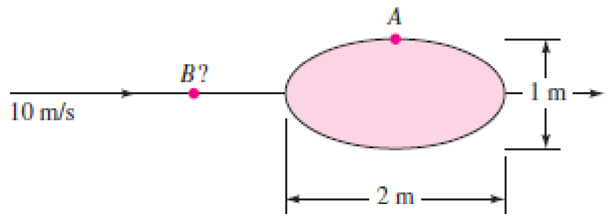
6. A steady, two-dimensional flow has the following velocity potential in polar coordinates:

$$\phi = Cr\cos\theta + K\ln r$$

where C and K are constants. Determine the stream function $\psi(r,\theta)$ for this flow. Let C be a velocity scale U and let $K = UL$; sketch what the flow might represent.

7. A Rankine oval 2 m long and 1 m high is immersed in a stream $U_\infty = 10$ m/s, as in Fig. P8.37. Estimate (a) the velocity at point A and (b) the location of point B where a particle approaching

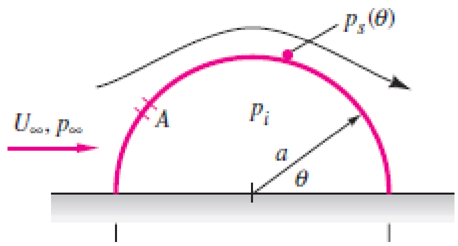
the stagnation point achieves its maximum deceleration. Use the expression for velocity potential derived in the class.



P8.37

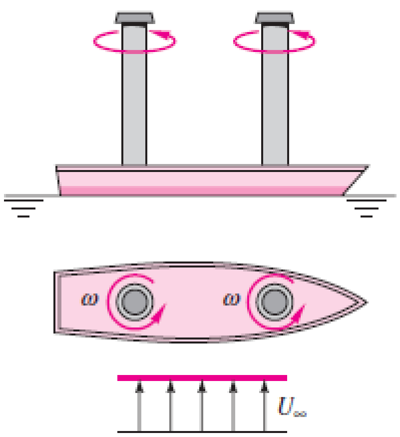
8. A large Rankine oval, with a = 1 and h = 1 m, is immersed in 20°C water flowing at 10 m/s. The upstream pressure on the oval centerline is 200 kPa. Calculate (a) the value of m; and (b) the pressure on the top of the oval (analogous to point A in Fig. P8.37).

9. Wind at U_∞ and p_∞ flows past a Quonset (prefabricated) hut which is a half-cylinder of radius a and length L (Fig. P8.48). The internal pressure is p_i. Using inviscid theory, derive an expression for the upward force on the hut due to the difference between p_i and p_s.



P8.48

10. The original Flettner rotor ship was approximately 30 m long, displaced 800 tons, and had a wetted area of 325 m^2. As sketched in Fig. P8.54, it had two rotors 15m high and 3m in diameter rotating at 750 rotations per min. The measured lift and drag coefficients for each rotor were about 10 and 4, respectively. If the ship is moored (stationary) and subjected to a crosswind of 8 m/s, as in Fig. P8.54, what will be the aerodynamic force parallel and normal to the ship centerline? Compare these numbers with those obtained from potential theory.



P8.54