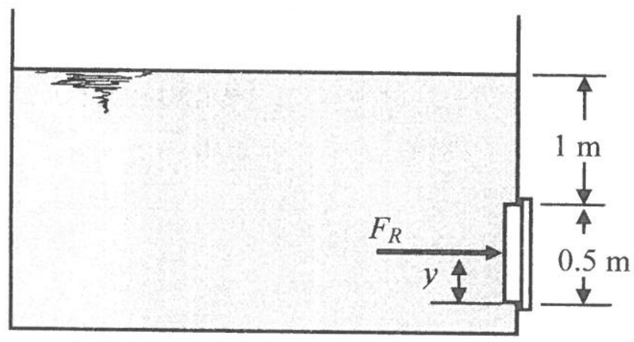
(15%)

1. A water tank has a square 0.5 × 0.5 m^2 plate bolted to one side of its wall. Determine the magnitude F_R and location y of the resultant force on the attached plate. (Specific weight of water is 10 kN/m^3)



(10%)

2. The velocity field of an incompressible, steady flow is given by $\vec{V}(u,v,w) = u\vec{i} + v\vec{j} + w\vec{k}$,

where

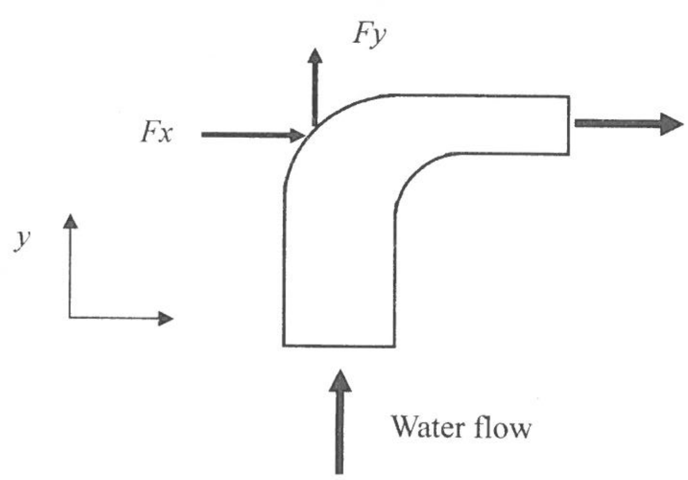
$u = x^2 - y^2 + z$

$v = x - zy - z^2$

Determine the form of the z component, w, required to satisfy the continuity equation.

(25%)

3. Water flows through a horizontal, 90° pipe bend as shown in the figure. The cross-sectional areas of the pipe inlet and outlet are 20 cm^2 and 6 cm^2, respectively. The absolute pressure at the entrance is 150 kPa. The flow velocity of the water is 10 m/s when it exits the pipe. Calculate the horizontal components of the anchoring force required to hold the pipe in place. (Ambient pressure is 100 kPa. Water density is 1000 kg/m^3)

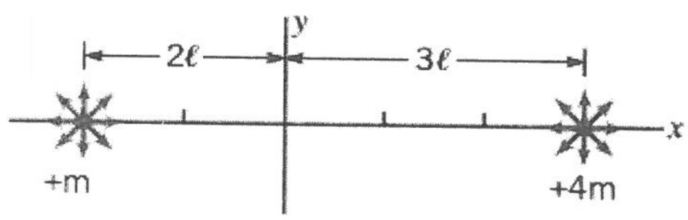


(20%)

4. The drag on a 2 m diameter satellite dish due to a 100 km/h wind is to be determined through a wind tunnel test using a geometry similar 0.4 m diameter model dish. Assume standard air for both model and prototype and the drag (D) is a function of the diameter of the dish (d), the speed of the air (v), the viscosity of the air (μ), the density of the air (ρ).
   (a) Please determine a suitable set of dimensionless variables for this problem, the drag being the independent variable. (10%)
   (b) What air speed should the model test be run. (5%)
   (c) With all similarity conditions satisfied, the measured drag on the model was determined to be 200 N. What is the predicted drag on the prototype dish? (5%)

(15%)

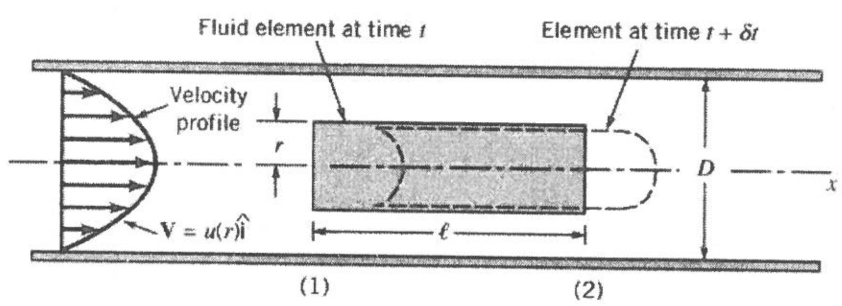
5. Two sources, one of strength m and the other with strength 4 m, are located on the x axis as shown below. Determine the location of the stagnation point the flow produced by these sources.



(15%)

6. For a fully developed laminar flowing in a pipe (Hagen-Poiseuille flow), shown below. Please show that the pressure drop can be calculated as a function of the length of the fluid element, the shear stress at the wall and the diameter of the pipe as shown in the following equation.

$$\Delta p = \frac{4l\tau_w}{D}$$



Supplementary information

TABLE 6.1
Summary of Basic, Plane Potential Flows.

Description of Flow Field	Velocity Potential	Stream Function	Velocity Components[a]
Uniform flow at angle α with the x axis (see Fig. 6.16*b*)	$\phi = U(x \cos\alpha + y \sin\alpha)$	$\psi = U(y\cos\alpha - x\sin\alpha)$	$u = U\cos\alpha$ $v = U\sin\alpha$
Source or sink (see Fig. 6.17) $m > 0$ source $m < 0$ sink	$\phi = \frac{m}{2\pi}\ln r$	$\psi = \frac{m}{2\pi}\theta$	$v_r = \frac{m}{2\pi r}$ $v_\theta = 0$
Free vortex (see Fig. 6.18) $\Gamma > 0$ counterclockwise motion $\Gamma < 0$ clockwise motion	$\phi = \frac{\Gamma}{2\pi}\theta$	$\psi = -\frac{\Gamma}{2\pi}\ln r$	$v_r = 0$ $v_\theta = \frac{\Gamma}{2\pi r}$
Doublet (see Fig. 6.23)	$\phi = \frac{K\cos\theta}{r}$	$\psi = -\frac{K\sin\theta}{r}$	$v_r = -\frac{K\cos\theta}{r^2}$ $v_\theta = -\frac{K\sin\theta}{r^2}$

[a]Velocity components are related to the velocity potential and stream function through the relationships:

$$u = \frac{\partial\phi}{\partial x} = \frac{\partial\psi}{\partial y} \quad v = \frac{\partial\phi}{\partial y} = -\frac{\partial\psi}{\partial x} \quad v_r = \frac{\partial\phi}{\partial r} = \frac{1}{r}\frac{\partial\psi}{\partial\theta} \quad v_\theta = \frac{1}{r}\frac{\partial\phi}{\partial\theta} = -\frac{\partial\psi}{\partial r}$$