1. Consider the piston-cylinder combination and the connected pipe as shown in the figure. The valve is kept open at all times. The piston stroke \( L = 0.1 \) m. The cylinder has a diameter of 0.1 m. The crank runs at a constant 300 rpm (revolutions per minute). The density of air is 1.2 kg/m\(^3\) and can be regarded as incompressible in this problem. Inside diameter of the pipe is 0.04 m. Calculate the magnitude and direction of the average velocity in the pipe at 0.05 seconds and 0.125 seconds. The variation of cylinder volume is given as follows.

\[
V = V_0 + AL(1 - \cos\omega t)
\]

Where \( A \) is the cross sectional area of the cylinder, \( L \) is the stroke, \( \omega \) is the rotational speed of the crank in radians per second, \( V_0 \) is a constant and \( t \) is the time in seconds. Show the control surface that you have selected and all your steps leading to the result. (Ans: \(-19.63 \text{ m/s, } 13.88 \text{ m/s}\))

2. A water jet pump is shown in the figure. The velocity of the jet is 25 m/s, while the velocity of the secondary stream is 5 m/s. The total area of the duct is 0.05 m\(^2\), while the jet area is 0.01 m\(^2\). The pressure of the jet and secondary stream are the same at the inlet of the duct. Assume that the water is completely mixed and leaves the duct in a uniform stream. Determine

a) the speed at the exit of the duct and
b) the pressure difference between the inlet and exit of the duct.

(Ans: a) 9 m/s, b) 64 kPa)

3. The relative flow about the wing of an aircraft can be simplified, as shown in the figure. The flow approaches the wing at a uniform flow of \( U_0 \). Although the flow is again uniform with a velocity of \( U_0 \) at the downstream of the wing, it is now deflected by an angle \( \theta \) from the initial direction due to
the presence of the wing. Determine the x and y components of the force on the wing per unit length. The density of the fluid is \( \rho \). \( \text{(Ans: } \rho U_0^2 h(1 - \cos \theta), \rho U_0^2 h \sin \theta ) \) 

4. An incompressible fluid with a density of \( \rho \) is flowing steadily through a pipe with a length of \( L \) and a radius of \( R \), as shown in the figure. The pressure at the inlet and exit of the pipe are \( p_1 \) and \( p_2 \) respectively. The velocity distribution at the inlet is uniform and it is given by \( u = u_{\text{max}}(1 - r^2/R^2) \) at the exit. Determine 
   a) the uniform inlet velocity and 
   b) the frictional force acting on the walls of the pipe. 

\( \text{(Ans: a) } \frac{U_{\text{max}}}{2}; \text{ b) } \pi R^2 \left( p_1 - p_2 - \frac{\rho U_{\text{max}}^2}{12} \right) \) 

5. A jet of water leaves the stationary nozzle at a speed of 30 m/s and impinges on a moving vane tangentially at point A, as shown in the figure. The exit diameter of the nozzle is 0.01 m. The vane which is moving with a constant velocity of 5 m/s in the x-direction, deflects the jet by an angle of 150° from the horizontal at point B. Determine the force exerted by the fluid on the vane in the x-direction. The density of water is 1000 kg/m³. \( \text{(Ans: 91.6 N) } \)
6. Water with a density of 1000 kg/m$^3$ flows steadily through a horizontal offset with a diameter of 0.2 m, as shown in the Figure. The volumetric flow rate is 0.5 m$^3$/s and the gage pressures at sections 1 and 2 are 350 kPa and 300 kPa, respectively. Assuming uniform flow at each section, determine the force and the torque that are exerted by the offset on its support. \textbf{(Ans: -1571 N} \mathbf{i}, \mathbf{0 N} \mathbf{j}, \mathbf{363.4 kNm} \mathbf{k})

7. An incompressible water jet of velocity $V_j = 8$ m/s impinges normal to a flat plate which moves to the right at velocity $V_p = 2$ m/s as shown in the figure. Find the force required to keep the plate moving at constant velocity if the jet density is 1000 kg/m$^3$ and the jet area $A_j = 0.0003$ m$^2$. Neglect the gravitational and frictional effects. Assume steady flow with respect to the moving plate and the jet is splitting into two equal branches, one upward and one downward. \textbf{(Ans: 10.8 N)