Problem 1 (20 points):

a. The pressure drop in a pipe with a diameter of 1 mm, length of 1 m, and a flow rate of 5 m$^3$/s is 4 kPa. The diameter is increased to 2 mm, the length of the pipe is increased to 2 m, and the flow rate is increased to 20 m$^3$/s. What is the pressure drop if a) flow is laminar, and b) flow is turbulent and the friction factor remains unchanged?

b. Consider flow of air, with density of 1 kg/m$^3$ and a free stream velocity of 5 m/s past a plate that is 4 m along the flow and 1 m wide. If the momentum boundary layer thickness is 1 mm at the trailing edge of the plate, what is the total frictional force on the plate in Newtons? If the boundary layer is laminar, what is the momentum boundary layer thickness at 1 m from the leading edge?

c. The power supplied to a centrifugal pump is 25 hp when the flow rate is 700 gpm, shaft speed is 1800 rpm, and the head rise is 90 ft. Estimate the head rise and the power supplied to the pump when the pump speed is 1200 rpm. Assume that the efficiency of the pump remains the same.

d. In an adiabatic flow in a duct with friction, the Mach number at section 1 is 0.4 and the temperature is 300 K. Estimate the temperature at section 2 where the Mach number is 0.8. If friction can be neglected, estimate the pressure in psia in section 2 if the pressure at section 1 is 100 psia.
Problem 2(20 points):

In a chemical processing plant, the liquid is pumped from an open tank through a 0.1 m vertical pipe as shown in the figure below. A valve is located in the pipe, and the minor loss coefficient for the valve as a function of valve setting is shown in the figure. The pump head-capacity relationship is given by the equation

\[ h = 52 - 1.01 \times 10^{-2} Q^2, \]

where \( h \) is in meters and \( Q \) is in m\(^3\)/s. Assume that \( f = 0.02 \) and all minor losses except for the valve are negligible. Determine

1. the flow rate when the valve is fully open.
2. the valve setting when the flow rate is reduced by 50%.
Problem 3 (20 points):

A centrifugal pump impeller is rotating at 1200 rpm in the direction shown in the figure. The flow enters parallel to the axis of rotation and leaves at 30° to the radial direction. The absolute exit velocity is 90 ft/s.

a. Draw the velocity triangle for the impeller exit.

b. Estimate the torque and power supplied to the pump if the density of the fluid is 64.4 lbm/ft³.
Problem 4 (20 points):
A Boeing 747 has a mass of 300 metric tons, a wingspan of 65 m and wing area of 530 $m^2$. The drag coefficient at zero lift is 0.02.

a. Determine the optimum cruising speed in kmph and the engine power in kW when the plane is flying at 10 km. Explain why the speed is optimum.

b. Determine the engine power when the plane is traveling at 200 kilometers per hour at sea level, just before it lands. Estimate the ratio of the induced drag to the total drag, and the associated downwash velocity in m/s.

Problem 5 (20 points):
Airflow through a smooth well-insulated 4” diameter pipe occurs at 1200 lbm/minute. At section (1), the air is at 100 psia and 80°F. Determine

1) the minimum pressure and the maximum speed that can occur in the pipe.

2) the length of duct in feet between section (1) and the location of maximum speed if the friction factor is 0.02.

**Hint: Use Equations or Tables on page 726 in Fox and McDonald.**

Problem 6 (20 points):
An aircraft cruises at Mach 2.0 at an altitude of 15 km. The air first enters a diffuser in which the Mach number is decreased to 1.2, at which point a normal shock occurs. The air is then decelerated before it enters a compressor inlet at Mach number=0.4.

1. Determine the temperature, pressure, and the stagnation pressure of the air at the compressor inlet.

2. Draw the T-s diagram corresponding to the flow.