Open book
Read each problem carefully before beginning to work on the answer.
Solve all problems using symbols and then substitute numerical values as a last step.
State all assumptions!
Show your work and draw a box around your final answers.

1) A constant head tank supplies water to a horizontal concrete pipe (ε = 0.3 mm) 1.5 km in length and 30 cm in diameter. The end of the pipe is fitted with a converging nozzle that gradually reduces the exit flow diameter to 15 cm. The manufacturer supplied a value of \( K_L = 0.04 \) for this fitting. The system is sketched below:

![Diagram](image)

The system as shown above produces a flow rate of 0.309 m³/s in the pipe. A client has hired you to specify the power supplied by a pump, to be added around the mid-point of the horizontal pipe, to produce the same flow rate if the converging nozzle at the outlet is replaced with a new nozzle with an exit flow diameter of only 10 cm.

What is the power that must be supplied by the pump?

2) You are faced with the following flow:
The only information you are given is that the flow depth in the supercritical region is 0.35 m. Recognizing that this is not enough information to determine the flow velocity anywhere you reach for a pencil and insert it just into the flow. The result is a wave pattern as shown below (you grab a ruler and make the measurements shown in the figure):

3) Air flows at 20 °C in a wind tunnel over the bottom of the tunnel. The flow is initiated in a manner such that you know the boundary layer starts at the point labeled $x = 0$ in the figure below.

Given the locations of the four Pitot tubes shown in the picture, determine what you expect the four manometer readings to be (manometer fluid is water at 20 °C) if the free stream velocity is $U_\infty = 15$ m/s.