UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

FINAL EXAMINATION, December 2001

MIE 414 - APPLIED FLUID MECHANICS

Examiner: C. R. Ethier

STUDENT NAME: ______________________________

STUDENT ID NUMBER: ______________________________

Open book (Type X)
All calculator types allowed
Time allotted: 2.5 hours
Circled quantities in margins are marks for each subquestion

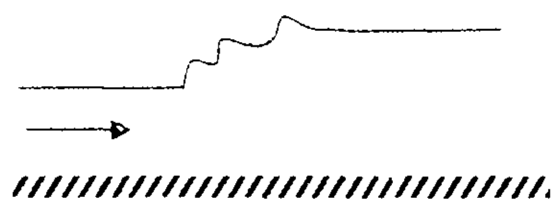
Reminder: for questions requiring numerical answers, units are required and worth 50%

Important Note: when using the compressible flow tables, you do not need to interpolate between tabulated values. Simply use the closest entry. Please indicate which table (B-1, 2, 3 or 4) you are using at each step.

Question	Maximum Mark	Actual Mark
1	12	
2	22	
3	22	
4	22	
5	22	
Total	**100**	

Question 1.

Water flows in a uniform channel having a slope of 6 degrees. The channel is 1 m wide and the water depth is 0.1 m. The channel is made from brick (Manning n = 0.015). A hydraulic jump is triggered by a small roughness element (see side view in Figure). What is the fluid depth immediately downstream of the hydraulic jump?



Question 2.

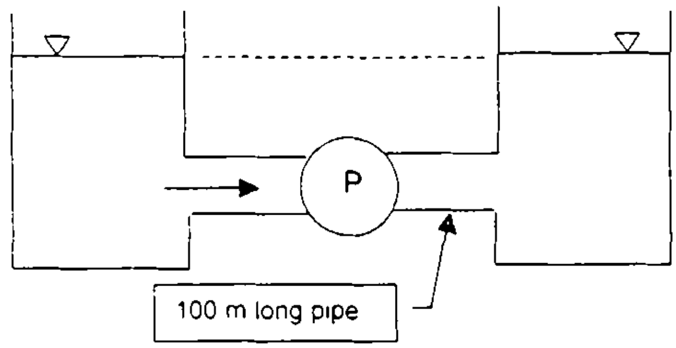
At steady state, a given pump has an impeller speed n_o and a head curve of the form $H = a - b\,Q^2$, where a and b are coefficients. Assume that the pumped fluid is water.

11 (a) When the same pump is started from rest, the impeller speed n increases as some function of time, t. Show that the head curve at any time t is given by

$$H(t) = a\,(n(t)/n_o)^2 - bQ(t)^2$$

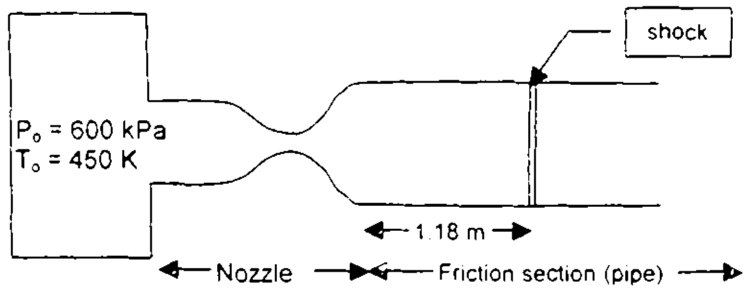
where the dependence of H, n and Q on time has been explicitly shown as H(t), n(t), and Q(t). **Hint**: use the idea of a homologous series to relate steady state conditions to time-varying conditions. Here the only variable that changes between the 2 members of the series is impeller speed n.

11 (b) This pump is used to deliver water between two reservoirs at the same elevation, as shown at right. The pump is initially turned off, and is suddenly switched on at time t=0. Neglecting all head losses, compute the acceleration of a fluid particle in the pipe at the instant when $Q(t) = 3\ m^3/s$ and $n(t) = 300$ rpm. Note that this is an unsteady flow. Use the following data:



$n_o = 1200$ rpm
$a = 35$ m
$b = 0.2\ s^2/m^5$

Question 3.

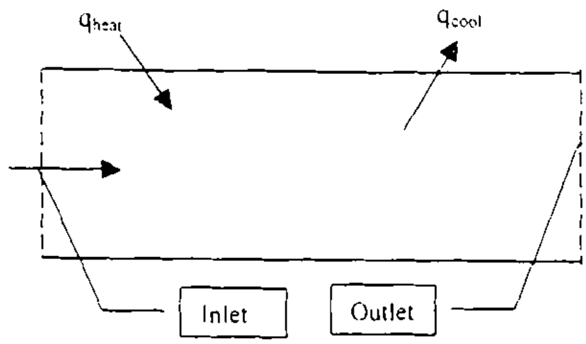


Air flows from a reservoir through a converging-diverging nozzle, and then through a section of pipe with constant cross-sectional area A_{pipe} = 0.10 m^2. You may neglect friction in the nozzle, but not in the pipe, where f = 0.03. It is known that the flow is sonic at the nozzle throat and that there is a shock in the pipe 1.18 m downstream of the end of the nozzle (see diagram). The mass flow rate is 22.86 kg/s. Find the total length of the pipe such that the flow is sonic at the end of the pipe.

Physical properties: For air: R = 287 m^2/s^2 K; c_p = 1005 m^2/s^2 K.

Question 4.

Air enters a duct of constant area in which friction can be neglected. The inlet and outlet properties are listed below. It is known that there are no shocks in the flow. In the first part of the duct, heat is added to the air, while in the second part of the duct, the air is cooled.



14 (a) What is the rate of heating, q_{heat}?

8 (b) What is the rate of cooling, q_{cool}?

Hint: Look at the tables for flow with heat addition, and think hard about how the outlet pressure can get all the way down to 18.7 kPa. Physical properties: For air, $R = 287\ m^2/s^2\ K$; $c_p = 1005\ m^2/s^2\ K$.

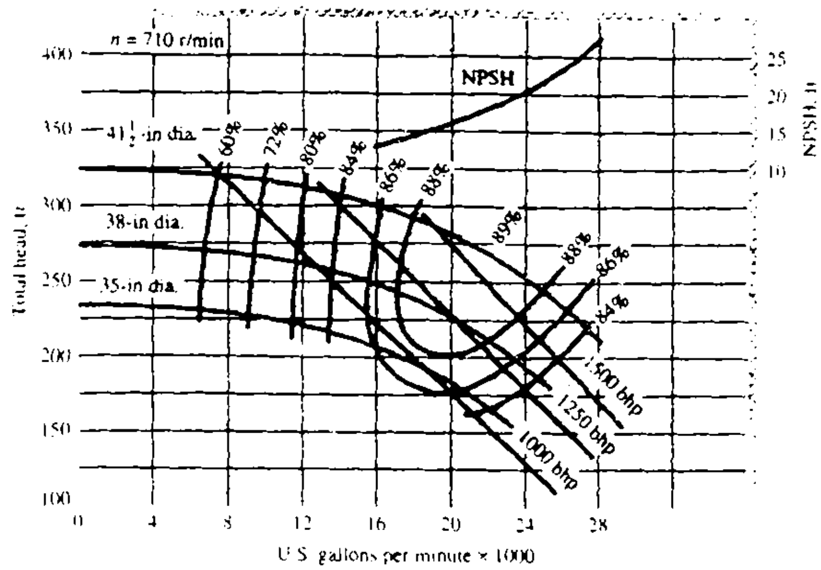
Given data

At the inlet: $p = 300$ kPa absolute, $T = 420$ K, cross-sectional area $= 0.02\ m^2$, mass flow rate $=$ 10.2 kg/s.

At the outlet: $p = 18.7$ kPa absolute

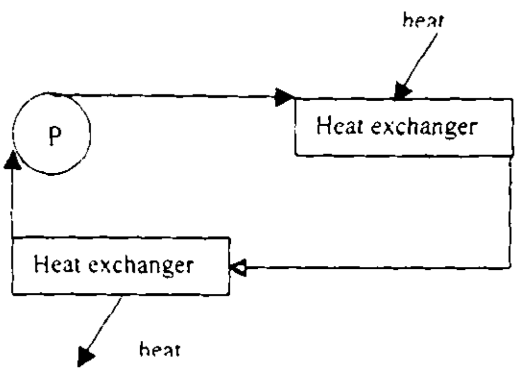
Question 5.

As part of a refrigeration system, water is pumped in a loop containing 2 heat exchangers. Each heat exchanger has a minor loss coefficient of K = 17.4, based on the water velocity in the 20" diameter inlet to the heat exchanger. You may neglect losses in the remainder of the piping system, as well as height variations through the system.



12 (a) If the 38" diameter pump from the graph at right is used, what is the resulting flow rate?

10 (b) What should the pressure be at the outlet of the pump to avoid cavitation anywhere in the system? The pipe diameter is 20 inches.



Physical properties: For water ρ=62.4 lbm/ft^3; ν = 1.4 x 10^{-5} ft^2/s; p_v = 0.26 psia. You may neglect changes in physical properties due to temperature variations.

Careful about units!

Note that 1 US gpm = 2.228 x 10^{-3} ft^3/s.