C A R L E T O N   U N I V E R S I T Y

FINAL
EXAMINATION
December 2007

DURATION: 3.0 **HOURS** **No. of Students:** 120

Department Name & Course Number: Mechanical & Aerospace Engineering MAAE 2300

Course Instructor(s): Prof. J. Gaydos

AUTHORIZED MEMORANDA

Any Calculator, One Aid Sheet (8.5" X 11.0")

Students **MUST** count the number of pages in this examination question paper **before** beginning to write, and report any discrepancy immediately to a proctor. This question paper has 5 pages.

This examination question paper **MAY NOT** be taken from the examination room.

ANSWER ALL QUESTIONS (Assigned Marks per Question indicated below)

Question 1 (20 Marks)

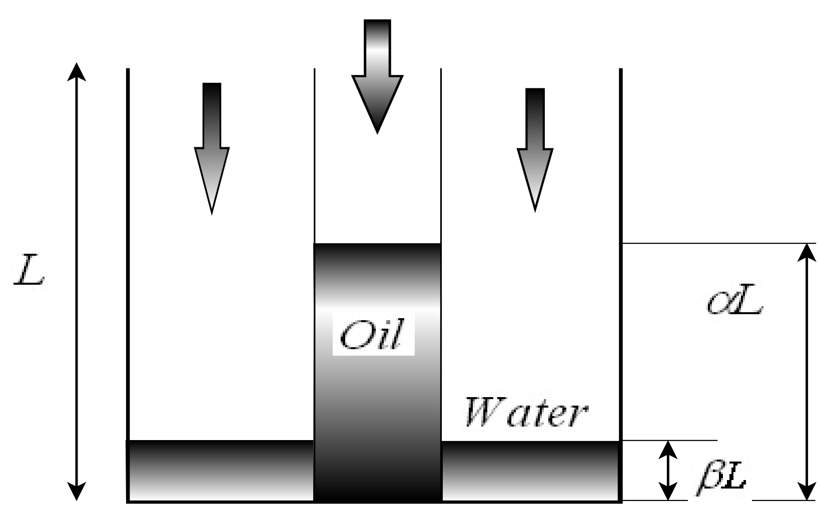
Briefly define or explain the following terms or concepts:

(a) Define kinematic viscosity in terms of dynamic viscosity and give SI units.
(b) Evaluate the specific gravity of an oily fluid with a specific weight of 7.7?
(c) The reason a Bell-mouth inlet is used to draw fluid into a pipe?
(d) Why the static pressure is lower/higher on the outer wall of a curved pipe than on the inner wall.
(e) Definition of the hydraulic diameter and its value for a triangular, cross-section duct with a side-length of 10 cm and three equal angles?
(f) You are on an elevator that is accelerating upward at a rate of 2 m/s^2 with a good cup of java (coffee) in your left hand. During the trip up you drop your fluid's book but hold on to your java cup. What is the approximate difference in pressure between the coffee at the bottom of the cup and at the free surface. You may assume that the java cup is a cylinder with a coffee depth of 12 cm and that the density of coffee is approximately the same as the density of pure water; that is, 1100 kg/m^3.
(g) Fundamental reason why Bernoulli's equation does not work for pipe flow?
(h) If a one-arm sprinkler is positioned to rotate in a plane and the exiting fluid flows out-off the arm in the same plane, then by how much can you increase the torque on the sprinkler if you double the average velocity of the exiting water and you double the length of the sprinkler arm?
(i) The method(s) that we used in this course to account for the dissipation of energy during fluid flow?

Question 2 (20 Marks)

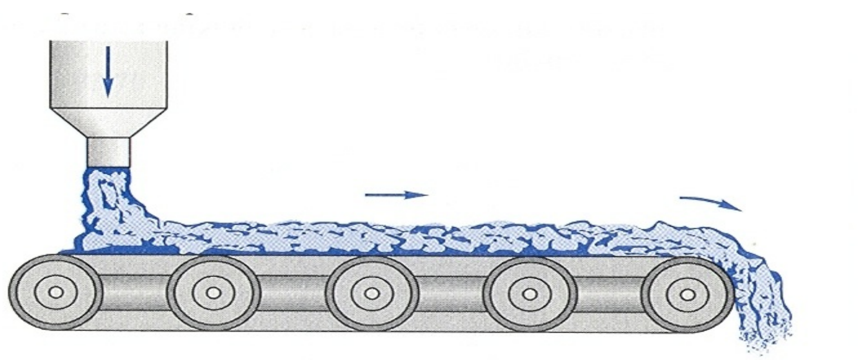
A thin cuvette (a rectangular vessel), of dimensions $L \times l \times l$, is placed within a larger cube, of dimensions $L \times L \times L$, where $l << L$. One hopes to use this arrangement to estimate the density of the liquid filling the cuvette. The empty cuvette has a weight $F_C = 0.002N$. Prior to the measurement, the cuvette is filled with the unknown oily liquid to a depth αL where $\alpha < 1$ so that the oily liquid's volume is known to be $\alpha L l^2$. After the oily liquid has been added to the cuvette, water is then added to the cube until the cuvette just begins to float. At this floating state, the water depth, denoted as βL where $\beta < \alpha < 1$, is measured.

(a) If the ratio of water depth to oily liquid depth is $\beta/\alpha = 1/3$ where $\alpha = 1/4$ and if the two dimensions are $l = 2$ cm and $L = 5l$, then estimate the density of the unknown oily liquid?
(b) For this arrangement, what is the most dense, oily liquid that can be measured if water is used as the outermost liquid?
(c) Would you recommend this arrangement for measuring density or would you suggest design changes? (Hint: Estimate the stability of your design versus the stability of the design shown below).



Question 3 (15 Marks)

Gravel is dumped from a hopper shown below, at a rate of 650 N/s, onto a moving belt. The gravel is then passed-off the end of the belt. The drive wheels are 80 cm in diameter and they rotate clockwise at a rate of 150 rev/min. Neglecting system friction and air drag, estimate the power required to drive this belt.



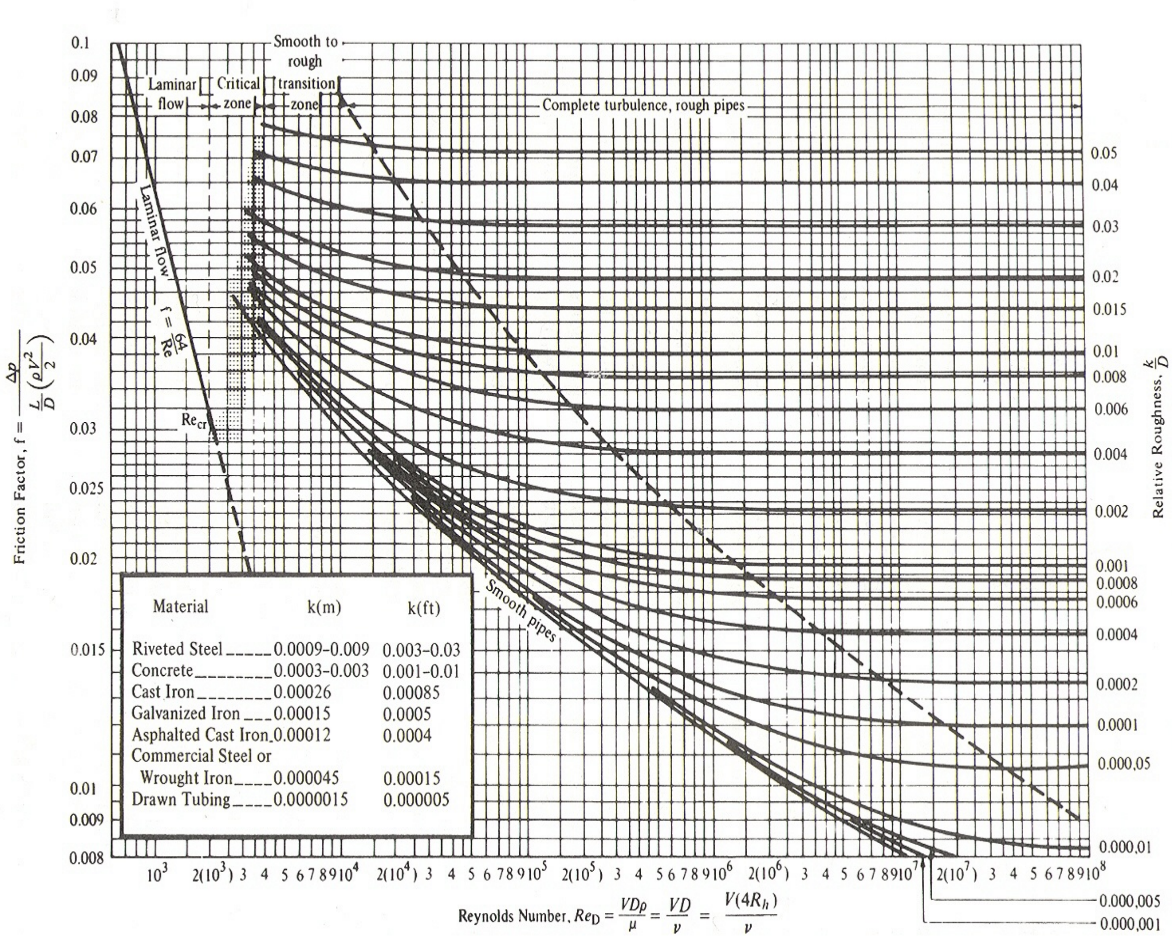
Question 4 (25 Marks)

In ancient Egypt, circular vessels filled with water were used as crude clocks. The vessels were shaped so that water drained from the vessel's bottom through a very small hole. The best shapes permitted the water surface level to drop at an almost constant rate S. Assume that the water drains from a small hole of fixed, cross-sectional area A.

(a) Find an expression for the radius R of the water vessel as a function of the water surface level H during water drainage, assuming constant rate S and a hole area A.
(b) Provide a sketch of your water vessel clock design with its small drainage hole showing the vessel radius R and the water surface level H above the horizontal level of the cross-sectional area A.
(c) Obtain an expression for the volume of water needed so that the clock will operate for T_{op} hours.
(d) If your vessel is a cylinder (NOT THE SHAPE CONSIDERED ABOVE) of radius $R_{cyl} = 15$ cm filled with water to a height $H = 50$ cm (initially), with a drainage hole area of $A = 2$ mm^2, then estimate the time, ΔT, required for the water surface level to reach the lower level $H = 40$ cm.
(e) If you attach a smooth, vertical pipe, of cross-sectional area $A = 2$ mm^2 and total pipe length $L = 50$ cm, to the drainage hole of the cylindrical water vessel

considered in part (d), then by how much would you change the period ΔT ? You may ignore entrance losses between the vessel and the smooth pipe?

Moody Diagram



Question 5 (20 Marks)

Nozzles are common in many, everyday devices. Consider the nozzle attached to the end of a typical laboratory sink faucet (see sketch below). In this situation, the conical nozzle has inlet and exit diameters of 16 mm and 5 mm, respectively. The nozzle axis is vertical and the axial distance between Section (1) and Section (2) is 30 mm. The nozzle mass is 0.1 kg. If the water flow rate is 0.6 litres/s (where one litres has a volume of 1000 mm^3), then

(a) Estimate the mass flow rate through this faucet,
(b) The average flow rate through the two cross-sections, and
(c) The anchoring force (magnitude and direction) required to hold this conical nozzle in place.