CARLETON UNIVERSITY
Department of Mechanical and Aerospace Engineering

ENGINEERING MAAE 2300 - FLUID MECHANICS I
Example Final Examinations

Answers:

December 2005

1. d = 2.657 m

   The force required in the cable is 24,525 N. The moment due to this about the hinge H must be balance by the moment do to the hydrostatic force F_R acting normal to the gate at the centre of pressure. There is no net contribution due to the free surface pressure P_S since it is balanced by P_{atm} acting on the back side of the gate.

2. Q = 0.491 m^3/s

3. (a) V_{out} = 12.7 m/s

   For parts (b) to (d) a value of V_{out} = 15 m/s was to be used. Depending on whether the volume flow rate (and mass flow rate) was adjusted to be consistent with this, slightly different values will be obtained (and were accepted) for parts (b) to (d).

   (b) Depending on the assumptions made, would obtain either 49 or 10 N. Either answer was accepted, if the assumptions were clearly stated.
   (c) 300 N. Would slide in positive y direction.
   (d) 6.7 HP

4. Solved as an example in lectures.

5. (a) 0.75 mm
   (b) 0.31 °C
   (c) 149 m

December 2003

1. (a) $F_H = 3.521 \times 10^6$ N at 16.987 m from free surface.
   (b) $F_H = 2.825 \times 10^6$ N

2. H = 40.9 m

3. (a) Q = 64.9 m^3/s
   (b) F = 760,000 N

4. $M = 2.01 \times 10^4$ Nm $\dot{W} = 3950$ HP

5. (a) $\dot{W}_{pump} = 543$ kW $\dot{W}_{shaft} = 679$ kW
(b) $y_{Cmax} = 236$ m
(c) Move pump closer to point C. In the area of C, replace some of the pipe with pipe of larger diameter to reduce the flow velocity and thus raise the static pressure.

December 2002

1. Note that parts AB and BC are rigidly connected to form an L-shaped gate.
h = 1.346 m

2. (a) (i) Y (ii) N (there are losses through the screens)
(iii) Y (iv) N (is an energy increase due to fan work)
(b) V = 72.33 m/s
(c) $\dot{W}_{fan} = 18.39$ kW $\dot{W}_{shaft} = 30.65$ kW
(d) (i) Increased
(ii) F = 144.3 N (in tension)

3. (a) $F_x = 98.7$ lb_f $F_y = 0$ $M_y = 148$ ft-lb_f
(b) $\eta_{fan} = 65.8\%$

4. N = 49.6 RPM

5. (a) $\Delta P_{12} = 50580$ Pa
(b) $Q = 18.1$ m^3/hr Oil is flowing upward.

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

Final
EXAMINATION
December 2005

DURATION: **3** HOURS No. of Students: **123**

Department Name & Course Number: **Mechanical & Aerospace Engineering, MAAE 2300A**

Instructor(s) S.A. Sjolander

AUTHORIZED MEMORANDA
1 sheet 8 1/2 x 11, both sides, any non-transmitting calculator

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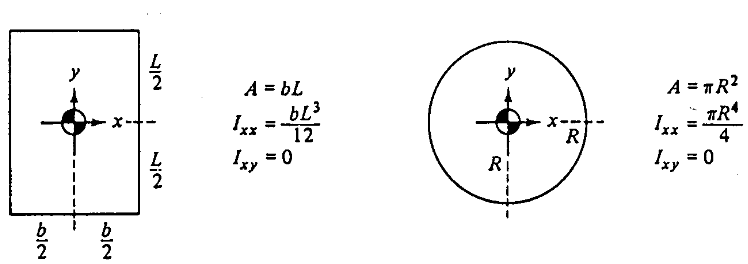
ATTEMPT ALL QUESTIONS. THE VALUE OF EACH QUESTION IS GIVEN IN THE MARGIN. DRAW COMPLETE AND FULLY-LABELLED FREE-BODY DIAGRAMS OR CONTROL VOLUMES WHERE APPROPRIATE.

Geometric properties of common cross sections:



Miscellaneous data:

Air: R = 287 Nm/kgK
C_p = 1005 Nm/kgK
C_v = 716 Nm/kgK

Water: ρ = 1000 kg/m^3
= 62.4 lb_m/ft^3
C_v = 4180 Nm/kgK

$^oR = ^oF + 460$ $^oK = ^oC + 273$ 1 litre = 1000 cm^3

g = 32.174 ft/sec^2
= 9.81 m/s^2

1 HP = 550 ft-lb_f/sec
= 745 Nm/s

See Page 7 for additional data.

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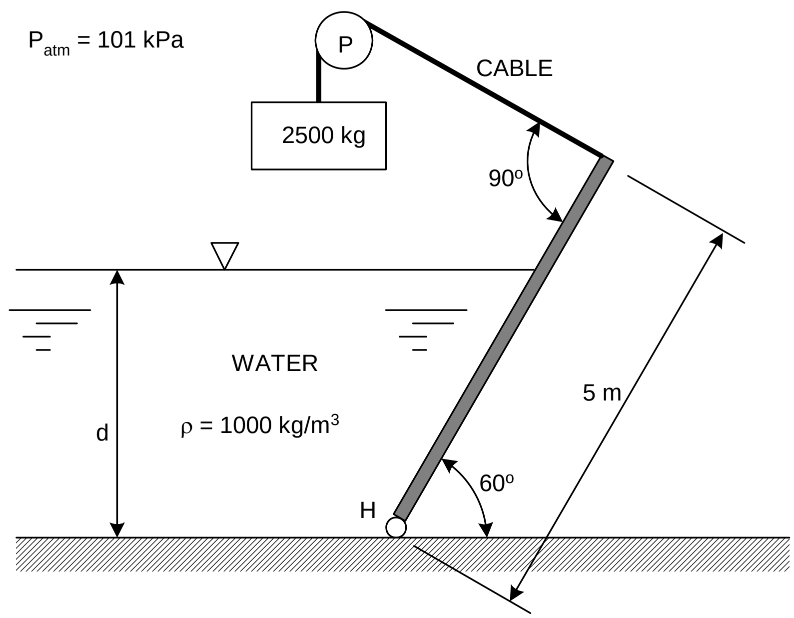
1. The gate shown is 3 m wide in the horizontal direction. For the analysis, the mass of the gate and the cable that connects it to the 2500 kg counterweight can be neglected. There is no friction at the hinge H or at the pulley P. What is the depth d of the water in the reservoir for the conditions shown in the drawing?

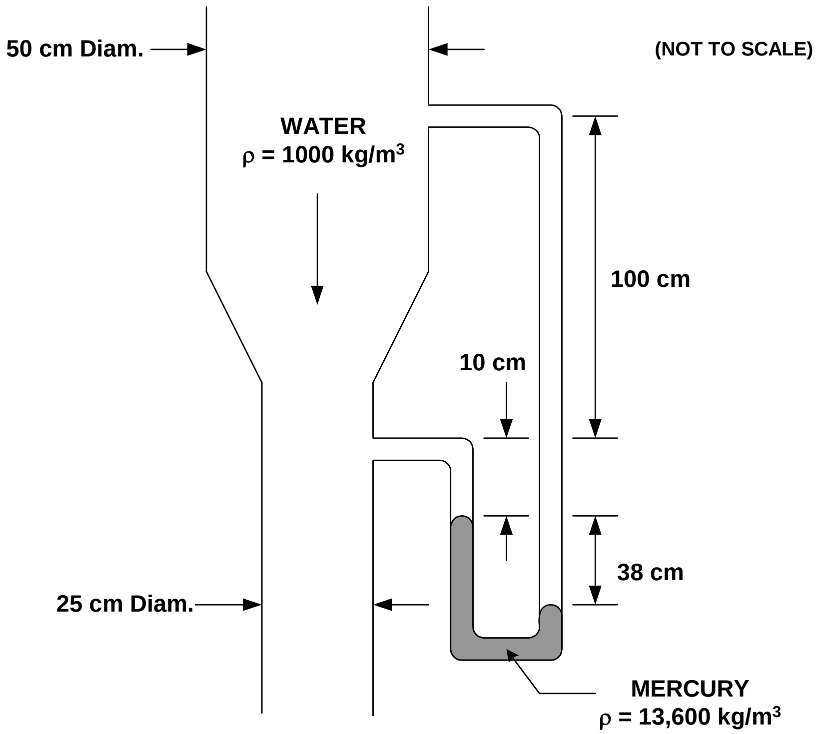
[20]



(NOT TO SCALE)

2 Determine the volume flow rate of water, in m^3/s, downward in the vertical contracting pipe shown in the drawing. State any simplifying assumptions made.

[15]



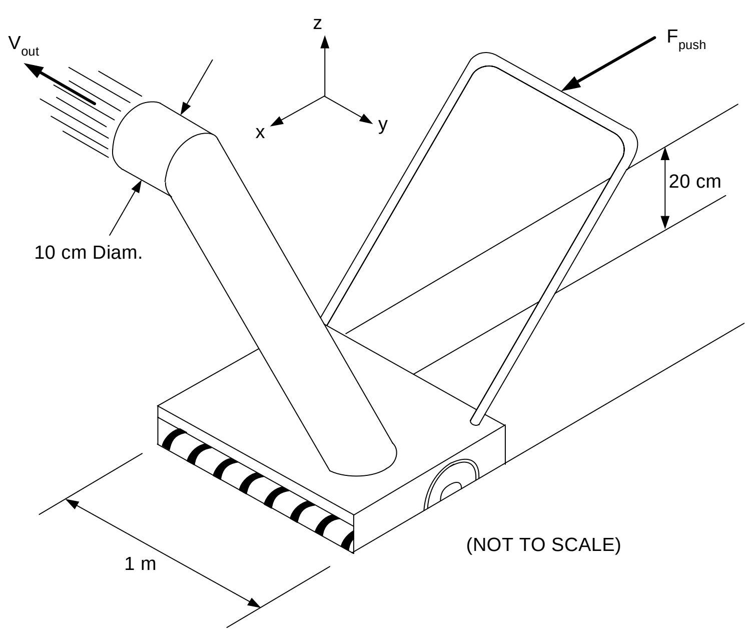
3. The snowblower shown in the drawing is being used clear a path in some wet snow which is 20 cm deep. The path is 1 m wide and the density of the snow is estimated to be 200 kg/m^3. The snow is discharged horizontally, at right angles to the path, through the circular pipe shown. The outlet of the discharge pipe is at 1.5 m above the level of the ground. The machine is being pushed at a constant speed of 0.5 m/s along the path. State clearly any simplifying assumptions that you need to make to solve the individual parts of problem.

[4] (a) What is the discharge velocity of the snow, V_{out}, as it leaves the snowblower?

For the remaining parts of the problem, use a value of V_{out} = 15 m/s. (**Note**: This is <u>not</u> necessarily the value you should have obtained in part (a)).

[8] (b) Estimate the force in the x direction, F_{push}, that is required to push the snowblower.
[5] (c) Estimate the sideways force that is exerted on the snowblower when it is operating. The rubber tires are intended to prevent the snowblower from sliding under the action of this sideways force. Assume that the layers of snow along the edges of the path do not apply any forces on the blower in the y direction. If the blower started to slide sideways, would it slide in the positive or negative y direction as shown in the drawing? Briefly explain briefly your reasoning.
[5] (d) Estimate the power, in horsepower, of the motor that must be installed in the machine to drive the rotor that "pumps" the snow. Assume that blower has an efficiency of 50%. Recall that 1 HP = 745 Watts.

[22]

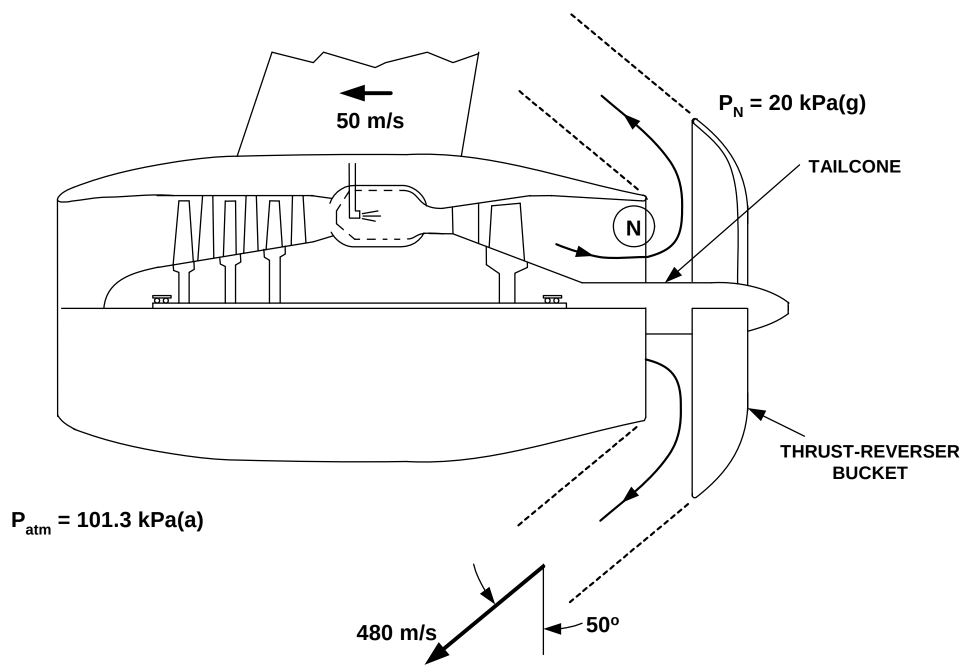


4. The drawing shows a section through a jet engine mounted on the wing of an aircraft. During landing, the thrust-reverser buckets deploy as shown and they deflect the exhaust flow partly forward with a velocity of 480 m/s relative to the engine. The thrust reverser buckets form a circle. The mass flow rate of air through the engine is 175 kg/s.

[8] (a) If the aircraft has a forward speed of 50 m/s, what force in the horizontal direction does the engine exert on the aircraft with the thrust reverser deployed as shown?

[10] (b) In the jet pipe (plane N as marked on the drawing) the flow has a cross-sectional area of 0.40 m^2 and the gases have a pressure of 20 kPa(g) and a velocity of 390 m/s. What is the force in the tailcone that supports the thrust-reverser buckets? Is the tailcone in compression or tension?

[18]



5. At an oil loading terminal, oil is stored in a large tank which is connected to the loading point by 200 m of 10 cm diameter piping. The free surface of the tank is 50 m above the loading point and the oil flows under the effects of gravity only. The oil must be delivered at the tanker truck with a pressure of 10 kPa(g). With age, the pipe has corroded and the increased roughness has caused the maximum flow rate in the pipe to drop to 100 m^3/hr. The piping system has no fittings other than those shown in the drawing. The three elbows each have a loss coefficient K = 0.3.

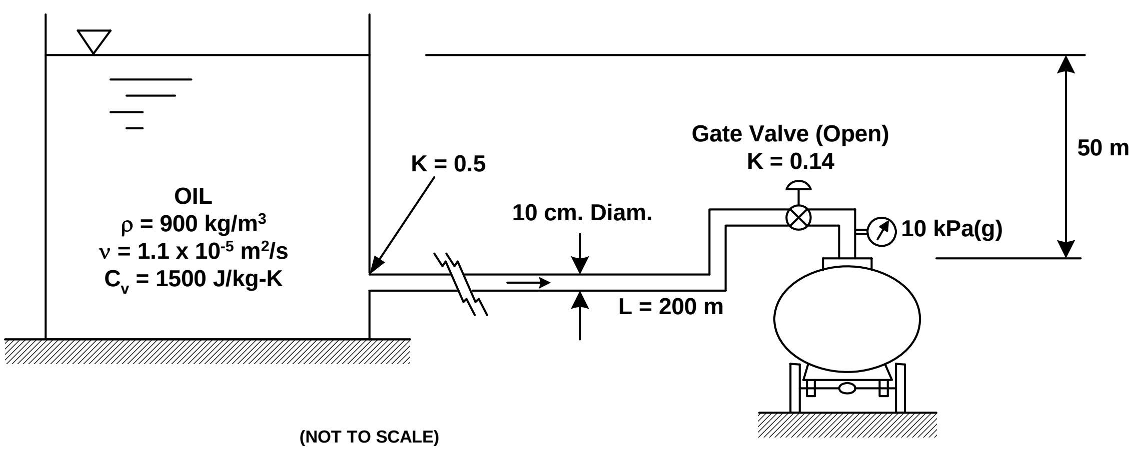
[10] (a) What is the average roughness height, in mm, of the roughness on the inside surface of the corroded pipe?

For parts (b) and (c), assume that the average roughness height for the corroded pipe is 0.75 mm (**N.B**. This is not necessarily the value you should have obtained in part (a).)

[5] (b) What is the temperature change in the oil as it flows from the large tank to the truck pipe?

[10] (c) The terminal manager has asked you to increase the maximum available flow rate to 120 m^3/hr and you suggest replacing some of the corroded pipe with new, smooth pipe of the same diameter. What length of pipe should be replaced with new, smooth pipe if the same delivery pressure is to be maintained?

[25]



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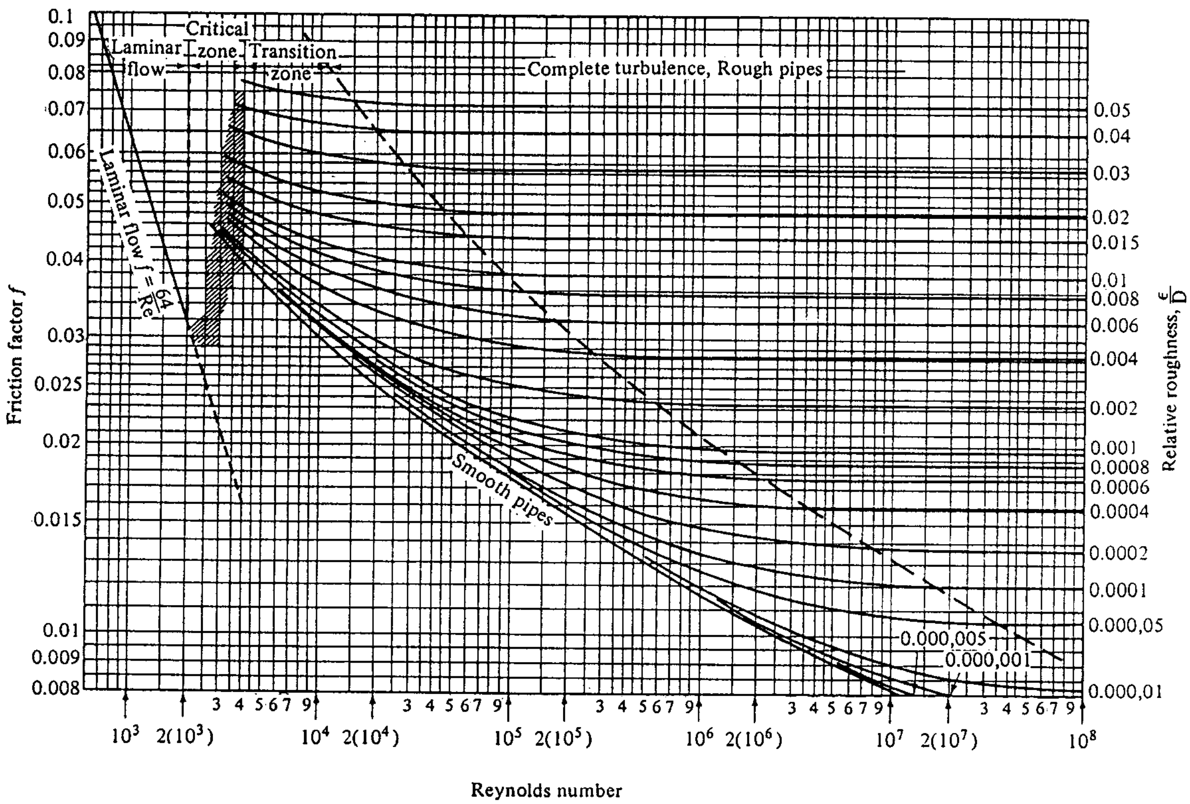

$$f = \frac{h_f}{\frac{L}{D}\frac{V^2}{2g}} \qquad Reynolds\ Number = \frac{VD}{\nu}$$

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

Final
EXAMINATION
December 2003

DURATION: **3** HOURS   No. of Students: **143**

Department Name & Course Number: **Mechanical & Aerospace Engineering, MAAE 2300A**
Instructor(s) S.A. Sjolander

AUTHORIZED MEMORANDA
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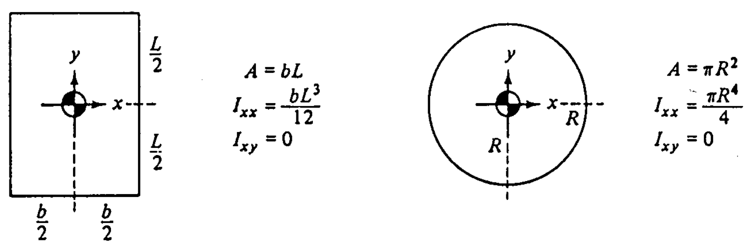
Geometric properties of common cross sections:



Miscellaneous data:

Air: $R = 287$ Nm/kgK
$C_p = 1005$ Nm/kgK
$C_v = 716$ Nm/kgK

Water: $\rho = 1000$ kg/m^3
$= 62.4$ lb$_m$/ft^3
$C_v = 4180$ Nm/kgK

$^oR = {^oF} + 460$ $^oK = {^oC} + 273$ 1 litre = 1000 cm^3

$g = 32.174$ ft/sec^2
$= 9.81$ m/s^2

1 HP = 550 ft-lb$_f$/sec
= 745 Nm/s

See Page 7 for additional data.

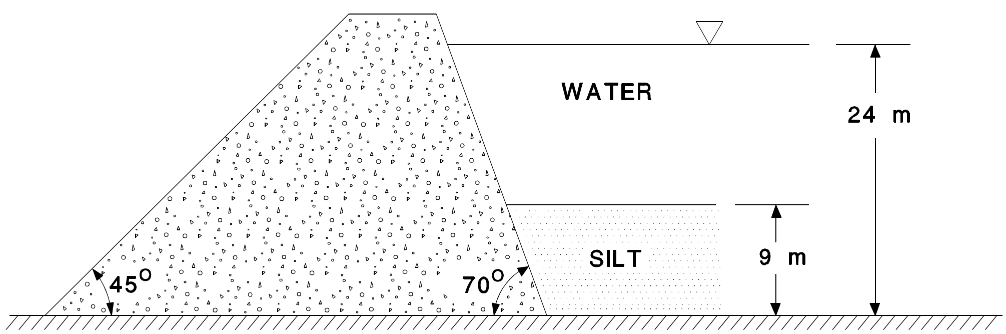
1. The concrete dam shown in the drawing was built to create a water reservoir. After some years it is noticed that a layer of silt has accumulated on the bottom of the reservoir to a depth of 9 m. Concern has therefore arisen about the increased horizontal force which the dam must now support. You have been called in as a consultant to assess the situation.

You begin by examining some samples of the silt. You find that it is saturated with water and conclude that it will behave essentially as a very dense liquid. Your samples show that the density is about 2750 kg/m^3.

[15] (a) What is the magnitude and line of action of the net horizontal fluid force acting on a section of the dam which is 1 m wide?

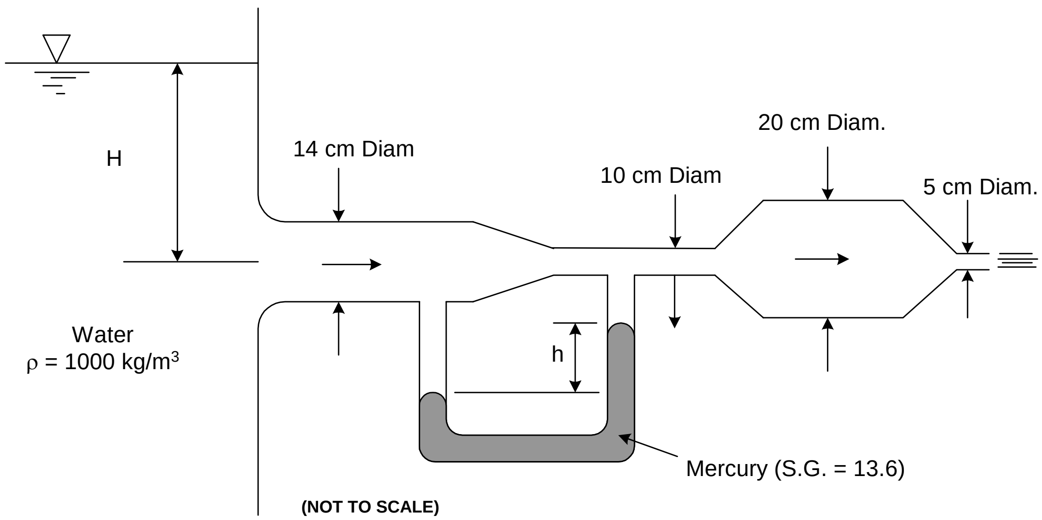
[5] (b) What net horizontal fluid force was acting on the same 1 m width when the dam was new? The surface of the water is 24 m above the base of the dam in both parts (a) and (b). You do not need to determine the line of action of the force in part (b).

[20]



(NOT TO SCALE)

2. Water flows through the system shown in the drawing. For your analysis assume one-dimensional flow and neglect friction and all other losses in the system. Determine the height of water, H, in the tank if h = 15 cm for the mercury U-tube manometer.



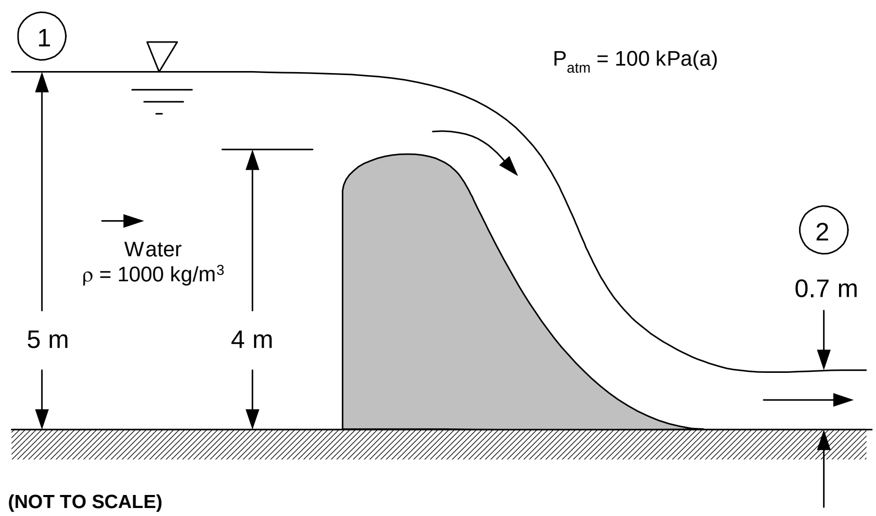
[20]

3. The drawing shows the spillway in a river. The spillway is located in a channel that is 10 m wide in the horizontal direction. In the analyses that follow, friction may be neglected.

[10] (a) For the depths of water shown before and after the spillway determine the flow rate of water, in m^3/s, that is flowing over the spillway.

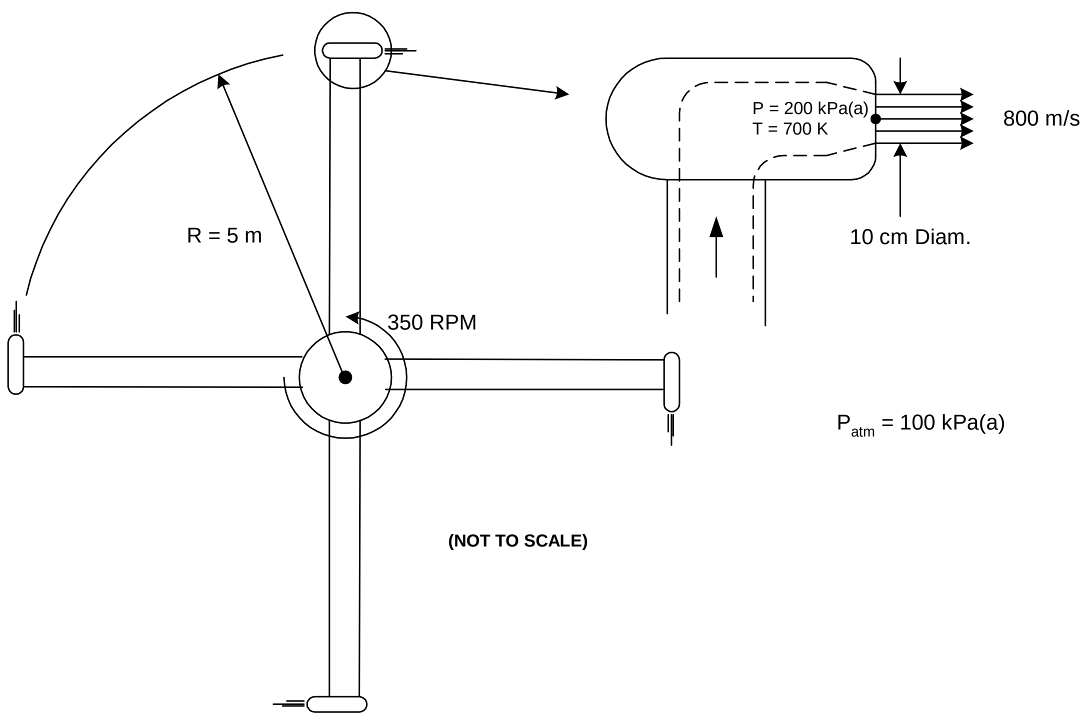
[10] (b) Assuming a volume flow rate of 60 m^3/s (**Note**: This is <u>not</u> necessarily the value you should have obtained in part (a)), and the same depths of water as shown in the drawing, determine the total horizontal force on the spillway.

[20]



4. The gear box connecting the engine to the rotor is an importance source of vibrations and maintenance problems in helicopters. The drawing shows a concept for a helicopter rotor that has no gear box. Instead, the hot exhaust gases from the gas turbine engine are piped to propelling nozzles at the tip of each rotor blade. The thrust developed by these nozzles provides the moment that drives the rotor. The flow entering the rotor ducting has no swirl. The flow leaves each nozzle in the tangential direction with a velocity relative to the nozzle of 800 m/s. At the nozzle exit, the gas has a static pressure of 200 kPa(a) and a temperature of 700 K. The hot gases may be assumed to have the same properties as air at these temperature and pressure conditions. If the rotor is rotating at 350 RPM, determine the moment about the axis of rotation of the rotor developed by this system. What is the effective power, in horsepower, developed by this drive system?

[20]



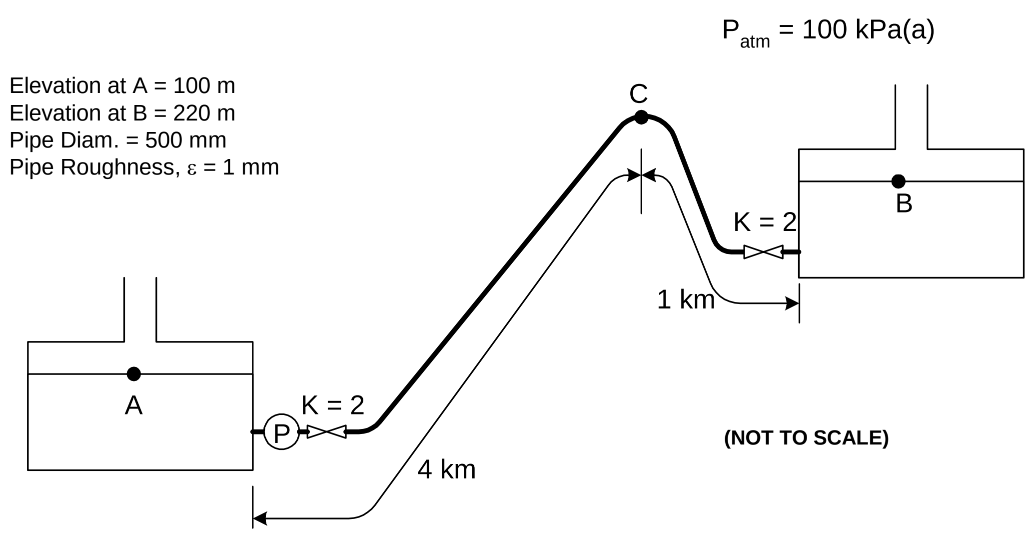
5. Gasoline (S.G. = 0.81) is to be pumped at 400 litres/s in a pipeline from point A to point B. Both of the tanks are open to the atmosphere. The pipe is to be laid on the surface of the ground, which has a high point at location C. The pipe includes two valves located at the inlet and outlet of the pipeline; in the fully open position, the valves have a loss coefficient K = 2.0 . For the temperature conditions in the system, the gasoline has a viscosity $\nu = 4.26 \times 10^{-7}$ m^2/s and a vapour pressure P_v = 55.2 kPa(a). Other relevant data are shown on the drawing.

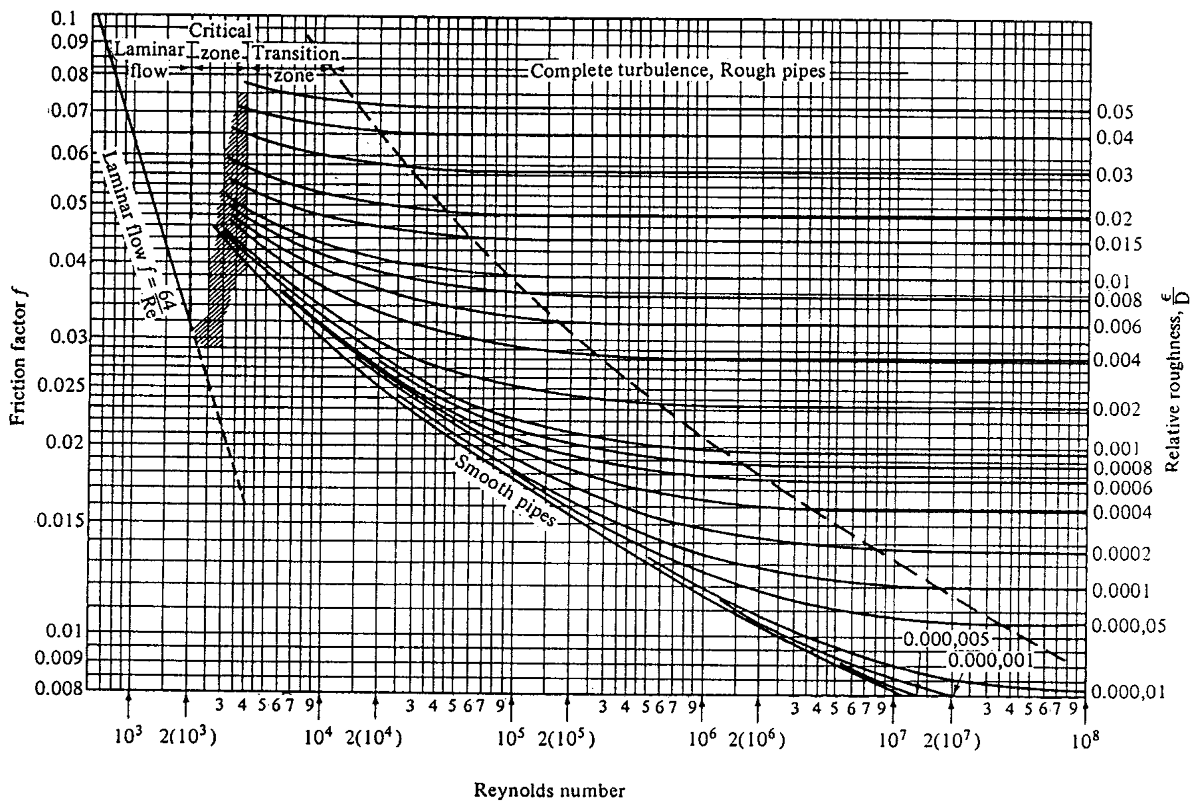
[10] (a) Determine the power of the electrical motor that must be installed to drive the pump (labelled P) if the pump has an efficiency of 80%.

[6] (b) If the pressure in the gasoline goes below the vapour pressure, the gasoline will start to boil. This is undesirable. What is the maximum elevation allowable at location C if boiling of the gasoline is to be avoided?

[4] (c) Suppose that the topography is such the elevation at point C is higher than the value you obtained in part (b). To avoid boiling, one solution would be to bury the pipeline such that point C was below the maximum allowable elevation. However, the customer wants to keep the pipeline above the ground. Also, the pump, valves and pipes have already been purchased. As the consulting engineer on this project you have been asked to recommend a solution. Suggest <u>two</u> possible modifications to the system that will allow the required flow rate to be delivered without boiling occurring. Your modifications should be as cheap as possible. Explain <u>very</u> briefly why each of your modifications will prevent boiling.

___
[20]





$$f = \frac{h_f}{\frac{L}{D}\frac{V^2}{2g}} \qquad\qquad Reynolds\ Number = \frac{VD}{\nu}$$

Carleton UNIVERSITY

FINAL

EXAMINATION

DECEMBER, 2002

DURATION 3 **HOUR** **No. of Students:** 140

Department Name & Course Mechanical & Aerospace Engineering

Course 86.230A Instructor(s) **S.A. Sjolander**

AUTHORIZED MEMORANDA

Calculator, 1 sheet 8 1/2 x 11 (both sides)

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In addition to this question paper, students require: an examination yes X no ❑

a Scantron sheet yes ❑ no X

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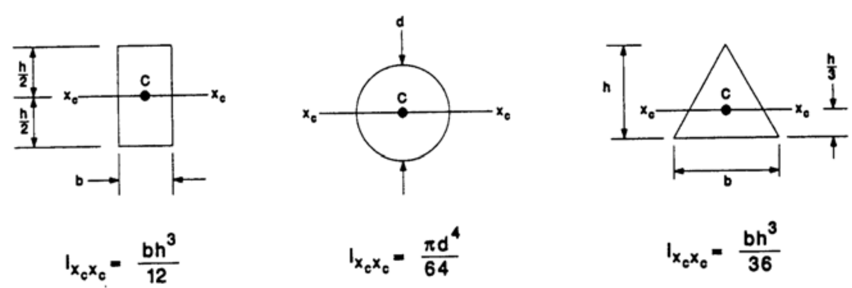
Second Moments of Area for Some Common Shapes



Miscellaneous data:

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$= 53.35$ ft-lb_f/lb_mR
$C_p = 1005$ Nm/kgK
$C_v = 716$ Nm/kgK

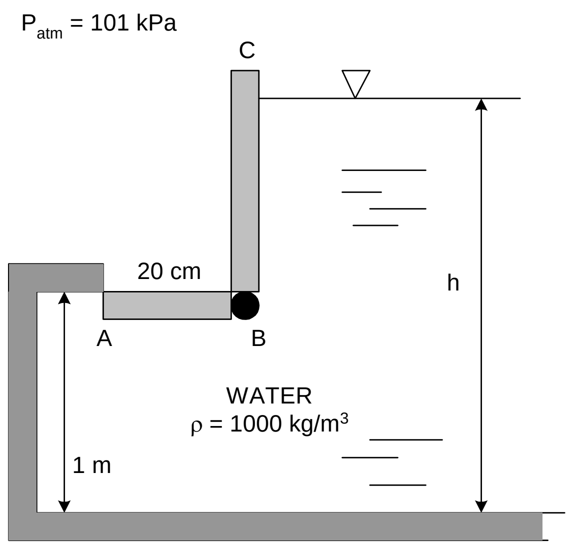
Water: $\rho = 1000$ kg/m^3
$= 62.4$ lb_m/ft^3
$C_v = 4180$ Nm/kgK

$^oR = {}^oF + 460$ $^oK = {}^oC + 273$
$g = 32.174$ ft/sec^2 1 HP = 550 ft-lb_f/sec
$= 9.81$ m/s^2 $= 745$ Nm/s

See Pg 7 for additional data.

1. Gate ABC shown in the drawing has a fixed hinge line at B and is 2 m wide in the horizontal direction. The gate will open to release water if the water level becomes too high. Determine the depth of water h at which the gate will begin to open.

[15]



2. The drawing shows the cross-section of a small, open-circuit wind tunnel. The flow is driven by the fan located downstream of the test section. The wind tunnel draws air from the laboratory through the bellmouth inlet and discharges it again to the laboratory at the diffuser outlet. The screens in the settling chamber reduce the turbulence of the flow. Assume that the flow is one-dimensional and that the density of the air is constant throughout the wind tunnel. The fluid in the manometers is water with a density of 1000 kg/m^3.

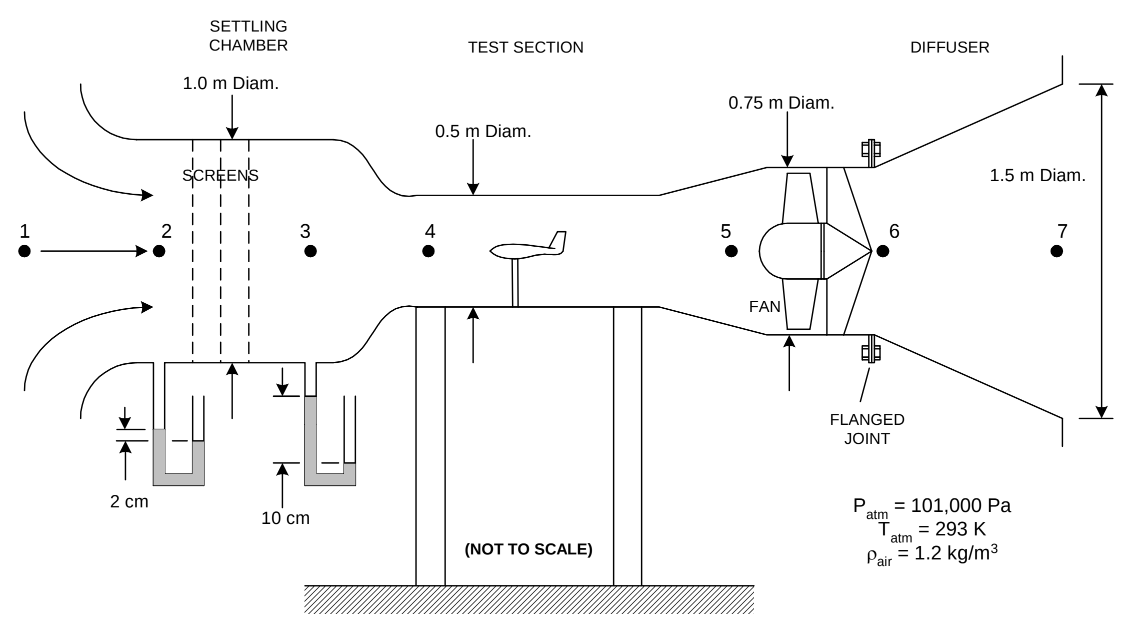
[3] (a) Can Bernoulli's equation be applied between the following points in the flow? Answer YES or NO. If your answer is NO, explain <u>in one sentence</u> why Bernoulli's is not applicable.
(i) Between (1) and (2). (ii) Between (1) and (4).
(iii) Between (3) and (4). (iv) Between (4) and (7).

[4] (b) For the conditions shown in the drawing, what is the velocity in the test section (Point (4)) in m/s?

[8] (c) For a test section velocity of 70.0 m/s (N.B. This is not necessarily the velocity you should have obtained in (b)) estimate the shaft power in kW needed to drive the fan if it has an efficiency of 60%. The total pressure losses due to skin friction on the walls and the drag of the model in the test section are estimated to be $0.1(\frac{1}{2}\rho V_{TS}^2)$ where V_{TS} is the velocity in the test section.

[10] (d) The outlet diffuser is connected to the wind tunnel by bolts at the flanged joint.
(i) If the diffuser were removed, would the power required to drive the fan for a given test section velocity be increased, decreased or remain the same? Briefly explain your reasoning.
(ii) For the test section velocity in part (c), what is the horizontal force in the flanged joint? Indicate clearly whether the joint is in compression or tension.

[25]

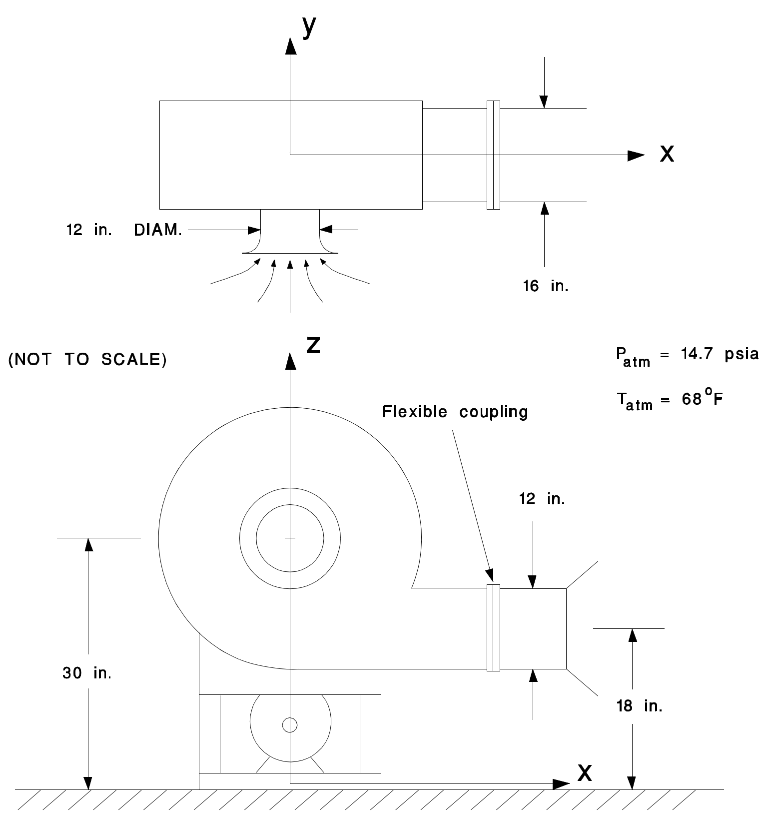


3. The drawing shows the centrifugal fan on the wind tunnel used by two of your T.A.s for their research. The fan delivers the air flow through a rectangular outlet duct that measures 12 in. x 16 in.. This duct is connected to the wind tunnel by a flexible coupling, as indicated. At the normal operating point the fan delivers 8000 ft^3/min of air with a total or stagnation pressure of 12 inches of water. At this operating point, electrical measurements indicate that the electric motor driving the fan is delivering 23 HP.

[15] (a) Determine the forces in the x and y directions and the moment about the y axis that the support stand will exert on the floor. Neglect density changes in the air.

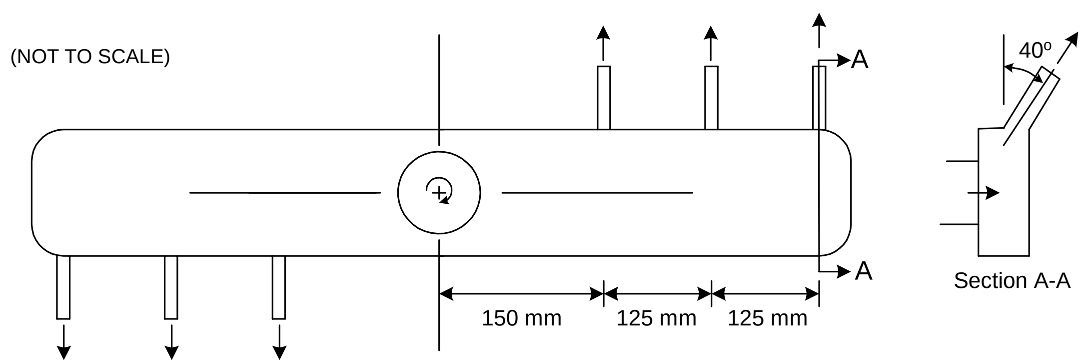
[5] (b) What is the efficiency of the fan?

[20]



4. The drawing shows the rotating spray bar in a dishwasher. The flow rate of water is 15 litres per minute. Each of the six nozzles has a diameter of 5 mm and the flow rate is the same for each of the nozzles. The friction in the pivot holding the spray bar can be neglected. The water enters the spray bar with no swirl (no tangential velocity). Estimate the rotation rate of the arm in revolutions per minute. Recall that 1 m^3 = 1000 litres.

[20]

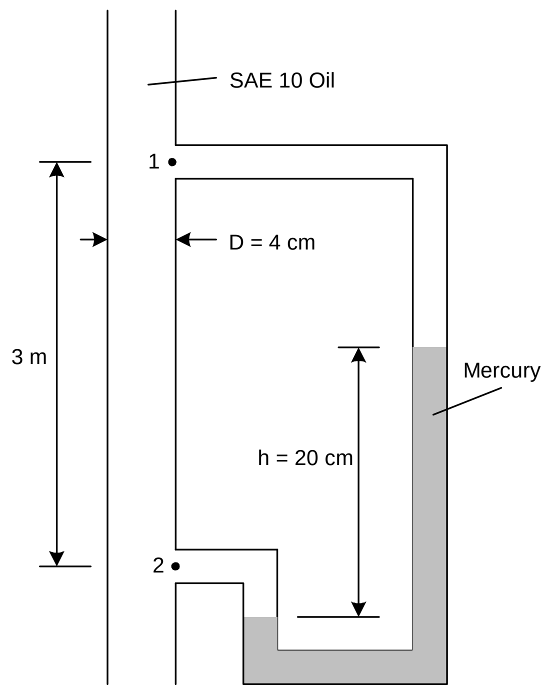


5. SAE 10 oil flows through the vertical 4 cm diameter pipe shown in the drawing. Assume that the oil has a density ρ = 870 kg/m^3 and a viscosity μ = 0.104 kg/ms. The pipe is smooth. With the mercury manometer reading h = 20 cm, determine:

[6] (a) The pressure difference between taps 1 and 2. The density of mercury is 13,600 kg/m^3 .

[14] (b) The direction of the flow and the corresponding volume flow rate in m^3/hr.

[20]



Moody Diagram for Circular Pipe Flow