FLUID MECHANICS QUALIFIER EXAM

DEPARTMENT OF MECHANICAL ENGINEERING
MICHIGAN STATE UNIVERSITY

JANUARY 2007

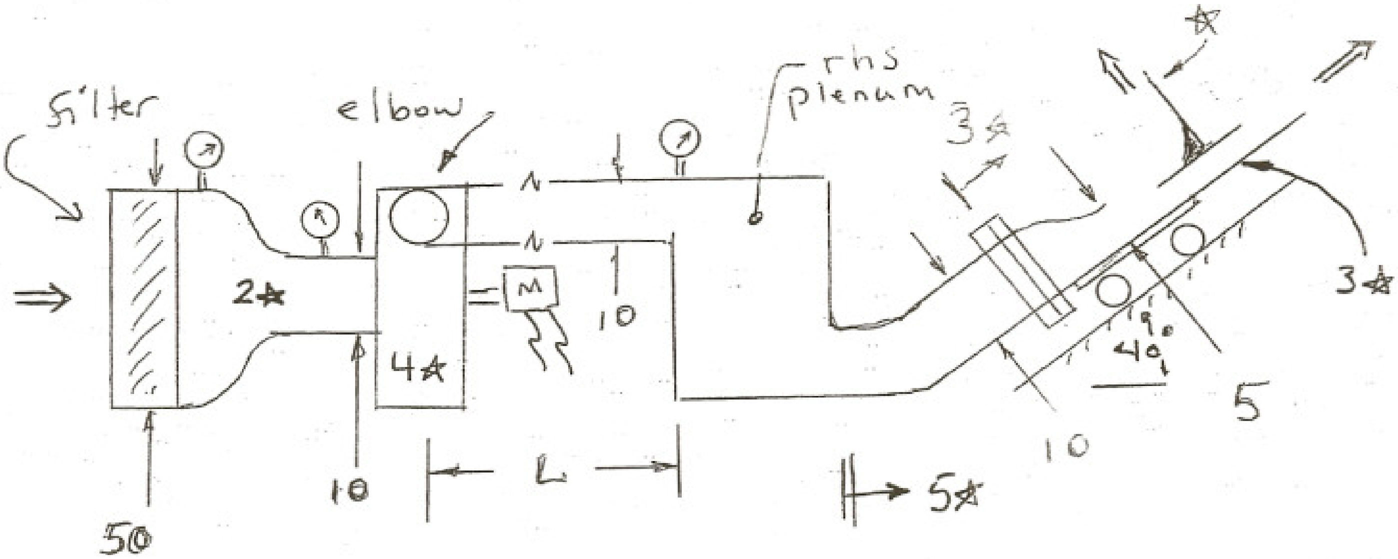
PREPARED BY J.F. FOSS AND H. KI

This exam is open book, open notes, closed neighbor's paper.

(35) 1. The flow system shown below delivers clean air to the apparatus on the right hand side (rhs) of the figure. The first part of the question (a) deals with the delivery system, the second part (b) deals with the apparatus.

(17) a) The centrifugal blower, downstream of the filter, ingests atmospheric air and delivers it to the plenum that feeds the apparatus. The loss coefficient for the filter is $(K = \lambda / V)$ where $\lambda = 3 m/\sec$ and V is the velocity at the face of the filter. The discharge coefficient for the contraction is 0.97. The motor and blower have an efficiency of 83%. The L=100m long, 10 cm diameter wrought iron pipe is connected to the blower output by a standard elbow. The inlet and outlet blower diameters are 10cm.

Determine the pressure difference across the contraction if the flow rate is 0.36 m^3/sec. The gage pressure at the inlet to the rhs plenum is 200Pa. Determine the electrical power supplied to the blower motor.



⟹ Shows air flow

★ Deflector

2★ Contraction, $D_D = 0.97$

3★ Rolling part

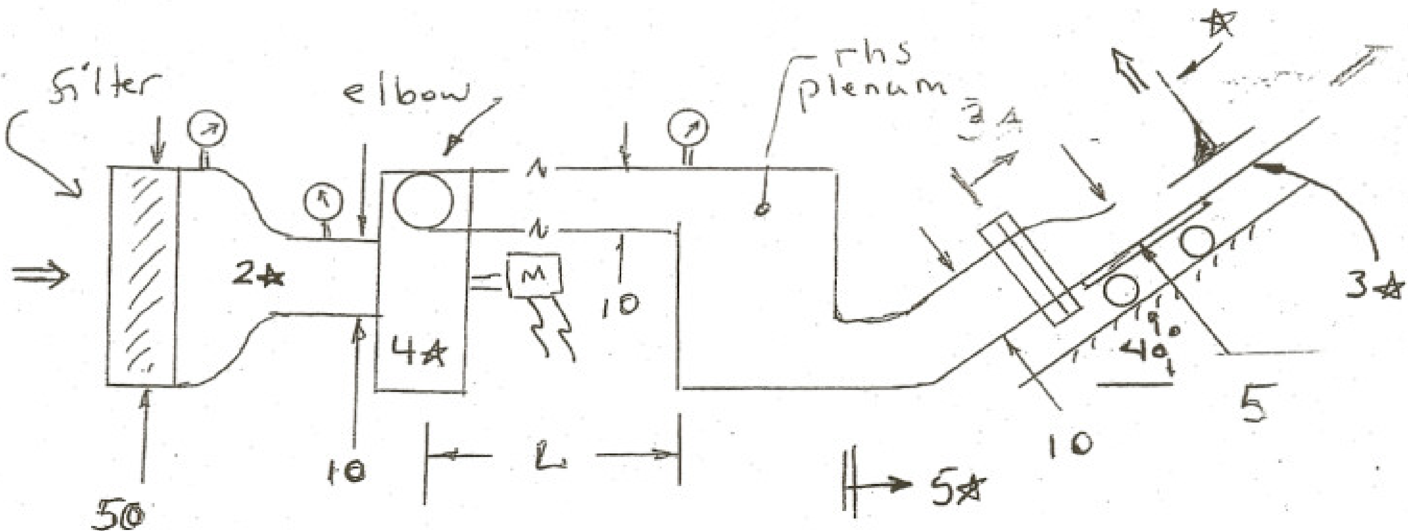
4★ Blower

5★ Rhs apparatus

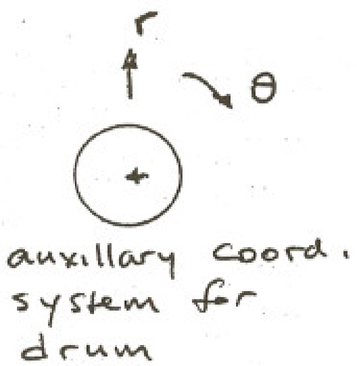
Notes: L=100m, filterbox is square, all dimensions in cm

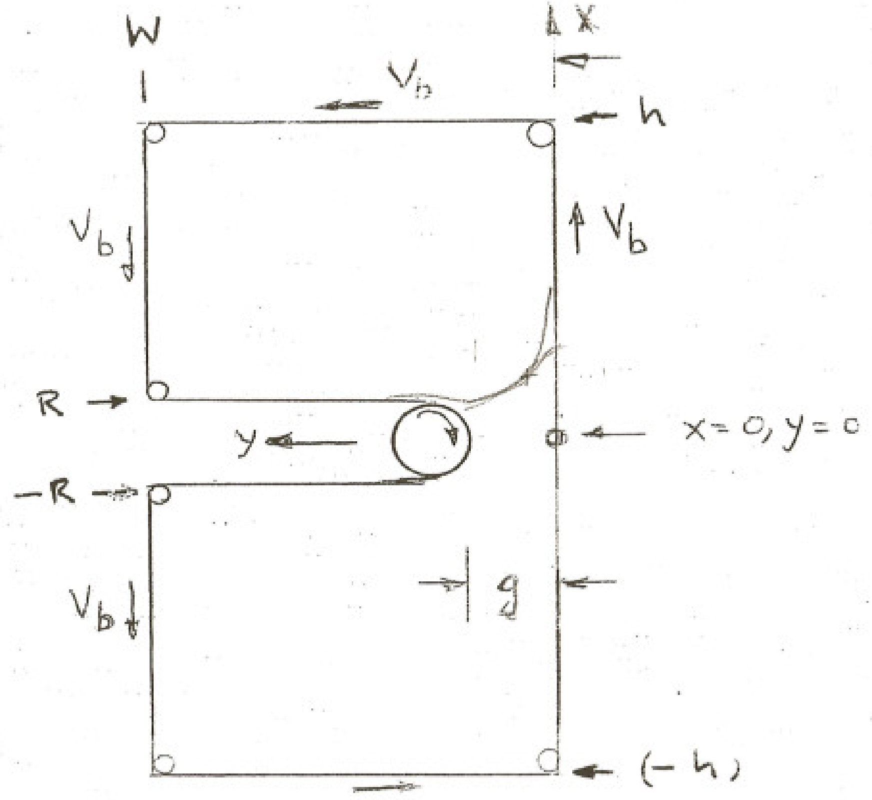
(18) b) The mass of the rolling part of the rhs apparatus is 0.85Kg. The slope of the inclined plane is 40 degrees. The flow from the rhs plenum is directed into a rectangular duct (25cm wide, 10cm high) that is terminated at a flange. The rolling part of the apparatus has a companion flange (25x10). The flow passage of the rolling part "necks down" such that a flow passage of ($25x5cm^2$) exists at atmospheric pressure. A flow deflector, attached to the rolling part, is positioned such that 2 cm of the "top part" of the jet is directed away from the wall. The lower 3 cm of the jet flow continues parallel to the wall.

Is it required to provide a mechanical "clamp" to avoid having the rolling part move away from the flange? What normal force is exerted by the rolling part *on* the inclined surface?



(25) 2. An endless belt is driven along the interior of a chamber. See the plan view sketch for the belt and the driving drum. The chamber is rectangular: length=2h, width=W. The chamber, which bounds the belt, is not shown. The belt is guided by idler-rods at all locations where a change of direction occurs. The rotation of the drum (left side) propels the belt. The chamber is covered such that the motion of the fluid is contained within the chamber. The flow is planar; the height is very large compared with the gap dimension: g. The belt has been in motion for a "very long" time.





(2) a) Establish the governing equations such that the solution: u(x,y), v(x,y) and p(x,y) could be obtained. This is a viscous dominated flow (relatively low Reynolds number).

(4) b) What boundary conditions would you specify?

(2) c) If a solution could be obtained, the streamline pattern would be known. Sketch plausible streamline pattern from the minimum gap (g) to the top of the chamber.

(2) d) Show a plausible u(y) distribution at x=0. Be *careful* with the magnitudes of u(y What integral constraint must be satisfied by u(y)?

(1) e) Viscous flows that are fully developed can be analytically solved with relativ ease. Is this a fully developed flow? Support your answer with a brief comment.

(7) f) Consider the location:

$$\frac{x}{g} = 0.2, \quad \frac{y}{g} = 0.8.$$

State the *signs* of the terms shown below and briefly justify your answers.

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = -\frac{1}{\rho} \frac{\partial p}{\partial x} + \nu \left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right]$$

[1] [2] [3] [4] [5] [6] [x] [7]

(3) g) If the container were insulated, qualitatively describe the temperature-time history and give a physical justification for your answer. For a constant belt speed, would the continuing time history lead to turbulence if the fluid were:

i) a gas
ii) a liquid

State and justify your answers.

(4) h) If turbulence did occur, how would the equation in part (f) be changed? Explain the sign of the velocity correlation: $\overline{u'v'}$, that would exist at x/g=0.2, y/g=0.8.

3. A heavy, smooth sphere attached to a string should hang at an angle θ when immersed in a stream of velocity U as shown in the figure below. The diameter of the sphere is 3 cm and the flow is sea-level standard air. The drag coefficient vs. Reynolds number is simplified and given in Figure B.

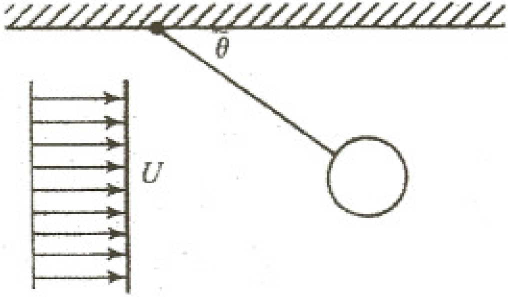


Figure A

a) Derive an expression for θ as a function of sphere and flow properties. **(6 pts)**

b) If the density of the sphere is 7860 kg/m^3 and the velocity of air is 40 m/s, what is θ? **(6 pts)**

c) Find the range of sphere density that makes the string hang at θ=45° at **two different velocity** values of air. **(8 pts)**

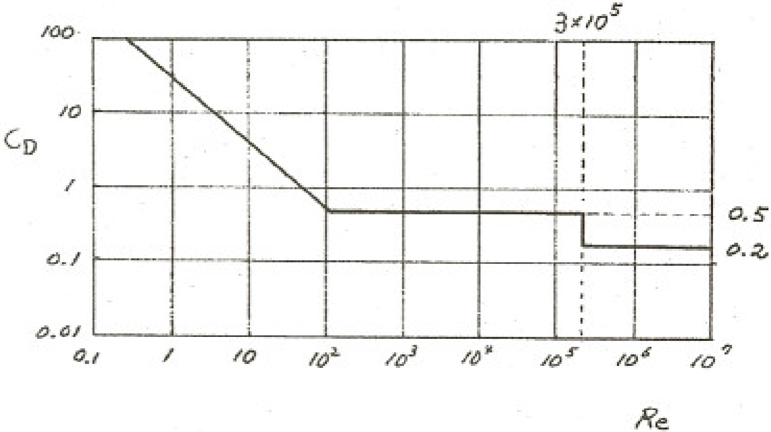


Figure B

4.

a) A 1/5 torpedo model is being studied in a wind tunnel using compressed air having a density of 26 kg/m^3 and a kinematic viscosity of 5.8×10^{-7} m^2/s. The drag is found to be 8 N when air velocity is 30 m/s. Find the drag of the prototype when it moves under dynamically similar conditions through sea water having a density of 1.025×10^3 kg/m^3 and a kinematic viscosity of 1.6×10^{-6} m^2/s. **(10 pts)**

b) A 1/10 model of a supersonic wing tested at 700 m/s in air at 20°C and 1 atm shows a pitchin moment of 250 Nm. If Reynolds number effects are negligible, what will be the pitching momer of the prototype wing flying at the same Mach number at 8 km standard altitude? **(10 pts)**