Code No._____

Ph.D. Qualifier Exam — Fluid Mechanics

Department of Mechanical Engineering
Michigan State University

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Directions: One open book permitted

All problems carry equal weight.

Exam prepared by Profs. Brereton and Foss

(35) 1. This problem involves several aspects of a common flow system.

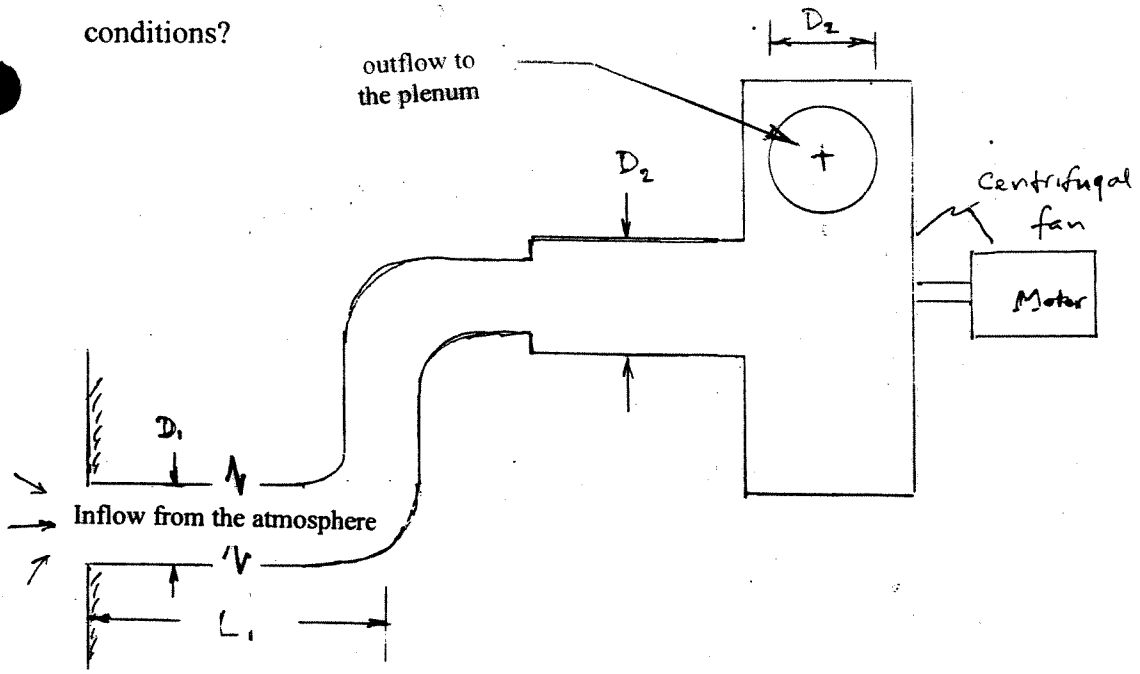
(10) a) Atmospheric air (STP) enters the piping system under the action of the large centrifugal fan. (The inlet and outlet diameters of the piping system are D_1 and D_2). The flow rate: $q=0.736\ m^3/sec$, is delivered to a plenum chamber at a pressure level of 1.5KPa by the fan. See part (b) for the "plenum" whose definition is: *plenum*: "a condition in which the pressure of the air in an enclosed space is greater than that of the outside atmosphere."

The mechanical efficiency of the fan is 82%.

The pipe lengths, after the elbow at the distance L_1 from the inlet, are shown to scale. (That is, they are short).

i) What is the pressure rise (Δp) provided by the fan?

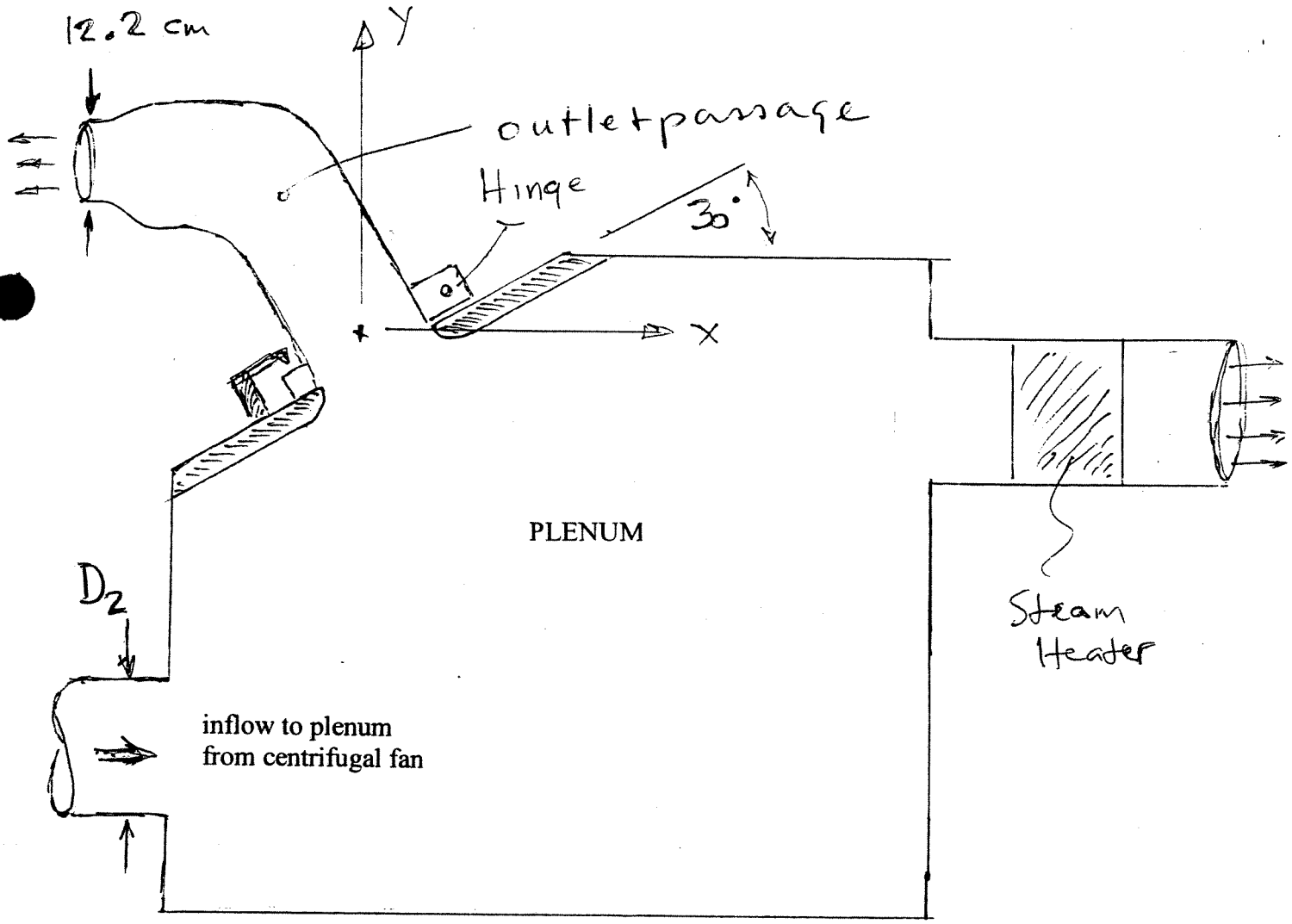
ii) What shaft power (watts) must be provided by the electric motor for these conditions?



Pipe 1	Pipe 2	Elbows
$D_1 = 25$ cm	$D_2 = 35$ cm	Standard
$L_1 = 40$m		(flanged)
Galvanized Iron		

CAUTION: A control volume solution *without* a defined c.v. cannot be graded!

(5) b) There are two outlet flow paths from the plenum shown below. Twenty percent of the inflow leaves through a duct system which contains a steam heater. This 30cm diameter duct exhausts to atmospheric pressure with a uniform temperature of 80°C. State the average velocity at the duct exit.



(20) c) Eighty percent of the flow into the plenum exhausts through the "outlet passage" shown on the preceding sketch.

The x-y coordinate system for this flow is centered on the outlet orifice of diameter 20cm. The hinge, that supports the outlet passage, is located 15 cm from the orifice center point:

x,y for the hinge = 15 cos 30 (cm); 15 sin 30 (cm).

The exit nozzle is centered at:

x,y for the exit: –45 cm, + 30cm

and its discharge is in the negative x-direction. The nozzle diameter is 12.2cm.

The outlet passage is held down by a latch at 15 cm from the orifice center point:

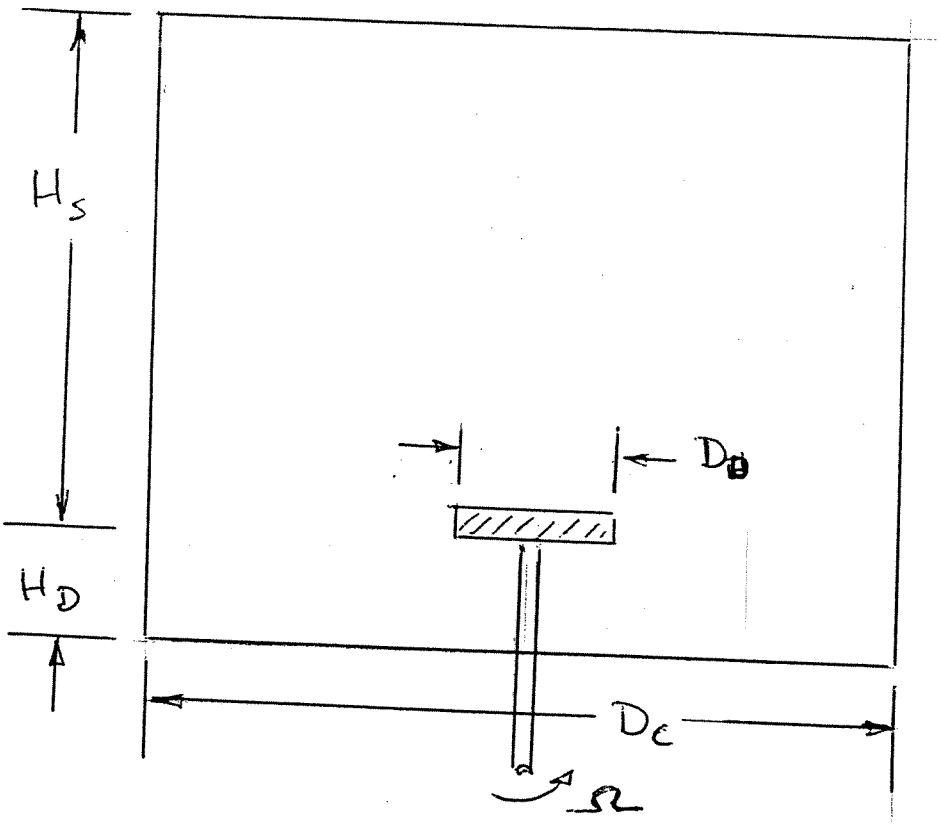
x,y latch: –15 cos 30 (cm), –15 sin 30 (cm)

What force must be applied by the latch?

(Note, center of gravity of the 2.0 N weight outlet passage is at x=–20 cm, y=15 cm).

(15) 2. A disc, of diameter D_D, is placed in a cylinder (diameter = D_c) and rotated at a rate Ω. The disc is H_D above the lower surface and H_s below the upper "surface" that can either be (i) the top cover of the cylinder for an air environment, or (ii) a free surface at atmospheric pressure for a liquid environment. (Both types of fluids are Newtonian). It is considered to be apparent that the spinning disc will create an outward flow from the center of the disc.

(2) a) Define an appropriate "characteristic velocity" (L/t) and a characteristic length scale (L) for this problem.



(3) b) The *air* prototype is to be investigated using a water model. The following features describe the air prototype:

$$D_D = 10 \text{ cm}, \quad D_c = 50 \text{ cm}, \quad H_s = 100 \text{ cm}$$

$$H_D = 10 \text{ cm}, \quad \Omega = 2000 \text{ rpm}$$

The water model is established with $D_D = 15$ cm. State the other conditions of the model and briefly justify your answers.

(2) c) If glycerin is mixed with the water of part (b), one can obtain a 20% increase in the fluid viscosity. What will change between (b) and (c)? Show your work.

(3) d) A pressure tap at the center of the disc, top surface, is used to record the following Δp:

$$\Delta p = p(z = H_s, r = 0) - p(z = 0, r = 0)$$

For a measured value of Δp in the model, state $\Delta p)_{prototype}$ as

$$\Delta p)_{prototype} = \Delta p)_{model} [\quad] \qquad \text{(fill in [ ]).}$$

Show your work.

(2) e) The bearings in the model *and* prototype can be considered to offer negligible resistance to rotation. If P_p is the power to drive the prototype and P_m is the power to drive the model, fill in [ ] for:

$$P_p = P_m [\quad].$$

(3) f) A curious experimentalist decides to reduce the H_s level for the experiment of part (b). It is noted that, when H_s is at 60% of its height in (b), the free surface is no longer flat. Rather, a dimple, or a depression, has appeared on the centerline. state the "new" parameter that is important in the model that is not present in the prototype *and* state its numerical value.