National Exams May 2010

04-Bio-A7, Fluid Mechanics

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

1. The differential energy equation for incompressible two dimensional flow through a "Darcy equation" porous medium is approximately

$$\rho c_p \frac{\sigma}{\mu}\frac{\partial p}{\partial x}\frac{\partial T}{\partial x} + \rho c_p \frac{\sigma}{\mu}\frac{\partial p}{\partial y}\frac{\partial T}{\partial y} + k\frac{\partial^2 T}{\partial y^2} = 0$$

where σ is the permeability of the porous medium. All other symbols have their usual meanings.

a) What are the appropriate dimensions for σ?
b) Non dimensionalize this equation using (L, U, ρ, T_o) as scaling constants, and discuss any dimensionless parameters that arise.

Choose either 2a or 2b

2a. When the pump shown below draws 220 m^3/hr of water at 20°C from the reservoir, the total friction head loss is 5 m. The flow discharges through a nozzle to the atmosphere. Estimate the pump power in kW delivered to the water.

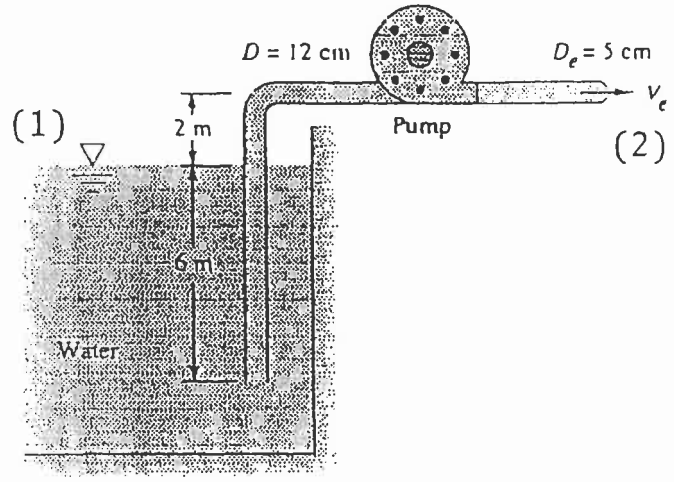

Figure for Question 2a.

2b. The pump shown below creates a 20°C water jet oriented to travel a maximum horizontal distance. System friction head losses are 6.5 m. The jet may be approximated by the trajectory of frictionless particles. What power must be delivered by the pump?

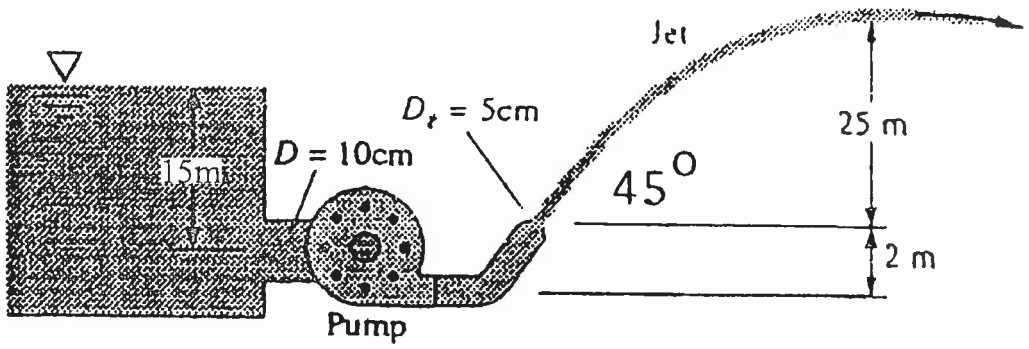

Figure for Question 2b.

3. A tank is constructed of a series of cylinders having diameters of 0.3, 0.25 and 0.15 m as shown below. The tank contain oil (γ_{oil} = **8.95 kN/m^3**), water (γ_{water} = **9.8 kN/m^3**), and glycerin ($\gamma_{glycerin}$ =**12.4 kN/m^3**) and a mercury ($\gamma_{mercury}$ = **133 kN/m^3**) is attached to the bottom as illustrated. Calculate the manometer reading **h**.

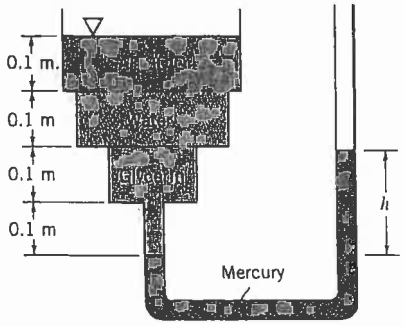

Figure for Question 3.

4. A two dimensional velocity field is given by

$$\mathbf{V}=(x^2-y^2+x)\mathbf{i} - (2xy+y)\mathbf{j}$$

in arbitrary unites. At (x,y)=(1,2) , compute
a) The acceleration a_x and a_y
b) The velocity component in the direction of $\theta=45^\circ$

Choose either 5a or 5b

5a. SAE 30 oil at 20°C flows in the 3-cm diameter pipe as shown below, which slopes at 37°. For the pressure measurements shown, determine
a) Whether the flow is up or down
b) The flow rate in m^3/hr

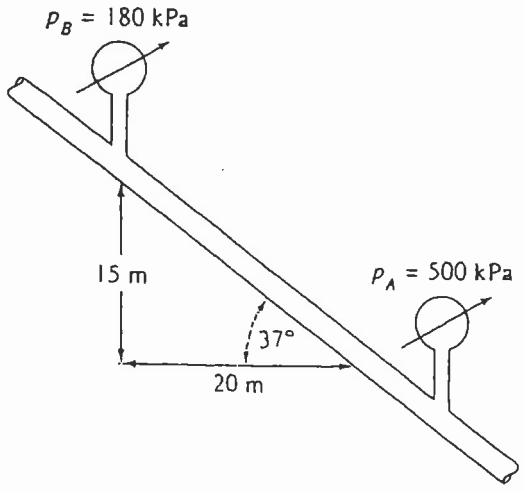

Figure for Question 5a.

5b.A blower delivers air at 3000 m^3/hr to the duct circuit in below figure. Each duct is commercial steel and of square cross section, with side lengths $a_1=a_3=20$ cm and $a_2=a_4=12$ cm. Assuming sea level air conditions, estimate the power required if the blower has an efficiency of 75 percent. Neglect minor losses.

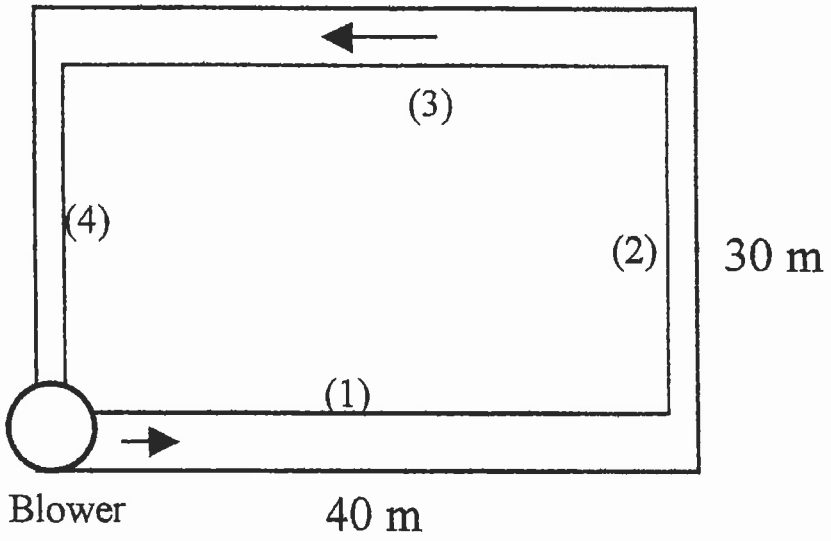

Figure for Question 5b.