Note: See last page for additional handout page

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Exam 2

CM3120

Monday 11 February 2019

Name:

Instructions:

i. Closed book, closed notes. One 8.5" by 11" study sheet allowed, two sided; you may use a calculator; you may not use the internet or a cell phone. All work on the exam must be your own.

ii. Write your solution on one side of the page only. Do not write on the back of any pages.

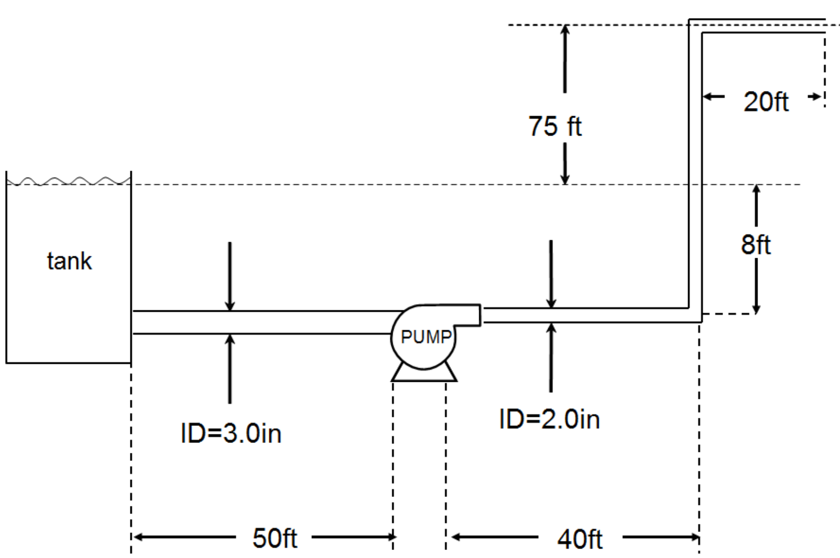
iii. Please be neat. Only neat answers will be granted partial credit.

iv. Significant figures always count.

v. Please box your final answers.

1. (20 points) Dimensional analysis is an important technique we introduce when we wish to understand very complex systems. For three of the following dimensionless numbers that arise in momentum or heat transfer give the following two pieces of information a) the formula for the definition of the quantity and b) a sentence indicating the significance of this dimensionless quantity.
   a. Reynolds number
   b. Nusselt number
   c. Biot number
   d. Peclet number
   e. Prandtl number

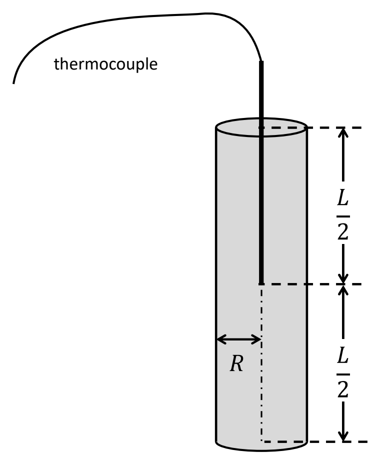
2. (20 points) For the piping system sketched below, with room temperature water moving from left to right, what is the work done on the fluid by the pump? The average fluid velocity at the pump discharge is 1.32 ft/s. The friction loss for all the piping and fittings is $F/g = 4.2\ ft\ head$. The tank is open to the atmosphere; the pipe discharges fluid to the atmosphere. Give your answer in $ft\ lb_f/s$.



3. (20 points) A long copper wire (diameter $= 0.635\ cm$) is placed in a rapidly moving stream of air that is at a temperature of 37^oC. Initially the wire is at temperature 7^oC. The heat transfer coefficient between the air and the wire is $150\ W/m^2K$. How long will it take for the wire to reach the air temperature within one degree C? Give your answer in seconds.

4. (20 points) What are the partial differential equation and the boundary/initial conditions that must be solved in order to obtain the time-dependent temperature at the center of a rod subjected to the following experiment (indicate all your assumptions):

> A very long cylindrical rod of length L and radius R is initially equilibrated in a bath of temperature T_{bath}. Suddenly, the rod is submerged in a rapidly flowing bath of fluid of higher temperature T_{new}. The rod has a thermocouple embedded down its axis with the thermocouple tip lodged exactly halfway down the length of the rod. The heat transfer coefficient from the fluid to the rod is within the range of typical values for forced convection in liquids.



5. (20 points) Brass parts (identical, oddly shaped, each piece has a mass M with surface area S, both known) are ejected at regular intervals from a machine that fabricates them. When ejected, the very hot parts at temperature T_0 enter a moving air stream where the air temperature is T_{bulk}. Create a model (an equation) that, when solved, will allow us to calculate the temperature of the part as a function of time (state your assumptions). Give values for all the quantities needed to evaluate the model. Choose values that would give an "optimistic" scenario, that is, one that produces the shortest plausible time for the part to cool to a target temperature T_1. Indicate the values of the quantities you specify in the SI (metric) system of units (m, kg, s).

Additional Constants/Properties

Stephan-Boltzmann constant: $\sigma = 5.676 \times 10^{-8} \frac{W}{m^2K^4}$

Table: Emissivity $\boldsymbol{\varepsilon}$ of solids ($\mathbf{300K}$)

Material	ε
Aluminum foil	0.04
Asbestos board	0.96
Brass, polished	0.03
Brass, dull plate	0.22
Cast iron, turned and heated	0.60-0.70
Concrete	0.85
Ice, smooth	0.966
Ice, rough	0.985
Plaster	0.98
Roofing paper	0.91
Sand	0.76
Steel, Oxidized	0.79
Wrought Iron	0.94

Reference: Engineering Toolbox,
www.engineeringtoolbox.com/emissivity-coefficients-d_447.html