

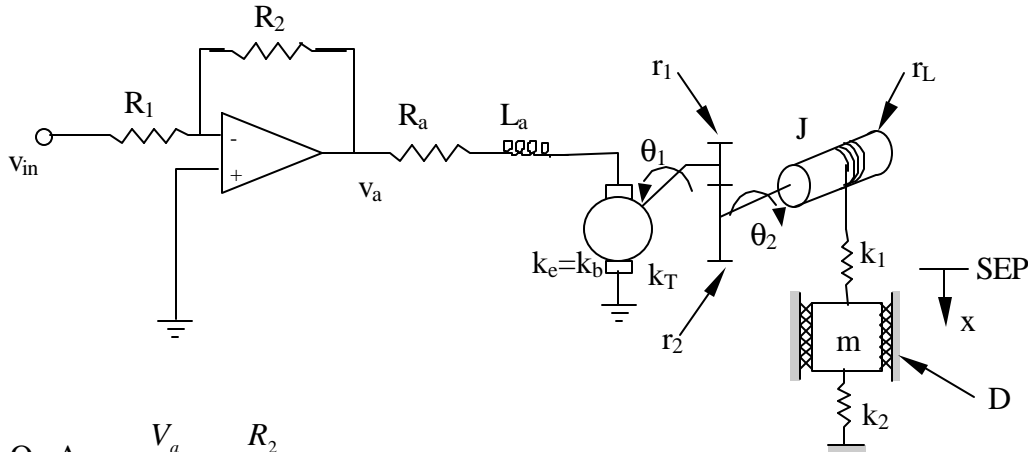
Name _____ Section _____

ES205
Examination II
April 21, 2000

| Problem | Score |
|---------|-------|
| 1 | /20 |
| 2 | /20 |
| 2 | /30 |
| 3 | /30 |
| Total | /100 |

Show all work for credit
AND
Turn in your signed help sheet

For the system shown below draw a block diagram. The governing equations are shown below (some in Laplace domain and others in time domain).



$$\text{Op Amp: } \frac{V_a}{E_1} = -\frac{R_2}{R_1}$$

$$\text{Loop Eqn.: } -V_a + I_a R_a + L_a s I_a + E_b = 0$$

$$\text{Back emf: } E_b = k_b s \theta_1$$

$$\text{Torque: } T_1 = k_T I_a$$

$$\text{Gears: } r_1 \boldsymbol{\varphi} = r_2 \boldsymbol{\varphi}$$

$$T_1 r_2 = T_2 r_1$$

$$\text{Load 1: } J \ddot{\theta}_2 + k_1 r_L^2 \theta_2 - r_L k_1 X = T_2$$

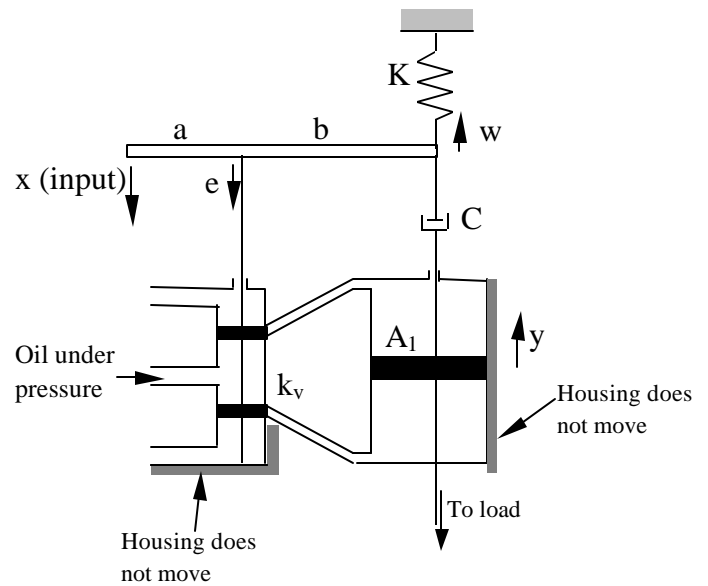
$$\text{Load 2: } (m s^2 + D s + k_1 + k_2) X - k_1 r_L \boldsymbol{\varphi} = 0$$

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Problem 2

20 pts
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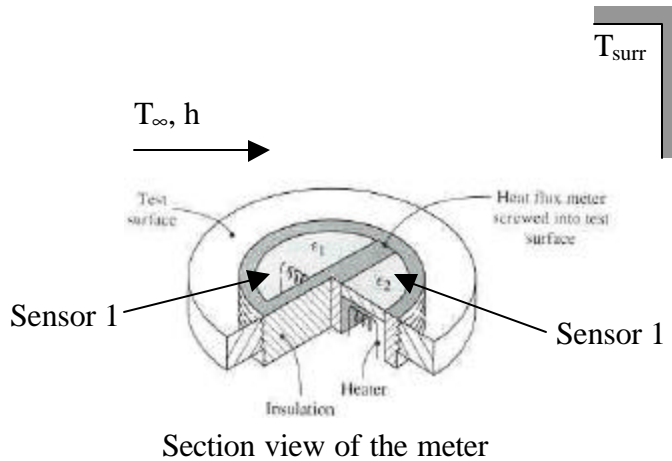
Determine the equations necessary to determine the equation of motion for the hydraulic amplifier shown below. The input is x and the output is y . **Do not find the EOM but number the equations that you would use and generate a list of the unknown variables.** Assume the force required to move the control valve and the mass of the input lever are negligible.



A natural convection heat transfer coefficient meter is intended for situations where the air temperature T_∞ is known but the surrounding surfaces are at an unknown temperature, T_{surr} . The two sensors that make up the meter each have a surface area of 1 cm^2 , one has a surface coating of emittance $\epsilon_1 = 0.9$, and the other has an emittance of $\epsilon_2 = 0.1$. The rear surface of the sensors is well insulated. When $T_\infty = 300 \text{ K}$ and the test surface is at 320 K , the power inputs required to maintain the sensors at 320 K are $\dot{W}_{in_1} = 21.7 \text{ mW}$ and $\dot{W}_{in_2} = 8.28 \text{ mW}$. The Stefan-Boltzman constant is $\sigma = 5.67 \times 10^{-8} \text{ W}/(\text{m}^2 \cdot \text{K}^4)$. Determine:

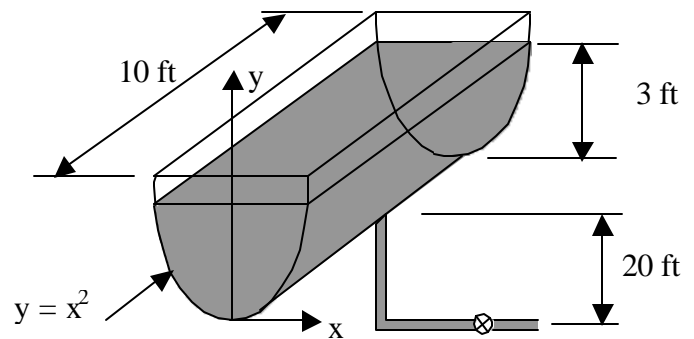
- the temperature of the surroundings and the heat transfer coefficient
- If the power to sensor one is turned off, determine a differential equation for the temperature of the sensor. State your assumptions and what parameters for the system you would need to be given.

Note: Be sure to identify your system or systems and save all numerical substitutions and algebra (or plugging the equations into Maple) until the end of the exam (a list of unknowns and numbered equations for part a) will get you most of the points).



A tank of water with a cross section given by $y = x^2$, as shown below is connected to a 50-ft-long, 0.5 in ID steel pipe that contains four 90° standard elbows and a gate valve ($k_{90^\circ} = 0.95$, $k_{\text{gate}} = 0.16$, $\epsilon = 0.00015$ ft, and $\nu = 0.739 \times 10^{-5}$ ft²/s). If the 10 ft long tank is initially filled to a depth of 3 ft and the pipe outlet is 20 ft below the bottom of the tank, determine:

- the initial flow rate
- a differential equation for the height of fluid in the tank. Assume that the friction factor you determined in part a) is valid for the whole draining process.



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