ENCH 501 Transport Phenomena University of Calgary Name_____

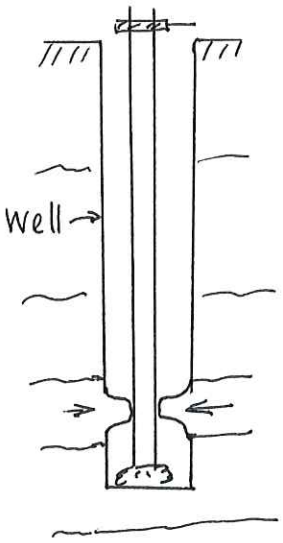
Quiz #1 / Time Allowed: 45 minutes Only a "cheat sheet" is allowed. September 15, 2015 AJ

Q. 1 (10 points)

A vertical well is being drilled in an oil field. The drilling is being done with grade S steel pipes screwed together to form a "string". Each pipe, when horizontal, is 10 m long. The nominal diameter of the pipe is 4 inches (actual external diameter is 11.43 cm or 4.5", actual inside diameter is 9.25 cm or 3.64") and its mass per unit length is 18.77 kg/m. The Young's modulus for the steel pipe is 206.85 GPa. The drill bit at the bottom end of the string is wider than the pipes, thus the well diameter is larger than the pipe diameter. You may neglect the weight of the bit relative to the string's weight.

(a) (***6 pts***) At one stage, drilling was stopped, the pipe was clamped at ground level and the string was pulled up until the drill bit just lifted from the bottom of the well. If the string is observed to have stretched by 196.4 mm, how many pipes are in the string? You may assume that the stretching is elastic.

Show important steps in your analysis.



(b) (4 pts) The string is lowered and drilling continued. The wall of the well, at a certain distance below the ground level, suddenly collapsed tightly around the string at one instance and the drilling could not continue. The operator clamped the pipe at ground level and tried to lift the string up without success. It was observed that when a force of 150 kN was applied to pull the string up, an extension of 225 mm was recorded. How far down below the ground surface, in the well, did the collapse occur?

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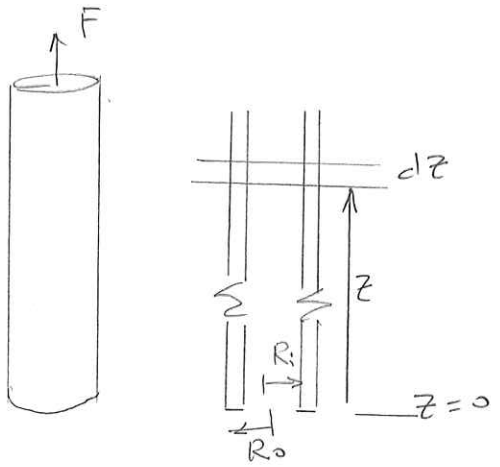
ENCH 501 F2015 Quiz #1 Solution Sept 15, 2015
GJ

Q The string stretches under its own weight. Assume Hooke's law is obeyed and the extension is elastic.



The force needed to lift the string up, F, equals the weight of the string.

Consider element dz under tension from the load below:

$$\text{The stress } \sigma = \frac{\text{Force}}{\text{Area}} = \frac{m_L z g}{A} = E\frac{d\psi}{dz}$$

m_L = mass string / length ; $A = \pi(R_o^2 - R_i^2)$; $d\psi$ is the extension obtained for element dz

$$\alpha z = \frac{d\psi}{dz} \quad \text{where} \quad \alpha = \frac{m_L g}{AE}, \text{ a constant}$$

This is an o.d.e. subject to condition $z=0$, $\psi=0$

At the top of the string, $z=L$, $\psi = \psi_L$

$$\therefore \alpha \int_0^L z\,dz = \int_0^{\psi_L} d\psi \quad \text{or} \quad \psi_L = \frac{\alpha L^2}{2} = \Delta L$$

Substitute numbers

$$\frac{m_L g}{AE}\frac{L^2}{2} = \frac{18.77(9.81)}{3.547(10^{-3})(206.85)(10^9)}\frac{L^2}{2} = 0.1964\ m$$

$L = 1251.058\ m$ This the depth of the well.

The number of pipes in the string = 126.

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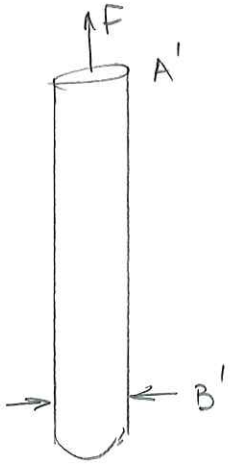
b



The strings is now held firmly at point B' where the collapse occured. It is also held at point A' to prevent the strings shrinking under its own weight. A force equal to the weight of the strings is already being applied during drilling and it remains applied with the collapse. The extra force applied to pull the strings up = 150 kN. This is the force that will stretch the strings further.

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \text{Young's modulus} \times \text{strain}$$

$$\sigma = \frac{150(10^3)}{\pi\left(0.05715^2 - 0.04623^2\right)} = 206.85(10^9)\,\frac{0.225}{L}$$

This is an equation to solve for L, the distance of the region of collapse to the top of the strings. The rest of the strings below B' is not important for the calculation.

$$L = 1{,}100.55 \text{ m}$$

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