The University of Calgary
Department of Chemical & Petroleum Engineering

ENCH 501: Transport Processes Quiz #1 **September 17, 2002**

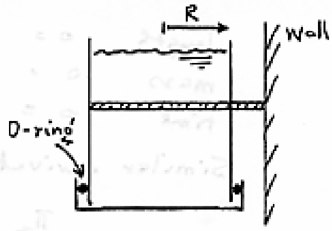
Time Allowed: 40 mins. **Name:**

Problem #1 (4 points)

A cannister at an auto-repair centre is attached to a wall by straps around the cylindrical body. At the bottom of the cannister is a cover held in place by an O-ring (see sketch). A liquid or granular material such as dust is normally stored in the cannister.

Identify ***a dimensionless quantity and the limit it can attain*** before the bottom cover falls off.

Given: The maximum shearing force (per unit peripheral length) on O-ring to trigger slip is τ N/m, the material stored has a density ρ and it occupies to a height h in a cannister of radius R.



Problem #2 (6 points)

The edge of a paper towel or the bottom of a block of consolidated sand is dipped into a pool of a liquid.
(a) Identify the variables and parameters important for estimating the percolation rate (m/s) of the liquid in the porous medium.
(b) Determine the dimensionless quantities for the uptake process. (Show steps.)

Problem #1 Force of gravity on bottom plate = Restraining Force at the limit

or $h\rho g\,(\pi R^2) \le \tau\,(2\pi R)$ or $\dfrac{h\rho g R}{\tau} \le 2$

pressure x area force x perimeter →

Problem #2

(a) $\underset{\text{vel}}{V} = f(\underset{\text{viscosity}}{\mu}, \overset{\text{density}}{\rho}, \underset{\text{surface tension}}{\sigma}, \overset{\text{acceleration of gravity}}{g}, d_{pore}, D_{particle}, \underset{\text{porosity}}{\varepsilon})$

(b) Number of variables $n = 8$
✓ ✓ Dimensions $j = 3$ ∴ 5 dimensionless quantities.

2 dimensionless variables are ε and $d_{pore}/D_{particle}$

$\therefore V = h(\mu, \rho, \sigma, g, d_{pore})$

Dimensions $\frac{L}{t}$ $\frac{m}{Lt}$ $\frac{M}{L^3}$ $\frac{M}{t^2}$ $\frac{L}{t^2}$ L

Select 3 variables, e.g. V, μ, ρ

$$\Pi_1 = V^a \mu^b \rho^c \tau^d$$

$$\Pi_2 = V^{a'} \mu^{b'} \rho^{c'} g^{d'}$$

$$\Pi_3 = V^{a''} \mu^{b''} \rho^{c''} d^{d''}$$

solve for each

$$\Pi_1 = M^0 L^0 t^0 = \left(\frac{L}{t}\right)^a \left(\frac{M}{Lt}\right)^b \left(\frac{M}{L^3}\right)^c \left(\frac{M}{t^2}\right)^d$$

$$\left.\begin{array}{ll} \text{length} & 0 = a - b - 3c \\ \text{mass} & 0 = b + c + d \\ \text{time} & 0 = -a - b - 2d \end{array}\right\} \Rightarrow a = b = -d,\ c = 0$$

$$\text{so } \Pi_1 = \left(\frac{\tau}{V\mu}\right)^d$$

Similar derivation shows

$$\Pi_2 = \left(\frac{\mu g}{V^3 \rho}\right)^d$$

and

$$\Pi_3 = \left(\frac{V \rho d}{\mu}\right)^d$$

Hence

$$\frac{V\rho d}{\mu} = \psi\left(\frac{\tau}{V\mu}, \frac{\mu g}{V^3 \rho}, \frac{d}{D}, \varepsilon\right)$$

Other dimensionless groups are valid. It depends on which 3 variables were selected for the derivations.