ENCH 501 Transport Phenomena University of Calgary Quiz 1 AJ

Time Allowed: 30 minutes Only a "cheat sheet" can be consulted. Sept 16, 2014

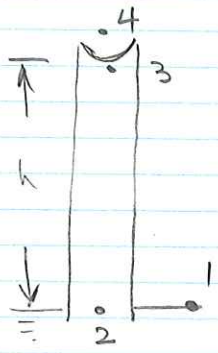
1. (**4** points) At an establishment, full-time workers get 20 vacation days in a calendar year. This is equivalent to 4 weeks. An individual on part-time employment works three days per week instead of five. If vacations are pro-rated, how many weeks of vacation will the part-time worker get off per year? Explain.
2. (**6** points) The production of sintered glass involves fusing together beads of glass to form a porous medium. Consider cylindrical pieces of sintered glass that were initially clean and dry (zero saturation). The curved surfaces were sealed so that only the two flat ends are open to air. Held in a vertical orientation, one end of the cylinder is just immersed into pure water. Water rises through the "capillaries". A student observed that water rises to the higher end of the cylinder for certain specimens but not for others. The primary difference is the length of time allowed for sintering. This is related to the final average pore size for the sintered glass.
   (a) What dimensionless quantity would help you predict whether water will be pulled to the top surface or not? State your assumptions.
   (b) If water is just pulled to the other end of a specimen that is 21 cm above the water surface, estimate the effective pore diameter for the porous medium. Assume the contact angle is zero.

Data: σ_{water} = 72.8 mN/m; ρ_{water} = 998.2 kg/m^3; g = 9.806 m/s^2

ENCH 501 Quiz #1 Solution Fall 2014, Sept. 16

#1 The part-time worker gets $\frac{3}{5}(20)$ or 12 days of vacation per year. But the person works 3 days per week. Hence he or she gets 4 weeks off — just as the full time employee.

#2 (a) Treat the sintered block as a series of capillaries. With respect to one of them, one can get the following relationships. The water is pulled up by surface tension forces and resisted by gravity. Choose points 1–4, as per sketch.



$P_1 = P_2$ — same horizontal level in a fluid

$P_2 = P_3 + h\rho g$ — hydrostatic

$P_3 = P_4 - \frac{2\sigma}{r}$ — across a meniscus (see b.h.s.)

sum $0 = h\rho g - \frac{2\sigma}{r}$

At static equilibrium

$h\rho g = \frac{2\sigma}{r}$ and $h \uparrow$ as $\frac{2\sigma}{r} \uparrow$

Force balance

$\Delta P(\pi r^2) = (2\pi r)\sigma$

or $P_4 - P_3 = \Delta P = \frac{2\sigma}{r}$

∴ For water to be pulled to the top,

$\left(\frac{4\sigma}{d} =\right) \frac{2\sigma}{r} \geq h\rho g$ or $\frac{h\rho g d}{\sigma} \leq 4$ →

(b) Substitute the data, keeping the units consistent

$$\frac{(0.21)(998.2)(9.806)\,d}{72.8\,(10^{-3})} \leq 4$$

or $d \leq 0.000142\ m \left(1.42(10^{-4})_m\right)$

or $0.142\ mm$

→

Solution
Quiz #1 AJ

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1. (**4** points) At an establishment, full-time workers get 20 vacation days in a calendar year. This is equivalent to 4 weeks. An individual on part-time employment works three days per week instead of five. If vacations are pro-rated, how many weeks of vacation will the part-time worker get off per year?

Gets $\frac{3}{5} \times 20 =$ 12 days
But works 3 days/wk
∴ gets 4 wks off.

2. (**6** points) The production of sintered glass involves fusing together beads of glass to form a porous medium. Consider cylindrical pieces of sintered glass that were initially clean and dry (zero saturation). The curved surfaces were sealed so that only the two flat ends are open to air. Held in a vertical orientation, one end of the cylinder is just immersed into pure water. Water rises through the "capillaries". A student observed that water rises to the higher end of the cylinder for certain specimens but not for others. The primary difference is the length of time allowed for sintering. This is related to the final average pore size for the sintered glass.
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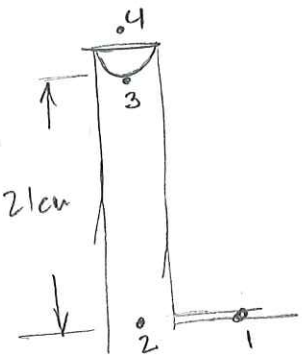
(a)



actually a little less because of the meniscus but - with small pores - the error is small

$P_1 = P_2$

$P_2 = P_3 + h\rho g$

$P_3 = P_4 - \frac{2\sigma}{r}$

$0 = h\rho g - \frac{2\sigma}{r}$

$\pi d\gamma = \Delta P \pi r^2$

$2\pi r\gamma = \Delta P \pi r^2$

$\frac{2\sigma}{r} = \Delta P$

$= P_4 - P_3$

or $h\rho g = \frac{2\sigma}{r}$ — to just reach the surface

To always reach the surface; $\frac{2\sigma}{r} \geq h\rho g$

$\frac{h\rho g r}{2\sigma} \leq 1$ or $\boxed{\frac{h\rho g d}{\sigma} \leq 4}$

(b)

$\frac{(0.21)(998.2)(9.806)\,d}{72.8\,(10^{-3})} \leq 4$ or $d \leq 0.000142$ m

or $1.42(10^{-4})$ m

or $\boxed{0.142 \text{ mm}}$