ENCH 501 Transport Phenomena University of Calgary

Name(s)________________________________, ____________________________________

Quiz #3 /

Take Home: Up to **2 students** may work together & submit one answer by **9am October 12, 2016** aJ

Lavender oil is an "essential oil" used in perfumes and fragrances, as a balm in aromatherapy and as food condiments and in flavouring. It also has antiseptic and anti-inflammatory properties. It is recovered from the flowers or the hair (indumentum) of leaves and stalks of the plant *Lavandula Angustifolia* and its variants by extraction or distillation. Distillation involves loading leaves and other plant materials into a still into which steam is continuously injected in a semi-batch process. The steam causes the glands containing the oil to release the organic mixture that constitute lavender. Both steam and lavender vapors are displaced out of the still and passed through a total condenser. Liquids drip into a collector vessel. Produced "spike" oil (density 905 kg/m^3) floats above water (density 998.2 kg/m^3) in the graduated vessel at room condition, say 20°C. For one experiment, the total amount of liquid collected as a function of time, W(t), and the mass fraction of the lavender oil in the collector vessel as a function of time $\overline{\omega_A}$ (t) are given below.
It is required that you determine the mass fraction of lavender in the vapor that is leaving the still as a function of time ω_A(t). Draw a sketch of the system. Do analysis and calculations, and report the results in a table. Prepare a plot of both ω_A(t) and $\overline{\omega_A}$ (t). Show your steps.

t, mins	Cumulative mass of liquid in collector, W(t) kg	Mass fraction of oil in collector, $\overline{\omega_A}$ (t)
-0.94	0	0.1725 (first droplet)
0	3.1982	0.1698
2	9.1541	0.1582
4	15.1441	0.1431
6	21.0720	0.1265
8	26.9921	0.1128
10	32.91798	0.1009
12	38.8218	0.09068
14	44.7117	0.08187
16	50.1362	0.07509
18	56.0857	0.06864
20	62.0203	0.06296
22	68.0016	0.05812
24	74.0012	0.05388
26	80.0302	0.050197
28	86.0375	0.046903
30	92.0339	0.044034

ENCH 501 F2016 Quiz #3 Solution

A plot of W vs t shows that $\frac{dW}{dt} = a\ constant = 2.95\ kg/min.$

The rate of which the oil is carried in the vapor in the still equals the rate at which the oil accumulates in the collector = $\omega_A \frac{dW}{dt}\ kg/min.$

The mass of oil in the collector is hence (from 0 to t)

$$\int_0^t \omega_A \frac{dW}{dt} dt = \bar{\omega}_A W$$

or

$$\bar{\omega}_A = \frac{dW}{dt} \int_0^t \omega_A dt/W\ ;$$

but $\frac{dW}{dt} = \frac{W}{t}$ if $t = 0$ is set to when $W = 0$, ∴ add 0.94 mins to the time column.

Hence the mass fraction in collector $\bar{\omega}_A = \frac{1}{t}\int_0^t \omega_A\, dt$ or $\bar{\omega}_A t = \int_0^t \omega_A dt$

Differentiate to get

$$\omega_A = \frac{d(\bar{\omega}_A t)}{dt}$$

Thus, a plot of $\bar{\omega}_A t$ vs t gives a curve that can be fitted with an equation.

Let $y = \bar{\omega}_A t$, then

$$y = (6.3138E - 8)\ t^5 - (7.7559E - 6)\ t^4 + (3.9991E - 4)\ t^3 - (1.1137E - 2)\ t^2 + (1.723E - 1)\ t + (1.6641E - 1)$$

$$R^2 = 9.9993E - 1$$

From the equation, $\frac{dy}{dt}$ or $\omega_A(t)$or can be evaluated at various values for t. (A 4th-order equation is not good enough.)