GEORGIA INSTITUTE OF TECHNOLOGY

COLLEGE OF ENGINEERING

BMED3300 – BIOTRANSPORT

QUIZ 3 (SPRING 2014) – KEMP

STUDENT NAME: Key

GTID NUMBER: ______________________

RECITATION SECTION: ______________________

(Section A is Wednesdays at 12 pm; Section B is Wednesdays at 10 am)

Closed Book
All non-communicating calculator types allowed
Time allotted: 15 minutes
Do all work in this booklet

Reminder: for questions that require numerical answers, units are required and worth 50%

Question	Maximum Mark	Actual Mark
1	9	
2	3	
Total	12	

1. There is currently a great deal of interest in delivering drugs (e.g. insulin) by inhalation, thus avoiding injection (e.g. Henry et al., Diabetes Care, 26:764, 2003). Aerosol droplets of density ρ_i and diameter D containing the drug would be inhaled and reach the small airways, where they would be absorbed into the blood. One problem is that droplets can have a hard time following tortuous pathways in the lungs, and run into airway walls before reaching their target destination. This depends on the speed of the air, V_{Air}, as well as the viscosity and density of the air, μ_{Air} ($kg \cdot s^{-1} \cdot m^{-1}$), and ρ_{Air}. Droplets can also sediment out of the air stream, which depends on gravitational acceleration, g.

a. Construct a π-matrix from the relevant parameters in this problem and confirm that 3 π-groups can be formed from these parameters.

	ρ_i	D	V_{air}	μ_{air}	ρ_{air}	g
M	1	0	0	1	1	0
L	-3	1	1	-1	-3	1
t	0	0	-1	-1	0	-2

+2

6 variables
rank = 3 $\qquad 6-3 = 3\ \pi$ groups +1

b. Taking V_{Air}, D and ~~ρ_i~~ ρ_{air} as the core group of variables, find ~~three~~ one π-groups.

$$M^0L^0t^0 = (V_{air})^a D^b \rho_i^c g = \left(\frac{L}{t}\right)^a L^b \left(\frac{M}{L^3}\right)^c \cdot \left(\frac{L}{t^2}\right)$$

M: $0 = c$

L: $0 = a + b - 3c + 1$

$a + b = -1$

t: $0 = -a - 2$

$a = -2$

$b = 1$

$$\pi_1 = V_{air}^{-2} D^1 \rho_i^0 g = \frac{D \cdot g}{V_{air}^2} = \left(\frac{t}{L}\right)^2 \cdot L \cdot \frac{L}{t^2} \checkmark$$

$$M^0L^0t^0 = (V_{air})^a D^b \rho_i^c \rho_{air} = \left(\frac{L}{t}\right)^a L^b \left(\frac{M}{L^3}\right)^c \left(\frac{M}{L^3}\right)$$

M: $0 = c + 1$

$c = -1$

L: $0 = a + b - 3c - 3$

$a = -b$

t: $0 = -a$

$$\pi_2 = \frac{\rho_{air}}{\rho_i}$$

$$M^0L^0t^0 = (V_{air})^a D^b \rho_i^c \mu = \left(\frac{L}{t}\right)^a L^b \left(\frac{M}{L^3}\right)^c \left(\frac{M}{L \cdot t}\right)$$

M: $0 = c + 1$

$c = -1$

L: $0 = a + b - 3c - 1$

$-2 = a + b$

t: $0 = -a - 1$

$a = -1$

$b = -1$

$$\pi_3 = V_{air}^{-1} D^{-1} \rho_i^{-1} \mu = \frac{\mu}{V_{air}\,\rho_i\, D} = \left(\frac{M}{L t}\right) \cdot \frac{1}{L} \cdot \frac{t}{L} \cdot \frac{L^3}{M}$$

μ_{air}

V_{air}, D, μ, ρ_i $\quad$ $V_{air}, D, \mu, \rho_{air}$ $\quad$ V_{air}, D, μ, g

$$M^0 L^0 t^0 = \left(\frac{L}{t}\right)^a L^b \left(\frac{m}{L \cdot t}\right)^c \left(\frac{m}{L^3}\right) +1$$

$M: \; 0 = c+1$

$c = -1 \qquad +1$

$L: \; 0 = a+b-c-3$

$0 = a+b-\cancel{2} \quad +1$

$$\pi_2 = \frac{V_{air}\,\rho_{air}\,D}{\mu}$$

$t: \; 0 = -a-c$

$0 = -a+1$

$a = 1$

$b = 1 \qquad +1$

$$\cancel{\pi_1 = \frac{D^5}{V_{air}} \cdot \mu\,\rho_i}$$

$$\cancel{\frac{L \cdot t}{L}}$$

$$\pi_1 = \frac{V_{air}\,\rho_i\,D}{\mu} \qquad \cancel{AH} +3$$

$$= \frac{L}{t} \cdot \frac{m}{L^3} \cdot L \cdot \frac{t\,L}{m} \checkmark$$

$$M^0 L^0 t^0 = \left(\frac{L}{t}\right)^a L^b \left(\frac{m}{L \cdot t}\right)^c \cdot \frac{L}{t^2}$$

$M: \; 0 = c$

$L: \; 0 = a+b-c+1$

$-1 = a+b$

$t: \; 0 = -a-c-2$

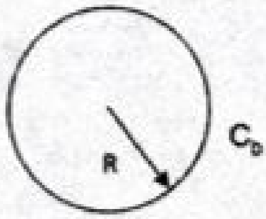
$a = -2$

$b = 1$

$$\pi_3 = \frac{D \cdot g}{V_{air}^2}$$

$$= L \cdot \frac{L}{t^2} \cdot \frac{t^2}{L^2} \checkmark$$

2. Medical implants are capable of releasing drugs at a constant rate into the systemic circulation, a convenient alternative to oral drug administration when a constant blood level of drug is desired in the patient for extended periods of time. Several slow-release corticosteroid intraocular implants are undergoing clinical trials for treating macular edema. Perhaps more familiar is the use of Norplant™, an implantable contraceptive device which releases the steroid hormone levonorgestrel into the blood when implanted under the skin in the arm. A new device is being considered which does not contain any surface coating, i.e. the implant of **spherical geometry** consists of a single bead of polymer gel material that the drug is imbedded in and can diffuse through. Consider the following definitions:



c_b = concentration of drug in the body fluid at the surface of the device (assume constant)

c_d = drug concentration in the implant

R = radius of the implant

D_{eff} = effective diffusion coefficient of the drug in the implant

a) What are the boundary conditions you would use for determining a solution?

at $r = R$, $c_d = c_b$ $\quad + 1\frac{1}{2}$

at $r = 0$, $\frac{\partial c_d}{\partial r} = 0$ $\quad + 1\frac{1}{2}$

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