(3)

$P = 10^8$ Pa $\quad L = 10^{-2}$ m

$\rho = 980$ kg/m³

$\gamma = 20\times10^{-3}$ N/m

$$u = \left(\frac{P}{\rho}\right)^{1/2} \qquad \mu = 1.2\times10^{-3} \text{ Pa.s}$$

$$\theta = \frac{L}{u} \qquad u = 319.44 \text{ m/s}$$

$$\theta = 3.13\times10^{-5} \text{ s}$$

$$\varepsilon = \frac{P}{\theta} \qquad \varepsilon = 3.195\times10^{12} \text{ W/m}^3$$

$$\ln(\lambda) = 0.75\ln(\mu) - 0.5\times\ln(\rho) - 0.25\ln(\varepsilon)$$

$$= -15.686$$

$$\lambda = \exp(-15.686) = 1.54\times10^{-7} \text{ m}$$

Assume that the drop is in inertial subrange. Therfore,

$$d = 4^{0.6}\times\varepsilon^{-0.4}\times\gamma^{0.6}\times\rho^{-0.2}$$

$$\ln d = 0.6\ln(4) - 0.4\ln(\varepsilon) + 0.6\ln(\gamma) - 0.2\ln(\rho)$$

$$= -14.41$$

$$d = 5.518\times10^{-7}$$

$$d > \lambda$$

$\therefore$ drop breakup is in inertial subrange

b.) $$v = v_{Stokes}\left(1 - \frac{\phi}{\phi_c}\right)^{k\phi_c}$$

$\rho_{oil} = 800$ kg/m³ $\quad \rho = 980$ kg/m³

$\phi_c = 0.74 \quad \phi = 0.3 \quad k = 1$

$\Delta\rho = (\rho - \rho_{oil}) = 180$ kg/m³

$R = \frac{d}{2} \quad g = 9.81$ m/s²

$$v_{Stokes} = \frac{2\Delta\rho R^2 g}{9\mu} = \frac{2\times180\times9.81\times\left(\frac{5.518\times10^{-7}}{2}\right)^2}{9\times1.2\times10^{-3}}$$

$$= 1.695\times10^{-8} \text{ m/s}$$

4.)

$\mu_d = 0.95\times10^{-3}$ Pa.s

$\mu = 10^{-3}$ Pa.s

$$q = \frac{\mu_d}{\mu} \qquad D = 0.12\text{m} \qquad h = 200\times10^{-6} \text{ m}$$

$$q = 0.95 \qquad \gamma = 0.01 \text{ N/m}$$

$$N = \frac{60000}{60} = 1000$$

$$G = \frac{\pi\cdot N\cdot D}{h} = 1.885\times10^6$$

$We_{crit} = 0.8$ for $q = 0.95$

$$r = \frac{2 \times 0.01 \times 0.8}{1.885 \times 10^{6} \times 10^{-3}} = 8.488 \times 10^{-6}$$

$$d = 2 \cdot r = 1.7 \times 10^{-5} \text{ m}$$

1.)

$T = 394.3$ K

$l = d = 0.0127$ m

$\varepsilon = 0.4$

$L = 3.66$ m

$P = 2.2$ atm

$G' = 2.45$ kg/m²s

$\mu = 2.265 \times 10^{-5}$

$$D_p = 0.0127 \times 0.874 = 0.0111$$

$$N_{Re,p} = \frac{0.0111 \times 2.45}{0.6 \times 2.265 \times 10^{-5}} = 2 \times 10^{3} = 2001.1$$

$P_1 = 2.23 \times 10^{5}$ Pa

$P_2 = 2.1 \times 10^{5}$ Pa.

$P_{av} = 2.165 \times 10^{5}$ Pa.

$$\rho_{av} = \frac{M P_{av}}{RT} = \frac{28.97 \times 2.165 \times 10^{5}}{8314.34 \times 394.3}$$

$$= 1.913 \text{ kg/m}^3$$

$$\frac{\Delta P \,(1.913) \times (0.0111)\,(0.4)^3}{(2.45)^2 \times 0.6 \times 3.66} = \frac{150}{2001.1} + 1.75$$

$$\Delta P = 1.77 \times 10^{4}$$

$$= 0.177 \times 10^{5} \text{ Pa.}$$

$$P_2 = 2.053 \times 10^{5} \text{ Pa}$$

Repeat till $P_1 - P_2$ is close enough to ΔP

2.) $\phi_s = 0.86$ $\quad \rho = 1200$ kg/m³

$T = 298$ K

$P = 202.65$ kPa

Particle size = 0.1 mm

$\varepsilon = 0.43$

bed diameter = 0.6 m

bed contains 350 kg of solids

(a) Volume of solids = $\dfrac{350 \text{ kg}}{1200 \text{ kg/m}^3} = 0.2917 \text{ m}^3$

Cross section of empty bed = $\pi \times (0.3)^2$

$= 0.283 \text{ m}^2.$

$$L_1 = \frac{0.2917}{0.283} = 1.031$$

$L_{mf} = L_2 \quad \varepsilon_{mf} = \varepsilon_2$

$$\frac{L_1}{L_{mf}} = \frac{1-\varepsilon_{mf}}{1-\varepsilon_1}$$

$$\frac{1.031}{L_{mf}} = \frac{1-0.43}{1-0}$$

$$L_{mf} = \frac{1.031}{0.57} = 1.81 \text{ m}$$

b.) at 202.65 Pa & 25°c

$\mu = 1.845 \times 10^{-5}$ Pa.s $\quad \rho = 1.187 \times 2$
$= 2.374$ kg/m3

$P = 2.0265 \times 10^{5}$ Pa

$D_p = 0.0001$ m

$\rho_p = 1200$ kg/m^3

$$\Delta p = L_{mf}(1-\varepsilon_{mf})(\rho_p - \rho)g$$

$$= 1.81 \times (0.57) \times (1200 - 2.374)(9.80665)$$

$$= 1.212 \times 10^4 \text{ Pa} = 0.1212 \times 10^5 \text{ Pa}$$

To calculate for V'_{mf}

$$\frac{1.75 \, N_{Re}^2}{0.86 \times 0.43^3} + \frac{150(0.57) N_{Re}}{(0.86)^2 \times (0.43)^3}$$

$$= (0.0001)^3 \frac{2.374(1200 - 2.374)(9.80665)}{(1.845 \times 10^{-5})^2}$$

$$265.6 N_{Re}^2 + 1454 N_{Re} - 81.9 = 0$$

$$N_{Re} = 0.0563 = \frac{D_p V'_{mf} \rho}{\mu}$$

$$V'_{mf} = 0.004374 \text{ m/s}$$

If $V'_{mf} = 0.0175$ m/s $\quad N_{Re} = 0.2252$

$$\frac{1.75 N_{Re}^2}{0.86 \times \varepsilon^3} + \frac{150 N_{Re}(1-\varepsilon)}{(0.86)^2 \times \varepsilon^3} = 81.9$$

$$\frac{0.1032}{\varepsilon^3} + 45.67 \frac{(1-\varepsilon)}{\varepsilon^3} = 81.9.$$

$$0.1032 + 45.67 = 81.9\varepsilon^3 + 45.67\varepsilon$$

$$45.7732 = 81.9\varepsilon^3 + 45.67\varepsilon$$

$$\varepsilon = 0.605$$