ENGG 201

What is Going On with Liquids?

(A Brief Outline of What is Important in Ch 8)

Chapter 8 – The Motion of Fluids

Main Concepts:

1. Viscosity (Section 8.1)
    a. How are the SHEAR STRESS and the SHEAR RATE related for Ideal, Newtonian, and Non-Newtonian fluids?
2. Flow of Fluids (Sections 8.2 - 8.5.2 (except 8.3.1))
    a. How are the PRESSURE, FLOW RATE, HEIGHT and LENGTH related for the flow of Ideal, and Newtonian Fluids?

Things to Remember:

Viscosity

1. Stress is a force applied over an area (pressure units).
2. Strain is a fractional change in length (or width or height) of an object (dimensionless).
3. Normal stress (σ_n= -P) (F perpendicular to A) results in Normal Strain ($\varepsilon=\Delta L/L_o$).
4. Shear stress (τ) (F parallel to A) results in Shear Strain ($\gamma=\Delta\xi/\Delta y$). We represent shear strain by the RATE of strain (du/dy) - They are related $\tau = C\frac{du}{dy}$
5. **Always draw a diagram** and label a) coordinate system (xyz or xr), b) the dimensions of the object, c) the magnitude and direction of the applied force, and d) the area over which the force is being applied.
6. Ideal Fluids
    a. Viscosity = 0 (C=0)
7. Newtonian Fluids
    a. Viscosity (μ) = constant. $\tau = -\mu\frac{du}{dy}$

8. Non-Newtonian Fluids

   a. Viscosity (μ) ≠ constant. $\mu_{app} = \dfrac{\tau}{\left(\dfrac{du}{dy}\right)}$

   b. Know types (names) of fluids

   c. Power-Law fluids $\tau = K\left(\dfrac{du}{dy}\right)^n$ (Use absolute value of du/dy)

      i. Plot log(τ) vs log(du/dy) – straight line – n=slope (n=1 → Newtonian, n<1 → pseudoplastic, n>1 → dilatent)

      ii. UNITS (n=dimensionless, K = Pa.s^n)

9. Viscometers – know how to calculate F from τ and vice versa
10. Viscometers – know how to calculate u from du/dy and vice versa

Flow of Fluids

11. Always calculate Reynolds Number $\mathrm{Re} = \dfrac{D\bar{u}\rho}{\mu}$
12. Three types of flow – Ideal, Real Laminar (Re<2100), and Real Turbulent (Re>4000).
13. Ideal Flow (μ=0) – Bernoulli Equation $\dfrac{P}{\rho} + gh + \dfrac{u^2}{2} = Const.$
14. Laminar Flow (Re<2100) $-\left[\dfrac{\Delta P}{L} + \rho g\dfrac{\Delta h}{L}\right] = \dfrac{32\mu\bar{u}}{D^2}$
15. Turbulent Flow (Re>4000) $-\left[\dfrac{\Delta P}{L} + \rho g\dfrac{\Delta h}{L}\right] = \dfrac{2f\bar{u}^2\rho}{D}$

    a. Get friction factor (f) from Moody diagram (log(f) vs log (Re)) – read log scale carefully!

16. Flow rate – volumetric $Q = \bar{u}A = \bar{u}\dfrac{\pi D^2}{4}$
17. Pump Power $Power = Q\Delta P$ where ΔP= pressure difference across pump
18. **ALWAYS Draw a Diagram** – Flow from 1 to 2, and then $\Delta P = P_2 - P_1$, $\Delta h = h_2 - h_1$
19. Pressure is always in Pa NOT kPa.

20. Setting up fluid flow problems
    a. If given u (or Q) ($Q = \bar{u}A$) → <u>Asked to find ΔP</u>
        i. Calculate Re
            1. Laminar – use $-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{32\mu\bar{u}}{D^2}$ and calculate <u>ΔP</u>
            2. Turbulent – use $-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{2 f\bar{u}^2\rho}{D}$ and calculate <u>ΔP</u>
    b. If given ΔP → <u>Asked to find u (or Q)</u> (Trial and Error)
        i. Assume Turbulent
        ii. Guess f (0.002 < f < 0.010)
        iii. Calculate u from $-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{2 f\bar{u}^2\rho}{D}$
        iv. Calculate Re from $\mathrm{Re} = \frac{D\bar{u}\rho}{\mu}$
            1. If Re < 2100, then laminar, STOP and use laminar equation
            2. If Re > 4000, Read f from friction factor chart –and compare to guess (If the same – STOP) (If different, use this f as a second guess)

<u>Examples of Typical Problems:</u>

Viscosity

1. Given τ and du/dy, calculate μ. (single point or table of data)
2. Given τ and μ, calculate du/dy. (single point or table of data)
3. Given μ and du/dy, calculate τ. (single point or table of data)
4. Given F, calculate τ, and vice versa.
5. Given u (or Q), calculate du/dy , and vice versa.
6. Obtain K and n for Power Law from data – use formula to get μ_{app}.
7. More … (see old finals)

Flow of Fluids

8. Can be given any two of ΔP, Δh, and u (or Q) and asked to find the 3^{rd}.
9. More … (See old finals).

FRICTION FACTOR CHART