(missed everything before this)

Mechanical efficiency of fluid matrix

$$e_M = \frac{power\ output\ from\ the\ motor}{power\ delivered\ by\ fluid} = \frac{P_O}{P_R}$$

[Problem 7.13]

Given pressure at point A is $-20\ kPa$

(By now, you should know the meaning of the minus sign in $-20\ kPa$, it means we are talking about gage pressure. Absolute pressure can never be negative.)

Given pressure at point B is $275\ kPa$

The fluid is oil, of sg (specific gravity) = 0.85, and flow rate is $75\ litres/minute$.

Energy loss is 2.5 times the velocity head in the discharge pipe. (You should know the meaning of velocity head)

Calculate the power delivered by the pump to the oil.

So write the general energy equation between A and B.

$$\frac{P_A}{\gamma_{oil}} + Z_A + \frac{v_A^2}{2g} + h_A + h_R + h_L = \frac{P_B}{\gamma_{oil}} + Z_B + \frac{v_B^2}{2g}$$

Calculate v_A and v_B first

$$Q = 75\frac{litres}{minute} = 75 \cdot \frac{1\ minute}{60\ seconds} x10^{-3} = \frac{m^3}{s} = 1.25\ X\ 10^{-3}\frac{m^3}{s}$$

$$v_A = \frac{Q}{A_A} = \frac{1.25 \cdot 10^{-3}}{2.168\ \cdot 10^{-3}} = 0.577\ m/s$$

[FIX]

$$v_B = \frac{Q}{A_B} = \frac{1.25 \cdot 10^{-3}}{5.574\ \cdot 10^{-4}} = 2.243\ m/s$$

So, from the general energy equation

$$h_A = \frac{P_B - P_A}{\gamma_{oil}} + (Z_B - Z_A) + \frac{v_B^2 - v_A^2}{2g} + h_L$$

$$h_A = \frac{275 - (-20)}{(0.85)(9.81)} + 1.20 + \frac{(2.243)^2 - (0.577)^2}{2(9.81)} + 2.5\frac{(2.243)^2}{2(9.81)}$$

$$h_A = 37.46\ m$$

[FIX]

Practise problems from chapter 7

7.4, 7.23, 7.25, 7.35

Chapter 8 – Reynolds Number, Laminar Flow, Turbulent Flow, and energy losses due to friction

Laminar flow – As water flows from a faucet at a very low velocity, the flow appears to be smooth and steady. This is called laminar flow.

Turbulent flow – If the faucet is opened fully, the water has a high velocity and the flow is chaotic. This is called turbulent flow.

Engineers need some criterion to separate laminar and turbulent flow.

It is called "Reynolds number", based on the work of Osborne Reynolds.

This book uses symbol N_R for Reynolds number (most other books use R_e for Reynolds Number)

$$N_R = \frac{vD\rho}{m} = \frac{vD}{v} \ (need\ to\ memorize)$$

$\rho = fluid\ density, v = average\ velocity,$
$D = diameter\ of\ pipe, m = dynamic\ velocity,$
$v = kinematic\ viscosity$

If we look at units

$$N_R = \frac{\left(\frac{m}{s}\right)(m)\left(\frac{kg}{m^3}\right)}{\left(\frac{kg}{m \cdot s}\right)} = all\ units\ cancel$$

So, N_R is a unit-less or dimensionless number.

(you will come across many dimensionless numbers in engineering courses)

Reynolds number in a way represents the ratio of inertia to viscous forces.

$N_R < 2000\ Laminar\ Flow$

$N_R > 4000\ Turbulent\ Flow$

Between N_R of 2000 and 4000 is called transition flow. Transition flow is very difficult to analyze.

The cut-off limits such as 2000 and 4000 are not some exact numbers where laminar flow stops and turbulent flow starts.

Some books use 2200 or 2500 instead of 2000.

The term h_L used in the previous chapter for friction losses is also expressed as

$$h_L = f\ \left(\frac{L}{D}\right)\frac{v^2}{2g}$$

This equation is called Darcy's Equation and one of the most common equations used by practicing engineers. (You need not memorize it)

$h_L = energy\ loss\ due\ to\ friction$
$L = length\ of\ the\ flow\ section$
$D = diameter\ of\ pipe$
$v = velocity\ of\ flow$
$f = friction\ factor$ (dimensionless)

Darcy's equation is applicable to both laminar and turbulent flow. The only difference is that the friction factor (f) is calculated differently in laminar and turbulent flow.

For laminar flow $f = \frac{64}{N_R}$ $(need\ not\ memorize)$
Another equation for h_L for laminar flow is Hagen-Poisuville equation
$h_L = \dfrac{32mLv}{\gamma D^2}$ $(for\ laminar\ flow - need\ not\ memorize)$

Feb 8th / 17

If we equate Darcy equation and Hagen Poisuville equation

$[jumble\ of\ equations]$

For turbulent flow of fluids in circular pipes, it is common to use Darcy equation to calculate energy losses due to friction.

So, there is need to know the value of friction factor f for turbulent flow.

Moody chart (most commonly used chart by practicing engineers). Textbook has a big moody chart.

[diagram of moody chart]

In exam, you will be given a formula to calculate friction factor.

[diagram of smooth pipe]

Observations from the Moody chart

- For a given N_R, as the relative roughness $\frac{D}{\varepsilon}$ is increased, the friction factor decreases.
- For a given relative roughness, the friction factor f decreases with increasing N_R until the zone of complete turbulence is reached.
- Within the zone of complete turbulence, the Reynolds number has almost no effect on the friction factor.
- As the relative roughness increases, the value of N_R at which the zone of complete turbulence begins also increases.

In examination, you will be given an equation for calculating the friction factor in turbulent flow.

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\left(\frac{D}{\varepsilon}\right)} + \frac{5.74}{N_R^{0.9}}\right)\right]^2}$$

(Need not memorize)

Remember log means logarithm to base 10. In math courses, mostly you use ln – which is logarithm to base e. So, need to be careful in calculations.

Also, most formulas will be given, but you have to be familiar with symbols.

Also, you are expected to know stuff like area of circles (πr^2), circumference of circle ($2\pi r$).

[Problem 8.41]

Practise problems – 8.31

Chapter 9 – Velocity Profiles for Circular Sections and flow in non-circular sections.

Mostly, we deal with circular pipes.

There are many practical applications where the flow cross-section is not circular.

- Household air ducts are usually rectangular cross section.
- Pipe in a pipe – heat exchanges

[diagram of pipe in a pipe]

Velocity profiles are needed for engineering design calculations.

The fluid velocity at the pipe wall is 300 (no slip condition)

Local fluid velocity increases from 300 at the wall to a maximum at the centreline.

For laminar flow, the velocity profile is parabolic.

[diagram of a pipe of some kind]

The velocity u at any given radius r most books use this nomenclature, i.e. in general, v for average velocity, and u for local velocity at radius r)

[equation with u velocity]

u is the local velocity at radius r.

You need not memorize the formulas, but know the symbols.

Obviously the maximum velocity is at the centreline, where $r = 0$

So, the maximum $u_{max} = 2v$

So, for laminar flow in pipes, the maximum velocity is twice the average velocity.

For turbulenet flow, the velocity profile is somewhat flat.

[another diagram with Ro.. u.. etc.]

At the wall, the fluid velocity is 350 (no-slip condition)

Away from the wall, it increases rapidly.

$$u = v\left[1 + 1.43\sqrt{f} + 2.15\sqrt{f}\log\left(1 - \frac{r}{r_o}\right)\right]$$

f is friction factor

Flow in non-circular cross-sections.

A term "hydraulic radius" (Symbol R) is defined to deal with non circular cross-section.

$$R = \frac{cross - section\ area}{wetted\ perimeter} = \frac{A}{WP}$$

Note: WP is not W times P, it is the short form for wetted perimeter.

The wetted perimeter is defined as the sum of the length of the boundaries of the section acting in contact with the fluid.

Example: square duct

[picture with square duct, etc]