ENG 243 – Fluid Mechanics Study Guide

General

These notes are intended as a summary of the ENG 243 Fluid Mechanics course for 2005 only. The important notes from each section of the course will be highlighted here and will assist you with preparation and study programs. It should be noted that this is to be considered as a guide only.

You will note that I have not prescribed a text for this subject, however there are a number of books on sale in the bookshop (at very special prices) that will help you if you need to read further on the topics. I will suggest readings from each of the book below at the end of each summary.

(1) Fluid Mechanics with Engineering Applications – Franzini and Finnemore for $10 per copy – 13 copies available

(2) Solving problems in Fluid Mechanics Vol 1 – Douglas and Mathews for $10 per copy – 13 copies available

(3) Fundamentals of Fluid Mechanics – Munson, Young and Okiishi for $124 per copy.

It should be noted that there are a number of other texts and reference materials in the library that also cover this material, please feel free to access these or discuss readings further with me. Some texts that may be useful are: Kinsky – Fluid Mechanics Advanced Applications; Gerhart and Gross – Fundamentals of Fluid Mechanics.

We will not have practical sessions in Term 1, the sessions detailed in the course outline as practical will be used for tutorials and demonstrations. We will also use these sessions to complete lectures. As a guide, we will use three hours of each week for lectures and three hours for tutorials.

The tutorial sessions will be "unstructured", i.e. I will be there to help and guide you through the problem solving process. This is also a time for you to discuss any problems you are having with me and also to give me feedback on areas that you require extra. I expect that the assignments will be handed IAW the schedule of work. I will endeavour to guide you through the assignments but I will not solve the problems for you. We will lose one tutorial session with the Easter holiday (wk 5 - 25 Mar). The mid session test on Fluid Statics only will be held on the Thursday of the same week (24 Mar). Throughout the semester you will be tasked to carryout some self-study and reading. These self-study tasks will be assessed as part of the final examination and are detailed in the weekly summary below.

Fluid Statics

There are five tutorial sheets and two assignments to be completed in this section.

Week One

The student should understand the difference between fluid statics and fluid dynamics. Here we discuss the properties of fluids and one should work on understanding these. We will consider units and discuss Pascal's law; you should understand these units and how to apply Pascals law. Viscosity is one of the most significant fluid properties and one should understand how shear stress and strain are related in Newtonian fluids.

You should have a good understanding of capillarity. The surface tension coefficient is an important parameter and one should understand surface tension forces influence experimental work and error.

The concept of a compressible fluid is discussed and one should understand when one might treat a compressible fluid as an incompressible fluid. We will then develop the equation for vertical equilibrium in a fluid. The concepts of absolute, gauge, and differential pressures are developed. From here we carry out an analysis of forces on submerged horizontal plates.

The measurement of pressure and the principles of manometry are studied. Different forms of the manometer are introduced and the student should become proficient in calculating the pressures indicated in all commonly encountered manometers. You will need to master the skill of determining pressures in fluids using manometers.

Using the work we have covered you should be able to solve all of the problems in Tutorial sheets 1,2 and 3.

Suggested readings from above list:

1. Finnemore pp 1-67
2. Douglas pp 1-30
3. Munson pp 1-60

Week Two

Here we will extend the work from week one and consider the forces on submerged inclined planes. You should understand the difference between the centre of pressure and the centroid. You will need to be able to determine the location of the centroid and the centre of pressure, and from this calculate forces on the submerged plates. You will call on skills developed in year one and it will be assumed that you know how to determine the location of the centroid and calculate the second moment of area of a composite body. There will be a small allocation of time to refresh these topics should it be necessary. The tutorial problems are typical of those encountered in the analysis of forces on underwater valves and gates and you will need to be able to work through an analysis.

We will also look at the pressure prism approach to determining forces, and from this we will analyse the loads on submerged curved planes such as those seen in dam walls.

Using the work we have covered you should be able to commence the problems in Tutorial sheet 4 and the complete the extra selected problems given during the lectures.

Suggested readings from above list:

1. Finnemore pp 67-80
2. Douglas pp 30-50
3. Munson pp 61-74

Week Three

We commence our study of buoyancy forces. One should understand the concept of buoyancy. We will discuss Archimedes principal and apply it to reinforce the concept. From here we will study stability and derive the equations for static stability about the rolling and pitching axes of a floating body. We will introduce some common stability terminology that you should become familiar with. We will study a twin hull catamaran and drawn conclusions about its stability.

We will do a simple demonstration of stability using a telescoping aerial and float. Students should take the time to experiment with stability next time they are in a pool with a bottle of beer.

Using the work we have covered you should be able to complete the problems in Tutorial sheets 4 and 5 and hence determine the stability of floating objects.

Suggested readings from above list:

1. Finnemore pp 81-88
2. Douglas pp 51-71
3. Munson pp 74-78

Fluid Dynamics

There are six tutorial sheets and five assignments to be completed in this section.

Weeks Four and Five

We will wrap up the section on Fluid Statics and commence our study of Fluid Dynamics. At the end of week four's tutorial you should have completed all of the tutorial sheets (1-5) and both Assignments 1 and 2. We will summarise our fluid statics work and I will give you the 2004 mid session test to study. We will prepare for the mid session test that is scheduled to be held in week six.

We will commence our fluid dynamics study with the fundamental laws required for the analysis of fluid flow. We will look at the difference between the Lagrangian and Euleran approach to fluid studies. We discuss streamlines, streaklines, pathlines and steady flow. We will look at the total derivative and derive expressions for the acceleration of fluid particle. We will use these again in week 12.

Using the accelerations derived above we will derive the equations of motion for a streamline particle in inviscid flow and hence derive the Euler and Bernoulli's equations for flow along a streamline. We will look at some CFD studies of the desert rose EV and discuss the pressure distributions around the vehicle. We will relate our findings to the energy equation and discuss the concept of head.

We will discuss the conservation of mass and hence consider the continuity equation. Here we will look at the control volume approach (later we will study the differential approach).

Using the work we have covered you should be able to solve simple fluid flow problems by applying both Bernoulli's equation along a streamline and the equation of continuity. From here you can complete the problems in Tutorial sheet 6. You should fully understand the limitations of the Bernoulli equation and be able to state the assumptions when using it in the analysis of fluid flows.

Suggested readings from above list:

1. Finnemore Chapters 4 and 5. Exclude Cavitation, Vortex flows
2. Douglas Chapters 5 and 6
3. Munson See lecturer for details

Weeks Six, Seven and Eight

We carry on from week fives work and look at flow measurement devices. Using the theory developed we will do a practical experiment and look at the flow through a venturi. You should be able to analyse the flow through a venturi and determine the velocity and pressures throughout the flow. Using this you will be able to complete assignment 3.

We will commence our study of viscous flows. We will introduce the concept of the boundary layer and the parameters that are used to describe the forces in the boundary. We will briefly look at external flows and then focus our efforts on internal flows. You will conduct a reading assignment of the factors that influence the transition from laminar to turbulent flow in both external and internal flows; this will be assessed in the final exam.

We will derive the friction factor for a pipe and look at some well accepted correlations for internal flows. We will then derive an equation for the friction factor for laminar flow in a circular pipe. The student should understand the factors that influence the value of the friction factor in a pipe and be able to determine the factor using the moody diagram or an accepted correlation. We will also consider non circular pipes and the entrance region effects. Note the three types of problems that exist in pipe systems (i) head loss problem, (ii) Discharge problem, (iii) sizing problem.

Using the theory developed above we will include the friction factor in the Bernoulli equation and use this to solve pipe system problems. We will consider how we include fluid machinery in the energy balance. You should be able to solve for the three classes of problem mentioned above. We will also introduce minor losses into the Bernoulli equation. To complete this section we will look at the head equation again. You will do a reading assignment on the flow in pipes in parallel and series and gain an appreciation of the solution method for these types of system flows.

At the end of this session you should be able to solve fluid system problems and be able to determine: pumping requirements, energy extraction from turbines, fluid losses in a pipe, the head equation for a system. You should be conversant with the moody diagram and the application of various friction factor equations. You will be able to derive an expression for the friction factor from first principles. From here you will be able to complete Tutorial sheet 7 and assignment 4. To consolidate this work we carry out two practical experiments. The first will be to measure the losses in a pipe system and the second to look at the pressure losses and the transition from laminar to turbulent flow in a pipe.

Suggested readings from above list:

1. Finnemore Chapters 8 and 9
2. Douglas Chapters 10 and 13
3. Munson Chapters 8 and 9

Week 9

We will study the modelling of fluid systems by first studying dimensional analysis and similitude. Using the Buckingham PI theorem we will derive some of the significant groups of dimensionless parameters that are studied in fluid mechanics. We will show how using the method of similitude can use these parameters to solve large-scale problems. We will look at the significance of some of the derived parameters in solving problems in practice.

At the end of the session you should be able to derive dimensionless parameters using the Buckingham Pi Theorem and discuss their significance to the system being analysed. You will be able to validate some of the earlier theory we developed regarding the Moody diagram. You will be able to complete tutorial sheet 8 and assignment 5.

Suggested readings from above list:

1. Finnemore Chapters 8 and 9
2. Douglas Chapters 10 and 13
3. Munson Chapters 8 and 9

Week 10

This week we will consider newtons second law and derive the linear momentum equation. Using this we will consider the forces on a control volume. The forces on a nozzle and on a bend will be considered in detail. The forces on moving surfaces such as those found on a turbine blade will also be studied. A laboratory experiment will be used to validate the theory.

At the end of this session you will be able to construct a control volume around a system and determine the forces acting on the fluid. As you did with dynamics you should focus your efforts on drawing a good control volume and identifying the magnitude and direction of the applied forces. From this you will be able to determine reactions necessary to support the fluid loads.   You will be able to complete tutorial sheet 9 and assignment 6.

Suggested readings from above list:

1. Finnemore Chapter 6 – ignore the sections on machinery and rockets, these will discussed in later years
2. Douglas Chapter 8
3. Munson Chapter 5

Week 11

In this session we discuss channel flow (gravity driven flow). We commence this sessions discussing the applications for channel flow analysis and introduce the important dimensionless parameters. We discuss the friction slope and derive equations for the velocity of the fluid in a channel.   We consider the Darcy, Chezy and Manning formulae. You will conduct a reading assignment on (i) the optimisation of channel geometry, (ii) hydraulic jumps, and (iii) super/sub critical flows. We will apply the theory to practical problems and conduct a practical demonstration.

On completion you will be able to estimate the velocity and flow rate of fluid in both open and closed channels using the Darcy, Chezy or Manning friction methods. With the theory developed you will be able to complete tutorial sheet 10 and assignment 7.

Suggested readings from above list:

1. Finnemore Chapter 10
2. Douglas Chapter 15
3. Munson Chapter 10

Week 12

In this section we will consider viscous flows in general. We will first consider the continuity equation in differential form and then we will look at the full set of governing equations for viscous flows. From this we will derive the Navier-Stokes equations for an incompressible constant viscosity fluid and combine this with the continuity equation for incompressible flow to give the equations that describe the motion of a viscous incompressible fluid.

Following this we will analyse fluid flows by simplifying the equations derived above. On completion of this section you will be able to explain the terms in both the differential continuity equation and the Navier-stokes equations. You will also be able to complete tutorial sheet 11. After completing this section you will be ready to start considering CFD modelling.

Suggested readings from above list:

1. Munson Chapter 6

Week 13

This is a revision week. We will summarise the sections and look at the 2004 final examination. Unless we fall behind during the semester there will be no new work this week. All outstanding assignments and tutorials must be submitted by the end of the week.