The University of British Columbia
Department of Mechanical Engineering

NAME 566
Ship Dynamics and Control

COURSE INSTRUCTORS:

Unit 1 – Seakeeping

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Office Hours: any time the door is open (typically 09.00 – 16.00) or by appointment

Preferred contact is by e-mail

You are welcome to "friend" me on Facebook, but FB messages are not a good way to raise technical questions.

Also, I work a 40-hour week and often turn my electronics off (or go to sea) over the weekend.

Unit 2 – Manoeuvring

Dr. Peter Ostafichuk
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Office Hours: any time the door is open (typically 10.00 – 17.00) or by appointment

Preferred contact is by e-mail

COURSE OBJECTIVE

By the end of the course, students are expected to be able to:

1. Characterize a sea condition in standard terms of sea state
2. Predict the wave-induced motions of a ship
3. Present ship motions in standard tabular and graphical ways
4. Calculate the total sea-induced operability of a ship, for specific missions and operating conditions.

5. Describe the principles of operation of rudders and other control surfaces, and apply semi-empirical models to predict performance
6. Model and analyze manoeuvring behaviour of ships, including estimating turning radius, motion stability, and course keeping, using linear and non-linear methods
7. Interpret hydrodynamic derivatives and use them to describe ship characteristics
8. Describe the principles of operation of simple automatic control systems and the influence of common control strategies and parameters on ship response.
9. Simulate ship dynamics and control using MATLAB and Simulink.

MARK DISTRIBUTION

Unit 1 – Seakeeping (50%)

Problem Sets	20%	(Four problem sets)
Exam 1	15%	(given at, or near, 7 February)
Exam 2	15%	(given at, or near, 4 April)

Unit 2 – Manoeuvring and Control (50%)

In-lab assignments	10%	
Weekly quizzes	10%	(5% each for individual and team portions)
Exam 3	15%	(given at, or near, 13 March)
Exam 4	15%	(given at, or near, 27 March)

Students are expected to achieve at least a 68% average in the four exams, and an overall average of at least 68% to pass the course. The exams are normally knowledge, skills and values based. We plan to attempt having both a closed book and open book portion for the exams. The closed book sections will deal with basic knowledge and facts. These facts should be well understood by the naval architecture student and should be described in his/her own words. The open book section of the exam will test the student on skills and values. In general, this section will ask, "Are you able to apply your analytical skills to solve a particular ship problem and are you able to assess the results to provide a conclusion or recommendation for further action."

TEXTBOOK AND REFERENCES

The prescribed textbook for this course is volume III of the 1989 edition of PNA: "*Principles of Naval Architecture.*" The full text is available as PDF from Knovel via the UBC library on line. A hardcopy may be purchased from SNAME by sending an email request to Ms. Susan Evans: sevans@SNAME.org. The cost for the hardcopy is $30 + shipping.

UNIT 1 (SEAKEEPING) HOMEWORK

Assignments will usually be due two weeks after issue. I am new here and don't know what other courses you are taking, so if my due date conflicts badly with some big lab report in another class, please mention this when I give the assignment. I am happy help manage the workload for all of us. However let me warn you of a couple of things:

Students find that my homework assignments look deceptively simple: The calculations are easy, but it takes a lot of work to think your way through the process. Don't wait until the last minute to discover you have underestimated the amount of work required. Late submission of homework will be heavily penalized if it is done without my prior consent. (It is penalized somewhat less heavily if you let me know in advance.)

A word on homework preparation: Welcome to the professional world. Your boss will reject your work if you hand him a handwritten scrawl on a crumpled piece of paper. Your CLIENT will certainly reject such a product. For purposes of this class, I am your boss and your client. Make up your homework as you would for a customer. It is not required to use a word processor, but it helps. Whether you type it or not it must satisfy the following standards:

- write neatly and orderly
- describe the steps leading to the solution
- explain choices and assumptions you made
- summarize and discuss results with respect to their accuracy and significance (e.g. for example by comparing it with published data)
- summarize and discuss the impact these results have upon the design decision you are making. In other words: In light of this homework, so what? What does this mean to the ship, to the customer, to the project?

These elements will always be major components of the grade in the homework

Much of the homework will require you to get familiar with a spreadsheet program (Excel, etc), writing small programs, or using commercial software packages. I will try to introduce these packages in class, but there will still be a fair amount of self-learning involved. You all have excellent computer skills, indeed you pick up some of this software faster than I do. My skill will be in teaching you the naval architecture that you are using the software for.

UNIT 2 (MANOEUVRING AND CONTROL) MODULE QUIZZES

The teaching approach in Unit 2 will be similar to Unit 1, but it will further emphasize the idea of the "flipped classroom." In short, you will be responsible for learning simple concepts out of class through a series of reading assignments, and we will focus time in class and labs on applying those concepts. The reading assignments will form your foundation so it is essential that you complete them. In part to encourage you to complete the readings, and in part to give both you and me feedback whether you understood them, there will be multiple choice quizzes at the start of each module. The quizzes will focus on basic concepts (knowledge, comprehension, and simple analysis) rather than on deep understanding. For each module, you will first take a quiz individually, and then immediately afterward you will repeat the same quiz in pre-assigned teams. In the team test you will get a chance to share and test your understanding with your teammates and you will find out the correct answers.

TOPIC OUTLINE

Unit 1 - Seakeeping

Module A – Role & Reporting of Seakeeping
7-9 January 2015

Class A-1a The importance of seakeeping
- Ship motions at sea (PNA III 1)

Class A-1b The statistical nature of seakeeping
- Waves in the open ocean (PNA III 2.6)
- Wave slope and slope spectrum (PNA III 2.7)
- Frequency of encounter spectrum (PNA III 2.8)
- Ocean Wave Data (PNA III 2.10)
- Standardized idealized spectral families (PNA III 2.11)

Class A-2 Measuring seakeeping performance
- Types of motions (PNA III 3.1)
- Motion criteria (PNA III 7.1-7.3)
- Motion limits (PNA III 7.4-7.6)
- Calculating the Operability Index (OI) (PNA III 7.7)
- Calculating the Seakeeping Performance Index (SPI) (PNA III 7.8)

Module B – Wave-Induced Motions
21-23 January 2015
4-6 February 2015

Class B-1 The equations of motion
- 2-DOF Head sea harmonic case (PNA III 3.2)

Class B-2 The equations of motion
- 6-DOF Harmonic case (PNA III 3.3)

Class B-3 Strip Theory
- Strip theory (PNA III 3.4)
- Computations in 2D case (PNA III 3.5)

Class B-4 Motions in irregular seas
- Linear theory (PNA III 4.1)
- Long-crested zero-speed case (PNA III 4.2)
- Long-crested forward-speed case (PNA III 4.3)
- Short-crested case (PNA III 4.4)
- Statistics of maxima (PNA III 4.5)

Module C – Derived Responses
11-13 February 2015

Class C-1 Derived Responses 1
- Local and Relative Motions (PNA III 5.2)
- Shipping Water Forward (PNA III 5.3)
- Slamming (PNA III 5.4)

Class C-2 Derived Responses 2
- Yawing and Broaching (PNA III 5.5)
- Added Resistance & Powering in Waves (PNA III 5.6 & 5.7)
- Wave Loads (PNA III 5.8)

Module D – Design Aspects
1-3 April 2015

Class D-1 Design Aspects 1
- Factors Affecting Pitching and Heaving (PNA III 8.2)
- Factors Affecting Rolling (PNA III 8.4)

Class D-1 Design Aspects 1
- Other Design Considerations (PNA III 8.3)
- Seakeeping Design Procedures (PNA III 8.6)

Unit 2 – Steering and Control
Module 1 – Control Surfaces
24-27 February 2015

Class 1-1 Control Surfaces
- Describe the flow field, pressure distribution, and lift & drag forces on an airfoil (2D)
- Describe how forces on a control surface (3D) differ from an airfoil (2D) and the role aspect ratio plays on control surface performance
- Estimate lift, drag, and moment on a low-aspect ratio control surface using a semi- empirical method
- Describe practical and operational considerations for rudders and other control surfaces

Class 1-2 Wind Tunnel
- Convert lift and drag performance of a series of low aspect ratio airfoils into non- dimensional form
- Compare wind tunnel results to theoretical and semi-empirical predictions
- Identify discrepancies between measurement and prediction and identify possible sources of error
- Use wind tunnel data to size control surfaces for an AUV

Class 1-3 Selecting a Rudder

- Apply rudder sizing "rules of thumb" to determine an approximate preliminary rudder size
- Explain how ship and operational parameters might influence rudder size
- Select and size a rudder using operational parameters and a desired hydrodynamic derivative

Class 1-4 Control Implications

- Interpret marine vehicle response as a function of control action
- Identify possible coupling between control inputs and vehicle response

Module 2 – Ship Modelling
3-6 March 2015

Class 2-1 Hydrodynamic Derivatives

- Explain what hydrodynamic derivatives are, how they are determined, and how they are used
- Relate hydrodynamic derivatives to the operation of a vessel
- Determine the expected form (sign and relative magnitude) of common hydrodynamic derivatives
- Convert hydrodynamic derivatives between dimensional and non-dimensional form
- Use hydrodynamic derivatives to assess vessel directional stability

Class 2-2 State Space Representation

- Describe what state space representation is
- Convert a time-invariant linear system to state space representation
- Represent the coupled sway and yaw equations of motion for a ship in state space

Class 2-3 Analysis of Turning Vessel

- Interpret sway and yaw velocity (v and r) simulation time histories and determine:
    - General ship response, including steady state turn diameter
    - Directional instability
    - Relative location of pivot point
- Improve the rudder model by including information of V, v, and r

Class 2-4 Coupling and Nonlinearities

- Explain the limitations of linear, uncoupled models for ship hydrodynamics
- Describe several strategies for addressing linear model limitations
- Schematically implement an improved rudder model for simulation

Module 3 – Manoeuvring
10-14 March 2015

Class 3-1 Stability and Manoeuvring

- Describe different forms of manoeuvring stability
- Describe ship behaviour through the stages of a turn
- Identify the pivot point and centre of lateral resistance, and describe factors that will change these points
- Apply Nomoto's linear, first-order steering indices to describe manoeuvring behaviour
- Size a rudder based on a linear model to achieve desired manoeuvring characteristics of a vessel

Class 3-2 Standard Manoeuvres

- Describe the purpose, procedure, and measurements in standard manoeuvring tests
- Quantify:
    - Turning ability
    - Course changing ability
    - Straight-line / dynamic stability

Module 4 – Control
17-21 March 2015

Class 4-1 Control Introduction

- Describe the differences between guidance, navigation, and control
- Describe typical strategies for controlling ship heading
- Measure straight-line stability of a vessel with and without feedback control
- Explain the concepts of controllability and observability, in practical and mathematical terms
- Draw block diagrams of a basic PID feedback control system and a state-space plant models (both with and without noise and disturbances)

Class 4-2 Controller Performance and Tuning

- Describe in general terms the desired response characteristics of a controlled system
- Identify common measures of system response on a response curve
- Describe the characteristics of proportional, derivative, and integral action in a PID controller
- Describe the causes and effects of "integrator windup"
- Describe methods to tune PID controllers

Class 4-3 Control and Modelling Errors

- Explain the importance of correctly modelling the ship during controller design and the impacts of modelling errors

- Explain unexpected ship performance in terms of controller, rudder, and propeller actions

Class 4-4 Nonlinearities and Disturbances

- Describe control strategies to deal with known nonlinearities in plant behaviour
- Describe control strategies to deal with disturbances to the system (e.g. waves, current, etc.)
- Describe control strategies to deal with measurement noise

Module 5 – Noise and Disturbances
24-28 March 2015

Class 5-1 Control with Nonlinearities and Disturbances

- Implement control strategies to deal with known nonlinearities in plant behaviour
- Implement control strategies to deal with disturbances to the system (e.g. waves, current, etc.)
- Implement control strategies to deal with measurement noise

Class 5-2 A Very Brief Introduction to Intelligent and Optimal Control

- Describe the fundamental principles of fuzzy logic control, and potential advantages and disadvantages over conventional control
- Describe the fundamental principles of optimal control, and in particular the Linear Quadratic Regulator

CONNECT

I will use CONNECT extensively to distribute course material, and to communicate using the CONNECT e-mail interface. Please make sure that you can access the course, and check the site regularly. I won't always notify you when I post something.

ACADEMIC DISHONESTY POLICY

The academic enterprise is founded on honesty, civility, and integrity. As members of this enterprise, all students are expected to know, understand, and follow the codes of conduct regarding academic integrity. At the most basic level, this means submitting only original work done by you and acknowledging all sources of information or ideas and attributing them to others as required. This also means you should not cheat, copy, or mislead others about what is your work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore serious consequences arise and harsh sanctions are imposed. For example, incidences of plagiarism or cheating may result in a mark of zero on the assignment or exam and more serious consequences may apply if the matter is referred to the President's Advisory Committee on Student Discipline. Careful records are kept in order to monitor and prevent recurrences.

Cheating of any kind on an exam or quiz will not be tolerated. Plagiarism of another student's homework, class work, or project will not be tolerated. The first offense will result in a grade of "F" for the student(s) involved. If a second offense of cheating or plagiarism is determined, the matter will be discussed with the Chair of the Department.

ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES

Students who qualify for services will receive the academic modifications for which they are legally entitled. Students who require academic accommodations and support at UBC due to a disability or ongoing medical condition must register with Access and Diversity. It is the responsibility of the student to register and follow the procedures for obtaining assistance.

CLASSROOM CONDUCT

In brief: I will treat you like a professional colleague. I suggest you treat me like your boss. This means that you pay attention, don't nap, don't talk amongst yourselves while the boss is talking. When the boss calls a meeting you come on time, not five, ten, fifteen minutes late.

But more important than your body being present is that your mind must be present. Firstly, I don't think you can learn this material without paying attention to the lectures - there isn't a text book to rely upon. Secondly, this is your first participation in a professional environment. This – Naval Architecture – is what you are going to do for a living. Participate in the class with the same respect you intend to display on the job.

GRAMMAR AND PRESENTATION

As an engineer, your work will achieve nothing until it is communicated successfully to your client, to the fabricator, or to your boss. I know a lot of bright engineers whose careers are limited by impaired communication skills. Take the time now to improve these skills - they are as important as your calculus. But just like your calculus, there are tools to help you.

Use correct grammar in your work. Use the right words, and spell them correctly. There are a lot of clients and bosses out there who, like me, will tune out after the third or fourth faux pas.

As engineers, you understand the precision of numbers. But ask any lawyer: Words have the same degree of precision. You would never write "5" when you mean "7." You would never write \rho when you mean \pi. So don't write "then" when you mean "than." Learn to spell, learn to write, and learn to speak. This will serve you extremely well in your career.

In fact, it has been said that I am the sort of instructor who will give you extra points simply because you turned your homework in nicely bound and with a color cover sheet. It's true, and it's true because your boss and your client will react the same way. It won't turn an F into an A, but it can certainly work the other way!

Fortunately, there are a lot of tools to help you. Most of you know about the red underlining that MS-Word will insert in your document, when it thinks you may have misspelled a word. For starters, make sure your copy of Word has the spelling and grammar checking turned on. But be careful - we have a lot of words that Microsoft doesn't know!

Please don't describe any "planning boats" when you mean to talk about planing boats! But did you also know that Word will insert green underlining if it thinks that your grammar can be improved? You may need to turn on the "check grammar in this document" feature to get this, but I do find this feature useful.

As a rule of thumb, I would advise you to always accept Word's suggestions for grammar. Word will often tell you that you have written in passive voice, or that the sentence is too long, and so forth. Most of the time this advice is very good, and you should follow it.

Many people reject Word's suggestions, because they say "but I like to use this word." or "but that's not my writing style." If you are Hemingway then you are qualified to have your own style, but for the rest of us I will go so far as to say that if you accept all of Word's grammar suggestions then your document will be better than if you try to pick and choose. What I mean is, that Word "gets it wrong" less often than you. Or me!