Purdue University
School of Nuclear Engineering
NUCL 355 - Nuclear Thermal-Hydraulics Laboratory
Spring 2020

Credit Hours: 3

Instructor: S.T. Revankar, Office: WANG 4085, Email: shripad@purdue.edu, Phone: 496-1782**,**
Office Hours: Tuesday 10:30am-12:00pm or by appointment

Textbook(s): Lab Class Notes

Specific Course Information:

- **a.** Laboratory course corresponding to NUCL 350 and NUCL 351. Various fluid flow and heat transfer phenomena applied to nuclear reactor systems and design.
- **b.** Pre-requisite: NUCL 350; Pre or Co-requisite: NUCL 351
- **c.** Classification: Required

Course Objectives

a. To apply principles of fluid mechanics and heat transfer to laboratory experiments
b. To acquire skills on thermalhydraulics laboratory and team working
c. To acquire knowledge of the fluid flow and heat transfer through experimental observation, data acquisition and analysis
d. To develop communication skills through writing a technical report on experimental based fluid flow and heat transfer phenomena analysis

Student Outcomes

3. An ability to communicate effectively with a range of audiences.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

List of Topics:

Thirteen laboratory experiments that include flow visualization, basic fluid flow measurement, principle of hydraulic pressure, turbulence and vortex, drag force, pipe friction, flow around bodies, two phase flow regime, two-phase natural circulation, thermal conduction, free and forced convection, phase change, pool boiling and choked flow and reactor blow down.

This course will use **Blackboard Learn** to post information on this course, homework assignment, class notes and on campus emergency.

Lab Teaching Assistant: Mark Brown <brown214@purdue.edu>

Lecture: Tues. Thurs. 9:30-10:20am, Room: KNOY B033

Laboratory: M T W Th F 1:30-3:20pm, F 3:30pm-5:20pm, Room: ECE B086

Course Outline:
This course will provide students with laboratory practice on various fluid flow and heat transfer phenomena seen in nuclear reactor systems and design. The course consists of twelve laboratory experiments and one thermalhydraulics computational problem:

Lab 1: Basic Hydrostatic Pressure and Manometer Experiment
Lab 2: Reynolds Experiment
Lab 3: Flow Meters and DP Measurements
Lab 4: Flow around Bodies
Lab 5: Pipe Friction and Similarity Law
Lab 6: Drag Force on Spheres
Lab 7: Two-Phase Natural Circulation
Lab 8: Two-Phase Flow Regimes
Lab 9: Thermal Conduction
Lab 10: Natural and Forced Convection
Lab 11: Pool Boiling
Lab 12: Critical Flow and Phase Change (Blowdown Expt.)
Lab 13: Thermalhydraulics CFD Problem

Regular class attendance is required. If you cannot attend a particular lab session in a week please make arrangements with the instructor in advance to attend another session that week only. Each experiment is set for one week only. If you miss a laboratory for whole week no substitute experiments will be given and zero grade is counted for the missing laboratory.

Lab Reports

Students will perform experiments in groups. Each student will write a full lab report according to the format provided in the Lecture 1 handout for the following labs:

Lab 3
Lab 6
Lab 10
Lab 12

The report must be prepared according to the attached guidelines. For the other labs, each person will submit a partial lab report consisting of: *Short Introduction, Data (original and reduced), Sample Calculations, Analysis and Discussion, and Conclusions*.

Homework
A prelab homework problem will be given with every experiment handout. The objective of the prelab homework is to acquaint the student with the concepts to be investigated during the experiment.

Due Dates: A prelab homework will be assigned on each Tuesday class and will be due on the following Tuesday class before laboratory experiments are conducted. The lab reports will be due on respective following lab hours. No delay is accepted for prelab homework. A penalty of 20% per day will be deducted for each day late for lab reports, and no lab reports will be accepted more than four days late.

Exams: Two Exams, one midterm and a final inclusive of all course material will be given.

Grading
The course grade will be based upon lab reports, homework assignments and exams. Each prelab will be worth 10 points of the lab report. All full lab reports will have three times the weight of a partial lab report. Homework assignments will be weighted equally.

Lab reports including homework (Total 13)	75% (prelab 10%+report 90%)
Exam 1	10%
Final Exam	15%

It is anticipated that the course grade will be assigned as:

A	90% or above
B	80%-89%
C	70%-79%
D, F, I	as warranted

Attendance Policy:

Since many of the topics to be covered can only be adequately treated by class discussion, regular attendance is mandatory to meet the objectives of the course. Please see University attendance and grief absence policy at *https://www.purdue.edu/studentregulations/regulations_procedures/classes.html*

Excessive unexcused absences will be reflected in the grade. Students are responsible for all material covered during class, including assignments and quizzes. If the instructor is late, students are required to wait 15 minutes before leaving.

Academic Integrity

http://www.purdue.edu/odos/osrr/academic-integrity/index.html

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.

Purdue Honors Pledge.

"As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue."

https://www.purdue.edu/provost/teachinglearning/honor-pledge.html

Diversity & Inclusion

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. Purdue's nondiscrimination policy can be found at: http://www.purdue.edu/purdue/ea_eou_statement.html.

CAPS Information

Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at (765)494-6995 and http://www.purdue.edu/caps/ during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business

Campus Emergency: *In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Here are ways to get information about changes in this course.* (i) Check on messages in for this course in Blackboard (ii) My email (shripad@purdue.edu), (iii) Phone: (765-496-1782)

EMERGENCY PREPAREDNESS

As we begin this semester I want to take a few minutes and discuss emergency preparedness. Purdue University is a very safe campus and there is a low probability that a serious incident will occur here at Purdue. However, just as we receive a "safety briefing" each time we get on an aircraft, we want to emphasize our emergency procedures for evacuation and shelter in place incidents. Our preparedness will be critical IF an unexpected event occurs!

Emergency preparedness is your personal responsibility. Purdue University is actively preparing for natural disasters or human-caused incidents with the ultimate goal of maintaining a safe and secure campus. Let's review the following procedures:

- For any emergency call 911.
- There are nearly 300 Emergency Telephone Systems throughout campus that connect directly to the Purdue Police Department (PUPD). If you feel threatened or need help, push the button and you will be connected to the PUPD.
- If we hear a fire alarm we will immediately evacuate the building and proceed

  Assembly Areas –Admin/BO: North side of Duncan Annex (EE) by Northwestern Ave.

  SOET: South side of Duncan Annex by (EE) dock

  ECN: South side of Duncan Annex by (EE) dock

  Assembly Areas – Secondary location (in case of inclement weather):

  Admin/BO: Potter 1st floor, POTR is directly west of Knoy

  - **Do not use the elevator.**
  - Go over evacuation route…see specific Building Emergency Plan.
- If we are notified of a Shelter in Place requirement for a tornado warning we will shelter in the lowest level of this building away from windows and doors. Our preferred locations in KNOY Hall are LOWER BASEMENT: Administration, Business Office, CMT, and ECN
  UPPER BASEMENT: CGT, CIT, and SOET.
- If we are notified of a Shelter in Place requirement for a hazardous materials release we will shelter in our classroom shutting any open doors and windows.
- If we are notified of a Shelter in Place requirement for a civil disturbance such as a shooting we will shelter in a room that is securable preferably without windows. Our preferred location is BASEMENT: Administration, Business Office, CMT, and ECN
  UPPER BASEMENT: CGT, CIT, and SOET.

NOTE: Each building will have different evacuation & shelter locations. The specific Building Emergency Plan will provide specific locations and procedures

EMERGENCY PREPAREDNESS SYLLABUS ATTACHMENT

EMERGENCY NOTIFICATION PROCEDURES are based on a simple concept if you hear a fire alarm inside, proceed outside. If you hear a siren outside, proceed inside.

- **Indoor Fire Alarms** mean to stop class or research and immediately **evacuate** the building.
  - Proceed to your Emergency Assembly Area away from building doors. **Remain outside** until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave.

- **All Hazards Outdoor Emergency Warning Sirens** mean to immediately seek shelter (**Shelter in Place**) in a safe location within the closest building.
  - Shelter in place means seeking immediate shelter inside a building or University residence. This course of action may need to be taken during a tornado, a civil disturbance including a shooting or release of hazardous materials in the outside air. Once safely inside, find out more details about the emergency*. **Remain in place** until police, fire, or other emergency response personnel provide additional guidance or tell you it is safe to leave.

**In both cases, you should seek additional clarifying information by all means possible. Purdue Home page, email alert, TV, radio, etc. review the Purdue Emergency Warning Notification System multi-communication layers at*
http://www.purdue.edu/ehps/emergency_preparedness/warning-system.html

EMERGENCY RESPONSE PROCEDURES:

- Review the **Emergency Procedures Guidelines**
  https://www.purdue.edu/emergency_preparedness/flipchart/index.html
- Review the **Building Emergency Plan** (available from the building deputy) for:
  - o evacuation routes, exit points, and emergency assembly area
  - o when and how to evacuate the building.
  - o shelter in place procedures and locations
  - o additional building specific procedures and requirements.

EMERGENCY PREPAREDNESS AWARENESS VIDEOS

- "Shots Fired on Campus: When Lightning Strikes," is a 20-minute active shooter awareness video that illustrates what to look for and how to prepare and react to this type of incident. See: http://www.purdue.edu/securePurdue/news/2010/emergency-preparedness-shots-fired-on-campus-video.cfm (Link is also located on the EP website)

MORE INFORMATION

Reference the Emergency Preparedness web site for additional information:
http://www.purdue.edu/emergency_preparedness

NUCL 355

Thermal Hydraulics Laboratory
Grading scale for full lab reports
Spring 2019

	SECTION	POINTS
1.	PRE-LAB PROBLEM	10
2.	EXECUTIVE SUMMARY	5
3.	INTRODUCTION	5
4.	EXPERIMENTAL APPARATUS	3
5.	DATA ACQUISITION + APPENDIX A-1: RAW DATA	10
6.	ANALYSIS AND DISCUSSION	
	THEORY	10
	RESULTS & DISCUSSION	15
7.	UNUSUAL OBSERVATIONS	5
8.	CONCLUSIONS	10
9.	REFERENCES	1
10.	APPENDIX A-2: REDUCED DATA	5
11.	APPENDIX A-3: SAMPLE CALCULATIONS	6
12.	APPENDIX A-4: ERROR ANALYSIS	5
QUALITY AND OVERALL PRESENTATION		10
	TOTAL	100

Partial lab reports

Prelab	10
Short introduction	5
Data (original and reduced)	15
Analysis and discussion	40
Sample calculations	10
Conclusions	20
Total	100

School of Nuclear Engineering
Purdue University
West Lafayette, IN 47907

NUCL 355
Spring 2020
GUIDELINES ON THE PREPARATION OF THE FULL LABORATORY REPORT

Instructions:

1. Reports should be typed or word-processed. A legible hand written report is also acceptable in case typing or word-processing cannot be done. In the latter case, use a medium hardness pencil and a good eraser to facilitate writing

2. Use good English (*see Additional Remarks and Cautions*)

3. Graphs and figures should be clearly drawn with appropriate legends for axes and lines and they should be provided with complete figure captions.

4. Reports found deficient will need to be resubmitted with some loss of credit.

The front page will contain the following information:

School of Nuclear Engineering
Purdue University

Title of the Experiment/CFD Problem

A Report of the Experiment/CFD Problem Conducted by
(Names of the members in the group)

Written by
NAME of the Author

Date

NUCL 355
Instructor NAME

The report will contain the following sections, with each section beginning on a new page.

1. Executive Summary

In this section an extended abstract will state the nature of the experiment, the purpose of the experiment, the major findings and the main conclusions derived from the experiment. This part should be self-contained without reference to the body of text. It could contain an equation or two if necessary but no figures. *(approximately 500 words)*

2. Introduction and Theoretical Considerations

Start out by stating in simple words the motivation for this particular experiment. Continue by stating what is expected to be demonstrated, discovered or to be proven. Give subsequently the theoretical background on whose premises the experimental results will be tested and compared with. To a limited extent, make an effort to present what other relevant information is available in the literature, both experimental and theoretical. *(2-3 pages)*

3. Description of the Experiment/CFD Problem

Include a schematic figure to illustrate the set-up. Number various components so that you can describe the apparatus. Make sure that you can identify in detail all the instruments you use, including the name of manufacturer and instrument serial number as appropriate. Expand portions of the apparatus in separate drawings if necessary to show important details. The figure should contain self-explanatory captions. (*1-2 pages*)

4. Data Acquisition

In this section describe the procedure used to collect the data in systematic order. Enter this raw data in Appendix A-1 under the title Original Data. This section should be concise such that other person would be able to use the data for analysis. (*1-2 pages*)

5. Analysis and Discussion of the Experiment data /CFD Problem

In this section you will include Reduced Data in the form required to analyze and discuss them under the premises set forth in the Introduction. These tables will normally be an abbreviated version of those appearing in Appendix A-2.

Use self-explanatory figures/illustrations to compare your data with other available theoretical or Experiment/CFD Problem results. Critically examine your data and explain any deviations observed from your expectations under the light of Error Analysis included in the Appendix A-4. For each figure and table, use separate pages in the order they are referred to in the body of the text. (*2-5 pages*)

6. Unusual Observations and Unexpected Findings

In this section record any observation made that you cannot explain from first principles. You should make an effort to offer tentative explanation. (*1 page*)

7. Conclusions, Recommendations and Comments

In this section cite the conclusions drawn from the Experiment/CFD Problem. What was shown or failed to be shown, or any new finding, should be stated in a concise way. Conclude this section by providing recommendations such as alternative methods of performing the Experiment/CFD Problem to make it more successful. Also feel free to make comments on what you liked best or least in this particular Experiment/CFD Problem *(1-2 pages)*

8. List of References

The references will be numbered in order they appear in the text, e.g.,

3. Pitts, Donald R. and Leighton E. Sissom, "Heat Transfer", Schaum's Outline Series In Engineering, McGraw-Hill Book Company, 1977.

4. Giedt W.H., "Investigation of Variation of Point Unit-Heat-Transfer Coefficient Around a Cylinder Normal to an Air Stream", Trans. ASME vol. 71, 1949, pp 375-381.

Appendices

A-1 Original Data

Here you will copy from your lab book all data and pertinent notes recorded during the Experiment/CFD Problem either by you or your group member. Make sure to include the names of team members that provided the data information.

A-2 Reduced Data

Most of the time you will have original data in the form of voltages currents or length (such as manometer level), which need to be reduced to the physical quantities such as pressure, temperature or some non-dimensional number. In this appendix, tabulate the required reduced data.

A-3 Sample Calculations

Here you should enter sample calculations you performed to reduce your data to the form needed for comparison/discussion as described above.

A-4 Error Analysis

In this section you should analyze all your data statistically, so that you can estimate the error and reliability of your data. Make sure to identify systematic and random errors and error propagation while reducing data. Do not reject any data without sound explanation. Be critical and conservative in your error estimations.

Additional Remarks and Cautions

All reports should be typed/word processed or hand-written in pencil with clear legible handwriting without crossing-out or sloppy appearance. The quality of your English will be carefully evaluated. Unacceptable reports will be given back for revision with some loss of credit. It is to the best of your interest to submit a good report the first time.