COURSE OUTLINE

Faculty & School: Faculty of Engineering, School of Chemical and Renewable Energy Engineering Department : Department of Energy Engineering.	
Code and Subject: **SKTN 3224 – Thermal Hydraulics + Lab** Total Lecture Hours: **56 hrs**	**Semester: I** **Academic Session: 20202021**

Lecturer **Room No.** **Telephone No.** **E-mail**	: : : :	Mohsin Mohd Sies N01-324 mohsin@utm.my
Synopsis	:	This course covers the thermo-fluid dynamic phenomena and analysis methods for conventional and nucler power stations. Fundamental processes of heat generation and transport in nuclear reactors. Effects of boiling and critical heat flux. Fundamentals of reactor thermal and hydraulic design. Specific topics include: kinematics and dynamics of two-phase flows, boiling, and critical conditions, single channel transient analysis, loop analysis including single and two phase natural circulation, and subchannel analysis. Students will also perform laboratory experiments to reinforce understanding of thermal hydraulic phenomena.
Prerequisites	:	SKPP 2113 Thermodynamics SKPU 1123 Fluid Mechanics SKPN 2xx3 Heat Transfer

Learning Outcomes:
By the end of the course, students should be able to:

No.	Course Learning Outcome	Programme Learning Outcome(s) Addressed	Bloom Taxonomy	Weightage (%)	Assessment Methods
CO1.	Explain basic concepts of two-phase flows and heat transfer and how they apply to nuclear reactor systems	PO1	C1	15	Quiz, HW, Test, Final exam, Laboratory
CO2.	Formulate, analyze and solve simple problems in single- and two-phase flows	PO1	C4	15	Quiz, HW, Test, Final exam, Laboratory
CO3.	Apply fluid mechanics analysis to two-phase systems, including flow regime maps, void-quality relations, pressure drop, and critical flow	PO1, PO2	C4	15	Quiz, HW, Test, Final exam, Laboratory

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CO4.	Apply heat transfer analysis on boiling inside reactors and understand the importance of boiling crisis, and their implications on reactor design	PO1, PO2	C4	15	Quiz, HW, Test, Final exam, Laboratory
CO5.	Perform thermalhydraulic analysis on transient single channel, multiple, subchannels, and loops	PO1, PO2	C4	15	Quiz, HW, Test, Final exam
CO6.	Perform core thermal design, with attention to design uncertainty analysis and hot channel factors, and reflect on thermal limitations in nuclear power plant.	PO1, PO2	C6	15	Quiz, HW, Test, Final exam
CO7.	Ability to plan and conduct the appropriate experimental procedures, in addressing a given thermal-hydraulics case, analyze and present the results.	PO9	A4	10	Lab Report Oral presentation

Program Outcomes (PO) related to the course:

PO1 Apply knowledge of mathematics, science, engineering fundamentals, and nuclear engineering principles to the solution of complex engineering problems.

PO4 Ability to conduct investigation of complex engineering problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions

PO9 Ability to communicate effectively through written and oral modes to all levels of society.

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Student Learning Time

Teaching and Learning Activities	**Student Learning Time (hours)**
1. Face to Face Learning	
a. Lecturer-Centered Learning i. Lecture	 56
b. Student-Centered Learning (SCL) i. Laboratory ii. Student-centered learning activities - Active Learning, Project Based Learning	 30 16
2. Self-Directed Learning	
a. Non-face-to-face learning or student-centered learning (SCL) such as manual, assignment, module, e-Learning, etc.	28
b. Revision	30
c. Assessment Preparations	8
3. Formal Assessment	
a. Continuous Assessment	5
b. Final Exam	3
Total (SLT)	168

Teaching Methods

This course utilizes cooperative learning approach. At the beginning of the semester, students will be divided into groups of four and are assigned to sit together in their respective group. The group team members will help each other during problems solving session in class. The same grouping will be used in the laboratory sessions.

For soft skill, students will be assessed on Critical Thinking and Problem Solving (CTPS) through open-ended laboratory sessions. They are to come up with experimental approach and conduct the experiment based on given problems that are based on theoretical treatments in class.

Weekly Schedule

Week	Topic	
1	**1. Course Introduction** Review of nuclear power plant systems and thermal components Heat generation in reactor core Decay heat **Lab 1** Convective heat transfer experiment – Theory and preparation, literature review and experiment planning	*It is expected that students will be able to:* • Analyze the process of heat generation in fuel • Perform calculations on the heat transfer process from fuel to coolant *It is expected that students will be able to:* • Understand the objective of the experiment and relate to previous knowledge of convective heat transfer • Identify relevant parameters that need to be investigated to reach said objectives • Plan experiment accordingly
2	**2. Two phase flow** Two-phase flow definitions Conservation equations **Lab 1** Convective heat transfer experiment – Performance of experiment, data collection and analysis, report writing	*It is expected that students will be able to:* • Describe the concept of two phase flow • Analyze two phase flow from conservation equations *It is expected that students will be able to:* • Perform the experiment and data collection carefully • Analyze and process data to get the desired results and draw proper conclusions • Write a clear technical report
3	**2. Two phase flow** Flow patterns Flow maps, Bubbly flow, Slug flow, Annular flow **Lab 1** Convective heat transfer experiment – Report submission, oral presentation and general discussion	*It is expected that students will be able to:* • Characterize the different types of two phase flow • Identify different two phase flow regimes • Sketch the different flow regimes *It is expected that students will be able to:* • Orally present the experiment and results in a clear and complete manner • Answer any questions relating to the experiment and results

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4	**2. Two phase flow** Pressure drop in two phase flow The Lockhart and Martinelli Model The Martinelli-Nelson Model **Lab 2** Two-phase flow experiment (constructing the flow regime map) – Theory and preparation, literature review and experiment planning	*It is expected that students will be able to:* • Analyze the pressure drop factors in two phase flow • Perform calculations on the pressure drop in two phase flow *It is expected that students will be able to:* • Understand the objective of the experiment and relate to previous knowledge of two-phase flow • Identify relevant parameters that need to be investigated to reach said objectives • Plan experiment accordingly
5	**2. Two phase flow** Critical Flow General Description of the Phenomenon Importance of the Phenomenon for Nuclear Technology Critical Flow for a Perfect Gas Two-Phase Critical Flow Models **Lab 2** Two-phase flow experiment (constructing the flow regime map) – Performance of experiment, data collection and analysis, report writing	*It is expected that students will be able to:* • Describe the phenomenon of critical flow • Identify how critical flow occurs in single and two phase flows • Analyze critical flow in two phase flows *It is expected that students will be able to:* • Perform the experiment and data collection carefully • Analyze and process data to get the desired results and draw proper conclusions • Write a clear technical report
6	**2. Two phase flow** Instabilities Classification of Instabilities Static Instabilities Dynamic Instabilities **Lab 2** Two-phase flow experiment (constructing the flow regime map) – Report submission, oral presentation and general discussion	*It is expected that students will be able to:* • Describe the phenomenon of instabilities in pipe flows • Identify different types of instabilities in pipe flows *It is expected that students will be able to:* • Orally present the experiment and results in a clear and complete manner • Answer any questions relating to the experiment and results
7	**3. Two-phase heat transfer** Boiling process Bubble nucleation Pool boiling	*It is expected that students will be able to:* • Describe the process of boiling • Understand the importance of nucleation sites in boiling • Identify the different boiling types

	Lab 3 Boiling heat transfer experiment, investigation of the boiling curve – Theory and preparation, literature review and experiment planning	*It is expected that students will be able to:* • Understand the objective of the experiment and relate to previous knowledge of boiling heat transfer • Identify relevant parameters that need to be investigated to reach said objectives • Plan experiment accordingly
8	**Mid-Semester Break**	
9	**3. Two-phase heat transfer** Subcooled and saturated flow boiling Boiling Curve **Lab 3** Boiling heat transfer experiment, investigation of the boiling curve – Performance of experiment, data collection and analysis, report writing	*It is expected that students will be able to:* • Describe and characterize the boiling curve • Calculate heat flux for different boiling regimes *It is expected that students will be able to:* • Perform the experiment and data collection carefully • Analyze and process data to get the desired results and draw proper conclusions • Write a clear technical report
10	**4. Boiling crisis** Departure from nucleate boiling, Dryout **Lab 3** Boiling heat transfer experiment, investigation of the boiling curve – Report submission, oral presentation and general discussion	*It is expected that students will be able to:* • Discuss the importance of DNB in nuclear reactor safety • Identify methods to avoid DNB and dryout in nuclear reactor *It is expected that students will be able to:* • Orally present the experiment and results in a clear and complete manner • Answer any questions relating to the experiment and results
11	**4. Boiling crisis** Post-boiling-crisis heat transfer Condensation **Lab 4** Boiling crisis experiment – Theory and preparation, literature review and experiment planning	*It is expected that students will be able to:* • Discuss coolant loss accident scenarios in reactors • Analyze condensation process and perform calculations *It is expected that students will be able to:* • Understand the objective of the experiment and relate to previous knowledge of the boiling crisis

		• Identify relevant parameters that need to be investigated to reach said objectives • Plan experiment accordingly
12	**5. Thermal design and analysis methodologies** Reactor Thermal Hydraulic Design Problem Hydraulic Configuration and boundary conditions Types of flows for reactor core Approaches for reactor analysis **Lab 4** Boiling crisis experiment – Performance of experiment, data collection and analysis, report writing	*It is expected that students will be able to:* • Understand the scope of reactor design from the thermal hydraulics aspects • Set up the thermal hydraulic design problem • Identify different approaches for reactor thermal hydraulics design analysis *It is expected that students will be able to:* • Perform the experiment and data collection carefully • Analyze and process data to get the desired results and draw proper conclusions • Write a clear technical report
13	**5. Thermal design and analysis methodologies** Single Heated Channel (Steady State Analysis) Steady state single phase flow in a heated channel Steady state, two phase flow in a heated channel Equilibrium conditions **Lab 4** Boiling crisis experiment – Report submission, oral presentation and general discussion	*It is expected that students will be able to:* • Describe the single heated channel view of reactor core thermal analysis • Perform steady state analysis of single phase flow in a single heated channel • Perform steady state analysis of two phase flow in a single heated channel *It is expected that students will be able to:* • Orally present the experiment and results in a clear and complete manner • Answer any questions relating to the experiment and results
14	**5. Thermal design and analysis methodologies** Loop analysis Loop flow equations Steady state, single phase, natural circulation Steady state, two phase, natural circulation Loop transients	*It is expected that students will be able to:* • Describe, identify and sketch the flow loops involved in reactor thermal analysis • Perform steady state analysis of single phase flow in reactor loops • Perform steady state analysis of two phase flow in reactor loops • Identify transient phenomena that occur in flow loops
15	**5. Thermal design and analysis methodologies** Treatment of uncertainties Hot spots and subfactors	*It is expected that students will be able to:* • Identify factors towards uncertainties in the thermal design process

	Overall core reliability	• Perform analysis on hot spot calculations involving subfactors
16	**Study Week**	
17 -19	**Final Examination**	

References:

1. N. E. Todreas and M. Kazimi, Nuclear Systems Volume I: Thermal Hydraulic Fundamentals. Taylor & Francis; 2nd edition (1989).
2. Introduction to Nuclear Engineering (3rd Edition) John R. Lamarsh, Anthony J. Baratta
3. M.M El Wakil, *Nuclear Heat Transport,* American Nuclear Society, 1978.
4. Incropera, M., and Dewitt, W., *Introduction to Heat Transfer*, 5th edition, Wiley, New York.
5. Glasstone & A. Sesonske , Nuclear reactor engineering reactor systems engineering fourth edition volume 2
6. Holman, J P, Experimental Methods for Engineers, McGraw-Hill

Assessment:

No.	Assessment	Number	% each	% total	Dates
1	Homework & Quizzes	5	2	10	As scheduled
2	Tests (Test 1 and Test 2)	2	15	30	Test 1 before and Test 2 after mid-semester break
3	Laboratory	4	5	20	As scheduled
4	Final Exam	1	40	40	As scheduled
	Overall Total			**100**	

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