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Dimensional Analysis and Similitude for Researchers, Scientists, and Professionals

Subtitle: A comprehensive study on dimensional analysis and similitude to assist researchers, scientists, and professionals in understanding the derivation of new dimensionless numbers and their significant applications to science and engineering.

1.0 Course Faculty Information

Name: Prof. Dr. M. Enamul Hossain
NSRIC Chair Professor in Sustainable Energy
NSRIC Inc., Toronto, Ontario, Canada

2.0 Course Information

Course(s) Codes	ENG-AC00392
Class Days	Follow posting in NSRIC LMS system
Class Time	Follow posting in NSRIC LMS system
Course Credit Hours	1
Class Location	NSRIC online platform
prerequisites and/or co-requisites	n/a
Level /A, E, H, I, K12, M, P, S, T, U, V, W	P

Note: The below classification of courses is related to any areas of knowledge:
A: Advanced level academic level courses; **C**: Canadian immigration and training courses; **E**: Executive courses; **H**: Higher-level courses (i.e., graduate courses); **I**: Intermediate courses (i.e., university preparatory courses – Grade XII+); **K12**: Foundational, and lower-level courses; **M**: Mid-level courses (i.e., undergraduate courses); **P**: Professional courses; **S**: Short/seminar courses; **T**: Training courses; **U:** Tutorial Courses; **V:** Vocational training courses; and **W**: Workshop courses.

3.0 Professor Information

Name	Prof. Dr. M. Enamul Hossain
Title	NSRIC Chair Professor in Sustainable Energy
Contact Information	enamulh@nsric.ca; dr.mehossain@gmail.com
Office Location	NSRIC online platform
Office Hours	10: 30 am – 11:30 am EST (Monday) by email appointment

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4.0 Target Audiences

- Science and engineering undergraduate/graduate-level students.
- Early career engineers, supervisors, managers, scientists, researchers, and professionals.
- Diploma and vocational training student.
- Any student who is interested in thermal engineering.
- Any student who is interested in automobile engineering.

5.0 Course Descriptions

This course introduces the audience to the fundamental concepts and an in-depth analysis of dimensional analysis and similitude, similarity, model, and prototype. The course covers the fundamental aspects of the topic and offers a comprehensive research guideline for researchers and professionals. It focuses on the dimensions and units, types of similitudes, typical forces and dimensionless parameters, principles, parameterization development, applications of dimensional analysis and similarity. This course further examines topics such as dimensional analysis, significant dimensionless numbers including a list of numbers in general, the Buckingham π −theorem, some general considerations related to dimensional analysis, similitude, and an in-depth analysis of how to develop new dimensionless numbers through seven research articles of Prof. Hossain (Lecture 8 to 14). Concepts, theory, and real-world examples are blended through clear lecture notes, live sessions, learning activities, understanding questions, and research articles. Several case studies are also included to relate and apply the theoretical and conceptual material learned in the course to a real-world example.

The course explains each concept in detail with enough guidelines, examples, and illustrations by employing different fields of application in research articles. This approach will make the students master developing and identifying new dimensional numbers in their respective fields of study.

This course is a foundation, resource guide and an excellent source for science and engineering students, early career professionals, scientists, researchers, and executives who want to learn concepts, design, dimensions, and in-depth investigations through enough practices of the theories and examples of derivations with critical examinations. The course is designed for individuals and students who need to understand the basics of subjects matter too. The course contains a total of seven lectures, and seven research articles where each lecture comprises 15 to 30 PowerPoint presentation slides and pdf documents. The course is also designed with three quizzes and one project.

Keywords: dimensional analysis, similitude, analysis and design, important dimensionless numbers, Buckingham π −theorem, viscous flow, enclosed surfaces, Reynolds number, Euler number, Aeroelasticity number, Bagnold number, Bingham

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number, Biot number, Bond (Eötvös) number, Boussinesq number, Brinkman number, Capillarity number, Capillary number, Darcy coefficient, Fourier number, Froude number, Mach number, Merkel number, Mobility parameter, Nusselt number, Ocvirk number, Péclet number, Poiseuille number, Poisson's ratio, Power number, Hossain number, Prandtl number, Pressure number, Ramberg number, Radiation number, Rossby number, Sherwood number, Size number, Spalding number, Stanton number, Stefan number, Stokes number, Taylor number, Thoma number, Thomson number, Marangoni number, Weber number, Womerseley number etc.

6.0 Course Learning Outcomes

Students who complete this course can achieve the following course learning outcomes (CLOs):

CLO1: Ability to show how to use dimensional analysis to specify the least amount of data needed to study the behavior of a fluid experimentally.

CLO2: Ability to identify the dimensions and units and verify the dimensional homogeneity of the relationship.

CLO3: Ability to determine whether equations are dimensionally homogeneous.

CLO4: Apply dimensional analysis to predict formulas which connect variables in given circumstances.

CLO5: Ability to analyze a process for deriving new dimensional groups.

CLO6: Ability to understand how the flow behavior depends on the types of forces that influence the flow and to present essential sets of dimensionless numbers that involve these forces.

CLO7: Ability to analyze the dimensional analysis procedure by obtaining groups of dimensionless numbers using the Buckingham π −theorem.

CLO8: Ability to analyze the prototype and model to scale up or down.

CLO9: Ability to develop and identify new dimensional numbers in the respective fields of study.

CLO10: Using the prototype and model flows, the ability to compare the parameter values between the two flows and make experimental design changes to achieve the similitude requirements.

CLO11: Ability to plan and carry out experiments and enables one to scale up results from model to prototype.

CLO12: Identify the important dimensionless groups of variables, reduce the model to a minimal form, and make it easy to assess the asymptotic behavior of the system.

CLO13: The ability to identify the forces that govern the physical processes and choose the relevant dimensionless parameters to simplify the experimental setup when faced with a flow problem.

CLO14: The ability to design a model to investigate relevant physical processes and mechanisms through experiments using engineering judgment, which is necessary for the prototype flow.

CLO15: After understanding units and dimensions, conduct dimensional analysis to derive important dimensionless parameters.

CLO16: By combining the experimental data and dimensionless parameters, the ability to develop relationships for the parameter of interest.

7.0 How the course supports the attainment of student outcomes

Student Learning Outcomes (1-6)						
1	2	3	4	5	6	7
Moderate	Moderate	Moderate	Low	Moderate	Moderate	Excellent

8.0 Course Materials

Online course materials

- Online presentation documents in pdf form.
- Audio/visual recording of lectures (Optional).
- Online tutorial and meeting with students upon request.
- Workout examples for hands-on experience.
- Assignments and MCQs in the form of evaluation at the NSRIC online MLS system
- Reading materials, if any, in pdf form

Textbook and resources (If any)

1. Fluid Mechanics, R.C. Hibbeler, Pearson Education Canada.

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References:

1) Fluid Mechanics, 6/E, Swaffield, Jack, Douglas & Gasiorek, Pearson Education Canada, 2011
2) Course Notes of Prof. Hossain.
3) Scientific articles of Prof. Hossain related to dimensional analysis and similitude.

9.0 Academic Integrity

Students are encouraged to have a look at the NSRIC's statement of academic integrity on the NSRIC website. It is noted that by signing this syllabus, you will acknowledge that you have understood that any detected plagiarism should be reported.

10. Assessment for Grade

This course is a professional course not an academic course (i.e., K12, and university level courses). Therefore, there will not be any assessment based on individual and team performance as shown in Table 1. However, the course contains four quizzes and assignments to make the assessment. Students will receive a "***Certificate of completion***" after successful completion of the course.

Table 1: NSRIC grading system.

Type of Assessment	Grade %
Participation/Engagement/Performance	10%
Assignments	0%
Quizzes (3)	30%
Research Project	60%
Midterm Exam I	0%
Midterm Exam II	0%
Final Exam	0%
Total	**100%**

Important Note:

i) The below classified courses (i.e., academic courses) will only be evaluated based on the grade system shown in Table 2. A grade and certificate will be issued for the student(s) and participant(s).
A: Advanced level academic level courses; **H**: Higher-level courses (i.e., graduate courses); **I**: Intermediate courses (i.e., university preparatory courses –

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Grade XII+); **K12**: Foundational, and lower-level courses; **M**: Mid-level courses (i.e., undergraduate courses).

ii) The below-classified courses will **not** be evaluated based on the grading system shown in Table 2. A certificate will be issued for the student(s) and participant(s).

E: Executive courses; **P**: Professional courses; **S**: Short/seminar courses; **T**: Training courses; **U:** Tutorial Courses; **V:** Vocational training courses; and **W**: Workshop courses.

Participation/Engagement/Performance

Your participation in every aspect of the course is important for the learning process. Your engagement in every discussion in the course, and due delivery of all practices will be fruitful. These efforts from your side will reflect your performance in the course delivery and your commitments. This performance is the reflection of your dream grade!!

At the end of the term, below Table 2 will be used for translating your marks into a "Latter Grade" based on the NSRIC grading policy.

Table 2: NSRIC grading system.

Marks	Letter Grade	Points	Description
≥ 93	A+	4.00	Outstanding
≥ 90	A	3.75	
≥ 87	A-	3.50	Excellent
≥ 84	B+	3.25	Very good
≥ 81	B	3.0	
≥ 78	B-	2.75	Moderately Good
≥ 75	C+	2.50	Good
≥ 72	C	2.25	
≥ 69	C-	2.0	Moderately Good
≥ 66	D+	1.75	Pass
≥ 63	D	1.50	
≥ 60	D-	1.25	Poor Pass
< 60	F	0	Failing

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11.0 Advice and additional requirements

I advise you to:

- Please contact me if you need any help.
- Students are expected to attend all scheduled online lecture classes.
- Students are expected to study from the course materials and/or textbooks, which will help them to read and understand easily.
- Students are encouraged to write notes during lectures/presentations (pdf PowerPoint presentations and additional materials, if any).
- Students are encouraged to attend online platform classes on time because late attendee disrupts the class flow for both the instructor and the other students.

Additional information (During the Online Course offering Period)

- The PowerPoint course materials and video lectures will be available on the NSRIC Platform.
- There will be scheduled discussion/tutorial sessions based on the request at the class scheduled time. All students must attend this session (Need the student's email request).
- There will be an office hour for students on Monday from 10:30 am to 11:30 am EST (Toronto, Canada time). Students need to send an email request so that a Zoom meeting can be arranged. In addition, any time students can set up an online appointment (i.e., phone, zoom, or other mode of communication) based on the availability of the course instructor. However, students should request an email to set up this type of meeting.

12.0 Course Topics

- Dimensional analysis and similitude.
- Model and prototype.
- Dimensions and units.
- Dimensionless parameters.
- Applications of dimensional analysis and similarity.
- Buckingham π −theorem.
- Several cases study.

Requirements/Instructions

Students are advised to register for all drilling engineering modules courses to become a master in the subject area.

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14.0 Course Contents and Schedule

Lec. No.	Module	Topics	Remarks
		Module I	
01	Dimensional analysis	Introduction and dimensional analysis 1	
02	Dimensional analysis	Steps toward the similarity groups	
03	Dimensional analysis	Important dimensionless numbers 1	
04	Dimensional analysis	List of dimensionless numbers 2	Quiz 1
05	Dimensional analysis	Buckingham π–theorem	
06	Similitude	Similitude 1	
07	Similitude	Similitude 2	
08	Scaling criteria	Dimensionless number and scaling criteria 1	Quiz 2
09	Scaling criteria	Dimensionless number and scaling criteria 2	
10	Scaling criteria	Dimensionless number and scaling criteria 3	
11	Case study	New dimensionless numbers and case study 1	
12	Case study	New dimensionless numbers and case study 2	Quiz 3
13	Case study	New dimensionless numbers and case study 3	
14	Case study	New dimensionless numbers and case study 4	
15	Project	Project submission (A draft)	last day
Final Project – The manuscript submission date is within two weeks of the course completion			

Prepared by Prof. M. Enamul Hossain, NSRIC Chair Professor in Sustainable Energy, Dept. of Petroleum Engineering, OE Division, NSRIC Inc., Toronto, ON, Canada.