

Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

Expected Implementation in Academic Year	AY2022-2023
Semester/Trimester/Others (specify approx. Start/End date)	Semester 2
Course Author * Faculty proposing/revising the course	Yong Ee Hou
Course Author Email	eehou@ntu.edu.sg
Course Title	Calculus for Physics
Course Code	MH1803
Academic Units	4
Contact Hours	52
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	MH1802: Calculus for the Sciences
Co-requisites	
Pre-requisite to	
Mutually exclusive to	MH1101, MH1800, MH1801, MH2100, CY1602, RE1021
Replacement course to	
Remarks (if any)	

Course Aims

This course aims to equip students with

- mathematical knowledge and analytical skills so that they are able to apply techniques of multivariable calculus of scalar and vector functions, ordinary differential equations and partial differential equations (along with their existing mathematical skills) to solve relevant scientific problems.
- mathematical reading skills so that they can read and understand related mathematical content in the basic and popular scientific and engineering literature; and
- mathematical communication skills so that they can effectively and rigorously present their mathematical ideas to mathematicians, scientists and engineers.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Apply techniques listed in 6 main topics (below), whenever appropriate, to solve physics problems.
ILO 2	Cite examples of the applications of differential equations in Physics and conversely formulate descriptions of relevant scientific phenomena or experiments using multivariable calculus, vector analysis and differential equations.
ILO 3	<p>Differentiable Calculus of Scalar Functions</p> <p>Determine the partial derivatives for a given multivariable function and recognize the geometrical interpretations of the derivatives.</p> <p>Determine the total differential of a multivariable function.</p> <p>Determine the directional derivatives, gradient of a scalar field and recognize the physical interpretation of these quantities.</p> <p>Find stationary values of functions of 1 and 2 variables</p> <p>Apply the methods of Lagrange multipliers to solve optimization problems with constraints</p>
ILO 4	<p>(2) Integral Calculus of Scalar Functions</p> <p>Perform double or triple integral to determine surface areas and volumes in 3D space, in Cartesian, cylindrical, and spherical coordinates.</p> <p>Find Jacobian for coordinate transformation in 2 and 3 dimensions.</p> <p>Use the appropriate coordinates (cylindrical, spherical etc.) when solving problems with the corresponding symmetry and perform coordinate transformations.</p>
ILO 5	<p>Differentiable Calculus of Vector Functions</p> <p>Cite examples of scalar field, vector fields in Physics.</p> <p>Apply concepts of vectors, vector products to solve simple problems in 3D space.</p> <p>Determine the curvature, tangent vector, normal vector, bi-normal vector and arc length for a given curve in 3D space.</p> <p>Determine tangent planes and normal vectors of a given 2D surface in 3D.</p> <p>Determine the area element and total area of a given 2D surface in 3D.</p> <p>Determine the div, curl of a vector field and recognize the physical meanings of these quantities.</p> <p>Apply identities involving grad, div and curl to prove identities in vector calculus.</p> <p>Determine surface and volume integrals of vector fields.</p> <p>Apply grad, div, curl and the Laplacian in cylindrical and spherical coordinates.</p>

ILO 6	<p>Integral Calculus of Vector Functions</p> <p>Determine the line integral for a given vector field along any path.</p> <p>Ascertain if a vector field is conservative and if so, determine the potential function.</p> <p>Understand the fundamental theorem for gradients.</p> <p>Calculate the flux of a vector field across a surface S.</p> <p>Calculate the circulation of a vector field along a space curve.</p> <p>Apply Divergence theorem and Stokes' theorem to solve related problems.</p> <p>Cite examples of physical laws in Physics involving div, curl and Laplacian (such as in mechanics and electrodynamics).</p> <p>Calculate integrals involving Heaviside function and Dirac delta function.</p>
ILO 7	<p>Ordinary Differential Equations (ODE)</p> <p>Understand the different terminologies in ordinary differential equations.</p> <p>Understand the difference between boundary value & initial value problems.</p> <p>Solve simple first order ODE, e.g., linear, separable-variable, etc.</p> <p>Understand strategy to solve linear, higher order homogeneous/inhomogeneous ODEs using complementary function and particular integral.</p> <p>Cite examples of applications in Physics involving the above listed differential equations.</p> <p>Understand terminologies used in epidemic modelling.</p> <p>Understand simple epidemic models such as SI, SIS, and SIR.</p>
ILO 8	<p>Partial Differential Equations (PDE)</p> <p>Understand the different terminologies in partial differential equations.</p> <p>Solve first order linear PDE with constant/variable coefficients.</p> <p>Understand the different types of boundary conditions.</p> <p>Perform simple classification of 2nd order partial differential equations.</p> <p>Calculate the convolution of two functions.</p> <p>Derive the solution to the 1D diffusion/heat equation using Green's function.</p> <p>Basic understanding of numerical approaches to solving PDEs, particularly diffusion/heat equation.</p>

Course Content

There are 6 main topics in this course, designed to provide student with a solid mathematical foundation:

(1) Differentiable Calculus of Scalar Functions

- Multivariable scalar functions, partial derivatives, total differentials, grad, stationary values, and Lagrange multipliers.

(2) Integral Calculus of Scalar Functions

- Double and triple Integration of scalar fields, surface integrals, volume integrals, coordinate transformation from Cartesian to polar/cylindrical/spherical coordinates.

(3) Differentiable Calculus of Vector Functions

- Multivariable vector functions, curves and surfaces in 3D space, differentiation of vectors, tangent vectors, normal vectors, curvature, grad, div, curl, and Laplacian.

(4) Integral Calculus of Vector Functions

- Line integrals, path independence, conservative fields, surface/volume integrals of vector fields, Divergence Theorem, Stokes' Theorem and Green's Theorem (in 2D).

(5) Ordinary Differential Equations (ODE)

- Introduction to ordinary differential equations, initial/boundary value problems, homogeneous/inhomogeneous ODEs, complementary functions, particular integral, epidemic modelling (i.e., SI, SIS, SIR).

(6) Partial Differential Equations (PDE)

- Introduction to partial differential equations, terminologies, boundary conditions, solution to 1D diffusion equation.

Reading and References (if applicable)

Calculus of Several Variables, Serge Lang. Springer, 3rd edition (1996). ISBN-13: 978-0387964058.

Mathematical Methods for Physics and Engineering: A Comprehensive Guide, K. F. Riley, M. P. Hobson, S. J. Bence. Cambridge University Press, 3rd edition (March 13, 2006). ISBN 0521861535.

Mathematical Methods in the Physical Sciences, Mary L. Boas. Wiley, 3rd edition (July 22, 2005). ISBN-13: 978-0471198260.

Basic Training in Mathematics: A Fitness Program for Science Students, R. Shankar. Springer, 1st edition (April 30, 1995). ISBN-13: 978-0306450365.

Calculus (Vol 1 and 2), Tom M Apostol, Wiley, 2nd edition (2016 and 2007). ISBN-13: 978-0471000051 (Vol 1), ISBN-13: 978-8126515202 (Vol 2).

Mathematical Methods for Physicists, George B. Arfken, Hans J. Weber, Frank E. Harris. ELSEVIER INDIA, 7th edition (January 1, 2012). ISBN-13: 978-9381269558.

Differential Equations, Dynamical Systems, and an Introduction to Chaos, Morris W. Hirsch, Stephen Smale, Robert L. Devaney. Academic Press, 3rd edition (March 26, 2012). ISBN-13: 978-0123820105.

Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering, Second Edition (Studies in Nonlinearity), Steven H. Strogatz. CRC Press; 2nd edition (March 1, 2015). ISBN-13: 978-0813349107.

Partial Differential Equations: An Introduction, Walter A. Strauss, Wiley, 2nd (2017). ISBN-13: 978-0470054567.

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Differential Calculus of Multivariable Scalar Functions	3-5	Lecture notes 1		
2	Differential Calculus of Multivariable Scalar Functions	6, 7	Lecture notes 1		
3	Integral Calculus of Multivariable Scalar Functions	8	Lecture notes 2		
4	Integral Calculus of Multivariable Scalar Functions	9-10	Lecture notes 2		
5	Differential Calculus of Multivariable Vector Functions	11- 15	Lecture notes 3		
6	Differential Calculus of Multivariable Vector Functions	16- 17	Lecture notes 3		
7	Differential Calculus of Multivariable Vector Functions	18- 19	lecture notes 3		
8	Integral Calculus of Multivariable Vector Functions	2-23	Lecture notes 4		
9	Integral Calculus of Multivariable Vector Functions	24- 25	lecture notes 4		
10	Integral Calculus of Multivariable Vector Functions	24- 25	lecture notes 4		

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
11	Ordinary Differential Equations (ODE)	28-33	lecture notes 5		
12	Ordinary Differential Equations (ODE), Partial Differential Equations (PDE)	34-38	lecture notes 5, 6		
13	Partial Differential Equations (PDE)	1,2, 39 - 41	lecture notes 6		

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Derivation of formulas and demonstrating problem solving (Lecture and Tutorial)	Train students to be independent learners who can derive ideas/concepts from first principles and take ownership of their own learning. Help students understand the motivation behind mathematical theorems, definitions, and formulas. Develop the train of thought in problem solving.
Problem solving and critical thinking (Lecture and Tutorial)	Develop competence in solving calculus related problems.
In-class participation (Lecture)	Develop critical thinking, communication skills and competence in mathematics, particularly calculus. Students also have an opportunity to work/discuss with their peers.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Assignment(Assignment)	All	Competence, Written Communication	20		Individual	Analytic	Extended Abstract
2	Continuous Assessment (CA): Class Participation(In-class participation)	All	Competence, Communication	5		Individual	Analytic	Extended Abstract
3	Continuous Assessment (CA): Test/Quiz(Midterm Test 1)	3 - 17	Competence	12.5		Individual	Analytic	Extended Abstract
4	Continuous Assessment (CA): Test/Quiz(Midterm Test 2)	18 - 32	Competence	12.5		Individual	Analytic	Extended Abstract
5	Summative Assessment (EXAM): Final exam(Final Examination)	All	Competence, Written Communication	50		Individual	Analytic	Extended Abstract

Description of Assessment Components (if applicable)

Formative Feedback

[Component 1] Feedback on progress and understanding is provided through the 6 assignments (1 for each topic).

[Component 2] Formative feedback is given through real-time, interactive, computer-based Q&A (via Wooclap) and discussion during lectures as well as weekly tutorial lessons.

[Component 3, 4] Feedback is also given after each midterm on the common mistakes and level of difficulty of the problems.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Creative Thinking	Intermediate
Curiosity	Intermediate
Digital Fluency	Intermediate
Learning Agility	Advanced
Problem Solving	Advanced

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

Policy (Absenteeism)

Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class (particularly the mid-terms), you have to:

1. Send an email to the instructor regarding the absence and request for a replacement class.
2. Submit the original Medical Certificate* to administrator.
3. Attend the assigned replacement class (subject to availability).

*The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

Policy (Others, if applicable)

Diversity and inclusion policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science.

It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences, and that honours your identities; including ethnicity, gender, socioeconomic status, sexual orientation, religion or ability.

To help accomplish this:

- If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety disorder or social phobia;
- If you feel like your performance in the class is being impacted by your experiences outside of class;
- If something was said in class (by anyone, including the instructor) that made you feel uncomfortable;

Please speak to your teaching team, our school pastoral officer or a peer or senior (either in-person or via email) about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: using preferred pronouns and names; being respectful of others opinions and actively making sure all voices are being heard; and refraining from the use of derogatory or demeaning speech or actions.

All members of the class are expected to adhere to the NTU anti-harassment policy. if you witness something that goes against this or have any other concerns, please speak to your instructors or a faculty member.