Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2022/23	**Semester**	2
Course Coordinator	Yong Ee Hou		
Course Code	MH1803		
Course Title	Calculus for Physics		
Pre-requisites	MH1802: Calculus for the Sciences		
Mutually exclusive	MH1101, MH1800, MH1801, MH2100, CY1602, RE1021		
No of AUs	4 AUs		
Contact Hours	4 hours per week (2 hours of Lecture; 2 hours of Tutorial)		
Proposal Date	16 November 2022		

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.

Intended Learning Outcomes (ILO)

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

1. Apply techniques listed in 6 main topics (below), whenever appropriate, to solve physics problems.
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.

(1) Differentiable Calculus of Scalar Functions

3. Determine the partial derivatives for a given multivariable function and recognize the geometrical interpretations of the derivatives.
4. Determine the total differential of a multivariable function.
5. Determine the directional derivatives, gradient of a scalar field and recognize the physical interpretation of these quantities.
6. Find stationary values of functions of 1 and 2 variables
7. Apply the methods of Lagrange multipliers to solve optimization problems with constraints

(2) Integral Calculus of Scalar Functions

8. Perform double or triple integral to determine surface areas and volumes in 3D space, in Cartesian, cylindrical, and spherical coordinates.
9. Find Jacobian for coordinate transformation in 2 and 3 dimensions.
10. Use the appropriate coordinates (cylindrical, spherical etc.) when solving problems with the corresponding symmetry and perform coordinate transformations.

(3) Differentiable Calculus of Vector Functions

11. Cite examples of scalar field, vector fields in Physics.
12. Apply concepts of vectors, vector products to solve simple problems in 3D space.

13. Determine the curvature, tangent vector, normal vector, bi-normal vector and arc length for a given curve in 3D space.
14. Determine tangent planes and normal vectors of a given 2D surface in 3D.
15. Determine the area element and total area of a given 2D surface in 3D.
16. Determine the div, curl of a vector field and recognize the physical meanings of these quantities.
17. Apply identities involving grad, div and curl to prove identities in vector calculus.
18. Determine surface and volume integrals of vector fields.
19. Apply grad, div, curl and the Laplacian in cylindrical and spherical coordinates.

(4) Integral Calculus of Vector Functions

20. Determine the line integral for a given vector field along any path.
21. Ascertain if a vector field is conservative and if so, determine the potential function.
22. Understand the fundamental theorem for gradients.
23. Calculate the flux of a vector field across a surface S.
24. Calculate the circulation of a vector field along a space curve.
25. Apply Divergence theorem and Stokes' theorem to solve related problems.
26. Cite examples of physical laws in Physics involving div, curl and Laplacian (such as in mechanics and electrodynamics).
27. Calculate integrals involving Heaviside function and Dirac delta function.

(5) Ordinary Differential Equations (ODE)

28. Understand the different terminologies in ordinary differential equations.
29. Understand the difference between boundary value & initial value problems.
30. Solve simple first order ODE, e.g., linear, separable-variable, etc.
31. Understand strategy to solve linear, higher order homogeneous/inhomogeneous ODEs using complementary function and particular integral.
32. Cite examples of applications in Physics involving the above listed differential equations.
33. Understand terminologies used in epidemic modelling.
34. Understand simple epidemic models such as SI, SIS, and SIR.

(6) Partial Differential Equations (PDE)

35. Understand the different terminologies in partial differential equations.
36. Solve first order linear PDE with constant/variable coefficients.
37. Understand the different types of boundary conditions.
38. Perform simple classification of 2^{nd} order partial differential equations.
39. Calculate the convolution of two functions.
40. Derive the solution to the 1D diffusion/heat equation using Green's function.
41. Basic understanding of numerical approaches to solving PDEs, particularly diffusion/heat equation.

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.

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team / Individual	Assessment Rubrics
Assignment	All	Competence, Written Communication	20%	Individual	Point-based marking, (not rubrics based)
In-class participation	All	Competence, Communication	5%	Individual	Point-based marking, (not rubrics based)
Midterm Test 1	3 - 17	Competence	12.5%	Individual	Point-based marking (not rubrics based)
Midterm Test 2	18 - 32	Competence	12.5%	Individual	Point-based marking (not rubrics based)
Final Examination	All	Competence, Written Communication	50%	Individual	Point-based marking (not rubrics based)
Total			100%		

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.

Learning and Teaching approach

Approach	How does this approach support students 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.

Reading and References

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 1and 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.

Course Policies and Student Responsibilities

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.

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. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Yong Ee Hou	SPMS-PAP 04 05	+65 6316 2966	eehou@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Differential Calculus of Multivariable Scalar Functions	3, 4, 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/Midterm 1
8	Integral Calculus of Multivariable Vector Functions	20 - 23	Lecture notes 4
9	Integral Calculus of Multivariable Vector Functions	24, 25	Lecture notes 4

10	Integral Calculus of Multivariable Vector Functions	26, 27	Lecture notes 4
11	Ordinary Differential Equations (ODE)	28 - 33	Lecture notes 5/Midterm 2
12	Ordinary Differential Equations (ODE), Partial Differential Equations (PDE)	34 - 38	Lecture notes 5 and Lecture notes 6
13	Partial Differential Equations (PDE)	1,2, 39 - 41	Lecture notes 6

Midterms - to be conducted during regular lecture timeslot

Graduate Attributes

What we want our graduates from Physics and Applied Physics to be able to do:

Upon the successful completion of the PHY, APHY, PHME, PHMP and PHMS programs, graduates should be able to:

Competency	1	demonstrate a rigorous understanding of the core theories and principles of physics involving (but not limited to) areas such as classical mechanics, electromagnetism, thermal physics and quantum mechanics [PHMS only] demonstrate a rigorous understanding of the core theories and principles of mathematical sciences involving (but not limited to) areas such as analysis, algebra and statistical analysis
	2	read and understand undergraduate level physics content independently;
	3	make educated guesses / estimations of physical quantities in general;
	4	apply fundamental physics knowledge, logical reasoning, mathematical and computational skills to analyse, model and solve problems;
	5	develop theoretical descriptions of physical phenomena with an understanding of the underlying assumptions and limitations;
	6	critically evaluate and distinguish sources of scientific/non-scientific information and to recommend appropriate decisions and choices when needed;
	7	demonstrate the ability to design and conduct experiments in a Physics laboratory, to make measurements, analyse and interpret data to draw valid conclusions.

Creativity	1	propose valid approaches to tackle open-ended problems in unexplored domains;
	2	offer valid alternative perspectives/approaches to a given situation or problem.

Communication	1	describe physical phenomena with scientifically sound principles;
	2	communicate (in writing and speaking) scientific and non-scientific ideas effectively to professional scientists and to the general public;
	3	communicate effectively with team members when working in a group.

Character	1	uphold absolute integrity when conducting scientific experiments, reporting and using the scientific results;
	2	readily pick up new skills, particularly technology related ones, to tackle new problems;
	3	contribute as a valued team member when working in a group.

Civic Mindedness	1	put together the skills and knowledge into their work in an effective, responsible and ethical manner for the benefits of society.