Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	AY17/18	**Semester**	2
Course Coordinator	Ho Shen Yong		
Course Code	MH1803		
Course Title	Calculus for Physics		
Pre-requisites	MH1802: Calculus for the Sciences		
Mutually exclusive	MH1800 Calculus for the Sciences 1, MH1801 Calculus for the Sciences 2		
No of AUs	4 AUs		
Contact Hours	4 hours per week (2 hours of Lecture; 2 hours of tutorial)		
Proposal Date	22 Mar 2017		

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, vector analysis, ordinary 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. 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;
2. apply techniques listed below, whenever appropriate, to solve physics problems;

Vectors and Multivariable Calculus (VMC)

3. apply concepts of vectors, vector products to solve simple problems in 3D space;
4. determine the curvature, tangent vector, normal vector, bi-normal vector and arc length for a given curve in 3D space;
5. determine the partial derivatives for a given multivariable function and recognize the geometrical interpretations of the derivatives;
6. apply chain rule and implicit differentiation, whenever appropriate, to determine derivatives;
7. determine the directional derivatives, gradient of a scalar field and recognize the physical interpretation of these quantities;
8. determine tangent planes and normal vectors to surfaces in 3D space;
9. determine the minima or maxima of a given multivariable function;
10. perform double or triple integral to determine surface areas and volumes in 3D space;
11. use the appropriate coordinates (cylindrical, spherical etc) when solving problems with the corresponding symmetry and perform coordinate transformations;

Vector Analysis (VA)

12. cite examples of scalar field, vector fields in Physics;
13. determine the div, curl of a vector field and recognize the physical meanings of these quantities;
14. apply identities involving grad, div and curl to prove identities in vector calculus;
15. ascertain if a vector field is conservative and if so, determine the potential function;
16. apply Green's theorem to solve related problems;
17. determine surface and volume integrals of vector fields;
18. apply Divergence theorem and Stoke's theorem to solve related problems;
19. derive the expressions for grad, div, curl and the Laplacian in cylindrical and spherical coordinates;
20. cite examples of physical laws in Physics involving vector analysis (such as in mechanics and electrodynamics);

Ordinary Differential Equations (ODE)

21. apply the power series method and Frobenius method, whenever appropriate, to determine the solutions of differential equations (such as Legendre's Equation and Bessel's Equation);
22. recognize Sturm-Liouville problems, understand their properties and appreciate the usefulness of the orthogonal properties of eigenfunctions in solving differential equations;
23. perform Fourier analysis of periodic functions and Fourier Transforms of functions;
24. cite examples of applications in Physics involving the above listed differential equations;

Partial Differential Equations (PDE)

25. perform simple classification of partial differential equations;
26. derive the 1D wave equation and according to a given problem, determine the initial and boundary conditions;
27. derive the 1D heat transfer equation and according to a given problem, determine the initial and boundary conditions;
28. apply the appropriate techniques (such as separation of variables, expansion using eigenfunctions) to solve basic partial differential equations including the 1D wave equation and heat equation;
29. apply the appropriate techniques to solve the 2D Laplace equation in Cartesian coordinates and polar coordinates.

Course Content

Vectors and Multivariable Calculus (VMC)

Vectors; Scalar and Vector products; Curves and Surfaces in 3D space; Differentiation of Vectors; Tangent vectors, Normal vectors and Curvature;

Multivariable Functions; Partial Derivatives; Scalar Fields and Gradients; Tangent lines and Tangent planes; Maxima and Minima.

Double and Triple Integration; Surface and Volume Integrals; Cylindrical, Spherical Coordinates and general coordinate transformation.

Vector Analysis (VA)

Grad, Div, Curl and Laplacian; Line Integrals; Path Independence and Conservative Fields; Green's Theorem; Surface and Volume Integrals of Vector Fields; Divergence Theorem and Stokes' Theorem.

Ordinary Differential Equations (ODE)

Power Series Solutions of ODE – Legendre's Equation, Bessel Equation and applications in Physics; Sturm-Liouville Problems, their properties and orthogonal functions; Fourier Analysis, Fourier Transform and applications.

Partial Differential Equations (PDE)

Introduction to Partial Differential Equations; 1D Wave Equation; 1D Heat Flow equation; Fourier Transform and Applications in PDE; 2D Laplace Equations.

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO	Weighting	Team / Individual	Assessment Rubrics

		or Graduate Attributes			
1. Final Examination	All	Competence, written communication	60%	Individual	Point-based marking (not rubrics based)
2. Continuous Assessment – Component 1 (Weekly Assignments / Quiz)	All	Competence	12%	Individual	Point-based marking, automated marking (not rubrics based)
3. Continuous Assessment – Component 2 (Visualization of Ideas in Mathematics Project)	Student selected	Competence, Communication, Creativity	12%	Pair	Appendix A2
4. Mid Term 1	VMC / VA	Competence	8%	Individual	Point-based marking (not rubrics based)
5. Mid Term 2	VA / ODE	Competence	8%	Individual	Point-based marking (not rubrics based)
Total			100%		

Formative feedback

[Component 2] Formative feedback is given through discussion within tutorial lessons as well as interactive, computer based hints and pointers in the online assignments/weekly assignments.

[Component 3] Formative feedback on the group assignment is given at milestone checks when student groups provide intermediate milestone progress reports.

[Component 4, 5] 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	Train students to be independent learners who are able to derive ideas/concepts from first principles and take ownership

solving (Lecture and Tutorial)	of their own learning. Help students understand the motivation behind mathematical theorems, definitions and formulas. Develop the train of thought in problem solving and presentation skills in presenting mathematical solutions.
Problem solving (Lecture and Tutorial)	Develop competence in solving calculus related problems.
Peer Instruction (Lecture and Tutorial)	Develop communication skills and competence in mathematics, particularly calculus. The students also have an opportunity to work with their peers.
Visualization of Ideas in Mathematics Project (Outside curriculum time and formative during tutorial)	Develop physical intuition, independence and competence in solving physics problems. Relate scientific phenomena / experimental results to vector calculus and differential equations. The designing of the project also allow the students to be creative. The students also have an opportunity to work as a team.

Reading and References

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.
Calculus of Several Variables, Serge Lang. Springer, 3rd edition (1996). ISBN-13: 978-0387964058.
Advanced Engineering Mathematics, Erwin Kreyszig. Wiley, 10th edition (2011). ISBN-13: 978-0470458365.
Advanced Engineering Mathematics, K A Stroud. Industrial Press, 5th edition (2011). ISBN-13: 978-0831134495.
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).
Calculus for Engineers, Donald Trim. Pearson Education Canada, 3rd edition (2004), ISBN-13: 978-0131411951.
Differential Equations with Applications and Historical Notes, George F Simmons. Chapman and Hall/CRC, 3rd edition (2016), ISBN-13: 978-1498702591.
Introduction to vector analysis and tensor analysis, Robert C Wrede. Dover Pub, revised edition (1972), ISBN-13: 978-0486618791.
Partial Differential Equations for Scientists and Engineers, Stanley J Farlow, Dover Pub, reprint edition (1993), ISBN-13: 978-0486676203.

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
Ho Shen Yong	PAP 03-07	65927816	hosy@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Review of Applications of Differential and Integral Calculus in Physics	1, 2	#
2	Vectors and 3D Analytical Geometry	VMC 3 - 5	#
3	Differential Calculus of Multivariable Functions	VMC 5 - 9	#
4	Integral Calculus of Multivariable Functions	VMC 10 - 11	#
5	Vector Calculus – Grad, Div and Curl	VMC 7, VA 12 - 15	#
6	Vector Integral Calculus; Green's Theorem, Divergence Theorem and Stokes' Theorem.	VA 16 - 20	MT1*
7	Review of Applications of ODEs in Physics; Power Series Solutions of ODE – Legendre's equation and applications in Physics	ODE 21 – 22, 24	# PR1
8	Power Series Solutions of ODE – Bessel's equation and applications in Physics Sturm-Liouville problems and orthogonal functions	ODE 21 – 22, 24	#
9	Fourier Analysis, Fourier Transform and applications in Physics	ODE 23	#
10	Introduction to Partial Differential Equations – One Dimensional Wave Equation;	PDE 25 – 26, 28	MT2*
11	Partial Differential Equations: One Dimensional Heat Flow equation; Fourier Transform and Applications in PDE	PDE 27, 28	# PR2
12	Laplace Equation	PDE 29	#
13	Revision	All ILOs	Project Presentation

MT* Mid-term - to be conducted off regular curriculum time (in the evenings or Saturdays)
Pre/Post-lecture online assignments; Post Lecture tutorial lessons
PR – short progress report of project synopsis to tutors

Appendix A2: Assessment Criteria for Visualization of Ideas in Mathematics Project (Peer Assessment)

This will be given to the students at the beginning of the course.

Criteria	Performance Level			
	4	**3**	**2**	**1**
Does this project involve some use of Mathematics and Science in this course?	Involves the novel application of existing mathematical /scientific principles and/or discovery of new scientific principles.	The project was designed based on sound mathematical /scientific principles.	The project was designed based loosely on mathematical /scientific principles and involved mainly uneducated guesses.	No Mathematics or Science involved in this project.
Are the Mathematics and Science accurate and correct?	Science is accurate and Mathematics is rigorous.	The project contains some minor arguments that may not be correct.	The project contains some dubious arguments.	The project is flawed scientifically or mathematically.
Are the Mathematics and Science of the project presented clearly?	Very clearly explained.	Clearly explained with one or two vague points.	Somewhat unclear and the presentation is not totally coherent.	Badly explained and the presentation is incoherent.
How original are the ideas?	Absolutely original.	Not totally original but has made significant modifications of existing ideas.	Not totally original but has made some modifications of existing ideas.	The project is a direct copy of existing ideas without the slightest modifications or improvements.
Is the project presented creatively, i.e. artistic appeal?	Very creative and captivating.	Creative with some interesting approach.	Quite conventional and traditional.	Nothing creative or appealing.