

## COURSE OUTLINE

Course Title	Seminar in Mathematical Physics		
Course Code	PH4511		
Offered	Study Year 4, Semester 2		
Course Coordinator	Andrew Kricker (Assoc Prof) Cheong Siew Ann (Assoc Prof)	<a href="mailto:ajkricker@ntu.edu.sg">ajkricker@ntu.edu.sg</a> <a href="mailto:cheongsa@ntu.edu.sg">cheongsa@ntu.edu.sg</a>	6513 7458 6513 8084
Pre-requisites	None		
AU	2		
Contact hours	Seminar: 26 (Seminars: 6 × 2, Term Paper & Presentations: 7 × 2)		
Approved for delivery from			
Last revised	21 November 2022		

### Course Aims

This course aims to help students in the Double Major BSc. in Physics and Mathematical Sciences (PHMS) appreciate the intimate connections between mathematics and physics, through a series of seminars given by theoretical physicists who employ cutting-edge mathematical tools for their research and pure/applied mathematicians who work in areas of mathematics that can potentially be applied to physics. PHMS students will deepen this appreciation by reading up, writing up, and presenting on mathematical physics topics of their own choosing.

### Intended Learning Outcomes

Upon successfully completing this course, you should be able to:

1. Describe how different areas of pure and applied mathematics have been used in physics.
2. Describe ideas generated in physics that have led to fruitful research in mathematics.
3. Explain how to search for research papers on mathematical physics topics, read and summarize them, and thereafter communicate the main ideas to an intelligent but non-expert audience.

### Course Content

The course will consist of 6 seminars on an assortment of mathematical physics topics, given by speakers invited by the two course co-coordinators. These seminars will comprise one-hour of talk given by the speakers, and another one hour of Q&A. PHMS students are required to ask at least one question in each seminar. There is plenty of time to do so, since enrolment

will be limited to the 10 or so PHMS students in each cohort. Questions submitted in the form of emails after the seminar, and after deeper reflection, will also be accepted.

PHMS students will also write a term paper over the semester. This will be assessed in four stages: (1) a 1-page proposal giving the topic, explaining why it is important, and include 2-3 important references; (2) a 4-page progress report elaborating on the importance of the selected topic, and a preliminary survey of the literature with an expanded bibliography of 5-10 references; (3) a 10-page full report expanding on the literature survey, and an outlook detailing 2-3 future research directions; and (4) a 25-min presentation of the term paper to the PH4511 class.

## Assessment

Component	Course ILOs tested	SPMS-MAS/PAP Graduate Attributes tested	Weighting	Team / Individual	Assessment Rubrics
<b>Continuous Assessment</b>					
<b>Seminars</b>					
Q&A	1, 2	<b>Competency (1, 2, 3, 6; a, b, c, d)</b> <b>Creativity (1, 2; a, b, c, d)</b> <b>Communication (1, 2; a, b)</b>	10	individual	See Appendix for rubric
<b>Term Paper</b>					
Proposal	1, 2, 3	<b>Competency (1, 2, 3, 6; a, b, c, d)</b> <b>Creativity (1, 2; a, b, c, d)</b> <b>Communication (1, 2; a, b)</b>	10	individual	See Appendix for rubric
Progress Report	1, 2, 3	<b>Competency (1, 2, 3, 6; a, b, c, d)</b> <b>Creativity (1, 2; a, b, c, d)</b> <b>Communication (1, 2; a, b)</b>	20	individual	See Appendix for rubric
Final Report	1, 2, 3	<b>Competency (1, 2, 3, 6; a, b, c, d)</b> <b>Creativity (1, 2; a, b, c, d)</b> <b>Communication (1, 2; a, b)</b>	30	individual	See Appendix for rubric
Presentation	1, 2, 3	<b>Competency (1, 2, 3, 6; a, b, c, d)</b>	30	individual	See Appendix for rubric

		<b>Creativity (1, 2; a, b, c, d)</b> <b>Communication (1, 2; a, b)</b>			
		<b>Total</b>	<b>100%</b>		

## Formative Feedback

To get PHMS students to learn how to ask questions during seminars, we will post the best questions asked, the replies given by the speaker, and comments provided by the course co-ordinators after every seminar. We grade these questions out of a maximum of 2 per seminar. If a student asked no questions, he/she will receive 0 mark for that seminar. If the student asked a simple question for clarification purposes, he/she will receive 1 mark for the seminar. The student will receive 2 marks if he/she asked a question that seeks to link the mathematics to physics. If a student asked multiple questions, we will note each question and its reply. We will provide the list of all questions (and their replies) to the speaker, and ask him/her to classify the questions. A student's Q&A score for a given seminar will be the highest mark given to any of his/her questions. We will also track the performance of each PHMS student for this assessment item over the semester, and provide guidance if the student is not doing well.

The overall aim of the term paper and presentation is for PHMS students to improve their communication skills. For this purpose, we require submissions at three stages in the writing of the term paper. For the proposal, we require students to pick the topics they would like to work on, explain why they are important, and identify the most important references they should read for the rest of the term paper. Feedback will be given on the choice of topics, how compelling their explanations are, and whether they have picked the most important references to start from. For the progress report, we require students to identify more references, and start summarizing them. Based on this tentative summary and the proposal feedback, students should improve their Introduction explaining the importance of their topics. We will provide a second round of feedback for this Introduction, to suggest final improvements. We will also feedback on the tentative summary, to educate students on the finer points on literature survey. For the final report, we expect students to have finalized their conclusions and their literature reviews, and also a short conclusion incorporating an outlook on a few future research directions. Our feedback on this final report will focus on whether the literature review is thorough and well thought through, and whether they made convincing connections between the mathematics reviewed and the physics they believe it can be applied to.

## Learning and Teaching Approach

<b>Seminars</b> (12 hours)	6 seminars by invited speakers, distributed between theoretical physicists and mathematical physicists, to expose PHMS students to the use of sophisticated mathematical structures in physics. Each seminar will consist of one hour of talk by the speaker, and another hour of Q&A by the audience and PHMS students. The Q&A is to encourage PHMS students to think about the talk on the spot, and learn how to ask meaningful questions. However, we allow students to submit questions via email after the talk, and would include such questions for grading.
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<b>Term Paper &amp; Presentation</b> (14 hours)	In Week 3, we will not have a seminar, but a briefing on the expectations on the overall term paper. Specifically, we will explain how to find a topic to read up on, how to find the most important papers on the topic, and how to argue for the importance of the topic. In Week 7, we will again use the seminar time to brief students on the expectations of the progress report. In particular, we will explain to students how to incorporate comments from the proposal to fully flesh out the Introduction, how to find more relevant papers, and how to synthesize advances described in these papers into a coherent whole. Thereafter, from Week 9 to Week 13, students will do 25-min individual presentations on their topics. Students are expected to treat these in the same way as seminars given by invited speakers, and engage their peers through asking questions. For the proposal and progress report, we aim to develop students' scholarship and communication skills. For the final report and presentation, we aim to develop students' communication and presentation skills.
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## Reading and References

No designated reading and reference for this course.

Students will be reading up on different books and journal papers depending on the topic they pick.

## Course Policies and Student Responsibilities

### (1) General

Students are expected to attend all seminars, and participate actively in the Q&A.

### (2) Absenteeism

Absence from seminars without a valid reason will affect your overall course grade. Valid reasons include falling sick (supported by a medical certificate) and participation in NTU's approved activities (supported by an excuse letter from the relevant bodies).

### (3) Absence Due to Medical or Other Reasons

If you are sick and not able to attend a seminar, please submit a copy of your Medical Certificate (or another relevant document) to the school to obtain official leave. In this case, your seminar grade will be pro-rated based on the seminars you attended. There are no make-up seminars.

## 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
Andrew Kricker (Assoc Prof)	SPMS-MAS-04-18	6513 7458	<a href="mailto:ajkricker@ntu.edu.sg">ajkricker@ntu.edu.sg</a>
Cheong Siew Ann (Assoc Prof)	SPMS-PAP-04-03	6513 8084	<a href="mailto:cheongsa@ntu.edu.sg">cheongsa@ntu.edu.sg</a>

## Planned Weekly Schedule

Week	Topic	Course ILO	Readings/ Activities
1	Seminar 1	1, 2	
2	Seminar 2	1, 2	
3	Briefing for Term Paper Proposal	1, 2, 3	
4	Seminar 3	1, 2	Submit Proposal
5	Seminar 4	1, 2	
6	Seminar 5	1, 2	
7	Briefing for Term Paper Progress Report	1, 2, 3	
8	Seminar 6	1, 2	Submit Progress Report
9	Presentation for Final Term Paper	1, 2	
10	Presentation for Final Term Paper	1, 2	
11	Presentation for Final Term Paper	1, 2	
12	Presentation for Final Term Paper	1, 2	
13	Presentation for Final Term Paper	1, 2, 3	Submit Final Report

## Appendix 1: Assessment Rubrics

### *Rubric for Q&A (10%)*

Criteria	0 mark	1 mark	2 marks
Q&A	No questions asked, or question asked not relevant to seminar	Question asked only to clarify definitions or remarks made by speaker	Question asked insightful, with the goal to link the mathematics to its applications in physics
		<b>Total:</b>	/2

### *Rubric for Term Paper Proposal (10%)*

Criteria	Far Exceed Expectations (9-10)	Exceed Expectations (7-8)	Meet Expectations (5-6)	Below Expectations (3-4)	Far Below Expectations (0-2)
Significance of Topic	Able to explain masterfully what topic is about, and compelling why it is important.	Able to explain masterfully what topic is about, and why it is important.	Able to explain what topic is about, and why it is important.	Able to explain what topic is, but not why it is important.	Not able to explain what topic is, nor why it is important.
Work Done So Far	Able to describe most previous works on the topic, and synthesize them into a coherent body of work.	Able to describe many previous works on the topic.	Able to describe a few previous works on the topic.	Able to list previous works, but not able to describe the work done.	Not able to list previous works, not describe the work done.
Connections with Physics	Excellent explanation of how the topic is connected to physics	Good explanation of how the topic is connected to physics	Simple explanation of how the topic is connected to physics	Poor explanation of how the topic is connected to physics	No explanation of how the topic is connected to physics
				<b>Total:</b>	/30
				<b>Weighted Total:</b>	/10

### *Rubric for Term Paper Progress Report (20%)*

Criteria	Far Exceed Expectations (9-10)	Exceed Expectations (7-8)	Meet Expectations (5-6)	Below Expectations (3-4)	Far Below Expectations (0-2)
Significance of Topic	Thorough explanations of the topic and its importance, based on comments given on the proposal.	Thorough explanations of the topic and its importance, based on comments given on the proposal.	Expand on the explanation of the topic, and why it is important, based on comments given on the proposal.	Expand on the explanations of the topic or its importance, based on comments given on the proposal.	Did not expand on explanations.

	Injection of original ideas.				
Literature Survey	Thorough survey and synthesis of previous works on the topic, based on comments given on the proposal.	Thorough survey of previous works on the topic, based on comments given on the proposal.	Able to describe many previous works on the topic, based on comments given on the proposal.	Able to describe a few previous works on the topic, based on comments given on the proposal.	No improvements beyond proposal.
Ideas Behind Topic	Able to describe all the main ideas behind the topic, in your own words.	Able to describe all the main ideas behind the topic.	Able to describe most of the main ideas behind the topic.	Able to describe few of the main ideas behind the topic.	Not able to describe any ideas behind the topic.
Connection to Physics	Excellent explanation of how topic is connected to physics, including original ideas	Excellent explanation of how the topic is connected to physics, based on comments given on proposal.	Good explanation of how the topic is connected to physics, based on comments given on proposal.	Simple explanation of how the topic is connected to physics, based on comments given on proposal.	Little or no improvement to explanation, after comments on proposal.
Outlook	Excellent description of remaining work to be done, including optional items that can be done if time is available	Excellent description of remaining work to be done	Clear description of remaining work to be done	Vague description of remaining work to be done	No description of remaining work to be done
				<b>Total:</b>	/50
				<b>Weighted Total:</b>	/20

*Rubric for Term Paper Final Report (30%)*

Criteria	Far Exceed Expectations (9-10)	Exceed Expectations (7-8)	Meet Expectations (5-6)	Below Expectations (3-4)	Far Below Expectations (0-2)
Significance of Topic	Excellent explanations of topic and its importance, including the use of original ideas and examples	Excellent explanations of the topic and its importance, based on comments given on the progress report.	Thorough explanation of the topic, and why it is important, based on comments given on the progress report.	Expand on the explanation of the topic, and why it is important, based on comments given on the progress report.	Did not expand on explanations.
Literature Survey	Excellent survey and	Thorough survey and	Thorough survey of	Able to describe	No improvements

	synthesis of previous works on topic.	synthesis of previous works on the topic, based on comments given on the progress report.	previous works on the topic, based on comments given on the progress report.	many previous works on the topic, based on comments given on the progress report.	beyond progress report.
Ideas Behind Topic	Able to describe and synthesize the main ideas behind topic, using your own words.	Able to describe all the main ideas behind the topic, based on comments given on the progress report, in your own words.	Able to describe all the main ideas behind the topic, based on comments given on the progress report.	Able to describe most of the main ideas behind the topic, based on comments given on the progress report.	No improvements beyond progress report.
Conclusions and Outlook	Excellent summary of topic reviewed. Excellent synthesis of possible future works.	Excellent summary of topic reviewed. Excellent description of possible future work.	Clear summary of topic reviewed. Clear description of possible future work.	Vague summary of topic reviewed. Vague description of possible future work.	Vague summary of topic reviewed. No description of possible future work.
References	Between 30 and 50 references	Between 20 and 30 references	About 20 references	Fewer than 20 references	Fewer than 10 references
				<b>Total:</b>	/50
				<b>Weighted Total:</b>	/30

*Rubric for Term Paper Final Presentation (30%)*

Criteria	Far Exceed Expectations (9-10)	Exceed Expectations (7-8)	Meet Expectations (5-6)	Below Expectations (3-4)	Far Below Expectations (0-2)
Overall Organization	Background of topic described in extreme depth, and includes original ideas. Excellent time management.	Background of topic described in great depth. Great time management.	Background of topic described in depth. Good time management.	Background of topic described at some depth. Below average time management.	Background of topic not described at any level of details. Poor time management.
Visual Presentation	Visuals very helpful to audience.	Visuals helpful to audience.	Visuals somewhat helpful to audience.	Visuals only of minor help to audience.	Visuals not helpful to audience.
Oral Presentation	Ideas presented very clearly, with illustrative examples. Besides	Ideas presented very clearly. All required information provided. No errors.	Ideas presented clearly. Most required information provided. Only minor errors.	Ideas mostly unclear. Provided some of required information.	Ideas not presented clearly. Provided little to none of required information

	required information, also provided additional information. No errors.			Some major errors.	about topic. Major errors.
Q&A	Able to answer all questions showing mastery of topic. Extreme confidence in answering questions.	Able to answer all questions showing understanding of topic. Very confident in answering questions.	Able to answer most questions. Confident when answering questions.	Able to answer a few questions. Shows some confidence when answering questions.	Not able to answer questions. Not confident answering questions.
				<b>Total:</b>	/40
				<b>Weighted Total:</b>	/30

## **SPMS-MAS Graduate Attributes**

A graduate from SPMS-MAS is expected to possess the following attributes:

### **1. Competence**

- a. Independently process and interpret mathematical theories and methodologies, and apply them to solve problems
- b. Formulate mathematical statements precisely using rigorous mathematical language
- c. Discover patterns by abstraction from examples
- d. Use computer technology to solve problems, and to communicate mathematical ideas

### **2. Creativity**

- a. Critically assess the applicability of mathematical tools in the workplace
- b. Build on the connection between subfields of mathematics to tackle new problems
- c. Develop new applications of existing techniques
- d. Critically analyse data from a multitude of sources

### **3. Communication**

- a. Present mathematics ideas logically and coherently at the appropriate level for the intended audience
- b. Work in teams on complicated projects that require applications of mathematics, and communicate the results verbally and in written form

### **4. Civic-mindedness**

- a. Develop and communicate mathematical ideas and concepts relevant in everyday life for the benefits of society

### **5. Character**

- a. Act in socially responsible and ethical ways in line with the societal expectations of a mathematics professional, particularly in relation to analysis of data, computer security, numerical computations and algorithms

## SPMS-PAP 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:

<b>Competency</b>	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.

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

<b>Communication</b>	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.

<b>Character</b>	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.

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