Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2022/23	Semester	1
Course Coordinator	Chia Ee Min, Elbert (Assoc. Prof.)		
Course Code	PH1198		
Course Title	Physics Laboratory Ia		
Pre-requisites	Physics at A or H2 level or equivalent		
No of AUs	2 AU		
Contact Hours	48 hours (1 hour lesson and 3 hours hands on laboratory work in Physics Year 1 Teaching Lab per Week, Week 2-13)		
Proposal Date	30 June 2022		
Course Aims			

This course aims to:

a. build a basic understanding of experimentation, data handling and error treatment.

b. begin building your basic observational skills and analysis of experimental results.

c. show how experiments further knowledge in physics.

Intended Learning Outcomes (ILO)

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

1. Design methods to take scientific measurements and use them to support experimental conclusions.

2. Determine and discuss the different sources of errors and uncertainties.

3. Write a lab report with appropriate figures, captions, and references.

4. Perform error analysis and understand the propagation of errors.

5. Perform curve fitting by doing weighted or unweighted linear or nonlinear regression using softwares like Origin, Matlab or Python

6. Keep a proper lab notebook, and exercise basic scientific data management.

7. Discuss deviations between theory and experiment.

8. Design customized experiment to test hypothesis, acquire and analyze data, and present and discuss experimental results

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Course Content
This course will train you in basic experimental physics that include topics in mechanics and basic optics. The laboratory sessions are designed to provide an active learning experience where key concepts can be better appreciated. You will also learn about data acquisition, error analysis, error distribution and fitting procedures.

Assessment (includes both continuous and summative assessment)

- You will be assessed by an online assignment system (NTULearn), Laboratory Teaching Assistant(s) and faculty member(s) from NTU.
- The shown weightage for Component 1a. is the cumulative weightage over 3 different experiments.
- The shown weightage Component 1b. is the weightage for 1 experiment.
- The shown weightage for Components 2. to 4. are the cumulative weightage over 4 different experiments.

Component	Course LO Tested (Pg 2)	Related Programme LO or Graduate Attributes (Pg 14-15)	Weighting	Team / Individual	Assessment Rubrics
1a. Experiments Laboratory Half-Reports	LO 1-5 & 7	Competency (1,2,4,5,6,7) Creativity (2) Communication (1,2,3) Character (1,2)	18%	Individual	Rubrics marking - Appendix 1
1b. Experiments Laboratory Full-Report	LO 1-5 & 7	Competency (1,2,4,5,6,7) Creativity (2) Communication (1,2,3) Character (1,2)	6%	Individual	Rubrics marking - Appendix 2
2. Experiments Laboratory Notebook	LO 1-2, 4, 6	Competency (3,6,7) Creativity (2) Character (1)	12%	Individual	Rubrics marking - Appendix 3
3. Experiments In-Class Assessments	LO 2, 4-5, 7	Creativity (2) Communication (1,2,3) Character (1,2,3	15%	Individual	Rubrics marking - Appendix 4
4. Pre-Experiments Online Quiz	LO 1 & 7	Competency (2,4,5,6)	9%	Individual	Point-based marking (not rubric-based) using NTULearn
5a. Course Mini-Project: Student Project	LO 1-2, 4-5, 7-8	Competency (1,2,3,4,5,6,7) Creativity (2) Communication (1,2,3) Character (1,2,3)	24%	Team	Rubrics marking **Student Project** - Appendix 5

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5b. Course Mini-Project: Presentation	LO 1-2, 4-5, 7-8	Competency (1,2,3,4,5,6,7) Creativity (1,2) Communication (1,2,3) Character (1,3)	16%	Individual	Rubrics marking **Presentation** - Appendix 6
Total			100%		

Formative feedback

Formative feedback is given through multiple discussion sessions with the various experiments' teaching assistants as well as through the returned marked reports and project presentation.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Experiments Laboratory Half-/Full-Reports	You would be able to receive feedback from the markers who had graded your reports and use the feedback in the next experiment/lab course.
Experiments Laboratory Notebook	You would be able to receive feedback from the markers who had graded your notebooks and use the feedback in the next experiment/lab course.
Experiments in-Class Assessments	You would be asked warm-up and in-depth questions by the teaching assistant(s) conducting the experiment and can receive feedback from the instructor's observations regarding your level of understanding of your experiment.
Pre-Experiments Online Quiz	You would be introduced to the experiment you would be working on and visualise the methods to conduct the experiment through an online learning portal.
Mini-Project	You would be required to design an experiment as a team to explore a physical phenomenon. You are also required to present the experiment's findings to your course-mates. You would be able to receive feedback via your presentation remarks.

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Reading and References
1.   An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements, 2nd ed, John R. Taylor, University Science Books, 978-0935702750, 1996
2.   Experimentation: An Introduction to Measurement Theory & Experiment Design, 3rd ed, David C. Baird, Addison-Wesley, 978-0133032987, 1994

Course Policies and Student Responsibilities
Absence Due to Medical or Other Reasons

If you are sick and unable to attend your laboratory or viva sessions, you have to:

1. Send an email to the lab manager regarding the absence and request for a replacement / make-up laboratory or viva session.
2. Submit the original Medical Certificate***** or official letter of excuse to administrator.
3. Attend the assigned replacement session (*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
Chia Ee Min, Elbert (Assoc. Prof.)	SPMS-PAP-04-13	+65 6513 8132	ElbertChia@ntu.edu.sg

Planned Weekly Schedule
Dependent on assigned experiment schedule as provided by the Physics Year 1 lab manager, Ms. Tam Qian Xin

Appendix 1: Examiner's Assessment Rubrics for PH1198 Physics Lab Ia
Part 1a: Laboratory Half-Report

Sections of the laboratory Half Report	Far Exceeds Expectations (14 - 15)	Exceeds Expectations in some areas (12 - 13)	Meets Expectations (9 - 11)	Meets Expectations in some areas (6 - 8)	Below Expectations (0 - 5)	Score
Results Section *Meeting Requirements & Presentation Clarity* suggested consideration Point(s); • Did the student present all the experimental results as required in that experiment's lab manual? • Did the student investigate certain physical aspects of the experiment outside the requirements of the lab manual? • Are the results presented in an organised and coherent style with named diagrams & tables for easy reference?	All of the required results were presented. Presented results were well-organised , tabulated. Appreciable initiative investigating phenomena outside the requirements.	All of the required results were presented. Presented results were well-organised and tabulated. Some initiative investigating phenomena outside the requirements.	Most of the required results were presented. Presented results were organised and tabulated.	Some of the required results were presented. Presented results were disorganised and not tabulated.	None of the required results were presented. Any presented results were messy and not tabulated.	/ 15
Presentation of Experimental Error suggested consideration point(s); • If an experiment requires so, is the student able to perform error propagation correctly? • Is the student able to obtain uncertainties within the reasonable bounds of the apparatus used or from calculations? • Has the student included experimentally obtained errors in their tabulated results in the form of uncertainties? If presenting graphical results, in the form of error bars?	All of the required uncertainties were presented. Uncertainties obtained were contextually realistic. Explanation was provided. Correct uncertainties from error propagation. Method was provided.	All of the required uncertainties were presented. Uncertainties obtained were contextually realistic. Correct uncertainties from error propagation.	Most of the required uncertainties were presented. Uncertainties obtained were contextually unrealistic.	Some of the required uncertainties were presented. Uncertainties obtained were contextually unrealistic.	No uncertainties were presented.	/ 15

Sections of the laboratory Half Report	Far Exceeds Expectations (14 - 15)	Exceeds Expectations in some areas (12 - 13)	Meets Expectations (9 - 11)	Meets Expectations in some areas (6 - 8)	Below Expectations (0 - 5)	Score
Results Section *Presentation of fitting results* suggested consideration point(s); • If an experiment requires so, is the student able to perform curve fitting using the recommended software? • Has the student utilised the correct fitting function & results based on the experiment's theoretical considerations? • Has the student provided the fitting results? (Score to be merged with **Results Section** *Meeting Requirements & Presentation Clarity* should graphical fitting be not required in a particular experiment.)	The required data plots were presented. Fitting results were presented. Choice of fitting function & fitting results were presented and explained.	The required data plots were presented. Fitting results were presented. Choice of fitting function & fitting results were presented.	The required data plots were presented. Fitting results were presented. Choice of fitting function & fitting results were not presented.	The required data plots were presented. No fitting results were presented.	No data plots nor fitting results were presented.	/ 15
Sections of the laboratory Half Report	Far Exceeds Expectations (18 - 20)	Exceeds Expectations in some areas (15 - 17)	Meets Expectations (12 - 14)	Meets Expectations in some areas (9 - 11)	Below Expectations (0 - 8)	Score
Discussion Section *Obtaining Error Trends from Experimental Results* suggested consideration point(s); • Is the student able to relate their obtained experimental results with the experiment's theoretical predication through the use of an appropriate quantifier (e.g. % differences, p-values, etc.) ? • Is the student able to explain and make educated benchmarks of the experiment's accuracy and precision from the provided apparatus? • Is the student able to compare their obtained experimental results against the benchmarks of accuracy and precision? • Is the student able to identify trends in their results or data (e.g. asymmetry, skewed results towards a particular value, etc.) through suitable quantifiers of errors (e.g. % differences, uncertainties, etc..)?	Required quantifiers used. Well-reasoned attempts at benchmarking the experiment's accuracy & precision. Successful attempts at identifying error trends in presented results.	Required quantifiers used. Reasonable attempts at benchmarking the experiment's accuracy & precision. Determined attempts at identifying error trends in presented results.	Required quantifiers used. Some attempts at benchmarking the experiment's accuracy & precision Some attempts at identifying error trends in presented results.	Required quantifiers used. No attempts at benchmarking the experiment's accuracy & precision	Absence of any quantifiers used. Omission of any attempts at determining the apparatus accuracy & precision.	/ 20

Sections of the laboratory Half Report	Far Exceeds Expectations (23 - 25)	Exceeds Expectations in some areas (20 - 22)	Meets Expectations (16 - 19)	Meets Expectations in some areas (11 - 15)	Below Expectations (0 - 10)	Score
Discussion Section *Evaluation of Errors' Impact on Experimental Results* suggested consideration point(s); • Has the student done only a qualitative analysis of the identified errors? • Has the student identified possible errors from observing the trend of errors? • Is the student able to identify one or two major causes of error in this experiment? • Has the student made an attempt at quantifying the impact of possible errors after identifying them? • Has the student suggested improvements to experimental procedure to reduce said identified errors? Or has the student supported current procedures as superior at reducing experimental errors?	<u>Appreciable</u> attempts at <u>quantifiable</u> error analysis. <u>In-Depth qualitative</u> error analysis. <u>Well-reasoned discussion</u> on the experimental impact of errors.	<u>Some attempts at quantifiable</u> error analysis. <u>Considerable qualitative</u> error analysis. <u>Considerable discussion</u> on the experimental impact of errors.	<u>Considerable qualitative</u> error analysis. <u>Some discussion</u> on the experimental impact of errors.	<u>Brief and short qualitative</u> error analysis. <u>Brief discussion</u> on the experimental impact of errors.	Error analysis was <u>completely omitted</u>.	/ 25
	Far Exceeds Expectations (9 - 10)	Exceeds Expectations in some areas (7 - 8)	Meets Expectations (5 - 6)	Meets Expectations in some areas (1 - 4)	Below Expectations (0)	Score
Conclusion Section suggested consideration point(s); • Has the student evaluated the success of their experiment via obtained experimental goals and suitable quantifiers? • Has the student identified the most prominent source of error and had given suggestions to improve the experiment? Conclusion Section is at most 2 paragraphs.	Experiment's goals are <u>fully</u> met . <u>Detailed mention</u> of any concluding evaluations, has interesting observations.	Experiment's goals are <u>fully</u> met . <u>Some mention</u> of any concluding evaluations.	Brief. Experiment's goals are <u>fully</u> met <u>Little mention</u> of any concluding evaluations.	Very brief. Experiment's goals are <u>not fully</u> met . <u>Absence</u> of any concluding evaluations.	The conclusion section was <u>completely omitted</u>.	/ 10
					[1]Total :	/ 100

[1]Normalised to 100%.

Appendix 2: Examiner's Assessment Rubrics for PH1199 Physics Lab Ia
Part 1b: Laboratory Full-Report

Sections of the Laboratory Full Report	Far Exceeds Expectations (5)	Exceeds Expectations in some areas (4)	Meets Expectations (2 - 3)	Meets Expectations in some areas (1)	Below Expectations (0)	Score
Introduction & Theory Section suggested consideration point(s); • Did the student state the explicit, and any implicit, goals of their experiment? • Did the student use relevant theories to predict the experiment's outcome? • Are there additional concepts outside those provided in the lab manual presented in depth to aid in the experiment's investigations?	All of the experiment goal(s) were stated. Presented relevant theories were accurate together with more complex theories.	All of the experiment goal(s) were stated. Presented relevant theories were accurate.	Most of the experiment goal(s) were stated. Presented relevant theories had minor errors.	Some of the experiment goal(s) were stated. Presented theories had some errors or were irrelevant.	None of the experiment goal(s) were stated. Presented theories had major errors or were irrelevant.	/ 5

	Far Exceeds Expectations (18 - 20)	Exceeds Expectations in some areas (15 - 17)	Meets Expectations (12 - 14)	Meets Expectations in some areas (9 - 11)	Below Expectations (0 - 8)	Score
Procedure Section suggested consideration point(s); • Did the student have additional experimental procedures aside from those provided in the lab manual? • Is the student able to provide a pictorial overview of their experiment for the ease of understanding? • How did the student process their data with methods based on fore-mentioned theoretical expressions? • Did the student state how they evaluated their experimental set-up or apparatus to determine quantifiable errors?	Extensive procedural details provided, referenced the lab manual's procedure steps specifically as needed. Annotated diagram(s) of the experiment set-up provided. Appreciable attempts to reduce or deduce experimental error.	Lots of procedural details provided, referenced the lab manual procedures. Annotated diagram(s) of the experiment set-up provided. Appreciable attempts to reduce or deduce experimental error.	Some procedural details provided, copied directly from the lab manual. Simple annotated diagram(s) of the experiment set-up provided. Some attempts to reduce or deduce experimental error.	Few procedural details provided, copied directly from the lab manual. Simple diagram(s) of the experiment set-up provided. Some attempts to reduce or deduce experimental error.	Little or no procedural details provided. No diagram(s) of the experiment set-up provided. Absence of attempts to reduce or deduce experimental error.	/ 20

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Sections of the Laboratory Full Report	Far Exceeds Expectations (10)	Exceeds Expectations in some areas (7 - 9)	Meets Expectations (6 - 8)	Meets Expectations in some areas (4 - 5)	Below Expectations (0 - 3)	Score
Results Section *Meeting Requirements & Presentation Clarity* suggested consideration Point(s); • Did the student present all the experimental results as required in that experiment's lab manual? • Did the student investigate certain physical aspects of the experiment outside the requirements of the lab manual? • Are the results presented in an organised and coherent style with named diagrams & tables for easy reference?	All of the required <u>results</u> were presented. Presented results were <u>well-organised</u> , <u>tabulated</u>. <u>Appreciable initiative</u> investigating phenomena outside the requirements.	All of the required <u>results</u> were presented. Presented results were <u>well-organised</u> and <u>tabulated</u>. <u>Some initiative</u> investigating phenomena outside the requirements.	Most of the required <u>results</u> were presented. Presented results were <u>organised</u> and <u>tabulated</u>.	Some of the required <u>results</u> were presented. Presented results were <u>disorganised</u> and <u>not tabulated</u>.	None of the required <u>results</u> were presented. Any presented results were <u>messy</u> and <u>not tabulated</u>.	/ 10
Presentation of Experimental Error suggested consideration point(s); • If an experiment requires so, is the student able to perform error propagation correctly? • Is the student able to obtain uncertainties within the reasonable bounds of the apparatus used or from calculations? • Has the student included experimentally obtained errors in their tabulated results in the form of uncertainties? If presenting graphical results, in the form of error bars?	All of the required <u>uncertainties</u> were presented. Uncertainties obtained were <u>contextually realistic</u>. <u>Explanation was provided</u>. <u>Correct</u> uncertainties from error propagation. <u>Method was provided</u>.	All of the required <u>uncertainties</u> were presented. Uncertainties obtained were <u>contextually realistic</u>. <u>Correct</u> uncertainties from error propagation.	Most of the required <u>uncertainties</u> were presented. Uncertainties obtained were <u>contextually unrealistic</u>.	Some of the required <u>uncertainties</u> were presented. Uncertainties obtained were <u>contextually unrealistic</u>.	<u>No uncertainties</u> were presented.	/ 10

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Sections of the Laboratory Full Report	Far Exceeds Expectations (10)	Exceeds Expectations in some areas (7 - 9)	Meets Expectations (6 - 8)	Meets Expectations in some areas (4 - 5)	Below Expectations (0 - 3)	Score
Results Section *Presentation of fitting results* suggested consideration point(s); • If an experiment requires so, is the student able to perform curve fitting using the recommended software? • Has the student utilised the correct fitting function & results based on the experiment's theoretical considerations? • Has the student provided the fitting results? (Score to be merged with **Results Section** *Meeting Requirements & Presentation Clarity* should graphical fitting be not required in a particular experiment.)	The <u>required data plots</u> were presented. <u>Fitting results</u> were presented. Choice of fitting function & fitting results were <u>presented and explained</u>.	The <u>required data plots</u> were presented. <u>Fitting results</u> were presented. Choice of fitting function & fitting results were <u>presented</u>.	The <u>required data plots</u> were presented. <u>Fitting results</u> were presented. Choice of fitting function & fitting results were <u>not presented</u>.	The <u>required data plots</u> were presented. <u>No fitting results</u> were presented.	<u>No data plots nor fitting results</u> were presented.	/ 10

	Far Exceeds Expectations (18 - 20)	Exceeds Expectations in some areas (15 - 17)	Meets Expectations (12 - 14)	Meets Expectations in some areas (9 - 11)	Below Expectations (0 - 8)	Score
Discussion Section *Obtaining Error Trends from Experimental Results* suggested consideration point(s); • Is the student able to relate their obtained experimental results with the experiment's theoretical predication through the use of an appropriate quantifier (e.g. % differences, p-values, etc.) ? • Is the student able to explain and make educated benchmarks of the experiment's accuracy and precision from the provided apparatus? • Is the student able to compare their obtained experimental results against the benchmarks of accuracy and precision? • Is the student able to identify trends in their results or data (e.g. asymmetry, skewed results towards a particular value, etc.) through suitable quantifiers of errors (e.g. % differences, uncertainties, etc..)?	<u>Required quantifiers</u> used. <u>Well-reasoned attempts</u> at benchmarking the experiment's accuracy & precision. <u>Successful attempts</u> at identifying error trends in presented results.	<u>Required quantifiers</u> used. <u>Reasonable attempts</u> at benchmarking the experiment's accuracy & precision. <u>Determined attempts</u> at identifying error trends in presented results.	<u>Required quantifiers</u> used. <u>Some attempts</u> at benchmarking the experiment's accuracy & precision <u>Some attempts</u> at identifying error trends in presented results.	<u>Required quantifiers</u> used. <u>No attempts</u> at benchmarking the experiment's accuracy & precision	<u>Absence of any quantifiers</u> used. <u>Omission of any attempts</u> at determining the apparatus accuracy & precision.	/ 20

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Sections of the Laboratory Full Report	Far Exceeds Expectations (18 - 20)	Exceeds Expectations in some areas (15 - 17)	Meets Expectations (12 - 14)	Meets Expectations in some areas (9 - 11)	Below Expectations (0 - 8)	Score
Discussion Section *Evaluation of Errors' Impact on Experimental Results* suggested consideration point(s); • Has the student done only a qualitative analysis of the identified errors? • Has the student identified possible errors from observing the trend of errors? • Is the student able to identify one or two major causes of error in this experiment? • Has the student made an attempt at quantifying the impact of possible errors after identifying them? • Has the student suggested improvements to experimental procedure to reduce said identified errors? Or has the student supported current procedures as superior at reducing experimental errors?	Appreciable attempts at quantifiable error analysis. In-Depth qualitative error analysis. Well-reasoned discussion on the experimental impact of errors.	Some attempts at quantifiable error analysis. Considerable qualitative error analysis. Considerable discussion on the experimental impact of errors.	Considerable qualitative error analysis. Some discussion on the experimental impact of errors.	Brief and short qualitative error analysis. Brief discussion on the experimental impact of errors.	Error analysis was completely omitted.	/ 20

	Far Exceeds Expectations (5)	Exceeds Expectations in some areas (4)	Meets Expectations (2 - 3)	Meets Expectations in some areas (1)	Below Expectations (0)	Score
Conclusion Section suggested consideration point(s); • Has the student evaluated the success of their experiment via obtained experimental goals and suitable quantifiers? • Has the student identified the most prominent source of error and had given suggestions to improve the experiment? Conclusion Section is at most 2 paragraphs.	Experiment's goals are fully met . Detailed mention of any concluding evaluations, has interesting observations.	Experiment's goals are fully met . Some mention of any concluding evaluations.	Brief. Experiment's goals are fully met Little mention of any concluding evaluations.	Very brief. Experiment's goals are not fully met . Absence of any concluding evaluations.	The conclusion section was completely omitted.	/ 5
					[1]Total :	/ 100

[1]Normalised to 100%.

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Appendix 3: Examiner's Assessment Rubrics for PH1198 Physics Lab Ia
Part 2: Laboratory Notebook

	Far Exceeds Expectations (61 - 70)	Exceeds Expectations in some areas (51 - 60)	Meets Expectations (31 - 50)	Meets Expectations in some areas (11 - 30)	Below Expectations (0 – 10)	Score
Data Entry suggested consideration point(s); • Did the student record all relevant data as required by the experiment? • Did the student record their experimental settings, should if the need arises to redo the experiment? • Did the student have rough sketches of their experimental set-up? • Did the student note down any additional procedure or experimental steps to supplement the lab manual's instructions? • Has the student listed down any interesting observations? Were there any extra investigations into any mentioned interesting observations?	<u>All</u> data were recorded. <u>Excellent</u> portrayal of the experimental set-up. <u>Detailed</u> procedures <u>outside</u> of the lab manual instructions were recorded and explained. <u>Listed & attempted</u> investigation of interesting observations.	<u>All</u> data were recorded. <u>Detailed</u> experimental set-up information was recorded. <u>Listed some</u> interesting observations with <u>cursory</u> investigations.	<u>All</u> data were recorded. <u>Some</u> experimental set-up information was recorded.	<u>Some</u> data were recorded. <u>Some</u> experimental set-up information was recorded.	<u>Little to no</u> data was recorded.	/ 70
	(26 - 30)	(20 - 25)	(13 - 19)	(1 - 12)	(0)	
Uncertainties & Experimental Errors suggested consideration point(s); • Is the student able to obtain uncertainties within the reasonable bounds of the apparatus used or from calculations? • If an experiment requires so, is the student able to perform error propagation correctly? • Has the student included or derived any error propagating expressions as rough workings?	<u>All</u> of the required <u>uncertainties</u> were presented. Uncertainties obtained were <u>contextually realistic</u>. <u>Correct</u> uncertainties from error propagation. <u>Method was provided</u>. <u>Detailed derivation & method</u> was provided.	<u>All</u> of the required <u>uncertainties</u> were presented. Uncertainties obtained were <u>contextually realistic</u>. <u>Correct</u> uncertainties from error propagation. <u>Brief derivation & method</u> was provided.	<u>Most</u> of the <u>required uncertainties</u> were presented. Uncertainties obtained were <u>contextually unrealistic</u>.	<u>Some</u> of the <u>required uncertainties</u> were presented. Uncertainties obtained were <u>contextually unrealistic</u>.	<u>No uncertainties</u> were presented.	/ 30
					[1]Total :	/ 100

[1]Normalised to 100%.

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Appendix 4: Examiner's Assessment Rubrics for PH1198 Physics Laboratory Ia
Part 3: In-Class Assessments

	Far Exceeds Expectations (61 - 70)	Exceeds Expectations in some areas (51 - 60)	Meets Expectations (31 - 50)	Meets Expectations in some areas (11 - 30)	Below Expectations (0 – 10)	Score
Experimental Aspects suggested consideration point(s); • Is the student able to understand the theoretical reasoning for this experiment? • Did the student do their own research on topics they are unfamiliar with? • How much did the laboratory teaching assistant have to guide the student? (First laboratory course for freshmen. Low expectations on any prior lab experiences.)	Has an excellent grasp of rudimentary physical concepts before instruction. Readily applies new concepts to the experimental context. Has done extensive research into the experimental topic prior to attempting experiment.	Has a strong grasp of rudimentary physical concepts before instruction. Able to apply most new concepts to the experimental context. Has done some research into the experimental topic prior to attempting experiment.	Able to understand most rudimentary physical concepts before instruction. Able to apply some new concepts to the experimental context.	Able to understand rudimentary physical concepts after instruction. Able to apply some new concepts to the experimental context.	Unable to understand any rudimentary physical concepts despite instruction.	/ 70
	(26 - 30)	(20 - 25)	(13 - 19)	(1 - 12)	(0)	
Soft Skills & Teamwork suggested consideration point(s); • Is the student able to work with their assigned teammate(s)? • Is the student able to take initiative and lead? • Is the student able to seek assistance with understanding the experiment, or conversely help their teammate(s) who are having difficulty with understanding the experiment's needs?	Present for all lab session in an active role. Completes assigned experimental tasks. Has a critical role by successfully leading the team to understand and complete the team's experiments.	Present for all lab session in an active role. Completes assigned experimental tasks. Has an initiative to assist other members to understand and complete the experiments.	Present for all lab session in a limited active role. Completes assigned experimental tasks. Has an initiative to ask for help if required.	Present for all lab sessions in a passive role. Mostly copies from other teammates. In a mostly administrative rather than experimental role. Lacks initiative to ask for help	Missing from all group sessions or did not assist with any tasks or team mates throughout the session. Disruptive behaviour.	/ 30
					[1]Total :	/ 100

[1]Normalised to 100%.

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Appendix 5: Examiner's Assessment Rubrics for PH1198 Physics Laboratory Ia
Part 5a: Course Mini-Projects (Student Project)

	Far Exceeds Expectations (21 - 25)	Exceeds Expectations in some areas (16 - 20)	Meets Expectations (11- 15)	Meets Expectations in some areas (6 - 10)	Below Expectations (0 - 5)	Score
Originality of Project Idea suggested consideration point(s); • Did the students came up with a novel experiment? • Was their experiment a modification of an existing one? • Were the laboratory equipment provided used in a new and novel way? • Did the students design and make their own equipment for this project?	Experiment designed was <u>completely different from existing experiments</u>.	Experiment designed was <u>a modification of existing experiments</u> with <u>several distinct differing</u> feature.	Experiment designed was <u>a modification of existing experiments</u> with <u>a distinct differing</u> feature.	Experiment designed was <u>a slight modification of existing experiments</u> with <u>little differing</u> features.	Experiment designed was <u>a direct copy of existing experiments</u>.	/ 25
Design of the Experiment & Apparatus suggested consideration point(s); • Are the procedures laid out by the students able to test their intended phenomena? • Was their range of provided laboratory equipment adequate for the experimental task(s)? • Did the students have to design and create new working apparatus to supplement their existing equipment?	The designed procedures, provided and/or designed apparatus <u>were able to fulfil all of</u> the experiment's goals and be useful potentially in future expansions of the experiment's goals.	The designed procedures, provided and/or designed apparatus <u>were able to fulfil all of</u> the experiment's goals.	The designed procedures, provided and/or designed apparatus <u>were able to fulfil most of</u> the experiment's goals.	The designed procedures, provided and/or designed apparatus <u>were able to fulfil a few of</u> the experiment's goals.	The designed procedures, provided and/or designed apparatus <u>were not able to fulfil</u> the experiment's goals.	/ 25
Experimentally Obtained Data suggested consideration point(s); • Did the students record all relevant data as required by their experiment's goals? • Were the students' data processing methods effective at supporting their investigations? • Did the students presented their data clearly?	Relevant data was presented <u>very clearly</u>. <u>No errors</u> in how the students handled their data.	Relevant data was presented <u>clearly</u>. <u>Few or no minor errors</u> in how the students handled their data.	Data was presented <u>some-what clearly</u>. <u>Some minor errors</u> in how the students handled their data.	Data was presented <u>mostly unclearly</u>. <u>Few major errors</u> in how the students handled their data.	Data was <u>not presented clearly</u>. <u>Lots of major errors</u> in how the students handled their data.	/ 25

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	Far Exceeds Expectations (21 - 25)	Exceeds Expectations in some areas (16 - 20)	Meets Expectations (11 - 15)	Meets Expectations in some areas (6 - 10)	Below Expectations (0 - 5)	Score
Error analysis suggested consideration point(s); • Are the students able to obtain uncertainties within the reasonable bounds of the apparatus used or from calculations? • Were the students able to identify errors in their designed experiment? • Were the students able to suggest improvements to their designed experiment?	Able to obtain and propagate uncertainties, aware that errors exist in their design, able to determine the extent of the errors' impact and suggest good improvements to their design.	Able to obtain and propagate uncertainties, aware that errors exist in their design, somewhat able to determine the extent of the errors' impact and suggest some improvements to their design.	Able to obtain & propagate some basic uncertainties, aware that errors exist in their design but unable to determine the extent of the errors' impact, suggests simple improvements to their design.	Able to obtain some basic uncertainties, somewhat aware that errors exist in their design but not aware of the errors' impact.	Unable to obtain uncertainties, unaware that errors exist in their design.	/ 25
Please note that all members are expected to actively participate in the project. If any member is unable to do so due to valid reason (e.g., medical/family issue), we provide half score; If absent without valid reason, zero score. If there is contribution by providing ideas that are accepted by other team members, but the member is unable to physically participate in the project, also half score. In all such cases, there will be an interview with the course coordinator to ascertain the circumstances resulting in the student's lack of participation before their final grade is decided.					[1]Total :	/ 100

[1]Normalised to 100%.

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Appendix 6: Examiner's Assessment Rubrics for PH1198 Physics Laboratory Ia
Part 5b: Course Mini-Projects (Presentation)

	Far Exceeds Expectations (21 - 25)	Exceeds Expectations in some areas (16 - 20)	Meets Expectations (11 - 15)	Meets Expectations in some areas (6 - 10)	Below Expectations (0 - 5)	Score
Visual Presentation suggested consideration point(s); • Are the slides informative? • Are the slides too cluttered or too sparse? • Did the students include visualisations of their set-up? Were the slides well animated?	The visuals were <u>very helpful</u> to the audience.	The visuals were <u>helpful</u> to the audience.	The visuals were <u>somewhat helpful</u> to the audience.	The visuals were <u>mostly helpful</u> to the audience.	The visuals were <u>not helpful</u> to the audience.	/ 25
Oral Presentation suggested consideration point(s); • Was the presentation audible? • Did the students vary their tone to emphases on key issues? • Was the physical concepts delivered in a clear and concise manner? • Was time managed well? Did the students have equal speaking time?	Ideas were presented <u>very clearly</u>. Provided <u>more than the required</u> info about the project. <u>Accurate</u> concepts delivered. <u>Excellent</u> time management. <u>Engaging</u> presentation.	Ideas were presented <u>clearly</u>. Provided <u>the required</u> info about the project. <u>Mostly accurate</u> concepts delivered. <u>Excellent</u> time management.	Ideas were presented <u>some-what clearly</u>. Provided <u>most of the required</u> info about the project. <u>Mostly accurate</u> concepts delivered.	Ideas were <u>mostly unclear</u>. Provided <u>some of the required</u> info about the project. <u>Some major errors</u> in concepts delivered.	Ideas were <u>not presented clearly</u>. Provided <u>little to none of the required</u> info about the project. <u>Major errors</u> in concepts delivered.	/ 25

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	Far Exceeds Expectations (46 - 50)	Exceeds Expectations in some areas (36 - 45)	Meets Expectations (21 - 35)	Meets Expectations in some areas (11 - 20)	Below Expectations (0 - 10)	Score
Q&A Session suggested consideration point(s); • Did the students understand the questions and answer to the point? • Were the students confident of their answer? • Were the students able to engage in a meaningful & civil discussion with the audience?	Very Productive discussions and deep analyses. Critiques extends beyond the requirements of the project into new scenarios.	Productive discussions and analyses. Critiques involved different aspects of the project, how the different aspects interact with each other and corresponding impacts.	Some discussions and analyses. Critiques involved more than a single aspect of the project. Unable to debate relationships between the project's aspects.	Little discussions and analyses. Critiques involved only a single aspect of the project.	Absence of a response, discussions, analyses or critique.	/ 50
Please note that all group members are expected to actively participate in the presentation. We will be assessing each student individually for the presentation. In specific cases (e.g., medical/family issue) where a member is absent for a valid reason, there will be an interview with the course coordinator to ascertain the circumstances for the student's lack of participation before their final grade is decided.					[1]Total :	/ 100

[1]Normalised to 100%

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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, PHDA, 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. |