Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2020-21	**Semester**	2
Course Coordinator	Chong Yidong (Assoc. Prof)		
Course Code	PH2199		
Course Title	Physics Laboratory IIb		
Pre-requisites	PH1199 or CY1400		
No of AUs	2 AU		
Contact Hours	4 Hours in Physics Year 2 Teaching Lab per Week		
Proposal Date	3 March 2020		

Course Aims

This course aims to:

a. build understanding of experimentation in key topics of physics.

b. provide foundation knowledge for experimental physics

c. begin building observational skills of physical phenomena.

d. 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. Write a lab report with appropriate figures, captions, and references.
2. Perform error analysis and understand the propagation of errors.
3. Perform curve fitting by doing weighted or unweighted linear or nonlinear regression using softwares like Origin, Matlab or Python
4. Keep a proper lab notebook, and exercise basic scientific data management.
5. Discuss deviations between theory and experiment.
6. Use various experimental techniques, e.g. lock-in amplification, to reduce measurement errors.
7. Use various statistical procedures to reduce irremovable sources of error, e.g. radioactive decay.
8. Perform moderately sophisticated optical system assembly and alignment.
9. Use certain programming languages at an introductory level to process or obtain data.

Course Content

The students will understand the fundamentals of proper experimentation and its importance to discovery and knowledge of physics. The students will acquire skills and knowledge related to the key areas of physics.

Assessment (includes both continuous and summative assessment)

- You will be assessed by an online assignment system (NTULearn), Laboratory Teaching Assistant(s) and Faculty Members from NTU.
- The shown weightage for Components 1 and 2. is the cumulative weightage over 4 different experiments.

Component	Course LO Tested (Pg 12)	Related Programme LO or Graduate Attributes (Pg 19-20)	Weighting	Team / Individual	Assessment Rubrics
1. Experiments Laboratory Full-Reports	LO 1-9	Competency (1,2,4,5,6,7) Creativity (2) Communication (1,2,3) Character (1,2)	57%	Individual	Rubrics marking - Appendix 1 (Pg 16-17)
2. Experiment(s)' Viva Voce & Discussion (Faculty Member viva is experiment specific)	LO 1-9	Competency (1,2,3,4,5,6,7) Creativity (1,2) Communication (1,2) Character (1,2,3)	38%	Individual	Rubrics marking - Appendix 2 (Pg 18)
1. Safety & Error Analysis Pre-course Quiz	LO 2, 4, 6-8	Competency (1,2,3,4,5,6,7) Creativity (1,2) Character (3)	5%	Individual	Points Based Marking via NTULearn
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.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Experiments Laboratory 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.
Experiment(s)' Viva Voce & Discussion	You would be asked warm-up and in-depth questions by the teaching assistant conducting the viva. You would be tested on their depth of understanding of the various experimental aspects. You receive feedback through interactions with the teaching assistant.

Safety & Error Analysis Pre-course Quiz	You would take a test using the NTULearn online assignment system in order to gauge your understanding of safety in the lab and understanding of the various means of dealing with errors in your experiments. You would receive feedback via your grades on NTULearn.

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
3. Various reference notes provided on NTULearn during the course.

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
Chong Yidong (Assoc. Prof)	SPMS-PAP-04-02	+65 6316 2967	Yidong@ntu.edu.sg

Planned Weekly Schedule

Dependent on assigned experiment schedule as provided by the Physics Year 2 lab manager, Ms Moo Aun Mee.

Appendix 1: Examiner's Assessment Rubrics for PH2199 Physics Laboratory IIb
Part 1: Laboratory Full-Report

Sections of the Laboratory Full Report	**Far Exceeds Expectations** (22-25)	**Exceeds Expectations in some areas** (16-21)	**Meets Expectations** (11 - 15)	**Meets Expectations in some areas** (6-10)	**Below Expectations** (0-5)	**Score**
Introduction, Theory & Procedure Section suggested consideration point(s); • Did the student state the explicit, and any implicit, goals of their experiment? • 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?	All of the experiment goal(s) were stated. Extensive procedural details provided, referenced the lab manual's procedure steps specifically as needed. Appreciable attempts to reduce or deduce experimental error.	All of the experiment goal(s) were stated. Lots of procedural details provided, referenced the lab manual procedures. Appreciable attempts to reduce or deduce experimental error.	Most of the experiment goal(s) were stated. Some procedural details provided, copied directly from the lab manual. Some attempts to reduce or deduce experimental error.	Some of the experiment goal(s) were stated. Few procedural details provided, copied directly from the lab manual. Some attempts to reduce or deduce experimental error.	None of the experiment goal(s) were stated. Little or no procedural details provided. Absence of attempts to reduce or deduce experimental error.	/ 25
	(26-30)	(21 - 25)	(14 - 20)	(6 – 13)	(0 - 5)	
Results Section 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? • 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? • If an experiment requires so, o is the student able to perform curve fitting using the recommended software? o Has the student utilised the correct fitting function & results based on the experiment's theoretical considerations? o Has the student provided the fitting results?	All of the required results were presented. Presented results were well-organised , tabulated. Considerable initiative investigating phenomena outside the requirements. ---------- All of the required uncertainties were presented. Uncertainties obtained were contextually realistic. Explanation was provided. Correct uncertainties from error propagation. Method was provided. ---------- The required data plots were presented. Fitting results were presented. Choice of fitting function & fitting results were presented and explained.	All of the required results were presented. Presented results were well-organised and tabulated. Appreciable initiative investigating phenomena outside the requirements. ---------- All of the required uncertainties were presented. Uncertainties obtained were contextually realistic. Correct uncertainties from error propagation. ---------- The required data plots were presented. Fitting results were presented. Choice of fitting function & fitting results were presented.	Most of the required results were presented. Presented results were organised and tabulated. Some initiative investigating phenomena outside the requirements. ---------- Most of the required uncertainties were presented. Uncertainties obtained were contextually unrealistic. ---------- The required data plots were presented. Fitting results were presented. Choice of fitting function & fitting results were not presented.	Some of the required results were presented. Presented results were disorganised and not tabulated. Some of the required uncertainties were presented. Uncertainties obtained were contextually unrealistic. The required data plots were presented. No fitting results were presented.	None of the required results were presented. Any presented results were messy and not tabulated. No uncertainties were presented. No data plots nor fitting results were presented.	/ 30

Sections of the Laboratory Full Report	**Far Exceeds Expectations** (35 - 40)	**Exceeds Expectations in some areas** (30 - 34)	**Meets Expectations** (16 - 29)	**Meets Expectations in some areas** (6 - 15)	**Below Expectations** (0 - 5)	**Score**
Discussion Section 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..)? • 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 supported current procedures?	Required quantifiers used. Well-reasoned attempts at benchmarking the experiment's accuracy & precision. Successful attempts at identifying error trends in presented results. Excellent attempts at quantifiable error analysis. In-Depth qualitative error analysis. Well-reasoned discussion on the experimental impact of errors.	Required quantifiers used. Reasonable attempts at benchmarking the experiment's accuracy & precision. Determined attempts at identifying error trends in presented results. Appreciable attempts at quantifiable error analysis. Considerable qualitative error analysis. Considerable discussion on the experimental impact of errors.	Required quantifiers used. Some attempts at benchmarking the experiment's accuracy & precision Some attempts at identifying error trends in presented results. Some attempts at quantifiable error analysis. Considerable qualitative error analysis. Some discussion on the experimental impact of errors.	Required quantifiers used. No attempts at benchmarking the experiment's accuracy & precision Brief and short qualitative error analysis. Brief discussion on the experimental impact of errors.	Absence of any quantifiers used. Omission of any attempts at determining the apparatus accuracy & precision. Error analysis was completely omitted.	/ 40
	(5)	(4)	(2 - 3)	(1)	(0)	
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%.

Appendix 2: Examiner's Assessment Rubrics for PH2199 Physics Laboratory IIb
Part 2: Experiment(s)' Viva Voce & Discussion

	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**
Experiment Theoretical Understanding suggested consideration point(s); • Did the student have a firm grasp of the physical theories behind the experiment? • Does the student understand the scientific significance of their experiment?	Demonstrated extremely thorough understanding of the experiment's physics.	Demonstrated thorough understanding of the experiment's physics.	Demonstrated considerable understanding of the experiment's physics.	Demonstrated limited understanding of the experiment's physics.	Demonstrated completely no understanding of the experiment's physics.	/ 25
Understanding of Experimental Methodology suggested consideration point(s); • Did the student have a good understanding of the experimental design, instrumentation and data acquisition? • Did the student explain and perform any additional procedures outside of the lab manual's instructions?	Demonstrated an expert understanding of the experiment's methodology. Significant number of additional procedures, supported with detailed explanations	Demonstrated through understanding of the experiment's methodology. Appreciable number of additional procedures, supported with simple explanations	Demonstrated considerable understanding of the experiment's methodology. Limited number of additional procedures, supported with simple explanations	Demonstrated limited understanding of the experiment's methodology.	Demonstrated completely no understanding of the experiment's methodology.	/ 25
Analysis of Experimental Data suggested consideration point(s); • Is the student able to support their analysis from their obtained data or observed data trends? • Is the student able to use their analysis to support their experimental deductions (e.g. errors of significance, prove of existence, etc..) ?	Able to extensively support their analysis through use of appropriate data. Deduced aspects are strongly supported by their analysis.	Able to support their analysis through use of appropriate data. Deduced aspects are somehow supported by their analysis.	Able to support their analysis through use of reasonably appropriate data. Deduced aspects are weakly supported by their analysis.	Able to weakly support their analysis through use of reasonably appropriate data. Few to none deduced aspects. Deduced aspects are weakly supported by their analysis.	No Analysis . Unable to support their analysis through use of data. Absence of any deduced aspects.	/ 25
Communication Skills suggested consideration point(s);	Very productive discussions and deep analyses.	Productive discussions and analyses.	Some discussions and analyses.	Little discussions and analyses.	Absence of a response, discussions or analyses	

• 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 faculty member?	Ideas were presented very clearly.	Ideas were presented clearly.	Ideas were presented some-what clearly.	Ideas were mostly unclear.	Ideas were not presented clearly.	/ 25
					[1]Total :	/ 100

[1]Normalised to 100%.

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 and PHMA 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 [PHMA 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.