Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2023/24	**Semester**	2
Course Coordinator	A/P Cesare Soci and Asst. Prof. Shen Yijie		
Course Code	PH2301		
Course Title	Physical Optics		
Pre-requisites	PH1105		
No of AUs	3 AU		
Contact Hours	PH2301 (2 hr – lecture; 1 hr – tutorial)		
Proposal Date	11 September 2023		

Course Aims

This course aims to equip you with the basic concepts and problem-solving skills in geometrical (ray) optics and physical (wave) optics. *Geometrical optics* will help you understand the basics of light reflection and refraction and the use of simple optical elements such as mirrors, prisms and lenses, to create more complex optical systems such as microscopes and telescopes. *Physical optics* will help you understand the phenomena of light wave propagation, interference, diffraction, and polarization, and the use of such devices as interferometers, anti- and high-reflection coatings, gratings, polarizers, and quarter-wave plates. These knowledge and skills lay the foundation for subsequent higher-level courses in photonics and applied physics and are very useful in the optical engineering and design profession.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, you will be able to distinguish between light rays and light waves and to:

Geometrical Optics (GO)

1. derive and explain the laws of geometrical optics from Huygens' or Fermat's principles;
2. analyse and solve problems on reflection, refraction, and total internal reflection;

Optical Instrumentation (OI)

3. explain the functionalities and mechanism of optical elements (e.g., lenses, prisms) and optical systems (e.g., magnifier, microscope, telescope, camera, the eye);
4. solve dispersion and imaging problems;

Matrix Methods in Paraxial Optics (MM)

5. combine matrices that represent individual translations, reflections and refractions to derive the system-ray transfer matrix of a given optical system;
6. analyze ray tracing of different optical systems involving lenses and mirrors and solve problems on geometrical optics;

Wave Equations and Superposition (WES)

7. solve problems for 1-D waves (such as phase velocity, group velocity, complex representations of waves, superposition and addition of waves);
8. analyze and solve problems on addition of waves of same and different frequency;
9. understand Maxwell's equations for describing electromagnetic or light waves;

Interference and Diffraction (INT)

10. apply the principle of superposition to derive the conditions for interference and solve problems involving interference (such as single and multilayer films);

Diffraction (DIF)

11. analyze and solve problems using conditions for Fraunhofer and Fresnel diffraction;

Polarization (POL)

12. explain the phenomenon of polarization (such as nature of polarized light and existence of different polarization states) and the working principles of optical devices (such as birefringence, phase retardation and optical activity);

13. analyze and solve problems on polarization (such as Brewster's angle and polarization by reflection or reflection from multilayer films using the transfer matrix formalism);
14. analyze and solve problems on polarization state transformation by Poincaré sphere and geometric phase.

Course Content

Part 1. GEOMETRICAL (RAY) OPTICS

Geometrical Optics (GO)
Huygens' and Fermat's principles
Reflection
Refraction
Total internal reflection

Optical Instrumentation (OI)
Mirrors
Thin lenses
Prisms
Optical systems (magnifier, microscope, telescope, camera, the eye…)

Matrix Methods in paraxial optics (MM)
The matrix system (translation, reflection, refraction)
Thick lenses
System-ray transfer matrix
Analytical ray tracing

Part 2. PHYSICAL (WAVE) OPTICS

Wave Equations and Superposition (WES)
One-dimensional wave equation
Harmonic waves
Phase and group velocities
Complex representation and phasors
Three-dimensional waves
Superposition principle and addition of waves
Maxwell's equations

Interference (INT)
Conditions for interference
Interference fringes
Double-slit experiment
Interference in dielectric films
Optical interferometry

Diffraction (DIF)
Fraunhofer diffraction
Diffraction grating
Fresnel diffraction

Polarization (POL)
Light polarization
Production of polarized light (by dichroism, reflection, scattering…)
Control of polarization (birefringence, optical activity, phase retardation…)
Matrix treatment of polarization (Jones vectors)
Poincaré sphere and geometric phase

Assessment (includes both continuous and summative assessment)

Component	ILO Tested	Weighting	Team/ Individual	Assessment Rubrics
1. Final Examination	All	60%	Individual	Point-based marking (not rubric-based)
2. CA1: Homework & Online Assessment	All	20%	Individual	Point-based marking (not rubric-based)
3. CA2: Mid-term Test	**GO** 1-2 **OI** 3-4 **MM** 5-6 **WES** 7-9	20%	Individual	Point-based marking (not rubric-based)
Total		100%		

Formative feedback

Formative feedback is given through discussion within tutorial lessons.

Formative feedback is given via the student response application Learning Catalytics where you are required to answer on your mobile devices' questions posted during lecture/tutorial. Feedback is always provided for your response to each question.

Feedback is also given after the midterm test on the common mistakes and level of difficulty of the problems. Past exam questions are made available for you.

Learning and Teaching approach

Approach	How does this approach support you in achieving the learning outcomes?
Use of Learning Catalytics (tutorial and lecture)	You are able to see how well your peers answer questions and thus understand your relative progress in comprehension.
Lectures	Warm-up questions will be raised first, followed by lectures that further explain the physics based on the questions. Then wrap-up questions will also be provided.
Tutorial	You will review main concepts learned in lectures with TAs. This helps you to digest and understand better.
Homework	The homework comprises standard textbook practice questions that are covered during tutorial.

Reading and References

Introduction to Optics, 3rd Edition, by Frank L. Pedrotti, Leno M. Pedrotti, and Leno S. Pedrotti. ISBN 10: 1108428266 / ISBN 13: 9781108428262, Cambridge University Press, 2017

Course Policies and Student Responsibilities

Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class / Mid-terms, you have to:

1. Send an email to the instructor regarding the absence and request for a replacement class and make-up mid-terms.
2. Submit the Medical Certificate* or official letter of excuse to administrator.
3. Attend the assigned replacement class (*subject to availability*) and make-up mid-terms.

* 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.

On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning.

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
A/P Cesare Soci	SPMS-PAP-03-03	65141045	csoci@ntu.edu.sg
Asst. Prof. Shen Yijie	SPMS-PAP-04-10	91616322	yijie.shen@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	ILO	Readings/ Activities
1	Geometrical optics	**GO 1-2**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 1 and Chapter 2
2	Optical instrumentation	**OI 3-4**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 3

3	Optical systems and the matrix system	**MM 5-6**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapters 3 and 19, Chapter 18
4	Wave Equations	**WES 7-8**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 4, Chapter 5
5	Superposition of waves	**WES 8-9**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 5
6	Electromagnetic waves	**WES 9**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 4, Chapter 25
7	Light rays and light waves	**GO-OI-MM-WES**	Mid-Term Test
8	Interference	**INT 10**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 7
9	Optical interferometry and Fraunhofer Diffraction	**INT 10** **DIF 11**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 8 and Chapter 11
10	Diffraction grating and Fresnel diffraction	**DIF 11**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 12 and Chapter 13
11	Polarization	**POL 12-13**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 14 and Chapter 15
12	Polarization	**POL 13-14**	Pre-lecture videos, Lecture Notes, Introduction to Optics by Pedrotti, Chapter 22 and Chapter 23
13	Revision	All	Lecture notes