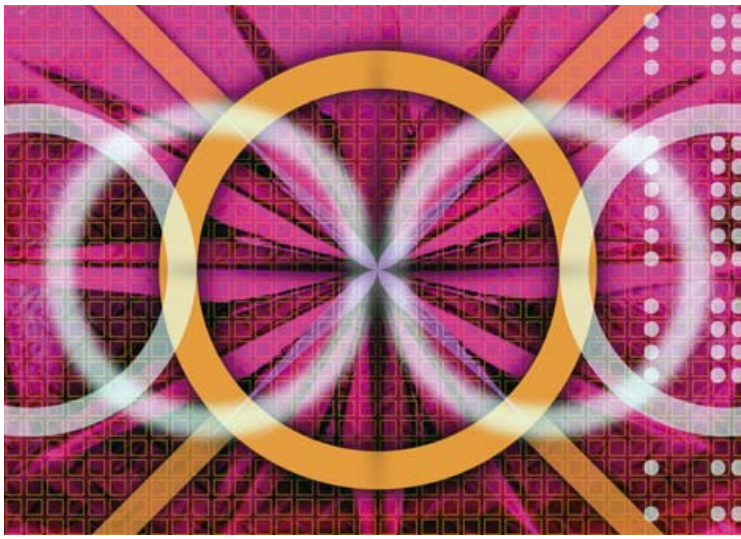
Geometrical Optics and Physical Optics

By Herimanda A. **Ramilison**



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NOTICE

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I. Geometrical Optics and Physical Optics

Herimanda A. Ramilison (This section is unnecessary and should be deleted)

II. Introductory Course or Basic Notions Required

To follow this module, the learner must master the following concepts:

Trigonometric equations, solution of first order equations with a single unknown variable, the concept of mirror images;

The fundamental principles of dynamics (vectorial representation of a force, graphical representation using a coordinates system);

General theorems of kinetic energy, angular momentum;

The following energy-related definitions: kinetic and potential energy stored in a capacitor, in a coil, mechanical or electrical (system?); (The highlighted in yellow is vague)

Ohm's Law (study of electronic oscillators);

The mesh or loop rule applied to an electrical circuit;

The potential difference at the terminals of a coil, a resistor and a capacitor;

Solution of the following differential equations: second order, linear, with constant coefficients, with or without a second variable;

Sinusoidal movements;

Complex representation of a sinusoidal magnitude with respect to time;

Fresnel vectors;

Partial derivative (differential?) equations.;

III. Timetable Distribution

Unit 1 Geometrical Optics : 50 hours
Unit 2 Oscillations : 15 hours
Unit 3 Waves: 15 hours
Unit 4 Sound waves : 10 hours
Unit 5 Interference of Light: 30 hours

IV. Teaching Material

Computer with CD-ROM, video projector, television, Internet access, word processor, Excel, PowerPoint…

V. Module Justification/Importance

The current module is part of a teacher training program.

It will enable the learners to understand what they see (rainbows, mirages…), comprehend how to improve vision (eyeglasses, a magnifying glass, a microscope, a telescope…).

To possess knowledge about vibratory or oscillatory movement relative to a common notion: waves. This module explains the fact that it is impossible to obtain a very narrow ray of light simply by decreasing the diameter of the exit point.

VI. Contents

6.1 Overview

In this module, the concept of light's behavior when reflected from the same medium or at the interface between two different media will be treated.

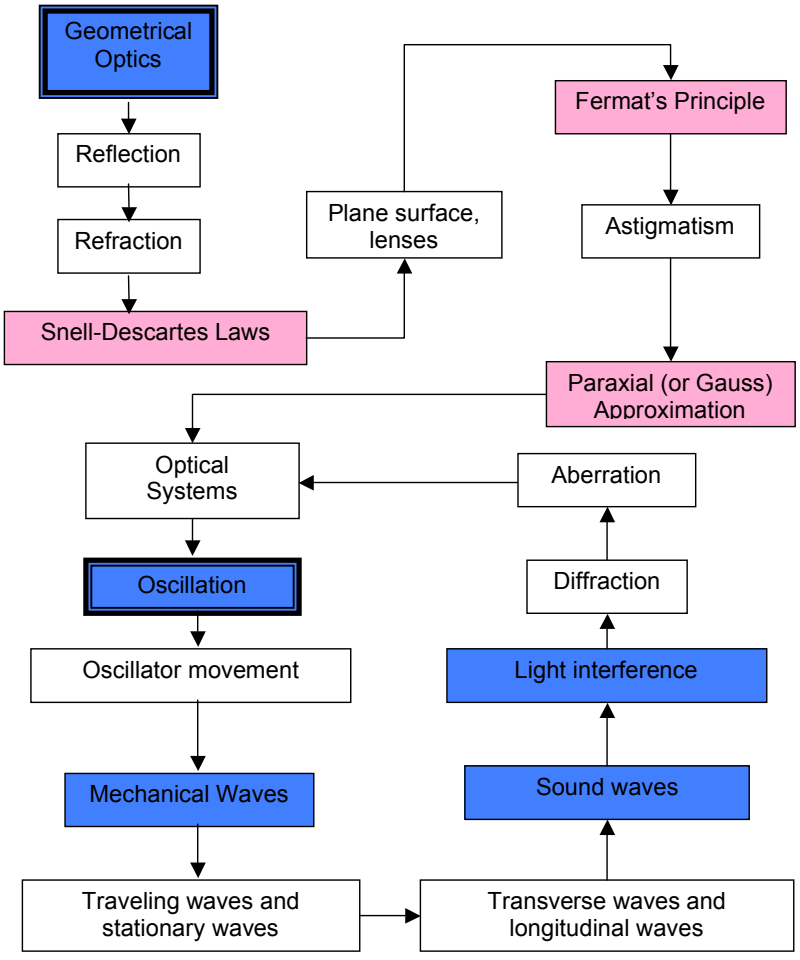
The construction of images obtained through optical systems and different types of lenses will be discussed. Certain optical systems will be presented in this module: the eye, a magnifying glass, a microscope, a telescope, a camera, along with the way they work by calculating focal lengths, magnification and vergency (optical power). The module explains the comprehension and correction of vision problems: farsightedness, nearsightedness.

The next step will be to explain essential wave-related concepts, along with the way they interact. The observation that the pitch of sound from a siren changes when the source or receiver or both moves will be elucidated. The concept of phase will allow the understanding of phenomena such as interference or diffraction when two apparently identical phenomena are superimposed.

The current module deals with:

- Reflection, refraction,
- Polarization, Brewster's Law,
- Plane mirrors, curved mirrors,
- Curved refractive surfaces,
- Thin lenses,
- Optical instruments,
- Harmonic oscillators,
- Standing waves and resonance,
- The Doppler Effect,
- Beats,
- The Superposition Principle,
- Light wave interference and diffraction.

6.2 Schematic Representation



VII. General Objectives

The learner must be able to :

Knowledge Goals

- Recall Descartes' Laws,
- Recall Brewster's Law,

Method Goals

Theoretical Abilities:

- Understand polarisation,
- Understand the functioning of optical systems,
- Understand oscillatory movement;
- Understand characteristic wave elements ;
- Understand wave superposition ;
- Understand the elaboration of a simple question ;
  (how will understanding be measured?)

Practical or Experimental Abilities

- In a team, demonstrate an experiment about reflection using a mirror, paper and needles ;
- Find the image of a real object using a converging lens ;
- Converse with colleagues by chatting online.(A social chat? Be specific)

VIII. Specific Learning Objectives (Learning Goals)

Unit 1 Geometrical Optics

Specific Knowledge Goals:

Recall Descartes' Laws;
Describe a thin lens using its definition;
Describe the optical components of a microscope;

Specific Theoretical Ability Goals:

Apply Descartes' Laws;
Apply the Paraxial Approximation;
Determine the focal length for a curved mirror,
Determine the focal length for a thin lens;
Determine vergency; (optical power)
Determine magnification;
Determine lens characteristics required to correct myopia;

Specific Practical Ability Goals

In a team, carry out the reflection experiment using a mirror, paper and needles;
Experimentally determine an object's image through a thin lens;
Build an object's image using a combination of several thin lenses
Build an image for a farsighted person;

Unit 2 Oscillations

Specific Knowledge Goals:

Recall the definitions for oscillatory movement characteristics;

Specific Theoretical Ability Goals :

Determine the characteristic elements of oscillatory movement;
Use the equations related to oscillations;

Unit 3 Waves and Sound Waves

Specific Knowledge Goals:

Recall the definitions for wave characteristics;
Recall sound wave equations

Specific Theoretical Ability Goals:

Identify the different wave types;
Explain energy transfer;
Apply the wave equation to sound;
Explain the nature of the decibel scale;
Describe sound waves emitted from a point source;
Explain the effects of relative movement between sources of sound

Unit 4 Light Interference

Specific Knowledge Goals:

Recall the conditions needed to produce interferences;

Specific Theoretical Ability Goals:

Identify interferences by wave front division;
Identify interferences by amplitude division;
Explain the effects of superposition;
Explain diffraction.

Optional Educational Objective:

Create a short question
TIC integration (Specify what TIC means)
Communicate via the Web (What is the specific reason for this?)

IX. Teaching and Learning Activities

9.1 Preliminary / Initial Evaluation

Preliminary Evaluation Title

Geometrical Optics and Physical Optics

Justification

This consists of finding out what the learner already knows about optics and waves.

QUESTIONS

1. The mirror image of a point A is point A', which can be observed by any observer O if all the beams reflected by the mirror M from A seem to come from point A'.

   a. True
   b. False

2. A lens is a centered system made up of a …….. homogenous and …… medium and restricted by two ……. surfaces with radii R_1 and R_2, respectively.

   Fill in the blanks with one word each.

3. Match up the following columns by associating the right letter and number together: (each formula describes one of the concepts)

a. Vergency (optical power)	1. $\frac{\lvert A'B' \rvert}{\lvert AB \rvert}$ ($\lvert A'B' \rvert$ = *image length*) ($\lvert AB \rvert$ = *object length*)
b. Magnification	2. $\frac{\alpha'}{\alpha}$ (*image apparent diameter*) (*object apparent diameter*)
c. Enlargement	3. $\frac{1}{f}$

4. A magnifying glass is used to:

   a. decrease the apparent diameter of an object's image compared to the object as seen by the naked eye.
   b. enlarge the apparent diameter of an object's image compared to the object as seen by the naked eye.
   c. shift the apparent diameter of an object's image compared to the object as seen by the naked eye.

   Check off the right answer(s).

5. Observing a solar eclipse with a magnifying glass:

   a. can cause blindness
   b. can cause short-sightedness
   c. can cause far-sightedness
   d. is not harmful

   Check off the right answer(s).

6. A plane mirror has a surface that is

   a. flat,
   b. curved,
   c. transparent,
   d. polished,
   e. reflective.

   Check off the right answer(s).

7. In a plane mirror, the image of an object is:

   a. reversed
   b. upside-down
   c. superimposable onto the object

   Check off the right answer(s).

8. With a converging lens, the image of an object is:

   a. real
   b. virtual

   Check off the right answer.

9. If the height of the waves in relation to sea level is 2 meters, their amplitude is:

   a. 1 meter
   b. 2 meter
   c. 4 meter

   Check off the right answer.

10. If the matter is moving in a direction that is parallel to the wave's direction of propagation, the wave is said to be:

    a. traveling
    b. stationary
    c. longitudinal
    d. transverse

    Check off the right answer(s).

11. If the matter is moving in a direction that is perpendicular to the wave's direction of propagation, the wave is said to be:

    a. traveling
    b. stationary
    c. longitudinal
    d. transverse

    Check off the right answer(s).

12. Two waves with the same frequency are superimposed; constructive interference is obtained when the phase difference is:

    a. 0 b. $\frac{\pi}{2}$ c. π

    Check off the right answer(s).

13. Two waves with the same frequency are superimposed; destructive interference is obtained when the phase difference is :

    a. 0 b. $\frac{\pi}{2}$ c. π

    Check off the right answer(s).

14. The sound of an ambulance's siren as it approaches:

    a. does not change
    b. becomes more high-pitched
    c. becomes more low-pitched

    Check off the right answer.

Preliminary Evaluation Title

Geometrical Optics and Physical Optics

Answer key

1.

a. Good answer. You certainly know how to construct the image of an object through a mirror.
b. Be careful, take your time to answer.

2. A lens is a centered system made up of a **transparent**, homogenous and **isotropic** medium restricted by two **curved** surfaces with radii R_1 and R_2, respectively.

Very good. You understand the definition of a lens.

If the student switches certain words by writing isotropic instead of transparent, for example, give the following feedback: You've confused isotropic and transparent, please try again.

If the student writes transparent instead of curved, give the following feedback: You have confused transparent and curved, please try again.

3.

a3. Good combination. The expression truly is the vergency (optical power) formula.
b1. Good job. The formula really is the one that describes magnification.
c2. Good answer. This equation is used to determine enlargement.

4.

a. Try again. You most likely have never used a magnifying glass.
b. Good job, you know what a magnifying glass does.
c. Careful, a magnifying glass doesn't have that role.

5.

a. Congratulations. You have understood that you must never look at a solar eclipse with a magnifying glass.
b. It's stronger than myopia.
c. It's more acute than far-sightedness.
d. Watch out, a magnifying glass does indeed damage the eye.

6.

a. Good job. A plane mirror's surface is indeed flat, just like its name suggests.
b. Careful. Why curved?
c. Do you know what transparent means?
d. Good answer. A plane mirror's surface must be polished.
e. Very good. In fact, a plane mirror's surface must be reflective or we would not be able to see our reflection.

7.

a. Good answer. You noticed that right and left are switched around.
b. Certainly not ; the head is not on the bottom with the feet on top is it ?

8.

a. Very good. The image truly is real.
b. Why virtual? It is not a diverging lens.

9

a. Sea-level must not be below the height of the waves.
b. Good answer; average sea-level is the same as the height of the waves.
c. Sea-level cannot be twice the height of the waves.

10.

a. Try again.
b. Careful, most definitely not stationary.
c. Congratulations. The wave that is moving in a direction that is parallel to the direction of propagation is indeed called longitudinal.
d. Take your time, a transverse wave travels perpendicularly to the direction of propagation.

11.

a. Try again after rereading the question
b. Careful, most definitely not stationary.
c. A longitudinal wave travels parallel to the direction of propagation. Try again.
d. Good job. If the wave is moving perpendicularly to the direction of propagation, it is called transverse.

12.

a. Good answer. The interference will be constructive.
b. Give it some thought before answering.
c. Read the question again. The two waves are not opposed to one another.

13. Two waves with the same frequency that have a phase difference of will produce a destructive interference.

a. Careful, the two waves are out of phase.

b. Careful, what does a phase difference of $\frac{\pi}{2}$ remind you of?

c. Good answer. In this case, the interference is destructive since π represents opposing phases.

14. The sound of an ambulance's siren is more high-pitched as it approaches.

a. Careful, the sound cannot keep the same pitch as the ambulance is moving.

b. Good job. The siren's sound does indeed become more high-pitched as the ambulance gets closer.

c. Most certainly not, try again.

Preliminary Evaluation Title

Geometrical Optics and Physical Optics

Educational comments for the learner

If you have obtained over 75 %, your interest in optics is obvious. I encourage you to continue on with this work since I am convinced that we will be able to work very well together. You will see that studying optics is a very fascinating field.

You have between 50 % and 75 %, you result is very promising, optics are not unknown to you. We will have lots of work to do throughout this course. I can assure you that you have chosen a very fascinating subject. Good luck.

You have between 35 % and 50 %, which of course is not perfect. Yet I feel that you are truly willing to succeed in this field, and we are going to need that will power. To be honest with you, the field you have chosen is very fascinating, but it takes a lot of work. To begin with, there will be a certain amount of catching up for you to do. That will be the condition for us to achieve success.

You have obtained less than 35 %. You have lots of work ahead of you, since in addition to the current module you will have to review your previous optics courses.

X. Key Concepts (Glossary)

1. **Amplitude**: The scalar measurement (a coordinate) of a positive number that describes the magnitude of a wave's oscillation compared to its average value.
2. **Diffraction**: A wave's behavior when it comes across an obstacle that isn't perfectly transparent to it. (This definition can be made more precise)
3. **Boundary**: The surface between two transparent media. The rays remain rectilinear through a homogenous and isotropic medium; they are deviated when they cross a boundary or when they meet a reflective surface.
4. **Interference**: A phenomenon caused when waves meet.
5. **Wavelength**: The distance between two successive peaks or troughs on a periodic wave. (You may generalize this by noting that iy is the repeat distance of a point on a wave)
6. **Wave**: The propagation of a perturbation that creates reversible local physical property variations as it passes by. Since the perturbation's intensity can be simulated using energy, a wave can be described as the transportation of energy without the transportation of matter. A wave is described by a function A($\vec{x}$,t), $\vec{x}$ being its position in space (vector) and t being time. (tidy up the highlighted so that they are properly aligned)
7. **Polarization**: A property of vectorial waves, like light. The fact that these waves are described by vectors helps to differentiate them from other types of waves, like sound waves, and implies the presence of the polarization phenomenon. (This definition could be made more precise by using standard textbooks or physics dictionary)
8. **Reflection**: A wave's sudden change of direction at the interface between two environments. After being reflected, the wave remains in its initial propagation environment. (This definition does not distinguish reflection from refraction which also involves change in direction. Combine the two sentences)
9. **Refraction**: The deviation of a wave as it crosses from one medium to another. Generally speaking, refraction is the result of a medium's change in impedance (acoustic impedance?), where a wave's speed will change between two media.
10. **Astigmatism**: A system is said to be *rigorously stigmatic* when all of the rays coming from a single point (an isogenous source) and going through the system all have converging supports (Vague translation. Use of Physics dictionary would help in the definition) .