

COURSE / UNIT STUDY GUIDES

SPH 103 : WAVES AND OPTICS

Lecturers:

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Introduction to the Course unit

The course comprises three parts: Waves, Geometrical Optics and an Introduction to Wave optics.

A wave is a disturbance that transfers energy from one point to another without imparting net motion to the medium through which it propagates. Many examples of waves and oscillations seen in our daily lives will be given. The concepts such as displacement, velocity, acceleration, and energy are used to describe mechanical waves.

The first part of the course begins with a brief study of periodic vibrations (simple harmonic motions) and continues with a systematic study of waves: wave motion, wave equation, propagation of elastic waves in a solid and in a spring; harmonic waves and their properties, superposition principle for waves, interferences of waves, standing waves in a string and column of air; the classical and relativistic Doppler Effects.

In the second part of the course/unit, we state and use the Huygens' and the Fermat's principles to derive the laws of reflection and refraction. A systematic study of spherical mirrors, thin lenses and optical instruments is done.

In the last part of the course/unit, we use the Huygens' Principle to briefly describe the phenomena of interferences and diffraction of light.

Aims: The course aims at enhancing students' knowledge in the areas of waves and optics.

Specific objectives: At the end of the course the student should be able to:

1. Describe the simple harmonic motion, the damped harmonic motion, forced vibrations and resonance;
2. Define the concept of wave and give examples of the main categories of waves;
3. Describe the wave motion and the properties of the main categories of waves;
4. Derive the one – dimensional wave equation;
5. Describe the propagation of elastic waves in a solid rod and in a spring and solve related exercises/ problems;

6. Describe harmonic waves;
7. State the Principle of Superposition for Waves and use it to explain the phenomena of interference of waves and standing waves;
8. Explain the concepts of sound intensity, beats, and shock waves;
9. Describe standing waves on a string and in a vibrating column of air and solve related exercises / problems;
10. Describe the three characteristics of a sound;
11. Explain the Doppler effect for sound and light waves and solve related exercises/ problems;
12. By using the Huygens' principle derive geometrically the laws of reflection and refraction of light waves;
13. State the Fermat's principle and use it to derive the laws of reflection and refraction of light;
14. Derive the mirror and thin – lens equations and use them to solve various exercises/problems;
15. Use algebraic and graphical methods for analyzing image formation in spherical mirrors and thin lenses;
16. Describe the main optical instruments and give their main performances and limitations;
17. Explain the concepts of magnification and resolving power of some optical instruments.

SPH 103: Course outline

1. **The Simple harmonic motion, the damped harmonic motion, forced oscillations and resonance;**
2. **Wave motion:** definitions and examples of waves, description of wave motion, general equation of wave motion, transverse and longitudinal waves, superposition of waves, phase velocity and group velocity , standing waves on a string and in a vibrating column of air, resonance, energy and information transfer by waves
3. **Propagation of waves in different media:** elastic waves in a spring and in a solid rod, pressure waves in a column of gas, transverse waves on a string, longitudinal elastic waves in a bar, longitudinal waves in a column of gas, surface waves in a liquid.
4. **Waves in two dimensions:** Wavefronts; Huygens' principle; reflection and refraction of waves;
5. **Sound waves:** Vibrating systems and sources of sound: vibrations of air in pipes open at one end or both ends; acoustics: the characteristics of a sound (quality, pitch and loudness). stringed instruments; beats.
6. **The Doppler Effects** for sound waves and for electromagnetic waves;
7. **Fermat's principle :** statement, use of the principle to derive the laws reflection and refraction, total internal reflection;
8. **Reflection at the surface of a spherical mirror:** types of mirrors, locating images by ray tracing, mirror equation; applications.

9. **Thin lenses:** types of lenses, locating images by ray tracing, thin - lens formula, lens aberrations, the prism - dispersion;

10. **Optical Instruments:** the human eye, magnifying glass, compound microscope, telescope; the magnification and resolving power of optical instruments.

Assessment: Assessment of the course shall comprise two CATs given a total of 30 marks and a Final Exam marked out of 70 marks

REFERENCES

1. JONES, E. & CHILDERS (1999). *Contemporary college Physics (3rd ed.)*. The McGraw – Hill Companies, Inc., N.Y.
2. HALLIDAY, D., RESNICK R. & KRANE, K. *Physics, Vol. 2., 5th Ed.* John Wiley & Sons, inc. N.Y.
3. Jenny S. O'LEARY & Nakudukuru L. Das (1993). *Physics I*. Nairobi University Press.
4. Frank L. PEDROTTI, S. J. & Leno S. PEDROTTI (1993). *Introduction to Optics (2nd Edition)*. Pearson Education, Inc., Pearson Prentice Hall, N. J., USA.
5. Frank L. PEDROTTI, S. J., Leno M. PEDROTTI, and Leno S. PEDROTTI (2007). *Introduction to optics (3rd Edition)*. Pearson Education, Inc., Pearson Prentice Hall, N. J., USA.

pressure waves in a column of gas, transverse waves on a string, transverse elastic waves in a bar, longitudinal waves in a column of gas, surface waves in a liquid.

4. **Waves in two dimensions**: Wavefronts; Huygen's principle; reflection of waves; refraction of waves; (reflection and transmission of waves at interface);

5. **Sound waves**: Vibrating systems and sources of sound: vibrations of air in pipes open at one end or both ends; stringed instruments; beats; the Doppler Effect for sound waves; acoustics: the characteristics of a sound (quality, pitch and loudness).

Part II: Optics

11. **Introduction to waves optics: interference of light and Fraunhofer diffraction.**

12. **Approximations of geometrical optics**: ray model of light and the formation of images.

13. **Fermat's principle** : statement, use of the principle to derive the laws reflection and refraction, total internal reflection, the Doppler effect for light (relativistic

Doppler effect) ;

4. **Aplanatic points and aplanatic surfaces for reflection and refraction; application of aplanatic points on a spherical surface;**

5. **Reflection at the surface of a spherical mirror**: types of mirrors, locating images by ray tracing, mirror equation;

6. **Thin lenses and lens aberrations**: types of lenses, locating images by ray tracing, thin lens formula, lens aberrations, the prism - dispersion;

7. **Optical instruments**: the human eye, magnifying glass, compound microscope, telescope.

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