Study Guide on Christiann Huygens' *Treatise on Light*

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OUTLINE

Chapter 1 introduces the theory of light as a wave and what is now known as "Huygens' Principle." The remaining chapters explore how these concepts can be applied to reflection (Chapter 2), refraction in most transparent objects (Chapter 3), refraction in air (Chapter 4), birefringence in calcite crystal (Chapter 5), and geometries for focusing optics, such as lenses (Chapter 6). Another division of the work follows theoretical versus practical content. Chapters 1-3 cover more general principles of optics while Chapters 4-6 concern the practical application of these principles. If there is only time for an abridged reading, Chapters 1-4 are recommended. The inclusion of Chapter 4 with the theoretical content provides a short, 6-page example of the extension of the theory of refraction to observed atmospheric phenomena.

Chapter I. "On Rays Propagated in Straight Lines" (p.6 – 28):

- Light is proposed as a wave produced via the successive motion of particles.
- Huygens considers whether the speed of light is infinite or finite.
- He discusses the mechanics of the motion of the particle collisions composing these waves, drawing analogies to sound.
- He later introduces what is now called "Huygens' Principle," which states that each point in a wavefront acts as a new source for the successive wavefront.

Chapter II. "On Reflexion" (p. 29 – 34):

- Huygens provides two proofs of the Law of Reflection (i.e. the angle of incidence equals the angle of reflection off of a surface) in two-dimensional and three-dimensional space.

Chapter III. "On Refraction" (p. 35 – 51):

- Huygens gives three explanations of how particles of ether penetrate solids and an explanation for why some objects are transparent and others are not.
- The ratio of the sines of the angles of the incidence and refracted ray (a.k.a. Snell's Law) for light entering and exiting a material is derived from Huygens' Principle.
- Huygens explains why reflection within a material is enhanced with a slight change in angle (a.k.a. total internal reflection)
- He demonstrates that light takes the path of least time between two points under his wave theory.

Chapter IV. "On the Refraction of the Air" (p. 52 – 58):

- Huygens summarizes phenomena in which objects do not appear as they ought to if light traveled in a straight line because of the density of or amount of moisture in air.
- He applies his wave theory to the situation of an observer looking at a tower and light from the Sun hitting the Earth.

Chapter V. "On the Strange Refraction of Iceland Crystal" (p. 59 – 109):

*This chapter is broken into 43 articles followed by unenumerated material

- Huygens summarizes the material properties of the Iceland crystal, which is today known as calcite (Articles 1 – 5).
- He describes the two different refractions that occur when light passes through the crystal. This property is now called birefringence (Art. 6 – 17).
- A modification to the spherical waves used earlier is proposed. Here, Huygens considers spheroidal waves propagating in calcite and explores their various geometric properties and derives the observed reflection and refraction angles (Art. 18 – 38).
- He discusses the phenomenon of double images when looking through the crystal and explaining this as a result of the refractive properties previously explored (Art. 39 – 43).
- He then provides additional explanations of refraction along other axes of the crystal and the methods by which he cut and polished the surfaces.
- Some observations of the unexplained refractive behavior of light passing through two separate crystals are detailed.
- Huygens proposes the material structure of the crystal based on his observations.
- Some geometric calculations that were assumed earlier in the chapter are worked out at the end.

Chapter VI. "On the Figures of Transparent Bodies: Which serve for Refraction and for Reflexion" (p. 110 – 132):

- Huygens determines the shape of optics needed to focus light from one point to another via the wave theory account of refraction and reflection.
- He employs a similar analysis for when one of the points is infinitely far away (parallel rays).
- Huygens then considers other "ovals" found in Descartes' *Dioptrics*.
- These principles are generalized to other kinds of curves.
- Huygens describes refraction and reflection in a glass sphere.

GLOSSARY OF TERMS

1. **Aquafortis**: Nitric acid
2. **Cycloid**: A mathematical curve generated by tracing a point on the circumference of a circle as it is rolled along a straight line
3. **Diaphanous**: translucent

4. **Quicksilver**: mercury
5. **Ratio of the Sines**: Snell's Law
6. **Rock Crystal**: quartz
7. **Toise**: an old French unit of distance. One toise corresponds to 6 feet.

QUESTIONS ON THE WHOLE WORK

1. Huygens proposes the propagation of light waves as compression waves similar to sound, relying upon the collision of atoms (or small composite bodies) to mediate these waves. He even goes so far as to say that "[i]t is inconceivable to doubt that light consists in the motion of some sort of matter" (9). In what sense does this theory rely upon an atomistic view of matter? Does a wave theory for light require the existence of atoms?
2. The other principle of Huygens' theory of light posits that a wavefront is composed of infinitely many smaller wavefronts combined simultaneously at a point. Can this geometric argument be reconciled with the atomistic view of wave propagation?
3. What properties of the "Ether" are necessary for it to function as Huygens describes?
4. What are Huygens' reasons for proposing the existence of the "ethereal matter" even though he proposes a theory of transparency without it (35)?
5. In Chapter V, Huygens devotes several pages to the material properties of the Iceland Crystal. How relevant are a material's properties to the study of optics?

QUESTIONS ON THE OUTLINED PARTS

Chapter I:

1. Does the notion that light is the motion of matter imply that it has finite speed? Is Huygens correct to say that to hold the contrary is "incomprehensible?"
2. The figure on page 24 is drawn by Huygens to illustrate how "infinitely feeble" waves can form a single wavefront. One frequent critique of Huygens' principle is that it does not distinguish between forward and backward propagation of waves. What further information would be needed to know that the wave is traveling forwards? Consider Huygens' discussion on page 20.

Chapter III:

1. How does the propagation of light differ for each "mode" of transparency proposed?
2. Why does Huygens' include a proof for light traveling according to the path of least time? Does it support his geometric theory for light?

Chapter V:

1. Why does Huygens propose that the Iceland Crystal is composed of spheroidal particles?
2. Consider the remarks on page 103. Does Huygens adequately explain the physical cause of the spheroidal waves in the Iceland Crystal?

Chapter VI:

1. On page 111, Huygens suggests that the shapes of the optical figures he details in the chapter "further confirm our Theory of refraction." Is a theory confirmed or supported by its applications? How should one understand this remark?