Subject: **Precision Optics II** Grade: 10-11 Unit #: 1 Title: **Lens Function & Design**

UNIT OVERVIEW: Students are introduced to the nature of light, glass, and the interplay between the two in order to understand how optical elements are designed and assembled together to create quality images. Students will understand optics and engineering content, which is embedded throughout the year, so that students build on the fundamentals of advanced manufacturing processes learned in Precision Optics I. Students develop habits of mind and skills necessary to manufacture, test, and evaluate a finished good, based on customer specifications.

STAGE ONE: Identify Desired Results

Established Goals/Standards

Established Goals (CDOS)

Standard 1: Students will be knowledgeable about the world of work […] and relate personal skills, aptitude and abilities to future career decisions.

Standard 2: Students will demonstrate how academic knowledge and skills are applied in workplace and other settings.

Standard 3a: Students will demonstrate mastery of the foundation skills and competencies essential for success in the workplace.

Standard 3b: Students who choose a career major will acquire the career specific technical knowledge/skills to progress toward gainful employment, career advancement and success in postsecondary programs.

Long-Term Transfer Goal

At the end of this unit, students will use what they have learned to independently… examine ray diagrams for several optics systems and evaluate and compare the predicted image quality created by each optic with special attention paid to the type and severity of first order aberrations. Students will construct an illustrated essay. This essay will indicate the student's level of understanding about how lenses are designed to control light.

Meaning

Enduring Understandings

Students will understand that…

- *Optics is the science of controlling light.*
- *Simple rays are used by engineers and lens designers to illustrate the path of light through an optic.*
- *The performance of a lens (system) depends on each lens' shape, orientation, glass type, and alignment within the system.*
- *Real lens systems are designed to minimize deviations from ideal, but every system creates images with some degree of aberration.*

Essential Questions

Students will consider such questions as…

1. How do we choose the right optic to make light do what we want?
2. Why does curve and composition of the glass matter?
3. What can we "get away with" when designing optics?
4. How do optical designers maximize the performance of an optical system?

Acquisition

What knowledge will students learn as part of this unit?

- *Light is a packet of massless radiant energy that travels, in a vacuum, at the cosmic speed limit, c. c = 300,000,000 m/s = 786,000 mph, 7.5 times around the Earth/s, to the moon in 1.3 seconds. A single packet is called a photon.*
- *The Electromagnetic Spectrum is the array of photon types organized by wavelength, energy, or frequency. Visible light is a narrow band within this array.*
- *Law of Reflection at air-glass boundaries.*

What skills will students learn as part of this unit?

- Identify a lens as positive or negative and convex or concave or meniscus.
- Use the lens maker's equation to predict the focal length of a lens based on its radii of curvature and index of refraction.
- Using ray diagrams to predict the location of best image for a given lens.
- Identify aberration type based on analysis of marginal, paraxial, and chief ray intersections.

		• *Law of Refraction (Snell's Law) at air-glass boundaries.* • *Index of refraction is a measure of a glass's optical density and degree to which it can bend light.* • *The lens maker's equation ($\phi = [n-1][1/R_1 - 1/R_2]$) is used to determine a theoretical focal length of a lens based on the radii of curvature and index of refraction.* • *Dispersive index is a measure of a glass's ability to diffract light differently according to color (dispersion).* • *A glass map is a 2-D organization of glass types according to index of refraction (at 589.3 nm) and dispersive index.* • *Positive lenses cause light to converge. Negative lenses cause light to diverge.* • *Lenses can be convex, concave or meniscus.* • *Optical engineers use ray diagrams to describe the motion of light through an optical system.* • *Marginal, paraxial, and chief rays are drawn to show different aspects of light's motion through an optical system.*	

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STAGE TWO: Determine Acceptable Evidence

Evaluative Criteria	Assessment Evidence
(T) Examine a series of ray diagrams for different lens systems and compare/comment on the predicted quality of each lens' image. 1. (A) How completely does the student know the EM spectrum? 2. (A/M) How well can a student characterize what happens when rays of light strike a plane surface? 3. (A/M) How well can a student characterize what happens when rays of light strike a curved surface? 4. (A) How well can a student ID a lens type and function based on its shape? 5. How well can a student interpret a glass map? 6. (A) How completely can a student manipulate the lens maker's equation to predict the power and focal length of a given lens? 7. (M) How well can a student identify aberrations based on ray diagrams? 8. (T) How effectively can a student weigh pros and cons to determine the best fix for a given aberration? 9.	Performance Tasks: **Characterize the elements in an optical system and evaluate the design choices based on the types of aberrations that exist in a ray diagram sketch.** Other Assessment Evidence: 1. EM spectrum inventory. **[What is light?]** 2. Snell's Law & reflection experiment with rectangular prisms. **[How does light interact with matter]** 3. Snell's Law experiment and light through concave and convex prisms. **[How does light interact with matter?]** 4. Illustrated Essay #1: What happens when light hits an air-glass boundary? 5. Lens shape and lens function identification worksheet. **[Why does curve matter?]** 6. Dispersion demo & glass map interpretation assignment. **[Why does composition matter?]** 7. Lens Maker's Equation worksheet and Excel spreadsheet. **[Why does curve & composition matter?]** 8. Ideal Ray Diagram reading and questions. **[What can we get away with when designing optics?]** 9. Real Ray Diagrams & Lens Aberrations interpretation worksheet. **[What can we get away with when designing optics?]** 10. Lens aberrations corrections worksheet. **[How do optical designers maximize the performance of an optical system?]** 11. Illustrated Essay #2: What variables impact image quality and what choices determine the final lens design? **[What can we get away with when designing optics?]**

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Code	STAGE THREE: Plan Learning Experiences	
	Learning Events:	Evidence of learning: *(formative assessment)*
A	1. Investigating the EM spectrum: interactions between light and matter.	1. Analyze a situation and identify the type of EM radiation at play.
A	2. Light's journey from air into and out of glass: What happens at the boundaries and in the bulk?	2. Qualitatively predict the path of light from air into glass and back into air **and** predict light's path when it reflects at a surface.
A/M	3. Law of Reflection & Snell's Law 'plane' experiment.	
A/M	4. Law of Reflection and Snell's Law 'curved' experiment	
M	5. Identifying a lens type based on shape.	3. Accurately discuss and illustrate the principle of dispersion and the dispersive index of glass.
A	6. Fill in the box "before and after" light beams.	
M	7. Experiencing the dispersion of white light through prisms.	4. Correctly identify glass types based on refractive and dispersive indices.
A/M	8. Reading and interpreting a Schott Glass Map and glass codes.	
A	9. Comparing and contrasting two optical glass types.	5. Comparing and contrasting properties of two glass types from given glass codes.
A/M	10. Lens Maker's Equation by hand and with Excel.	
M	11. Ideal Ray Diagram reading.	6. Calculate lens power and focal length from curvature and glass code.
A	12. Real Ray Diagrams lecture.	
M	13. Introduction to lens aberrations.	7. Match the change in light ray paths with the appropriate lens shape.
A/M	14. Correcting lens aberrations.	
T	15. Evaluating lens choices based on aberrations.	8. Match the correct aberration with ray diagram.