A Guide to Geometric Optics

Teaching Approach

In this series we explain geometric optics. These lessons have been designed to be used as a teaching tool, either as individual lessons or as a series, or they can be used as a revision tool. This series revises previous knowledge on reflection in plain mirrors. The series then investigates refraction and the refractive index. Snell's Law is covered. Finally total internal reflection and the critical angle are discussed. We also explain the uses of total internal reflection. In the series refraction and total internal reflection is practically demonstrated. Ideally, similar demonstrations should be done in class and the students should be allowed to make conclusions of their own, but if this is not possible, the demonstrations in these lessons can be used.
Video Summaries

Some videos have a ‘PAUSE’ moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given.

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day’s lesson; if desired, learners can be given specific questions to answer in preparation for the next day’s lesson

1. Revision of Reflection of Light
   In this lesson we revise reflection and reflection in plane mirrors. The law of reflection is stated.

2. Introduction to Refraction
   In this lesson we look at how light is refracted as it moves from one medium to another. This is demonstrated with the use of objects in a swimming pool, and analysing ray diagrams. Refraction is defined.

3. Measuring Refraction of Light
   Light refraction is investigated. Refraction is related to optical density. The normal, optical density, angle of incidence, and refraction are defined. A ray diagram is used to show the path of light rays through different media.

4. Refractive Index
   The refractive index is defined. Speed of light is constant in a medium with a maximum value in a vacuum. Refractive index is related to optical density. Calculations are done to calculate refractive index.

5. Snell’s Law
   In this lesson Snell’s law is stated and explained. Snell’s law was used to calculate the angle of refraction. It is shown that the sizes of the angles of incidence and refraction are related to the speed of the light through the medium.
6. Total internal reflection
   In this lesson total internal reflection is practically demonstrated. The critical angle is explained and the conditions required for total internal reflection are listed. Ray diagrams are also used to explain this.

7. Applications of Total Internal Reflection
   In this lesson we use Snell’s Law to calculate the critical angle. Optical fibres are introduced and their uses in medicine and telecommunications are explained.
## Resource Material

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<th>Resource</th>
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<td><strong>1. Revision of Reflection of Light</strong></td>
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<td><strong>4. Refractive Index</strong></td>
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<td>8. Applications of Total Internal Reflection</td>
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Task

**Question 1**
State the law of reflection.

**Question 2**
Explain the meaning of the following terms:
1.1. Angle of incidence
1.2. Angle of refraction
1.3. Normal

**Question 3**
Make a labelled sketch of a refracted ray passing through a rectangular glass block.

**Question 4**
What is the speed of light in a vacuum?

**Question 5**
The speed of light in ice is $2.29 \times 10^8 \text{ m} \cdot \text{s}^{-1}$. Calculate its refractive index.

**Question 6**
Write the equation that is Snell’s Law.

**Question 7**
Calculate the angle of refraction when light passes from glass (\(n_{\text{glass}} = 1.52\)) to a vacuum with an angle in incidence of $35^\circ$.

**Question 8**
What is a critical angle?

**Question 9**
A beam of light passes from ice into air. Calculate the critical angle for light passing from the ice (\(n_{\text{ice}} = 1.31\)) to the air.

**Question 10**
List the conditions for total internal reflection.

**Question 11**
Explain the concept of total internal reflection.

**Question 12**
Use your knowledge of total internal reflection to explain how a periscope using glass prisms works. Draw a ray diagram.
Task Answers

Question 1
The angle of incidence equals the angle of reflection.

Question 2
2.1 The angle of incidence is the angle between the direction of the incident ray and the normal.
2.2 The angle of refraction is the angle between the direction of the refracted ray and the normal.
2.3 The normal is a line draw at right angles to the boundary surface.

Question 3

Question 4
3 \times 10^8 \text{ m} \cdot \text{s}^{-1}

Question 5
\begin{align*}
v_{\text{ice}} &= 2.29 \times 10^8 \text{ m} \cdot \text{s}^{-1} \\
c &= 3 \times 10^8 \text{ m} \cdot \text{s}^{-1} \\
n &= \frac{c}{v} \\
 &= \frac{3 \times 10^8}{2.29 \times 10^8} \\
 &= 1.31
\end{align*}

Question 6
\begin{align*}
n_1 \sin \theta_1 &= n_2 \sin \theta_2
\end{align*}

Question 7
\begin{align*}
n_1 \sin \theta_1 &= n_2 \sin \theta_2 \\
n_1 &= 1.52 \\
\theta_1 &= 35 \\
n_2 &= 1 \\
\theta_2 &= ?
\end{align*}

\begin{align*}
1.52 \sin 35 &= 1 \sin \theta_2 \\
\text{Therefore, the angle of refraction } \theta_2 &= 60.67^\circ
\end{align*}
**Question 8**
A critical angle for two media is the angle of incidence that results in an angle of refraction of 90° when light travels towards the medium of lower optical density.

**Question 9**
\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
\[ n_1 = 1,31 \]
\[ n_2 = 1 \]
\[ \theta_1 = ? \]
\[ \theta_2 = 90° \]
so
\[ 1,31 \sin \theta_1 = 1 \sin 90 \]
Therefore, the critical angle \( \theta_1 = 49,76° \)

**Question 10**
Light must travel towards a transparent medium with a lower refractive index (or optical density) and the angle of incidence of the light must be larger than the critical angle of the media.

**Question 11**
This is when all the incident light on a boundary is reflected back into the medium from which it came.

**Question 12**
The incident light from the object travels straight through the first boundary of the right angled prism, then undergoes total internal reflection and is reflected down the periscope. Here the exact same process occurs but in the opposite direction, and the image is seen by the observer.
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