### Critical Learning
- The behavior of light depends on the materials with which it interacts.
- Characteristics of images found in mirrors can be represented in a ray diagram.
- The fundamental concept of structure and function focuses on the relationship between the function of a human-made object and the form that the object takes.

### Guiding Questions
- How does light behave when it interacts with a plane mirror?
- How can a ray diagram represent the characteristics of an image formed when light reflects from the surface of a plane mirror?

### Curriculum Expectations

#### Scientific Investigation Skills and Career Exploration

**A1.** Demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analyzing and interpreting, and communicating)

- **A1.5** conduct inquiries, controlling some variables, adapting or extending procedures as required, and using standard equipment and materials safely, accurately, and effectively to collect observations and data
- **A1.6** gather data from laboratory and other sources, and organize and record the data using appropriate formats, including tables, flow charts, graphs, and/or diagrams
- **A1.8** analyze and interpret qualitative and/or quantitative data to determine whether the evidence supports or refutes the initial prediction or hypothesis, identifying possible sources of error, bias, or uncertainty
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions
- **A1.11** communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language in a variety of formats
- **A1.12** use appropriate numeric, symbolic, and graphic modes of representation, and appropriate units of measurement

**Physics: Light and Applications of Optics**

**E2.** Investigate, through inquiry, properties of light, and predict its behavior in mirrors and as it passes through different media

- **E2.1** use appropriate terminology related to light and optics including but not limited to: angle of incidence, angle of reflection, angle of refraction, centre of curvature, focal length, luminescence, magnification, principal axis, radius of curvature, and vertex [C]
- **E2.2** use an inquiry process to investigate the laws of reflection; use these laws to explain the characteristics of images formed by plane mirrors; and draw ray diagrams to illustrate their observations [PR, AI, C]

**E3.** demonstrate an understanding of characteristics and properties of light, particularly with respect to reflection and refraction and the addition and subtraction of colour

- **E3.3** explain the laws of reflection of light, and identify how light reflects from various types of mirrors

### Learning Goals

**Students will be able to:**

- use ray diagrams to illustrate observations using plane mirrors
- use the laws of reflection to predict and explain the characteristics of images formed in plane mirrors
- demonstrate inquiry skills of performing and recording, analyzing and interpreting, and communication
### Instructional Components and Context

<table>
<thead>
<tr>
<th>Readiness</th>
<th>Terminology</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Drawing ray diagrams (from Lesson 4) • Collaborative norms and skills, e.g., taking roles, taking turns, disagreeing agreeably • Safety procedures • Use of a protractor</td>
<td>• Angle of incidence • Angle of reflection • Image • Normal • Plane mirror • Ray diagram • Real image • Virtual image</td>
<td>• Optical devices (actual or images) with functional plane mirror(s), e.g., overhead projector, kaleidoscope, SLR camera, rear-view mirror, dressing room mirror, periscope • Ray boxes, plane mirrors (several small ones, one large), pencil, ruler, protractor, two identical objects to be observed (e.g., candle, chess piece, nail, etc.)</td>
</tr>
</tbody>
</table>

### Resources

**Websites**
- Hands On Optics
- Ray Optics
- Optics Videos

**Reference (for parallax method)**
**Light Reflects (Part 1)** Lesson 6

**Minds On (Elicit, Engage)**

**Small Groups → Investigating Using Mirrors**
Distribute a variety of reflective surfaces (e.g., large spoon, dark sun glasses), one to each group. Working in their groups, students describe what they see as look at the image in the mirror. They refer to a chart of characteristics of images. Students identify real-life applications of these types of mirrors, (e.g., fun-house mirrors, security mirrors). Debrief by inviting student responses.

**Whole Class → Previewing Learning Goals**
Share the learning goals and the guiding questions for this lesson. Review any safety procedures pertinent to this lesson.

**Pause and Ponder**

**QuickTip**
Support students’ use of descriptive language for images by prompting with examples or using word banks.

**Action! (Explore, Explain)**

**Small Groups/Whole Class → Reading a Procedure and Conducting an Investigation**
Distribute Procedures and Material List handout and highlighters to groups. Preview the handout, and cue students to the features and the structure of the text (e.g., lists) and the strategies they can use to read the text. Students read over the procedure, and as they do so, highlight key words that are familiar in one colour and unfamiliar key words in another colour. Post a list of unfamiliar words. In a think-aloud, sort out the meanings of words. Use another think-aloud to show students how visualizing while reading a procedure can clarify meaning. Allow time for students to reread for meaning.

Students complete the investigation by following the procedure, using the given materials. Debrief by having students share observations, and note any similarities and differences. Prompt students to draw a conclusion regarding the equality of the angle of incidence to the angle of reflection, within error limits.

Students prepare a summary diagram labeling the following: incident ray, angle of incidence, angle of reflection, reflected ray, the normal.

**Individual/Small Groups → Investigating in Stations**
Set up a second set of stations. (Note: The objects to be observed must be taller than the height of the mirror.)

Distribute a second set of procedures and materials list. Students read procedure, and as they do, they monitor their use of strategies to identify key words, sort out unfamiliar words and visualize. Debrief by asking students if and how they used these comprehension strategies.

Distribute investigation materials. Students complete the investigation by following the procedure. Pairs combine to compare observations.

**Whole Class → Debriefing and Note-taking**
Ask one member of each group to report their conclusions emphasizing the properties of the image, (e.g., is virtual, has the same size, has the same shape, stays in the same location regardless of the motion of the observer, is as far behind the mirror as the object is in front of the mirror, is laterally inverted). With the students, draw some broader conclusions based on the reports. Students jot notes on these conclusions.

**Consolidation (Elaborate, Evaluate, Extend)**

**Whole Class → Demonstrating Drawing a Ray Diagram**
Using one of the student’s sheets from the second investigation, draw at least two rays that show the entire path of light from the object to the eye (including arrow heads to show the direction of the light) and then to the image. Note that this is the more reliable way of locating the virtual image.

**Pairs → Investigating with Mirrors in Stations**
Using two plane mirrors and an object, examine how many ways two mirrors can be used to make more than one image. Consider a few other challenges:
- Arrange the mirrors to produce only two images, and then the greatest number of images.
- Does the number of images observed depend on the placement of the eye?
- Are all the images identical to one another and to the object?
- How many images are produced if the mirrors are placed parallel to each other but in opposite sides of the object?

**Individual → Drawing Conclusions**
On an exit ticket, students write conclusions about their observations.

**QuickTip**
Use information from the exit ticket to inform instruction and plan guided practice.
Minds On (Elicit, Engage)

Characteristics of images

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sample Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>larger, smaller, same size (as object)</td>
</tr>
<tr>
<td>attitude</td>
<td>erect, inverted</td>
</tr>
<tr>
<td>kind</td>
<td>virtual, real</td>
</tr>
<tr>
<td>location</td>
<td>undefined, at principle focus, or x cm from the optical centre</td>
</tr>
</tbody>
</table>

Safety Procedures

Teachers must model safe practices at all times and communicate safety expectations to students in accordance with school board and Ministry of Education policies and Ministry of Labour regulations. Teachers are responsible for ensuring the safety of students during classroom activities and also for encouraging and motivating students to assume responsibility for their own safety and the safety of others. Teachers must also ensure that students have the knowledge and skills needed for safe participation in science activities.

To carry out their responsibilities with regard to safety, it is important for teachers to have:

- concern for their own safety and that of their students
- the knowledge necessary to use the materials, equipment, and procedures involved in science safely
- knowledge concerning the care of living things – plants and animals – that are brought into the classroom
- the skills needed to perform tasks efficiently and safely

Students demonstrate that they have the knowledge, skills, and habits of mind required for safe participation in science activities when they:

- maintain a well-organized and uncluttered work space
- follow established safety procedures
- identify possible safety concerns
- suggest and implement appropriate safety procedures
- carefully follow the instructions and example of the teacher
- consistently show care and concern for their own safety and that of others

Various kinds of health and safety issues can arise when learning involves field trips. Out of-school field trips can provide an exciting and authentic dimension to students' learning experiences. They also take the teacher and students out of the predictable classroom environment and into unfamiliar settings. Teachers must preview and plan these activities carefully to protect students' health and safety.

The Ontario Curriculum, Grades 9 and 10: Science, 2009

Action! (Explore, Explain)

Think-Aloud

A Think-Aloud is an instructional scaffold that models thinking processes, making the invisible visible. In a think-aloud, the teacher verbalizes how effective readers process the text, e.g., by monitoring comprehension and using strategies to construct meaning. While teachers can think aloud at any point in an instructional sequence, think-alouds are frequent during the modelling phase of the gradual release model and during read-alouds.

See Think Literacy Subject-Specific Examples: Language/English, Grades 7-9, Engaging in Reading: Reading Between the Lines/Inference, page 3.

A think-aloud is, therefore, a form of explicit instruction that requires teachers to be aware of their own thinking processes and that helps student think about their thinking. Developing metacognitive awareness is an important aspect of learning.

See Metacognition Guide.

Consolidation (Elaborate, Evaluate, Extend)

Exit Card

Exit cards prompt students to write responses that allow reflection on learning, for example, during the consolidation of a lesson. The exit card response can be used to provide assessment information.

See Student Success DI Package 2010, DI Scrapbook.
Sample Procedures 1 and 2 Handout

Materials
- ray box
- plane mirror
- two plain sheets of paper on which is drawn a solid line (labelled “mirror”) with a perpendicular dotted line (“the normal”) drawn approximately in the middle of the solid line
- pencils and rulers
- protractor
- data table

Sample Procedure 1
1. Place the plane mirror on the solid line.
2. Using a single slit on the ray box, shine a ray of light on the mirror.
3. Using a ruler, draw this light ray on the paper. Then, using a ruler, draw where the light ray is reflected on the paper.
4. Using a protractor, measure the angle of the incoming (or incident) light ray. Then, measure the angle of the reflected light ray. Record these on the paper in the ray diagram. (Remember to measure the angles with respect to the dotted line).
5. Move the ray box to another location.
6. Repeat steps 2-4 three more times to gather valid data.
7. Complete a table of values to summarize their observations.

<table>
<thead>
<tr>
<th>Location</th>
<th>Angle of incidence</th>
<th>Angle of reflection</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</table>

Sample Procedure 2
1. Using the second sheet of plain paper, place the plane mirror on the solid line.
2. Place one of the ‘objects to be observed’ on the paper, about 10 cm away from the mirror.
3. Place your head so you can see the image of the object. Then, move your head from side to side. Describe what you observe.
4. Answer the following questions:
   a. Where does the image appear to be located?
   b. Does the image stay in the same location, or does it change location as you move your head?
5. Using the “parallax method” (see Reference list), place the second “object to be observed” at the location of the image of the object. Mark this location on the paper.
6. Move your head to a new location and repeat procedure (4).
7. Repeat steps 2-6 three more times to gather valid data.
8. Answer the following questions:
   a. Describe the appearance (e.g., size, shape, lateral inversion, etc.) of the image. Is there a unique location where all observers would agree that the image is located (provided they can see the image)? If so, where?
   b. Is there a reliable way of predicting this location accurately using another method? If so, how?
## Monitoring Performance Checklist Template

**Investigation** ____________________________________________  **Date** ____________________________________________

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Student Names</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Applies proper procedures for the use and care of the equipment</strong></td>
<td>Student 1</td>
</tr>
<tr>
<td>A1.4 [IP]</td>
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<tr>
<td><strong>Follows instructions provided by teacher or developed by class or group</strong></td>
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<tr>
<td>A1.5 [PR]</td>
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<tr>
<td><strong>Uses all required lab equipment safely</strong></td>
<td></td>
</tr>
<tr>
<td>A1.5 [PR]</td>
<td></td>
</tr>
<tr>
<td><strong>Uses equipment accurately and effectively to ensure repeatable results</strong></td>
<td></td>
</tr>
<tr>
<td>A1.5 [PR]</td>
<td></td>
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<tr>
<td><strong>Adheres to the rules of conduct in effect during inquiry activities</strong></td>
<td></td>
</tr>
<tr>
<td>A1.5 [PR]</td>
<td></td>
</tr>
<tr>
<td><strong>Returns all equipment clean to the correct storage area or as instructed otherwise</strong></td>
<td></td>
</tr>
<tr>
<td>A1.5 [PR]</td>
<td></td>
</tr>
<tr>
<td><strong>Creates tables or graphs that present the observation in a logical manner and include appropriate symbols and units</strong></td>
<td></td>
</tr>
<tr>
<td>A1.6 [PR], A1.12 [C]</td>
<td></td>
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</tbody>
</table>

**LITERACY GAINS** TRANSFORMING INSTRUCTIONAL PRACTICE SUPPORTS GRADE 10 SCIENCE