### Critical Learning
- The behaviour of light depends on the materials with which it interacts.
- Observations of light can be represented in a ray diagram.

### Guiding Questions
- How do light rays behave when they interact with different materials?
- How does a ray diagram represent the phenomenon of how light behaves?

### 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, analysing 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
- **A1.12** 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 behaviour and predict its behaviour 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]
- **E2.5** investigate how various objects or media reflect, transmit, or absorb light, and record their observations using ray diagrams. [PR, C]

### Learning Goals
Students will be able to:
- perform investigations to determine how a variety of materials reflect, transmit or absorb light
- use a ray diagram to explain their understanding about the interaction of light with matter
- describe observations and draw conclusions, using correct terminology

### Instructional Components and Context

#### Readiness
- Transmit
- Absorb
- Reflect
- Opaque
- Translucent
- Transparent

#### Terminology
- Radiometer and/or light meter
- Light sources of reasonable intensity, e.g., flashlights
- Various materials:
  - Translucent, e.g., wax, waxed paper, cloudy liquid
  - Transparent, e.g., plastic wrap, coloured solution
  - Opaque, e.g., shiny metal, wood, white plastic, coloured paper
- Ray boxes
- Rulers, paper, pencils
- *Live Safe!, Work Smart!*, pp. 51-52, 57-60

#### Materials
**Minds On (Elicit, Engage)**

**Whole Class ➔ Predicting and Observing in a Demonstration**

Preview the demonstration by identifying the equipment, set up and any safety concerns related to the demonstration. In a Think Aloud, model using the Predict-Explain-Observe-Explain strategy during a demonstration. Use a device, e.g., a radiometer and/or light meter with a low intensity light, thinking aloud the predictions, explanations, and observations during the process. Repeat the procedure, inviting students to share their predictions, explanations, and observations for (1) a high intensity light, and (2) with no light. Debrief by inviting responses about all three demonstrations. Extend the discussion by pointing out that (1) light energy is transferred to the object, (2) kinetic energy is produced when the light was on, and (3) more research is needed to explain what happened.

**Pairs/Small Groups/Whole Class ➔ Investigating How Light Behaves**

Distribute a Predict-Explain-Observe-Explain recording sheet.

Working in pairs, students select materials (one opaque, one translucent and one transparent) and set up the equipment as in the demonstration. They list their materials in the appropriate column on the recording sheet. They discuss and record their prediction and explanation of how the radiometer or light meter will respond for each material. Pairs hold an opaque, translucent, or transparent material, one at a time, in front of the light source. They record their observations and explanations for each of the materials. Circulate and monitor students’ use of the strategy and procedure, and their understanding. Pairs form small groups to share and compare observations. Debrief as a whole class by inviting students to share responses. Note any instances where the observations did not match their predictions, and how this may have shifted their thinking. Extend the discussion by using question prompts to draw some conclusions about particular kinds of materials.

**Whole Class ➔ Sharing the Learning Goals**

Introduce the learning goals and the guiding questions for this lesson. Review safety procedures.

**Action! (Explore, Explain)**

**Whole Class ➔ Modeling the Use of Ray Diagram**

Introduce the ray box, and demonstrate its use. Explain the word ‘ray.’ Using a Think Aloud, model drawing a ray diagram, e.g., using a ruler and arrows indicating the direction of a ray. Demonstrate how to use dots to get the most accurate line of a narrow beam from the ray box, and then use a pencil and ruler to carefully draw the observed ray. Post the sample ray diagram. Continuing the think aloud, draw a conclusion about the ray diagram. Make connections to what students experienced in the Minds On.

Using the modeled sample(s), co-construct success criteria for quality ray drawings. Record and post the criteria with the modeled ray diagram for easy reference. Tell students they will be investigating the question: How do light rays behave when they interact with different materials? Students review the question, and ask clarifying questions (e.g., what are the different materials?). Review the goals of the investigation: (1) discover the behaviour of light rays when they interact with different materials, and (2) draw ray diagrams based on co-constructed criteria. Discuss controlling variables.

**Pairs ➔ Investigating using Ray Boxes**

Distribute different materials so that each pair has two different types of materials to investigate (e.g., translucent and transparent). For each material, students

- use a ray box to shine light on materials and observe the rays of light
- carefully trace the path of the rays of light to start a ray diagram
- note the intensity and colour of any ray that has interacted with matter on the diagram

**Whole Class ➔ Drawing Conclusions**

Debrief by inviting student responses based on their investigation. Extend the discussion by drawing conclusions based on the observations of intensity and colour of any ray that has interacted with matter. Post conclusions using key words: transmit, absorb and reflect.
<table>
<thead>
<tr>
<th><strong>Light and Matter</strong> Lesson 3</th>
<th>Grade 10, Science, Applied SNC2P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consolidation (Elaborate, Evaluate, Extend)</strong></td>
<td><strong>Pause and Ponder</strong></td>
</tr>
<tr>
<td><strong>Pairs → Selecting and Reflecting</strong></td>
<td></td>
</tr>
<tr>
<td>Pairs choose a ray diagram to revise for submission, and make revisions based on their self-assessment and any teacher feedback. They add a conclusion to their ray diagram submit it for feedback.</td>
<td><strong>AOL</strong> Use ray diagrams and conclusions to check student understanding, and provide additional support, where needed.</td>
</tr>
</tbody>
</table>
Minds On (Elicit, Engage)

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 a form of explicit instruction that requires teachers to be aware of their own thinking processes and that helps students think about their thinking. Developing metacognitive awareness is an important aspect of learning. See Metacognition Guide.

Model
Modelling is a component of explicit instruction that is particularly helpful for struggling learners. According to the gradual release of responsibility model for instruction, modelling is done by the teacher and students observe (I do, you watch). This is followed by shared practice (I do, you help) and guided practice (you do, peers help), and finally independent practice (you do, I help if necessary). See the Strategy Implementation Continuum for a detailed chart of this framework.

Predict-Explain-Observe-Explain
Predict-Explain-Observe-Explain is a strategy used during the investigation of a scientific phenomenon. It prompts students to make predictions prior to a demonstration, thereby helping them make more careful and focused observations. It is also motivates students to want to find an answer. Students share their predictions with their peers, think about their own learning and construct new understanding. During observation, students note what they see and/or hear, feel. When students explain, they are encouraged to think metacognitively by sharing any shifts or discrepancies between their predictions and the observations.

The P-E-O-E graphic organizer below is structured so that students can see how their predictions compare with their final explanations.

See Predict-Explain-Observe-Explain Recording Sheet.

Strategy Implementation Continuum
It is important that the teacher model each strategy or skill with a think-aloud before engaging students in shared and guided practice. See the Strategy Implementation Continuum (gradual release model). Provide feedback on effective strategy use as students use the strategy.

Sample Question Prompts
- What might be different between shiny and dark materials?
- If the light energy was absorbed by black materials, what would happen?
- How could we measure this change? (change in temperature of material, intensity of light reflected)
- Which materials should we use? (white, shiny, black, dark colour)
- Do each of the types of materials interact with light in the same way?
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

Specific Safety Notes for this Lesson
When working with a heat source, students should:
- wear goggles
- take care that hair, clothing, and hands are a safe distance from the heat source
- never reach over a heat source

When working with electricity, students should:
- never use electrical equipment around liquids or with wet hands
- unplug an electrical device by pulling on the plug and not the electrical cord
- make sure electrical cords are placed where people cannot trip over them
- use only grounded electrical equipment unless the equipment is “doubly insulated” and with a polarized plug

Action! (Explore, Explain)
Co-constructing Success Criteria
Co-constructing criteria is the process of working collaboratively with students to develop the criteria and indicators (i.e., success criteria) for successful demonstration of knowledge and/or skills related to learning goal.

Success Criteria
Success criteria provide students with a clear description of what successful attainment of learning goals looks like. When students know and understand the success criteria, they are more likely to have a clearer picture of the targeted learning, and know what they need to do to be successful. Developing success criteria early in a unit or task, encourages students to actively monitor and self-regulate their own learning as they are developing and practising new knowledge and skills.

When developing criteria:
- describe observable behaviours in clear, detailed, student friendly language
- create descriptions which allows for a range of performance
- ensure that the list of criteria is manageable
- engage students in the development process (co-construction) – this encourages a shared understanding of the criteria, gives students a greater sense of control, and initiates students in the use of specific language which describes their learning

When using success criteria:
- post the criteria, e.g., on an anchor chart, and refer to it when discussing learning goals and providing feedback
- invite students to discuss their learning and performance, making specific references to the success criteria
- develop other assessment tools, e.g., checklists, rubrics that are based on the assessment criteria, and make explicit for students the connections
- use anonymous samples of work, and engage students in analysing and critiquing the samples, using the one of more of the success criteria
- provide multiple opportunities for students to analyse and critique their own work, make adjustments, if needed, and set goals and next steps

**Predict-Explain-Observe-Explain Recording Sheet**

- **BEFORE:** Look carefully at the objects. Make your predictions before the demonstration:
  What will happen when light is shone on the objects? Explain your predictions.
- **DURING:** Record your observations during the demonstration.
- **AFTER:** Recalling what you already know, explain your observations.

<table>
<thead>
<tr>
<th>Opaque Material Example:</th>
<th>Translucent Material Example:</th>
<th>Transparent Material Example:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predict</td>
<td>Predict</td>
<td>Predict</td>
</tr>
<tr>
<td>Explain</td>
<td>Explain</td>
<td>Explain</td>
</tr>
<tr>
<td>Observe</td>
<td>Observe</td>
<td>Observe</td>
</tr>
<tr>
<td>Explain</td>
<td>Explain</td>
<td>Explain</td>
</tr>
</tbody>
</table>
# Monitoring Performance Checklist Template

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Student Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applies proper procedures for the use and care of the equipment</td>
<td>Student 1</td>
</tr>
<tr>
<td>A1.4[IP]</td>
<td>Student 2</td>
</tr>
<tr>
<td>Follows instructions provided by teacher or developed by class or group</td>
<td></td>
</tr>
<tr>
<td>A1.5[PR]</td>
<td></td>
</tr>
<tr>
<td>Uses all required lab equipment safely</td>
<td></td>
</tr>
<tr>
<td>A1.5[PR]</td>
<td></td>
</tr>
<tr>
<td>Uses equipment accurately and effectively to ensure repeatable results</td>
<td></td>
</tr>
<tr>
<td>A1.5[PR]</td>
<td></td>
</tr>
<tr>
<td>Adheres to the rules of conduct in effect during inquiry activities</td>
<td></td>
</tr>
<tr>
<td>A1.5[PR]</td>
<td></td>
</tr>
<tr>
<td>Returns all equipment clean to the correct storage area or as instructed</td>
<td></td>
</tr>
<tr>
<td>A1.5[PR]</td>
<td></td>
</tr>
<tr>
<td>Creates tables or graphs that present the observation in a logical</td>
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</tr>
<tr>
<td>manner and include appropriate symbols and units</td>
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<tr>
<td>A1.6 [PR], A1.12[C]</td>
<td></td>
</tr>
</tbody>
</table>