



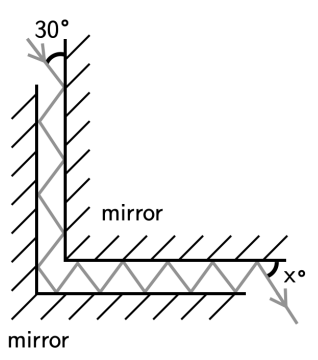
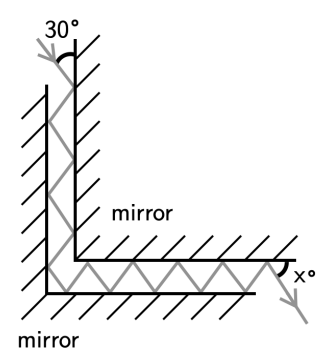
Optics (B/C) - 2023-24 Regional Questions

- Use this document to submit fully developed questions for use on the Division B and C Regional tests.
- **Images:** Keep in mind that students may have a binder of any type of information. Students may have studied or have in the binder images or diagrams for a particular topic that are top results with a google search, from Wikipedia, or from one of the main SO websites or references. Using top hits for simple images is one strategy to make a question easier to answer. For more complex diagrams with more complex questions or identifying labels, top results images may be acceptable for Division B, but for Division C should be avoided. Spend time to find or create a unique image for the question.
- The total number of questions for each test will be ~80 questions (average of 1 minute per question, for 2 students).
 - The number and difficulty of questions should be spread evenly across all of the topics.
 - Writers should generate ~100-120 questions each for Div B and Div C regional tests, so that there are extra questions that may be used on the state test.
 - Use a separate row in the tables for each question. Keep similar/equivalent questions for B and C in the same row.
- Refer to [MSO Test Writing Guidelines](#) for DOK/Bloom's taxonomy reference regarding levels of thinking and proportions of easy/medium/hard questions.
- Initial topics focus for each writer to finalize questions on:
 - **James Guo - (1) and (2)**
 -  **(3) and (4)**
 -  **(5) through (8)**

References resources for question development:

- <https://ophysics.com/l.html> - lots of simulations for virtual experiments. Make unique problems/graphics.
- <https://phet.colorado.edu/en/simulations/filter?subjects=light-and-radiation&type=html,prototype>
- <https://www.physicsclassroom.com/Physics-Interactives/Light-and-Color>
- <https://www.physicsclassroom.com/Physics-Interactives/Reflection-and-Mirrors>
- <https://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses>
- https://physicsmonster.org/content/simulation/simulation_optics_geometric/index.html
- <https://physicsmonster.org/> - lecture notes, labs, slides, and simulations across all physics content
- Topics for Division B Regional Tournaments:
 - (1) [Reflection, specular & diffuse](#)
 - (2) [Refraction, index of refraction, and prisms \(deviation & dispersion\)](#)
 - (3) [Mirrors & lenses: convex, concave, plain; ray tracing; focal length; real, virtual, erect, and inverted objects and images; magnification](#)

- (4) [Color theory: additive & subtractive; primary & secondary colors; absorption & reflection](#)
- (5) [Structure and function of the human eye](#)
- Topics for Division C Regional Tournaments:
 - All Division B Regional Topics
 - (6) [Snell's law & critical angle](#)
 - (7) [Lens maker's equation & thin lens approximation](#)
 - (8) [Polarization: films & scattering, Brewster's angle](#)

Reflection, specular & diffuse	
Division B (~20 questions)	Division C (~15 questions)
<p>Use the following information to answer problems 1 to 4. (Reflection "Maze"). Assume that you have built the following system composed of two "L"-shaped mirrors. Assume that the "L"-shape has a right angle at the intersection and the mirrors are either normal or parallel.</p>  <p>1. Based on "_____", when measured with respect to the normal, the angle of incidence is the same as the angle of reflection. (a) The law of reflection. (b) The law of refraction. (c) Snell's Law. (d) The law of superposition. (e) Special relativity.</p> <p>2. In the above setup, a light beam gets into the "maze" with 30° as marked. Assume that the light beam gets through, what should be the measurement of the angle x°? (a) 15°. (b) 30°. (c) 45°. (d) 60°. (e) 75°.</p>	<p>Use the following information to answer problems 1 to 5. (Reflection "Maze"). Assume that you have built the following system composed of two "L"-shaped mirrors. Assume that the "L"-shape has a right angle at the intersection and the mirrors are either normal or parallel.</p>  <p>1. Based on "_____", when measured with respect to the normal, the angle of incidence is the same as the angle of reflection. (a) The law of reflection. (b) The law of refraction. (c) Snell's Law. (d) The law of superposition. (e) Special relativity.</p> <p>2. In the above setup, a light beam gets into the "maze" with 30° as marked. Assume that the light beam gets through, what should be the measurement of the angle x°? (a) 15°. (b) 30°. (c) 45°. (d) 60°. (e) 75°.</p>

<p>3. In this case, we may apply the law in question (1) because one could interpret light as _____. (Select all that applies.) (a) photon particles. (b) a longitudinal wave. (c) a transverse wave.</p> <p>4. More than evaluating light, we may also apply the law in question (1) for _____. (Select all that applies.) (a) sound waves. (b) gravitational force. (c) trajectory for a bouncing ball.</p>	<p>3. In this case, we may apply the law in question (1) because one could interpret light as _____. (Select all that applies.) (a) photon particles. (b) a longitudinal wave. (c) a transverse wave.</p> <p>4. More than evaluating light, we may also apply the law in question (1) for _____. (Select all that applies.) (a) sound waves. (b) gravitational force. (c) trajectory for a bouncing ball on a perfectly elastic wall. (d) trajectory for a bouncing ball on a non-perfectly elastic wall.</p> <p>5. Suppose that someone touches the bottom “L”-shaped so that it rotates for a certain degree of angle and moves a little bit. Assume that the light beam with an angle marked as 30° could still get through the device, is the angle x° guaranteed to be the same? (a) yes. (b) no.</p>
<p>5. Suppose that you are in standard conditions, you shoot a beam of light to a mirror and it reflects, what is closest to the speed of light after reflection? (a) 3.2×10^8 m/s. (b) 3.0×10^8 m/s. (c) 2.8×10^8 m/s. (d) 2.6×10^8 m/s. (e) depends on what the medium is.</p>	<p>6. Suppose that you shoot a beam of light to a mirror at a speed of c and it reflects, what is closest to the speed of light after reflection? (a) $1.2c$ (b) c (c) $0.99c$ (d) $0.9c$ (e) depends on what the medium is.</p>
<p><i>Use the following information to answer problems 6 to 8.</i> (Mirrors throughout history). Mirrors are important in many scenarios, and there are many mirrors found at various historical stages world-wide.</p> <p>6. An observer is able to see the image of the mirror as a result of the _____ of light. (a) reflection. (b) mirroring. (c) duplication. (d) replication. (e) refraction.</p> <p>7. At many archaeological sites, archaeologists have found bronze mirrors with one side of the mirror polished. Where can people see a mirrored image of themselves? (a) The polished side. (b) The unpolished side. (c) On both sides.</p> <p>8. Although designed for mirroring an image, many of these mirrors are not “doing their jobs” well, what could be the reasons for this result? (Select all that applies.) (a) The surfaces are corroded.</p>	<p><i>Use the following information to answer problems 7 to 8.</i> (Mirrors throughout history). Mirrors are important in many scenarios, and there are many mirrors found at various historical stages world-wide.</p> <p>7. At many archaeological sites, archaeologists have found bronze mirrors. The polishing of the surface _____. (a) keeps the specular reflection of the bronze surface. (b) makes the specular reflection into diffuse reflection. (c) makes the diffuse reflection into specular reflection. (d) keeps the diffuse reflection of the bronze surface. (e) becomes a source of light.</p> <p>8. Although designed for mirroring an image, many of these mirrors are not “doing their jobs” well, what could be the reasons for this result? (Select all that applies.) (a) The surfaces are oxidized. (b) The surfaces are reduced. (c) The surfaces reacted with certain substances .</p>

(b) The surfaces are covered with other substances.

(c) The mirrors are mostly broken into pieces.

(d) The mirrors are mostly broken into pieces.

(e) The mirrors lose their layer that allows diffuse reflection.

Use the following information to answer problems 9 to 12.

(Types of reflections). There are many types of surfaces, which have different properties.

9. Which of the following surfaces induce specular reflection? (Select all that applies.)

(a) Still water. (b) Ground. **(c) Glass mirrors.** **(d) Flat ice surface.**

10. What are the properties of specular reflection? (Select all that applies.)

(a) Reflected rays are parallel.

(b) Reflected rays are scattered.

(c) An image is formed.

(d) No image is formed.

11. Suppose that you are on a field trip during a moon night. The surroundings are so dim that you cannot firmly see the grounds. Assume that the moon is in front of you, you should be avoiding stepping on the areas that are _____. (Select all that applies.)

(a) very bright. (b) very dark. (c) dim.

12. Now, assume that you have walked far enough that the moon is now behind you, now, you should be avoiding stepping on the areas that are _____. (Select all that applies.)

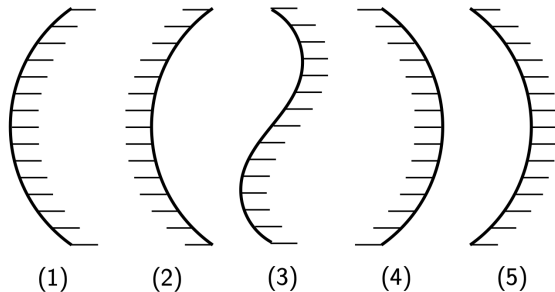
(a) very bright. **(b) very dark.** (c) dim.

9. Suppose that you are on a field trip during a moon night. The surroundings are so dim that you cannot firmly see the grounds. Assume that the moon is in front of you, you should be avoiding stepping on the areas that are **(bright/dark)**. Explain your choice.

Sol'n: The very bright areas means that there would be specular reflection, which implies that there are either water or ice surfaces, which is dangerous for you to walk on.

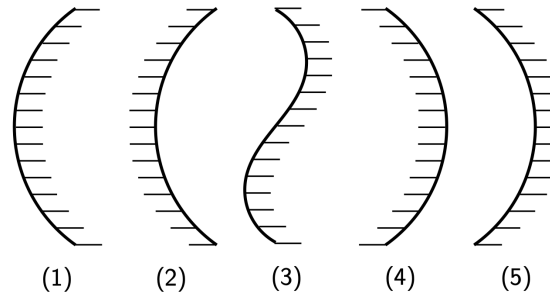
Use the following information to answer problems 13 to 16.

(Curved Mirrors). Curved mirrors are extensively used in many scenarios.



Use the following information to answer problems 10 to 11.

(Curved Mirrors). Curved mirrors are extensively used in many scenarios.



13. Which of the following mirrors are convex?

- (a) 1 and 2.
- (b) 1, 2, and 3.
- (c) 2 and 5.**
- (d) 2, 3, and 5.
- (e) 3 and 5.

14. Which of the following mirrors are concave?

- (a) Only all the mirrors that are not selected in question (13).
- (b) Only some but not all of the mirrors that are not selected in question (13).**
- (c) Only some mirrors selected in question (13).
- (d) Some mirrors selected in question (13) and some mirrors that are not selected in question (13).
- (e) No mirrors are concave.

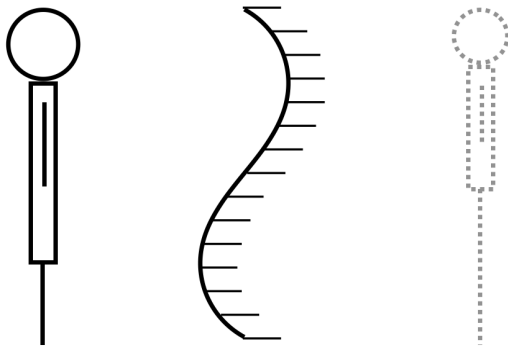
15. List 3 places where convex mirrors are used and functionalities.

Sol'n: Some places for using are:

- **Parking lot to extend the field of vision.**
- **Pedestrian crossing for people to see unexpected places.**
- **Solar power plant for converging sunlight.**

16. Distorting mirrors are sometimes used as a fun activity in amusement parks. Draw one of them below and describe how it will distort a person.

Example:



In this distorting mirror, the person would view themselves having longer legs but shorter upper body.

10. Mark all the convex mirrors, and list 3 places where convex mirrors are used and functionalities.

Sol'n: 2 and 5. Some places for using are:

- **Parking lot to extend the field of vision.**
- **Pedestrian crossing for people to see unexpected places.**
- **Solar power plant for converging sunlight.**

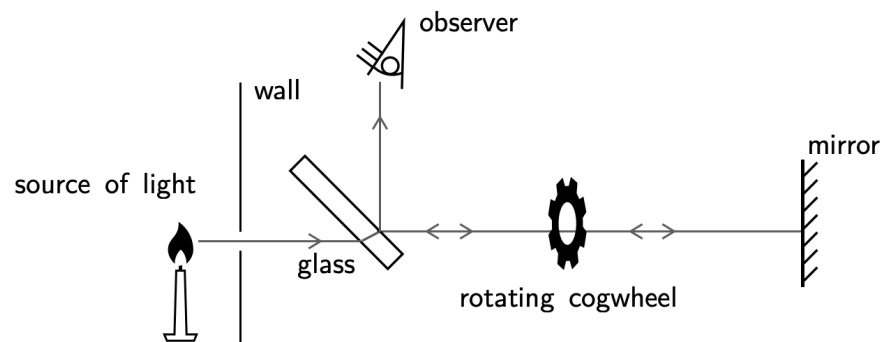
11. Convex and concave are related to concavity in mathematics. Assume that you have a convex or concave mirror that is smooth, briefly explain how the mirror should look like.

Sol'n: Here are some accepted responses:

- **The mirror should be always bending in the same direction.**
- **The mirror should have a consistent concavity (second derivative).**
- **The mirror should has its rate of change changing consistently (monotonic rate of change)**
- **The mirror should focus or diverge all lights to or from a point.**

Use the following information to answer problems 17 to 20.

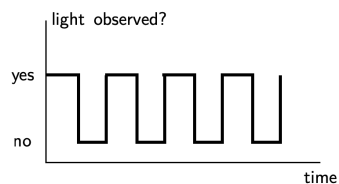
(Foucault Method). Mirrors come out to be helpful in various science experiments. In this problem, you will be guided to measure the speed of light using mirrors.



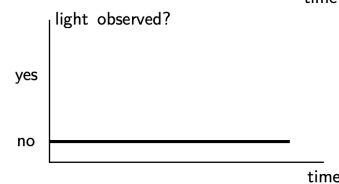
17. This experiment is valid on which of the following laws? (Select all that applies.)

(a) **The law of reflection.** (b) **The law of refraction.** (c) Snell's Law. (d) The law of superposition. (e) Special relativity.

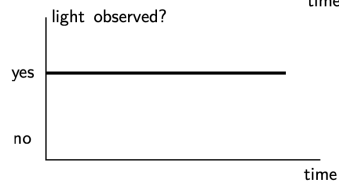
The cogwheel of this experiment is the key in the measuring of the speed of light. During the experiment, the observer might observe the following three states.



State I.



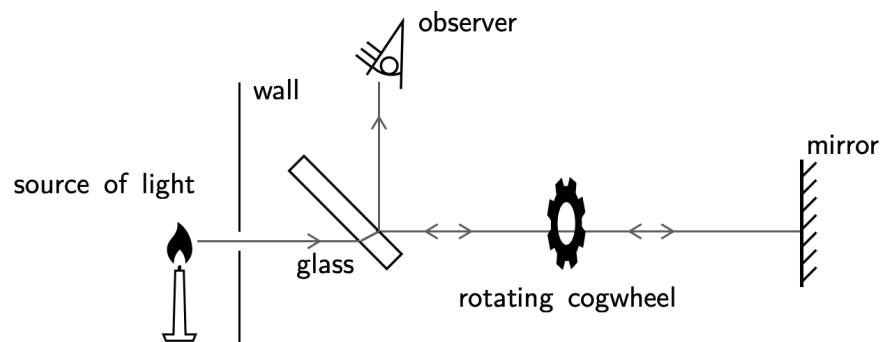
State II.



State III.

Use the following information to answer problems 12 to 15.

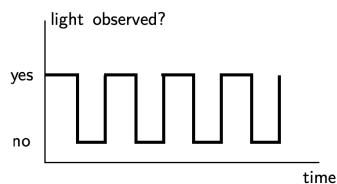
(Foucault Method). Mirrors come out to be helpful in various science experiments. In this problem, you will be guided to measure the speed of light using mirrors.



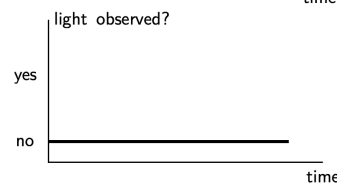
12. List all the laws that this experiment depends on.

Sol'n: The experiment depends on the law of reflection and the law of refraction.

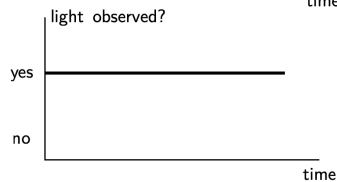
The cogwheel of this experiment is the key in the measuring of the speed of light. During the experiment, the observer might observe the following three states.



State I.



State II.



State III.

<p>18. When the cogwheel is not moving, which state(s) could the observer have?</p> <p>Sol'n: When the cogwheel is not moving, it is at State II or State III.</p> <p>19. When the cogwheel starts moving, and as its speed increases, which state(s) could the observer have? Why?</p> <p>Sol'n: When the cogwheel starts moving, it is at State I since some light will be blocked either in their forward or backward. When the speed increases, it will at some moment reach State II since all light passing through the wheel will be blocked on their way back, and when speed increases more, it will get back to State I.</p> <p>20. How can this setup measure the speed of light? Can you think of any improvements?</p> <p>Sol'n: This setup measures the rotational speed of the cogwheel and the distance between the wheel and the mirror to derive a possible range of the speed of light. The experiment can be improved by:</p> <ul style="list-style-type: none"> - Increasing the number of teeth of the wheels. - Increasing the speed of the wheels. - Increasing the distance between the wheel and the mirror. - Increasing the number of experiments. 	<p>13. When the cogwheel is not moving, which state(s) could the observer have? Why?</p> <p>Sol'n: When the cogwheel is not moving, it is at State II (when the wheel blocks) or State III (when the wheel does not block).</p> <p>14. When the cogwheel starts moving, and as its speed increases, which state(s) could the observer have? Why?</p> <p>Sol'n: When the cogwheel starts moving, it is at State I since some light will be blocked either in their forward or backward. When the speed increases, it will at some moment reach State II since all light passing through the wheel will be blocked on their way back, and when speed increases more, it will get back to State I.</p> <p>15. How can this setup measure the speed of light? Can you think of any improvements?</p> <p>Sol'n: This setup measures the rotational speed of the cogwheel and the distance between the wheel and the mirror to derive a possible range of the speed of light. The experiment can be improved by:</p> <ul style="list-style-type: none"> - Increasing the number of teeth of the wheels. - Increasing the speed of the wheels. - Increasing the distance between the wheel and the mirror. - Increasing the number of experiments.
---	--

Refraction, index of refraction, and prisms (deviation & dispersion)	
Division B (~20 questions)	Division C (~15 questions)

Use the following information to answer problems 1 to 3.

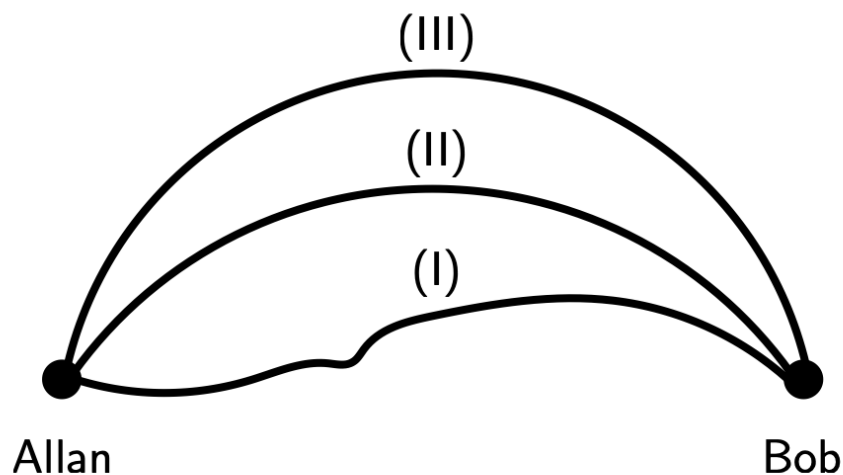
(Optic Fibers). In the current information age, optic fibers connect many internet usages and play the role of communication. Despite its wide usage, we are researching why it works here.

1. Optic fibers send information via ____.

(a) light. (b) sound. (c) air fluctuation. (d) electricity. (e) graviton.

2. Optic fibers achieve total internal reflection, it should be understood as a (reflection/**refraction**). The second medium should have a (**lower**/higher) index of refraction.

3. Allan wants to send a message to Bob via some optic fibers.



Which fiber would deliver the message slowest, why?

(a) Fiber (I) since it is not smooth enough.

(b) Fiber (III) since it has the longest length.

(c) Fiber (II) since it is a segment of a circle.

(d) All fibers have the same delivering speed since they have the same medium inside and outside the fiber.

Use the following information to answer problems 4 to 5.

(Fishing). Fishing is an interest of many people. In fact, fishes do not often be at the location that you see them, which is a cause of refraction.

Use the following information to answer problems 1 to 3.

(Optic Fibers). In the current information age, optic fibers connect many internet usages and play the role of communication. Despite its wide usage, we are researching why it works here.

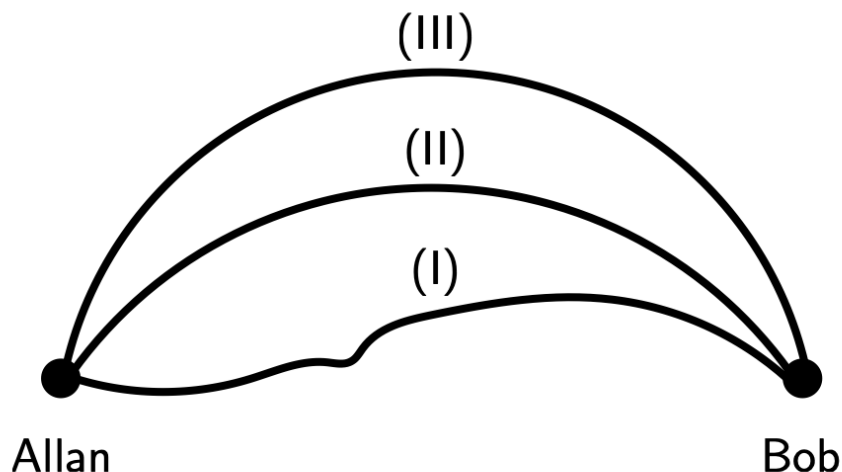
1. Optic fibers send information via ____.

(a) light. (b) sound. (c) air fluctuation. (d) electricity. (e) graviton.

2. Optic fibers achieve total internal reflection, it should be understood as a (reflection/**refraction**). Why?

Sol'n: The second medium has a lower index of refraction, then the light cannot get to the second medium with the larger refraction angle, hence, the light will only be kept internally.

3. Allan wants to send a message to Bob via some optic fibers.

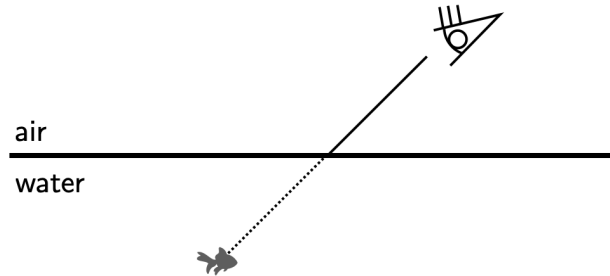


Which fiber would deliver the message slowest, why?

Sol'n: Fiber (III) is the slowest, since it has the longest length.

4. Fishing is an interest of many people. In fact, fishes do not often be at the location that you see them. You observe a fish in a pond. Assume that there are no fish out of water at this instance. Draw the path of the light, and explain the fact you use.

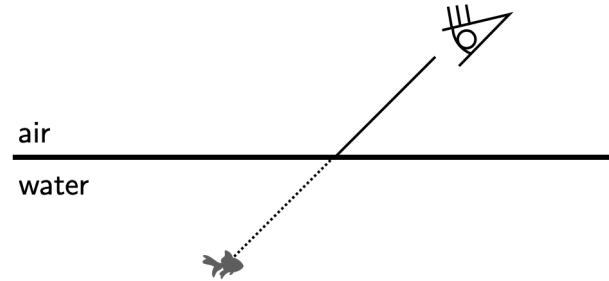
4. You observe a fish in a pond. Assume that there are no fish out of water at this instance. Where should the fish be?



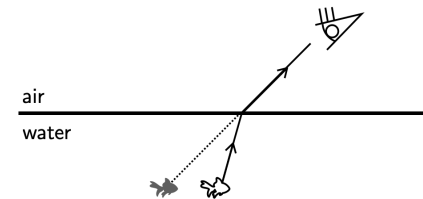
- (a) The fish should be on the left of the position that you see.
- (b) The fish should be exactly at the position that you see.
- (c) The fish should be on the right of position that you see.**
- (d) The fish could only be somewhere above the water.
- (e) There are no fish in the water.

5. This phenomena implies that water has a (**higher**/lower) refraction index.

6. Does the speed of light in the medium change? (**Yes**/No).



Sol'n:

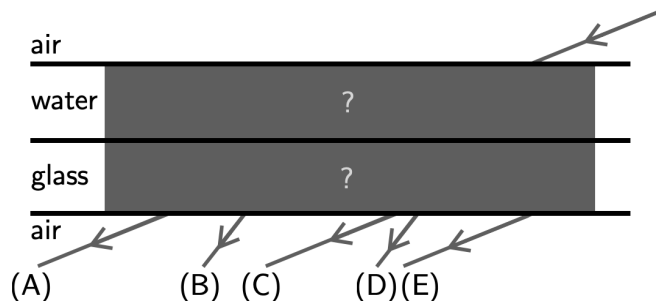


Uses the fact that water has a higher refractive index.

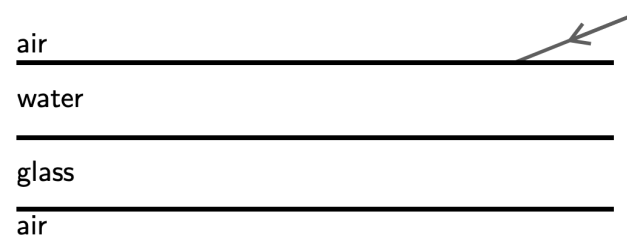
5. Does the speed of light in the medium change? How is that related to the index of refraction?

Sol'n: Yes. When the light travels to a medium of larger index of refraction, the speed of light

Use the following information to answer problems 7 to 8. (**Layers of mediums**). The following diagram describes a setup from air to water to glass and eventually to air. You may assume that the water is still and the edges between the layers are clear-cut.



6. The following diagram describes a setup from air to water to glass and eventually to air. You may assume that the water is still and the edges between the layers are clear-cut. Assume that an incident beam is as indicated on the diagram, complete the graph considering only refractions. Then, explain your illustration via index of refraction.



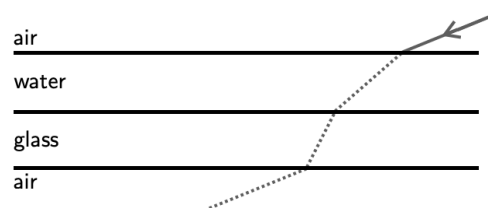
7. Given the setup, which arrow best represents how the light comes out from the device?

(a) A. (b) B. **(c) C.** (d) D. (e) E.

8. Order the three mediums from the lowest index of refraction to the highest.

Sol'n: air, water, and then glass.

Sol'n:



This is because air has the smallest index of refraction, then water, and glass has the largest index of refraction.

Use the following information to answer problems 9 to 12.

(A science experiment). In a lab, a class is asked to measure a specific property of some medium. Although you do not need to know how the experiment is done, you are asked to evaluate some procedures.

9. The _____ determines how much the path of light is bent, or refracted, when entering a material.

- (a) refractivity.
(b) reflectivity.
(c) refraction index.
(d) reflection index.
(e) light index.

10. The group of students calculated the following property in question (9) from the trials for a certain medium, which ones must be caused by an error (but not uncertainty ± 0.01 , for the sake of the problem, of the experiment). (Select all that applies.)

(a) 0.08. (b) 0.98. (c) 1.00. (d) 1.01. (e) 12.02.

11. Explain your answers to question (10).

Sol'n: The index of refraction cannot be less than 1.

12. The students concluded that the property in question (9) is 1.50 ± 0.02 , which medium is likely to be measured?

(a) vacuum. (b) air. (c) water. **(d) glass.** (e) diamond.

Use the following information to answer problems 7 to 9.

(A science experiment). In a lab, a class is asked to measure a specific property of some medium.

7. The _____ determines how much the path of light is bent, or refracted, when entering a material.

- (a) refractivity.
(b) reflectivity.
(c) refraction index.
(d) reflection index.
(e) light index.

8. The group of students collected the following data from the trials for a certain medium, which ones must be caused by an error (but not uncertainty ± 0.01 , for the sake of the problem, of the experiment). (Select all that applies.)

(a) 0.08. (b) 0.98. (c) 1.00. (d) 1.01. (e) 12.02.

9. Write down the equation that is used for this experiment (label the two mediums as 1 and 2, respectively, and use n for property being measured and θ for the angle with respect to normal).

Sol'n: Snell's Law, $n_1 \sin \theta_1 = n_2 \sin \theta_2$.

Use the following information to answer problems 13 to 18.

(Greenhouse gas). Science Olympiad concerns the mastering knowledge as well as environmental awareness about our Earth.

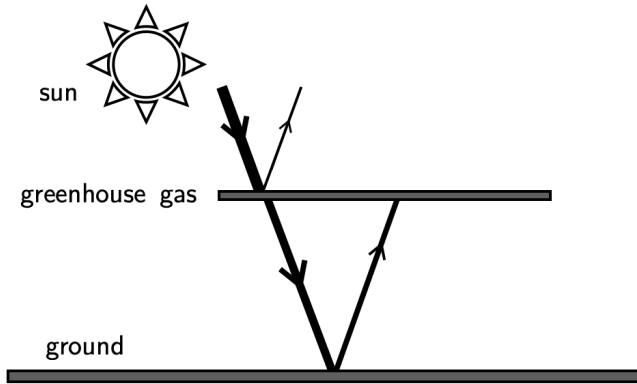
Use the following information to answer problems 10 to 13.

(Greenhouse gas). Science Olympiad concerns the mastering knowledge as well as environmental awareness about our Earth.

13. Greenhouse gasses are considered a factor of global warming, please give 3 greenhouse gasses.

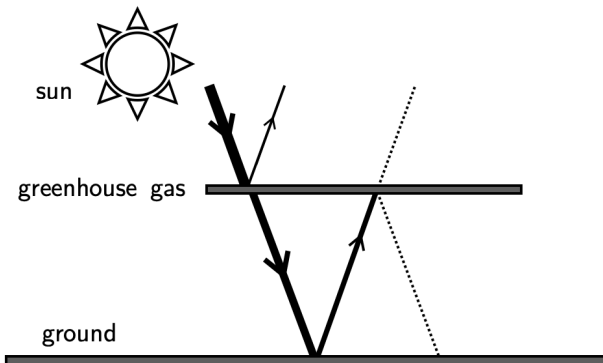
Sol'n: Carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, and water vapor.

Earth obtains a larger proportion of its heat from the radiation of sunlight. The greenhouse gasses reflect and refract the sunlight, just like the following diagram.



14. Complete another reflection and refraction when the light gets to the greenhouse gas layer from the bottom.

Sol'n:

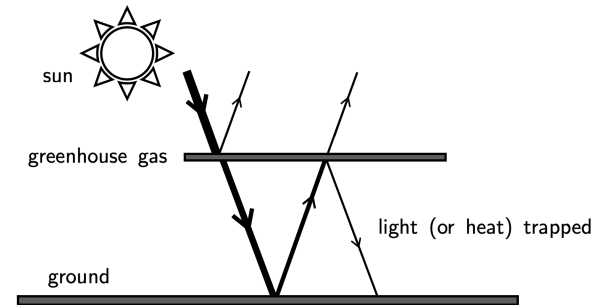


10. Greenhouse gasses are considered a factor of global warming, please give 5 greenhouse gasses.

Sol'n: Carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, and water vapor.

11. Make use of diagrams, explain how reflection/refraction of light causes global warming.

Sol'n: The greenhouse gasses reflect the light and have refraction at the same time. Thus, light (or heat) is trapped between the layer of greenhouse gas and the ground, which causes heat left on the surface of the Earth, which causes global warming.



12. Global warming is a significant issue on our planet. Explain 2 impacts that global warming has.

Sol'n: Global warming could cause the following:

- Sea level increases, less land can be used.
- The increase of temperature makes certain animals and plants unable to survive at the same location.
- Global warming breaks the equilibrium of many cases and causes creatures to be distincted.

13. One goal for a sustainable planet is to slow down global warming. Give 3 ways of slowing global warming.

Sol'n: Some ways to slow global warming is:

- Use less fossil fuels so there are less greenhouse gasses produced.
- Purify and clean the gas emissions from factories to reduce greenhouse.

15. The greenhouse gasses could reach an equilibrium for the global temperature when there are not too many greenhouse gasses. However, as there are more greenhouse gasses, (**more/less**) heat is trapped, so the temperature of the Earth's surface (**increases/decreases**).

16. Global warming is a significant issue on our planet. Explain 1 impact that global warming has.

Sol'n: Global warming could cause the following:

- **Sea level increases, less land can be used.**
- **The increase of temperature makes certain animals and plants unable to survive at the same location.**
- **Global warming breaks the equilibrium of many cases and causes creatures to be distincted.**

17. One goal for a sustainable planet is to slow down global warming. Give 2 ways of slowing global warming.

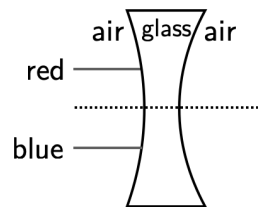
Sol'n: Some ways to slow global warming is:

- **Use less fossil fuels so there are less greenhouse gasses produced.**
- **Purify and clean the gas emissions from factories to reduce greenhouse.**
- **Make policies to promote greener and more sustainable energy.**
- **Plant trees and restore the deforestation that could absorb some greenhouse gasses.**

- **Make policies to promote greener and more sustainable energy.**
- **Plant trees and restore the deforestation that could absorb some greenhouse gasses.**

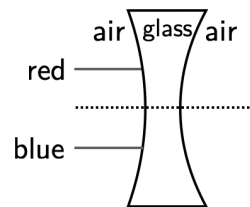
Use the following information to answer problems 18 to 20.

(Lenses and colorful lights). The invention of LED lights opens up opportunities for colorful things, now we will explore the refraction of light of different colors. The setup is as follows.



Use the following information to answer problems 14 to 15.

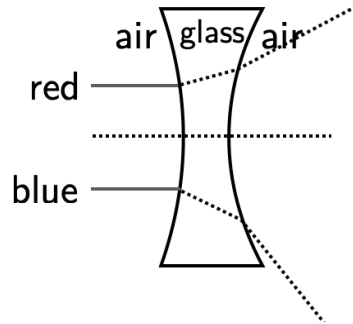
(Lenses and colorful lights). The invention of LED lights opens up opportunities for colorful things, now we will explore the refraction of light of different colors. The setup is as follows.



18. Comparatively, the wavelength of red light is (**larger**/smaller) than the wavelength of blue light.

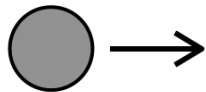
19. With your results from question (18), draw the corresponding diagram after the refractions. Make sure that you represent the differences caused by question (18).

Sol'n:



Then, we discuss the case when a yellow ball is moving towards you.

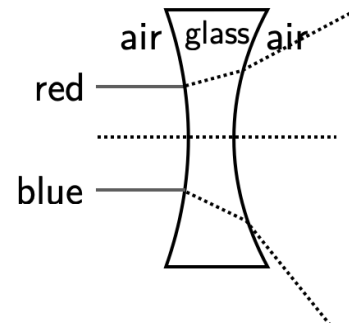
yellow



20. In this case, due to Doppler's Effect, the object would experience (redshift/**blueshift**) so the light has a (longer/**shorter**) wavelength.

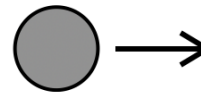
14. Draw the corresponding diagram after the refractions. Make sure that you take into consideration that the color of the lights are different.

Sol'n:



Then, we discuss the case when a yellow ball is moving towards you.

yellow



15. In this case, due to Doppler's Effect, the object would experience some change in wavelength. Briefly explain it.

Sol'n: It has **blueshift** so the light has a **shorter wavelength**.