

# Optics

## Division B/C

Georgia Tech Event Workshop Series  
2024-25



**01**

**RULES SHEET**

**02**

**DIFFICULT TOPICS**

**03**

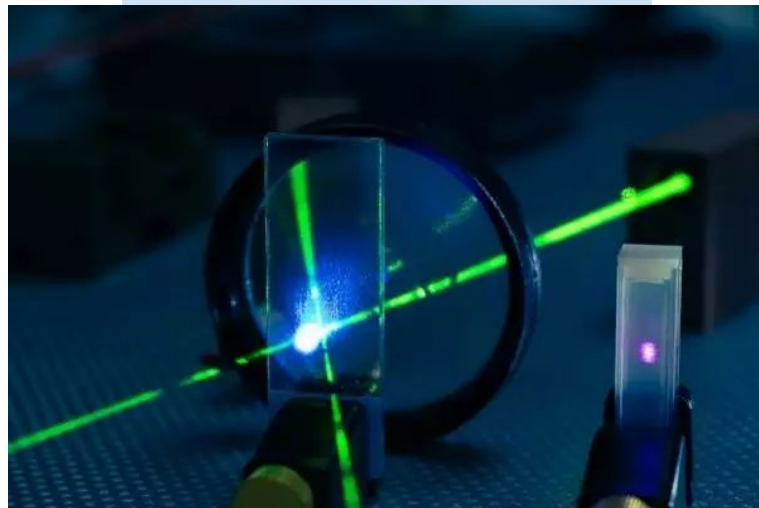
**COMMON QUESTIONS**

**04**

**TIPS FROM A VETERAN**

**05**

**OTHER FREE RESOURCES**





# The Rules Sheet

## ● Written Test

- Important to know every topic at least on the surface level!
- All supplement material can be in the binder
  - E.g., formulas and refractive indices

## ● Laser Shoot

- Practice with your partner!
  - You need to have ✨synergy✨
- Think first, act last!! Even if you work slow
- Make sure to stop on time
- Move with care


**OPTICS B**


See General Rules, Event Procedures & other Policies on [www.sosol.org](http://www.sosol.org) as they apply to every event.

1. **DESCRIPTION:** Teams will participate in an activity involving positioning mirrors to direct a laser beam towards a target and complete a written test on the principles of geometrics and physical optics.

**ALTERNATE ID:** 2 **EYE PROTECTION:** None Required

**CALCULATOR:** Class III **APPROXIMATE TIME:** 50 minutes

2. **EVENT PARAMETERS:**

- a. Each team may bring one three-ring binder of any size containing information in any form and from any source, attached using the available rings. Sheet protectors, laminations, tabs and labels are permitted. Participants may remove information or pages for their use during any part of the event.
- b. Each team may also bring tools, protractors, templates, supplies, writing utensils, and two calculators (Class III).
- c. Teams must not bring lasers, mirrors, other optical devices (aside from personal eyeglasses or contacts), or electronics (other than calculators).

3. **THE COMPETITIONS:**



**Part I: Written Test**

- a. Teams will be given a minimum of 20 minutes to complete a written test consisting of multiple choice, true-false, completion, or calculation questions/problems.
- b. Unless otherwise specified, answers must be in metric units with appropriate significant figures.
- c. The test will consist of at least 5 questions from each of the following areas:
  - i. Reflection and refraction: Specular & diffuse reflection; Law of Reflection; index of refraction; Snell's law; critical angle; and prism (deviation & dispersion)
  - ii. Mirrors & lenses: Curvature; concave, and plane mirrors and lenses; ray tracing; focal length; real, virtual, erect, and inverted objects and images; magnification
  - iii. Color theory: Additive & subtractive color theory; primary & secondary colors; absorption & reflection
- d. Questions on the test will use the following mathematical content:
  - i. Math expectations for Regional Tournaments:
    - (1) Primarily qualitative (non-computational) questions and ray tracing
    - (2) Standard arithmetic operations (including rates)
    - (3) Basic 2D geometry required for ray tracing. For example, parallel & perpendicular lines, rays, triangles (similar & congruent), and circles
    - (4) Simple trigonometric relations to enable use of trigonometric functions on a calculator.
  - ii. Math expectations for State & National Tournaments:
    - (1) All Regional expectations. Can also include qualitative questions, but students must show computational work.
    - (2) Simple algebra manipulations, including solving one equation for one variable

**Part II: Laser Shoot**

- a. The objective is to reflect a laser beam with mirrors around barriers towards the Target Point located on the wall opposite the laser.
- b. The event supervisor must select a Target Point location that is the same for all teams. Teams must not be informed of the location until it is their turn to compete in Part II of the event.
- c. The Event Supervisor must test the beam's alignment before each team is permitted to use the LSS (Laser Shoot Setup, as defined in Section 4).
- d. All mirrors must be placed in a home position designated by the event supervisor before each team is permitted to use the LSS.
- e. When teams are ready to begin, the event supervisor must give a countdown of "3, 2, 1, start" and start a timer. Event Supervisors must give teams a warning when 3 minutes have elapsed.

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**OPTICS C**


See General Rules, Event Procedures & other Policies on [www.sosol.org](http://www.sosol.org) as they apply to every event.

1. **DESCRIPTION:** Teams will participate in an activity involving positioning mirrors to direct a laser beam towards a target and complete a written test on the principles of geometrics and physical optics.

**ALTERNATE ID:** 2 **EYE PROTECTION:** None Required

**CALCULATOR:** Class III **APPROXIMATE TIME:** 50 minutes

2. **EVENT PARAMETERS:**

- a. Each team may bring one three-ring binder of any size containing information in any form and from any source, attached using the available rings. Sheet protectors, laminations, tabs and labels are permitted. Participants may remove information or pages for their use during any part of the event.
- b. Each team may also bring tools, protractors, templates, supplies, writing utensils, and two calculators (Class III).
- c. Teams must not bring lasers, mirrors, other optical devices (aside from personal eyeglasses or contacts), or electronics (other than calculators).

3. **THE COMPETITIONS:**


**Part I: Written Test**

- a. Teams will be given a minimum of 20 minutes to complete a written test consisting of multiple choice, true-false, completion, or calculation questions/problems.
- b. Unless otherwise specified, answers must be in metric units with appropriate significant figures.
- c. The test will consist of at least 5 questions from each of the following areas:
  - i. Reflection and refraction: Specular & diffuse reflection; Law of Reflection; index of refraction; Snell's law; critical angle; and prism (deviation & dispersion)
  - ii. Mirrors & lenses: Curvature; concave, and plane mirrors and lenses; ray tracing; focal length; real, virtual, erect, and inverted objects and images; magnification
  - iii. Color theory: Additive & subtractive color theory; primary & secondary colors; absorption & reflection
  - d. Questions on the test will use the following mathematical content:
    - i. Math expectations for Regional Tournaments:
      - (1) Basic 2D geometry required for ray tracing. For example, parallel & perpendicular lines, rays, triangles (similar & congruent), and circles
      - (2) Simple algebra manipulations, including solving one equation for one variable
    - ii. Math expectations for State & National Tournaments:
      - (1) All regional expectations
      - (2) More sophisticated algebra, such as solving systems of equations for multiple variables

**Part II: Laser Shoot**

- a. The objective is to reflect a laser beam with mirrors around barriers towards the Target Point located on the wall opposite the laser.
- b. The event supervisor must select a Target Point location that is the same for all teams. Teams must not be informed of the location until it is their turn to compete in Part II of the event.
- c. The Event Supervisor must test the beam's alignment before each team is permitted to use the LSS (Laser Shoot Setup, as defined in Section 4).
- d. All mirrors must be placed in a home position designated by the event supervisor before each team is permitted to use the LSS.

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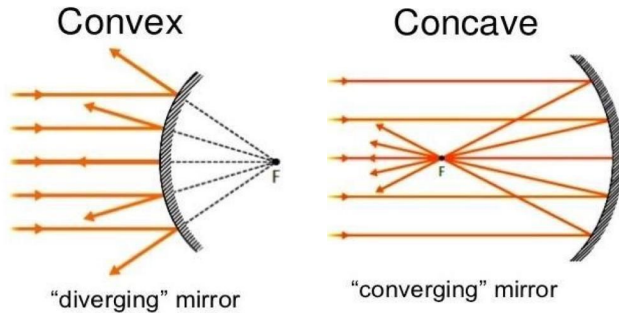
# DIFFICULT TOPICS

# Topic 1: Reflection & Refraction

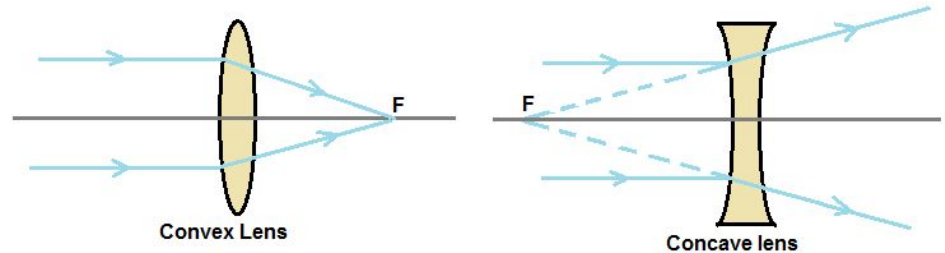
- Law of Reflection
  - Angle of incidence = angle of reflection
- Snell's Law
  - $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$
- Critical Angle
  - Angle of incidence where the angle of refraction is  $90^\circ$  (direct reflection)
  - $\theta = \arcsin(n_r/n_i)$
- Index of Refraction
  - $n = c/v$
  - Understand what happens to  $v$  when light enters a different medium

# Topic 2: Mirrors & Lenses

- Mirrors
  - Convex: curves “out”
  - Concave: like an entrance to a cave, caves “in”



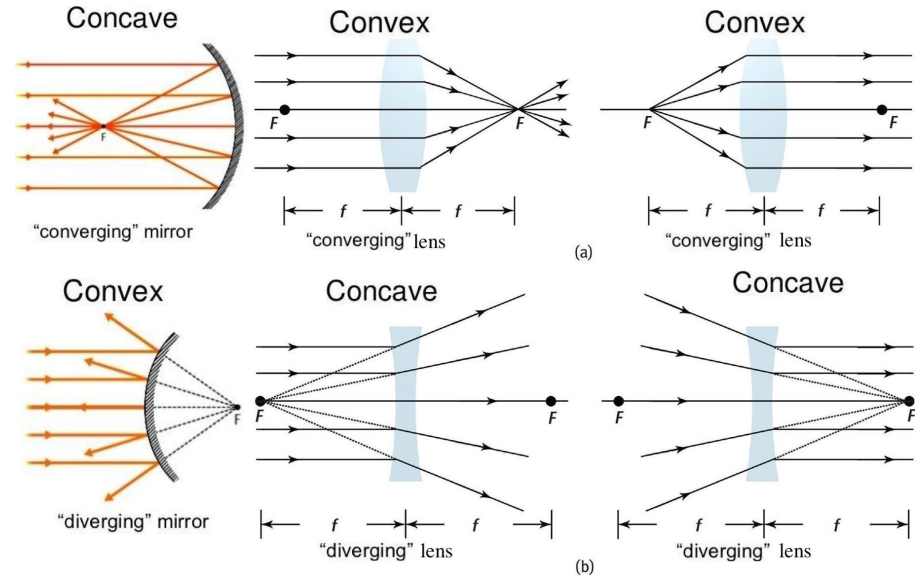
- Lenses
  - Convex: middle thicker than edges
  - Concave: middle thinner than edges





# Topic 2: Mirrors & Lenses

- Watch out for naming!
- Mirrors:
  - Concave: converging
  - Convex: diverging
- Lenses:
  - Concave: diverging
  - Convex: converging



- This is simply a reflection of how they interact with light

# Topic 2: Mirrors & Lenses

- Focal Length
  - $1/f = 1/u + 1/v$ 
    - $u$  = object to lens
    - $v$  = lens to image
- Magnification
  - $m = h_i/h_o = -d_i/d_o$ 
    - $i$  = image
    - $o$  = object
    - All distances are measured from the mirror/lens
- Often used in the context of vision correction
- Important to measure all distances/heights correctly!



# Topic 3: Color Theory

- Additive Color Theory
  - RGB (human vision)
  - More light added = brighter & lighter resulting color
- Subtractive Color Theory
  - CMY (pigments)
  - More color added = closer to black
- Primary and Secondary Colors
  - RGB/CMY vs. colors resulting from their mixing
- Absorption and Reflection
  - Which colors are absorbed/reflected when struck with, e.g., white light?



# COMMON QUESTIONS

All of the following questions have been pulled from past YJI exams (which can be found on our website) or the Text Exchange on SciOly Wiki

# Question 1

- If a concave mirror forms a real image 45 cm from the mirror when the object is 30 cm from the mirror, what is the focal length of the mirror, in cm?

**Solution:**

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{f} = \frac{1}{45} - \frac{1}{30} = \frac{2 - 3}{90}$$

$$\frac{1}{f} = \frac{-1}{90}$$

$$f = -90 \text{ cm}$$

## Question 2

- Light enters a diamond at an angle of  $30^\circ$  and bends to an angle of  $22^\circ$ . Calculate the index of refraction of the diamond, to the nearest thousandth.

**Solution:**

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

$$1 \cdot \sin(30^\circ) = n_2 \cdot \sin(22^\circ)$$

$$n_2 = \frac{\sin(30^\circ)}{\sin(22^\circ)}$$

$$n_2 = 1.335$$

# Question 3

- A ray of light passes through a glass prism ( $n = 1.5$ ) with an apex angle of  $60^\circ$ . Calculate the angle of minimum deviation, to the nearest hundredth of a degree.

**Solution:**

$$n = \frac{\sin\left(\frac{A + D_{\min}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$
$$\sin\left(\frac{A + D_{\min}}{2}\right) = n \cdot \sin\left(\frac{A}{2}\right)$$
$$\frac{A + D_{\min}}{2} = \arcsin\left(n \cdot \sin\left(\frac{A}{2}\right)\right)$$
$$D_{\min} = 2 \cdot \arcsin\left(n \cdot \sin\left(\frac{A}{2}\right)\right) - A$$
$$D_{\min} = 2 \cdot \arcsin\left(1.5 \cdot \sin\left(\frac{60^\circ}{2}\right)\right) - 60^\circ$$

$$D_{\min} = 37.18^\circ$$

# Tips from a Veteran

- Teamwork is key
  - Specialize in separate topics, especially those that you enjoy more
    - A good split is anatomy/color/basics & mirrors/lenses
- Organization of your binder is essential
  - Sort your binder in a logical manner
    - Sort it in a way you will *remember* on competition day
- Less is more
  - A lot of people move mirrors in the perfect position before moving it away for their final run :(
  - Limit your overthinking
- PRACTICE (nothing else to say)

# Additional Resources

## Example tests

- Tournament websites
- SciOly test exchange

[physicsclassroom.com](https://physicsclassroom.com)

[hyperphysics.phy-astr.gsu.edu](https://hyperphysics.phy-astr.gsu.edu) !

[phys.libretexts.org](https://phys.libretexts.org) !



THANKS!

