Optics B

Sierra Vista 2024 Invitational

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Team Number and Name:

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1. DO NOT OPEN THIS PACKET until you are told to begin. Listen to instructions first.
2. **You may rip apart the test**, but staple it together again before time is called.
3. **Test-taking Tips:** If you get stuck on a hard question, move on. Guess on questions you don't know. Cross out answers you know are wrong. Mark questions you want to come back to when you're done.
4. Answer in 3 significant figures
5. Answer scientific notation if there are leading or trailing zeroes
6. Answer in SI units unless otherwise specified
7. Have fun and good luck!

Multiple choice (2pts each):

1. What is the term for the bending of light as it passes from one medium to another?
   a) Reflection
   b) Refraction
   c) Diffraction
   d) Dispersion

2. Which lens is thicker at the center than at the edges?
   a) Diverging Meniscus
   b) Plano-convex lens
   c) Plano-concave lens
   d) Concave lens

3. What properties does the image at the focal point of a concave mirror have?
   a) Real and in front of the mirror
   b) Virtual and in front of the mirror
   c) Real and behind the mirror
   d) Virtual and behind the mirror

4. In the context of optics, which does the term "chromatic aberration" not refer to?
   a) Splitting of light into its component colors
   b) Blurring of the image
   c) Dispersion of light
   d) Distortion of color wavelengths

5. Which phenomenon causes the formation of a rainbow when sunlight passes through raindrops?
   a) Dispersion
   b) Diffraction
   c) Interference
   d) Polarization

6. What is the SI unit of optical power?
   a) Diopter
   b) Watt
   c) Lux
   d) Hertz

7. What is the critical angle in optics?
   a) The angle of incidence at which total internal reflection occurs
   b) The angle of refraction in a medium
   c) The angle of reflection from a mirror
   d) The angle at which diffraction is maximum

8. Which phenomenon is responsible for the formation of mirages in hot weather?
   a) Total internal reflection
   b) Dispersion
   c) Diffraction
   d) Interference

9. What is the relationship between the angle of incidence and the angle of reflection for a plane mirror?
   a) They are equal
   b) The angle of incidence is greater
   c) The angle of reflection is greater
   d) They are unrelated

10. Which type of lens is used to correct hypermetropia (farsightedness)?
    a) Convex lens
    b) Concave lens
    c) Bifocal lens
    d) Plano-convex lens

11. What happens to the speed of light when it enters a denser medium?
   a) It increases
   b) It remains constant
   c) It decreases
   d) It depends on the color of light

12. The phenomenon of diffraction is most pronounced when the size of the opening or obstacle is comparable to the:
   a) Wavelength of light
   b) Frequency of light
   c) Speed of light
   d) Intensity of light

13. What is the primary function of a camera lens aperture?
   a) To control focal length
   b) To focus light
   c) To filter colors
   d) To minimize aberrations

14. Which type of mirror is used in a rearview mirror of a car?
   a) Convex mirror
   b) Concave mirror
   c) Plane mirror
   d) Spherical mirror

15. What is the phenomenon where light waves cancel each other out, resulting in darkness or reduced intensity?
   a) Diffraction
   b) Interference
   c) Refraction
   d) Dispersion

16. Which of the following materials cannot polarize light?

a) Glass
b) Water
c) Marble
d) Copper

17. The phenomenon of total internal reflection is used in the operation of:
a) Microscopes
b) Telescopes
c) Fiber optics
d) Cameras

18. What is the process of separating white light into its component colors called?
a) Polarization
b) Dispersion
c) Refraction
d) Diffraction

19. Which color of light deviates the most when passing through a prism?
a) Red
b) Blue
c) Green
d) Yellow

20. The image formed by a convex lens for an object beyond its focal point is:
a) Real and inverted
b) Real and upright
c) Virtual and inverted
d) Virtual and upright

21. What is the phenomenon where light waves spread out when passing through a small opening or around an obstacle?
    a) Diffraction
    b) Reflection
    c) Refraction
    d) Interference

22. What is the SI unit of measurement for the wavelength of light?
    a) Hertz
    b) Newton
    c) Meter
    d) Nanometer

23. The bending of light waves as they pass through a prism is an example of:
    a) Refraction
    b) Reflection
    c) Dispersion
    d) Interference

24. Which of the following is not a primary color of light?
    a) Red
    b) Green
    c) Blue
    d) Yellow

25. What type of lens is used in a magnifying glass?
    a) Convex lens
    b) Concave lens
    c) Bifocal lens
    d) Plane lens

26. The phenomenon where light changes speed as it passes from one medium to another is the cause of which of the following?
   a) Reflection
   b) Refraction
   c) Diffraction
   d) Dispersion

27. What is the angle of incidence for light that undergoes total internal reflection?
   a) 0 degrees
   b) 90 degrees
   c) Less than the critical angle
   d) Greater than the critical angle

28. Which of the following is a property of a concave lens?
   a) Converging
   b) Diverging
   c) Thick at the center
   d) Forms real images

29. What happens to the focal length of a convex lens when it is placed in water?
   a) Increases
   b) Decreases
   c) Remains the same
   d) Becomes infinite

30. The dispersion of light into its component colors is responsible for the formation of:
   a) Rainbows
   b) Mirages
   c) Shadows
   d) Halos

Free Response (5pts each):

1. Explain how the phenomenon of total internal reflection is utilized in fiber optics technology. Provide examples of applications where fiber optics play a crucial role.

2. Describe the characteristics of a convex lens and explain how it forms images for objects placed at different distances. Include discussions on focal points and image magnification.

3. Discuss the factors that contribute to chromatic aberration in optical systems. How can this aberration be minimized or corrected in lenses?

4. Explain the concept of polarization in optics. Provide examples of natural and artificial sources of polarized light, and discuss the applications of polarizing filters.

5. Describe the working principle of a concave mirror and discuss its applications in everyday devices. How does the focal point of a concave mirror relate to image formation?

6. Discuss the role of diffraction in the behavior of light waves. Provide examples of situations where diffraction is observed and explain the impact on the resulting light patterns.

7. Explain how a camera aperture affects the exposure of an image. Discuss the trade-offs involved in selecting different aperture sizes.

8. Describe the phenomenon of dispersion in the context of optics. How does a prism disperse white light, and what is the order of colors in the spectrum?

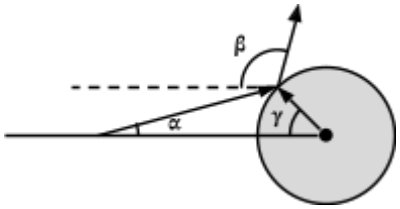
9. Discuss the concept of optical power in lenses. How is it measured, and how does it relate to the ability of a lens to converge or diverge light?

10. Explain the principle behind the operation of a lens in correcting hypermetropia (farsightedness). How does the shape of the lens address the focusing issue for individuals with hypermetropia?

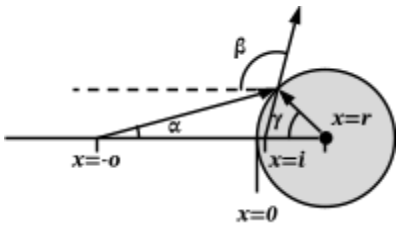
Extended Problems (show work for partial credit):

Mirror Mirror on the Ball (40 pts)

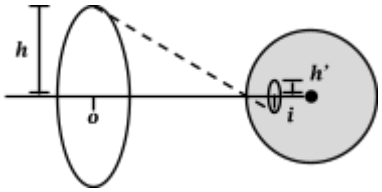
In this problem we will investigate the physics of spherical mirrors. In geometric optics, there are neat equations governing the position and size of images in curved mirrors. However, the equations we will explore in this problem are mere approximations, and real objects with finite size will appear slightly different and distorted than the equations suggest. This may be considered as a result of spherical aberration, where images appear distorted due to the imperfect geometric properties spherical surfaces posess regarding reflection. Assume paraaxial rays (rays travelling at a small angle from the center axis) for all parts of this problem. Angles in diagrams are greatly exaggerated for clarity.



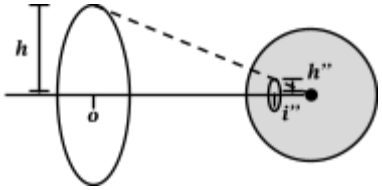
a. Consider a spherical mirror with its center on the x-axis. A ray of light travels at an angle α from the x-axis, hits the mirror, and reflects. The radius connecting the center of the circle to the point the light hit forms an angle γ with the x-axis. Find the angle β that the reflected ray forms with the x-axis. Express your answer in terms of α and γ. (3 pts)



b. If a point source produces many of these rays, an image will be formed inside the mirror. The location of this image is located at the intersection of the x-axis and the ray gotten by tracing the reflected ray found in part a backwards. The point source is located at a distance o from the front surface, the image is located at a distance i behind the front surface, and the mirror has a radius r. Using small angle approximation for all three angles, show that the following equation holds: $\frac{1}{i} = \frac{1}{o} + \frac{2}{r}$. (8 pts)



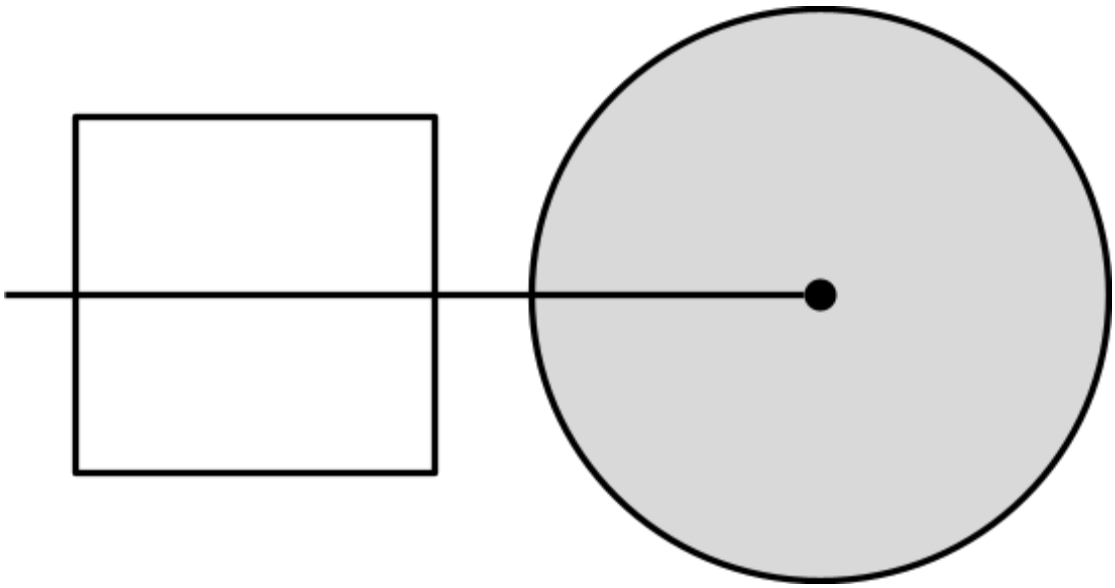
c. Instead of a point source, put a ring of radius h centered at the same spot, with its center axis aligned with the x-axis. If the traditional equations are used for spherical mirrors, one can find the radius of the resulting image by applying similar triangles. By using this method, find the image radius h'. Express your answer in terms of h, o, and r. (4 pts)



d. In reality, the image radius and position is slightly different. This is because in the part c we approximated the ring as a point source, and geometrically extended the argument to find its size. What actually happens is that each point on the ring is a point source, and the image for each point can be found via the method in part b. Using this new method, find the x-position i'' of the image. Express your answer in terms of h, o, and r. (6 pts)

e. Using the same method, find the image radius h''. Express your answer in terms of h, o, r , and i''. (4 pts)

f. Numerically evaluate the percent error of the image position $\%i = |\frac{i-i''}{i}|$ for a ring of radius 5 cm placed 10 cm from the surface of a spherical mirror with a radius 5cm. Do the same for the percent error of the image radius $\%h$. (8 pts)



g. A square frame is placed in front of a mirror as shown in the diagram. On the diagram, sketch the image formed by the frame as accurately as possible. Assume the frame is semi-transparent, so two parts of the frame cannot hide each other. (7 pts)