

USC Invitational

18 January 2025

Optics B TEST

Directions:

- You will have 50 minutes to complete this test along with the lab portion of the event.
- All electronic devices, except up to two stand-alone calculators, must be put away.
- If work is shown for FRQs, partial credit may be awarded for incorrect answers.
- Round answers reasonably. No deductions will be made for incorrect significant figures, but they may be used for tiebreaking.
- Use SI units unless specifically stated otherwise.
- Useful constant: $c = 3.00 \times 10^8 \text{ m/s}$
- Any provided diagrams may not be to scale unless specified.
- For ray-tracing questions, full credit will be awarded for at least **2 rays per lens/mirror** and all objects and images correctly drawn. The diagram does not need to be to scale, but must roughly show the locations of objects and images in relation to lenses/mirrors

1 Multiple Choice

1 point per question.

1. Identify the eye condition that someone with vision like that in Figure 1 is experiencing.
 - A. Myopia
 - B. Hyperopia
 - C. Glaucoma
 - D. Macular Degeneration
2. As a person ages, what ability of their eye tends to diminish the most?
 - A. Identifying faraway objects
 - B. Peripheral vision
 - C. Contracting ciliary muscles to decrease lens power
 - D. Contracting ciliary muscles to increase lens power
3. What part of the eye has the highest optical power?
 - A. Cornea
 - B. Lens
 - C. Aqueous Humor
 - D. Sclera
4. Dave's eye ranges from an optical power of 47.0 to 52.0. For simplicity, you can model his eye as one lens focusing light onto the retina, which is 20 mm away from the lens. What is the closest object to his eye that he can see clearly?
 - A. 16 cm
 - B. 25 cm
 - C. 50 cm
 - D. 75 cm
5. What condition does Dave definitely suffer from?
 - A. Myopia
 - B. Hyperopia
 - C. Astigmatism
 - D. Cataracts
6. Suppose that ideally, Dave should be able to see objects 20 cm in front of him clearly. What is the optical power of a lens that his doctor should prescribe him?
 - A. -2.0
 - B. -3.0
 - C. +2.0
 - D. +3.0
7. If Dave instead receives laser surgery to adjust his eye, what part of his eye will be altered?
 - A. Cornea
 - B. Lens
 - C. Iris
 - D. Retina
8. If Dave's cornea has an optical power of 43 D, what will be its optical power after the surgery? You can consider his eye as two thin lenses placed close to each other: the cornea and the lens. The cornea cannot accommodate its focal length to different objects but the lens can.
 - A. 40 D
 - B. 43 D
 - C. 45 D
 - D. 46 D
9. Some patients report seeing "halos" after receiving laser eye surgery. What type of aberration in the eye can cause this effect?
 - A. Chromatic
 - B. Comatic
 - C. Spherical
 - D. Astigmatism
10. The Balmer series for Hydrogen atoms is a series of emission lines for Hydrogen atoms that are concentrated in the visible spectrum. Using the Rydberg formula, where $1.097 \times 10^7 \text{ m}^{-1}$, what is the wavelength of the H- β line, which corresponds to a jump from quantum number 4 to quantum number 2?
 - A. 97 nm
 - B. 364 nm
 - C. 486 nm
 - D. 656 nm

11. What is the energy in joules associated with a single photon of H- β ?
- A. $3.03 \times 10^{-19} J$
 - B. $4.09 \times 10^{-19} J$
 - C. $5.44 \times 10^{-19} J$
 - D. $6.11 \times 10^{-19} J$
12. We observe an emission spectrum from a distant star with a H- β line with slightly lower wavelength than expected. What could be the cause of this?
- A. The star is moving away from us
 - B. The star is moving towards us
 - C. There is matter between us and the star causing gravitational lensing
 - D. The universe is expanding
13. A dye has the absorption spectrum shown in Figure 2. What is its color?
- A. Red
 - B. Yellow
 - C. Green
 - D. Blue
14. Ayushi is 5.00 feet tall and looks at her reflection in a plane mirror that is angled 5 degrees away from the vertical. How tall is her image?
- A. 4.96 feet
 - B. 4.98 feet
 - C. 5.00 feet
 - D. 5.02 feet
15. The speed of light in a material is 2×10^8 m/s. What is the material's index of refraction?
- A. 1.2
 - B. 1.5
 - C. 2.0
 - D. 0.75
16. A light ray strikes a mirror at an angle of 35° to the normal. What is the angle of reflection?
- A. 35°
 - B. 30°
 - C. 45°
 - D. 55°
17. Why do you see a clear image of yourself in a polished metal mirror but not on a white sheet of paper, even though both reflect light?
- A. Light is reflected uniformly by the mirror, but scattered by the paper.
 - B. The paper absorbs most of the light, while the mirror reflects nearly all of it in a specific direction.
 - C. Mirrors transmit some light in addition to reflection, whereas the paper does not.
 - D. Mirrors are brighter than paper because they reflect light more efficiently and in a specific way.
18. What type of lens is used in glasses to correct nearsightedness (myopia)?
- A. Convex lens
 - B. Concave lens
 - C. Cylindrical lens
 - D. Bifocal lens
19. Which of the following is corrected using cylindrical lenses in glasses?
- A. Myopia
 - B. Hyperopia
 - C. Astigmatism
 - D. Presbyopia
20. In a simple periscope, how are the mirrors positioned to allow light to travel through the device?
- A. At a 45° angle to the horizontal, facing each other.
 - B. At a 90° angle to the horizontal, parallel to each other.
 - C. At a 45° angle to the horizontal, back-to-back.
 - D. At a 30° angle to the horizontal, facing away from each other.
21. What is the "index error" in the context of using instruments like a sextant?
- A. It is the error caused by the improper handling of the sextant.
 - B. It is the error due to the incorrect alignment of the instrument's index mirror and horizon mirror.
 - C. It is the error caused by measuring angles with a non-standard unit.
 - D. It is the error that occurs when the sextant is used in a moving environment.

22. How can the index error of a sextant be corrected?
- A. By measuring the angle between two distant objects multiple times and averaging the results.
 - B. By recalibrating the sextant using a standard angular reference tool.
 - C. By ensuring the sextant is used only at sea level under clear conditions.
 - D. By adjusting the horizon mirror until it aligns with the index mirror.
23. A fish is swimming 2 meters below the surface of water ($n = 1.33$). At what angle to the normal must light exit the water surface to refract at 45° in air?
- A. $29.54.00^\circ$
 - B. 32.12°
 - C. 35.71°
 - D. 38.04°
24. Say you try to hit the fish with a spear, aiming directly at the fish. Will you hit it?
- A. No, because light refracts at the water surface, making the fish appear higher than it actually is.
 - B. Yes, because the light travels straight through the water without bending.
 - C. No, because water magnifies the fish, making it appear larger and closer.
 - D. Yes, because the apparent position of the fish matches its real position.
25. What are the primary colors of light in the additive color model?
- A. Red, Yellow, Blue
 - B. Red, Green, Blue
 - C. Cyan, Magenta, Yellow
 - D. Blue, Yellow, Green
26. In the additive color model, what are the three secondary colors formed by combining the primary colors of light?
- A. Cyan, Magenta, Yellow
 - B. Red, Green, Blue
 - C. Orange, Purple, Green
 - D. Yellow, Green, Blue
27. Why does a yellow piece of paper look yellow under white light?
- A. The paper absorbs blue light and reflects red and green light, which combine to appear yellow.
 - B. The paper absorbs red and green light and reflects blue light, giving it a yellow appearance.
 - C. The paper emits yellow light when illuminated by white light.
 - D. The paper absorbs all other colors except yellow, which it reflects.
28. How does changing the focal length of a camera lens affect the image?
- A. Increasing the focal length magnifies the subject and narrows the field of view.
 - B. Increasing the focal length reduces the subject size and broadens the field of view.
 - C. Decreasing the focal length magnifies the subject and narrows the field of view.
 - D. Decreasing the focal length has no effect on the magnification or field of view.
29. Why are compound microscopes typically used instead of simple microscopes for high magnifications?
- A. Compound microscopes combine the magnification of two lenses, allowing for greater total magnification.
 - B. Compound microscopes use larger lenses, which produce higher magnifications than smaller lenses.
 - C. Compound microscopes reduce the amount of light needed for high magnification.
 - D. Compound microscopes require less alignment, making them easier to use for high magnifications.

30. What is Snell's Law?
- A. The angle of incidence equals the angle of reflection.
 - B. The product of the refractive index and the sine of the angle of incidence is constant across the boundary between two media.
 - C. The refractive index is proportional to the wavelength of light passing through a medium.
 - D. Light bends only when passing from a denser medium to a less dense medium.

2 Free Response

1. (11 points)
 - (a) (2 points) Jeffrey uses a magnifying glass to look at a bug. He places the magnifying glass 5 cm above the bug, and he sees that the bug looks upright and magnified 2x. What is the focal length of the magnifying glass?
 - (b) (3 points) He then places another identical magnifying glass directly in between the first magnifying glass and the bug, 2.5 cm between each object. Complete the ray tracing diagram in your answer sheet
 - (c) (4 points) Is the resulting image real or virtual? Where is the resulting image?
 - (d) (2 points) What is the magnification of this lens system?
2. (2 points) The "infrared window" is a window of wavelengths between 8 and 14 microns (refer to figure 3) in the Earth's atmosphere that is crucial in regulating its temperatures and preventing warming. Why?
3. (4 points) A light ray enters a prism with an apex angle of 60° and a refractive index of 1.6. The angle of incidence is 40° . If the ray emerges symmetrically, calculate the angle of deviation.
4. (2 points) Provide one example each of an everyday item that uses additive and subtractive color theory.
5. (2 points) Hypothetically, a shirt that appeared to be blue under white light had a red light shone upon it. What color would the shirt appear to be now, and why?
6. (3 points) Describe the role of the aperture, lens, and sensor in a camera.
7. (3 points) What type of telescope is a Schmidt-Cassegrain telescope? Why is it popular among amateur astronomers? (3 points: 1 point for identifying the type of telescope, 2 points for explaining its popularity.)
8. (5 points) Advanced optical designs like the Ritchey-Chrétien telescope are commonly used in professional astronomy. Describe the design of a Ritchey-Chrétien telescope, including its unique optical elements and the advantages it provides over simpler designs. Why is it particularly suitable for astrophotography and large observatories? (5 points)

3 Images

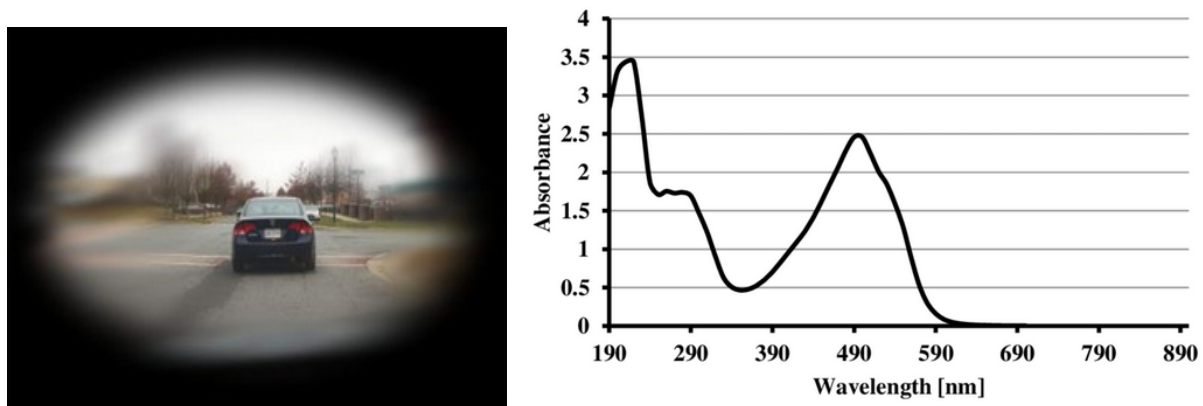


Figure 1: Figure for MCQ 1

Figure 2: Figure for MCQ 13

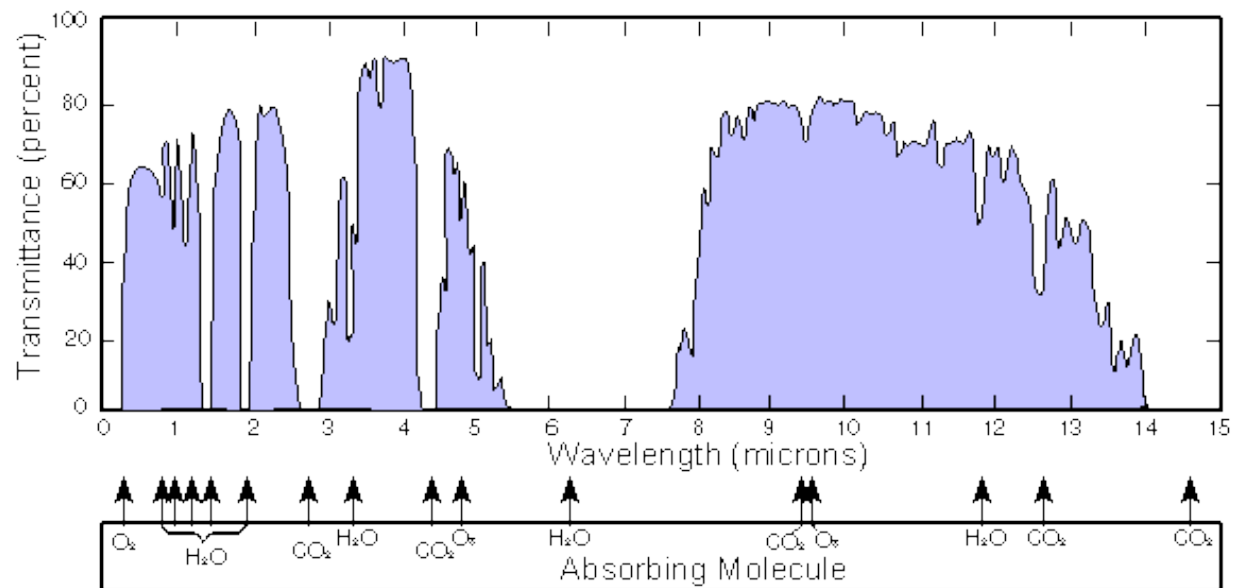


Figure 3: Figure for FRQ 2