USC Invitational

18 January 2025

Optics B KEY

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 used for tiebreaking.
- Use SI units unless specifically stated otherwise.
- Useful constant: $c = 3.00 \times 10^8$ 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. C	2. D	3. A	4. C	5. B
6. D	7. A	8. D	9. C	10. C
11. B	12. B	13. A	14. C	15. B
16. A	17. A	18. B	19. C	20. A
21. B	22. D	23. B	24. A	25. B
26. A	27. A	28. A	29. A	30. B

2 Free Response

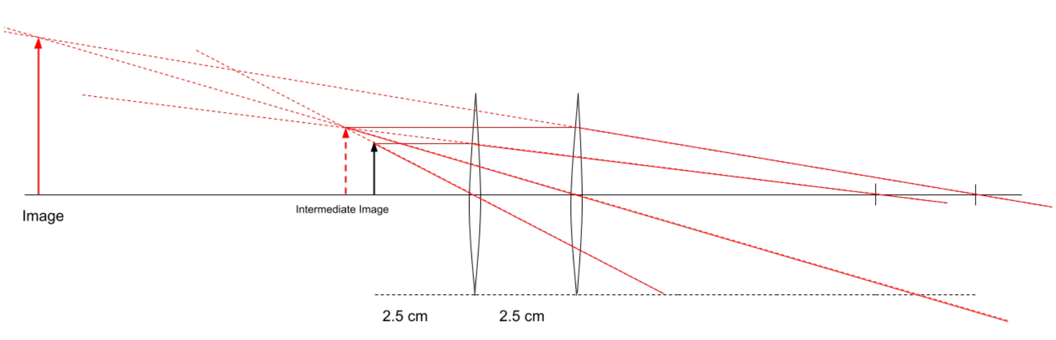
1. (11 points)

   (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?

   Solution:
   +2pt for answer: 10 cm
   OR
   +1pt for correct writing the lens equation and attempting to use the magnification relationship M $= -s_i/s_o$ as a constraint.

   (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

   Solution:



+0.5pt for each correct ray (up to +2) for partial credit. This means you get +1pt for correctly tracing the first intermediate image.

(c) (4 points) Is the resulting image real or virtual? Where is the resulting image?

Solution:
+1pt: Virtual
AND
+3pt for location: 14 cm behind the original lens (or equivalent)
OR
+1pt for correctly applying the lens equation the first time with object distance 2.5 cm and focal length 10 cm
+1pt for correctly setting up the lens equation the second time with object distance 2.5 + 3.33 cm and focal length 10 cm

(d) (2 points) What is the magnification of this lens system?

Solution:
+2pt for answer: 3.2
OR +1pt for getting magnification of first lens: 3.33/2.5 = 1.33

2. (2 points) The "infrared window" is a window of wavelengths between 8 and 14 microns (refer to figure **??**) in the Earth's atmosphere that is crucial in regulating its temperatures and preventing warming. Why?

Solution:
+1pt: Atmosphere transmits a lot of this radiation outwards, as evidenced by the spectrum
+1pt: Infrared light contributes to a lot of the heating of earth, so allowing it to escape in controlled amounts has a large impact on the earth's temperature

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.

Solution:
+1pt: Correctly sets up the problem, identifying $r_1 = r_2 = \frac{A}{2}$ due to symmetry, and using Snell's law $\sin i = n \sin r_1$ to calculate r_1.
+1pt: Applies Snell's law correctly to calculate $\sin r_1 = \frac{\sin 40^\circ}{1.6}$ and determines r_1.
+1pt: Uses the deviation formula $\delta = 2i - A$ and substitutes the correct values ($i = 40^\circ$, $A = 60^\circ$).
+1pt: Correctly calculates the angle of deviation as $\delta = 20^\circ$.

4. (2 points) Provide one example each of an everyday item that uses additive and subtractive color theory.

Solution:
Additive Color Theory (1 point possible):

- Example: TV/Computer screens, projectors, digital displays, or VR/AR devices that use red, green, and blue light to create colors.

Subtractive Color Theory (1 point possible):

- Example: Color printers, paint mixing, or film photography that use cyan, magenta, yellow, and black (CMYK) pigments to produce colors.

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?

Solution:
+1pt: Correctly states that the shirt would appear black or dark.
+1pt: Explains that the shirt reflects blue light under white light, but under red light, there are no blue wavelengths to reflect, so the shirt absorbs the red light and appears black.

6. (3 points) Describe the role of the aperture, lens, and sensor in a camera.

Solution:
+1pt: The aperture controls the amount of light entering the camera by adjusting its size. A larger aperture allows more light in, while a smaller aperture reduces the amount of light.
+1pt: The lens focuses light onto the camera sensor by bending and directing the light rays to form a sharp image.
+1pt: The sensor captures the incoming light and converts it into an electronic signal, creating the digital image.

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.)

Solution:
+1pt: A Schmidt–Cassegrain telescope is a type of catadioptric telescope that combines mirrors and lenses in its design.
+2pt: It is popular among amateur astronomers because it combines the long focal length of a refracting telescope with the lower cost per aperture of a reflecting telescope. Its compact and portable design makes it easy to transport and ideal for its given aperture, adding to its appeal for amateurs.

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)

Solution:
+2pt: The Ritchey–Chrétien telescope is a type of reflecting telescope that uses a hyperbolic primary mirror and a hyperbolic secondary mirror. This combination eliminates coma and spherical aberration, providing sharp images across a wide field of view.

+1pt: Unlike simpler designs, it does not require a corrector plate and has no chromatic aberration, making it ideal for professional applications.
+1pt: Its wide field of view and ability to produce diffraction-limited images make it particularly suitable for astrophotography and observing faint objects in the deep sky.
+1pt: The design is scalable, allowing for large apertures without significant loss of optical quality, which is essential for large observatories and space telescopes.