

OPTICS — SOLUTION KEY

Total Points: 50 | Questions: 5 | Date: February 20, 2026

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AI-generated graduate-level physics assignment. Contains 5 questions covering key concepts. Includes content from 1 document(s).

Question 1

10.0 points

Explain how the phenomenon of diffraction limits the resolution of optical systems. Discuss the role of the aperture size and wavelength.

ANSWER

Diffraction limits the resolution of optical systems because it causes light to spread when it encounters an aperture, leading to blurring of the image. The smaller the aperture, the more significant the diffraction effects, impacting the system's ability to distinguish between closely spaced objects. The resolution limit can be described by the equation

for the diffraction limit, $\theta = \frac{1.22 \lambda}{D}$, where λ is the wavelength of the light and D is the diameter of the aperture.

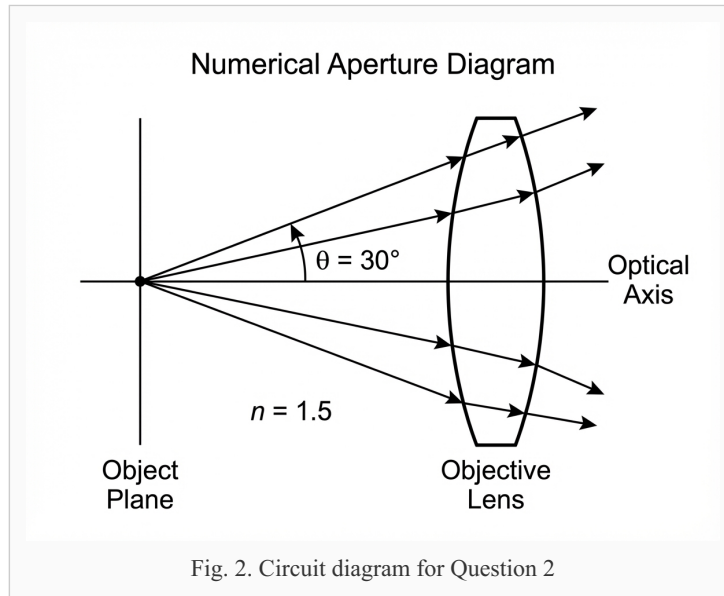
GRADING RUBRIC

- Clearly explains diffraction's impact on resolution (3 points) - Describes relationship between aperture size and resolution (3 points) - Describes relationship between wavelength and resolution (2 points) - Use of diffraction limit formula with explanation (2 points)

Question 2

8.0 points

Calculate the numerical aperture (NA) of the microscope objective lens shown in the diagram below, given a refractive index of 1.5 and a half-angle of acceptance of 30 degrees.

**ANSWER**

The numerical aperture (NA) is calculated using the formula $NA = n \sin(\theta)$, where n is the refractive index and θ is the half-angle of acceptance. Therefore, $NA = 1.5 * \sin(30) = 0.75$.

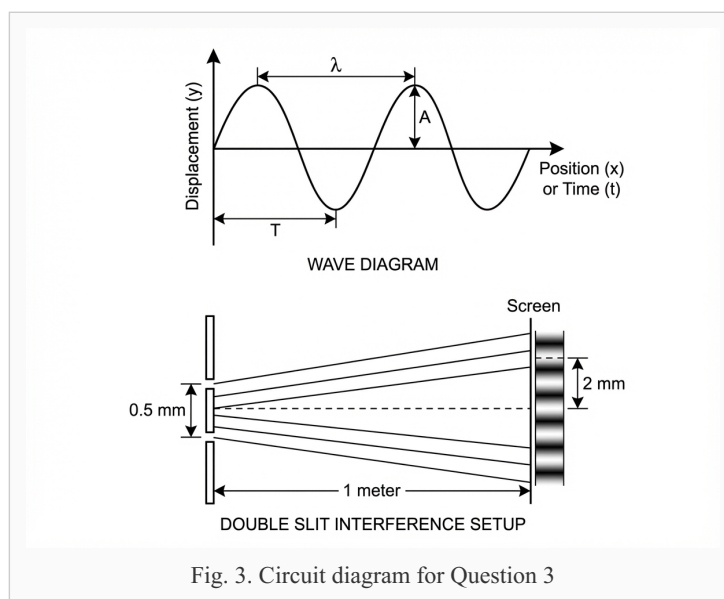
GRADING RUBRIC

- Correctly identifies and applies the formula for NA (4 points) - Correct calculation of NA using a calculator or by hand (4 points)

Question 3

12.0 points

Analyze the interference pattern in the diagram below of light passing through a double slit. Determine the wavelength of light used if the slit separation is 0.5 mm and the distance between the central maximum and first-order maximum is 2 mm at a screen 1 meter away.

**ANSWER**

The wavelength λ can be determined using the formula $\lambda = \frac{xd}{L}$, where x is the distance between fringes (2 mm), d is the slit separation (0.5 mm), and L is the distance to the screen (1 m). Plugging in the values, $\lambda = \frac{2 \times 10^{-3} \times 0.5 \times 10^{-3}}{1} = 1 \times 10^{-6}$ m or 1000 nm.

GRADING RUBRIC

- Correct application of the double-slit interference formula (4 points) - Correct substitutions and unit conversions (4 points) - Accurate calculation of the wavelength (4 points)

Question 4

10.0 points

A laser emits light with a total power of 5 mW and operates at a wavelength of 650 nm. Calculate the number of photons emitted by the laser per second.

ANSWER

The energy of a single photon can be calculated using $E = \frac{hc}{\lambda}$, where $h = 6.626 \times 10^{-34}$ J·s is Planck's constant, $c = 3 \times 10^8$ m/s is the speed of light, and $\lambda = 650 \times 10^{-9}$ m is the wavelength. The power of the laser $P = 5 \times 10^{-3}$ W = Joule/second. The number of photons $n = \frac{P}{E}$, substituting the values, $E = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{650 \times 10^{-9}} = 3.06 \times 10^{-19}$ J, $n = \frac{5 \times 10^{-3}}{3.06 \times 10^{-19}} \approx 1.634 \times 10^{16}$ photons/second.

GRADING RUBRIC

- Correct calculation of photon energy (4 points) - Correct use of power to find photon emission rate (4 points) - Units are handled correctly throughout (2 points)

Question 5

10.0 points

Describe the process and importance of phase coherence in producing a stable laser beam. How does it affect the coherence length?

ANSWER

Phase coherence in a laser beam refers to the uniform phase relationship between the light waves emitted, ensuring that they combine constructively to produce a stable and monochromatic wave. This coherence is crucial for maintaining the beam's collimation and intensity over long distances. A high degree of phase coherence increases the coherence length, which is the distance over which the wave fronts remain consistently phased. This is essential in applications like holography and interferometry that require precise control of light. In summary, phase coherence contributes to the stability of the laser beam and its effective application in various precise technologies.

GRADING RUBRIC

- Explanation of phase coherence and its establishment in laser (3 points) - Discussion on the impact of phase coherence on the beam's stability and operations (3 points) - Analysis of the relationship between phase coherence and coherence length (4 points)