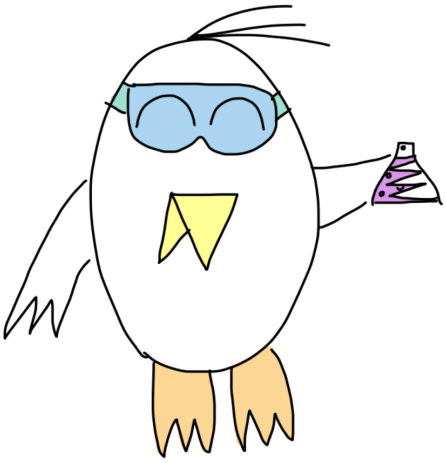
'Iolani Science Olympiad Pre-Nationals Practice

Division C

OPTICS TORTURE TEST



Name _____

Honolulu
2025

1 Baby Food

1. A soap film (n = 1.33) is viewed in air under white light. What is the minimum non-zero film thickness for which constructive interference of green light (λ = 540 nm) occurs in reflected light?

2. Light of wavelength 600 nm is incident on a diffraction grating with 5000 lines/cm. At what angle does the first-order maximum appear?

3 .In a double slit experiment with slit separation d=0.2 mm and screen distance L=1.0 m, monochromatic light of wavelength 500 nm is used. A thin film of thickness t and refractive index n=1.5 is placed in front of one slit, causing the central maximum to shift by one fringe width. What is the minimum thickness t of the film?

4. A telescope has an objective lens of diameter 10 cm and observes light of wavelength 500 nm. What is the angular resolution limit (in radians) due to diffraction?

5. In a Michelson interferometer using light of wavelength 600 nm, how far must one mirror be moved to cause 300 fringes to pass by?

6. A ray of white light is incident on one face of an equilateral prism (60° apex angle) at an angle of 50.0° (with respect to the normal). The prism is in air. The refractive index of the prism is:

$$n_{red} = 1.515, \quad n_{violet} = 1.530$$

Calclate the angular dispersion between red and violet rays as they emerge from the prism.

2 Evil GRIN

Consider a lens with an index of refraction described by $n(x) = n_0(1 + \alpha x^2)$, where x is the transverse coordinate from the optic axis. A parallel ray enters this medium. Derive the trajectory of the ray through the medium and determine its eventual focal point. Assume $\alpha < 0$.

3 Aberrations

Consider a thin lens where the focal length depends on the radial distance from the center: $f(r) = f_0 + \epsilon r^2$. A collimated beam enters the lens. Derive the intensity profile at a screen placed a distance f_0 away along the optical axis. (Feel free to keep your expression in terms of an integral).

4 Laser

A Fabry-Perot laser has a standing wave electric field given by

$$E(x, y, z) = E_0 \cos\left(\frac{m\pi z}{L}\right) \exp\left(-\frac{x^2 + y^2}{w^2}\right)$$

Compute the mode volume. (*Hint: The mode volume (or modal volume) of an optical cavity is a measure of how concentrated the electromagnetic energy of a single cavity mode is in space, expressed as an effective volume in which most of the energy associated with an electromagentic mode is confined. It is given by* $V = \frac{\int |E|^2 dV}{|E_{max}|^2}$)

5 Sexy matrix laser

Given two spherical mirrors of radii R_1 and R_2 separated by distance L, derive the general condition for optical cavity stability.