Physics 10164 - Exam 4D

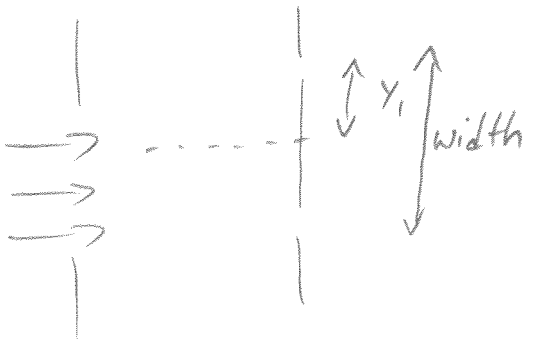
Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box and remember to include correct units and significant figures.

1. (30 pts) Light of wavelength 663 nm is incident on a single slit of width 0.33 mm. The light creates a diffraction pattern on the wall 2.2 meters away.

a) What is the width (in mm) of the central maximum of the single-slit diffraction pattern?

b) If a different, shorter wavelength is used (440 nm), will the width of the central maximum increase or decrease? Justify your answer mathematically or logically.

a) 1st minimum: $\frac{a y_1}{L} = \lambda$



$$y_1 = \frac{\lambda L}{a} = \frac{(663\times10^{-9})(2.2)}{0.33\times10^{-3}}$$

$$= .00442\,m$$

$$y_1 = 4.4\,mm$$

width of central max $= 2y_1 =$ **8.8 mm**

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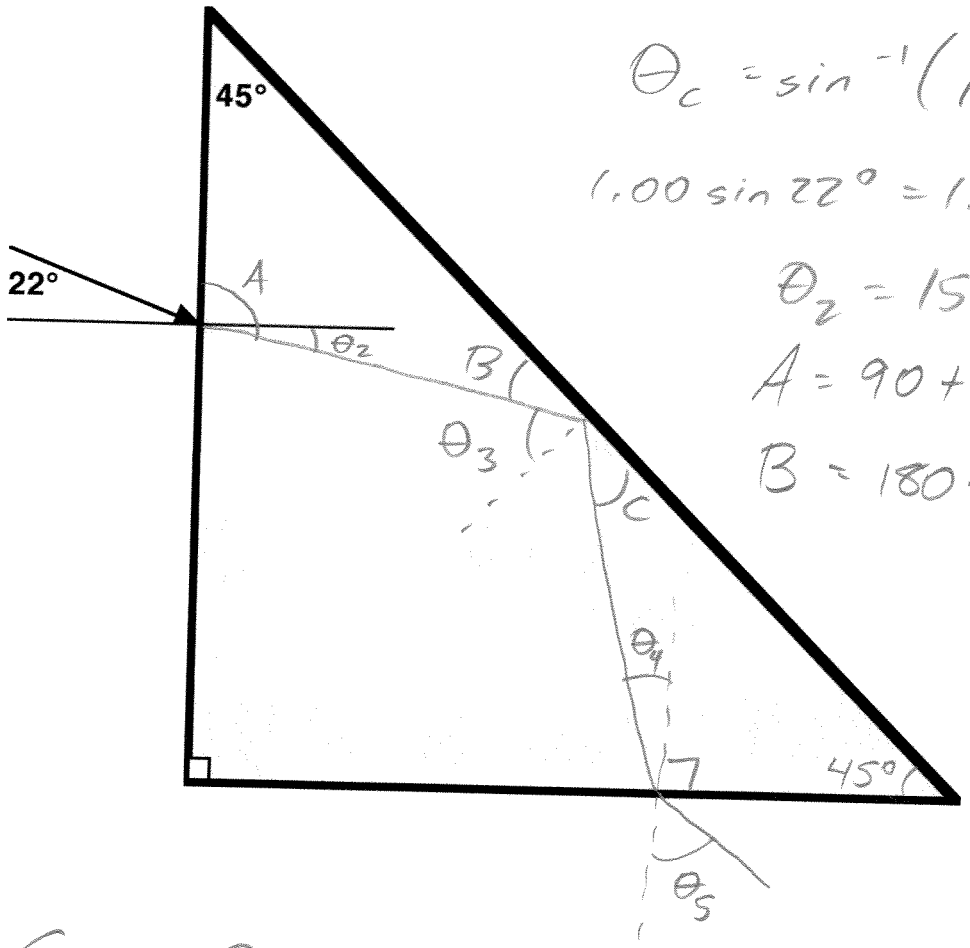
b) Since $y_1 \propto \lambda$, If $\lambda \downarrow$, $y_1 \downarrow$, width $\downarrow$

2. (40 pts) Light is incident on the 45-45-90 prism below at an angle of 22° as shown. The prism has an index of refraction of 1.44 and is surrounded by air. Show on the diagram below where the light exits the prism and calculate the angle of refraction after it exits. Show your work and clearly label all angles.



$\theta_c = \sin^{-1}\left(\frac{1}{1.44}\right) = 44°$

$1.00 \sin 22° = 1.44 \sin \theta_2$

$\theta_2 = 15.1°$

$A = 90 + \theta_2 = 105.1°$

$B = 180 - A - 45$

$= 30°$

$\theta_3 = 90 - B$

$= 60°$

Since $\theta_3 > \theta_{crit}$, light reflects

$C = 30°$ (congruent with B)

$\theta_4 = 180 - C - 45 - 90 = 15°$

$1.44 \sin 15° = 1.00 \sin \theta_5$

$\theta_5 = 22°$

3. (30 pts) A diffraction grating has 2500 lines/cm, and white light incident from the normal reflects off the grating.

a) What is the angular separation between blue (400 nm) and red (700 nm) light in the 2nd order spectrum?

b) How many orders of the complete visible spectrum (400 nm - 700 nm) are visible?

$2500 \text{ lines/cm} = 250{,}000 \text{ lines/m}$

$d = \frac{1}{250{,}000} = 4 \times 10^{-6} \text{ m}$

2nd order $d \sin\theta = 2\lambda$

$\theta = \sin^{-1}\left(\frac{2\lambda}{d}\right)$

a) $\lambda = 400\text{nm}$ $\theta = \sin^{-1}(0.2) = 11.5^\circ$

$\lambda = 700\text{nm}$ $\theta = \sin^{-1}(0.35) = 20.5^\circ$

$\Delta\theta = 9.0^\circ$

b) $d \sin 90 = m\lambda_{red}$

$m = \frac{d \sin 90}{700\text{nm}} = 5.71$

5 complete orders