n = 200
\( \chi = 18.0 \)
\( \sigma = 5.53 \)

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SHOW ALL WORK!! Report all numbers to three significant figures!
Use the conversion constants and data given on the front page.

(a) For a single slit illuminated by red light (\( \lambda = 650 \text{ nm} \)) the third minimum on
a screen 10.0 m away from the slit is 3.75 cm from the center. Find the wavelength
for which the fifth minimum is the same distance from the center. 390 nm

(b) A two-slit pattern shows the 7th, 14th, 21st, etc., maxima are missing. If the
slit spacing is 0.0250 cm, what is the slit width? 3.57 \times 10^{-3} \text{ cm}

(c) It is found that the total rotation of the plane of polarization by 10.0 cm
of a sugar solution is 127°. What is the difference between \( n_r \) and \( n_i \)? \( \lambda = 500 \text{ nm} \)

\[ 3.53 \times 10^{-6} \]

(d) Three polarizers are arranged with the transmission axes of each rotated 30°
from the one before. What is the maximum intensity of light (as a fraction
of the incident intensity \( I_0 \)) that can pass this system? \( I = 0.563 I_0 \)

\[ \frac{I_0}{\text{plane polarized}} \]

\[ \rightarrow I = ? \]

(e) Calculate the polarizing angle for a diamond (\( n = 2.42 \)) submerged in water
(\( n = 1.33 \)). The incident light is from the water side of the boundary.

61.2°
a) \[ 3 \lambda_1 = \alpha \sin \theta \approx \alpha \tan \theta = \alpha \frac{y}{D} \]
\[ \alpha = \frac{3 \lambda_1 D}{y} \quad \text{with} \quad \frac{y}{D} \ll 1 \]
\[ 5 \lambda_2 \approx \alpha \tan \theta = \frac{3 \lambda_1 D}{y} \quad \frac{y}{D} = 3 \lambda_2 \]
\[ \lambda_2 = \frac{3}{5} \lambda_1 = \frac{3}{5} \times 650 \text{nm} = 390 \text{nm} \]

b) \[ m \lambda = \alpha \sin \theta \quad \text{single slit minima} \]
\[ m \lambda = d \sin \theta \quad \text{double slit maxima} \]

For this problem
\[ m = 1, 2, 3, \ldots \]

Corresponds spatially to \[ M = 7, 14, 21, \ldots \]

So
\[ \frac{m \lambda}{M \lambda} = \frac{\alpha \sin \theta}{d \sin \theta} \]
\[ \alpha = d \frac{m}{M} = \frac{0.0250}{7} \text{ cm} \]
\[ \alpha = 3.657 \times 10^{-3} \text{ cm} \]
c) \[ \Phi = \frac{n d}{2} \Delta n \] 
\( n \) is a number \( \Rightarrow \) no units

\[ \Delta n = \frac{\Phi \lambda}{n d} = \frac{127 \left( \frac{170}{100} \right) (500 \times 10^{-9})}{\pi (0.100)} = 3.853 \times 10^{-6} \]

d) \( I_0 \) is plane polarized. To maximize the intensity, align the first polarizer's transmission axis with the incident polarized light, then

\[ I_0 \rightarrow I_1 = I_0 \rightarrow I_2 = I_1 \cos^2 \theta \rightarrow I_3 = I_2 \cos^2 \theta \]

\[ I_3 = I_2 \cos^2 \theta = I_1 \cos^4 \theta = I_0 \cos^4 \theta \quad ; \quad \theta = 30^\circ \]

\[ \Rightarrow I_{\text{max}} = \frac{0.563 I_0}{\text{in}} \]

Many people missed this one.

e) Polarizing angle \( \Rightarrow \tan \Theta_p = \frac{n_{\text{diamond}}}{n_{\text{water}}} = \frac{2.42}{1.33} \]

\[ \Theta_p = \tan^{-1} \left( \frac{2.42}{1.33} \right) = 61.2^\circ \]

-1 wrong significant figures/occurrence

-1 wrong units/occurrence
It is "customary" to give solutions in the same units as the problem is stated. There are certain exceptions, these are dictated by "taste."

Below is a list of reported correct answers.

a) $3.90 \text{ nm}$, $3.90 \times 10^{-9} \text{ m}$, $3.90 \times 10^{-5} \text{ cm}$, $3.90 \times 10^{-4} \text{ mm}$, $3.90 \times 10^{-2} \text{ m}$

b) $3.53 \times 10^{-3} \text{ cm}$, $3.53 \times 10^{-5} \text{ m}$, $3.53 \times 10^{-2} \text{ mm}$, $3.53 \times 10^{-2} \text{ cm}$

c) $3.53 \times 10^{-6}$ (no units)

d) $0.563 I_0$, $\frac{9}{32} I_0$, $0.563$, $\frac{9}{32}$

If you had the pleasure of taking the test in naval science bldg., you were not told the incident light was plane polarized. Assuming totally non-polarized incident light

$$I = \frac{1}{2} (0.563) I_0 = 0.282 I_0 = \frac{9}{32} I_0$$

e) $61.2^\circ$, $1.07 \text{ rad}$. Either one ok.