CHAPTER 24: WAVE OPTICS

24.1: YOUNG'S DOUBLE-SLIT EXPERIMENT

24.2: REFRACTIVE INDEX, LIGHT SPEED, AND WAVE COHERENCE

24.3 GRATINGS: AN APPLICATION OF INTERFERENCE

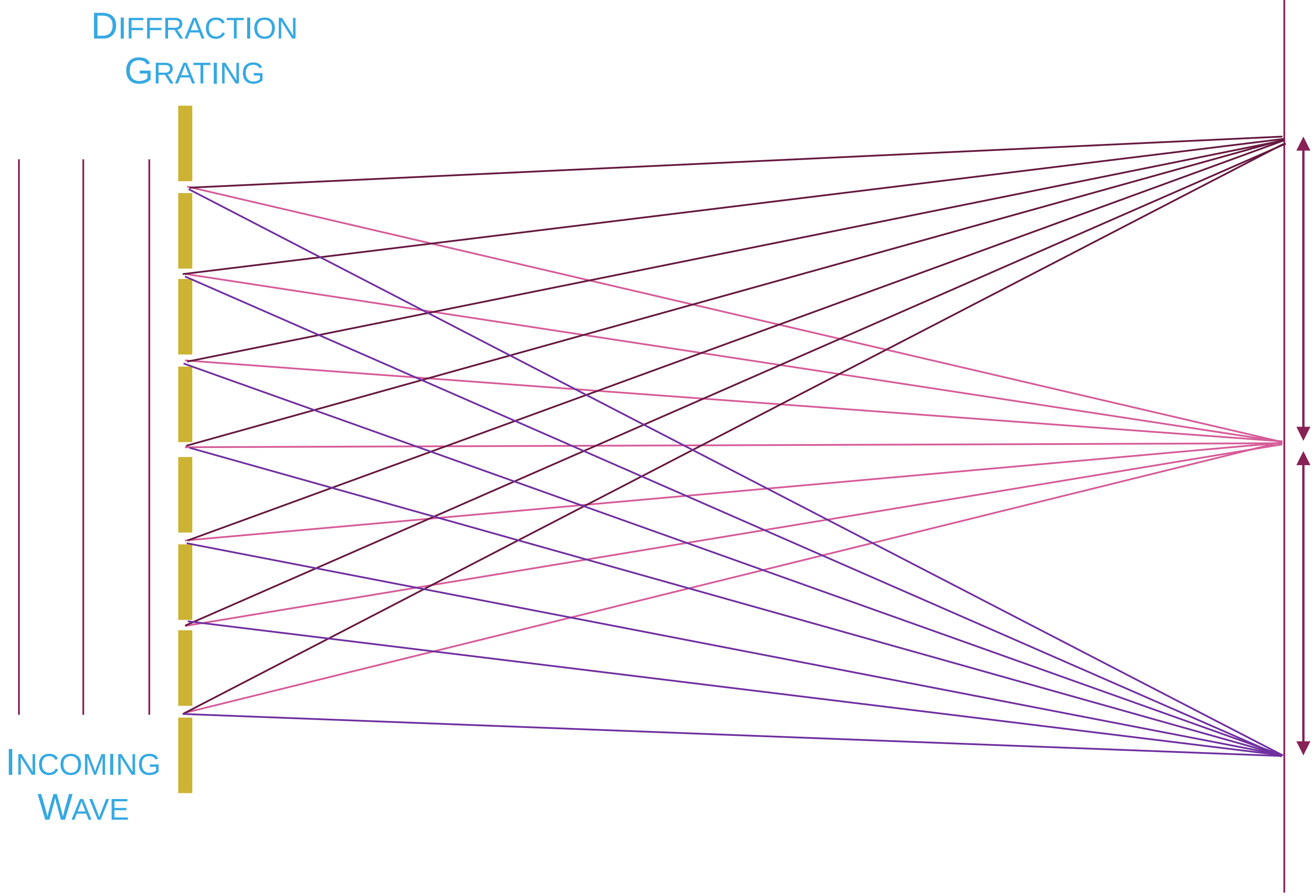
24.5 DIFFRACTION OF LIGHT

24.6: RESOLVING POWER

24.7 SKILLS FOR APPLYING THE WAVE MODEL OF LIGHT

24.4 THIN-FILMS INTERFERENCE*

24.3 Diffraction Grating



24.3 Diffraction Grating - observation

https://ophysics.com/l5b.html

Open the simulation and select “Grating in Place” option.

1. Use “default” settings and make observations about the position of spots along the ruler.
2. One at the time, change each of the settings:
   1. Screen to Grating Distance
   2. Grating lines per mm
   3. Wavelength

3. Report your observation regarding how changing each of them affects the position of the bright spots.

24.3 DIFFRACTION GRATING - OBSERVATION

Diffraction grating equation

$$\sin\theta_m = \frac{m\lambda}{d} \text{ where } m = 0, \pm 1, \pm 2, \pm 3, \dots .$$

θ_m – angular position of the bright spot
m – order of the bright spot
λ – wavelength of the light wave
d – slit separation

Note: the diffraction gratings are often labeled by the number of slits per millimeter/centimeter.

EXAMPLE 24C

Red light $\lambda = 650\ \mathrm{nm}$ passes through the diffraction grating characterized by $500\ \mathrm{slits/mm}$.

a) What is the angular position of the first maximum?

b) What is the separation between the bright spots on the screen placed 2.0 m away?

$$d \sin \theta_m = m\lambda$$

$$d = \frac{1}{number\ of\ lines\ per\ that\ length} = \frac{1}{500\,\frac{\mathrm{lines}}{\mathrm{mm}}} = \frac{1\ \mathrm{mm}}{500} = 2.0 \times 10^{-6}\ \mathrm{m}$$

$$d \sin \theta_1 = \lambda \rightarrow \sin \theta_1 = \frac{\lambda}{d} = \frac{(650 \times 10^{-9}\mathrm{m})}{2 \times 10^{-6}\mathrm{m}} = 0.325$$

$$\theta_1 \sim 19^o$$

Example 24c

Red light $\lambda = 650\ \mathrm{nm}$ passes through the diffraction grating characterized by $500\ \mathrm{slits/mm}$.

a) What is the angular position of the first maximum?
b) What is the separation between the bright spots on the screen placed 2.0 m away?

Depends which ones!

$$d \sin\theta_m = m\lambda \rightarrow \sin\theta_m = m\frac{\lambda}{d}$$

$$\sin\theta_1 = 1 * 0.325 \quad \rightarrow \theta_1 = 19^o$$

$$\sin\theta_2 = 2 * 0.325 \quad \rightarrow \theta_2 = 40.5^o$$

$$\sin\theta_3 = 3 * 0.325 \quad \rightarrow \theta_3 = 77^o$$

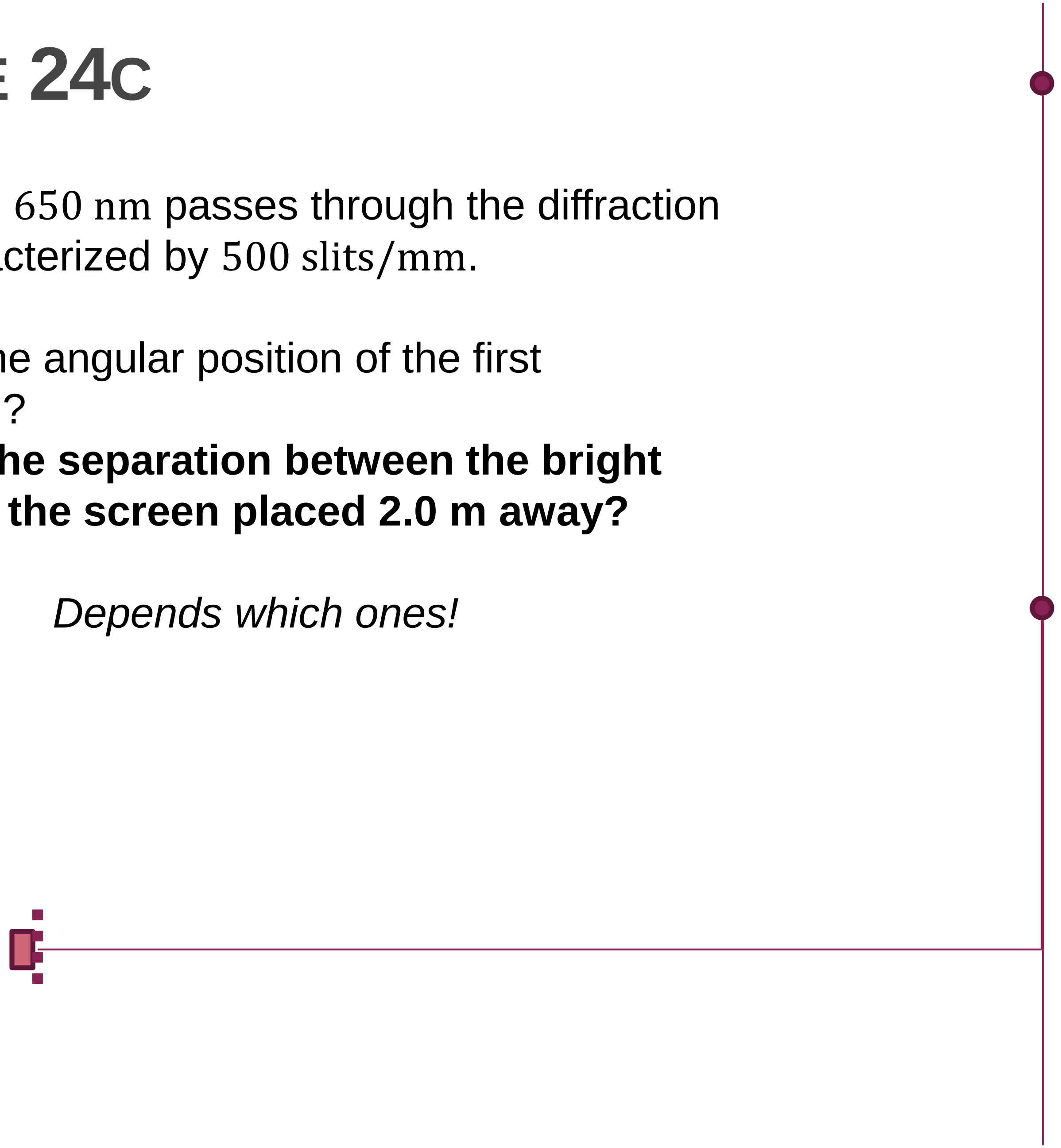
EXAMPLE 24C

Red light $\lambda = 650\ \mathrm{nm}$ passes through the diffraction grating characterized by $500\ \mathrm{slits/mm}$.

a) What is the angular position of the first maximum?

b) What is the separation between the bright spots on the screen placed 2.0 m away?

Depends which ones!



Someone asked!

INTENSITY IN DOUBLE SLIT – NOT FOR TEST, FYI

Light is an electromagnetic wave.
Wave arriving from one slit to any point along the screen can be written as

$$E_1(r,t) = E_0 \sin(\omega t)\,.$$

The other one is not exactly the same, it is shifted by a little bit (phase angle) that depends on the additional distance the other ray travelled, Δr ($\phi = \frac{2\pi}{\lambda} * \Delta r$).

$$E_2(r,t) = E_0 \sin(\omega t + \phi)$$

Those rays add by superposition. $E = E_1 + E_2$
We need to add sines so $E_0 \sin(\omega t) + E_0 \sin(\omega t + \phi) = E_0(\sin(\omega t) + \sin(\omega t + \phi)$

$$E = 2E \cos\frac{\phi}{2} \sin\left(\omega t + \frac{\phi}{2}\right)$$

We do not see the time dependent part, but we do see the amplitude variation…
…well, we actually see the **intensity, which is a square of it.**

$$I = 4E_0^2 \cos^2\frac{\phi}{2}$$

So depending on path difference, intensity varies!→ $\begin{cases} \phi = 0 \text{ when } \Delta r = n\lambda \\ \phi = \frac{n\pi}{2} \text{ when } \Delta r = n\left(\frac{\lambda}{2}\right) \end{cases}$