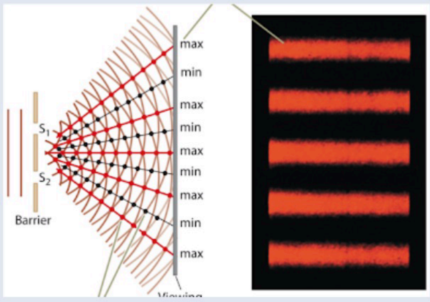
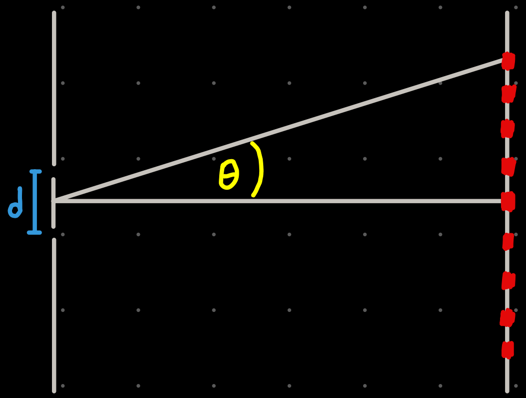
A plane monochromatic light wave is incident on a double slit. As the slit separation increases, what happens to the separation between the interference fringes on the screen?



We are asked to determine a relationship between the slit separation and the separation between interference fringes. We can use the condition for constructive interference: $d \sin \theta = m\lambda$.



The variables we're considering are d, the slit separation, and θ, the diffraction angle. The wavelength, λ, is held constant because the light source is not changing. The question is asking what happens to θ when d increases?

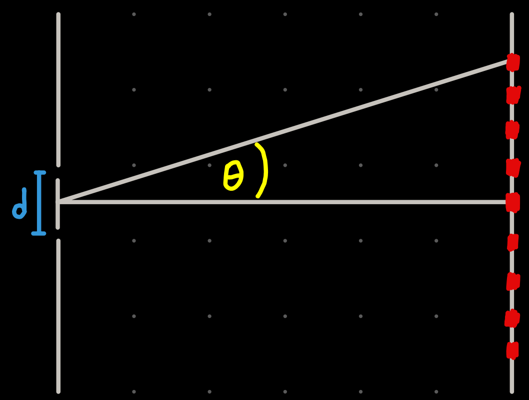
$d \sin \theta = \text{constant}$

if this increases

then this must decrease

→ If d increases, θ decreases. This means the interference fringes will appear closer to the center of the interference pattern. So the separation between the fringes decreases.

Suppose Young's double-slit experiment is performed in air using red light and then the apparatus is immersed in water. What happens to the interference pattern on the screen?



Let's look at the condition for constructive interference again: $d \sin\theta = m\lambda$. This time d remains constant because the slit separation is not affected by being submerged in water. Now, the wavelength, λ, is going to be affected because the wavelength of light changes when it travels in different mediums.

We learned in an earlier module that the wavelength of light in a medium is $\lambda_n = \frac{\lambda_0}{n}$ where λ_0 is the wavelength in a vacuum (or air) and n is the index of refraction of the medium.

When the apparatus is submerged in water, the wavelength of the light is shorter.

$$d \sin\theta = m\lambda$$

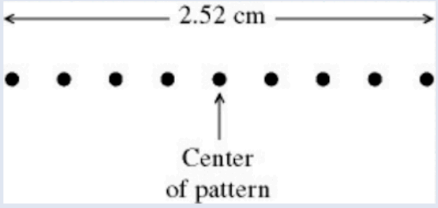
constant

this must also decrease

decreases when put under water

→ When the apparatus is submerged under water, the wavelength decreases, which causes θ to decrease. This means the interference fringes will be closer together.

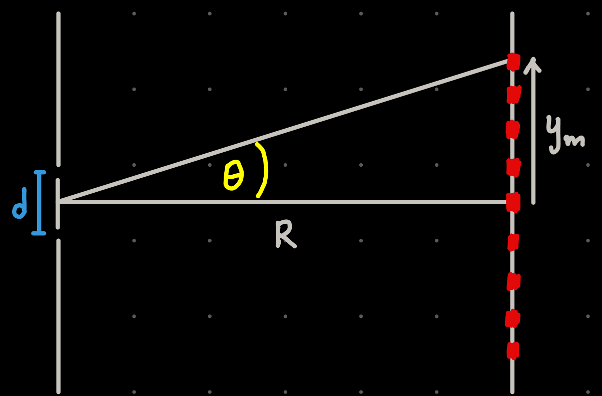
Coherent monochromatic light of wavelength 632.8 nm passes through a pair of thin parallel slits. The figure shows the central portion of the pattern of bright fringes viewed on a screen 1.40 m beyond the slits.



What is the distance between the two slits?

We are going to apply the condition for constructive interference : $d \sin\theta = m\lambda$ but we need to adjust the formula to include the linear position of the fringes. The formula is in terms of θ, which is an angular position.

We will use a small angle approximation : $\sin\theta \approx \tan\theta$ when θ is small.



This sketch is not drawn to scale. Actually the slit-to-screen distance (R) is much, much bigger than the distance to the fringes (y_m). Since $R >> y_m$, the angle θ is very small and the approximation is valid.

Looking at the triangle with R = adjacent and y_m = opposite to θ, we can say $\tan\theta = \frac{y_m}{R}$ and this is approximately equal to $\sin\theta$.

$$d \sin\theta = m\lambda \longrightarrow d \tan\theta = m\lambda \longrightarrow d\left(\frac{y_m}{R}\right) = m\lambda$$

Now we have a formula we can use with the information we're given.

$\lambda = 632.8$ nm

$R = 1.40$ m

Need to find d - the distance between the slits.

The diagram has labelled the distance from the 4th order maximum on the left to the 4th order maximum on the right as 2.52 cm. If we cut that in half, the distance from the central bright fringe to the 4th order maximum is $y_m = 1.26$ cm. This is all we need to find the slit spacing.

$$d\left(\frac{y_m}{R}\right) = m\lambda \longrightarrow d = \frac{m\lambda R}{y_m} \quad \text{where } m = 4 \text{ and } y_m = 1.26 \text{ cm}$$

$$d = \frac{(4)(632.8 \times 10^{-9}\,\text{m})(1.40\,\text{m})}{1.26 \times 10^{-2}\,\text{m}} = 2.81 \times 10^{-4}\,\text{m}$$

$$= 0.281 \text{ mm}$$