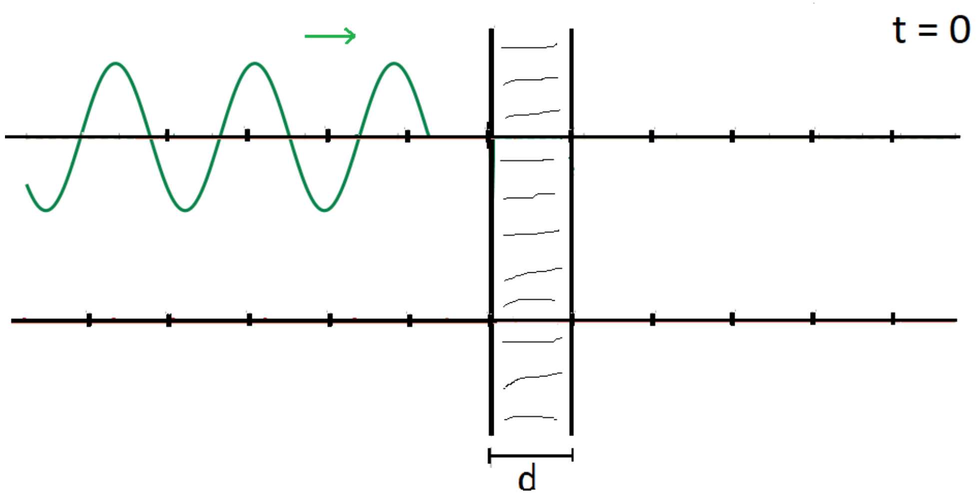
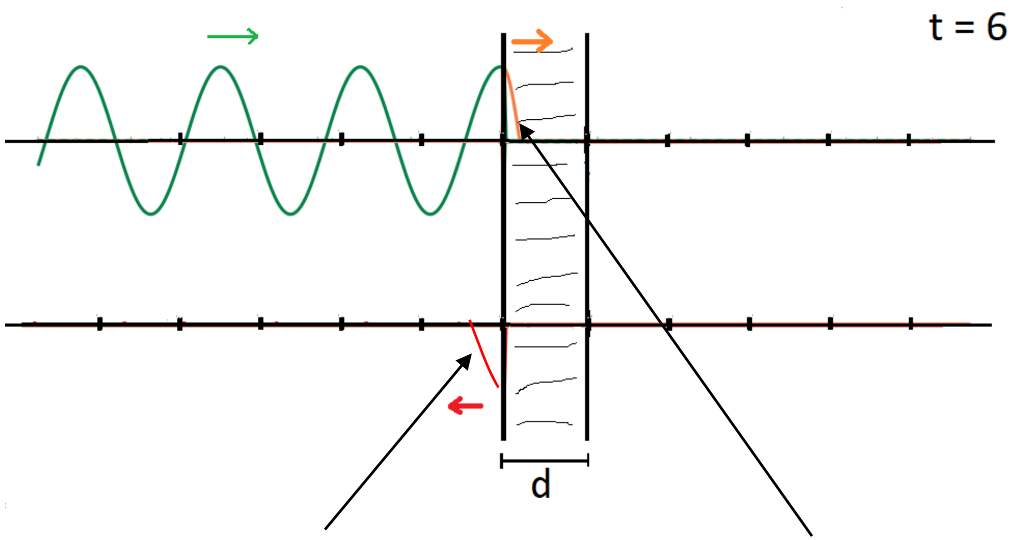
D.3 Single Source Interference: Transmission/Reflection

Now let's consider the interference between waves reflecting off the surfaces of something like a soap bubble, and examine how the swirl of colors gets created.

To illustrate we'll consider a λ = 10μm wave traveling at v = 1μm/s in air (n = 1), incident upon a d = 5μm wide soap bubble membrane (n = 2). On the top line I'll draw all the rightward waves, and on the bottom line, the leftward traveling reflections – gotta separate them out to keep diagram from getting too muddied.





Green wave is our incident wave coming from air.

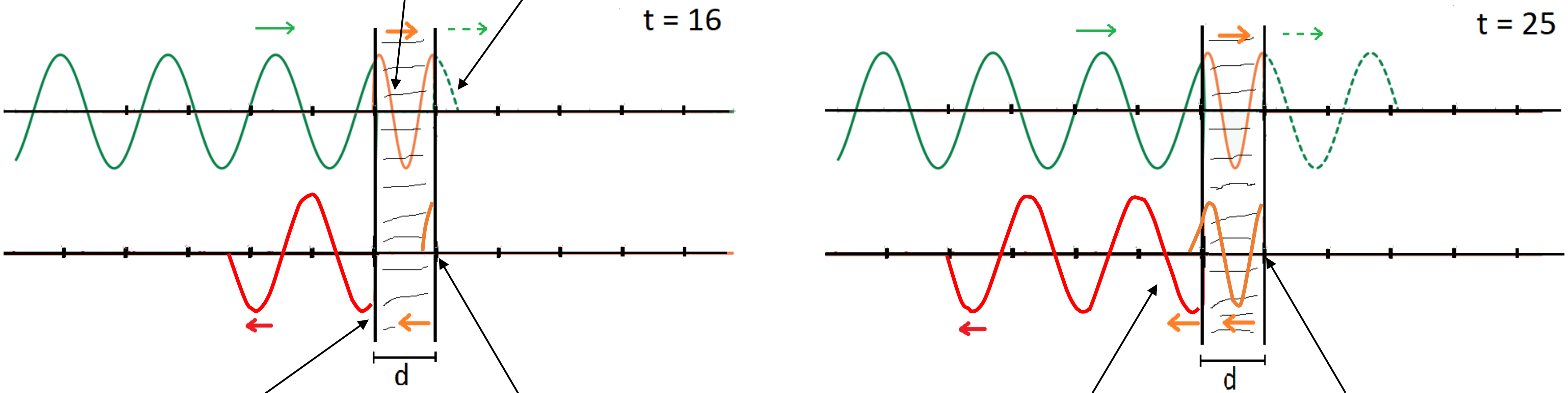
reflection inverts because n_2 (soap) > n_1 (air)

slows down and λ compresses because n_2(soap) > n_1(air)

D.3 Single Source Interference: Transmission/Reflection

slows and compresses b/c
n_2(soap) > n_1(air)

speeds up and expands b/c
n_2(air) < n_1(soap)



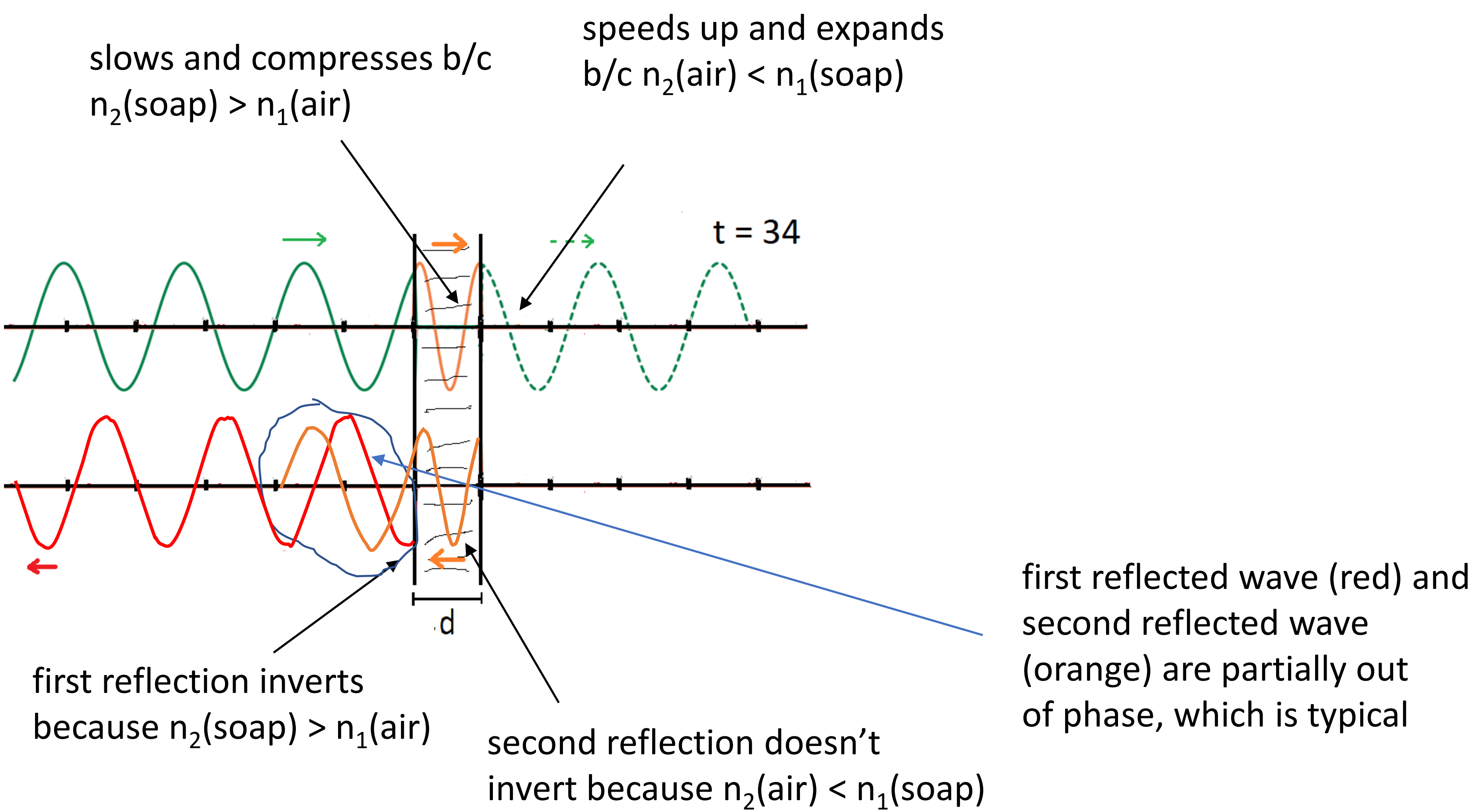
first reflection
inverts because
n_2(soap) > n_1(air)

second reflection
doesn’t invert because
n_2(air) < n_1(soap)

first reflection inverts
inverts because
n_2(soap) > n_1(air)

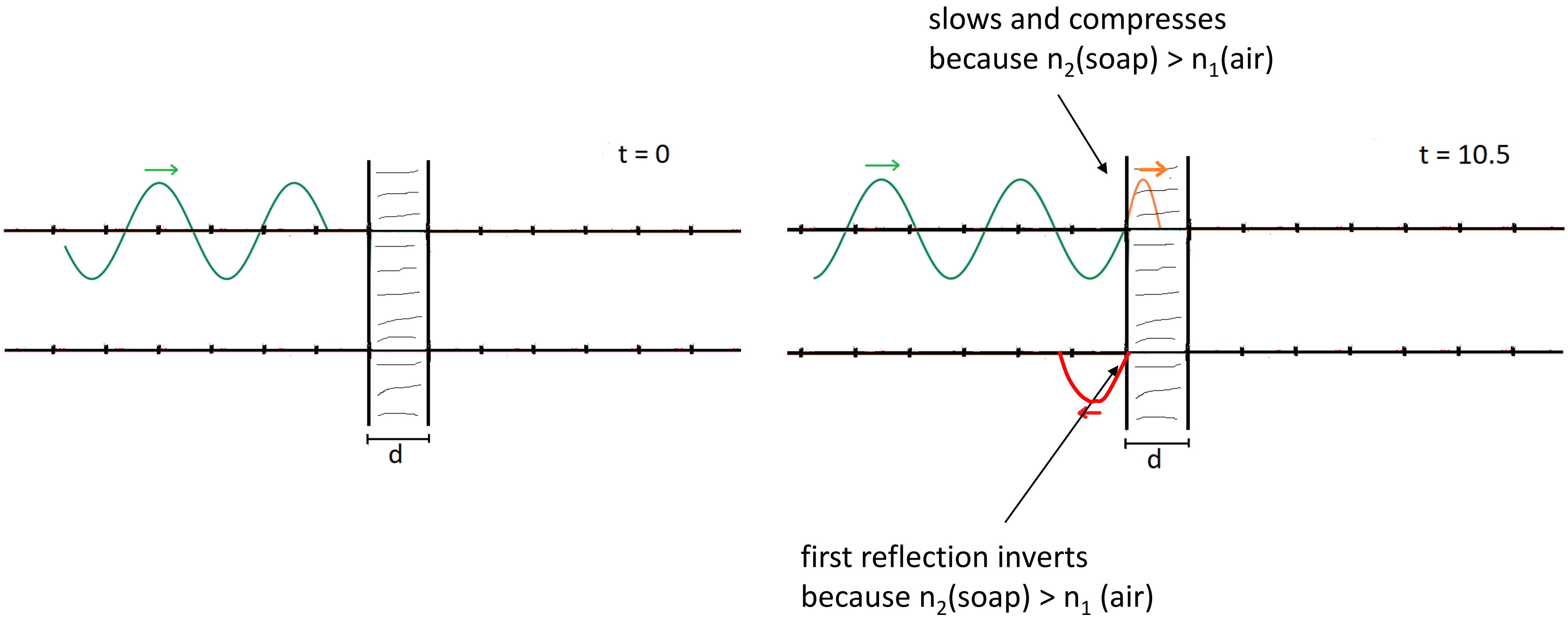
second reflection doesn’t
invert because n_2(air) < n_1(soap),
and note transmitted part
accelerates and lengthens

D.3 Single Source Interference: Transmission/Reflection

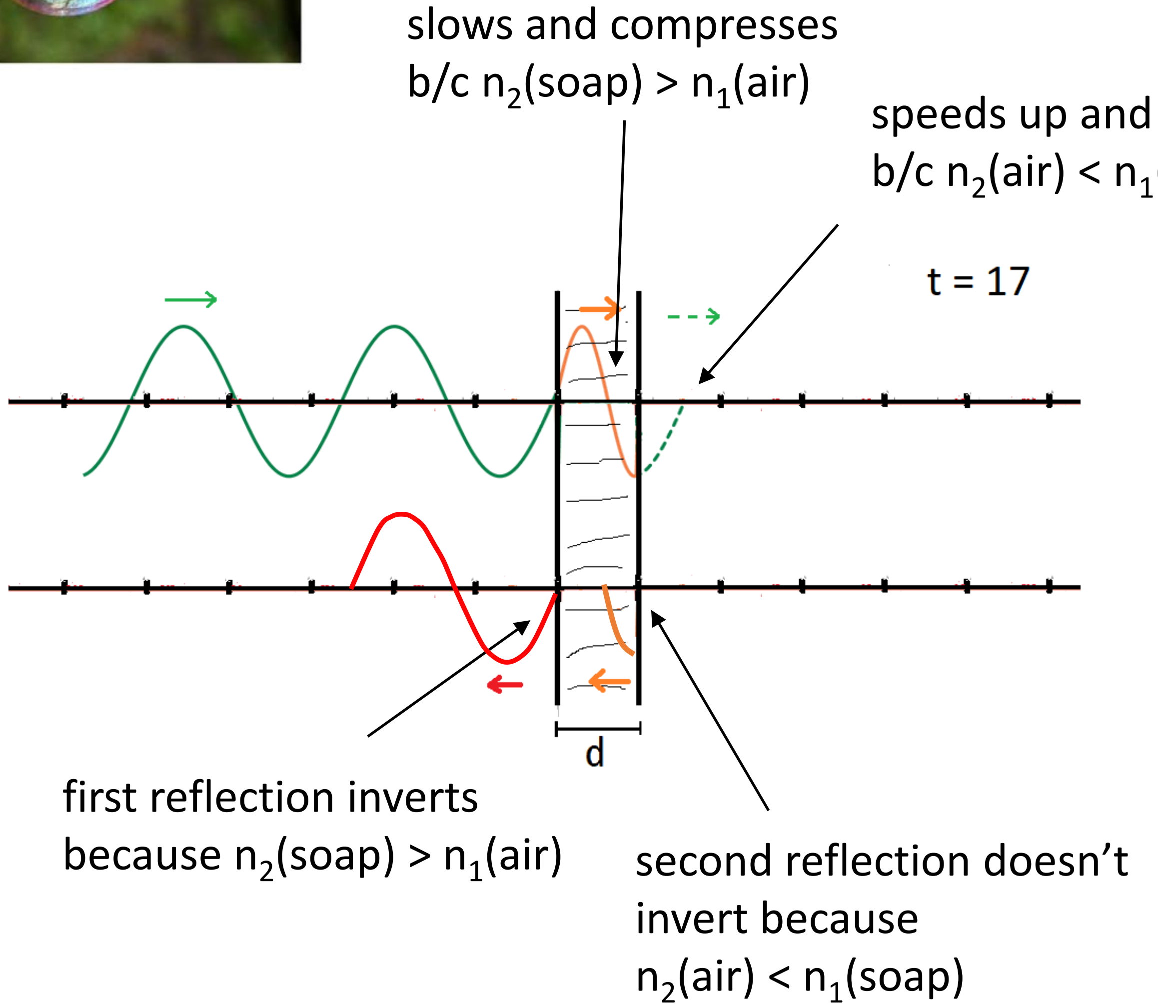


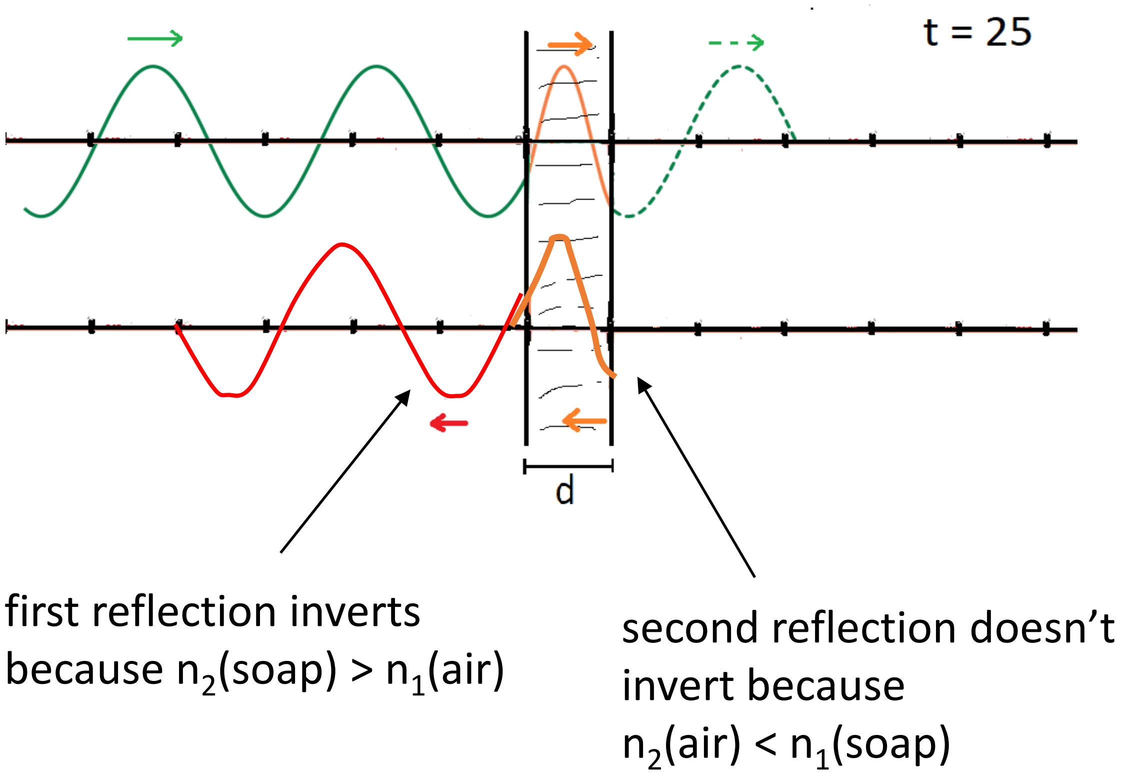
D.3 Single Source Interference: Transmission/Reflection

Now let's consider a λ = 13.3μm wave, again traveling at v = 1μm/s in air (n = 1), incident upon a d = 5μm wide soap bubble membrane (n = 2).



D.3 Single Source Interference: Transmission/Reflection

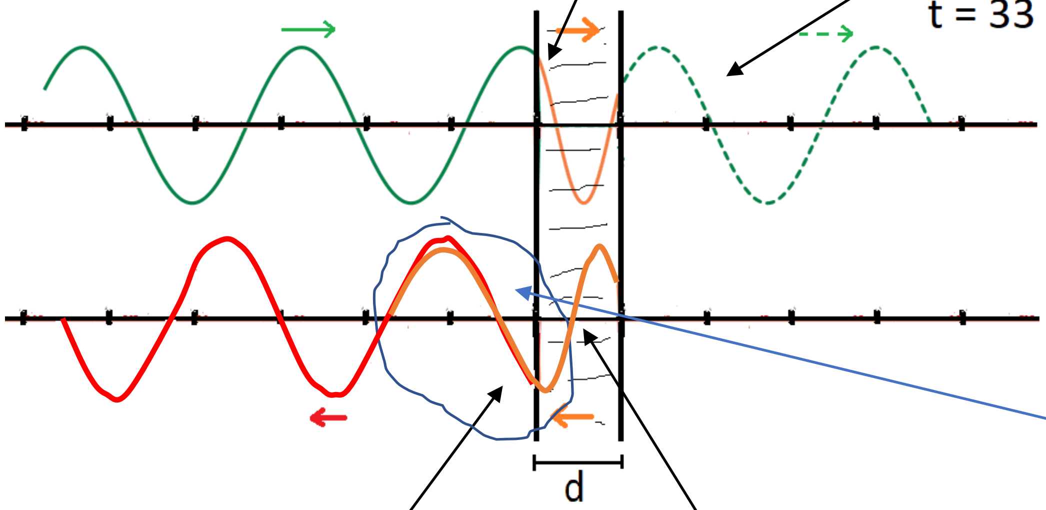




D.3 Single Source Interference: Transmission/Reflection

slows and compresses b/c n_2(soap) > n_1(air)

speeds up and expands b/c n_2(air) < n_1(soap)



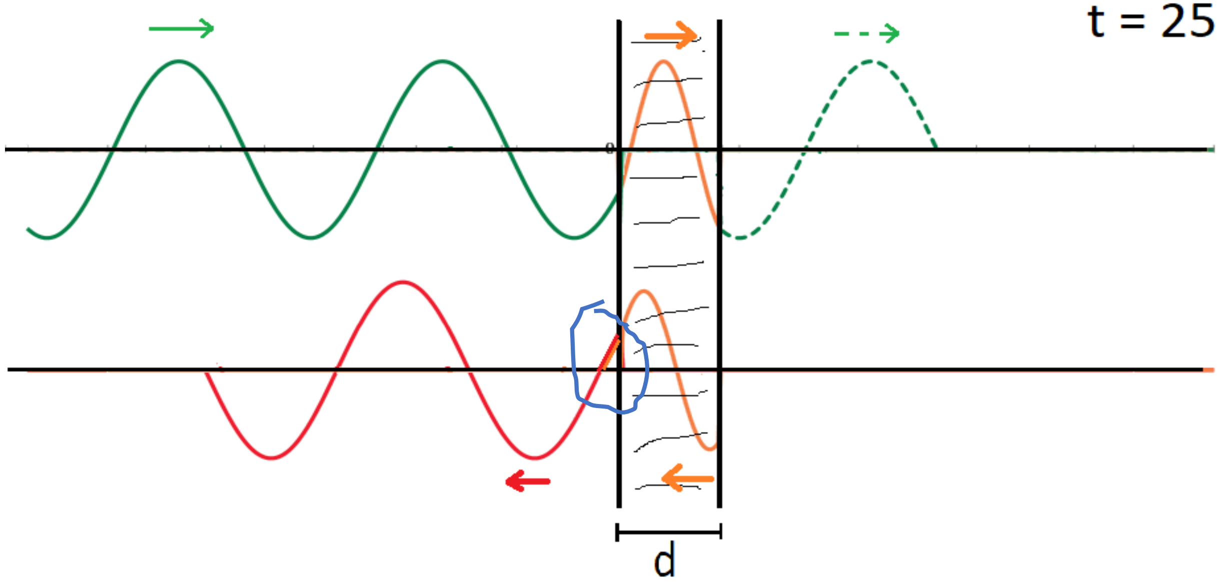
first reflection inverts because n_2(soap) > n_1(air)

second reflection doesn't invert because n_2(air) < n_1(soap)

first reflected wave (red) and second reflected wave (orange) overlap, and so net reflected wave will have a large amplitude, in fact larger than suggested by drawing b/c all successive reflections will continue to line up. This would manifest as a **bright** color.

D.3 Single Source Interference: Transmission/Reflection

If we consider why this happened, we can see (not really) it at t = 25s.
The second reflection (orange) joined back up *in phase* with the first reflection (red).



The change in phase of the first reflection at the point of joining back up will just be 0 or π, depending on whether the membrane is harder than the incident medium or not.

$$\Delta\varphi_1 = I_1\pi \qquad I_1 = 0,1$$

The change in phase of the second reflection, at the point of joining back up, will be the usual kΔx + Iπ, since it must travel through 2d to get back to the point where they rejoin. And I will be 0 or 1 depending on whether or not the transmission medium on the other side is harder than the membrane.

$$\Delta\varphi_2 = k_2\Delta x_2 + I_2\pi \qquad \Delta x_2 = 2d,\ I_2 = 0,1$$

Then condition for bright reflection: $\Delta\varphi_2 - \Delta\varphi_1 = 2\pi m$

And condition for zero reflection (and consequently perfect transmission) is: $\Delta\varphi_2 - \Delta\varphi_1 = 2\pi m_{1/2}$

D.3 Single Source Interference: Transmission/Reflection

For example, let's say we had a soap bubble with index of refraction n = 1.6, and thickness 400nm. Which wavelengths of (visible) light would be strongly reflected? Which would be strongly transmitted?

First the strong reflection….

$$\Delta\varphi_2 - \Delta\varphi_1 = 2\pi m$$

$$(k_2\Delta x_2 + I_2\pi) - (I_1\pi) = 2\pi m$$

$$\left(\frac{2\pi}{\lambda_2}\cdot 2L + 0\cdot\pi\right) - (1\cdot\pi) = 2\pi m$$

$$\frac{2L}{\lambda_2} - \frac{1}{2} = m$$

$$\lambda_2 = \frac{2L}{m+1/2} = \frac{2(400\text{nm})}{m+1/2} = \frac{800\text{nm}}{m+1/2}$$

But this is the wavelength in the soap, not the air. So use:

$$n_1\lambda_1 = n_2\lambda_2$$

$$(1)\lambda_1 = (1.6)\frac{800\text{nm}}{m+1/2}$$

$$\lambda_1 = \frac{1080\text{nm}}{m+1/2}$$

$$= \frac{1080\text{nm}}{0+1/2}, \frac{1080\text{nm}}{1+1/2}, \frac{1080\text{nm}}{2+1/2}, \frac{1080\text{nm}}{3+1/2}, \ldots$$

$$= 2160\text{nm},\ 720\text{nm},\ 430\text{nm},\ 310\text{nm}, \ldots$$

For a strong transmission, we just want a weak reflection. So we switch out m for $m_{1/2}$.

$$\lambda_1 = \frac{1080\text{nm}}{m_{1/2}+1/2}$$

$$= \frac{1080\text{nm}}{0.5+1/2}, \frac{1080\text{nm}}{1.5+1/2}, \frac{1080\text{nm}}{2.5+1/2}, \frac{1080\text{nm}}{3.5+1/2}, \ldots$$

$$= 1080\text{nm},\ 540\text{nm},\ 360\text{nm}, \ldots$$