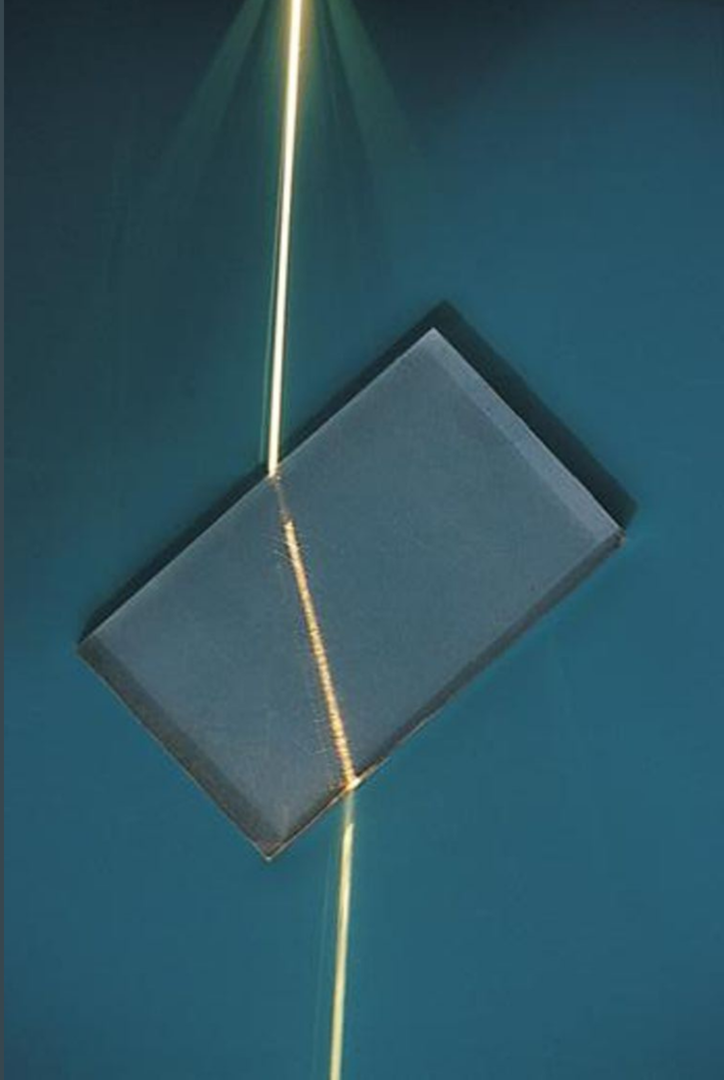
Recitation 2

Wow, hey, look, thin-film interference

Review: What you’ve done this week

Index of Refraction

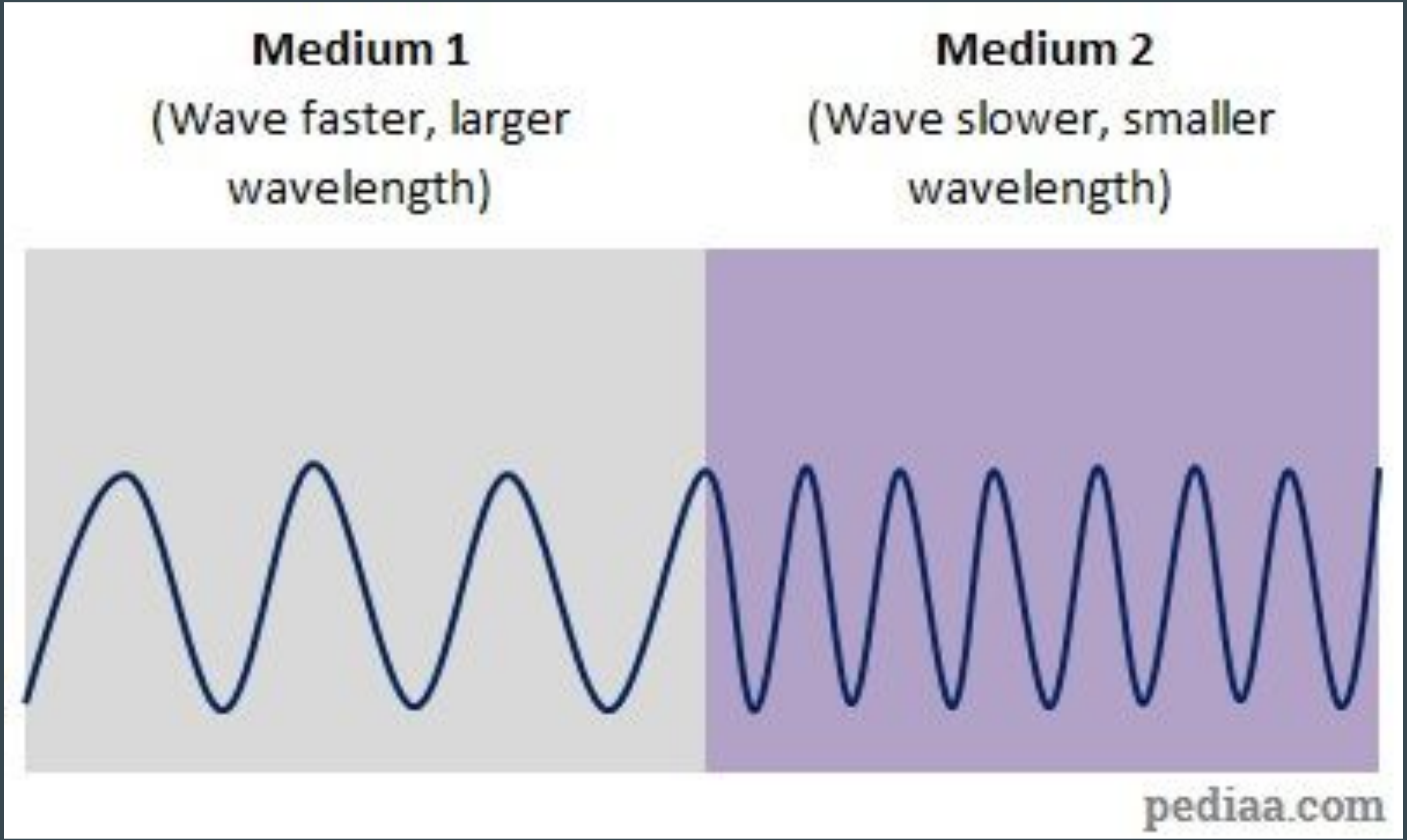
- Light’s velocity is at most c
    - Less than c in certain media
- Index of refraction n tells us how much it slows down



Examine The Equation

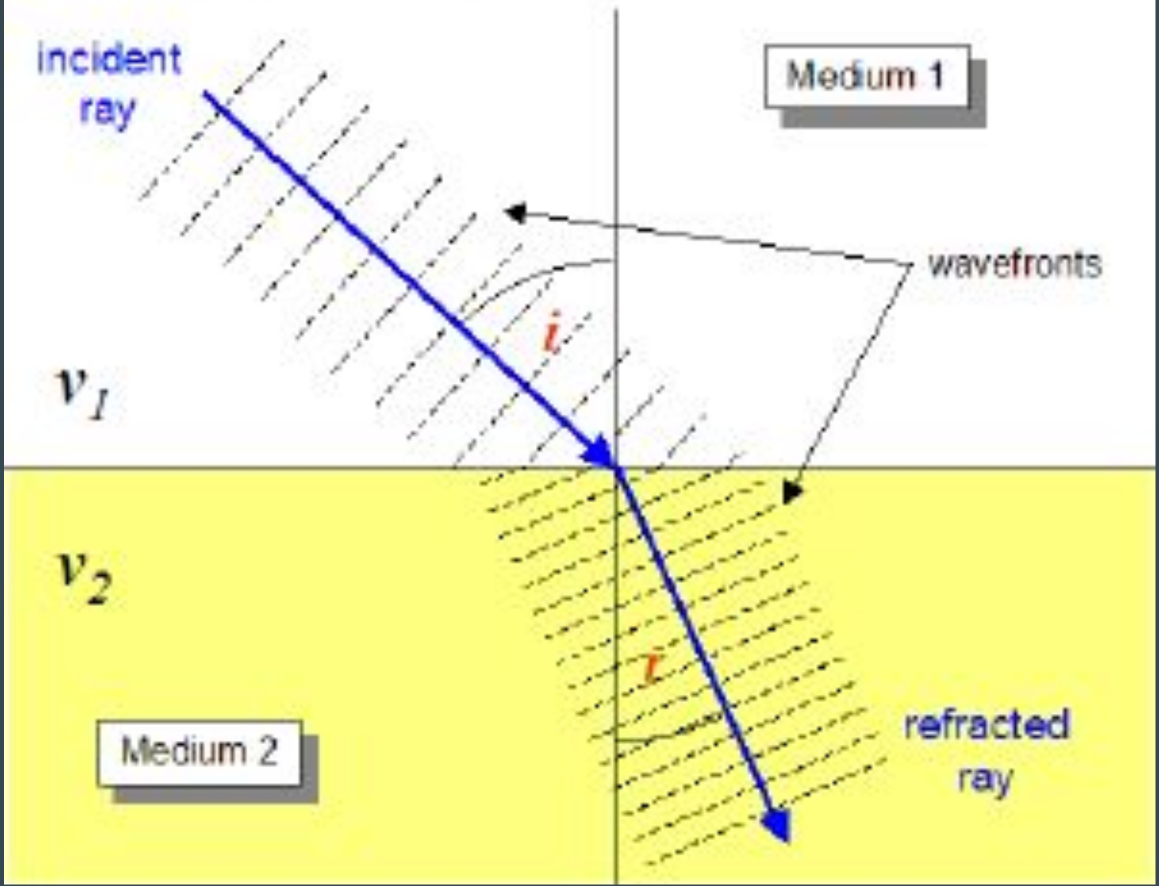
$$n = \frac{c}{v} \qquad v = f\lambda$$

1. Identify each of the parameters and how they relate to each other
2. What is the value of n in air? What does this mean about the velocity of the wave?
3. Are there any limitations on what n can be? Why or why not?
4. If we increase v, what happens to the frequency? What happens to the wavelength?



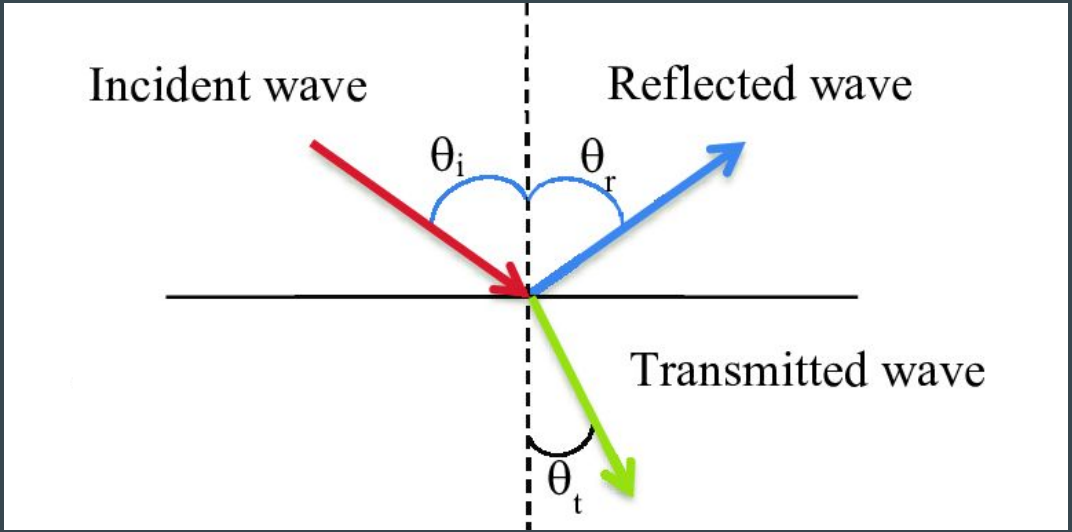
Medium 1
(Wave faster, larger wavelength)
Medium 2
(Wave slower, smaller wavelength)
pediaa.com

LAW OF REFRACTION



Reflection and Transmission

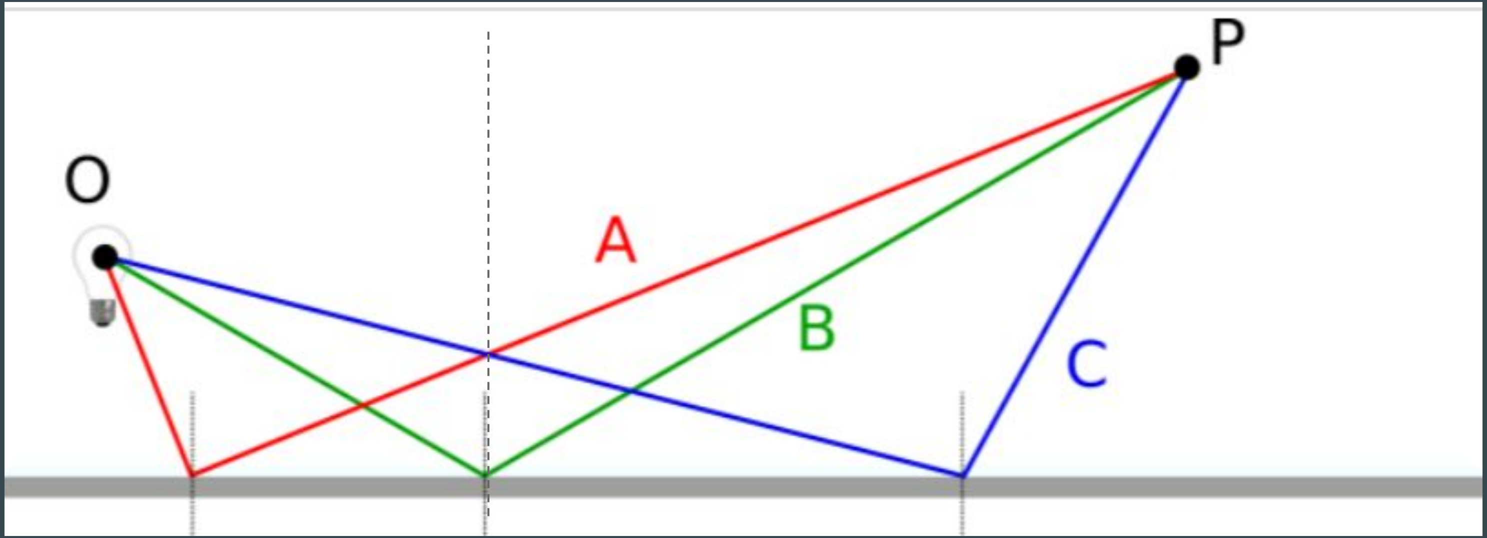
- Many physical scenarios involve light travelling from one medium to another
- Waves can reflect (bounce off the medium)
- Waves can transmit (travel across the boundary into the other medium)



$$\theta_i = \theta_R$$

Reflection

- The incident light is reflected at the same angle to the normal (law of reflection)
- This is the shortest path for the light to take (nature likes this!)
- Phase shift happens when the wave goes from a lower n to a higher n

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14

Transmission

- Light travels from one medium into another (they'll have different n!)
- The wave's phase doesn't change for transmission
- Light bends (refraction)

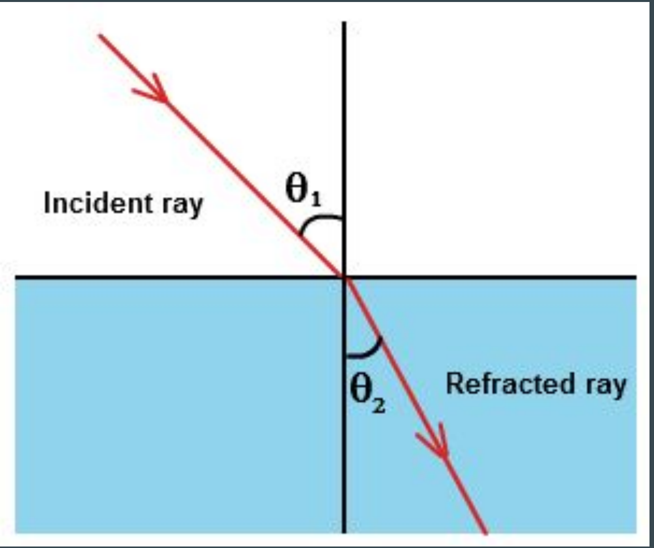
Snell's Law

- Describe the model in words
- Draw a picture to go with the model

$$n_i sin\theta_i = n_t sin\theta_t$$

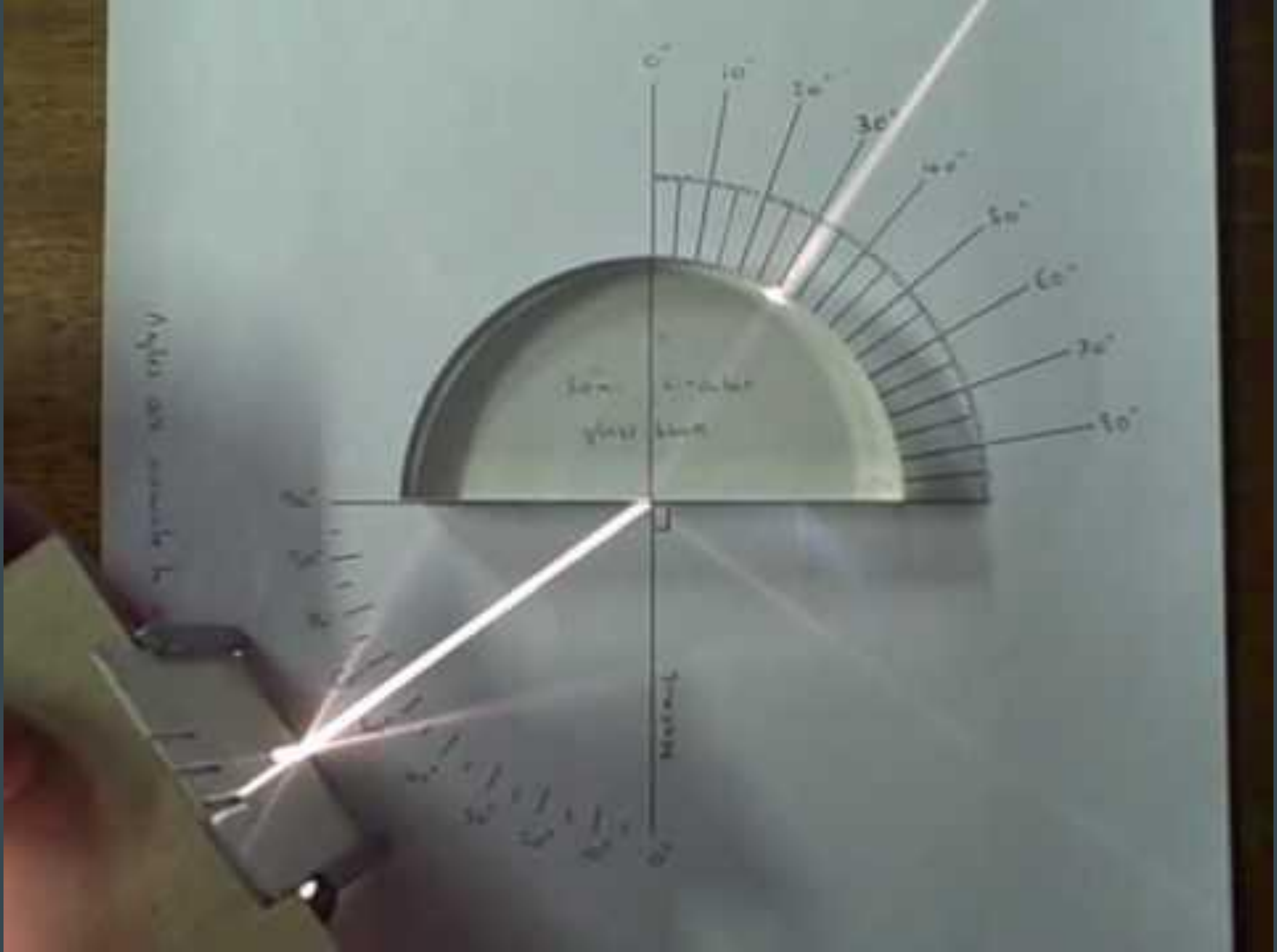
In words

The product of the index of refraction of one medium of **n** and the sine of the angle with respect to the normal that incident light comes in at is equal to the product of the index of refraction of another medium times the sine of the angle with respect to the normal that the refracted light exits at



n_i

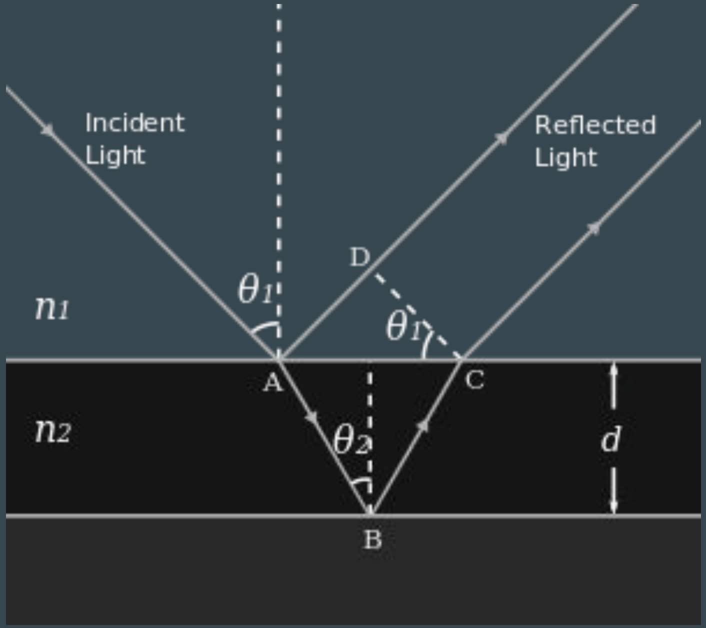
n_t


0°
10°
20°
30°
40°
50°
60°
70°
80°
semi circular
glass block

Thin-film Interference

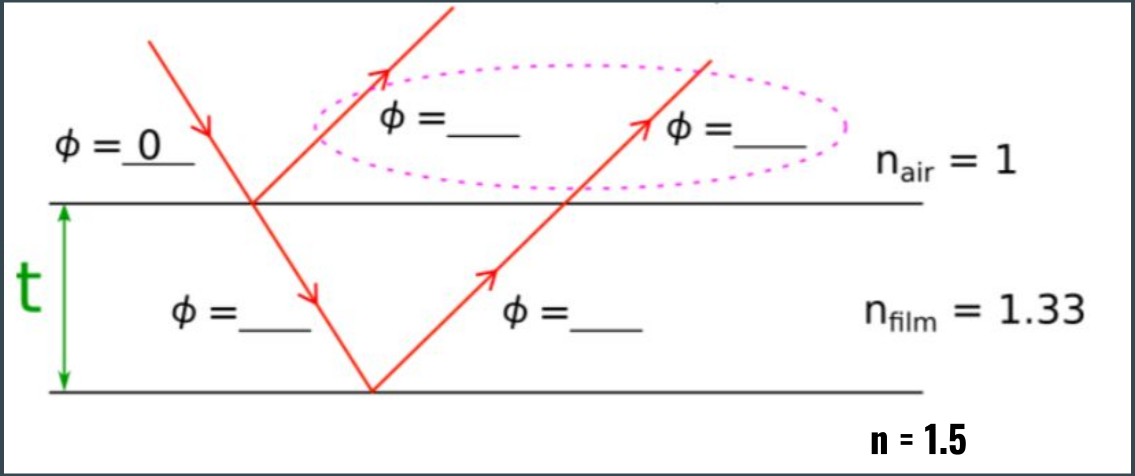
Thin-film interference

- Our understanding of reflection, transmission, and superposition let us model thin film interference
- Some light reflects off the top surface of the film and some transmits through the film and then reflects at the bottom surface
- The waves interfere



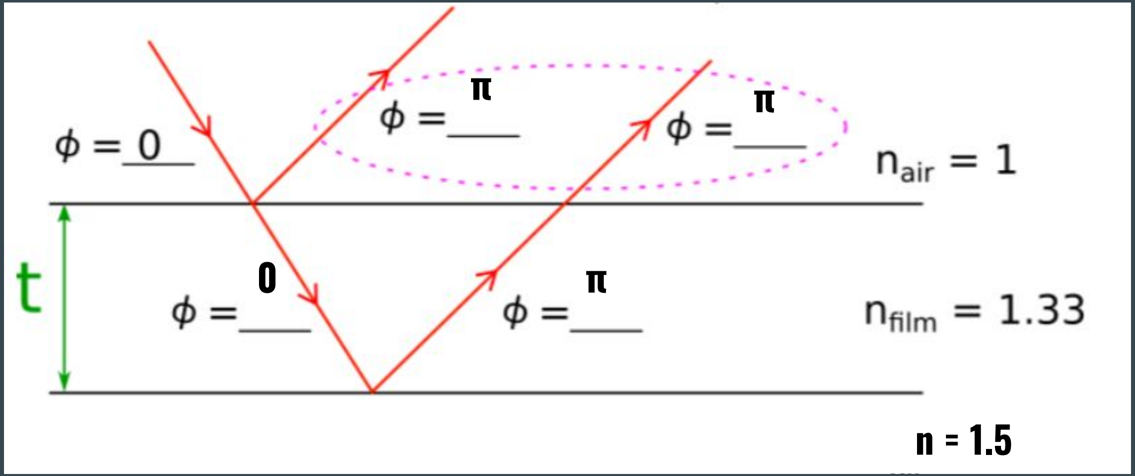
A Better Image

Case 1



1. Fill in the phase at each step
2. What is the phase difference of the rays?
3. What's the equation for constructive interference?
4. What's the equation for destructive interference?

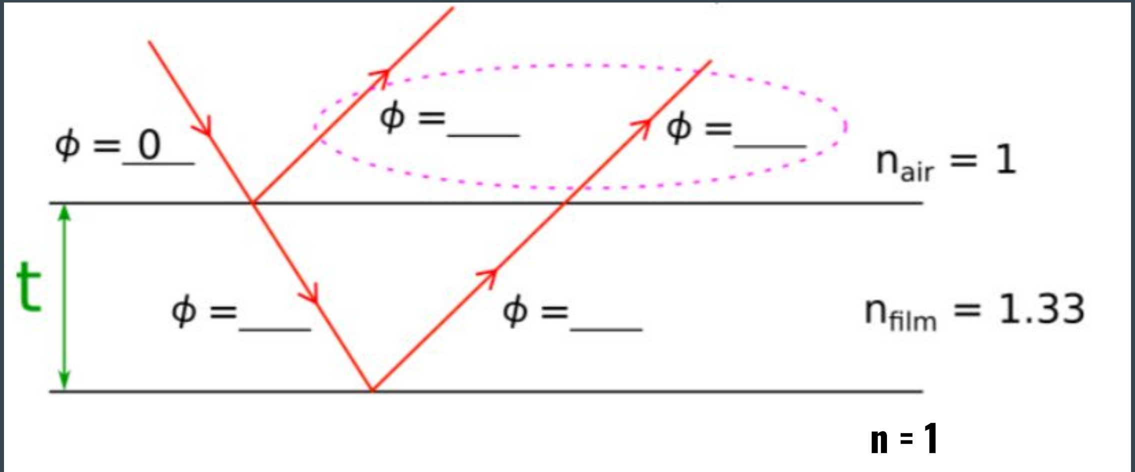
Case 1: No Phase Difference



Constructive Interference: $$2t = m\lambda_{film}$$

Destructive Interference: $$2t = (m + 1/2)\lambda_{film}$$

Case 2



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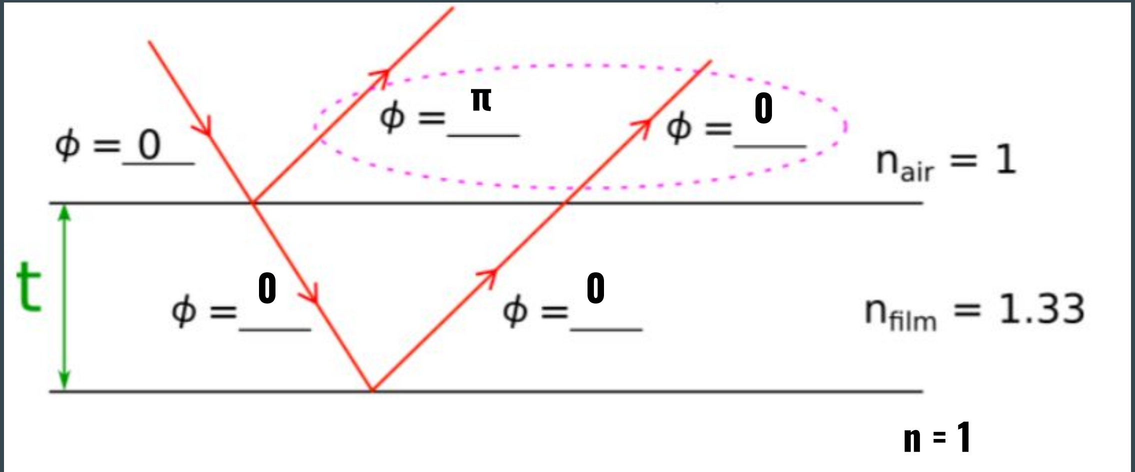
Case 2: Phase Difference of π



Constructive Interference: $$2t = (m + 1/2)\lambda_{film}$$

Destructive Interference: $$2t = m\lambda_{film}$$

Why it’s cool

Animals use this!

- Parasitic Wasp, Closterocerus coffeellae (top)
- Fruit fly, Drosophila melanogaster (bottom)
- Interference for certain backgrounds
- Possibly used for signaling to others

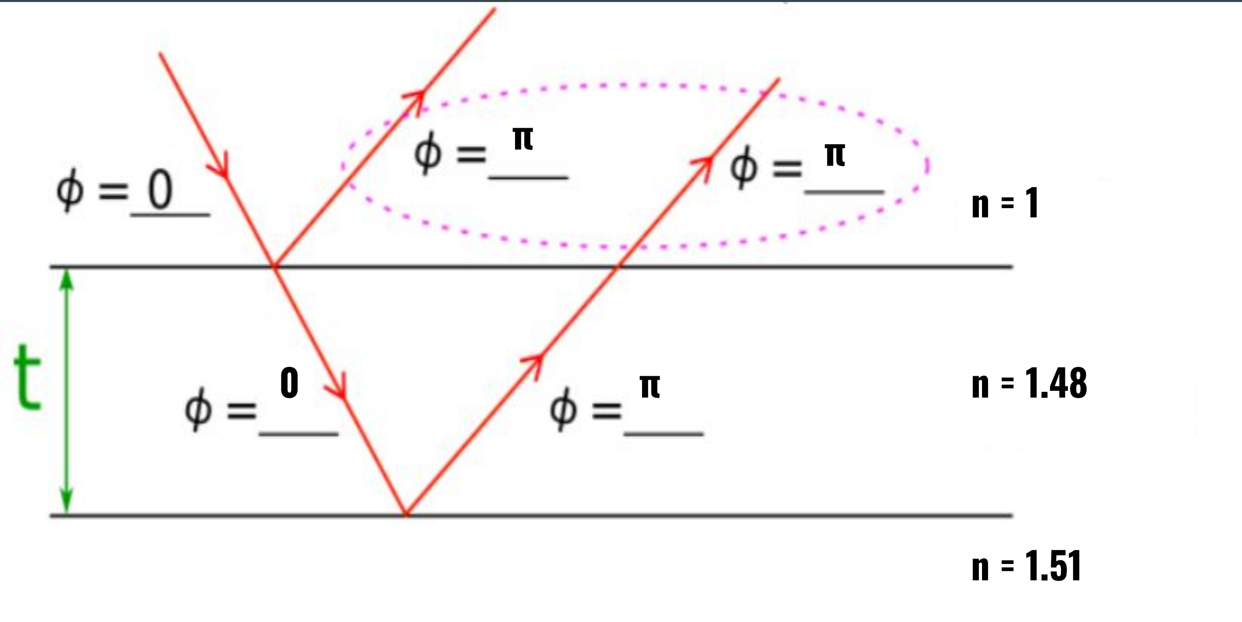
Putting it to practice

S18 Final Exam, Question 5

5. A thin film of oil is spread on a glass plate. A laser of $\lambda = 700$ nm is normally incident on the oil side of the plate and has **maximal** reflection. Which of the following conditions could make a laser of $\lambda = 350$ nm have **minimal** reflection?

☐ a) Leave the setup as it is.
☐ b) Make the oil thickness 1.5 times as thick.
☐ c) Double the thickness of oil.
☐ d) Halve the thickness of oil.
☐ e) Replace oil with an identical thickness of something with $n = 2.22$
☐ f) Replace oil with an identical thickness of something with $n = 1.85$
☐ g) Replace oil with an identical thickness of something with $n = 1.11$

Visualize the problem (include phases)



First, consider the 700 nm laser

5. A thin film of oil is spread on a glass plate. A laser of $\lambda = 700$ nm is normally incident on the oil side of the plate and has **maximal** reflection. Which of the following conditions could make a laser of $\lambda = 350$ nm have **minimal** reflection?

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What is the wavelength of the 700 nm light in oil? (n_oil = 1.48, n_glass = 1.51)

$$v_{oil} = f\lambda_{oil}$$

$$v_{oil} = \frac{c}{n}$$

$$f\lambda_{oil} = \frac{c}{n}$$

$$f\lambda_{oil} = \frac{f\lambda_{air}}{n}$$

$$\lambda_{oil} = \frac{\lambda_{air}}{n}$$

$$\lambda_{oil} = \frac{700nm}{1.48}$$

$$\lambda_{oil} = 472.97nm$$

Finding the thickness t

5. A thin film of oil is spread on a glass plate. A laser of $\lambda = 700$ nm is normally incident on the oil side of the plate and has **maximal** reflection. Which of the following conditions could make a laser of $\lambda = 350$ nm have **minimal** reflection?

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Find the thickness of the oil for the 700 nm wavelength laser going into the oil

Hint: Remember the constructive interference condition for TFI with no phase difference

Constructive Interference, no relative phase

$$2t = m\lambda_{film}$$

$$2t = m(472.97nm)$$

$$2t = (472.97nm)$$

$$t = \frac{1}{2}(472.97nm)$$

$$t = 236nm$$

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We will get constructive interference if

$$2t = m\lambda_{film}$$

- Leave the setup as is
- Double t
- Halve t
- t -> 1.5

If you solve for m, and m is an integer, we get constructive interference

Now to test e

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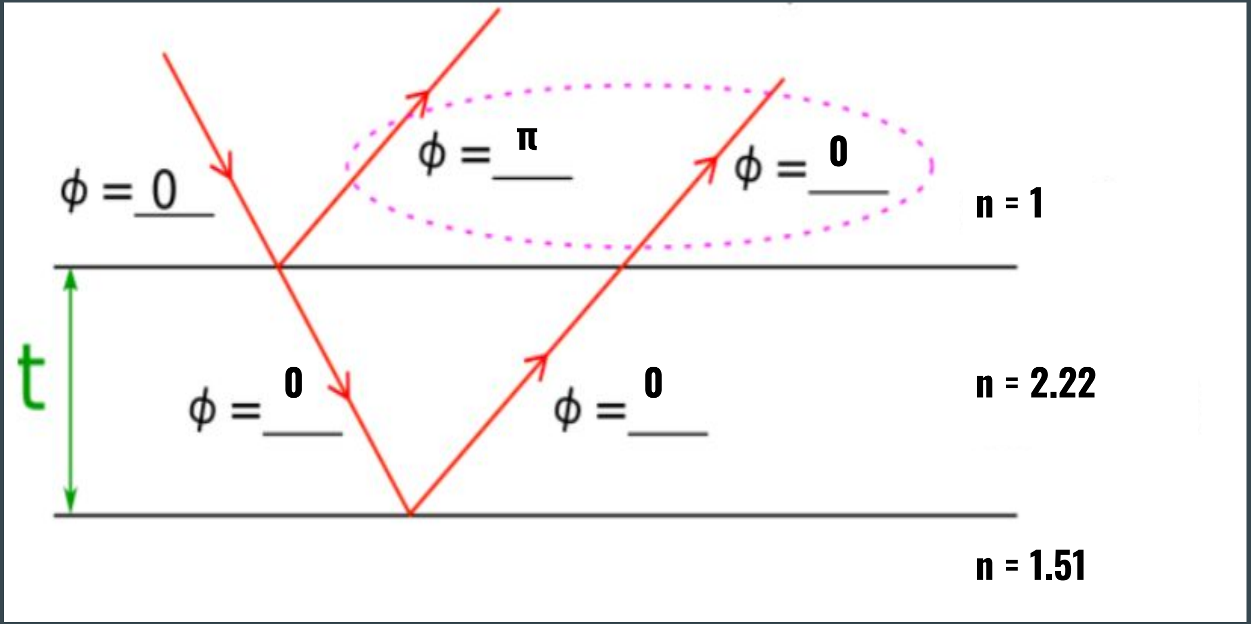
Draw the diagram for case e



No relative phase shift!

What’s the condition for destructive interference when there is a relative phase shift of pi?

$$2t = m\lambda_{film}$$

$$2(236nm) = m(\frac{350nm}{2.22})$$

$$m = 3$$

The value for m is an integer. For the relative phase shift case, this means we get destructive interference.

What's the condition for destructive interference when there is a relative phase shift of pi?

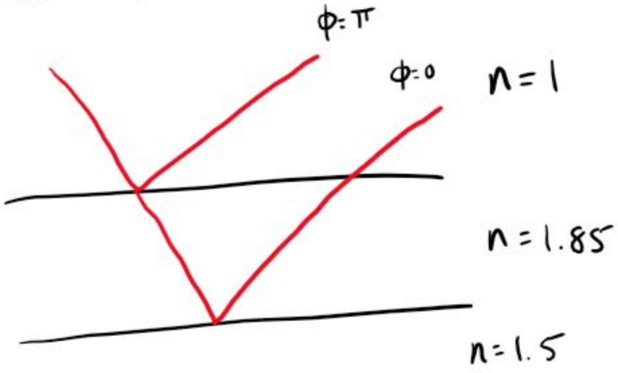
$$2t = m\lambda_{film}$$

$$2(236nm) = m(\frac{350nm}{2.22})$$

$$m = 3$$

The value for m is an integer. For the relative phase shift case, this means we get destructive interference.

Part f.



There is a relative phase. The equation for destructive interference is

$$2t = m\lambda_{film}$$

Now we can solve for m

$$2(236nm) = m\left(\frac{350nm}{1.85}\right)$$

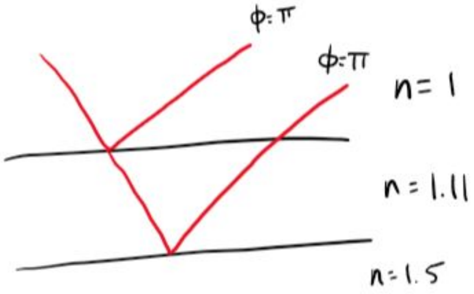
$$\Downarrow$$

$$m \approx 2.5$$

This is an integer plus 1/2. That looks like

$$2t = (m + 1/2)\lambda_{film}$$

if m was two. This is the condition for constructive interference. So f is not correct.



There is no relative phase difference. Then

$$2t = m\lambda_{film}$$

tells us about where we get constructive interference.

$$2(236nm) = m\left(\frac{350nm}{1.11}\right)$$

$$\Downarrow$$

$$m \approx 1.5$$

The value of m is an integer plus 1/2. In this case then that looks like

$$2t = (m + 1/2)\lambda$$

for m = 1. Then this does destructively interfere. Then g is correct.

Now to test f and g on your own!

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If we have time, do this one!

5. Which of the following thicknesses of an olive oil film ($n = 1.46$) sitting on top of water ($n = 1.33$) will result in constructive interference for yellow light ($\lambda = 578\ nm$) incident from the air above the oil?

- ☐ a) $578\ nm$
- ☐ b) $396\ nm$
- ☐ c) $297\ nm$
- ☐ d) $289\ nm$
- ☐ e) $198\ nm$
- ☐ f) $145\ nm$
- ☐ g) $99\ nm$