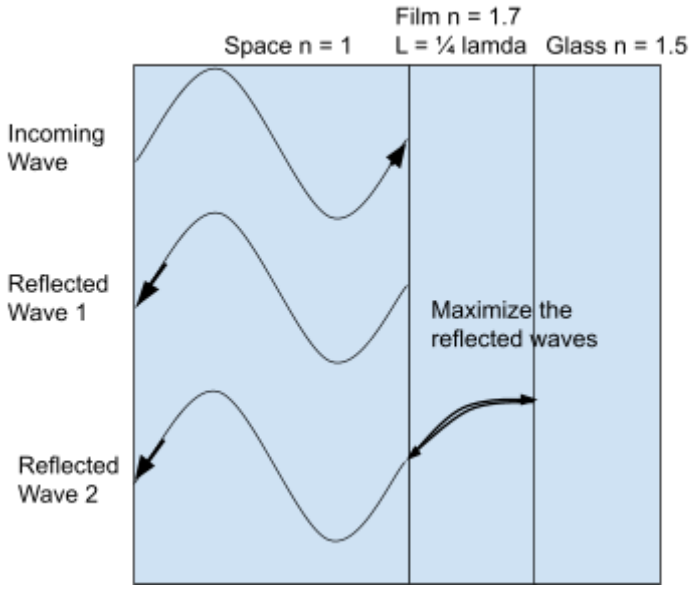
L;;;;;;;;;;;;;;;;; Christopher HuntPH 212

HIP 7

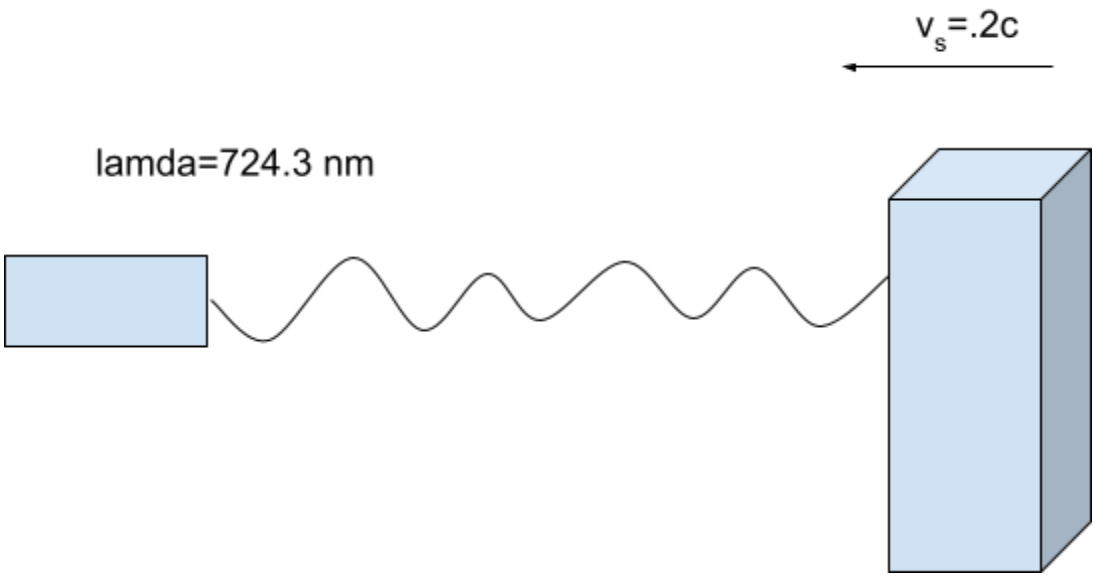
You are flying the TARDIS toward an evil DALEK at a speed of 0.20c. The DALEK attempts to exterminate you by firing a 724.3nm laser at you. Quickly, on the exterior of the glass (n = 1.5) door facing the DALEK, you have the TARDIS exude a thin layer of a substance with an index of refraction of n=1.7. What is the minimum thickness of this material needed in order to protect you from becoming “exterminated”?

In this problem we are looking to find the optimal reflection of the incoming lightwave. We begin by drawing three pictures of the light waves travelling through each medium, incoming wave, reflected wave 1 and reflected wave 2. Because the index of refraction is higher in the film than in the vacuum of space, the lightwave is refracted back shifted a pi’s length. Since the glass has a lower index of refraction from the film, the light reflected back does not get the same phase shift. So, in order to maximize reflection, the film must be ¼ wavelength thick.



So now this leaves us with the question of what is the wavelength of the light hitting the glass/film of the TARDIS.

Since the Tardis is approaching the light source at .2 times the speed of light, the light wave that will be penetrating the glass will experience a doppler shift.



The equation for finding the perceived lightwave caused by the doppler effect is:

$$\text{lamda}_+ = (1 - v_s/c)/ (1 + v_s/c))^{½} * \text{lamda}$$

Solve for lamda_+

$\text{lamda}_+=((1 - v_s/c)/ (1 + v_s/c))^{½} *\text{lamda} \rightarrow \text{lamda}_+ =(.8/1.2)^{½}*724.3 \rightarrow$ $\text{lamda}_+ = 591.4$ nm

Now that we know the wavelength of the light that is hitting the film we need to adjust for the change of speed of light in the film, this will give us the wavelength we need to find the necessary minimum thickness of the film.

Recall that the speed of light in a medium is v = c/n. Then recall the relationship between speed, wavelength, and frequency v = lamda*f

We will use lamda_1 to refer to the doppler shifted light hitting the medium and lamda_2 to be wavelength in the medium.

lamda_2*f = (lamda_1*f)/n → the frequency cancels out → $\text{lamda}_2= \text{lamda}_1$/n → $\text{lamda}_2 = 347.9$ nm

Now we can find the minimum thickness of the film.

L = ¼ * lamda_2 → L = 86.98 nm

The film can be a minimum of 86.98 nm thick in order to achieve maximum reflection of the perceived lightwave.

There are several reasonableness checks that we can do. By a unit check we find that we maintain nanometers as the final unit. Also we can check how the wavelength changes due to the doppler shift and when it passes through a medium. Because the observer is moving towards the light source at such a high speed, the perceived wavelength is shortened, we calculated a shorter wavelength after the doppler shift. Also, we know that when light enters a medium it slows down, we would expect the wavelength to shorten again, which we do.

Lecture Time: Name:

CATEGORY	EXEMPLARY (1.5)	ACCOMPLISHED (1)	DEVELOPING (0.5)	EMERGENT (0)
Problem Statement and Introduction	A new learning tool for our class is written	The problem is clearly presented for reader in your own words.	The problem is directly copied or is hard to follow.	You jump into some calculation
Picture	Your sketch could be dropped into a graphic novel as it stands.	There is a clear sketch, larger than a credit card, of the problem set up with important features and data noted	There is some sketch of the problem setup	What sketch?
Physics Tools	Appropriate physics tools are correlated to the exercise in textbook quality and size	Appropriate physics tools are correlated to the exercise. Appropriate tools include: pictures, FBDs, conservational laws utilized, etc...	Some physics tools are correlated to the exercise.	There are a few equations written.
Problem Solution Presentation	Solution is very clearly presented with intriguing asides or annotations	Solution is complete and clearly presented making no significant intuitive demands on the reader.	In your solution I have to read between the lines	Cliff notes version of solution with only high points present
Form	Your solution can serve as solution manual.	Drawing is larger than a credit card, organization is fluid, notation used is clear.	I could figure the path of your solution with effort.	You can read it.
Units		All units correctly given	Calculations & quantities are presented with units	Some units at the results
Solution		Correct	You are close	None/Not reasonable
Significant Figures		Correct Sig Figs	Makes effort to use correct significant figures	Copies the number from the calculator
Reasonableness	Provides more than one type of Reasonableness check.	Gives one clear rationale for appropriateness of the solution in the setting	Asserts that the answer is reasonable but really hasn't given any evidence	No discussion
All Self Graded		Done	Not Done	Done, but your self-assessment is different from mine by at least two steps.