**Physics 133-02: Physics II—Electricity, Magnetism, and Waves**
Thin Film

**Problem 1:** A lens made of glass with an index of refraction of 1.61 is to be coated with a thin layer of magnesium fluoride with an index of refraction of 1.38. The goal is to make an anti-reflective coating; that is, to choose the thickness $t$ of the film such that destructive interference occurs for reflected light.

a. Suppose you want to have destructive interference for the perpendicular reflection of light of wavelenght $550\,\text{nm}$ (as measured in air). What is the minimum thickness of the film?

b. Does that choice of thickness permit constructive interference for reflection of some other visible wavelength of light?

c. Suppose that in part (a), you picked the second-thinnest possible film. Would your answer to part (b) change?

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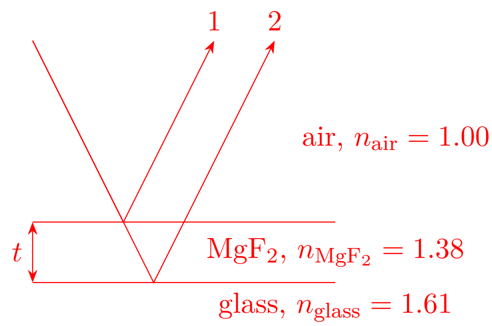


Consider the reflection of waves 1 and 2. Wave 1 is inverted upon reflection. Wave 2 is also inverted upon reflection. Thus there is a phase change of $\lambda/2$ for both waves, so the phase changes cancel when comparing path length differences.

For destructive interference between 1 and 2, then

$$2n_{MgF_2}t = (m + \frac{1}{2})\lambda$$
$$t = \frac{m + \frac{1}{2}\lambda}{2n_{MgF_2}}$$
$$t = \frac{m + \frac{1}{2} \times 550\,\mathrm{nm}}{2 \times 1.38}$$

For the thinnest film, pick $m = 0$. Then $t = 99.6\,\mathrm{nm}$.

b. Does that choice of thickness permit constructive interference for reflection of some other visible wavelength of light?

For constructive interference between waves 1 and 2, want

$$2n_{MgF_2}t = m\lambda$$
$$\lambda = \frac{2n_{MgF_2}t}{m}$$
$$\lambda = \frac{2 \times 1.38 \times 99.6\,\mathrm{nm}}{m}$$

| m | $\lambda$ | |
|---|---|---|
| 1 | 274.9 nm | ultraviolet |
| 2 | 137.4 nm | even shorter wavelength |

c. Suppose that in part (a), you picked the second-thinnest possible film. Would your answer to part (b) change?

In part (a), picking $m = 1$ gives $t = 298.9\,\text{nm}$. Then in part (b), the wavelenghts would be:

| m | $\lambda$ | |
|---|---|---|
| 1 | 825.0 nm | infrared |
| 2 | 412.5 nm | violet — visible! |
| 3 | 275.0 nm | ultraviolet |

For this thickness, yes, there would be constructive interference for violet light.