Question 7

10 points total	**Distribution of points**

(a) 1 point

The wavelength and frequency are related by $c = \lambda f$

$$f = \frac{c}{\lambda} = \frac{\left(3 \times 10^8 \text{ m/s}\right)}{\left(520 \times 10^{-9} \text{ m}\right)}$$

For a correct answer — 1 point

$$f = 5.77 \times 10^{14} \text{ Hz}$$

(b) 1 point

The frequency does not change when light travels in a different medium
For an answer that is consistent with part (a) — 1 point

$$f = 5.77 \times 10^{14} \text{ Hz}$$

(c) 2 points

For using a correct expression for the wavelength in oil — 1 point

$$\lambda_{\text{oil}} = \frac{\lambda_{\text{air}}}{n} \quad \text{or} \quad \lambda = \frac{\upsilon_{\text{oil}}}{f}$$

The second equation can be manipulated to obtain the first equation:

$$\lambda_{oil} = \frac{\upsilon}{f} = \frac{c/n}{f} = \frac{c}{f}\frac{1}{n} = \frac{\lambda_{air}}{n}$$

$$\lambda_{oil} = \frac{(520 \text{ nm})}{1.52}$$

For a correct numerical answer — 1 point

$$\lambda_{oil} = 342 \text{ nm}$$

Units 1 point

For correct units in two of the calculated responses in parts (a), (b), and (c) — 1 point

(d) 3 points

For selecting "Greater than" — 1 point
For mentioning that there must be a phase shift upon reflection at both interfaces — 1 point
For mentioning interference — 1 point

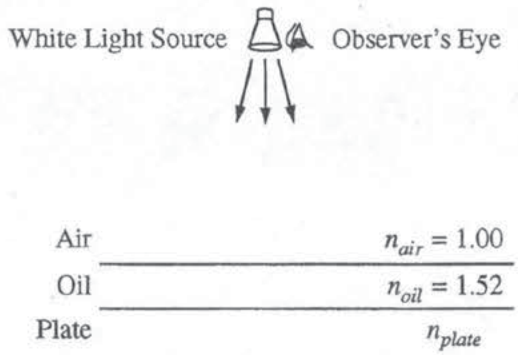
Example: There is constructive interference for the observed light. In the oil, the light traverses the oil thickness two times: $2 \times 171 \text{ nm} = 342 \text{ nm}$, or one wavelength in the oil. For <u>constructive</u> interference, reflections at the two interfaces must then have the same phase shift. Since the refractive index increases at the air-to-oil surface, it must also increase at the oil-to-plate surface, so $n_{\text{plate}} > n_{\text{oil}}$.

Question 7 (continued)

	Distribution of points
(e) 2 points	
For mentioning that the color shifts toward the red end of the visible spectrum	1 point
For mentioning that the light's path length in the oil increases	1 point

Example:

As the observer views the film from a larger angle, the light must travel a greater distance in the film. This creates constructive interference for a longer wavelength of light and causes the apparent film color to shift toward the red end of the visible spectrum.



Note: Figure not drawn to scale.

7. (10 points)

A thin layer of transparent oil is placed on top of a transparent plate. The oil film is then illuminated by white light shining onto the oil's surface, as shown in the figure above. To an observer standing right next to the light source and looking straight down on the oil film, the oil film appears green, corresponding to a wavelength of 520 nm in air. The oil has an index of refraction of 1.52.

(a) Determine the frequency of the green light in the air.

$\frac{c}{520 \cdot 10^{-9}} = 5.77 \cdot 10^{14}$ Hz

(b) Determine the frequency of the green light in the oil film.

$5.77 \cdot 10^{14}$ Hz

Frequency is unchanged.

(c) Calculate the wavelength of the green light in the oil film.

$\frac{520}{1.52} = 342$ nm

(d) The oil film thickness is half of the wavelength you found in part (c). Is the index of refraction of the plate greater than, less than, or equal to that of the oil?

✓ Greater than ____ Less than ____ Equal to

Justify your answer.

The light needs to have a phase shift when reflecting off the plate so that it will constructively interfere w/ the light which reflected off the oil surface.

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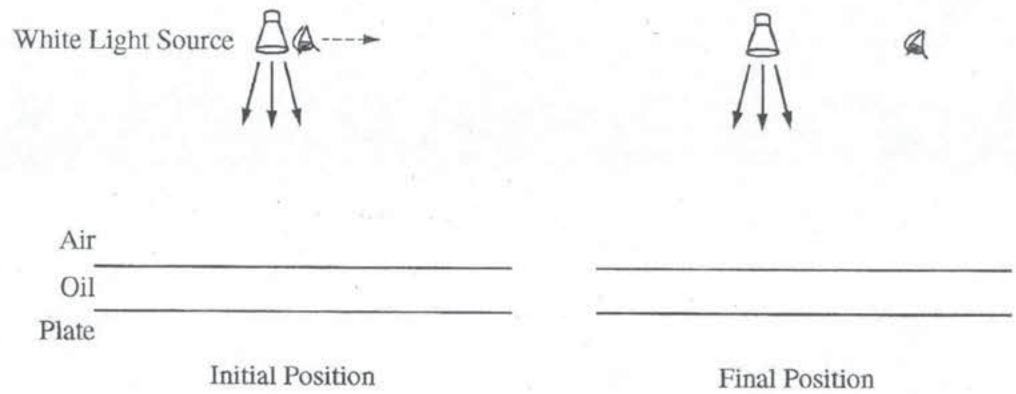
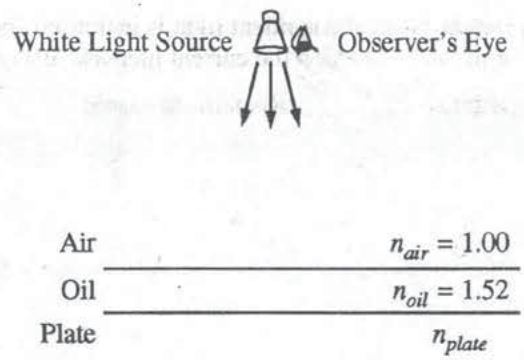


Note: Figure not drawn to scale.

(e) As the observer starts moving to the right away from the light source, as shown in the figures above, the film appears to change color. Describe the color change and give an explanation for this phenomenon.

The color will change to be more yellow, then orange, and then red. The light which enters the oil, reflects on the plate, and travels to the eye will have covered a greater distance inside the oil, requiring a larger wavelength to constructively interfere.



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7. (10 points)

A thin layer of transparent oil is placed on top of a transparent plate. The oil film is then illuminated by white light shining onto the oil's surface, as shown in the figure above. To an observer standing right next to the light source and looking straight down on the oil film, the oil film appears green, corresponding to a wavelength of 520 nm in air. The oil has an index of refraction of 1.52.

(a) Determine the frequency of the green light in the air.

$v = \lambda f$

$f = \frac{c}{\lambda} = \frac{3.0 \times 10^8 \text{ m/s}}{520 \times 10^{-9} \text{ m}}$

$f = 5.77 \times 10^{14}$ Hz

(b) Determine the frequency of the green light in the oil film.

$f = 5.77 \times 10^{14}$ Hz Frequency is not medium-dependent so it remains the same.

(c) Calculate the wavelength of the green light in the oil film.

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

$\lambda = \frac{v}{f}$ $\lambda = \frac{c}{nf} = \frac{3.0 \times 10^8 \text{ m/s}}{(1.52)(5.77 \times 10^{14} \text{ Hz})}$

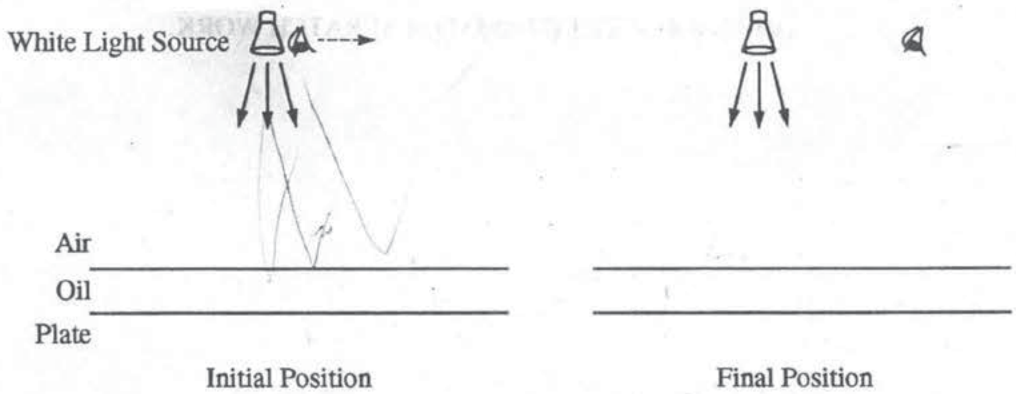
$\lambda = 3.42 \times 10^{-7}$ m

(d) The oil film thickness is half of the wavelength you found in part (c). Is the index of refraction of the plate greater than, less than, or equal to that of the oil?

____ Greater than ✓ Less than ____ Equal to

Justify your answer.

In order to see green light, there must be constructive interference. There is a phase change at the interface of air and oil, and to experience constructive interference there must be no phase change at the oil plate interface, so $n_{oil} > n_{plate}$.



Note: Figure not drawn to scale.

(e) As the observer starts moving to the right away from the light source, as shown in the figures above, the film appears to change color. Describe the color change and give an explanation for this phenomenon.

Color is frequency dependent, but there are no changes in frequency. Therefore, the color change must be a result of the light waves being out of phase and generating interference patterns, and the parts that are out of phase give the eye a sense of a new frequency, much like beats in sound waves. There are many different frequencies possible, like the rainbow on the surface of a soap bubble.

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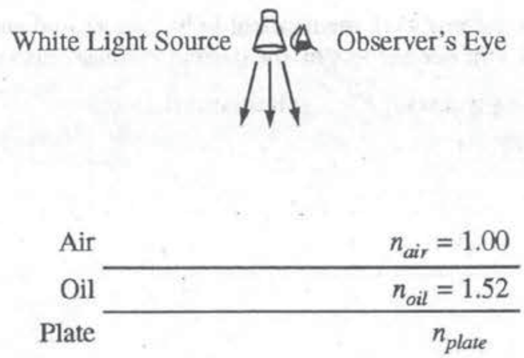

c, d

Note: Figure not drawn to scale.

7. (10 points)

A thin layer of transparent oil is placed on top of a transparent plate. The oil film is then illuminated by white light shining onto the oil's surface, as shown in the figure above. To an observer standing right next to the light source and looking straight down on the oil film, the oil film appears green, corresponding to a wavelength of 520 nm in air. The oil has an index of refraction of 1.52.

(a) Determine the frequency of the green light in the air.

$v = f\lambda$ $\quad n = \frac{c}{v}$ $\quad 1.00 = \frac{3\times10^8}{v}$ $\quad v = 3.\times10^8$ $\quad v = f\lambda$ $\quad 3\times10^8 = f(520)$ $\quad$ **f = 576923 nHz**

(b) Determine the frequency of the green light in the oil film.

$v = f\lambda$ $\quad n = cv$ $\quad n = \frac{c}{v}$ $\quad 1.52 = \frac{3\times10^8}{v}$ $\quad v = 1.97\times10^8$ $\quad v = f\lambda$ $\quad 1.97\times10^8 = f(520)$ $\quad$ **f = 378846 nHz**

(c) Calculate the wavelength of the green light in the oil film.

$n = \frac{c}{v}$ $\quad \frac{c}{n} = \lambda f$ $\quad v = \lambda f$ $\quad \frac{3\times10^8}{1.52} = \lambda(378846\,\text{nHz})$ $\quad$ **λ = 520.97 nm**

(d) The oil film thickness is half of the wavelength you found in part (c). Is the index of refraction of the plate greater than, less than, or equal to that of the oil?

X Greater than ____ Less than ____ Equal to

Justify your answer.

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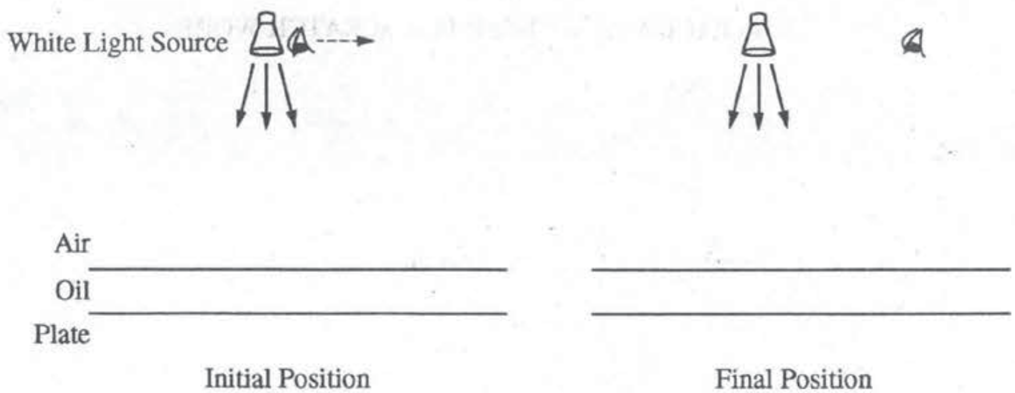

Note: Figure not drawn to scale.

(e) As the observer starts moving to the right away from the light source, as shown in the figures above, the film appears to change color. Describe the color change and give an explanation for this phenomenon.

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The color change is due to the different frequencies the naked eye can pick up. 400-700 nm. The colors change accordingly to red, orange yellow green blue and violet. He will see Blue and violet b/c of the way he is moving.

Question 7

Overview

The intent of this question was to assess student understanding of what happens to the velocity, wavelength, and frequency of light when it enters a material of a different refractive index. In particular, it assessed student understanding of the role of phase change and interference in creating a reflection maximum in thin films and the prediction, with justification, of how the color of the maximum will change as the thickness of the film increases.

Sample: 1A
Score: 10

Parts (a), (b), and (c) earned full credit, including the units point. The selection and explanation are correct for part (d). Part (e) earned full credit because it addresses the light shifting to the red due to the increase in the path length of the light.

Sample: 1B
Score: 7

Parts (a), (b), and (c) earned full credit, including the units point. No point was awarded for the selection in part (d), but 2 points were earned for the explanation. No points were awarded for part (e) because there were no valid statements.

Sample: 1C
Score: 2

The answer for part (a) was not correct and earned no credit. No point was awarded for part (b) because the answer was different than for part (a). One point was earned for part (c) because the correct expression was used, but the numerical answer was incorrect. In part (d), the correct selection earned 1 point but there was no explanation. Part (e) earned no credit because no valid statements were made. Because the units were incorrect in parts (a) and (b) no units point was awarded.