SPH 4U Name: ANSWER WINTER 2019

SPH 4U UNIT # 4 TAKE HOME TEST – THE WAVE NATURE OF LIGHT

Knowledge & Understanding / 5 Communication / 15 Application / 14 Thinking & Inquiry / 4

16 20

Knowledge & Understanding (5 Multiple Choice)

1. Several experiments are performed with light. Which of the following observations is not consistent with the wave model of light?
   a. The beam of light travels in a straight line.
   b. The speed of light is less in water than in air.
   c. The light can exhibit interference patterns when traveling through small openings.
   d. The light can be simultaneously reflected and transmitted at certain interfaces.
   e. The light can travel through a vacuum.

2. A wave with a high frequency has a:
   a. Small period
   b. Large period
   c. Small amplitude
   d. Large amplitude
   e. None of the above

$f = \frac{1}{T}$

3. Light must travel as a transverse wave because it
   a. can be polarized
   b. can travel through a vacuum
   c. slows down and bends toward the normal
   d. undergoes diffraction
   e. disperses when traveling through a glass prism

4. Electromagnetic waves consist of magnetic and electric fields that are
   a. Parallel to each other and to the direction of propagation, and oscillate in phase
   b. Perpendicular to each other and to the direction of propagation, and oscillate in phase
   c. Parallel to each other and to the direction of propagation, and oscillate out of phase
   d. Perpendicular to each other and to the direction of propagation, and oscillate out of phase
   e. None of the above

5. Light strikes a thin film viewed from above. To obtain the first reflected bright spot, the thickness of the film must be
   a. Much less than λ
   b. $\frac{\lambda}{4}$
   c. $\frac{\lambda}{2}$
   d. $\frac{3\lambda}{4}$
   e. λ

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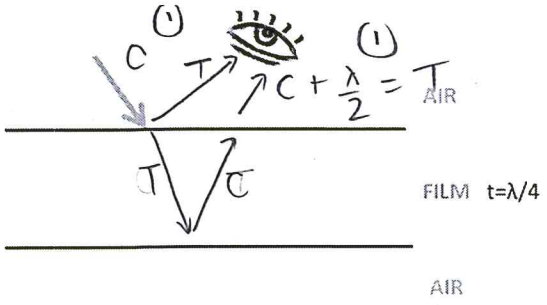
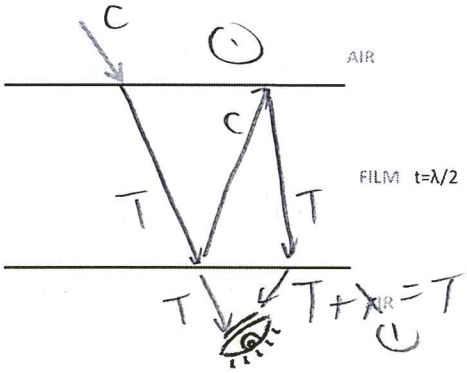
Communication (16 Marks)

1. For the following diagrams, identify which is transmission, and which is reflection. Then, determine the type of interference, by completing the diagrams. (8 marks)



Constructive. (1)

Reflection (1)

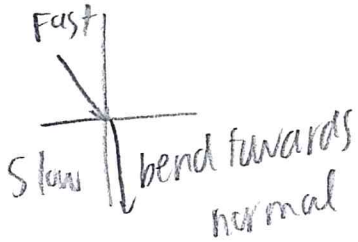


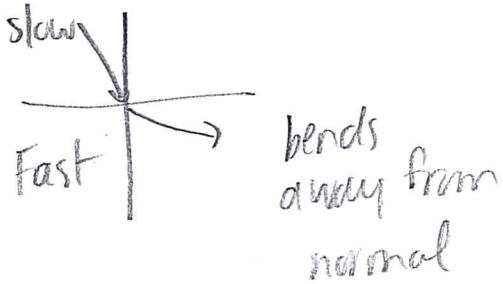
Constructive (1)

Transmission (1)

2. Explain why refraction occurs. (4 marks)

Refraction is the bending of light as it travels from one medium into another.





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3. Explain why a light wave can be polarized and how it is done. (4 marks)

- 2 perpendicular waves, in-phase
- polarized by removing one wave
- pass light through narrow slit oriented parallel to one of the waves

Calculations (18 Application Marks)

1. Light travels from water (n = 1.33) into glass (n = 1.52) at the edge of a fish tank. If the angle of incidence in the water is 22°, determine the angle of refraction in the glass. (3 marks)

$n_1 = 1.33$
$n_2 = 1.52$
$\theta_1 = 22°$
$\theta_2 = ?$ } ①

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ ①

$\theta_2 = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_2}\right)$

$\theta_2 = \sin^{-1}\left(\frac{1.33 \sin 22}{1.52}\right)$

$\theta_2 = 19°$ ①

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2. A monochromatic source of 450 nm illuminates two slits that are 3 μm apart. Find the angle at which the second order maximum occurs. (4 marks)

$\lambda = 450\text{nm}$
$= 4.5\times10^{-7}\text{m}$ (1)

$d = 3\mu\text{m}$
$= 3\times10^{-6}\text{m}$

(1)

$\theta = ?$

$m = 2$

$m\lambda = d\sin\theta$ (1)

$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right)$

$\theta = \sin^{-1}\left(\frac{2(4.5\times10^{-7}\text{m})}{3\times10^{-6}\text{m}}\right)$ (4)

$\theta = 17.4576°$

$\theta = 17°$ or $20°$ (1)

3. In a wave pool, one wave crest takes 2.0 s to travel the 35.0 m width of the pool. A wave is generated every 1.8 s. Find:

a. The speed of the waves (3 marks)

$t = 2.0\text{s}$
$d = 35.0\text{m}$ (1)
$v = ?$

$v = \frac{d}{t}$ (1)

$v = \frac{35.0\text{m}}{2.0\text{s}} = 17.5\text{m/s} = 18\text{m/s}$ (1) (3)

b. The frequency (2 marks)

$f = ?$
$N = 1$
$t = 1.8\text{s}$

$f = \frac{N}{t}$ (1)

$f = \frac{1}{1.8\text{s}} = 0.56\text{Hz}$ (1) (2)

c. The wavelength (2 marks)

$\lambda = ?$

$v = f\lambda$ (1)

$\lambda = \frac{v}{f} = \frac{17.5\text{m/s}}{0.556\text{Hz}} = 31.47482\text{m}$

$= 31\text{m}$ (1) (2)

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4. A camera lens (n = 1.52) is coated with a film of magnesium fluoride (n = 1.25). What should the least thickness of the film be to minimize reflected light with a wavelength of 550 nm? (4 marks)

$n_{air} = 1.00$

~~$n_c = 1.52$ not needed~~

$n_f = 1.25$

$t = ?$

minimize = destructive

$\lambda_{air} = 550\text{ nm} = 5.5\times10^{-7}\text{ m}$ (1)

reflected.

(1)

$$\frac{n_{air}}{n_f} = \frac{\lambda_f}{\lambda_{air}} \quad (1)$$

$$\lambda_f = \frac{n_{air}\lambda_{air}}{n_f}$$

$$\lambda_f = \frac{(1.00)(5.5\times10^{-7}\text{ m})}{1.25} = 4.4\times10^{-7}\text{ m} \quad (1)$$

$$t = \frac{\lambda}{2} \quad (1)$$

$$t = \frac{4.4\times10^{-7}\text{ m}}{2}$$

$$t = 2.2\times10^{-7}\text{ m} \quad (1)$$

Thinking & Inquiry (4 Marks)

1. Explain the separation of light into colours as light travels from air, into a glass prism by calculating the angle of refraction for red light (n = 1.46) and blue light (n = 1.47). Use your results to generalize a rule for the separation of light into colours through refraction. (4 marks)

Consider,

$n_r = 1.46$, $n_b = 1.47$, $n_{air} = 1.00$, $\theta_{airr} = \theta_{airb} = 45°$

For red:

$n_{air}\sin\theta_{airr} = n_r\sin\theta_r$

$$\theta_r = \sin^{-1}\left(\frac{n_{air}\sin\theta_{airr}}{n_r}\right)$$

$$\theta_r = \sin^{-1}\left(\frac{1.00\sin 45}{1.46}\right)$$

$\theta_r = 28.967911148°$

For blue,

$n_{air}\sin\theta_{airb} = n_b\sin\theta_b$

$$\theta_b = \sin^{-1}\left(\frac{n_{air}\sin\theta_{airb}}{n_b}\right)$$

$$\theta_b = \sin^{-1}\left(\frac{1.00\sin 45°}{1.47}\right)$$

$\theta_b = 28.75236918°$

As go from blue to red on spectrum, θ of refraction increases.

$n_f = 1.25$

$\lambda_1 = 5.50 \times 10^{-7}\ m$

$t = ?$

$$\frac{n_1}{n_f} = \frac{\lambda_f}{\lambda_1}$$

$$\lambda_f = \frac{n_1 \lambda_1}{n_f}$$

$$\lambda_f = \frac{(1.52)(5.5 \times 10^{-7})}{1.25}$$

$$\lambda_f = 6.688 \times 10^{-7}\ m$$

$$t = \frac{\lambda}{2} = \frac{6.688 \times 10^{-7}\ m}{2}$$

$$= 3.344 \times 10^{-7}\ m$$

$$= 3.34 \times 10^{-7}\ m$$

$n_f = 1.25$

$n_1 = 1.52$

$\lambda_f = 5.5 \times 10^{-7}\ m$

$t = ?$

$$\frac{n_f}{n_1} = \frac{\lambda_1}{\lambda_f}$$

$$\lambda_1 = \frac{n_f \lambda_f}{n_1}$$

$$\lambda_1 = \frac{(1.25)(5.5 \times 10^{-7})}{1.52}$$

$$\lambda_1 = 4.523 \times 10^{-7}\ m$$

$$t = \frac{\lambda}{2}$$

$$t = \frac{4.523 \times 10^{-7}}{2}$$

$$t = 2.2615 \times 10^{-7}\ m$$

$$t = 2.26 \times 10^{-7}\ m$$