PH202-1G
Spring 2014

Worksheet March 19

Interference

What is the principle of linear superposition? What phenomena does it describe?

The amplitude of overlapping waves can be added together. It describes wave interference phenomena.

Describe constructive interference and destructive interference.

Constructive interference - waves combine to make a bigger wave
Destructive interference - waves cancel out to make no wave at all

What condition must be met in order for interference to occur continuously at a point in space?

The sources of the waves must be coherent - emitting waves at the same frequency

Young's double-slit experiment

Describe Young's double-slit experiment. Why is it important?

Coherent light is directed onto two thin slits, creating an interference pattern (alternating bands of brightness and darkness) on a screen. It demonstrated that light is a wave.

Give a mathematical expression for the path length difference in the double-slit experiment.

$\Delta \ell = d \sin\theta$, where θ is the angle from the midline.

What angles from the midlines produce bright fringes? What angles produce dark fringes?

Bright: $\sin\theta = \frac{m\lambda}{d}$ Dark: $\sin\theta = \frac{(m+\frac{1}{2})\lambda}{d}$ where m is zero or a positive integer

How do you calculate the distance along the screen at which bright or dark fringes occur?

$\tan\theta = \frac{y}{L} \Rightarrow y = L\tan\theta$

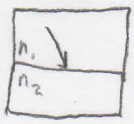
Thin-film interference

How do you calculate the wavelength of light within a thin film?

$\lambda_{film} = \frac{\lambda_{vacuum}}{n}$ Remember, wavelength is different in different media, but frequency is always the same.

During reflection at the boundary between two media, how do you know whether light will undergo a phase shift? What is the magnitude of this phase shift?

$n_1 < n_2$



If the index of refraction of the medium in which the light currently travels is less than the index of the medium on the other side of the boundary, a phase shift of $\frac{1}{2}\lambda$ or 180° occurs.

For incident light that is perpendicular to the thin film surface, what is the condition for constructive and destructive interference?

	Phase shift	No phase shift
Constructive	$2t + \frac{1}{2}\lambda = m\lambda$	$2t = m\lambda$
Destructive	$2t + \frac{1}{2}\lambda = (m+\frac{1}{2})\lambda$	$2t = (m+\frac{1}{2})\lambda$

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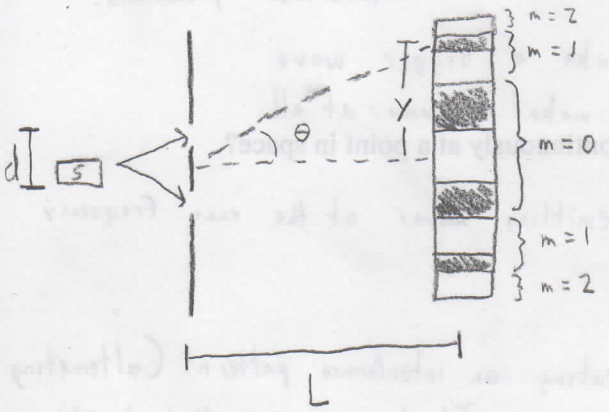
Problems

1. A double-slit experiment is performed by shining light from a red laser (wavelength 650 nm) on two thin slits separated by 0.15 mm. The second dark fringe in the resulting interference pattern is located 3.25 mm from the bright central fringe. a) What is the distance between the slits and the screen? b) What is the distance on the screen between the second dark fringe and the second bright fringe away from the central bright fringe?



a) 2nd dark fringe $\Rightarrow$ m = 1, destructive interference

$$d \sin\theta = \left(m + \tfrac{1}{2}\right)\lambda$$

$$\theta = \arcsin\left(\frac{\left(m+\frac{1}{2}\right)\lambda}{d}\right) = \arcsin\left(\frac{(1+1/2)\cdot 650\text{ nm}}{0.15\text{ mm}}\right) = 0.37^\circ$$

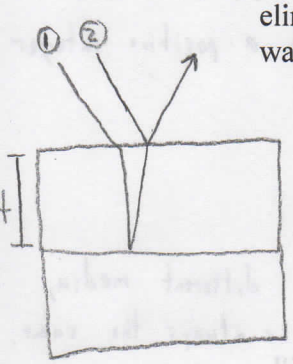
$$L = \frac{Y}{\tan\theta} = \frac{3.25\text{ mm}}{\tan 0.37^\circ} = \boxed{0.50\text{ m}}$$

b) 2nd bright fringe $\Rightarrow$ m = 2, constructive interference $\quad d\sin\theta = (m)\lambda$

$$\theta = \arcsin\left(\frac{m\lambda}{d}\right) = \arcsin\left(\frac{2\cdot 650\text{ nm}}{0.15\text{ mm}}\right) = 0.50^\circ \qquad y = L\tan\theta = 0.50\text{ m}\ \tan 0.50^\circ$$

$$y = 4.33\text{ mm} \qquad 4.33_{mm} - 3.25_{mm} = \boxed{1.08\text{ mm}}$$

2. When looking directly down onto a thin film of gasoline (refractive index 1.40) on a layer of water (refractive index 1.33), the film appears magenta because the green light has been eliminated by destructive interference. If the thin film of gasoline is 193 nm thick, what wavelength of light exhibits destructive interference to cause this color perception?



Light ray ① refracts through the gasoline, reflects from the water (no phase change since $n_1 > n_2$), and refracts through the air.

Light ray ② reflects from the gasoline (phase change since $n_1 < n_2$) and interferes with light ray ①.

The overall phase change is $\frac{1}{2}\lambda - 0 = \frac{1}{2}\lambda$.

Condition for destructive interference:

$$\left(m + \tfrac{1}{2}\right)\lambda = 2t + \tfrac{1}{2}\lambda$$

$$2t = \left(m + \tfrac{1}{2}\right)\lambda - \tfrac{1}{2}\lambda = m\lambda$$

Assume m = 1

$$\lambda_{film} = \frac{2t}{m} = \frac{2\cdot 193\text{ nm}}{1} = 386\text{ nm}$$

$$\lambda_{vacuum} = n\lambda_{film} = 1.40\cdot 386\text{ nm} = \boxed{540\text{ nm}}$$