Name: ______________________

Class: ______________________

Due Date: ______________________

C.3 Wave Phenomena

Understandings

- Waves traveling in two and three dimensions can be described through the concepts of wavefronts and rays.
- Wave behavior at boundaries in terms of reflection, refraction, and transmission.
- Wave diffraction around a body and through an aperture.
- Wavefront-ray diagrams showing refraction and diffraction.
- Snell's law, critical angle, and total internal reflection.
- Snell's law as given by $\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\ _1} = \frac{v_2}{v_1}$ where *n* is the refractive index and θ is the angle between the normal and the ray.
- Superposition of waves and wave pulses.
- Double-source interference requires coherent sources.
- The condition for constructive interference as given by path difference $= n\lambda$.
- The condition for destructive interference as given by path difference $= \left(n + \frac{1}{2}\right)\lambda$.
- Young's double-slit interference as given by $s = \frac{\lambda D}{d}$ where *s* is the separation of fringes, *d* is the separation of the slits, and *D* is the distance from the slits to the screen.

Equations

$$\frac{n_1}{n_2} = \frac{\sin\ _2}{\sin\theta_1} = \frac{v_2}{v_1}$$

Constructive interference: path difference $= n\lambda$

Destructive interference: path difference $= \left(n + \frac{1}{2}\right)\lambda$

$s = \frac{\lambda D}{d}$

Additional HL Understandings

- Single-slit diffraction including intensity patterns as given by $\theta = \frac{\lambda}{b}$ where b is the slit width.
- The single-slit pattern modulates the double slit interference pattern.
- Interference patterns from multiple slits and diffraction gratings as given by $n\lambda = d\sin\theta$.

Additional HL Equations

$\theta = \frac{\lambda}{b}$

$n\lambda = d\sin\theta$

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Use your favorite sources to answer the following questions

1. C: Define *wavefront.*

2. C: Define *ray.*

3. E: **Use a pencil and ruler!** Draw 3 wavefronts and 6 rays after a small rock falls vertically and hits water.

4. E: **Use a pencil and ruler!** Draw 2 wavefronts and 8 rays after a long thin rod falls horizontally and hits water.

5. C: Define *superposition.*

6. C: **Use a pencil and ruler!** Draw a before, during, and after image of two pulses on a rope traveling in opposite directions which go through constructive interference.

7. C: **Use a pencil and ruler!** Draw a before, during, and after image of two pulses on a rope traveling in opposite directions which go through destructive interference.

8. C: **Use a pencil and ruler!** Draw a before and after image of a single pulse wave on a string striking and being reflected from a vertical pole with a fixed end.

9. C: **Use a pencil and ruler!** Draw a before and after image of a single pulse wave on a string striking and being reflected from a vertical pole with a free/loose end.

10.C: What is the equation, units, and meaning of *index of refraction n*? What is the range of values for the *refractive index* of an object? What is the *refractive index* for a vacuum?

11.E: The speed of light in a vacuum is $3.00 \times 10^8\ \frac{\text{m}}{\text{s}}$ while the speed of light in a diamond is measured to be $1.24 \times 10^8\ \frac{\text{m}}{\text{s}}$. What is the index of refraction of diamond?

12.E: The index of refraction of light in water is $n_{\text{water}} = 1.33$. What is the speed of light in water?

13.E: Light, which has a wavelength of $\lambda = 450$ nm, is moving through Carbon Tetrachloride with a speed of $2.056 \times 10^8\ \frac{\text{m}}{\text{s}}$.

a. What is the index of refraction of Carbon Tetrachloride?

b. What is the frequency of this light wave as it passes through the Carbon Tetrachloride?

c. What will be the corresponding wavelength of this light wave in air?

14.E: Light, which has a wavelength of 625 nm in air, enters flint glass. The index of refraction of flint glass is approximately 1.63.

a. What is the speed of light in flint glass?

b. What will be the wavelength of this light within the glass?

c. What is the frequency of this light within the glass?

d. What is the frequency of this light in air?

15.C: **Use a pencil and ruler!** Define *reflection* and draw a labeled figure.

16.C: State the equation for the *law of reflection*.

17.C: **Use a pencil and ruler!** Define *refraction* and draw a labeled figure. (Do not confuse *refraction* with *rarefaction*!)
https://physics.bu.edu/~duffy/HTML5/refraction_block.html
https://physics.bu.edu/~duffy/HTML5/refraction.html

18.C: State the equation for refraction: *Snell's law*. **Use a pencil and ruler!** Draw an image describing *Snell's law*.

19.C: **Use a pencil and ruler!** Draw a detailed image of a ray traveling from a fast medium to a slow medium.

20.C: **Use a pencil and ruler!** Draw a detailed image of a ray traveling from a slow medium to a fast medium.

21.C: **Use a pencil and ruler!** Define *dispersion* and draw a labeled figure.

22.E: A wave, which has a wavelength of 1.40 m and a wave speed of 4.80 m/s, enters a second medium where the wavelength is reduced to 0.900 m. What will be the wave speed in the second medium?

23.A wave moving with a speed of 38.0 cm/s and having a wavelength of 4.50 cm strikes an interface at an angle of 57.0° relative to the normal. In the second medium the speed of the wave is reduced to 24.0 cm/s.

a. What will be the angle of the wave in the second medium?

b. What will be the wavelength in the second medium?

c. What will be the frequency of this wave in the first medium?

d. What will be the frequency of this wave in the second medium?

e. Which medium has a higher index of refraction?

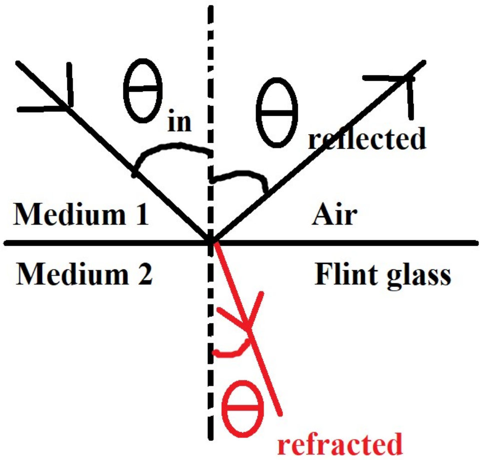
24.E: A wave moving with a speed of 1.25 m/s strikes an interface at an incident angle of 82.0°. After passing through the interface the angle shifts to 55.0° and the wavelength becomes 5.60 cm.

a. What will be the speed of this wave in the second medium?

b. What will be the wavelength in the first medium?

c. What will be the frequency in the second medium?

25.E: A light ray, which has a wavelength of 580 nm, strikes a horizontal interface going from air into flint glass. Given that the angle between the incident light ray and the normal to the interface is 47.0°. The index of refraction of flint glass is approximately 1.63.



a. What will be the corresponding angle in the flint glass?

b. What will be the wavelength of this light within the flint glass?

c. What will be the frequency of this light within the flint glass?

d. Some of the light reflects at the interface. What will be the angle between the reflected light ray and the normal to the interface?

26.E: A light beam traveling through glycerol, which has an index of refraction of 1.48, encounters an interface at an angle of 67.0° relative to the normal to the surface. The corresponding angle in the second medium is measured to be 50.5°. What is the index of refraction of the second medium?

27.E: A light wave moving through an unknown medium encounters an interface at an angle of 52.0° and then refracts to an angle of 45.2° into Lucite, which has an index of refraction of 1.50. What is the index of refraction of the first medium?

28.C: **Use a pencil and ruler!** Define *total internal reflection* and *critical angle*. Draw a labeled figure.

29.E: A light beam is moving from flint glass into water. What is the critical angle between these two mediums? The index of refraction of flint glass is 1.63 while the index of refraction of water is 1.33.

30.E: Determine the critical angle between the following two media:

a. diamond ($n = 2.42$) and water ($n = 1.33$)

b. alcohol ($n = 1.36$) and Lucite ($n = 1.50$)

c. Hot air ($n = 1.02$) and room temperature ($n = 1.00$)

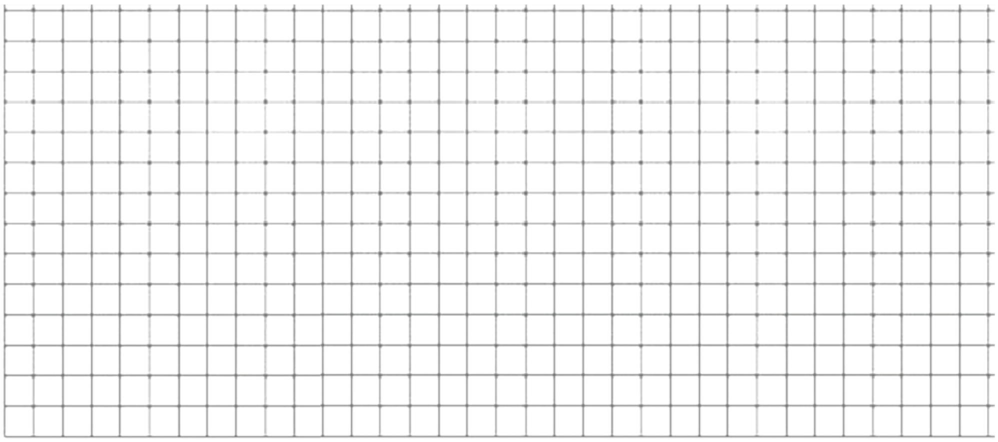
31.C: Define *diffraction*. Give two examples.

32.C: What is the relationship between the slit width and wavelength of the wave which gives maximum diffraction?

33.C: What is the relationship between the slit width and wavelength of the wave which gives minimum diffraction?

34.C: Light passes through a slit which is equal to the lights wavelength. What happens to the intensity of the central maximum as the slit width decreases?

35.C: **Use a pencil and ruler!** Draw an intensity vs. displacement graph for *single source interference*.



36.C: For double source interference state the equations for

a. constructive interference:

b. for destructive interference:

37.C: The equation for double slit wave interference is $s = \frac{\lambda D}{d}$. Define the following variables and draw a neat and detailed intensity vs. displacement graph for double slit interference:

s:

λ:

D:

d:

38.E: You are looking at a sodium discharge tube with $\lambda = 5{,}890$ Angstroms through a double slit which has a distance of 0.170 millimeters between the centers of the two slits. The light source is placed 1.20 m from the double slit. What will be the distance between the interference fringes visible on the screen?
https://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Youngs-Experiment/Youngs-Experiment-InteractiveV1

Additional HL Content

39.C: **Use a pencil!** Draw the lab setup and the intensity vs. distance graph for single slit diffraction.

40.C: Derive the equation $\theta = \frac{\lambda}{b}$. Define each variable.

41.C: What will happen to the thickness of the central maximum $2\theta = \frac{2\lambda}{b}$ if

a. the wavelength λ of a wave passing through a single slit is increased?

b. the wavelength λ of a wave passing through a single slit is decreased?

c. the opening of a single slit b is increased?

d. the opening of a single slit b is decreased?

42.C: What happens when white light passes through a single slit?

43.E: A monochromatic light source with a wavelength of 5,500 Angstroms is shined through a single slit onto a screen placed 75.0 cm from the slit. The distance between the center of the central antinode and the first node is measured to be 1.10 mm.

a. What is the width of the single slit?
https://sciencesims.com/sims/single-slit/

b. How far from the center of the central antinode will the fourth order node be found?

c. How far from the center of the central antinode will the second order antinode be found?

44.C: **Use a pencil!** Draw an intensity vs. displacement graph for Young's double slit experiment.
https://sciencesims.com/sims/double-slit/

https://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Youngs-Experiment/Youngs-Experiment-InteractiveV1

45.C: State the equation for double slit **constructive interference** and define each variable.

46.C: State the equation for double slit **destructive interference** and define each variable.

47.C: **Use a pencil and ruler!** Go to the following websites and carefully draw an *intensity vs. distance* graph for the following number of slits:

For one slit: https://sciencesims.com/sims/single-slit/
For 2-10 slits: https://www.geogebra.org/m/g6fsxcyn

One slit
Two slits
Three slits
Four slits

Five slits
Six slits
Seven slits
Eight slits
Nine slits

Ten slits

48.C: Describe the meaning of the single slit *envelope*.

49.C: What happens to the intensity pattern as the number of slits increases?
https://www.geogebra.org/m/g6fsxcyn

50.C: What is a *diffraction grating*? What is its purpose?

51.C: Describe the equation $n\lambda = d \sin\theta$ for multiple slit diffraction.

52.E: While observing a gas discharge tube through a diffraction grating, which has 600 slits/mm, you note that the first bright yellow emission line is visible at an angle of 20.6° from the center antinode. What is the wavelength of this yellow light?

53.E: A diffraction grating which contains 600 slits/mm is used to observe a gas discharge tube containing mercury gas and the first bright violet light is visible at an angle of 15.1° from the central antinode.

a. What is the wavelength of this light?

b. At what angle will the second order antinode appear?

54.E: While looking through a diffraction grating at a nitrogen discharge tube you note that light with a known wavelength of 5679 angstroms is visible at an angle of 37.0° from the central antinode. How many slits are there in this diffraction grating for each millimeter of width?

55.E: You are looking through a diffraction grating, which contains 520. slits for each millimeter of width, at a light source emitting light with a wavelength of 5890 angstroms. At which angles will the first and second order antinodes be visible?