

Harmonic series: a series of frequencies that includes the fundamental frequency and integral multiples of that fundamental frequency.

Node:

location of constant maximum destructive interference

Anti-node:

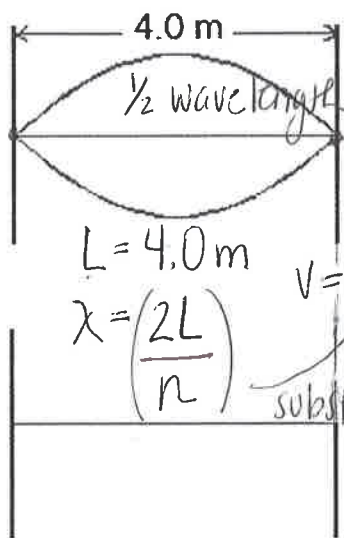
location of constant maximum constructive interference

$n = \#$ of the harmonic

For the standing waves shown below, sketch them in the spaces provided and determine their characteristics. The speed of the component waves making up these standing waves is $12 \text{ m/s} = V$

Name: fundamental

1st harmonic $n=1$



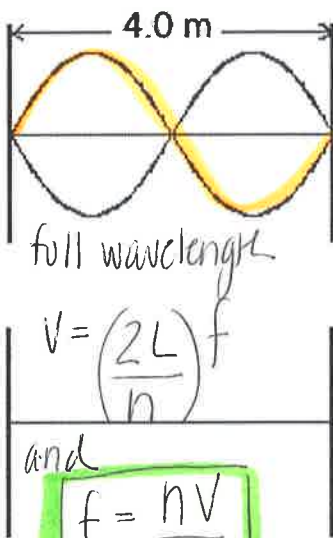
$$L = 4.0 \text{ m}$$

$$\lambda = \left(\frac{2L}{n} \right)$$

substitute

Name: 2nd harmonic

$n=2$

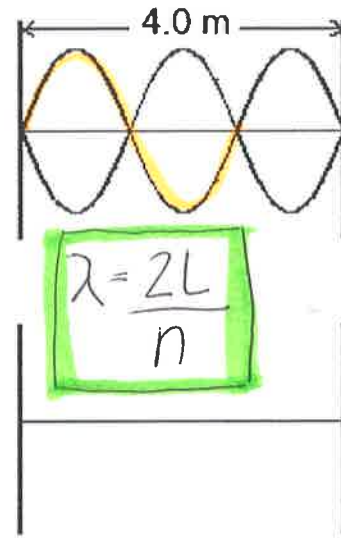


$$V = \left(\frac{2L}{n} \right) f$$

$$f = \frac{nV}{2L}$$

Name: 3rd harmonic

$n=3$



$$\lambda = \frac{2L}{n}$$

Wavelength	8.0m
Node(s)	2
Antinode(s)	1
Frequency	1.5Hz

Wavelength	4.0m
Node(s)	3
Antinode(s)	2
Frequency	3Hz

Wavelength	2.7m
Node(s)	4
Antinode(s)	3
Frequency	4.5Hz

$$f = \frac{V}{\lambda}$$

How do the frequencies of the harmonic waves compare to the frequency of the fundamental wave?

$n = \#$ of harmonic $f_i = \text{frequency of } 1^{\text{st}} \text{ harmonic}$

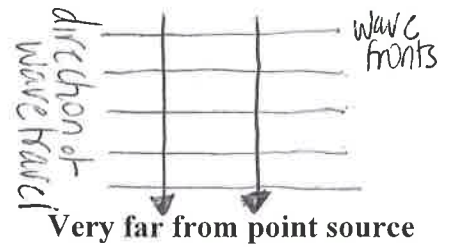
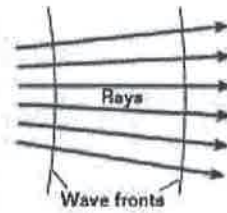
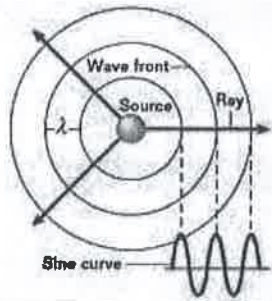
$$f_n = n f_i$$

What wave phenomena are responsible for the occurrence of standing waves?

reflection, superposition (destructive + constructive interference)
resonance (amplification of wave)

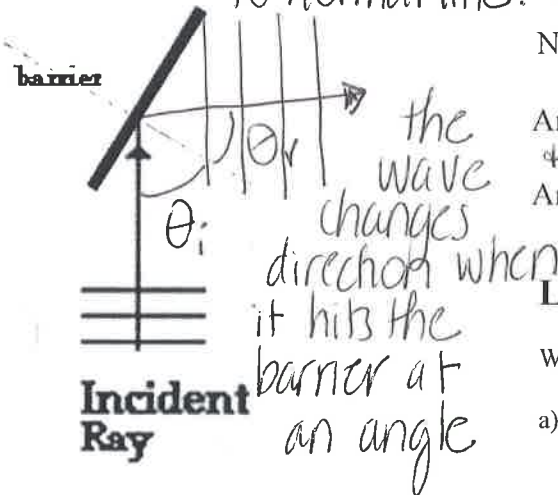
Waves in Two or Three Dimensions

Point Source – a single point that acts as a source of waves



Two-Dimensional Wave Phenomena

Reflection: ray is reflected off boundary at the same angle relative to normal line. Sketch in the reflected ray and wavefronts



Normal line: \perp to the boundary or barrier

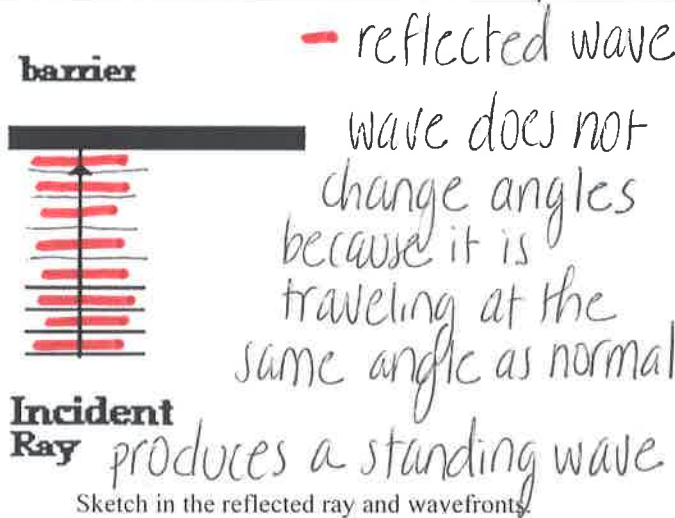
Angle of incidence: angle between incident ray + normal

Angle of reflection: angle between reflected ray + normal

Law of Reflection: $\theta_i = \theta_r$

When a wave reflects from a barrier, are there any changes in

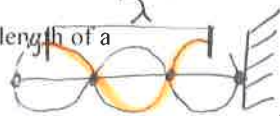
- | | | | | |
|---------------|-----------|----------------|---------------|-----------------------------|
| a) direction? | b) speed? | c) wavelength? | d) frequency? | e) phase? |
| yes | no | no | no | yes
out of phase by 180° |



What is the angle of incidence? $\theta_i = 0^\circ$

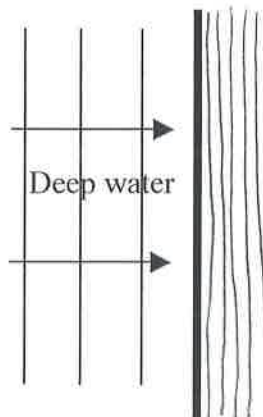
What is the angle of reflection? $\theta_r = 0^\circ$

Sketch and label the wavelength of a standing wave.



fixed barrier

Complete the diagram below showing the wave moving into shallow water.



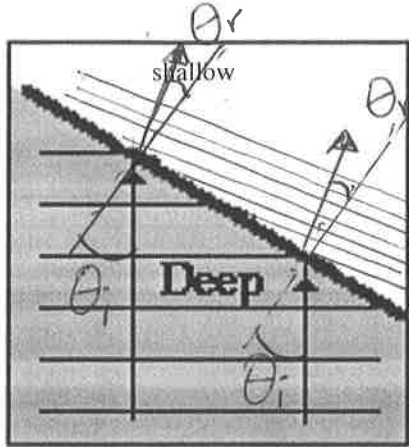
Shallow water

"f" stay the same

When a wave travels from deep water to shallow water, how do its characteristics change?

v – decreases in shallow water
 λ – also decreases

Refraction: wave changing direction of bending in a different medium

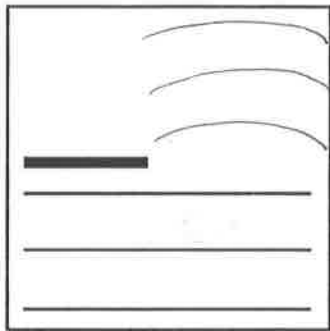


Complete the diagram showing the refraction of the wave.

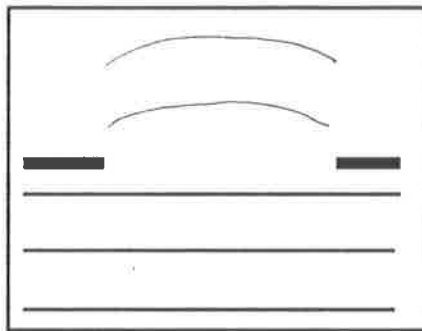
When a wave refracts, are there any changes in

- | | | | | |
|---------------|-----------|----------------|---------------|-----------|
| a) direction? | b) speed? | c) wavelength? | d) frequency? | e) phase? |
| yes | yes | yes | no | no |

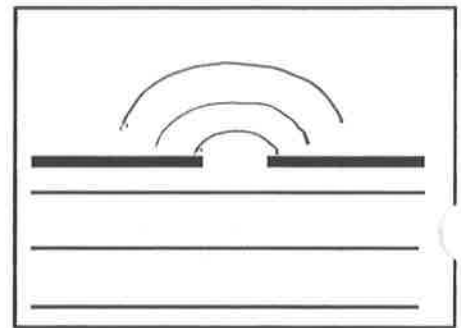
Diffraction: bending of a wave around a barrier



Complete the diagram showing the diffraction of a wave around the edge of a barrier.



Complete the diagram above showing diffraction through a wide opening.



Complete the diagram above showing diffraction through a narrow opening.

1. When a wave diffracts, are there any changes in

- | | | | | |
|---------------|-----------|----------------|---------------|-----------|
| a) direction? | b) speed? | c) wavelength? | d) frequency? | e) phase? |
| yes | no | no | no | no |

2. What happens to the diffraction pattern as the width of the opening decreases?

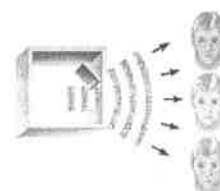
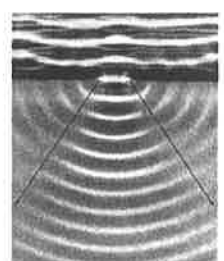
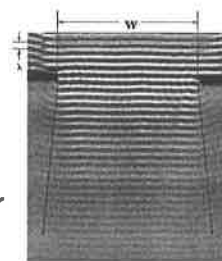
diffraction increases or becomes more noticeable

3. Condition for noticeable diffraction to occur:

width of opening is \approx width of wavelength

4. Why can you hear around a corner but can't see around a corner?

sound waves diffract more than visible light because they are longer in wavelength



(a) With diffraction



(b) Without diffraction