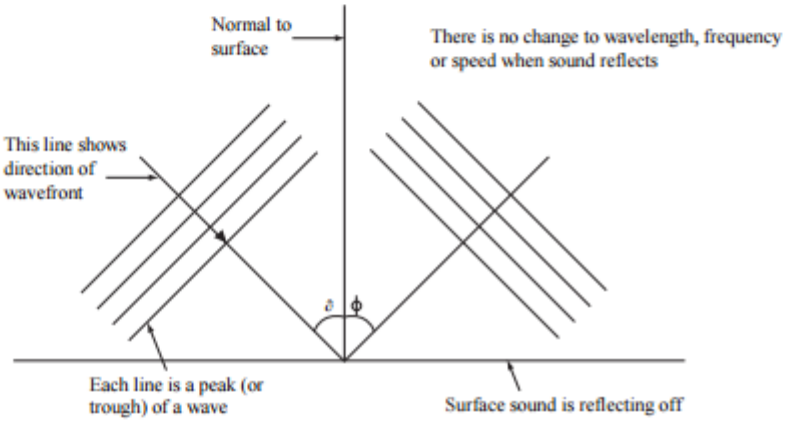
Problem Set 20

20.1 [a]

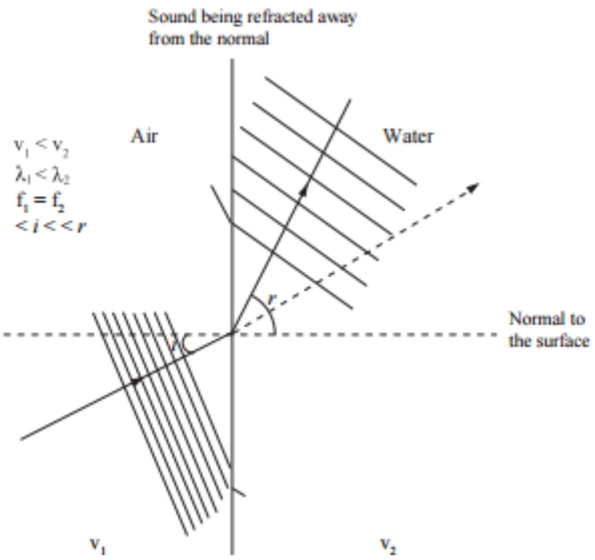


∂ = angle between incident wave and normal

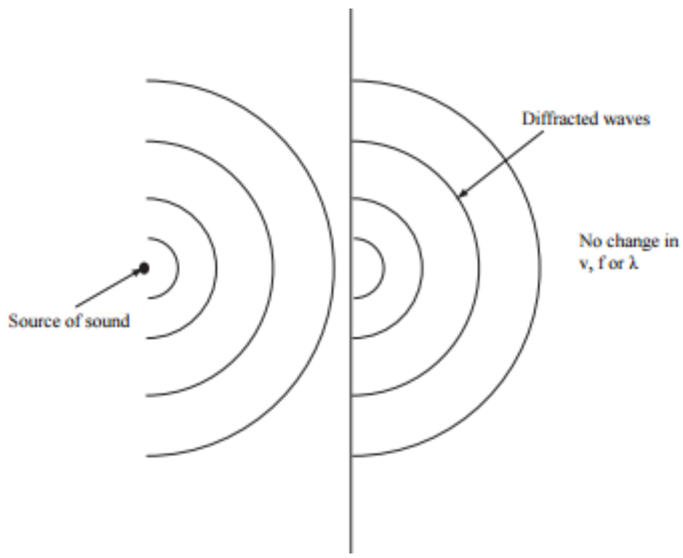
ϕ = angle between reflected wave and normal

∂ = ϕ

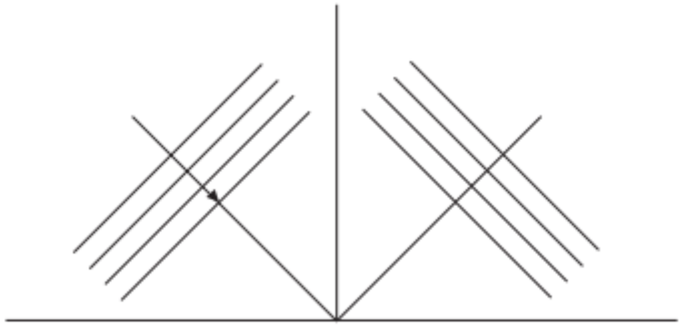
[b]



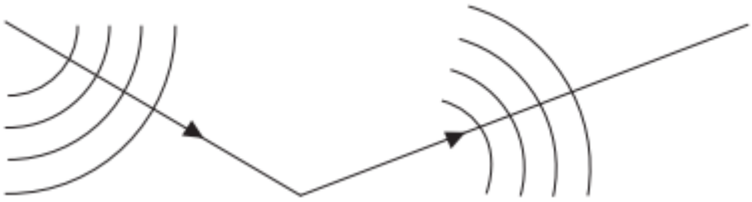
[c]



20.2 [a]



[b]



20.3 [a] It remains unchanged

[b] It remains unchanged

[c] $f = \frac{v}{\lambda} = \frac{335ms^{-1}}{10m} = 33.5\ Hz$

$f = \frac{335ms^{-1}}{0.02m} = 16.8\ khz$

Therefore the range of human hearing is 33.5 Hz to 16.8 kHz

20.4 The blind person has learned to use the sounds around them to indicate where obstacles are.

20.5 [a] $\lambda_{air} = \frac{v}{f} = \frac{335ms^{-1}}{180\times10^3Hz} = 1.86\ mm$

$\lambda_{water} = \frac{1500ms^{-1}}{180\times10^3Hz} = 8.09\ mm$

[b] The increased wavelength of ultrasound in water makes it more difficult for the dolphins to resolve fine detail.

[c] The bats that are flying high and fast need to use a louder signal to ensure that they hear the reflection. Bats flying slowly don't need the reflected sounds to travel over long distances so can use a quieter sound

20.6 0.1s is the time to travel to the bottom and back, so time to travel to depth is 0.05s.

$speed\times time = distance =$!"#$ $ms^{-1}\times0.05s = 72.8\ m$

20.7 [a] $number\ of\ pulses = \frac{0.2s}{0.002s} = 100$

[b] In 0.1s there will be 50 pulses.

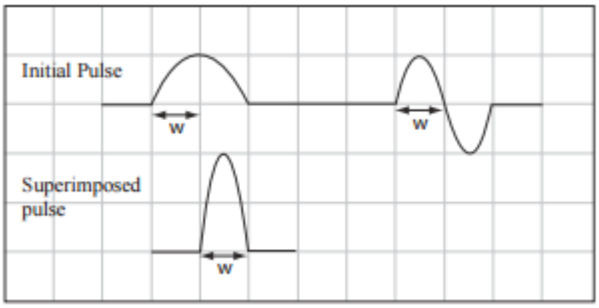
$$angle\ between\ pulses = \frac{angle\ of\ scan}{number\ of\ pulses} = \frac{40°}{50} = 0.8°$$

[c] $number\ of\ scans = \frac{time}{time\ per\ scan} = \frac{1s}{0.1s} = 10\ scans\ in\ 1\ second$

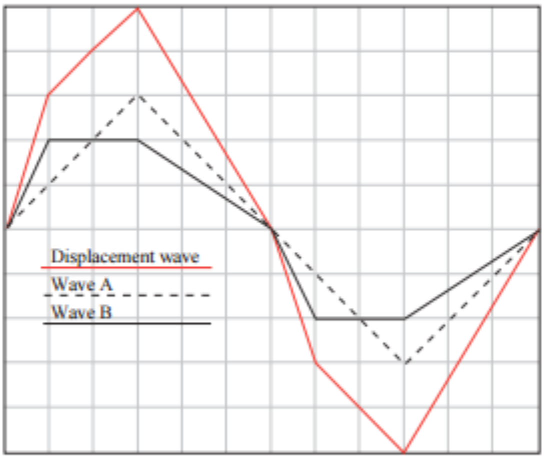
20.8 A lower frequency has a longer wavelength and are diffracted more so travel over more of the ocean

20.9 The water is getting shallower.

20.10



20.11



20.12 $\frac{\lambda}{4} = 0.120m$ (closed pipe)

$$f = \frac{v}{\lambda} = \frac{346ms^{-1}}{0.480m} = 721\ Hz$$

20.13 [a] $\lambda = 2L = 2\times0.5m = 1m$ (first harmonic of stringed instrument)

$v = f\lambda = 512Hz\times1m = 512ms^{-1}$

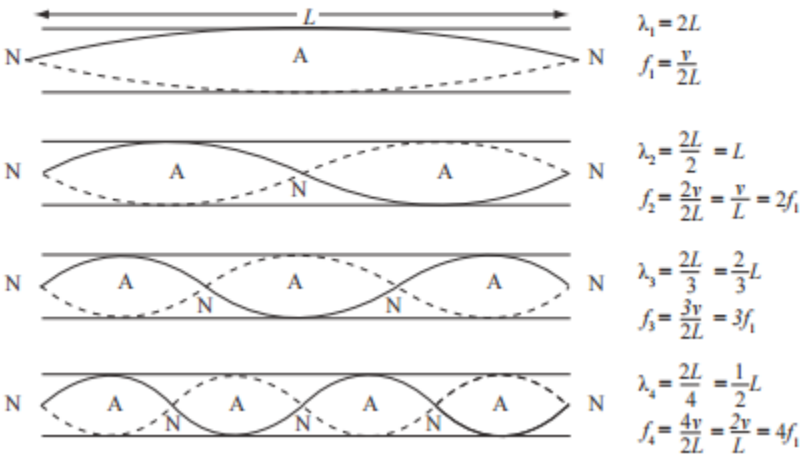
[b] The note changes because the length of the vibrating string changes. As the length decreases, the frequency increases, since $f \propto \frac{1}{L}$

[c] $f_1 = \frac{v}{2L} = \frac{210ms^{-1}}{2.5m} = 84\ Hz$

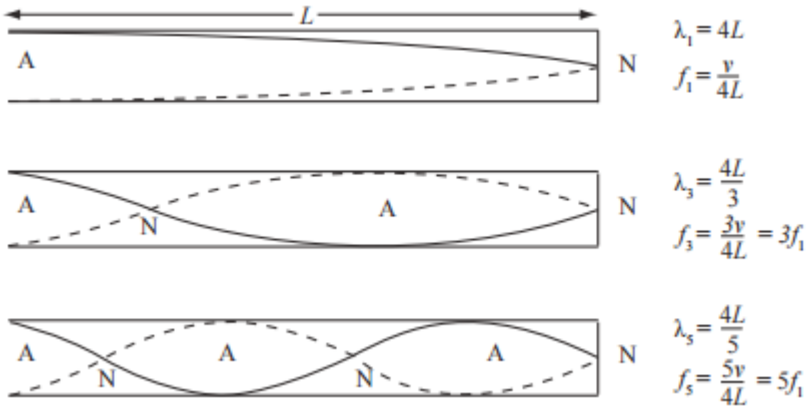
$f_2 = 2f_1 = 168\ Hz$

$f_3 = 3f_1 = 262\ Hz$

20.14 [a]



[b]



20.15 288 Hz, 320 Hz, 341 Hz, 384 Hz, 427 Hz, 480 Hz, 512 Hz (in each case multiply frequency of first harmonic by the ratio)

20.16 [a] The piano has the greatest range (3873 Hz)

[b] The bass singer produces the lowest frequency (80 Hz)

[c] The piano can produce the highest pitched note (3900 Hz)

[d] The Baritone's range is the most restricted at 300 Hz

20.17 [a] The left trace shows the loudest note. The vertical scale indicates the wave height is about 3.5 cm high compared with 2.8 cm for the right-hand trace

[b] Periodic time for the waves is shown by the horizontal scale. The left trace has a period corresponding to 2 squares, whereas with the right-hand trace, one wave occurs in about 1.2 squares. Frequency is inversely proportional to the period so the right-hand trace has a frequency ratio of 2 : 1.2 compare to the left i.e. 1.7 times greater frequency

[c] The wavelength of a wave is directly proportional to the Period of the wave, so the left-hand wave has the greater wavelength in the ratio 2 : 1.2 to the other wave i.e. a wavelength which is 1.7 times longer

20.18 [a] The lowest intensity points (pressure nodes) are 0.32 m apart, as shown by the graph. These are ½ of a wavelength apart which means the wavelength is 2 x 0.32 = 0.64 m

[b] $v = f\lambda = 512 \times 0.64 = 328\, ms^{-1}$

[c] The distance between a node and an adjacent antinode equals ¼ of a wavelength. The graph shows seven quarter wavelengths so it represents the 7th harmonic or 1¾ whole waves. Only closed pipes will produce harmonics which are odd multiples of one quarter of a wave. Hence it must be a closed pipe.

20.19 [a] Violins seem to be able to produce the largest range of frequencies.

[b] The double bass seems to have the most restricted range of frequencies.

20.20 [a] The lowest note would have the longest wavelength. This is produced by the oboe.

[b] The saxophone most likely would be an alto saxophone, looking at its waveform. Higher harmonics produce a sharper, spikier waveform and an alto instrument produces a more treble sound made by a greater number of higher harmonics added to the fundamental note.

[c] The different shaped traces show that there is a wide variation in harmonic content of the different instruments. By adding other harmonics to a basic fundamental note a complex waveform is produced, giving the instrument a unique timbre.

[d] Musical notes display a regular pattern in their waveform and noises display randomness. All the patterns show a repeated pattern and hence must be musical notes.

20.21 By placing the tuning fork in contact with a larger object this causes the other object to vibrate in sympathy (forced vibration). Because the other object has a larger surface area it can radiate a larger mass of air, which produces a louder sound as more energy is dissipated.

20.22 The wine glass has its own natural frequency at which it vibrates if struck (e.g. flicked with a finger). Sound waves coming from the singer cause regular air compressions to arrive and hit the glass. If the frequency of these compressions matches the natural frequency of the glass, they cause resonance to occur, where the amplitude of vibration builds up to a point where the glass can shatter.

20.23 In structures such as bridges, cables and chimneys the effect of winds can be to cause resonance in the structure which can be destructive. By adding mechanical systems that absorb the wind energy (damping) the amplitude of the vibrations can never build up to a destructive resonance level.

20.24 [a] Shape B would show the frequency outline for the Sheath-tail and Free-tail bats as this shows a shallow frequency range.

[b] Shape A displays the largest range of frequencies used

[c] Shape C has the longest timed call. This would match the Horseshoe and leaf-nosed bat.

20.25 Rattles in cars at a particular speed are caused by resonance in components of the body (body shell, springs etc.) The forcing frequency usually comes from unbalanced wheels which give regular pulses that can match the natural frequency of the components at a particular rotational frequency.

20.26 [a] 'Dead spots' are areas where sound levels are very soft and are caused by the destructive interference of two sound waves arriving at that area. One wave comes to a point straight from the instrument and the other wave arrives out of phase because it has travelled a greater distance due to reflection off a wall. Because the path difference between these two waves is an odd number of half wavelengths the sound pressure is cancelled at that point.

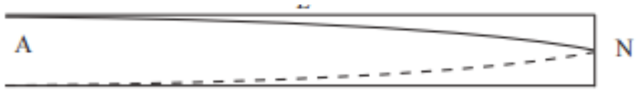
[b] In concert hall design 2 any sound waves striking the walls is partially absorbed which means that reflection is much less likely to occur and so the 'dead spots' problem is greatly reduced. Hall 2 is therefore the best design.

20.27

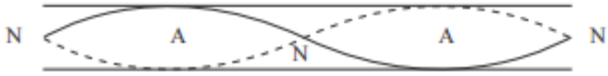
$$f = \frac{v}{\lambda} = \frac{346ms^{-1}}{1.4m} = 247\ Hz$$

$$\lambda = \frac{v}{f} = \frac{1450ms^{-1}}{247Hz} = 5.87\ m$$

20.28 [a] For all 20.28, displacementdiagrams are given



[b]



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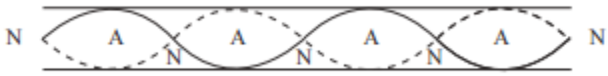

[d]

20.29 $d_{speaker1} = 3.6m, d_{speaker2} = \sqrt{3.6^2 + 1.1^2} = 3.76\ m$

$\Delta\lambda = d_2 - d_1 = 3.76m - 3.6m = 0.164\ m$

$\Delta\lambda = n\lambda$

$n = 1, \lambda = 0.164\ m$

$n = 2, \lambda = 0.0822\ m$

20.30 $d_{speaker1} = 2.85\ m, d_{speaker2} = \sqrt{2.85^2 + 2.5^2} = 3.79\ m$

$\Delta\lambda = d_2 - d_1 = 3.79m - 2.85m = 0.941\ m$

$\Delta\lambda = n\lambda$

$n = 1, \lambda = 0.941\ m$

$$f = \frac{v}{\lambda} = \frac{346ms^{-1}}{0.941m} = 368\ Hz$$

20.31 There are 7 quarter wavelengths (the string is acting like a closed pipe) and therefore is the 7th harmonic: $f = 7f_1$

$$f_1 = \frac{v}{\lambda} = \frac{20.4ms^{-1}}{4\times11.5m} = 0.443\ Hz$$

$f = 7f_1 = 7\times0.433Hz = 3.10\ Hz$

20.32 [a] The resultant wave is a "beat frequency". It is the result of the constructive and destructive interference. It is at its loudest when there is constructive interference and at its softest when there is destructive interference (amplitude is 0). Since the 2 waves are only slightly different frequencies the interference results in a waveform that 'beats' at this difference in frequencies.

[b] As both waves reach the middle, constructive interference occurs as the two waves are superimposed. This much larger wave has the combined energy of the two smaller waves and so can shatter the pipe, but only in the very middle where the constructive interference occurs.