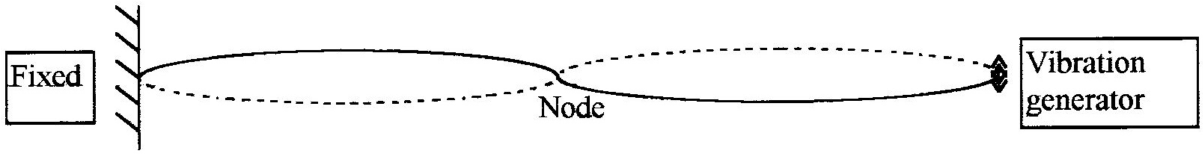
11 Waves phenomena review answers

Part A: Standing waves:

1. A string is connected to a vibration generator and the standing wave formed is shown below.

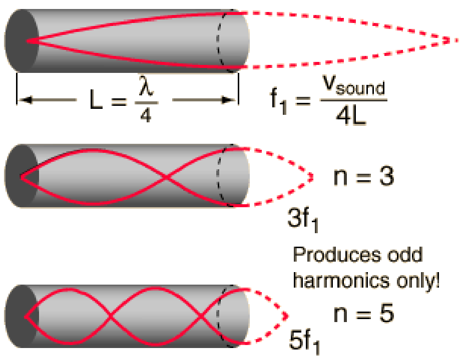


Sketch the wave that would form if:
(a) The string was doubled in length.
(b) The frequency of the vibration generator was increased by 50%.
(c) The string was put under a tension that doubled the speed of the wave along the string.
(d) The string was made heavier so that the speed of the wave along the string halved.

a) **The sketch would be as above but with two complete wavelengths**
b) **One and a half wavelengths now fit into the original length as increasing the frequency decreases the wavelength (if wave speed is constant)**
c) **If the speed is doubled and the frequency stays the same then wavelength is doubled so only half a wave would fit into the original length**
d) **If the speed is doubled and the frequency stays the same then wavelength is doubled so only half a wave would fit into the original length**

(e)In which of the situations above is the string vibrating at the fundamental frequency (first harmonic) **Situation c).**

(f) What is happening to the wave at the fixed point?
It is reflecting.

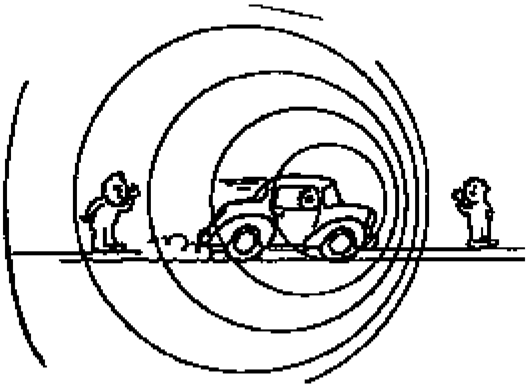


2. Standing waves can be set up in open ended pipes. When the wave reached the end it reflects but in a different way to the reflection at a closed end or at the end of a string standing wave. A high pressure pulse reaching the end will cause a low pressure pulse to bounce back and vice-versa.
Which line of the table is correct:?

Type of end	Open	Closed
Behaviour of wave at end	Node	Node
	Node	Antinode
	Antinode	**Node**
	Antinode	Antinode

Part B: Doppler effect:

1. Two listeners hear the frequency of a moving car engine at differently. The speed of sound is 340ms^{-1} and the speed of the car is 50ms^{-1}. The main frequency of the motor sound is 200Hz.



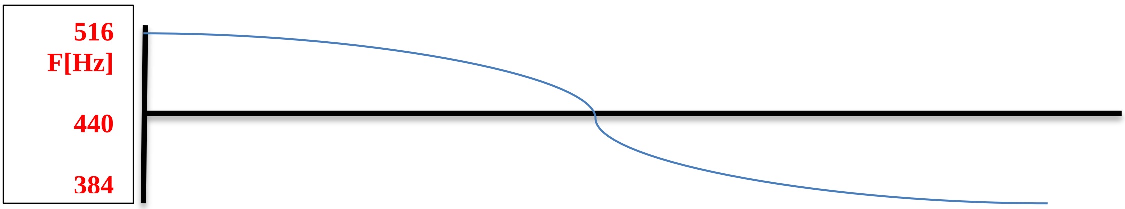
   a. Explain whether the listener who is in front of the car hear a higher frequency or a lower frequency than the listener behind the car.
   In front of the car the waves are compressed and so more waves arrive per second so frequency is higher.

   b. Calculate the frequency heard by the listener who is behind the car.
   Moving source:
   F observed = 200(340/(340+50)) = 170 Hz

$$f' = f\left(\frac{v}{v \pm u_s}\right) \quad \text{moving source}$$

$$f' = f\left(\frac{v \pm u_o}{v}\right) \quad \text{moving observer}$$

   c. frequency 440Hz sketch a graph of frequency heard by the driver as the driver passes the listener playing the note. Add values of frequency to the y axis.



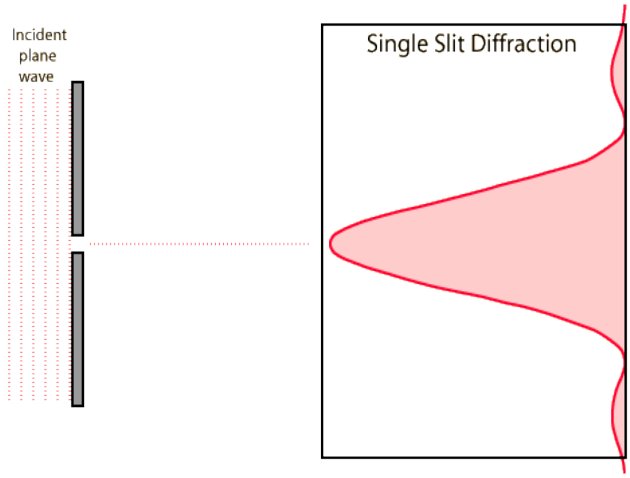
2. A source of 440Hz waves whose speed is 330ms^{-1} waves is travelling at 500ms^{-1}. Calculate the frequencies observed by a stationary listener for this approaching source. What does the negative result mean?
Moving source formula: f' = f(v-u)/v = 440(330-500)/330 = 440x-170/330 = -230Hz Rounded to 2s.f. the negative value means the observer is receiving the waves in the opposite order that they are sent in.

3. **M31 (the Andromeda galaxy) is approaching us at about 120.0 kms^{-1}. Some light it emits has a wavelength, relative to M31, of 480.0 nm. What is its wavelength as observed byus?**
Doppler for light formula: Δf = f(v/c)
f = c/λ = 3x10^{8} ÷ 4.8x10^{-7} = 6.25x10^{14}Hz
Δf = 6.25x10^{14}(1.2x10^{5}÷3x10^{8}) = 2.5x10^{11}Hz
So observed frequency is 6.25x10^{14}Hz + 2.5x10^{11}Hz = 6.2525x10^{14}Hz
Observed wavelength λ = f/c = 3x10^{8}÷6.2525x10^{14}Hz = 479.8 nm
[Note this answer can be got more easily…….480 x (1-v/c)]

Part C: Diffraction

1. When sketching intensity of the single slit diffraction pattern state three key elements of the sketch. **The central maximum is more than 3x higher than other maxima, the intensity is zero at the centre of the minima, the central maximum is significantly wider than the other maxima**

2. The derivation of the formula for finding the angle for the first minimum point in the diffraction pattern comes from assuming the light from each half of the slit will interfere destructively. This occurs when the path difference between the top of the slit and half way down the slit is equal to what value?
   Destructive interference when path difference is half a wavelength.



3. Derive the formula referred to in 2.
   http://nothingnerdy.wikispaces.com/11.3+Diffraction **(derivation is near the end of this web page)**
4. Electromagnetic waves from a source pass through a vertical slit of width $5x10^{-4}$m. A detector is used to detect the level of intensity arriving at a distance 1m away from the slit. The detector detects a strong continuous level intensity of radiation along a horizontal line of 5cm length. The detector is kept at the 1m distance. Estimate the wavelength of the radiation being used.
   If radiation is strong for 5cm the distance from centre of maxima to first minima is maybe 3cm.

0.03m

1m

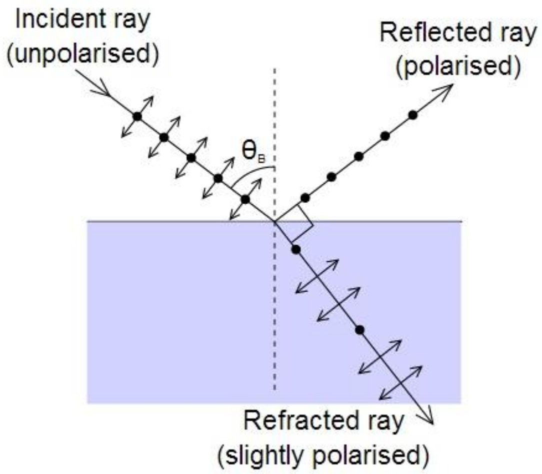
Angle is 0.03 radians.
θ = λ/b
λ = θ b = 0.03 x $5x10^{-4}$m= $1.5x10^{-5}$m= 0.015 mm

Part D: Resolution

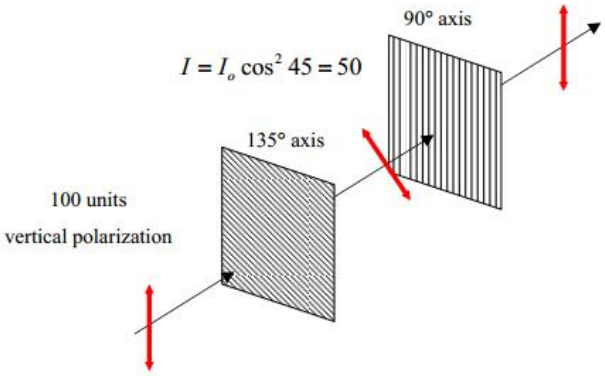
1. When waves pass through a gap or reflect off a narrow surface they diffract.
   a. Explain why smaller wavelengths are needed to accurately detect small objects.
      If the wavelength of light is similar in size to the bumps on a surface the light will diffract and making the bumps undetectable in that wavelength.
   b. Explain why an electron of energy 1 MeV can provide more resolution than light.
      The de Broglie wavelength of the electron = h/p so it the electron has enough energy its momentum p will be large making its wavelength smaller than light:
      $p = mv$ and $E_k = ½ mv^2$. ($E_k = 1x10^6$ x $1.6x10^{-19}$ J)
      So $p^2 = 2mE_k$ = 2 x $9.11x10^{-31}$x$1x10^6$ x $1.6x10^{-19}$
      P = $5.399x10^{-22}$ $kgms^{-2}$.
      λ = h/p = $6.63x10^{-34}$ ÷ $5.399x10^{-22}$ = $1.2x10^{-12}$m
2. The sand ripples on a beach are approximately 8cm apart. A camera is used to take a picture of a beach from a helicopter flying at a height of 500m. The camera lens has an aperture of 4mm. Explain whether the sand ripples on the beach will be resolved on the image of the camera.

   The angle made at the lens by two consecutive ripples is 0.08/500 = $1.6x10^{-4}$ radians.
   The resolution angle = 1.22 λ/b = 1.22x4x10-7/$4x10^{-3}$ = $1.22x10^{-4}$ radians so ripples will be just distinguishable in theory.

Part E: Polarization



1. Light can be polarized by reflection off water whose refractive index is 4/3. Calculate the angle of incidence that would cause the most polarization.
   Brewster's angle formula: n = tanθ_B
   θ_B=tan^{-1}(4/3) = 53^0.



2. Consider the diagram opposite and calculate the intensity of radiation in units that would pass through the second filter.
   The filter's angles of polarization are at 45 degrees to each other so using the formula on the digram:
   I = 100 x cos^2(45) = 50 units
3. Liquid crystal is optically active when a voltage is applied to it.
   a. Explain optically active
      The angle of at which the electric and magnetic fields of the light waves oscillate are rotated.
   b. Explain how this property can be used in back-lit LCD displays.
      If the angle of polarization can be changed in only certain regions then the amount of light passing through a filter can be changed in those regions. In a back-lit LCD display the activated regions will have less light passing through the filter and be dark on the display.