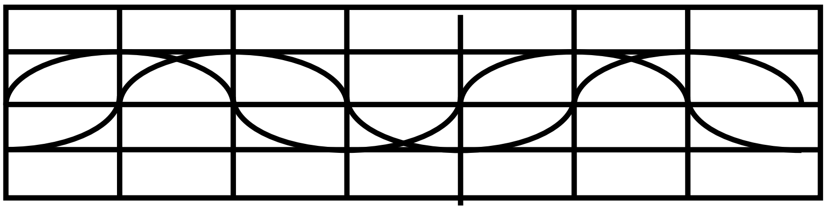
04 Oscillations and waves review answers

Part A: SHM:

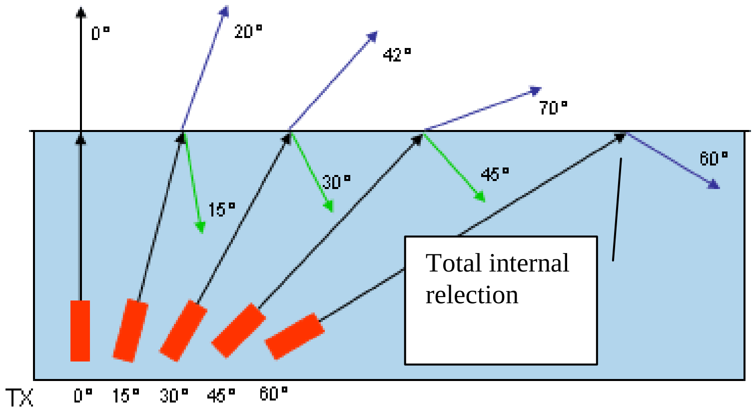
1. The condition for SHM can be simplified to this relationship:
   "Acceleration is proportional to negative displacement or a = -kx where k is constant"
   a. State the conditions necessary for SHM.
      SHM can occur in a system where the force on a body is directed towards its equilibrium position and the magnitude of the force is proportional to the displacement.
   b. Explain the significance of the minus in the above relationship.
      The minus sign indicted that the acceleration is in the opposite direction to the displacement.
2. A student connects a signal generator output to a cathode ray oscilloscope input. He gets the following trace on the oscilloscope using a time base of 5 ms per division and a voltage scale of 2 Volts per division.



   a. Calculate the period, frequency and amplitude of the signals.
      Period = time for one cycle = 4 squares = 20ms, Frequency = 1/T = 50Hz, Amplitude = 1 square = 2V
   b. What is the phase difference between the signals.
      One quarter of a cycle or 90 degrees or π/2 radians

Part B: Wave characteristics and properties

1. In an experiment lasers are used so that 5 light rays are travelling though a glass block as shown opposite.

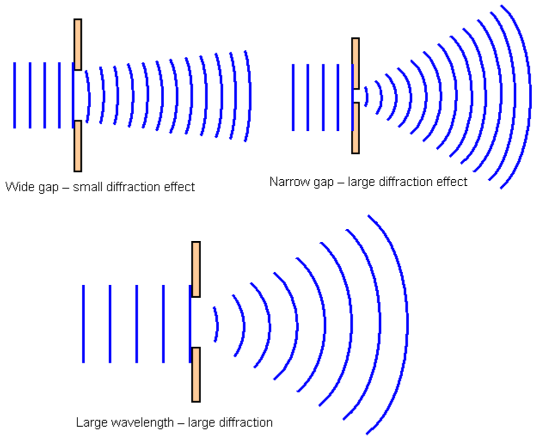


   a. Redraw the 45° ray to include a normal line and label the angle of incidence, reflection and refraction.
      Angles should be labeled from the added on normal line.
   b. Calculate the refractive index of the glass block.
      $n_1/n_2 = \sin\theta_2/\sin\theta_1$
      $n_2 = 1$
      sin(70)/sin(45) = 1.37
   c. Label the ray showing total internal reflection and calculate the critical angle for the block.
      $n_1/n_2 = \sin\theta_2/\sin\theta_1$
      $n_2 = 1$, at critical angle $\sin\theta_2 = 1$
      $1.37 = 1/\sin\theta_1$
      $\theta_1 = 46.9$ degrees

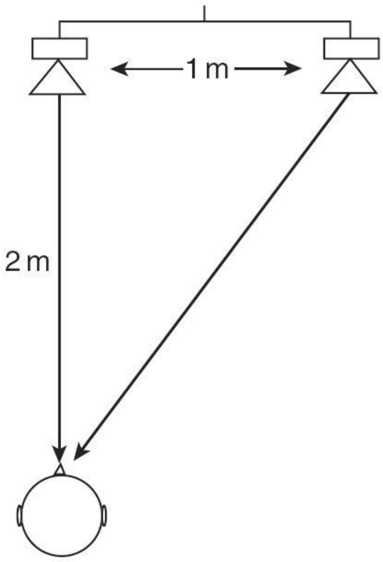
2. A light wave ($c=3.0\times10^8$m/s, $f=1\times10^{15}$Hz) travels into a glass block of refractive index n=1.4. The incident angle is 20°. Draw an accurate ray diagram of the refraction that occurs. State also the speed of light and the wavelength of the light in the glass.
   Angle of refraction should be $\sin^{-1}(\sin(20)/1.4) = 14.2°$

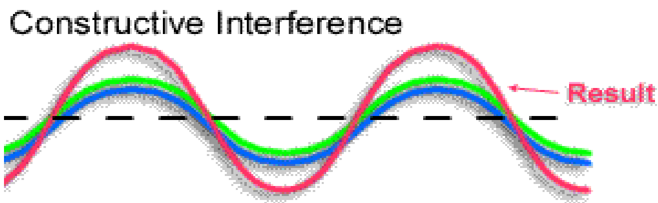
Speed = c/1.4 = 2.14x10^{8} ms^{-1}.
Wavelength = speed / frequency = 2.1x10^{-7}m

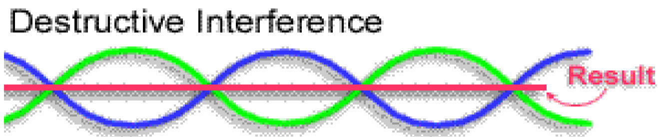
3. The diagrams opposite show diffraction of a wave as it passes through a gap.
   a. Explain why the first picture shows a moderate amount of diffraction. **Wavelength smaller than gap**
   b. Explain why the second two pictures show similar amounts of diffraction.
   Wavelength similar size to gap



4. Two loudspeakers are positioned as shown below. Pairs of identical notes are played through both loudspeakers simultaneously. The listener notes how loud the sound seems and then the frequency is changed. The listener notices that some notes are louder than others.
   a. Calculate the path difference for the listener from the two speakers. **0.24m**
   b. State the value of the path difference in terms of wavelength that creates destructive interference.
   c. Calculate the wavelength for the lowest pitch note that is quiet. **0.47m**
   d. Using a speed of sound of 330 ms^{-1} calculate the frequency of this note. **750Hz**







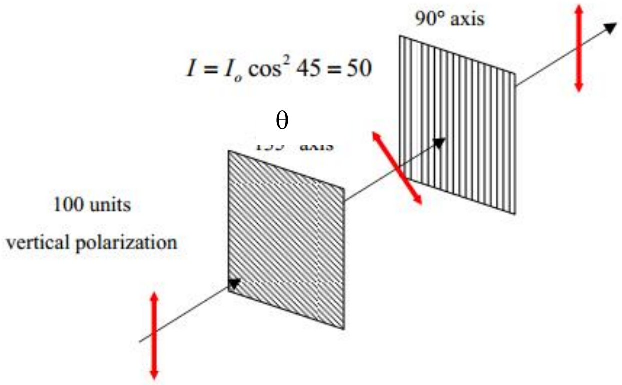
5. A water wave approaches a wall. The water wave has a speed of 2m/s and a frequency of 1Hz.

(a) What is its wavelength? **2m**

(b) The wave direction is straight into the wall and the water wave reflects. Explain why there will be places in the water where the wave height will be large and places where it will be small. **The reflected wave will superimpose on the incoming wave, in some places constructively and in others destructively.**

Part C: Polarization and Intensity

1. Light can be polarized by reflection off water. Use this fact to explain at what angle the plane of polarization of the sunglasses would be compared to the plane of polarization of the reflected light.
   The polarized sunglasses would have the plane of polarization perpendicular to the plane of polarization of the light so that the intensity of the reflected light is reduced.

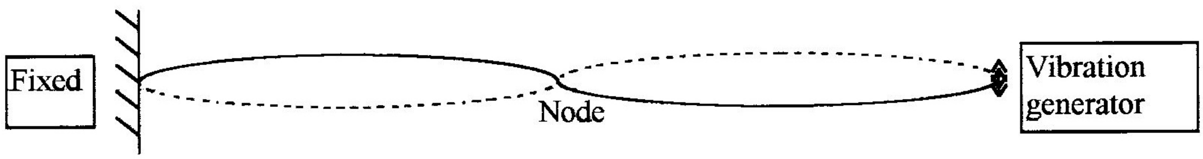


2. Consider the diagram opposite and calculate the intensity of radiation in units that would pass through the second filter.
   The filter's angles of polarization are at 45 degrees to each other so using the formula on the digram:
   $I = 100 \times \cos^2(45) = 50$ units

3. A radio transmitter is in operation. 10km away the intensity of the radiation is $2 \times 10^{-5} Wm^{-2}$.
   i) At a distance of 20km what will the intensity be?
   Intensity is inversely proportional to distance squared (for waves that spread out in three dimensions:
   Distance increased by (factor of) 2 so distance squared by 4 so intensity decrease by 4
   $2 \times 10^{-5} / 4 = 5 \times 10^{-6} W\ m^{-2}$.
   ii) By what factor will the amplitude of the signal have decreased?
   I varies with A^2 so it will have decreased by factor of 2.

Part D: Standing waves:

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



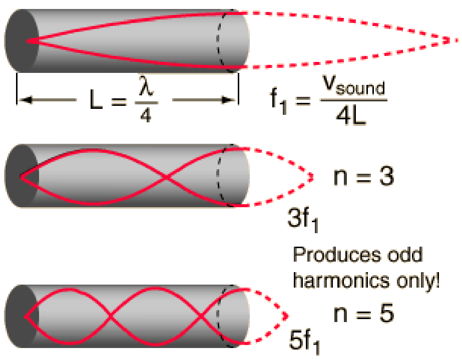
Sketch the wave that would form if:
(a) The string was doubled in length.
(b) The frequency of the vibration generator was increased by 50%.
(c) The string was put under a tension that doubled the speed of the wave along the string.
(d) The string was made heavier so that the speed of the wave along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



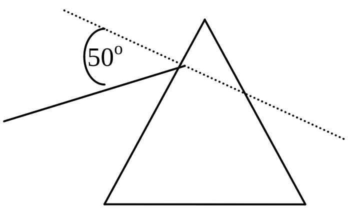
2. Standing waves can be set up in open ended pipes. When the wave reached the end it reflects but in a different way to the reflection at a closed end or at the end of a string standing wave. A high pressure pulse reaching the end will cause a low pressure pulse to bounce back and vice-versa.

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

Extension question:

A white light ray is incident on an equilateral glass prism of refractive as shown in the diagram. The refractive index of the glass is 1.40 for red light and 1.42 for violet.



(a) At what angle will the red light leave the block?
(b) At what angle will the violet light leave the block?
(c) Over how many degrees is the visible spectrum dispersed?

For red light:
Sin(r1) = sin(50)/1.4 so r1 = 33.173° by geometry i2=180-120-33.173 = 26.827°
Sin(r2)=sin(26.827)*1.4 so r2 = 39.2°
For blue light:
Sin(r1) = sin(50)/1.42 so r1 = 22.991° by geometry i2=180-120-33.173 = 37.001°
Sin(r2)=sin(37.001)*1.42 so r2 = 77.5°
The real difference in refractive index is much smaller than this so the difference between red and blue calculated here is much exaggerated.