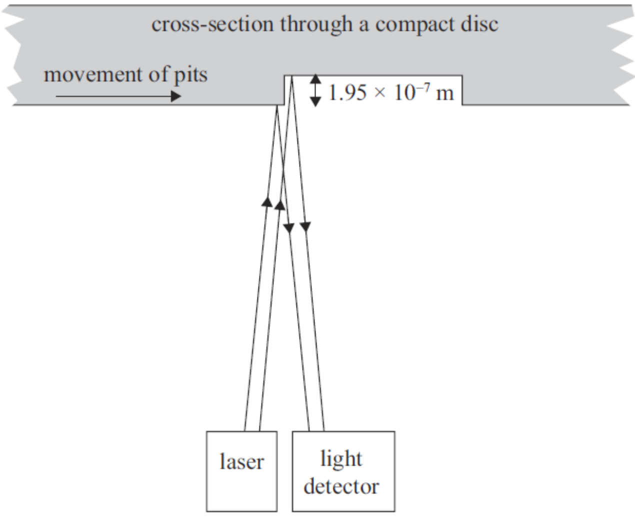
WAVES: WAVES BEHAVIOUR QUESTIONS

CD SPECTRUM (2010;3)

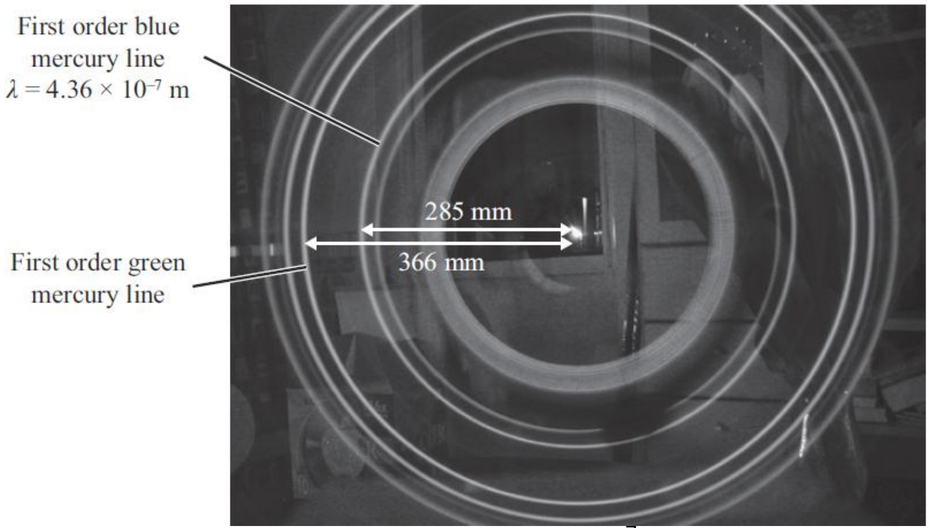
A compact disc (CD) is read with a laser light of wavelength 7.80×10^{-7}m. The recorded surface, on the bottom of the CD, has pits in it, which are 1.95×10^{-7}m deep. The CD rotates, moving the pits over a laser beam and varying the intensity of the reflected light. Consider a beam consisting of just two rays of light which reflect off the bottom of the CD.



(a) Explain how the intensity of the detected beam depends on whether the reflected rays are in phase or out of phase with each other when they arrive at the detector.

(b) The movement of the pits makes the intensity of the reflected beam vary between high and low so the detector receives a digital signal. Explain why the pits are made exactly 1.95×10^{-7} m deep.

The pits on a CD are in lines along one long spiral track. The tracks are essentially circles, 1.60×10^{-6} m apart. A teacher uses a CD to make a transparent plastic disc with this track pattern to use as a diffraction grating. He photographs a street lamp through the disc and obtains the picture below.



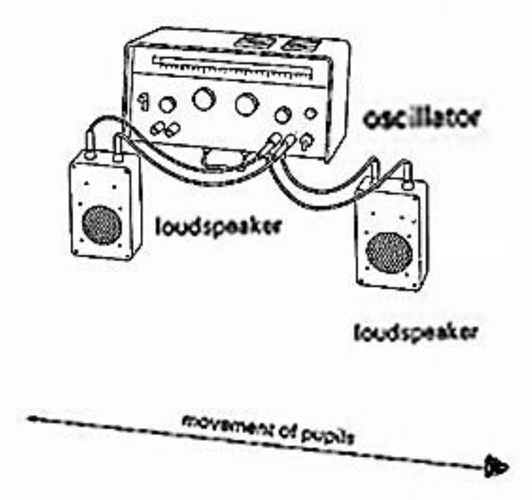
(c) Show that the first order blue mercury line ($\lambda = 4.36 \times 10^{-7}$ m) occurs at a diffraction angle of 15.8°.

(d) Use the distances marked on the photograph to calculate the wavelength of the first order green mercury line.

INTERFERENCE OF SOUND WAVES (2009;3)

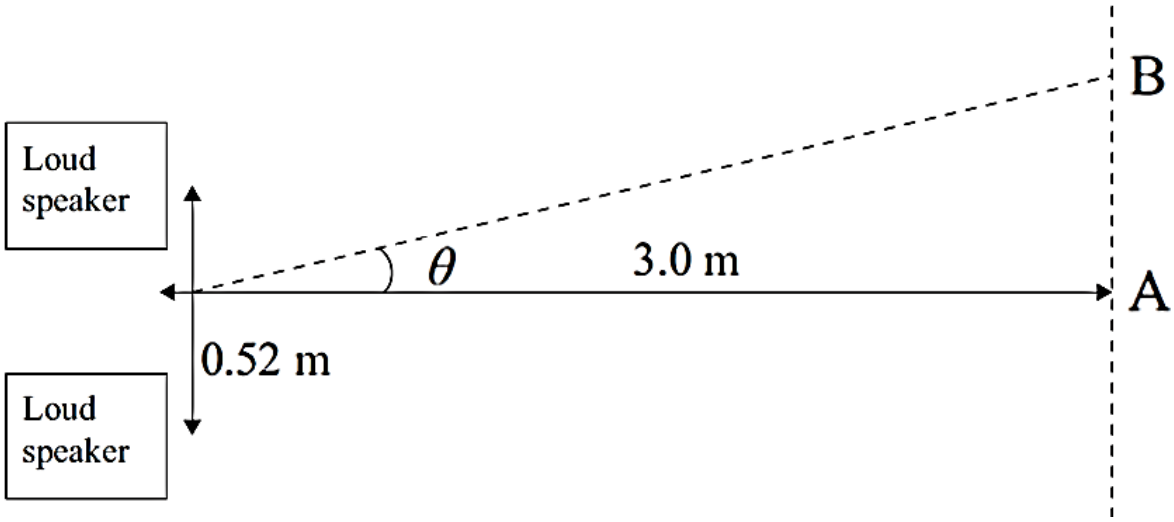
The speed of sound in air = 3.40×10^2 ms^{-1}

A teacher demonstrates interference of waves by connecting two speakers to a signal generator. The signal generator produces a single frequency. The instructions recommend that this demonstration is set up outdoors.



(a) Explain why the students hear regular quiet spots as they walk slowly in front of the loudspeakers (as shown in the diagram) and why the demonstration is not so effective in a typical classroom.

(b) Two microphones are used to detect the loudness of the sound and to identify nodes and antinodes. Microphone A is placed on the central antinode and microphone B is placed on an adjacent node. The loudspeakers are 0.52 m apart. The microphones are placed 3.0 m from the loudspeakers and the frequency is set to 1.30 kHz.

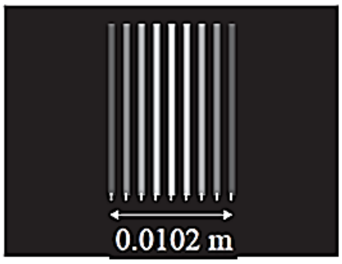


(c) Calculate:
(i) The wavelength of the sound waves.
(ii) The angular separation, θ, between microphones A and B.

INTERFERENCE (2008;3)

Interference techniques can be used in the quality control of the weaving process used to manufacture fabrics. This can be demonstrated in the laboratory by shining a narrow beam of laser light through a piece of fine gauze. The gaps between the woven threads of the gauze create multiple point sources of light and these interfere to produce a pattern of bright spots on a screen.

A student uses the vertical threads to make a diffraction grating and shines light from a laser through the threads to form a pattern of fringes on a screen, as shown below.

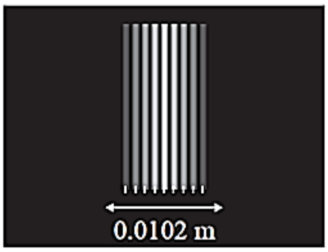


The grating is 2.14 m from the screen and the distance between the two outside bright lines is measured to be 0.0102 m. The wavelength of the laser light is 6.3×10^{-7} m. The student marks the lines on the screen.

(a) Calculate the average distance between two adjacent bright lines. Give your answer to the correct number of significant figures.

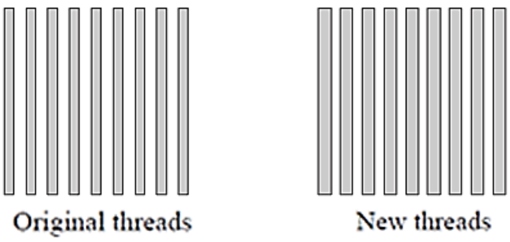
(b) Calculate the spacing of the threads.

(c) The threads that produced the pattern in the diagram on the opposite page are replaced with a new set of threads and the pattern shown in the diagram below is obtained.



Explain what this would tell you about the spacing of the threads in the new gauze.

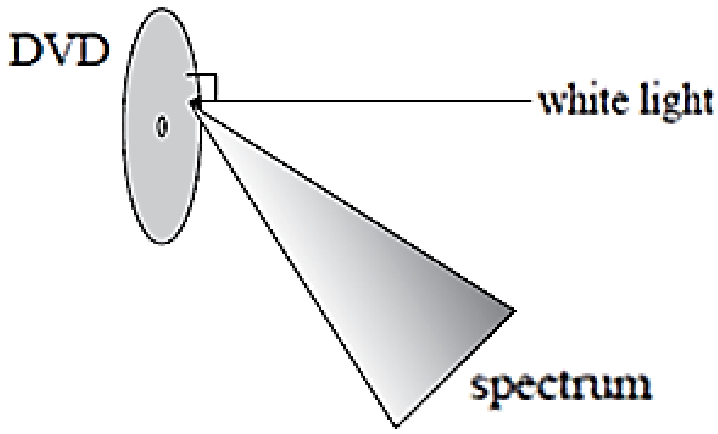
(d) The original threads are now replaced with thicker threads, with the same spacing as the original threads. The new interference pattern is in some ways the same, but in other ways it is different. Explain how the thicker threads will affect the pattern on the screen, and what will be unchanged.



(e) Light from a red laser (wavelength 6.70×10^{-7} m) is shone at a new diffraction grating. The light forms a pattern showing nine bright fringes spread across a distance of 4.0 cm. When the laser is replaced with a green laser, the interference pattern shows nine fringes spread out over a distance of 3.2 cm. Calculate the wavelength of the green laser.

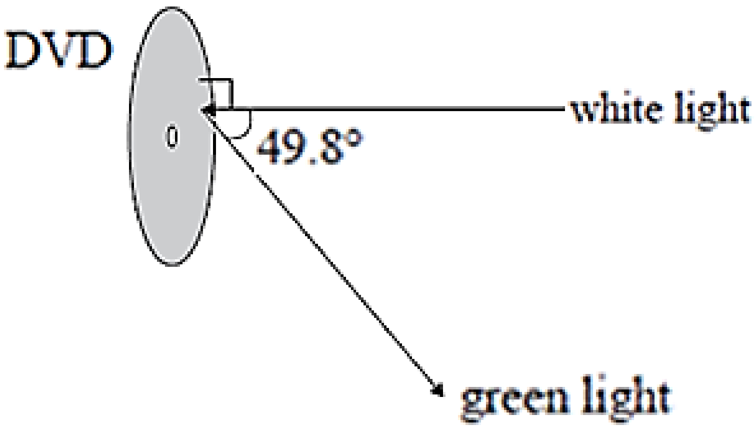
DIFFRACTION GRATING (2007;3)

The band Carlie plays in has produced a DVD of its performances. When looking at the DVD, Carlie sees a spectrum "reflected" from the surface of the DVD. The diagram below shows a first order spectrum being produced when white light is shone on to the DVD perpendicular to its surface.
The DVD can be modelled as a diffraction grating. On a DVD, lines are drawn on the surface. The distance between the lines is called the track spacing. The track spacing on the DVD is equivalent to the slit spacing of a diffraction grating.



Which colour light is seen "reflected" at the smallest angle in the spectrum?

The smallest angle at which green light is seen is 49.8°.
Green light has a wavelength of 5.65×10^{-7} m.



(a)
(i) Show that the spacing of the tracks on the DVD has an unrounded value of 7.3973×10^{-7} m.
(ii) Round this answer to the correct number of significant figures.

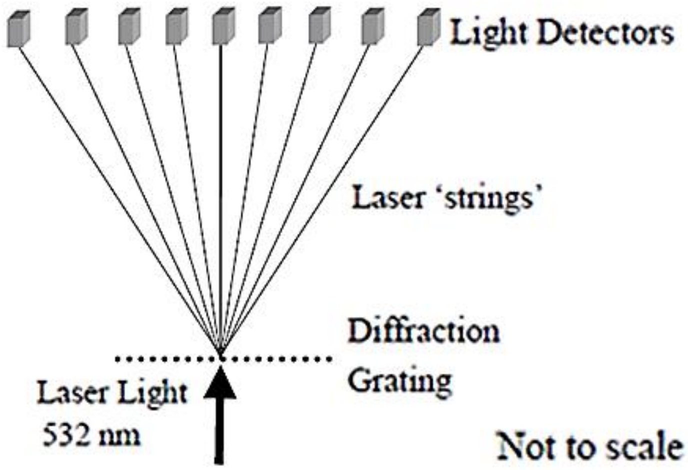
A CD produces spectra in the same way that a DVD produces spectra. The track spacing on a DVD is less than that on a CD.

(b) The angle at which violet light (wavelength 438×10^{-9} m) forms its first bright fringe when "reflected" from a CD is 20.4° less than the angle of the first bright fringe of violet light "reflected" from a DVD. Calculate the track spacing on a CD.

(c) More spectra are produced using a CD than a DVD. Explain why. (Calculations are not required.)

LASER HARP (2006;3)

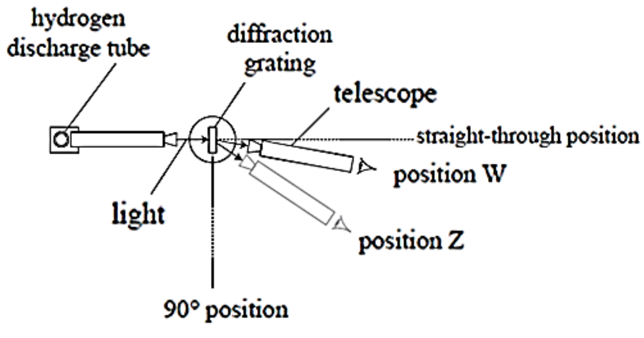
The harp 'strings' are the beams of light produced by shining green laser light, of wavelength 5.32 x 10^{-7} m, through a diffraction grating. Each beam is detected by a light sensor connected to an electronic circuit. When a beam is broken by the person playing the harp, the electronic circuit produces a note for that string.



(a) The angle to the detector for the first order beam is 6.00°. Show that the slit spacing on the diffraction grating is 5.09 x 10^{-6} m.
(b) To be able to play the harp easily, the maximum horizontal spread of the strings at a height of 1.00 m above the grating is 0.68 m (each outside string is 0.34 m horizontally out from the centre at this height). Calculate the number of 'strings' on the harp.
(c) Explain, in terms of constructive and destructive interference, why narrow beams of light are produced when light shines through a diffraction grating.

EMISSION SPECTRA (2005;2)

When a high voltage electrical discharge is applied to hydrogen at low pressures, light is emitted. This light is passed through a diffraction grating that has 6.1 x 10^3 lines per cm, and a spectrum of coloured lines is viewed through the telescope of a spectrometer. There are several different order spectra that can be viewed. Each order is made up of 4 coloured lines; red, green / blue, purple and violet. The following is a diagram of a spectrometer from above, showing how the telescope rotates about the position of the diffraction grating.

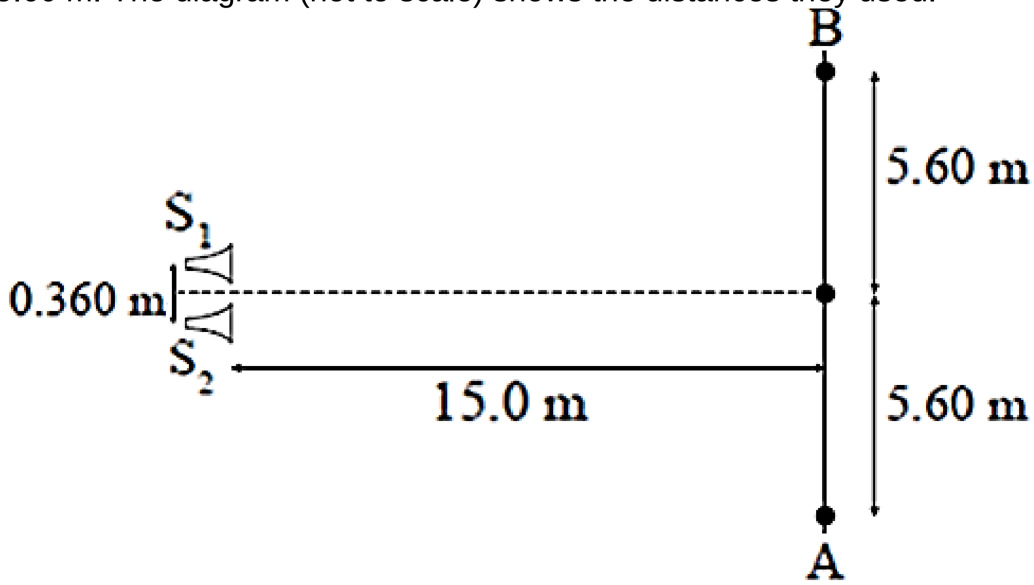


As the telescope is rotated from W to Z, each of the 4 lines of the first order spectrum is seen in turn.
(a) Explain which colour line would be seen first as the telescope rotates from W to Z.
(b) Show that the spacing of the slits in the diffraction grating is 1.6 x 10^6 m.
(c) The wavelength of the green / blue line is 4.86 x 10^7 m. Calculate the diffraction angle for this line in the first order spectrum.
(d) There are also several higher order spectra observed for hydrogen. It was found that the 3rd order purple line coincides with the 2nd order red line. If the angle for the red line in the 1st order spectrum is 23.5°, calculate the wavelength of the purple line.

(e) The diffraction grating was replaced with one that had half as many lines per cm. When the spectrometer telescope was rotated from the straight-through position to the 90° position, in order to see all the orders of hydrogen spectra, ONE difference that was seen was that the lines in the spectra were closer together than before. TWO other differences were seen. Assuming there is no change in the amount of light transmitted, describe and explain BOTH of the other two differences.

ANOTHER EXPERIMENTAL VALUE (2004;3)

The students were then asked to design an interference experiment to measure the speed of sound. One of the windows of the laboratory faced out over the playing fields. The students set the signal generator to a frequency of 2680 Hz, connected two speakers S_1 and S_2, and aimed the sound from them out of this window.
Each student walked along the line AB and marked the positions at which the sounds were loudest. From these marks, they estimated that the distance between adjacent positions of loud sound was 5.60 m. The diagram (not to scale) shows the distances they used.



(a) Explain why the sound the students heard varied in loudness.

(b) Using information from the diagram, show that the students calculated the wavelength of sound to be 0.126 m.

(c) From this wavelength, calculate the speed of sound.