Leaving Cert Physics Long Questions 2018 - 2002

6. *Waves, Sound and Light*

Please remember to photocopy 4 pages onto one sheet by going A3→A4 and using back to back on the photocopier

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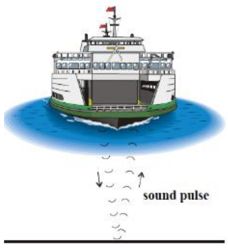
Waves and sound

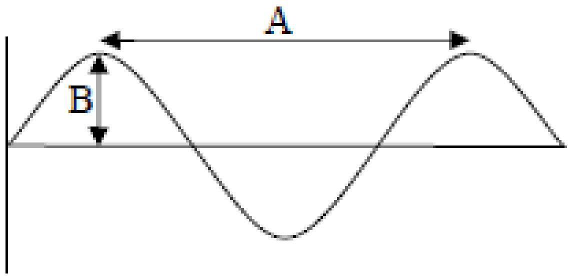
2006 Question 8 [Ordinary Level]



(i) Describe, using diagrams, the difference between transverse waves and longitudinal waves.
(ii) The speed of sound depends on the medium through which the sound is travelling. Explain how sound travels through a medium.
(iii) Describe an experiment to demonstrate that sound requires a medium to travel.
(iv) A ship detects the seabed by reflecting a pulse of high frequency sound from the seabed. The sound pulse is detected 0.4 s after it was sent out and the speed of sound in water is 1500 m s^{-1}.
Calculate the time taken for the pulse to reach the seabed.
(v) Calculate the depth of water under the ship.
(vi) Calculate the wavelength of the sound pulse when its frequency is 50 000 Hz.
(vii) Why is the speed of sound greater in water than in air?

2014 Question 12 (c) [Ordinary Level]

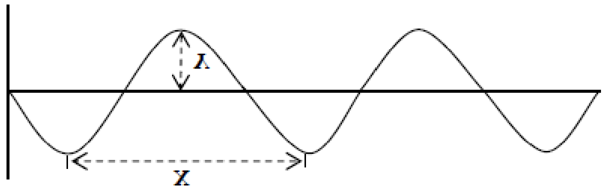
The diagram shows a transverse wave.



(i) Name the distances labelled A and B.
(ii) 20 waves pass a fixed point every second.
What is the frequency of the wave?
(iii) Calculate the velocity of the wave if distance A = 1.5 m.
(iv) Transverse waves can be polarised.
Name a type of wave that cannot be polarised.

2010 Question 7 [Ordinary Level]

The diagram shows a waveform.



(i) What is the name given to the distance X and Y?
(ii) What is meant by the frequency of a wave?
(iii) Explain the term natural frequency.
(iv) If the natural frequency of a string is 250 Hz calculate the wavelength of the sound wave produced (speed of sound = 340 m s^{-1}).
(v) State the wave property on which the loudness, the pitch, of a musical note depends.
(vi) An opera singer, singing a high pitched note, can shatter a glass. Explain why.
(vii) Describe a laboratory experiment to demonstrate resonance.

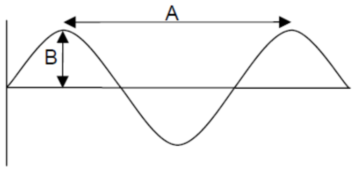
2007 Question 7 [Ordinary Level]

Resonance occurs when a vibrating object causes vibrations in nearby objects which have the same natural frequency.

(i) Explain the underlined terms.

(ii) Describe an experiment to demonstrate resonance.

(iii) The diagram shows the waveform of a musical note.



(iv) What is the name given to (i) the distance A, (ii) height B?

(v) Explain what is meant by the frequency of a wave.

(vi) State the wave property on which (i) the loudness, (ii) the pitch, of a note depends.

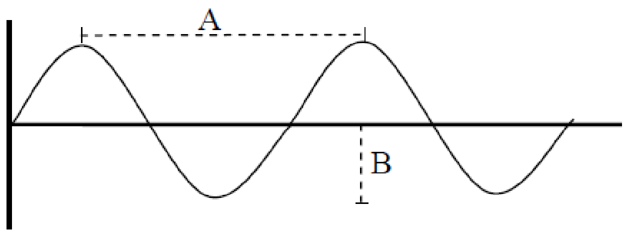
(vii) A tin-whistle produces a note of 256 Hz. Calculate the wavelength of this note.
The speed of sound in air is 340 m s^{-1}

2015 Question 7 [Ordinary Level]

(i) Explain the term *resonance*.

(ii) Describe a laboratory experiment to demonstrate resonance.

The diagram shows a waveform.



(iii) What is length A called?

(iv) What is length B called?

(v) What is meant by the frequency of a wave?

(vi) List three characteristics of a musical note.

(vii) What is meant by the term *natural frequency of an object*?

(viii) The natural frequency of a stretched string is 250 Hz.
Calculate the wavelength of the sound wave produced.
(speed of sound in air = 340 m s^{-1})

2011 Question 12 (b) [Ordinary Level]

(i) Loudness, pitch and quality are characteristics of a musical note.
Name the physical property of a sound wave on which each characteristic depends.

(ii) A bat detector allows us to hear the sounds emitted by bats. The detector is needed as humans cannot hear the sounds emitted by bats as they are outside our *frequency limits of audibility*.
What is meant by the frequency limits of audibility?

(iii) What name is given to a sound whose frequency is greater than our upper frequency limit of audibility?

(iv) A bat emitted a sound wave and detected its reflection from a wall 0.02 s later.
Calculate the distance of the bat from the wall.
(speed of sound in air = 340 m s^{-1})

2010 12 (c) [Higher Level]

(i) Explain the term resonance and describe a laboratory experiment to demonstrate it.

(ii) Give two characteristics of a musical note and name the physical property on which each characteristic depends.

(iii) Explain why a musical tune does not sound the same when played on different instruments.

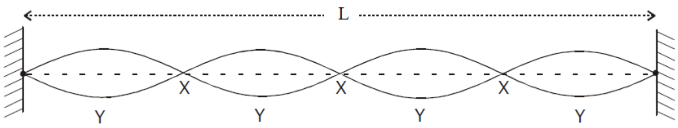
Stationary (standing) waves

2004 Question 8 [Ordinary Level]

(i) Sound from a vibrating object can cause diffraction and interference.
Explain the underlined terms.

(ii) Describe an experiment to demonstrate the interference of sound.

(iii) The diagram shows a stationary wave (standing wave) on a vibrating stretched string.



What is the name given to the points on the string marked (i) X, (ii) Y?

(iv) How many wavelengths are contained in the distance marked L?

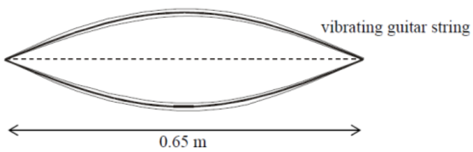
(v) State two factors on which the natural frequency of a stretched string depends.

(vi) A note of wavelength 1.4 m is produced from a stretched string. If the speed of sound in air is 340 m s^{-1}, calculate the frequency of the note.

2005 Question 12 (c) [Higher Level]

(i) The frequency of a stretched string depends on its length.
Give two other factors that affect the frequency of a stretched string.

(ii) The diagram shows a guitar string stretched between supports 0.65 m apart.
The string is vibrating at its first harmonic. The speed of sound in the string is 500 m s^{-1}. What is the frequency of vibration of the string?



(iii) Draw a diagram of the string when it vibrates at its second harmonic.

(iv) What is the frequency of the second harmonic?

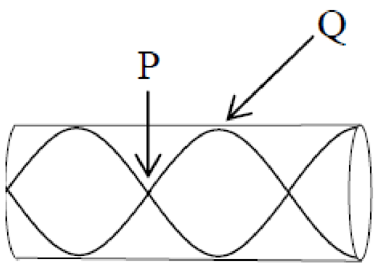
2011 Question 8 (a) [Higher Level] (speed of sound = 340 m s^{-1})

Destructive interference can occur when waves from coherent sources meet.

(i) Explain the underlined term.

(ii) Give two other conditions necessary for total destructive interference to occur.

(iii) The diagram shows a standing wave in a pipe closed at one end.
The length of the pipe is 90 cm.
Name the points on the wave labelled P and Q.



(iv) Calculate the frequency of the standing wave.

(v) What is the fundamental frequency of the pipe?

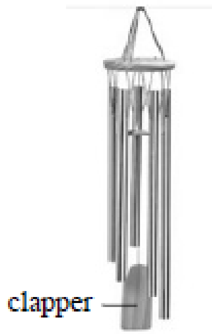
(vi) The clarinet is a wind instrument based on a pipe that is closed at one end.
What type of harmonics is produced by a clarinet?

2013 Question 7 [Higher Level] (speed of sound = 340 m s^{-1})

(i) What is meant by the term resonance?

(ii) How would resonance be demonstrated in the laboratory?

(iii) A set of wind chimes, as shown in the diagram, is made from different lengths of hollow metal tubing that are open at both ends. When the wind blows, the wind chimes are struck by a clapper and emit sounds.
The sound from one of the tubes was analysed.
The following frequencies were identified in the sound: 550 Hz, 1100 Hz and 1651 Hz.



(iv) What name is given to this set of frequencies?

(v) Draw labelled diagrams to show how the tube produces each of these frequencies.

(vi) The length of the metal tube is 30 cm.
Use any of the above frequencies to calculate a value for the speed of sound in air.

(vii) A sample of wire, of length 12 m and mass 48 g, was being tested for use as a guitar string.
A 64 cm length of the wire was fixed at both ends and plucked. The fundamental frequency of the sound produced was found to be 173 Hz. Calculate the tension in the wire.

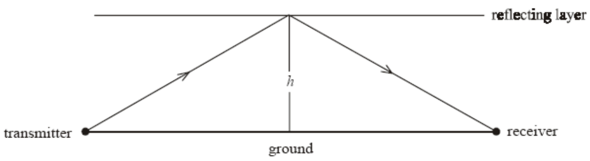
2015 Question 9 [Higher Level]
Musical instruments produce stationary (standing) waves.
Resonance also occurs in many instruments.
(i) What are stationary waves? How are they produced?
(ii) What is resonance?
(iii) Describe a laboratory experiment to demonstrate resonance.

A guitar is a string instrument.
The frequency of a stretched string depends on the tension of the string and on two other factors.
(iv) What are the two other factors?
(v) What effect does increasing the tension of the string from 36 N to 81 N have on the frequency of the string?
(vi) Explain, with the aid of labelled diagrams, why a pipe open at only one end produces half the number of harmonics as a pipe open at both ends.

(vii) A tin whistle consists of a pipe which is open at both ends.
A particular tin whistle has a fundamental frequency of 587 Hz when all of the holes on it are covered.
How long is the pipe?
(speed of sound in air = 340 m s^{-1})

2002 Question 7 [Higher Level]
(i) "Constructive interference and destructive interference take place when waves from two coherent sources meet."
Explain the underlined terms in the above statement.
(ii) What is the condition necessary for destructive interference to take place when waves from two coherent sources meet?
(iii) Describe an experiment that demonstrates the wave nature of light.

(iv) Radio waves of frequency 30 kHz are received at a location 1500 km from a transmitter.
The radio reception temporarily "fades" due to destructive interference between the waves travelling parallel to the ground and the waves reflected from a layer (ionosphere) of the earth's atmosphere, as indicated in the diagram.
Calculate the wavelength of the radio waves.



(v) What is the minimum distance that the reflected waves should travel for destructive interference to occur at the receiver?

(vi) The layer at which the waves are reflected is at a height h above the ground.
Calculate the minimum height of this layer for destructive interference to occur at the receiver.
(speed of light, c = 3.0×10^8 m s^{-1})

The Doppler effect

2012 Question 12 (c) [Ordinary Level]

The pitch of the sound emitted by the siren of a moving fire engine appears to change as it passes a stationary observer.

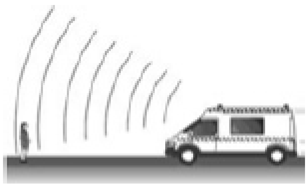
(i) Name this phenomenon.
(ii) Explain, with the aid of a diagram, how this phenomenon occurs.
(iii) Will the crew in the fire engine notice this phenomenon?
(iv) Give a reason for your answer.
(v) Give an application of this phenomenon.

2017 Question 8 [Ordinary Level]

Frequency and wavelength are properties associated with waves.

(i) What is meant by the frequency of a wave?
(ii) State the relationship between the frequency of a wave and its wavelength.

The diagram shows a person standing near an ambulance as it approaches with its siren on. As the ambulance passes, the person observes a change in the frequency of the siren.



(iii) What name is given to this effect?
(iv) Explain, with the aid of a labelled diagram, how this phenomenon occurs.
(v) Name one practical application of this phenomenon.

An electrical storm is seen before it is heard.

(vi) What does this indicate about the difference between sound waves and light waves?
(vii) State one other difference between sound waves and light waves.

When timing a 100 m sprint, a person stands at the finishing line and starts the stopwatch when he hears the starting gun fired at the starting line.

(viii) Calculate the difference in time the runner would receive if the stopwatch was started at *exactly* the same time as the starting gun was fired, i.e. without any delay caused by the time taken for the sound to travel 100 m.

(*speed of sound in air = 330 m* s^{-1})

2016 Question 12 (c) [Higher Level]

{I have deleted parts of this question which deal with Circular Motion; those sections appear in the "Circular Motion and SHM" long questions}

(i) What is meant by the Doppler effect?
A buzzer moves at a speed of 13 m s^{-1} in a vertical circle.
The buzzer emits a note of frequency 1.1 kHz.
An observer stands in the plane of motion of the buzzer, as shown in the diagram.

(ii) Calculate the maximum and minimum frequency of the note detected by an observer
(speed of sound in air = 340 m s^{-1})

2008 Question12 (b) [Higher Level]

(i) The pitch of a musical note depends on its frequency.
(ii) On what does (i) the quality, (ii) the loudness, of a musical note depend?
(iii) What is the Doppler Effect?
(iv) A rally car travelling at 55 m s^{-1} approaches a stationary observer. As the car passes, its engine is emitting a note with a pitch of 1520 Hz. What is the change in pitch observed as the car moves away?
{The wording here is confusing; the question is looking for the difference between the car's actual frequency and its apparent frequency as the car moves away)}
(v) Give an application of the Doppler Effect.

2014 Question 10 {first half} [Higher Level]

(i) What is the Doppler effect?
(ii) Explain, with the aid of labelled diagrams, how the Doppler effect occurs.
(iii) An ambulance siren emits a sound of frequency 750 Hz.
When the ambulance is travelling towards an observer, the frequency detected by the observer is 820 Hz.
What is the speed of the ambulance?
(iv) State two other practical applications of the Doppler effect.
(speed of sound in air = 340 m s^{-1})

2003 Question 7 [Higher Level]

(i) Describe an experiment to show that sound is a wave motion.
(ii) What is the Doppler Effect?
(iii) Explain, with the aid of labelled diagrams, how this phenomenon occurs.
(iv) Bats use high frequency waves to detect obstacles. A bat emits a wave of frequency 68 kHz and wavelength 5.0 mm towards the wall of a cave. It detects the reflected wave 20 ms later.
Calculate the speed of the wave and the distance of the bat from the wall.
(v) If the frequency of the reflected wave is 70 kHz, what is the speed of the bat towards the wall?
(vi) Give two other applications of the Doppler Effect.

2017 Question 7 {last 2 parts} [Higher Level]

(vii) Speed cameras use the Doppler effect to calculate the speed of vehicles.
Describe, with the aid of a labelled diagram, how the Doppler effect occurs.

(viii) A source that is emitting a sound wave of a certain frequency is approaching an observer.
The frequency observed is 15% more than the frequency of the sound wave emitted.
What is the speed of the source?
(*speed of sound in air = 340 m s^{-1}*)

2007 Question 7 [Higher Level]

(i) What is the Doppler Effect?
(ii) Explain, with the aid of labelled diagrams, how this phenomenon occurs.
(iii) The emission line spectrum of a star was analysed using the Doppler Effect.
Describe how an emission line spectrum is produced.
(iv) The red line emitted by a hydrogen discharge tube in the laboratory has a wavelength of 656 nm.
The same red line in the hydrogen spectrum of a moving star has a wavelength of 720 nm.
Is the star approaching the earth? Justify your answer.
(v) Calculate the frequency of the red line in the star's spectrum.
(vi) Calculate the speed of the moving star.
(speed of light = 3.00×10^8 m s^{-1})

2010 Question 7 [Higher Level]

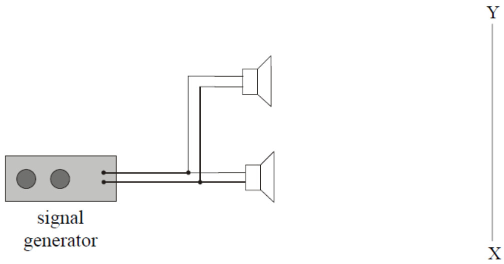
(i) What is the Doppler effect?
(ii) Explain, with the aid of labelled diagrams, how this phenomenon occurs.
(iii) Describe a laboratory experiment to demonstrate the Doppler effect.
(iv) What causes the red shift in the spectrum of a distant star?
(v) The yellow line emitted by a helium discharge tube in the laboratory has a wavelength of 587 nm.
The same yellow line in the helium spectrum of a star has a measured wavelength of 590 nm.
(vi) What can you deduce about the motion of the star?
(vii) Calculate the speed of the moving star.
(viii) Give another application of the Doppler effect.

Interference of sound

2005 Question 12 (b) [Ordinary Level]

(i) What is meant by (i) diffraction, (ii) interference, of a wave?

(ii) In an experiment, a signal generator was connected to two loudspeakers, as shown in the diagram. Both speakers are emitting a note of the same frequency and same amplitude.



(iii)A person walks along the line XY. Describe what the person hears.

(iv)What does this experiment demonstrate about the nature of sound?

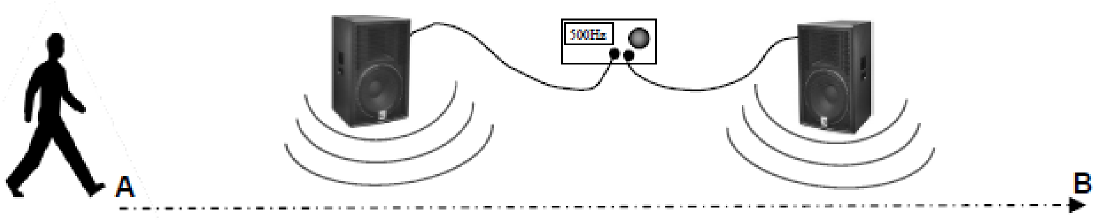
(v) What is meant by the amplitude of a wave?

2013 Question 8 [Ordinary Level]

(i) What is meant by the frequency of a wave?

(ii) Give the relationship between the frequency and the wavelength of a wave.

(iii)The diagram shows a student walking in front of two loudspeakers along the path between **A** and **B**. A signal generator set at 500 Hz is connected to the loudspeakers.



(iv)What will the student notice as he moves from **A** to **B**?

(v) Name this phenomenon.

(vi)Explain with the aid of a diagram how this phenomenon occurs.

(vii) Why should this phenomenon be taken into account in the placing of speakers in theatres or auditoriums?

The note produced by a guitar string depends on the <u>fundamental frequency</u> of the string. The quality of the note depends on the number of <u>overtones</u> produced. The loudness of a note is increased by resonance in the body of a guitar.

(viii) Explain the underlined terms.

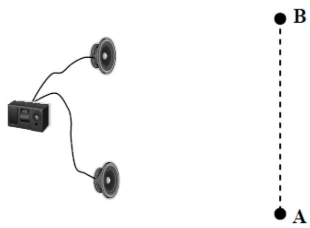
(ix)How can the note produced by a guitar string be changed?

(x) What is resonance?

2008 Question 8 [Ordinary Level]

The diagram shows a signal generator connected to two loudspeakers emitting the same note.

A person walks slowly along the line AB.



(i) What will the person notice?

(ii) Why does this effect occur?

(iii)What does this tell us about sound?

(iv)Describe an experiment to demonstrate that sound requires a medium to travel.

(v) The pitch of a note emitted by the siren of a fast moving ambulance appears to change as it passes a stationary observer. Name this phenomenon.

(vi)Explain how this phenomenon occurs.

(vii) Give an application of this phenomenon.

Sound intensity

2016 Question 7 [Ordinary Level]

(i) Sound and light travel as waves.
Sound travels as a longitudinal wave whereas light travels as a transverse wave.
Explain the underlined terms.

(ii) Describe a laboratory experiment which demonstrates that sound requires a medium to travel through.

(iii) Total internal reflection is the basis of operation of optical fibres.
With the aid of a labelled diagram, explain how total internal reflection occurs.

(iv) State two uses of optical fibres.

(v) The refractive index of a material in an optical fibre is 1.44.
Calculate the minimum angle at which light can strike the sides of the fibre and still be transmitted through the fibre.

(vi) The picture shows a sound-level meter, which is used to measure sound intensity level.
What is the unit of sound intensity level?

(vii) Why might a sound-level meter be used in a workplace?

2011 Question 8 (b) [Higher Level]

An audio speaker at a concert emits sound uniformly in all directions at a rate of 100 W.
Calculate the sound intensity experienced by a listener at a distance of 8 m from the speaker.
The listener moves back from the speaker to protect her hearing.
At what distance from the speaker is the sound intensity level reduced by 3 dB?

2007 Question 12 (b) [Higher Level]

(i) Define sound intensity.

(ii) A loudspeaker has a power rating of 25 mW.
What is the sound intensity at a distance of 3 m from the loudspeaker?

(iii) The loudspeaker is replaced by a speaker with a power rating of 50 mW.
What is the change in the sound intensity?

(iv) What is the change in the sound intensity level?

(v) The human ear is more sensitive to certain frequencies of sound.
How is this taken into account when measuring sound intensity levels?

2018 Question 7 [Higher Level]

(i) Resonance is a phenomenon that is associated with musical instruments. What is resonance?

(ii) Describe an experiment to demonstrate resonance.

A stretched string of a violin has a length of 328 mm and a mass of 0.126 g.
The string emits a note of 660 Hz when it vibrates at its fundamental frequency.

(iii) Calculate the tension in the string,

(iv) Calculate the speed of sound in the string.

(v) Draw a labelled diagram to represent the fundamental frequency of a stationary wave in a pipe that is closed at one end.

(vi) Define sound intensity.

A source emits sound in all directions.

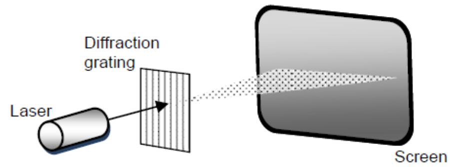
(vii) Describe the effect of doubling the distance from the source to an observer on the sound intensity measured

(viii) Describe the effect of doubling the distance from the source to an observer on the sound intensity *level* measured.

$$n\lambda = d \sin\vartheta$$

2009 Question 7 [Ordinary Level]

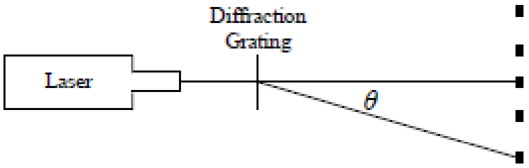
(i) In an experiment a beam of monochromatic light passes through a diffraction grating and strikes a screen.
(ii) Explain the underlined terms.
(iii) Describe what is observed on the screen.
(iv) Explain, with the aid of a diagram, how this phenomenon occurs.
(v) What does this experiment tell us about the nature of light?
(vi) Name the property of light that can be determined in this experiment.
(vii) What measurements must be taken to determine the property you named?



2014 Question 7 [Higher Level]

(i) What is meant by the terms (*i*) diffraction and (*ii*) interference?

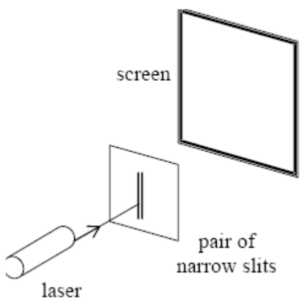
(ii) A laser produces a beam of red light with a wavelength of 709 nm. The beam is incident on a diffraction grating, as shown in the diagram. A diffraction pattern is formed on a screen. A second order image is detected at an angle of 34.6° from the central image.
Calculate the energy of each photon in the laser beam.



(iii) Sensors in the eye can respond to single photons. Where in the eye are these sensors located?
(iv) State two differences between the electromagnetic radiation emitted from a laser and the electromagnetic radiation emitted from a vapour lamp.
(v) Derive, with the aid of a labelled diagram, the diffraction grating formula.
(vi) Calculate the number of lines per millimetre on the grating used in the experiment.
(vii) What would be observed on the screen if the laser was replaced by a ray of white light?

2005 Question 7 [Higher Level]

A student used a laser, as shown, to demonstrate that light is a wave motion.
(i) Name the two phenomena that occur when the light passes through the pair of narrow slits.
(ii) A pattern is formed on the screen. Explain how the pattern is formed.
(iii) What is the effect on the pattern when the wavelength of the light is increased?
(iv) What is the effect on the pattern when the distance between the slits is increased?
(v) Describe an experiment to demonstrate that sound is also a wave motion.
(vi) Sound travels as longitudinal waves while light travels as transverse waves. Explain the difference between longitudinal and transverse waves.
(vii) Describe an experiment to demonstrate that light waves are transverse waves.



2009 Question 7 [Higher Level]

(i) When light shines on a compact disc it acts as a diffraction grating causing diffraction and dispersion of the light. Explain the underlined terms.
(ii) Derive the diffraction grating formula.
(iii) An interference pattern is formed on a screen when green light from a laser passes normally through a diffraction grating. The grating has 80 lines per mm and the distance from the grating to the screen is 90 cm. The distance between the third order images is 23.8 cm.
Calculate the wavelength of the green light.
(iv) Calculate the maximum number of images that are formed on the screen.
(v) The laser is replaced with a source of white light and a series of spectra are formed on the screen. Explain how the diffraction grating produces a spectrum.
(vi) Explain why a spectrum is not formed at the central (zero order) image.

2013 Question 12 (b) [Higher Level]

(i) A narrow beam of light undergoes dispersion when it passes through either a prism or a diffraction grating.
What is meant by dispersion?

(ii) Give two differences between what is observed when a narrow beam of light undergoes dispersion as it passes through a prism, and what is observed when a narrow beam of light undergoes dispersion as it passes through a diffraction grating.

(iii) Give another example of light undergoing dispersion.

(iv) Yellow light of wavelength 589 nm is produced in a low-pressure sodium vapour lamp.
What causes the sodium atoms to emit this light?

(v) Calculate the highest order image that could be produced when a beam of light of this wavelength is incident perpendicularly on a diffraction grating that has 300 lines per mm.

2017 Question 9 {last 2 parts} [Higher Level]

(iv) Draw a labelled diagram of a spectrometer and describe how a spectrometer and diffraction grating can be used to observe (*i*) a line spectrum and (*ii*) a continuous spectrum.

(v) Sodium emits visible light with a wavelength of 589 nm. This light is passed through a diffraction grating of 300 lines per mm.
Calculate the angular separation between the first line to the left of the central image and the first line to the right of the central image.

Dispersion of light

2015 Question 12 (b) [Ordinary Level]

(i) What is meant by dispersion of light?
(ii) What does dispersion of light indicate about the nature of white light?
(iii) Name two laboratory techniques that can be used to cause dispersion of light.
(iv) Describe one example of dispersion of light occurring in nature.
(v) The diagram shows stage lighting similar to that found in most theatres.
Only red, green and blue lights are needed to create all the colours needed on stage.
Explain why this is so.

2010 Question 12 (b) [Ordinary Level]

(i) What is meant by dispersion of light?
(ii) Describe an experiment to demonstrate the dispersion of light.
(iii) Give an example of the dispersion of light occurring in nature.
(iv) Only red, green and blue lights are needed to create most lighting effects.
Explain why

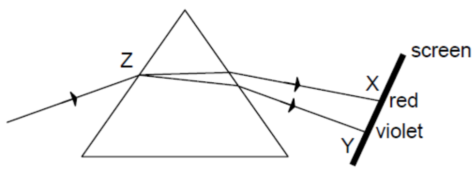
2012 Question 7 [Ordinary Level]

(i) Under certain conditions, light can undergo <u>diffraction</u> and <u>interference</u>.
Explain the underlined terms.
(ii) Describe an experiment to demonstrate the wave nature of light.
(iii) The photograph shows Polaroid sunglasses which reduce glare caused by sunlight.
Explain the term 'polarisation'.
(iv) Describe an experiment to demonstrate the polarisation of light.
(v) What type of wave motion does light have as indicated by the experiment in part (iv)?
(vi) Why are Polaroid sunglasses more effective than non-Polaroid sunglasses at reducing glare?

2007 Question 8 [Ordinary Level]

Dispersion occurs when a beam of white light passes through a prism forming a spectrum on a screen, as shown in the diagram.

(i) What is meant by the terms *dispersion* and *spectrum*?
(ii) What happens to the white light when it enters the prism at Z?
(iii) Name the invisible radiation formed on the screen at (i) region X, (ii) region Y.
(iv) Describe how to detect one of these invisible radiations.
(v) Give a use for one of these invisible radiations.
(vi) The colour on a TV screen is made by mixing the primary colours.
Name the primary colours.
(vii) How is a secondary colour (e.g. yellow) produced on a TV screen?



2018 Question 8 [Ordinary Level]
Diffraction and interference are properties associated with waves.
(i) Explain the underlined terms.
(ii) Describe an experiment to demonstrate the wave nature of light.

The photograph shows a liquid crystal display (LCD) monitor, which may require a polaroid panel to allow the image on the screen to be seen clearly.

(iii) What is meant by polarisation?
(iv) Describe an experiment to demonstrate the polarisation of light.
(v) Monitors of the kind shown use only three colours to form any image. What three colours are used?
(vi) Describe how these colours can be used to create any image.

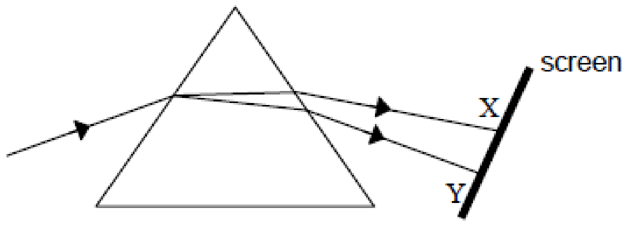
2016 Question 11 [Ordinary Level]
Read this passage and answer the questions below.
Experimentum crucis

Once he returned to Cambridge from the country in 1667, Newton began to gain honours with startling rapidity and became the second holder of the Lucasian Professorship in Mathematics, a position later held by Stephen Hawking. This new job obliged Newton to give occasional lectures but he was also able to spend much more time on experiments.
To isolate a single colour (or at least what the eye sees as a colour – a spectrum in fact consists of an innumerable range of colours, each blending into the next), he put a card with a hole in it next to a prism, only letting through a narrow band of light. Not only did he confirm his view that when this beam was passed through a second prism no different colours were produced – red light remained red, blue remained blue and so on – he discovered that red coloured light was bent much less by the prism than blue light. The degree of bending, the refraction, varied as he moved through the different colours.
He later referred to this discovery as the experimentum crucis, the crucial experiment, emphasising its significance as a turning point in the understanding of the nature of light. He had found something fundamental and new - that light was made up of colours that were distinct entities, impossible to change from one into the other, each bent differently by a prism. For good measure, his experiment explained why a prism worked at all. When a beam of light hit an ordinary block of glass there was no rainbow produced. As the light passed from air to glass it was true that the blue light would bend further than the red, splitting it out, but when it reached the far side of the block it would move back the other way an equal amount and the result would be to recombine the colours. The prism's triangular faces meant that the two opportunities to bend - towards the vertical of the first face and away from the vertical of the second - both resulted in movement in the same direction. The colours remained separate.
(Adapted from Light Years - The Extraordinary Story of Mankind's Fascination with Light,
Brian Clegg, Icon Books, 2015)

a) What word is used to describe the bending of light by a prism?
b) What does the spectrum of light consist of?
c) Which colour of light is bent the most?
d) Draw a diagram to show how a spectrum can be produced using a prism.
e) What was the significance of Newton's experiment?
f) Without using a prism, how else can a spectrum be produced?
g) Why is a spectrum not produced by an ordinary block of glass?
h) Name another field of physics for which Newton is famous.

2013 no.12 (b) [Higher Level]

The diagram shows a beam of white light undergoing refraction and dispersion as it passes through a prism.



(i) What is meant by dispersion?
(ii) What is observed on the screen between X and Y?
(iii) What information does dispersion give about the nature of white light?
(iv) Give another method for the dispersion of light.
(v) Give an everyday example of the dispersion of light.

2017 Question 7{first part} [Higher Level]

Colour filters and polarising filters can be used to enhance photographs.
We see objects because light reflects from them.

(i) What is reflection?
(ii) What primary colours of light (*i*) are absorbed and (*ii*) are reflected when white light shines on a red book?
(iii) What colour would the red book appear to be if colour filters were used so that the book was illuminated (*iii*) with green light and (*iv*) with red light?
(iv) What is polarisation?
(v) Describe how polarisation can be demonstrated in the laboratory.
(vi) Give an application of stress polarisation.

The electromagnetic spectrum

2008 Question 12 (b) [Ordinary Level]

Sunlight is made up of different colours and invisible radiations.

(i) How would you show the presence of the different colours in light?
(ii) Name two radiations in sunlight that the eye cannot detect.
(iii) Describe how to detect one of these radiations.
(iv) Give a use for this radiation.

2018 Question 12 (b) [Ordinary Level]

Sunlight is made up of visible light of different colours as well as many types of invisible radiation.

(i) How could you show the different colours present in visible light?
(ii) UV radiation is also present in sunlight.
(iii) What do the letters U and V stand for?
(iv) Compare the wavelength of UV radiation to the wavelength of infra-red (IR) radiation.
(v) Describe how to detect UV radiation.
(vi) State one use of UV radiation.

2006 Question 12 (b) [Ordinary Level]

The diagram shows the relative positions of electromagnetic radiations in terms of their wavelength.

gamma rays	A	UV	light	IR	microwaves	B

(i) Name the radiations marked A and B.
(ii) Give one property which is common to all electromagnetic radiations.
(iii) Which one of the radiations has the shortest wavelength?
(iv) Describe how IR radiation is detected.
(i) Give one use for microwaves.

2003 Question 12 (b) [Ordinary Level]

(i) Name two primary colours.
(ii) What are complementary colours?
(iii) White light is made up of light of different colours. Describe an experiment to demonstrate this.
(iv) The diagram shows a simple form of the electromagnetic spectrum, with wavelength increasing from left to right.
Copy this diagram and indicate on it the positions of the following:
microwaves; infrared; ultraviolet; X-rays.

short wavelength	→	long wavelength
gamma rays	light	radio waves

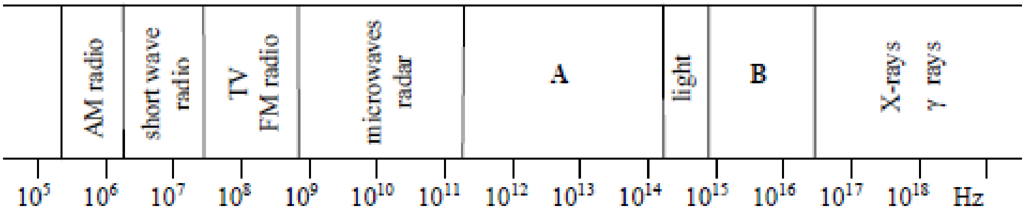
2002 Question 7 [Ordinary Level]

(i) The dispersion of white light can be produced by <u>refraction</u> or <u>diffraction</u>. Explain the underlined terms.
(ii) Describe an experiment to demonstrate the dispersion of white light.
(iii) The following table gives examples of electromagnetic waves and their typical wavelengths.

wave	radio	microwave	infrared	light	ultraviolet
wavelength	100 m	0.1m	1μm	600 nm	10 nm

(iv) Name one property that all of these waves have in common.
(v) What is the frequency of the radio waves? The speed of light is 3×10^8 m s^{-1}.
(vi) Describe how infrared radiation can be detected.
(vii) Give two uses of microwaves.

2012 Question 7 [Higher Level]



(i) The diagram shows a simplified version of the electromagnetic spectrum.
Name the sections labelled A and B in the diagram.
(ii) Describe how to detect each of these radiations.
(iii) An electromagnetic radiation has a wavelength of 4 m.
Name the section of the electromagnetic spectrum in which this radiation is located.
(iv) Distinguish between interference and diffraction.
(v) Can a diffraction grating which diffracts light also diffract X-rays? Justify your answer.
(vi) Light travels as a transverse wave.
Name another type of wave motion and give two differences between these two types of wave motion.

2010 Question 11 [Higher Level]
Read the following passage and answer the accompanying questions.

A person's exposure to radiation when using a mobile phone is measured in terms of the Specific Absorption Rate (SAR). This is a measure of the rate at which radio frequency energy is absorbed by a person's body during a phone call and is expressed in watts per kilogram.
A radio frequency wave penetrates the body to a depth that depends on its frequency. At mobile phone frequencies the wave energy is absorbed by about one centimetre of body tissue. The energy absorbed is converted into heat and is carried away by the body. Any adverse health effects from radio frequency waves are due to heating. Current scientific evidence indicates that exposure to radiation from mobile phones is unlikely to induce cancer.
(*Adapted from a Dept. of Communications, Energy and Natural Resources Press Release of 22 March 2007.*)

(i) Give two properties of radio waves.
(ii) In a three-minute phone call, 10 g of head tissue absorbs 0.36 J of radio frequency energy.
Calculate the SAR value.
(iii) What happens to the radio frequency energy absorbed by the body?
(iv) Why are radio frequency waves not very penetrating?
(v) A mobile phone converts the received radio frequency waves to sound waves.
What are the audible frequency limits for sound waves?
(vi) Give two safety precautions you should take when using a mobile phone.
(vii) A mobile phone transmits at 1200 MHz from its antenna.
Calculate the length of its antenna, which is one quarter of the wavelength that it transmits.
(viii) Name an electromagnetic wave which may induce cancer. Justify your answer.

Solutions to ordinary level *maths* questions

2017 Question 8

Calculate the difference in time the runner would receive

$time = \frac{distance}{speed} = \frac{100}{330}$ = 0.3 s

2015 Question 7

Calculate the wavelength of the sound wave produced.

$v = f\lambda$ $\lambda = v/f$ $\lambda = 340/250$ $\lambda = 1.36$ m

2014 Question 12 (c)

What is the frequency of the wave?

20 Hz

Calculate the velocity of the wave if distance A = 1.5 m.

$v = f\lambda = (20)(1.5) =$ 30 m s^{-1}

2011 Question 12 (b)

Calculate the distance of the bat from the wall.

Velocity = distance ÷ time. distance = velocity × time = 340 × .01 = 3.4 m

2010 Question 7

Calculate the wavelength of the sound wave produced.

$v = f\lambda$ $\lambda = v/f$ $\lambda = 340/250$ $\lambda = 1.36$ m

2007 Question 7

Calculate the wavelength of this note.

$c = f\lambda \Rightarrow \lambda = c/f \Rightarrow \lambda = 340/256 = 1.33$ m.

2006 Question 8

Calculate the time taken for the pulse to reach the seabed.

0.2 seconds.

Calculate the depth of water under the ship.

$v = s/t \Rightarrow s = v \times t \Rightarrow s = 1500 \times 0.2 = 300$ m.

Calculate the wavelength of the sound pulse when its frequency is 50 000 Hz.

$c = f\lambda \Rightarrow \lambda = c/f \Rightarrow \lambda = 1500/50000 = 0.03$ m.

2006 Question 12 (c)

What is the frequency of the wave?

20 Hz

Calculate the velocity of the wave if distance A = 1.5 m.

$v = f\lambda = (20)(1.5) = 30$ m s^{-1}

Solutions to *all* higher level questions

2018 Question 7

(i) **Resonance is a phenomenon that is associated with musical instruments. What is resonance?**
Resonance is the transfer of energy between two bodies of the same natural frequency

(ii) **Describe an experiment to demonstrate resonance.**
One of many possible demonstrations:
Stand two tuning forks of the same frequency on a wooden board
Set one tuning fork vibrating
Stop the first one vibrating and notice that the second tuning fork has started vibrating.

(iii)**Calculate the tension in the string**

μ = mass per unit length = $\frac{0.126\times10^{-3}}{0.328}$ = 3.84×10^{-4} kg m^{-1}

f = 600 Hz
l = 0.328 m
$\mu = 3.84 \times 10^{-4}$ kg m^{-1}

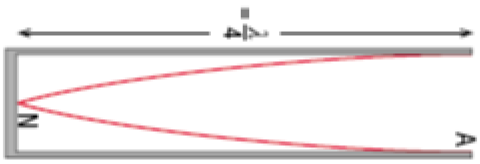
$$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} \quad \Rightarrow \quad 2lf = \sqrt{\frac{T}{\mu}}$$

$$4l^2f^2 = \frac{T}{\mu} \quad \Rightarrow \quad \mu\, 4l^2f^2 = T \qquad T = (3.84 \times 10^{-4})(4)(0.328)^2(600)^2$$

Answer: T = 72 N

(iv)**Calculate the speed of sound in the string.**
A violin string is tied (and so has a node) at both ends, so when plucked it sets up a standing wave whose length corresponds to half a wavelength
$\lambda = 2(0.328) = 0.656$ m
$v = f\lambda$
$v = (600)(0.656) = 433$ m s^{-1}

(v) **Draw a labelled diagram to represent the fundamental frequency of a stationary wave in a pipe that is closed at one end.**
See diagram



(vi)**Define sound intensity.**
Power per unit area

(vii) **Describe the effect of doubling the distance from the source to an observer on the sound intensity measured.**
$I = \frac{power}{surface\ area\ of\ a\ sphere} = \frac{power}{4\pi r^2}$

Intensity is therefore inversely proportional to the *square* of the distance, so if the distance goes up by a factor of 2 ("doubles") then the sound intensity goes down by a factor of 4.
So the sound intensity gets 4 times smaller.

(viii) **Describe the effect of doubling the distance from the source to an observer on the sound intensity *level* measured.**

If the sound intensity gets two times bigger (doubles) then the sound intensity level *goes up by 3 decibels*.

If the sound intensity *halves* (gets two times smaller) then the sound intensity level *goes down by 3 decibels*.

In this question the sound intensity gets 4 times smaller so it halved and halved again.

So the sound intensity level went down by 3 dB and then down by 3 dB again.

Answer:

The sound intensity level went down by 6 decibels

2017 Question 9 {last 2 parts}

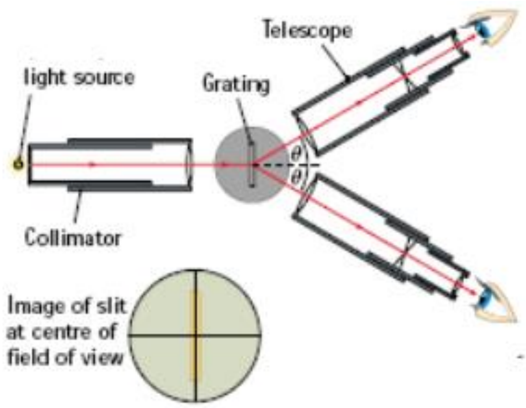
(iv) **Draw a labelled diagram of a spectrometer and describe how a spectrometer and diffraction grating can be used to observe (*i*) a line spectrum and (*ii*) a continuous spectrum.**

collimator (labelled)

table

telescope (labelled)

correct arrangement



Line spectrum: light source is a vapour lamp

Continuous spectrum: light source is a filament bulb / white light

(v) **Calculate the angular separation between the first line to the left of the central image and the first line to the right of the central image.**

If the grating has 300 lines per mm then it must have 300000 lines per m (because 1 m = 1000 mm)

$d = 1/300000 = 3.33 \times 10^{-6}$ m

$\lambda = 589 \times 10^{-9}$ m

$n = 1$

$n\lambda = d \sin\theta$ $\sin\theta = \frac{\lambda}{d}$ $\sin\theta = \frac{589\times10^{-9}}{3.33\times10^{-6}}$ $\theta = 10.2^0$ Angular separation = 20.4^0

2017 Question 7

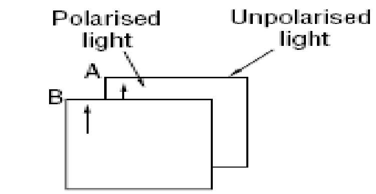
(i) **What is reflection?**
rebounding (of light) from an object

(ii) **What primary colours of light (*i*) are absorbed and (*ii*) are reflected when white light shines on a red book?**
White light is made up of red, green and blue light
When white light shines on a red book, it means that the green and blue must be absorbed while the red is reflected back to us.

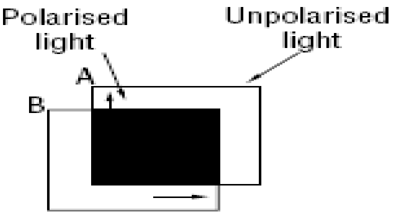
(iii) **What colour would the red book appear to be if colour filters were used so that the book was illuminated (*iii*) with green light and (*iv*) with red light?**
We know that a red book absorbs green light so if you illuminate it with only green light then nothing will be reflected back so the book will appear black.
If you illuminate it with red light then we know that this will get reflected back so the book will appear red.

(iv) **What is polarisation?**
Wave vibrations in one plane only

(v) **Describe how polarisation can be demonstrated in the laboratory.**
Two parallel polarising plates and a source of light
Rotate one plate until no light passes through the plates



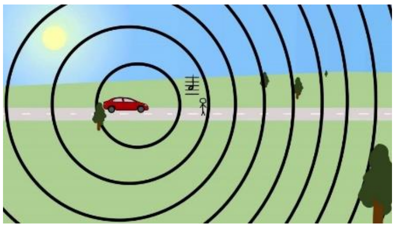
A produces plane polarised light which B transmits



A produces plane polarised light which B cuts off

(vi) **Give an application of stress polarisation.**
Checking for defects in plastics

(vii) **Describe, with the aid of a labelled diagram, how the Doppler effect occurs.**
Consider the soundwaves emitted from a car's engine with crests as shown as it moves to the right:
Ahead of the moving source, the crests are closer together than crests from a stationary source would be.
This means that the wavelength is smaller and the frequency is greater (more crests per second passing over the observer).



(viii) **The apparent frequency is 15% more than the actual frequency.**
$f' = 115\%$ of f $\qquad$ $f' = 1.15f$

$$f' = \frac{fc}{c-u} \qquad 1.15f = \frac{f(340)}{340-u}$$

cancel the fs

$$1.15 = \frac{(340)}{340-u}$$

$(1.15)(340 - u) = 340$ $\qquad$ $(1.15)(340) - (1.15)(u) = 340$ $\qquad$ $(1.15)(340) + 340 = (1.15)(u)$

$u = 44.3 \text{ m s}^{-1}$

2016 Question 12 (c)

(i) What is meant by the Doppler effect?

Apparent change in frequency of a wave due to relative motion between source and observer

(ii) Calculate the maximum and minimum frequency of the note detected by an observer

$u = 13\ \text{m s}^{-1}$

$f = 1.1\ \text{kHz} = 1100\ \text{Hz}$

The frequency of the note detected by an observer is a *maximum* as the buzzer moves *away from* the observer, so we use the positive sign below the line.

$f' = \dfrac{fc}{c+u}$ $\quad$ $f' = \dfrac{(1100)(340)}{340+13}$ $\quad$ $f'_{max} = 1143.7\ \text{Hz}$

The frequency of the note detected by an observer is a *minimum* as the buzzer moves *towards* the observer, so we use the negative sign below the line.

$f' = \dfrac{fc}{c-u}$ $\quad$ $f' = \dfrac{(1100)(340)}{340-13}$ $\quad$ $f'_{min} = 1059.5\ \text{Hz}$

2015 Question 9

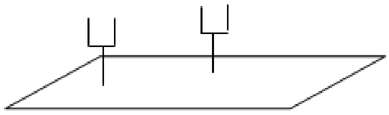
(i) What are stationary waves? How are they produced?

The amplitude of the wave at any point is constant // There is no net transfer of energy

(ii) What is resonance?

Transfer of energy between two bodies with the same (or similar) natural frequency
OR Resonance is the transfer of energy so that a body vibrates at its natural frequency.

(iii) Describe a laboratory experiment to demonstrate resonance.



Use two identical tuning forks (same frequency) and a sound-board.
Start one fork vibrating, place it on the sound-board and notice the sound.
Place the second tuning fork on the sound-board and then stop the first tuning fork from vibrating.
The second fork can now be heard.
Explanation:
The vibrations were passed from the first tuning fork via the sound-board to the second tuning fork.

(iv) What are the two other factors?

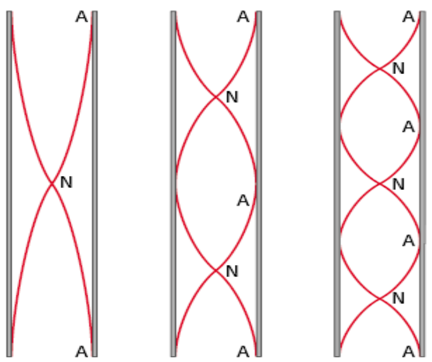
Length and *mass per unit length*

(v) What effect does increasing the tension of the string from 36 N to 81 N have on the frequency of the string?

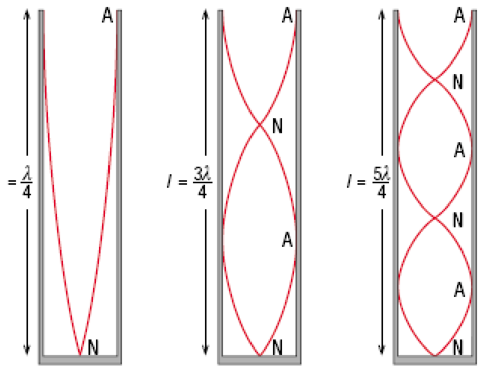
Tension increased by a factor of 2.25 (81÷ 36)
f $\propto \sqrt{T}$
$\sqrt{2.25} = 1.5$
frequency increases by a factor of 1.5

(vi) Explain, with the aid of labelled diagrams, why a pipe open at only one end produces half the number of harmonics as a pipe open at both ends.

Harmonics in a pipe open at *both* ends



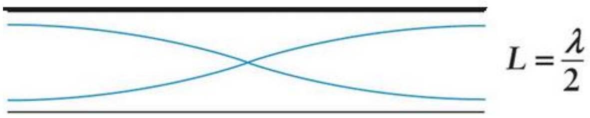
Harmonics in a pipe open at *one* end



Now that I think about it, this is a daft question; in theory you can get an infinite number of harmonics in both open *and* closed pipes, so no way do you only get half the number of harmonics in a closed pipe.
Feel free to disagree.

For what it's worth, the following is the marking scheme for this section:
Diagram of first harmonic for open pipe (3)
Diagram of other harmonic for same open pipe (3)
Diagram of first harmonic for closed pipe (3)
Diagram of other harmonic for same closed pipe (3)
All harmonics for open pipe, only odd harmonics for closed pipe (2)

(vii) How long is the pipe?



From the diagram we can see that the length of the pipe corresponds to half the wavelength. $l = \lambda/2$, so if we can work out the wavelength we can calculate the length from there.

$v = f\lambda \quad \Rightarrow \quad \lambda = \frac{v}{f} \quad \Rightarrow \quad \lambda = \frac{340}{587}$

$\lambda = 0.58$ m

$l = 0.29$ m

2014 Question 7

(i) What is meant by the terms (*i*) diffraction and (*ii*) interference?

Diffraction is the spreading of a wave into the space beyond a barrier/obstacle/gap

Interference occurs when waves from two sources meet to produce a wave of different amplitude.

(ii) Calculate the energy of each photon in the laser beam.

We need to use E = hf; we don't know the frequency but we do know the wavelength, so we can use $c = f\lambda$ to get an expression for f.

$$E = h\frac{c}{\lambda} \qquad = \frac{(6.6\times10^{-34})(3\times10^{8})}{709\times10^{-9}} \qquad = 2.8 \times 10^{-19}\ \text{J}$$

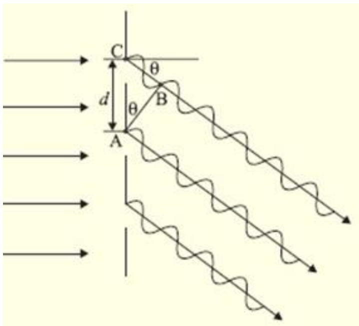
(iii) Where in the eye are these sensors located?

On the retina

(iv) State two differences between . . .

laser has only one frequency (or wavelength) / laser light is more powerful / laser light is coherent

(v) Derive, with the aid of a labelled diagram, the diffraction grating formula.



From the diagram we can see that

(i) For constructive interference to occur, the extra path length that the top ray travels must be an integer number of wavelengths **(nλ)** {Eqn (1)}

(ii) Using trigonometry, this extra path length is equal to **d sin θ,** where d is the slit width {Eqn (2)}

Equating (1) and (2) gives us **nλ = d Sin θ**

(vi) Calculate the number of lines per millimetre on the grating used in the experiment.

$\Rightarrow$ nλ = d Sinθ $\qquad d = \frac{n\lambda}{\sin\theta} \qquad d = \frac{(2)(709\times10^{-9})}{\sin 34.6} \qquad d = 0.000002497$ m

Now if a grating has n lines per m $\Rightarrow$ $\boldsymbol{d = \frac{1}{n}}$ **metres** $\qquad \Rightarrow \qquad n = \frac{1}{d}$

$\Rightarrow$ $n = \frac{1}{0.000002497}$ $\qquad$ = 400000 lines per m $\qquad$ = 400 lines per mm

(vii) What would be observed on the screen if the laser was replaced by a ray of white light?

Spectra

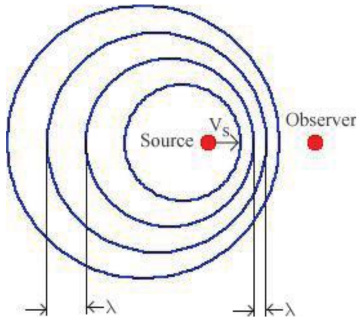
2014 Question 10 {first half}

(i) What is the Doppler effect?

The (apparent) change in the frequency (of a wave) due to the relative motion between the source (of the wave) and the observer

(ii) Explain, with the aid of labelled diagrams, how the Doppler effect occurs.

The circles represent the crests of sound waves emitted from the source.
In this case the source is moving to the right while emitting the waves.



The result is that:

1. Ahead of the moving source, the crests are closer together than crests from a stationary source would be. This means that the wavelength is smaller and the frequency is greater.
2. Behind the moving source, the crests are further apart than crests from the stationery source would be.
3. This means the wavelengths are greater and therefore the frequency is less.

(iii) What is the speed of the ambulance?

$f' = 820$ Hz
$f = 750$ Hz
$c = 340$ m s^{-1}
The ambulance is travelling towards an observer; therefore we use the ‘minus’ in the formula.

$$f' = \frac{fc}{c-u} \qquad 820 = \frac{(750)(340)}{340-u}$$

$$820(340-u) = 255000 \qquad 278800 - 820u = 255000 \qquad 278800 - 255000 = 820u$$

$$23800 = 820u \qquad u = 29 \text{ m s}^{-1}$$

(iv) State two other practical applications of the Doppler effect.

e.g. police “speed guns” / measuring velocities of stars / ultrasound (scan) / landing aircraft / weather forecasting

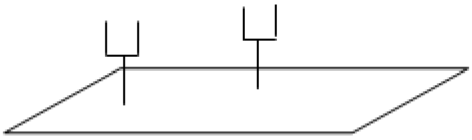
2013 Question 7

(i) What is meant by the term resonance?

Transfer of energy between two bodies with the same (or similar) natural frequency

OR Resonance is the transfer of energy so that a body vibrates at its natural frequency.

(ii) How would resonance be demonstrated in the laboratory?



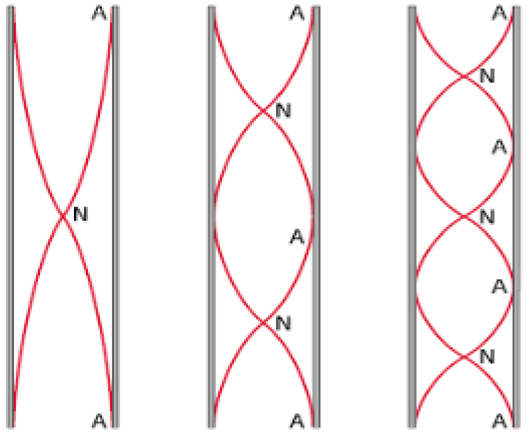
- Use two ***identical*** tuning forks (they must have the same frequency) and a sound-board.
- Start one fork vibrating and place it on the sound-board.
- Place the second tuning fork on the sound-board and then stop the first tuning fork from vibrating.
- The second fork can now be heard.

(iii) What name is given to this set of frequencies?

Harmonics or overtones

(iv) Draw labelled diagrams to show how the tube produces each of these frequencies.

See diagram



550 Hz (f) 1100 Hz ($2f$) 1651 Hz ($3f$)

(v) Use any of the above frequencies to calculate a value for the speed of sound in air.

The length of the metal tube is 30 cm = 0.3 m

The distance between two consecutive antinodes is $\frac{\lambda}{2}$

$0.3 = \frac{\lambda}{2}$ $\lambda = 0.60$ m $c = f\lambda$ $c = (550)(0.60) = 330$ m s^{-1}

A sample of wire, of length 12 m and mass 48 g, was being tested for use as a guitar string.
A 64 cm length of the wire was fixed at both ends and plucked. The fundamental frequency of the sound produced was found to be 173 Hz. Calculate the tension in the wire.

(vi) Calculate the tension in the wire.

l = 64 cm = 0.64 m f = 173 Hz

We need to use the formula $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

*{So before we do that we also need to calculate μ which represents the **mass per unit length**.*
To work this out we divide a sample length of the wire by its corresponding mass.
"A sample of wire, of length 12 m and mass 48 g . . ."}

$\mu = \frac{mass}{length} = \frac{0.048}{12}$ $\mu = 0.004$ kg m^{-1}

$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ $2lf = \sqrt{\frac{T}{\mu}}$ $4l^2f^2 = \frac{T}{\mu}$ $\mu\, 4l^2f^2 = T$

$T = (0.004)(4)(0.64)^2(173)^2$ T = 196 N

2013 Question 12 (b)

(i) What is meant by dispersion?

Dispersion is the separating out of the different colours present in white light.

(ii) Give two differences between . . .

Red light deviated least in a prism and deviated the most in a grating
Many spectra observable with a grating, only one with a prism

(iii) Give another example of light undergoing dispersion.

A rainbow

(iv) What causes the sodium atoms to emit this light?

Electrons changing energy levels

Calculate the highest order image that could be produced when a beam of light of this wavelength is incident perpendicularly on a diffraction grating that has 300 lines per mm.

{Here we will use the formula $n\lambda = d \, Sin \, \theta$

The maximum that θ could be is 90^0, so $Sin \, \theta = 1$ so the formula becomes $n\lambda = d$, $n = \frac{d}{\lambda}$}

$d = \frac{1}{300000} = 3.33 \times 10^{-6}$ m n = $\frac{3.33 \times 10^{-6}}{589 \times 10^{-9}}$ = 5.65

The highest order image is 5

2012 Question 7

(i) **Name the sections labelled A and B in the diagram.**
A: infra red /IR
B: ultra violet / UV

(ii) **Describe how to detect each of these radiations.**
A: thermometer (with blackened bulb) / temperature sensor /photographic plate / mobile phone camera
Effect e.g. rise in temperature *{Yup, I think this bit is daft also}*
B: (shine on) vaseline/detergents / phosphor
Effect e.g. fluorescence / glows *{refer to previous comment}*

(iii) **Name the section of the electromagnetic spectrum in which this radiation is located.**
{We can use the chart to help us here, but only if know the frequency}
$c = f\lambda \qquad f = \frac{c}{\lambda} = \frac{3\times10^8}{4} = 7.5 \times 10^7$ Hz
We can see from the chart that this falls approximately half-way between the *short wave radio* and the *TV/FM radio* sections, so either answer would have been acceptable

(iv) **Distinguish between interference and diffraction.**
Interference occurs when waves from different sources overlap to form a resultant wave of greater or lower amplitude.
Diffraction occurs when a wave spreads around an obstacle or an aperture.

(v) **Can a diffraction grating which diffracts light also diffract X-rays? Justify your answer.**
No.
For diffraction to occur the distance between slits (or line spacing) must be similar to the wavelength of the radiation, and the wavelength of light is very different to the wavelength of X-rays.

(vi) **Name another type of wave motion and give two differences between these two types of wave motion.**
Longitudinal.
Transverse can be polarized – longitudinal cannot.
Transverse waves vibrate *perpendicular* to the direction in which the wave travels.
Longitudinal waves vibrate *parallel* to the direction in which the wave travels.

2011 Question 8 (a)

(i) Explain the underlined terms

Coherent waves are waves which are the same frequency (or wavelength) and are in phase

(ii) Give two other conditions necessary for total destructive interference to occur.

The waves must have the same amplitude and be out of phase by 180^0 (crests over troughs).

(iii) Name the points on the wave labelled P and Q.

P represents a node, Q represents an anti-node.

(iv) Calculate the frequency of the standing wave.

The shape corresponds to 5/4 wavelengths

$\frac{5\lambda}{4} = 0.90\ m$ $\lambda = 0.720$ m $v = f\lambda$ $f = \frac{v}{\lambda} = \frac{340}{0.720}$ $f = 472.2$ Hz

(v) What is the fundamental frequency of the pipe?

The shape for the fundamental frequency corresponds to ¼ of a wavelength

$\frac{\lambda}{4} = 0.90$ $\lambda = 3.60$ m $f_0 = \frac{340}{3.60}$ $f_0 = 94.44$ Hz

(vi) What type of harmonics is produced by a clarinet?

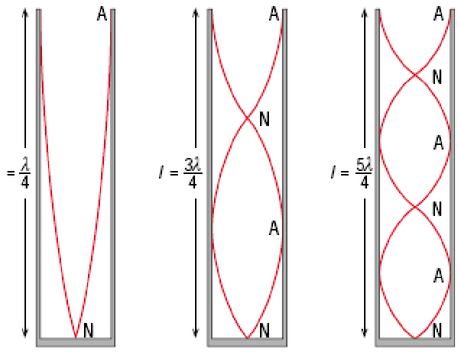
Odd harmonics

{Why odd?

See diagram. The length will either by $\frac{\lambda}{4}$, $\frac{3\lambda}{4}$, $\frac{5\lambda}{4}$ *etc*

So it's always an odd multiple.

Hence the term odd harmonics.}



2011 Question 8 (b)

(i) **Calculate the sound intensity experienced by a listener at a distance of 8 m from the speaker.**

The sound from the speaker expands in all directions, like an inflating balloon. The area that the energy is passing through therefore corresponds to the surface area of a sphere ($A = 4\pi r^2$)

$$SI = \frac{Power}{Area} = \frac{100}{4\pi 8^2}$$

SI = 0.124 W m^{-2}

(ii) **The listener moves back from the speaker to protect her hearing. At what distance from the speaker is the sound intensity level reduced by 3 dB? (speed of sound in air = 340 m s^{-1})**

{If the sound intensity level decreased by 3dB it means sound intensity went down by a factor of two (it went from 0.124 W m^{-2} to 0.062 W m^{-2}).}

$0.062 = \frac{100}{4\pi R^2}$ $R^2 = \frac{100}{4\pi(0.062)}$ R = 11.33 m

2010 Question 11

(i) Give two properties of radio waves.

They travel at speed of light, electromagnetic radiation, travel through vacuum, can be reflected, refracted, polarized etc.

(ii) Calculate the SAR value.

While there is nothing about SAR values in the syllabus, all the information we need to work with is given in the question. We are told that that the units of SAR are watts per kilogram. So $SAR = \frac{Power}{mass}$ *So first we need to calculate the power.*

$Power = \frac{Energy}{time} = \frac{0.36}{(3)(60)}$ = 0.002 W

$SAR = \frac{Power}{mass}$ = $\frac{0.002}{10\times10^{-3}}$ = = 0.20 W kg^{-1}

(iii) What happens to the radio frequency energy absorbed by the body?

It is converted into heat in the body.

(iv) Why are radio frequency waves not very penetrating?

They have a low frequency / long wavelength / low energy.

(v) What are the audible frequency limits for sound waves?

20 Hz to 20 000 Hz

(vi) Give two safety precautions you should take when using a mobile phone.

Keep phone at distance, use loudspeaker function, ‘no hands, brief calls only, direct antenna away from your head etc.

(vii) Calculate the length of its antenna, which is one quarter of the wavelength that it transmits.

f = 1200 MHz = 1200 × 10^6 Hz = 1.2 × 10^9 Hz

$\lambda = \frac{c}{f}$ = $\frac{3 \times 10^8}{1.2 \times 10^9}$ λ = 0.25 m

Length of antenna = ¼ of the wavelength = $\frac{0.25}{4}$ = 0.0625 m.

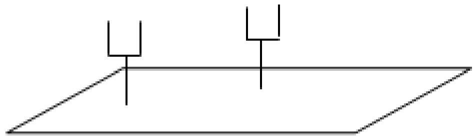
(viii) Name an electromagnetic wave which may induce cancer. Justify your answer.

Gamma rays / X-rays / UV - they can all cause ionization of body cells.

2010 Question 12 (c)

(i) Explain the term resonance and describe a laboratory experiment to demonstrate it.
Resonance is the transfer of energy so that a body vibrates at its natural frequency.

To Demonstrate Resonance



- Use two ***identical*** tuning forks (same frequency) and a sound-board.
- Start one fork vibrating, place it on the sound-board and notice the sound.
- Place the second tuning fork on the sound-board and then stop the first tuning fork from vibrating.
- The second fork can now be heard.
  NB: you must make reference to the fact that both tuning forks are of the same frequency

(ii) Give two characteristics of a musical note and name the physical property on which each characteristic depends.
Pitch: frequency
Loud: amplitude / intensity
Quality: number of harmonics and their relative strengths

(iii)Explain why a musical tune does not sound the same when played on different instruments.
Different instruments emit a fundamental frequency plus different combinations of overtones/harmonics.

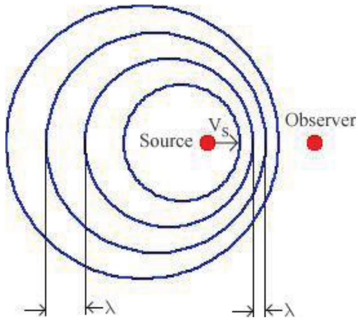
2010 Question 7

(i) What is the Doppler effect?

The Doppler effect is the apparent change in frequency due to the relative motion between a source and an observer.

(ii) Explain, with the aid of labelled diagrams, how this phenomenon occurs.

The circles represent the crests of sound waves emitted from the source.
In this case the source is moving to the right while emitting the waves.

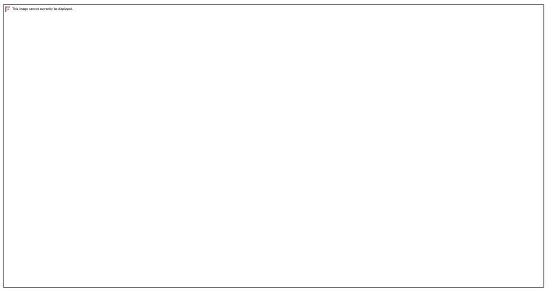


The result is that:

1. Ahead of the moving source, the crests are closer together than crests from a stationary source would be. This means that the wavelength is smaller and the frequency is greater.
2. Behind the moving source, the crests are further apart than crests from the stationery source would be.
3. This means the wavelengths are greater and therefore the frequency is less.

(iii)Describe a laboratory experiment to demonstrate the Doppler effect.

Attach a string to a buzzer.
Swing the buzzer over your head.
An observer will note a frequency change as the buzzer approaches then recedes from the observer.



(iv)What causes the red shift in the spectrum of a distant star?

Distant stars are moving away from us therefore the wavelengths increase.

(v) What can you deduce about the motion of the star?

The star is moving away from earth

(ix)**Calculate the speed of the moving star.**

$f = \frac{c}{\lambda} = \frac{3\times10^{8}}{587\times10^{-9}}$ $\qquad$ f = 5.11073 × 10^{14}

$f' = \frac{c}{\lambda'} = \frac{3\times10^{8}}{590\times10^{-9}}$ $\qquad$ f' = 5.08475 × 10^{14}

The star is moving *away from* earth therefore we use the '*plus'* in the formula: $\quad f' = \frac{fc}{c+u}$

$$5.08475\times10^{14} = \frac{(5.11073\times10^{14})(3\times10^{8})}{(3\times10^{8})+u}$$

$$(5.08475 \times 10^{14})[(3\times10^{8})+u] = 1.533219\times10^{23}$$

$$1.525425\times10^{23} + 5.08475 \times 10^{14}u = 1.533219\times10^{23}$$

$7.794\times10^{20} = 5.08475 \times 10^{14}u$ $\qquad$ $u = \frac{7.794\times10^{20}}{5.08475\times10^{14}}$ $\qquad$ Answer: u = 1.5333 × 10^{6} m s^{-1}

(vi)Give another application of the Doppler effect.

Radar, medical imaging, blood flow measurement (echocardiogram), temperature measurement, (underwater) acoustics, etc.

2009 Question 7

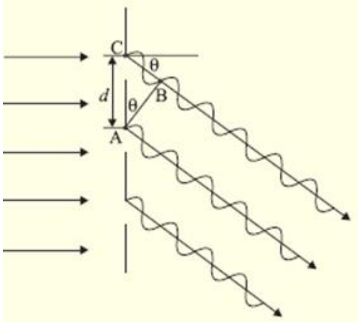
(i) Explain *diffraction*

Diffraction is the spreading out of a wave when it passes through a gap or passes by an obstacle.

(ii) Explain *dispersion*.

Dispersion is the splitting up of white light into its constituent colours.

(iii) Derive the diffraction grating formula.



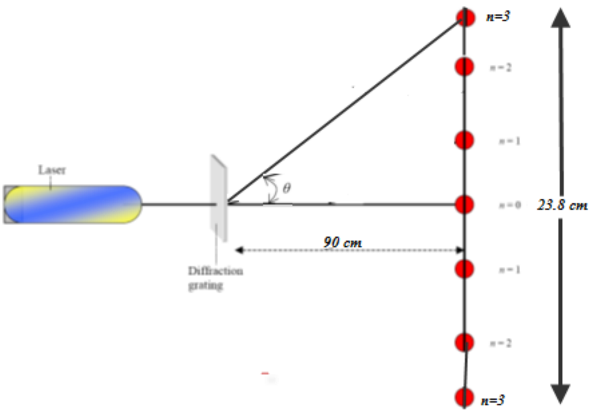
From the diagram we can see that

(i) For constructive interference to occur, the extra path length that the top ray travels must be an integer number of wavelengths ($n\lambda$) {Eqn (1)}

(ii) Using trigonometry, this extra path length is equal to $d \sin\theta$, where d is the slit width {Eqn (2)}

Equating (1) and (2) gives us $n\lambda = d \sin\theta$

(iv) Calculate the wavelength of the green light.



$d = \frac{1}{80000} = 1.25 \times 10^{-5}$ m

$\theta = \tan^{-1}\frac{opposite}{adjacent}$

From the diagram we can see that the adjacent is 0.90 m, while the opposite is $\frac{0{,}238}{2} = 0.119$ m

$\theta = \tan^{-1}\frac{0.119}{0.9} = 7.531^0$

n = 3

$n\lambda = d \sin\theta \quad \Rightarrow \quad \lambda = \frac{d\ \sin\theta}{n} = \frac{(1.25 \times 10^{-5})\,(\sin\theta)}{3} \Rightarrow \lambda = 546\times 10^{-9}$ m.

(v) Calculate the maximum number of images that are formed on the screen.

For maximum number $\theta = 90^0 \quad \Rightarrow \sin\theta = 1$

$n\lambda = d \sin\theta \quad \Rightarrow n\lambda = d \quad \Rightarrow n = \frac{d}{\lambda} = \frac{1.25 \times 10^{-5}}{551 \times 10^{-9}} \quad n = 22.7$

So the greatest whole number of images is 22.
But this is on one side only.
In total there will be 22 on either side, plus one in the middle, so total = 45

(vi) Explain how the diffraction grating produces a spectrum.

Different colours have different wavelengths so constructive interference occurs at different positions (different angles) for each separate wavelength.

(vii) Explain why a spectrum is not formed at the central (zero order) image.

At central image $\theta = 0$ so constructive interference occurs for all separate wavelengths at the same point so no separation of colours.

2008 Question 12 (b)

(i) On what does (i) the quality, (ii) the loudness, of a musical note depend?
Quality depends on the number of overtones their relative strengths.
Loudness depends on amplitude of the wave.

(ii) What is the Doppler Effect?
The Doppler effect is the apparent change in the frequency of a wave due to the relative motion between the source of the wave and the observer.

(iii) A rally car travelling at 55 m s^{-1} approaches a stationary observer. As the car passes, its engine is emitting a note with a pitch of 1520 Hz. What is the change in pitch observed as the car moves away *{i.e. between when it passes and as it moves away}*?

$f' = \frac{fc}{c \pm u}$ ⇒ $f' = \frac{1520(340)}{340 + 55}$ ⇒ $f^1 = 1308.35$ Hz

⇒ change in frequency = 1520 – 1308.35 = 211.65 Hz.

(iv) Give an application of the Doppler Effect.
Calculate speeds of stars or galaxies, speed traps.

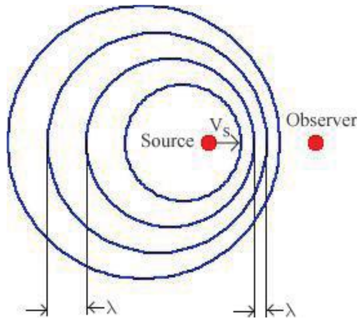
2007 Question 7

(vii) What is the Doppler effect?

The Doppler effect is the apparent change in the frequency of a wave due to the relative motion between the source of the wave and the observer.

(viii) Explain, with the aid of labelled diagrams, how this phenomenon occurs.

The circles represent the crests of sound waves emitted from the source.
In this case the source is moving to the right while emitting the waves.
The result is that:



1. Ahead of the moving source, the crests are closer together than crests from a stationary source would be. This means that the wavelength is smaller and the frequency is greater.
2. Behind the moving source, the crests are further apart than crests from the stationery source would be.
3. This means the wavelengths are greater and therefore the frequency is less.

(ix) Describe how an emission line spectrum is produced.

When the gas is heated the electrons in the gas are move up to higher orbital level and as they fall back down they emit electromagnetic radiation of a specific frequency.

(x) Is the star approaching the earth? Justify your answer.

No

The wavelength has increased therefore it must be moving away.

(xi) Calculate the frequency of the red line in the star's spectrum

$f' = \frac{c}{\lambda'}$ $\quad$ $f' = \frac{3\times10^8}{720\times10^{-9}}$ $\quad\Rightarrow\quad$ $f' = 4.17 \times 10^{14}$ Hz

$f = \frac{c}{\lambda}$ $\quad$ $f = \frac{3\times10^8}{656\times10^{-9}}$ $\quad\Rightarrow\quad$ $f = 4.57 \times 10^{14}$ Hz

(xii) Calculate the speed of the moving star

$f' = 4.17 \times 10^{14}$ Hz
$f = 4.57 \times 10^{14}$ Hz
$c = 3 \times 10^8$ m s^{-1}

The star is moving away from the earth, therefore we use 'plus' in the formula: $f' = \frac{fc}{c+u}$

$$4.17\times10^{14} = \frac{(4.57\times10^{14})(3\times10^8)}{(3\times10^8)+u}$$

$$4.17 \times 10^{14}[(3 \times 10^8) + u)] = 1.371 \times 10^{23}$$

$$1.251 \times 10^{23} + (4.17 \times 10^{14})(u) = 1.371 \times 10^{23}$$

$$(4.17 \times 10^{14})(u) = 1.371 \times 10^{23} - 1.251 \times 10^{23}$$

$$(4.17 \times 10^{14})(u) = 1.2 \times 10^{22}$$

$u = 2.88 \times 10^7$ m s^{-1}

2007 Question 12 (b)

(i) Define sound intensity.

Sound Intensity is defined as power per unit area.

(ii) What is the sound intensity at a distance of 3 m from the loudspeaker?

The sound energy from the speaker dissipates in 3 dimensions, similar to an expanding (spherical balloon). The area therefore corresponds to the surface area which the energy is passing through.

Surface area of sphere = $4\pi r^2$

$Sound\ Intensity = \frac{25 \times 10^{-3}}{4\pi(3)^2}$ S.I. = 2.21×10^{-4} W m^{-2}

(iii) What is the change in the sound intensity?

$Sound\ Intensity = \frac{50 \times 10^{-3}}{4\pi(3)^2}$ S.I. = 4.42×10^{-4} W m^{-2} The change is 2.21×10^{-4} W m^{-2}

(iv) What is the change in the sound intensity level?

{Note: Doubling the Sound Intensity increases the Sound Intensity Level by 3dB}

Answer: Sound intensity level increased by 3 dB

(v) How is this taken into account when measuring sound intensity levels?

There is an adapted scale which takes this into account called the *decibel adapted* (dBA) scale

2005 Question 7

(i) Name the two phenomena that occur when the light passes through the pair of narrow slits.
Diffraction and interference

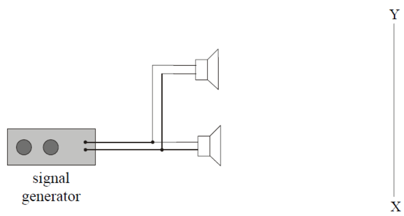
(ii) A pattern is formed on the screen. Explain how the pattern is formed.
The slits act as sources of two coherent waves which overlap to give areas of constructive interference (bright lines) and destructive interference (dark lines).

(iii) What is the effect on the pattern when the wavelength of the light is increased?
{$n\lambda = d \sin\theta$
If λ increases then the left hand side of this equation gets bigger, therefore the right hand side must get bigger. 'd' is fixed (we haven't changed the diffraction grating), so the only thing which can increase on the right hand side is $\sin\theta$. If $\sin\theta$ increases then θ increases.}
Answer: The pattern of bright images gets more spread out.

(iv) What is the effect on the pattern when the distance between the slits is increased?
{$n\lambda = d \sin\theta$
In this case both values on the left hand side can't change, so the total on the left is constant. Therefore the total on the right must remain constant. The only way for this value to remain constant if the distance between the slits (d) goes up is if $\sin\theta$ goes down.}
Answer: The pattern becomes less spread out.

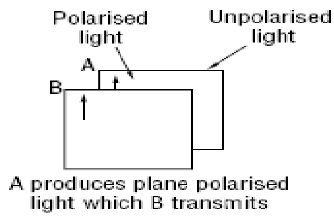
(v) Describe an experiment to demonstrate that sound is also a wave motion.

- Walking slowly from X to Y, you will notice the loudness of the sound increasing and decreasing at regular intervals.
  This is because sound waves from the two speakers will interfere both constructively and destructively, along the path XY.



(vi) Explain the difference between longitudinal and transverse waves.
Longitudinal waves: the direction of the vibrations is parallel to the direction of propagation of the wave.
Transverse wave: the direction of the vibrations is perpendicular to the direction of the wave.

(vii) Describe an experiment to demonstrate that light waves are transverse waves.
Light source and two pieces of polaroid as shown.
Rotate one polaroid relative to the other and note that the light intensity increases and decreases
Only transverse waves can be polarised, so light is a transverse wave.



2005 Question 12 (c)

(i) Give two other factors that affect the frequency of a stretched string.
Tension and mass per unit length

(ii) What is the frequency of vibration of the string?
{The distance from one node to the next in a standing wave corresponds to half a wavelength.}

$0.65 = \frac{\lambda}{2}$ $\lambda = (2)(0.65) = 1.3$ m

$v = f\lambda$ $\Rightarrow$ $f = \frac{v}{\lambda}$ $f = \frac{500}{1.3}$ $f = 384.6$ Hz

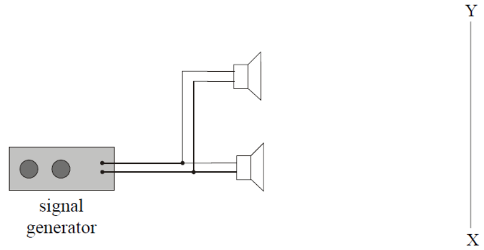
(iii) Draw a diagram of the string when it vibrates at its second harmonic.

(iv) What is the frequency of the second harmonic?
$f_{2nd} = 2(f_{1st}) = 769.2$ Hz

2003 Question 7

(i) Describe an experiment to show that sound is a wave motion.

1. Walking slowly from X to Y, you will notice the loudness of the sound increasing and decreasing at regular intervals.
2. This is because sound waves from the two speakers will interfere both constructively and destructively, along the path XY.



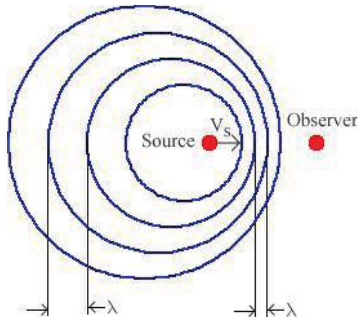
(ii) What is the Doppler effect?

The Doppler effect is the apparent change in the frequency of a wave due to the relative motion between the source of the wave and the observer.

(iii) Explain, with the aid of labelled diagrams, how this phenomenon occurs.

In this diagram the source is moving to the right while emitting the waves.
The result is that:

1. Ahead of the moving source, the crests are closer together than crests from the stationary source would be. This means that the wavelength is smaller and the frequency is greater.
2. Behind the moving source, the crests are further apart than crests from the stationery source would be.
3. This means the wavelengths are greater and therefore the frequency is less.



(iv) Calculate the speed of the wave.

$v = f\lambda$ $\quad v = (68000)(0.005) \quad = 340 \text{ m s}^{-1}$

(v) Calculate the distance of the bat from the wall.

$speed = \frac{distance}{time}$ $\quad$ distance = (speed)(time) $\quad$ distance = (340)(0.02) = 6.8 m.

Divide by two to get the distance going one way only. Distance of bat from wall = 3.4 m.

(vi) If the frequency of the reflected wave is 70 kHz, what is the speed of the bat towards the wall?

$f' = 70000$ Hz
$f = 68000$ Hz
$c = 340 \text{ m s}^{-1}$

{From the bat's perspective the wall is sending out a wave at a frequency of 68 kHz (the frequency of the wave doesn't change just because it was reflected).
Now because the bat is moving towards the source (the wall) we will need to use 'minus' rather than 'plus' in the formula.
*This is also an example of where the concept of **relative** motion applies; rather than the source of the wave moving towards the observer (the bat), the observer in this case is moving towards the source)}*

$$f' = \frac{fc}{c - u} \qquad 70000 = \frac{(68000)(340)}{340 - u} \qquad 70000(340 - u) = 23120000$$

$$23800000 - 70000u = 23120000 \qquad 23800000 - 23120000 = 70000u$$

$$6800000 = 70000u \qquad u = 9.71 \text{ m s}^{-1}$$

Alternatively we could have rearranged our formula at the beginning to give $u = \frac{f'c - fc}{f'}$ and then substituted in the values as required.

(vii) Give two other applications of the Doppler Effect.

Speed traps , speed of stars (red shift), landing aircraft, ultrasound (blood movement or heartbeat of foetus), weather forecasting.

2002 Question 7

(i) Explain the underlined terms in the above statement.

Constructive interference occurs when waves from two coherent sources meet to produce a wave of greater amplitude.

Coherent waves: Two waves are said to be coherent if they have the same frequency and are in phase.

(ii) What is the condition necessary for destructive interference to take place when waves from two coherent sources meet?

They must be out of phase by half a wavelength (this means that the crest of one wave will be over the trough of the other.

(iii) Describe an experiment that demonstrates the wave nature of light.

Shine a laser through a diffraction grating; an interference pattern will be produced on a screen, caused by interference of the light waves

(iv) Calculate the wavelength of the radio waves.

c = fλ ⇒ $\lambda = \frac{c}{f}$ $\lambda = \frac{3.0 \times 10^8}{30000}$ = 10000 m = 10 km

(v) What is the minimum distance that the reflected waves should travel for destructive interference to occur at the receiver?

{For destructive interference to occur the reflected wave must arrive out of phase, i.e. it must have travelled half a wavelength more than the regular wave.

The initial wave will have travelled 1500 km and half a wavelength is 5 km (worked out above) therefore the reflected wave must travel 1500 km + 5 km = 1505 km.}

(vi) Calculate the minimum height of this layer for destructive interference to occur at the receiver.

Use Pythagoras: $(\frac{1505}{2})^2 = h^2 + (\frac{1500}{2})^2$

h = 61 km = 61000 m