



# Leaving Cert Physics Notes

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## Introduction and tips for Leaving Certificate physics exam.

Physics is the study of the rules and principles governing the behaviour of the physical world in which we live. Physics seeks to provide explanations to observed phenomenon.

### Physics for Leaving Certificate.

These notes address the topics required to complete the higher level leaving certificate course. Much of the material is common to both ordinary and higher level. The material exclusively for higher level is marked with a \*\*\*.

These notes are intended as a revision aid. As such they do not go into details of experiments or practice calculations.

### The Exam paper- General tips

The leaving certificate exam is three hours long and consists of two sections.

Section A consists of four questions from which you must answer three. Each question carries 40 marks.

Section B consists of eight questions from which you must answer five. Each question carries 56 marks.

You should divide your time roughly as follows

Section A – around 16 minutes per question. Section B -around 23 minutes per question. This allows 10 minutes at the start of the paper to read ALL the instructions, read ALL the questions and select the ones you feel you can best answer.

It also allows a few minutes at the end to check over your work and make sure you haven't forgotten anything.

This is, of course, a rough guide. Some questions may take a little less time and some a little more, but if you keep the guidelines in mind you will avoid running badly out of time and so not doing yourself justice in the exam.

Some students have a tendency to answer extra questions in the exam. While it may be possible to fit in a single extra question, my experience shows that pupils who take a few minutes to go over their answers and check they have answered as fully and correctly as possible gain more marks than those who rush through questions too quickly in order to answer extra questions.

One final point about the exam – there are no points to be gained by leaving early! Make use of the full time allocated, go back over questions, expand on explanations etc. you will be surprised what careless slips you may uncover.

## Breakdown of paper

Section A examines the mandatory practicals which you are required to carry out as part of the course. Typically these questions involve describing how measurements were taken, graphing data and performing necessary calculations, and listing precautions and sources of error in the experiment.

The layout of these questions tends to be the same from year to year. Thus, this is an easy section to pick up marks in. You need to

- (i) Know the method for each experiment.
- (ii) Know what you graph against what. Very often the table of raw data given is not the suitable form for the graph. You will often have to manipulate the data and produce a new table of the data you will actually plot (e.g. in an experiment to measure the refractive index of a glass block the following measurements of angle of incidence and angle of refraction were taken. Plot a suitable graph and hence measure the refractive index of the glass

$i/^\circ$	15	25	35	45	55
$r/^\circ$	10	16.4	22.5	28.0	33.1

Before attempting the graph you must convert this data to a usable form – i.e. produce a table of  $\sin i$  and  $\sin r$ .

$\sin i$	0.26	0.42	0.57	0.71	0.82
$\sin r$	0.17	0.28	0.38	0.47	0.55

The suitable graph is  $\sin i$  against  $\sin r$

- (iii) Having plotted the graph know how to manipulate the data to give the relevant result (e.g. slope, intercept etc and what that means in the context of the particular experiment)
- (iv) For each experiment have a few ideas as to what the main sources of error are and what precautions should be taken to ensure accuracy.

### Section B:

Consists of eight questions from which you must attempt five.

Question 5 consists of ten short questions from which you need to answer eight. These cover the entire course but, as each short question is only worth 7 marks, nothing too complicated usually appears here. It generally consists of definitions, units and short calculations. If you have a good general overview of the course and have learnt definitions and laws this is an easy question to pick up high marks in, and indeed is a very popular question year after year.

Questions 6,7,8, and 9 address various topics. The layout of the questions can be a bit confusing. They don't label parts of questions (a) (b) (c) etc so it is necessary to read carefully and ensure that you attempt each part. I generally advise my students to put a line through each part when you have addressed it.

Question 10 has, to date, always consisted of two parts, (a) on particle physics or (b) on the applied electricity option. NOTE: there is no rule to say that these topics, or indeed any particular topic must be on the paper, but it would be unlikely that it will be omitted.

Question 11 contains a passage relating to some topical area of physics. NOTE: it is not a comprehension, the answers are not directly in the passage.

If the topic that appears in question 11 is one you are happy with this can be an easy question to gain high marks. The questions following the passage tend to be straight forward, worth 7 marks each, so, like question 5, quite manageable.

Question 12 consists of four parts, to answer two. Each part is from a different part of the course. Again the questions asked tend to be reasonably straightforward so if you have a good overall knowledge this is a good question to attempt.

### **Drawing Graphs:**

This is a very important part of the course and you will be likely to need to draw at least one graph in your exam.

Points to remember are

- (i) Make maximum use of the graph page – choose a suitable scale to best fill the page
- (ii) Use a sharp pencil
- (iii) Indicate points with an x
- (iv) Label the axes clearly
- (v) Draw the line of best fit – one line that passes as near as possible to the maximum number of points
- (vi) Beware of outliers (points significantly different to the normal)

In the chapters which follow, laws and formulae are highlighted in purple, derivations are in yellow,

## Chapter 1

## Optics and Waves

### Topic 1 – Geometric Optics

#### Properties of light.

Light is a form of energy. As such it can be converted into other forms of energy.

We can demonstrate this using a Solar cell – this is a device which converts light energy into electrical energy.

Light travels in straight lines – this is why shadows have straight edges.

#### Reflection of Light

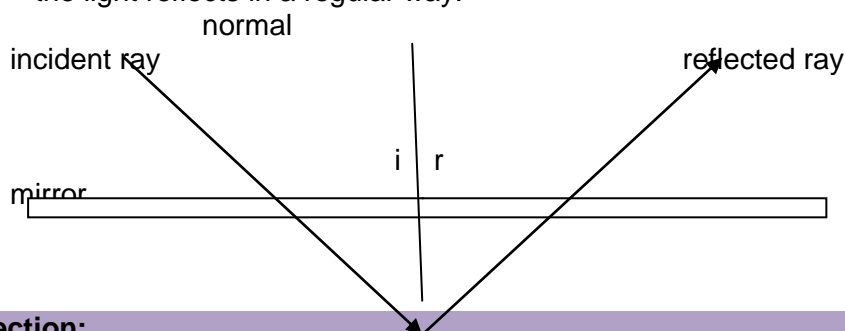
Reflection of light is the bouncing of light off an object

#### Plane Mirrors

There are two types of reflection

Diffuse reflection – when light shines onto a rough surface and is scattered in all directions (this is the case for most objects we see)

Regular reflection – when light shines onto a highly polished smooth surface – the light reflects in a regular way.



#### Laws of Reflection:

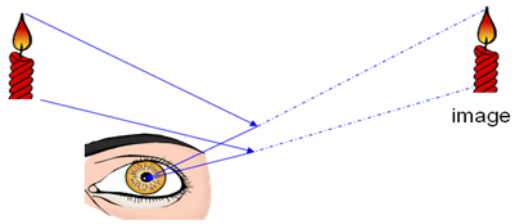
The incident ray, normal at the point of incidence and reflected ray all lie in the same plane

The angle of incidence = angle of reflection  $i = r$

Note: The angles of incidence and reflection are always measured from the normal (imaginary line perpendicular to the surface).

Image formation in a plane mirror:

Each ray reflects off the mirror obeying the laws of reflection ( $i = r$ ). To the observer looking at these reflected rays, the rays seem to have travelled in straight lines, so seem to have come from a point behind the mirror.



Note: the light rays are not actually passing through the mirror – they simply appear to have come from there. Such an image is called a virtual image

A real image is formed by the actual intersection of light rays. It can be formed on a screen.  
A virtual image is formed by the apparent intersection of light rays. It cannot be formed on a screen

Properties of image formed in plane mirror

<p>Image is</p> <ul style="list-style-type: none"> <li>Same size as object</li> <li>Same distance behind mirror as the object is in front</li> </ul>	<p>Virtual</p> <p>Laterally inverted(left to right)</p>
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**No Parallax:** When locating an image we use the method of no parallax. This means lining up the image with a search pin such that when you move your head from side to side they stay lined up (no relative motion)

### Spherical mirrors

There are two basic types of curved mirror  
 Concave mirror – curves inwards  
 Convex mirror- curves outwards

### Rules for image formation in a plane mirror

Angle of incidence = angle of reflection

Ray of light coming in parallel to principal axis is reflected out through the focus  
 Ray of light coming in through the focus is reflected out parallel to principal axis  
 Ray of light which comes in through the centre of curvature is reflected back along its own path

The image is formed where these rays meet

(These rules assume that the curvature of the mirror is small)

For a curved mirror the size, nature and location of the image depends on the size and location of the object.

### For a concave mirror

Object outside C	Image is real, inverted, diminished, located between F and C
Object at C	Image is real, inverted, same size as object, located at C
Object between C and F	Image is real, inverted, magnified, located outside C
Object at F	Image at infinity
Object inside F	Image is virtual, erect, magnified, located behind the mirror

Rays of light coming from a distant object all arrive at the mirror as a parallel beam and hence are reflected through the focus – the image of a distant object is always at the focus.

### Calculation of image position and size.

In performing these calculations the 'real is positive' convention is used. Real distances are given by positive numbers, virtual distances are given by negative numbers.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Where  $f$  = focal length,  $u$  = distance from object to mirror,  $v$  = distance from image to mirror.

$$\text{magnification } (m) = \frac{\text{image height}}{\text{object height}} = \frac{\text{image distance } v}{\text{object distance } u}$$

Uses of concave mirrors: reflector in headlights, make-up mirror, dentist mirror.

For a convex mirror:

The same rules for image formation apply, the difference being that the centre of curvature and the focus are now both behind the mirror, hence

Ray of light coming in parallel is reflected **as if it came from the focus**

Ray of light **heading for the focus** comes out parallel to the axis

The image formed in a convex mirror is always virtual, diminished and located behind the mirror.

**The same formulae can be used for a convex mirror remembering that  $v$  and  $f$  will always be negative in these calculations.**

Uses of convex mirrors:

As the image is always diminished, a convex mirror gives a wide field of view – hence used at concealed entrances, rearview mirror in car.



## Topic 2: Refraction of Light

Refraction is the bending of light on passing from one medium to another of differing density.

This occurs due to the different densities of the two media.

When light goes from less dense to more dense medium, it bends towards the normal.

When light goes from more dense to less dense medium it bends away from the normal.

### Laws of Refraction:

The incident ray, the normal at the point of incidence and the refracted ray are all in the same plane.

$$\frac{\sin i}{\sin r} = n, \quad (n = \text{refractive index of second medium with respect to first medium})$$

The refractive index is a ratio – it has no units.

The refractive index on going from medium A into medium B = 1/refractive index from B into A.

### Real and apparent depth:

When you look into a swimming pool it appears less deep than it really is. If you look at writing through a glass block the writing appears to be inside the block. These are both as a result of refraction.

$$n = \frac{\text{real depth}}{\text{apparent depth}}$$

The reason the light bends on entering a medium of different density is that the light slows down when it enters a denser medium. This can also be used as a basis for refractive index calculations

$$n = \frac{\text{Speed of light in air}}{\text{speed of light in medium}}$$

### Total internal reflection:

As light passes from a more dense to a less dense medium it bends away from the normal. As the angle of incidence increases so does the angle of refraction. Eventually an angle is reached where the light no longer escapes the block, but travels along the surface.

The angle of incidence for which the angle of refraction =  $90^\circ$  is called the critical angle,  $C$ .

If the angle of incidence is increased beyond the critical angle then the refracted ray bends back into the block. This is called Total Internal Reflection.

If you consider light travelling from more dense to less dense at the critical angle then

$$n = \frac{\sin i}{\sin r'} = \frac{\sin C}{\sin 90}$$

Looking at the problem the other way round, for light travelling into the more dense medium

$$n = \frac{\sin 90}{\sin C} = \frac{1}{\sin C}$$

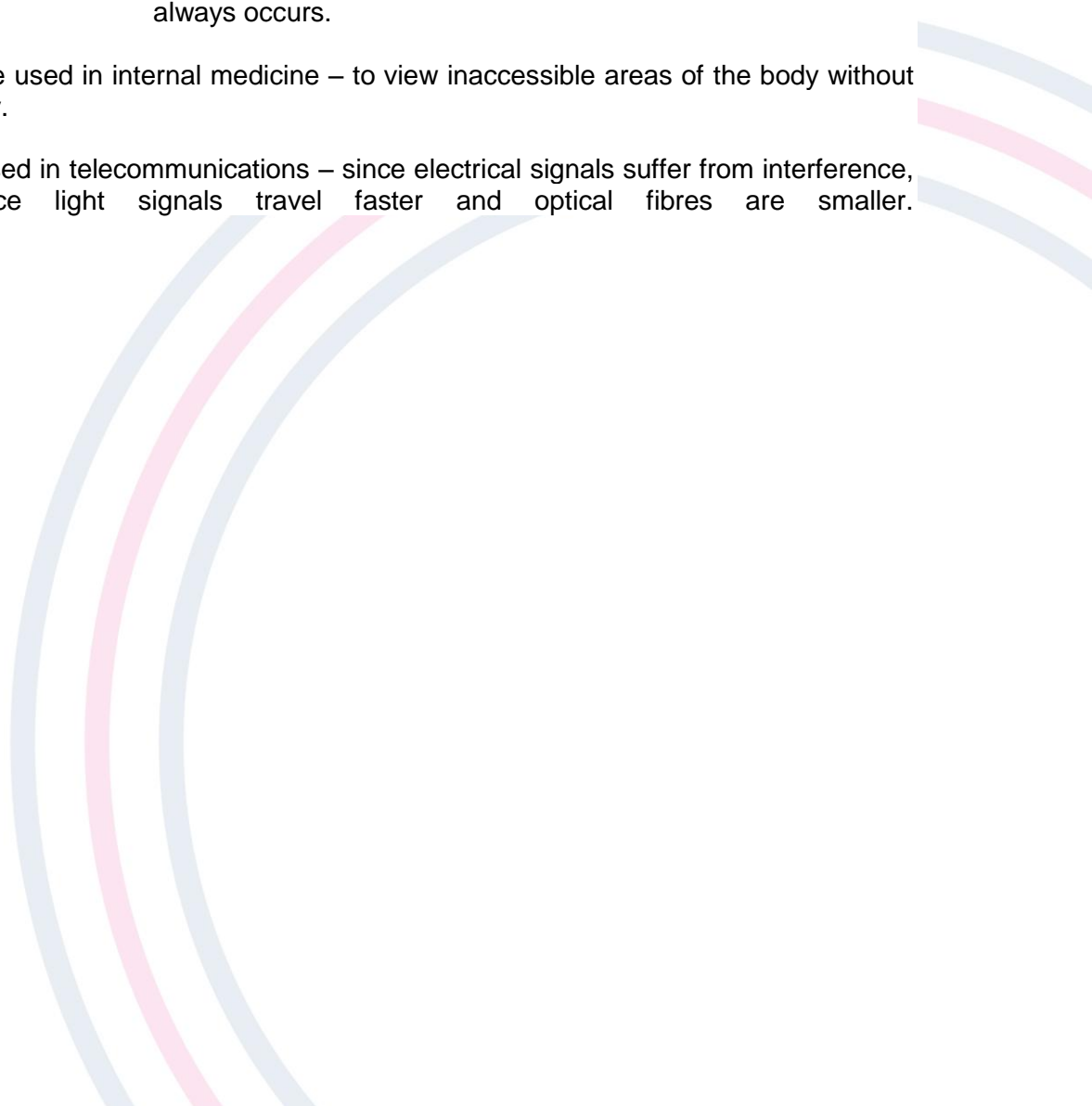
Total internal reflection has several applications. It can be used with a prism to turn light through  $90^\circ$  or through  $180^\circ$ . It is also used in optical fibres.

Optical fibres – are thin glass rods which can bend easily and so be used to carry light around corners. The light always hits the inside of the fibre at greater than the critical angle so total internal reflection occurs and the light travels along the fibre.

- Losses can occur if
- (i) the fibre is bent at too steep an angle – the light may not then hit at greater than the critical angle
  - (ii) Two fibres touch – light may then pass from one to another. This is prevented by coating each fibre with a layer of glass of lower refractive index. This ensures total internal reflection always occurs.

Optical fibres are used in internal medicine – to view inaccessible areas of the body without requiring surgery.

They are also used in telecommunications – since electrical signals suffer from interference, and also since light signals travel faster and optical fibres are smaller.



### Topic 3: Lenses

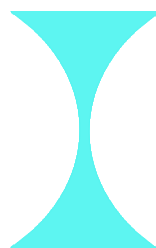
The most important topic in the study of refraction is that of lenses. Within a lens, the light bends on entering the lens and again on exiting the lens.

There are two main types of lense:

Converging (convex)



Diverging (concave)



Terminology:

As a lens has two refracting surfaces, a lens has two focal points, one on either side of the lens. (Note – for lenses we don't talk about C, we talk about the position 2F)

The midpoint of the lens is called the optical centre.

A straight line through the centre of the lens, at right angles to the surface, is called the principle axis.

#### Rules for image formation:

A ray of light which strikes the lens parallel to the principle axis travels through the lens and comes out through the focus on the other side.

A ray of light which passes through the focus on its own side before hitting the lens travels through the lens and comes out parallel to the principle axis

A ray of light which strikes the optical centre is undeviated.

The image is formed where these rays meet.

For a converging lens:

Object outside 2F	Image is real, inverted, diminished, located between F and 2F on the other side of the lens
Object at 2F	Image is real, inverted, same size as object, located at 2F on the other side of the lens
Object between 2F and F	Image is real, inverted, magnified, located outside 2F on the other side of the lens
Object at F	Image at infinity
Object inside F	Image is virtual, erect, magnified, located behind the object

For a diverging lens the image is always virtual, erect, smaller and on the same side of the lens as the object.

### Calculation of image position and size.

The same formulae can be applied to lenses as to mirrors. In performing these calculations the 'real is positive' convention is used. Real distances are given by positive numbers, virtual distances are given by negative numbers.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Where  $f$  = focal length,  $u$  = distance from object to lens,  $v$  = distance from image to lens.

$$\text{magnification } (m) = \frac{\text{image height}}{\text{object height}} = \frac{\text{image distance}}{\text{object distance}} = \frac{v}{u}$$

For a diverging lens:

The same rules for image formation apply, the difference being that the focus and image distance are now both negative.

### Power of a lens

The more common way of describing a lens is in terms of its power ( $p$ )

$$P = \frac{1}{f}. \text{ Measured in } m^{-1}.$$

Lens combinations

When two lenses are placed in contact the power of the system is given by

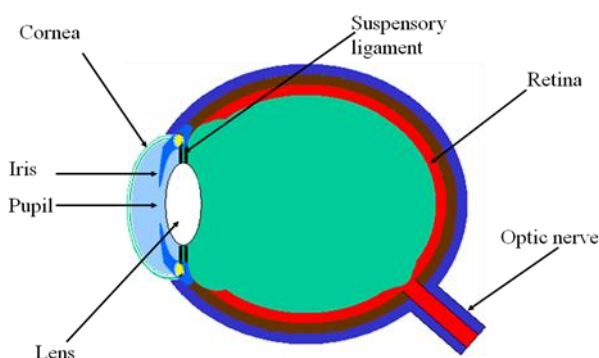
$$P_{\text{total}} = P_1 + P_2$$

Note: for converging lenses  $P$  is positive, for diverging lenses  $P$  is negative.

### The Eye

The single most important optical instrument is the human eye. The iris controls the amount of light that enters the eye through the opening called the pupil.

The focusing system of the eye consists of the cornea, aqueous humour, lens and vitreous humour.



The image is formed on the retina and the information transmitted to the brain via the optic nerve.

Note: the object is always outside the focus of the eye. Hence the image formed on the retina is always real and inverted. The brain translates this information into an image that is the right way up.

The eye needs to be able to focus on both distant objects and on nearby objects. It does this by changing the shape of the lens (thin for distant objects, fat for nearby objects).

The lens is surrounded by a ring of muscle called the ciliary muscle. For distant objects the muscle is relaxed, giving a thin lens. To view nearby objects the muscle contracts, creating a fatter lens. This ability of the lens to change shape as required is called **the power of accommodation**.

**Near point** = the nearest distance at which the eye can comfortably focus on an object

**Far point** = The furthest point at which the eye can focus on an object

### Defects of vision

In a short-sighted eye, even when the lens is at its thinnest, the light rays from a distant object form their image in front of the retina. This condition can be corrected with a diverging lens.

In a long-sighted eye, even when the lens is at its fattest, the light from a nearby object is brought to a focus behind the retina. This can be corrected by using a converging lens.

## Topic 4: Waves

A wave is a means of transferring energy from one point to another

Waves can be classified as mechanical – where the wave must have a medium to travel through, or electromagnetic, which can travel through a vacuum.

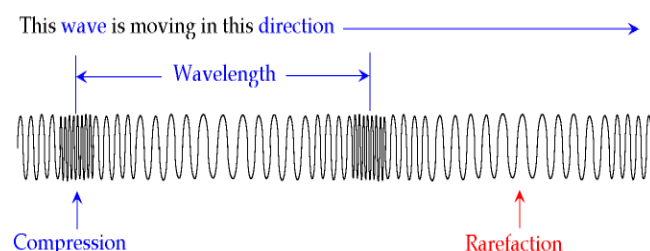
A travelling wave is a wave travelling out from a source, transferring the energy from the source to other places through which it passes.

A travelling wave can be one of two types

Transverse wave = where the direction of vibration is perpendicular to the direction of motion of the wave. Light travels as a transverse wave



Longitudinal wave = where the direction of vibration is parallel to the direction of motion of the wave. Sound travels as a longitudinal wave.



If the same motion is repeated periodically the wave is called a periodic travelling wave

### Terminology

Amplitude (A)= maximum displacement from equilibrium (m)

Wavelength ( $\lambda$ )= Distance from one point on a wavefront to the same point on the next wavefront (m)

Frequency (f)= number of complete wavefronts passing a point per second. (Hz)

### The wave equation

For any periodic wave, of frequency  $f$ , wavelength  $\lambda$  and travelling at speed  $c$  the following equation holds

$$C = f\lambda$$

## Properties of a Wave

All waves have the following properties:

Reflection, refraction, Diffraction and interference.

- Reflection of waves- bouncing of a wave off a barrier
- Refraction- The change in direction of a wave as it travels from a medium of one density to another density.
- Diffraction- the spreading out of a wave into a region beyond a barrier
- Interference – when two waves meet a new wave is formed. The new amplitude is the algebraic sum of the two original amplitudes

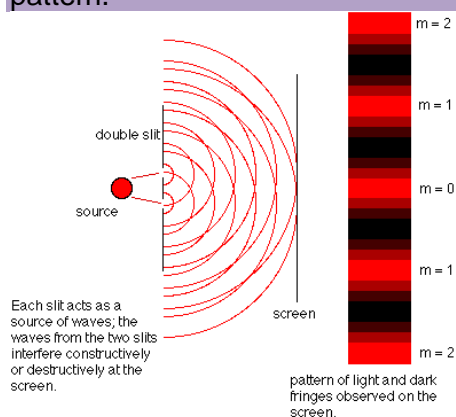
If the resulting amplitude is bigger than the original amplitudes the waves are said to undergo **constructive interference**, if the resulting amplitude is smaller than the original amplitude the waves are said to undergo **destructive interference**.

## Coherent sources

Two sources of periodic waves are said to be coherent if they are in phase( crests of both waves meeting, troughs meeting) or have a constant phase difference between them(one lags the other by a full wavelength or two full wavelengths etc.)

### Interference pattern

When waves from coherent sources meet the resulting wave pattern is called an interference pattern.



Looking along line  $C_0$  crest is meeting crest and trough is meeting trough – constructive interference- antinodal line

Looking along line  $D_1$  crest is meeting trough and trough is meeting crest – destructive interference – nodal line.

## Polarisation:

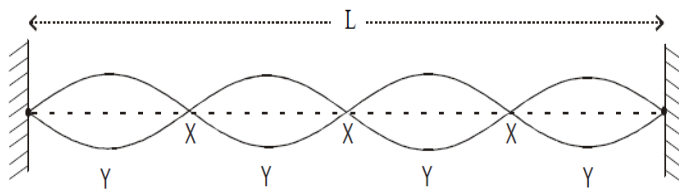
A Polaroid is a piece of transparent material which consists of long strings of molecules lined up next to each other. |As such, between the molecules there exist slits, parallel to each other.

Normal light is unpolarised – vibrates in all planes. When this light reaches the Polaroid only the light vibrating in the same plane as the slits in the Polaroid will get through – all other light is stopped. The light is now said to be plane polarized. If a second Polaroid is lined up with its slits parallel it will have no effect, if its slits are perpendicular no light gets through.

**NOTE: only transverse waves can be polarized.**

Stationary waves:

If a rope is held fixed at one end and the other end vibrated a stationary wave pattern can be set up.



Some points will be at rest (nodes=x) while other points will vibrate with a maximum amplitude(antinodes=y). The wave remains stationary.

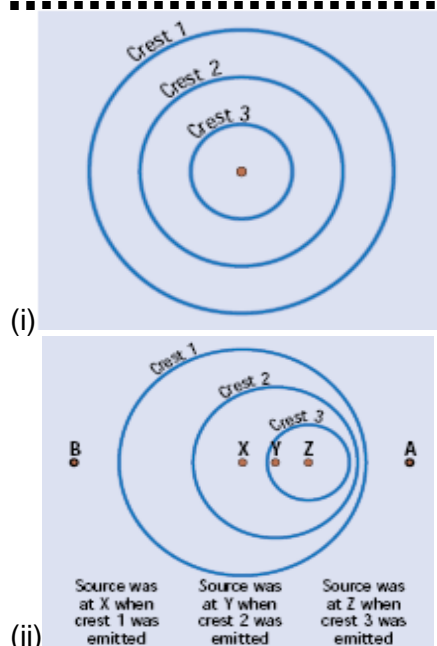
Distance between two consecutive nodes (or antinodes) =  $\frac{\lambda}{2}$

Distance between node and next antinode =  $\frac{\lambda}{4}$

Stationary waves can be set up in both transverse and longitudinal waves.

\*\*\*Doppler effect:

The apparent change in frequency of a wave due to the motion of the source of the wave.



In diagram (i) the source is stationary so all observer will observe the same distance between crests (i.e. the same wavelength)



In diagram (ii) the source is moving between emitting wavefronts so the observer at A observes wavefronts closer together than the stationary case while observer at B observes wavefronts further apart than the stationary case. Hence A observes a shorter wavelength (greater frequency) wave while the observer at B observes a longer wavelength (smaller frequency) wave.

Source approaching observer

$$f' = \frac{fc}{c - u}$$

Source moving away from observer

$$f' = \frac{fc}{c + u}$$

$f'$  = observed frequency,  $f$  = frequency emitted,  $c$  = speed of wave,  $u$  = speed of source.



## Topic 5: Sound as a wave

Sound is caused by a vibrating object. The sound travels away from this object as a longitudinal wave.

The vibrating object causes air molecules around it to vibrate, this vibration travels through the air as a series of compressions and rarefactions. When the wave hits the eardrum, the eardrum starts to vibrate with the same frequency – i.e the frequency of the source of the sound.

Proof that sound is a wave – sound shows all the properties of a wave – can be reflected (echo) refracted (heard more clearly on cold night than hot day due to bending of sound in different density air masses), diffracted (sound travels around corners) and shows interference patterns.

### Interference of sound:

If two speakers are set up 1m apart and you walk slowly along a line in front of them you will hear louder and quieter areas, due to constructive and destructive interference.

If you strike a tuning fork and rotate it near your ear you will hear a pattern of loud-quiet-loud-quiet etc due to interference between the two waves being produced by vibration of the two prongs of the fork.

Terminology:

Overtones – frequencies which are multiples of a certain frequency

Characteristics of a note:

- Loudness – depends on amplitude of the wave
- Pitch – depends on the frequency of the wave
- Quality – depends on the number and strengths of overtones.

Frequency limits of audibility – highest and lowest frequencies that can be heard by the human ear (20 Hz – 20kHz). (The upper limit decreases with age)

Resonance – the transfer of energy between two bodies having the same natural frequency (natural frequency – objects that are free to vibrate tend to do so at certain preferred frequencies called their natural frequencies)

\*\*\*Sound intensity – at a point is the rate at which sound energy is passing through unit area at right angles to the direction in which the sound is travelling ( $I = \text{Power}/\text{Area}$ ) – measured in watts per metre squared ( $\text{W m}^{-2}$ )

\*\*\*Threshold of hearing – the smallest sound intensity that the average human ear can detect at a frequency of 1kHz.

The sound level intensity – is a scale measuring the amount of sound energy per second carried into your ear. Because this can vary over a large range it is more convenient to use a decibel scale which allows you to represent a large range with a much smaller one. The relationship between sound intensity and sound intensity level is beyond the scope of the

leaving cert course but you need to be aware that **when the sound intensity doubles, the sound intensity level increases by 3dB.**

### Frequency response of the ear

The ear is more sensitive to some sounds than others. The ear responds best to sounds between 2000Hz and 4000Hz.

Hence, even though two sounds can have the same amount of energy, the ear will hear one as louder than the other depending on their frequency. A sound level meter is a device which mimics the response of the ear. It measures sound intensity level but includes a factor for the frequency response of the ear. It uses a decibel adapted scale (dBA).

### Noise Pollution

Very loud noises can immediately and permanently damage your hearing. Long term exposure to lower levels of noise can also damage hearing. Employers have a responsibility to protect hearing in their employees.

$\mu$   
\*\*\*Vibrations on a stretched string.

If a string is plucked, it can vibrate in a number of ways. The simplest mode of vibration is with a node at both ends (fixed points) and an antinode in the centre. – this string is vibrating at its fundamental frequency.

The string may also be made to vibrate in other modes.

Factors effecting the frequency of a stretched string:

Experimentally it can be shown that

$$f \propto 1/l$$

$$f \propto \sqrt{T}$$

$$f \propto \frac{1}{\sqrt{\mu}}$$

Linking these factors we get that the factors which determine the frequency of a string are given by

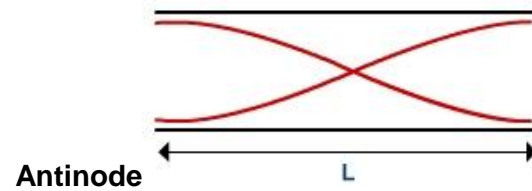
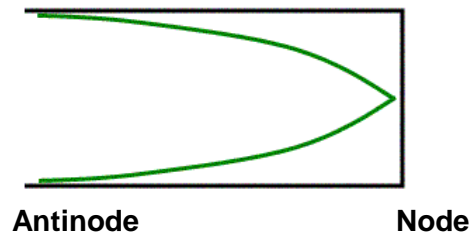
$$f = \frac{1}{2l} \sqrt{\frac{T}{\mu}}$$

- f = Frequency of the string
- l = length of the string
- T = Tension in the string
- $\mu$  = mass per unit length of the string

These dependencies can be experimentally verified using a sonometer.

### Closed and open pipes

If a pipe is closed at one end, open at the other, the simplest wave that can be set up in the pipe has a node at the closed end and antinode at the open end.

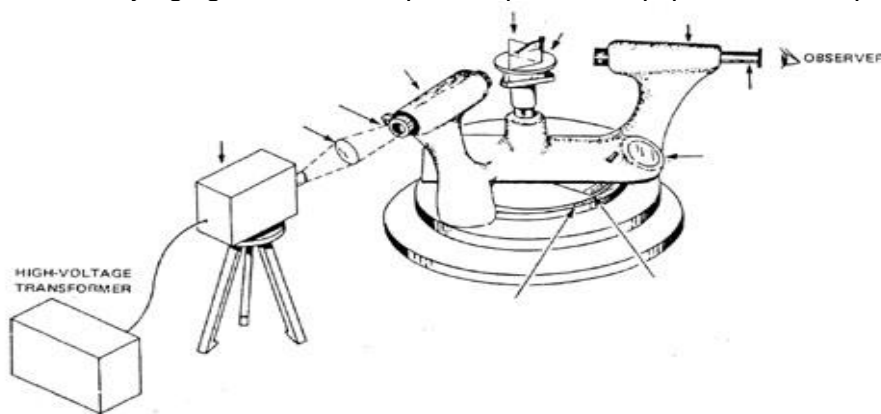


## Topic 6: Light as a wave

Historically light was originally thought to be a stream of fast moving particles . In the middle of the 17<sup>th</sup> century Huygens, a Dutch scientist, proposed that light was a wave. However he was unable to show all the wave properties. In 1802 Thomas Young performed an experiment (Young's slits experiment) that demonstrated the interference of light and so the belief became that light was a wave. This view was called into question at the beginning of the 20<sup>th</sup> century with the observation of the photoelectric effect.

### The Spectrometer:

When studying light the most important piece of equipment is the spectrometer.



This consists of:

The collimator – this consists of two tubes. The outer one has a convex lens at one end, the inner one has a slit at the other end. The distance from slit to lens = focal length of the lens. This means that light from the slit leaves the collimator as a parallel beam.

The telescope – this is an astronomical telescope which can be adjusted to receive parallel light from the collimator.

The turntable – free to rotate in circle. This has a vernier scale attached so that the angle can be read accurately.

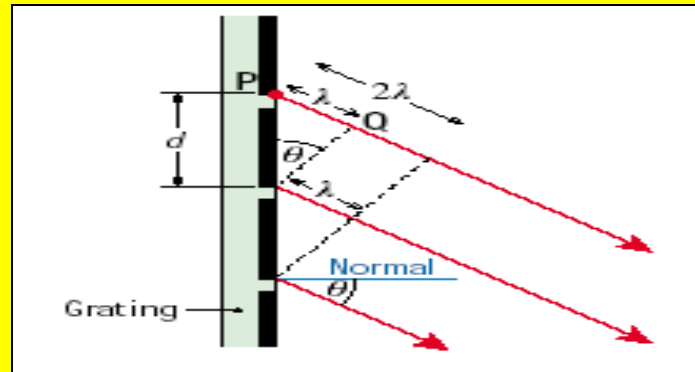
### The Diffraction Grating

This is a more complicated version of Young's slits. It consists of a piece of transparent material with a large number of parallel lines drawn on it. The grating constant = distance between two adjacent slits =  $1/\text{no of lines per mm}$ .

When light falls on a grating, the light passes through the slits and the emerging wavefronts interfere.

To derive the grating formula  $d \sin \theta = n \lambda$

Consider light incident perpendicularly on a grating. A series of bright fringes will be seen on the screen



### Position 1

Considering the bright spot directly opposite the gap.

The wave from P and the wave from one spacing below start off in phase. They travel the exact same distance to the screen opposite so they are still in phase when they arrive – constructive interference – a bright spot is seen.

Considering the bright spot at position 1.

Now the wave from P has to travel further than the wave from one spacing below. If the angle to position 1 is  $\Theta$ , this extra path =  $d \sin \Theta$ .

If a bright spot is observed at 1, the waves must be in phase at 1. Since the waves leave the grating in phase, the only way this can occur is if the extra path is  $\lambda$ , or  $2\lambda$  or  $3\lambda$  or  $n\lambda$  (where  $n = \text{integer}$ ).

Thus, for a bright spot  **$n\lambda = d \sin \Theta$**

NB The experiment to measure the wavelength of monochromatic light is a very important experiment. If describing this experiment you must know the adjustments which have to be made to the spectrometer before use.

### Adjustments to spectrometer.

- Adjust the eyepiece so cross hairs are in focus
- Focus telescope on distant object (for parallel light)
- Illuminate slit of collimator and adjust width to give narrow slit.
- Adjust position of slit until clear image is seen.
- Level the turntable.

### Dispersion of light.

Dispersion is the breaking up of light into its constituent colours. If you pass white light through a prism or grating each different wavelength is bent by a different amount so the white light splits into a spectrum from the longest wavelength red to the shortest wavelength

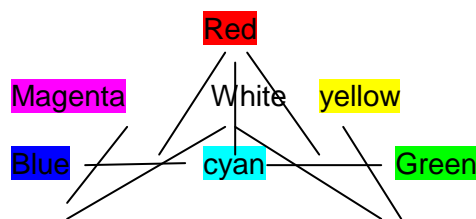
violet. Dispersion is responsible for the colours of a rainbow. This occurs when sunlight enters a raindrop and is refracted. This refraction causes the different wavelengths to be dispersed by different amounts giving a rainbow (spectrum).

## Colour Mixing

Primary colours = red, blue and green

Secondary colours = any two primary colours mixed in equal intensity

Complimentary colours = primary colour + secondary colour opposite – together give white light



Electromagnetic spectrum.

White light is just a small section ( $4 \times 10^{-7} \text{ m} - 7 \times 10^{-7} \text{ m}$ ) of the electromagnetic spectrum.

All electromagnetic waves have the following properties:

Reflection

Refraction

Polarisation. All obey the wave equation  $c = f \lambda$

Diffraction

Interference

They only differ by wavelength:

Electromagnetic spectrum	Gamma Ray	X-ray	UV	visible	Infrared	microwaves	TV and radio waves
Approx wavelength	0.01nm	1nm	0.1 $\mu\text{m}$	0.4 $\mu\text{m}$ – 0.7 $\mu\text{m}$	0.01mm	1cm	1km

Of particular interest in the electromagnetic spectrum are the parts bordering on visible light.

Ultraviolet = wavelengths just shorter than violet.

Properties – causes certain substances to fluoresce

- Effects a photographic plate
- Causes sunburn
- Causes photoemission
- Stopped by normal glass but not by quartz glass

Detergents contain fluorescent materials which cause the clothes to glow white in sunlight.

The sun produces UV. The ozone in the earth's upper atmosphere prevents much of this UV from reaching the earth.