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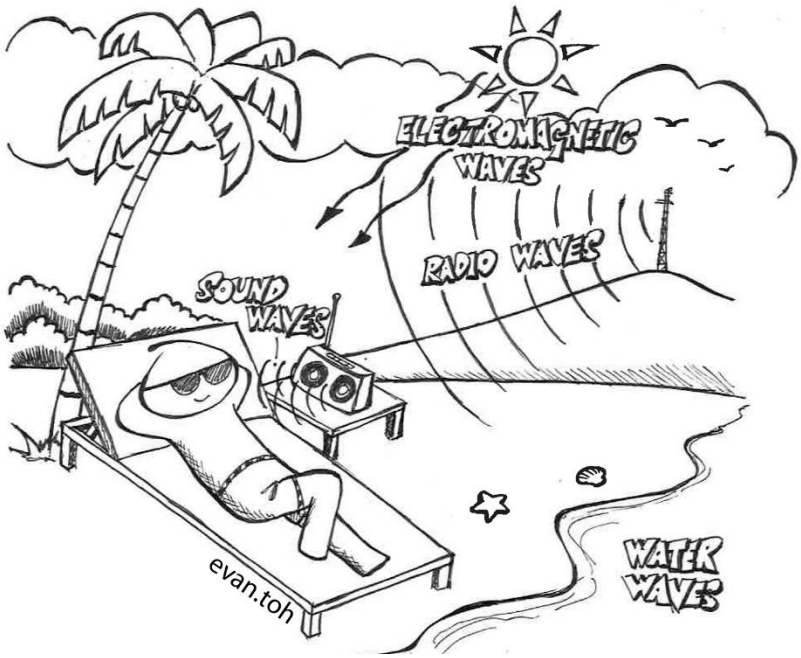
IGCSE Physics



Unit 4 – Waves

Name: .....

Class: ..... **Date:**.....

Summary

Lesson	Objectives : Students will be assessed on their ability to
Wave Properties	• describe longitudinal and transverse waves in ropes; springs and water where appropriate state the meaning of amplitude, frequency, wavelength and period of a wave. • recall that waves transfer energy and information without transferring matter use the relationship between frequency and time period: $f = 1/T$. • use the above relationships in different contexts including sound waves and electromagnetic waves.
Sound Waves	• recall that sound waves are longitudinal waves which can be reflected, refracted and diffracted • recall that the frequency range for human hearing is 20 Hz – 20 000 Hz. • appreciate that the loudness of a sound depends on the amplitude of vibration, • describe how to measure the speed of sound in air by a simple direct method.
Visualising Sound Waves	• understand how an oscilloscope and microphone can be used to display a sound wave, • use an oscilloscope to determine the frequency of a sound wave and appreciate that the pitch of a sound depends on the frequency of vibration
Wave Equation	• recall and use the relationship between the speed, frequency and wavelength of a wave: wave speed = frequency × wavelength, $v = f \times \lambda$
The EM Spectrum	• understand that light is part of a continuous electromagnetic spectrum. • Recall the order of the EM spectrum – including the visible colours. • Recall the uses of the various EM radiations. • Recall the dangers of high frequency EM waves.
Diffraction	• understand that waves can be diffracted through gaps or when they pass an edge, and that the extent of diffraction depends on the wavelength and the physical dimension of the gap.
Reflection	• recall that light waves are transverse waves which can be reflected. • recall that the angle of incidence equals the angle of reflection. • construct ray diagrams to illustrate the formation of a virtual image in a plane mirror.
Refraction	• describe experiments to investigate the refraction of light, using rectangular blocks, semicircular blocks and triangular prisms. • recall and use the relationship between refractive index, angle of incidence and angle of refraction

	$n = (\sin i) / (\sin r)$. • describe an experiment to determine the refractive index of glass, using a glass block.
Total Internal Reflection	• recall the meaning of critical angle *c* • recall and use the relationship between critical angle and refractive index: $\sin c = 1/n$
Communication Systems	• describe the role of total internal reflection in transmitting information along optical fibres and in prisms. • understand the difference between analogue and digital signals.

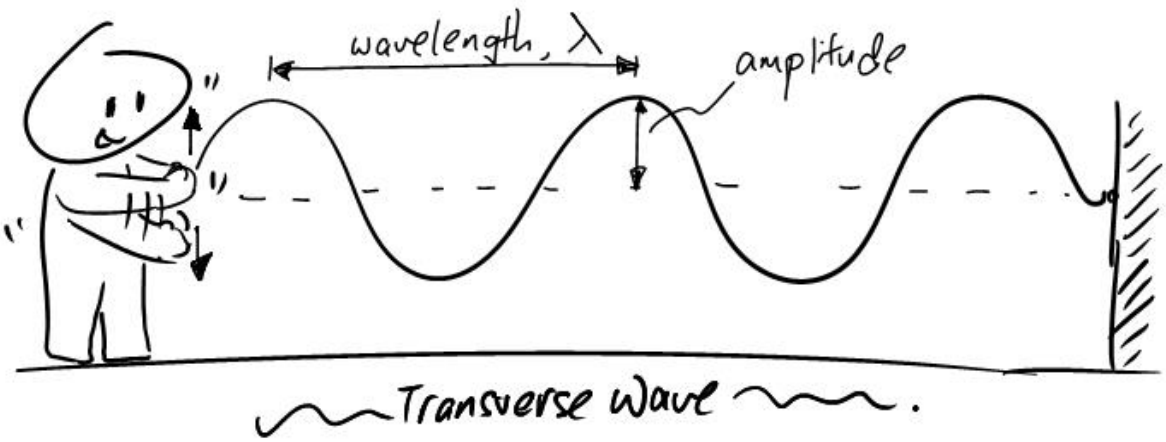
1 – Wave Properties

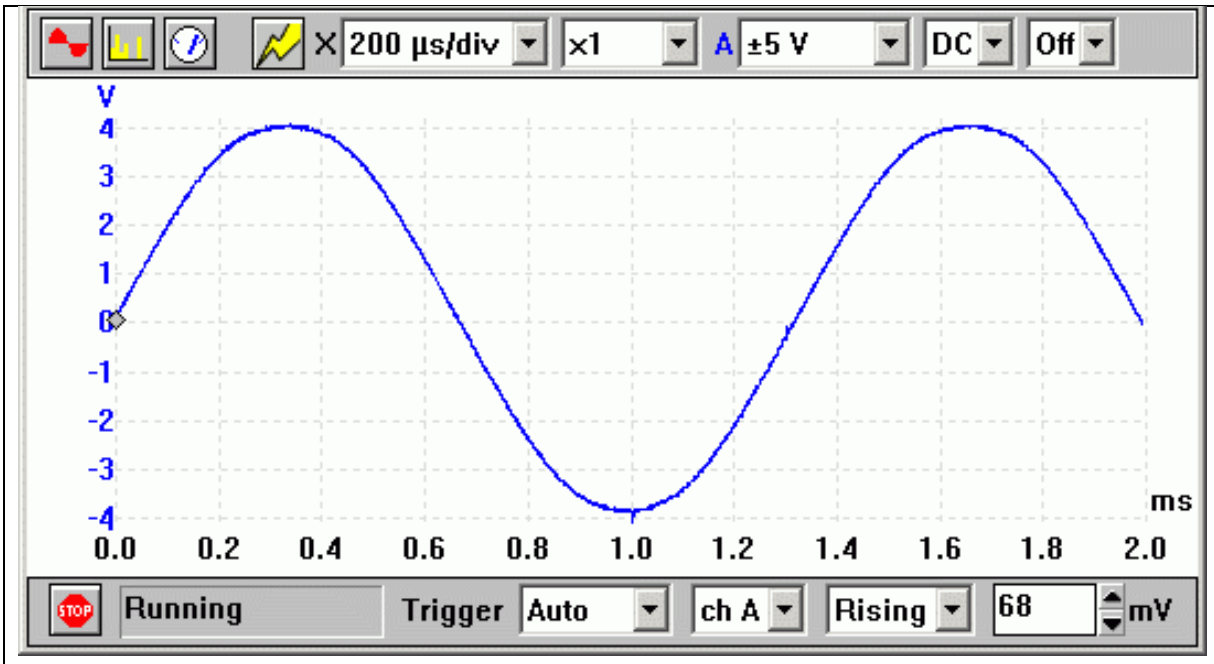
Objectives:

- describe longitudinal and transverse waves in ropes; springs and water where appropriate state the meaning of amplitude, frequency, wavelength and period of a wave.
- recall that waves transfer energy and information without transferring matter use the relationship between frequency and time period:

$$f = \frac{1}{T}.$$

- use the above relationships in different contexts including sound waves and electromagnetic waves.




X 200 µs/div
x1
A ±5 V
DC
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4
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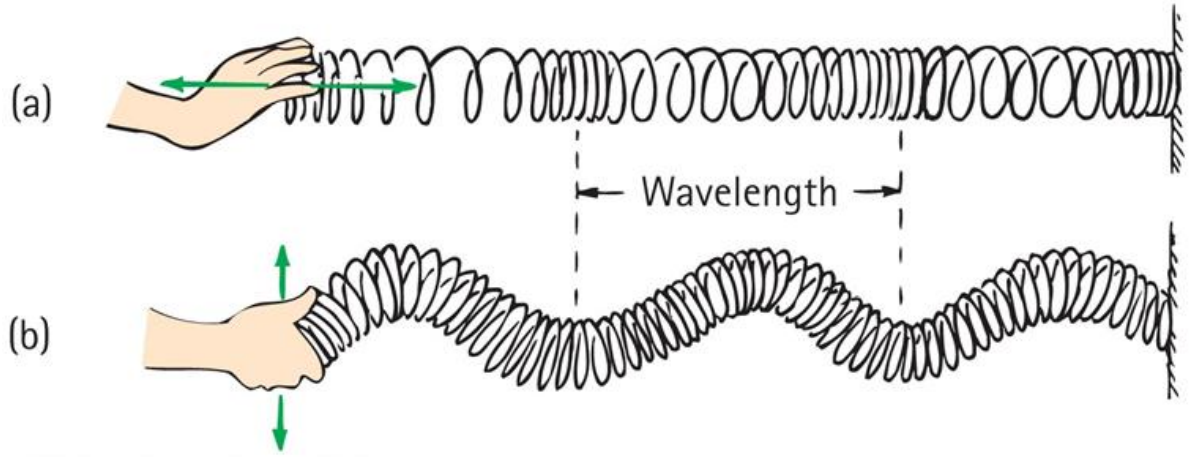
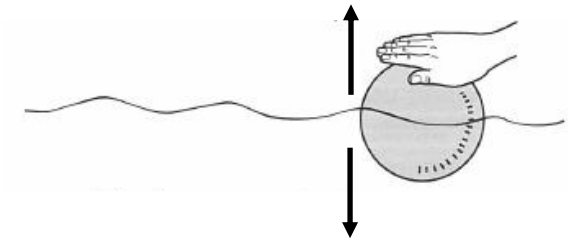

(a)
Wavelength
(b)

CW 4.1 - Wave Properties

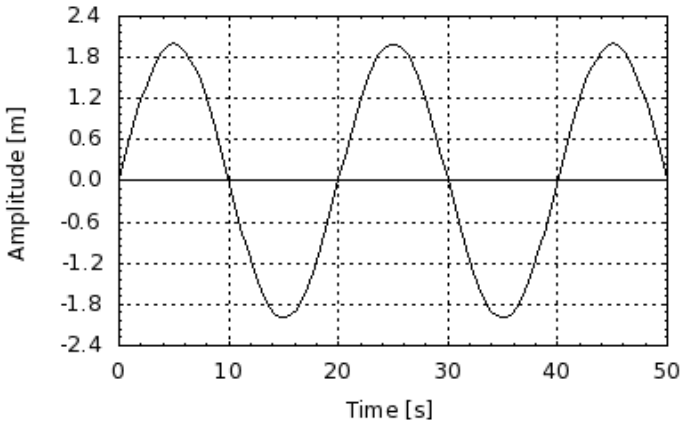
1. What is the difference between a longitudinal wave and a transverse wave? (1)



2. A man is pushing a ball up and down in a swimming pool to create waves on the surface as shown. If he pushes the ball up and down at a more rapid rate what happens to:

   a) The frequency of the waves produced? (1) .....
   b) The wavelength of the waves produced? (1) .....
   c) The speed of the waves produced? (1) .....
   d) The period of the waves produced? (1) .....

3. How could the man increase the amplitude of the waves? (1)



4. The graph above represents a wave.
   a) What is the period of this wave? (1) .....
   b) Calculate the frequency of the wave. (2)

   c) On the diagram above, indicate the amplitude of the wave. (1)
   d) On the diagram above, carefully draw a wave that has twice the frequency and half the amplitude of the wave shown. (2)

2 – Sound Waves

Objectives:

- recall that sound waves are longitudinal waves which can be reflected, refracted and diffracted
- recall that the frequency range for human hearing is 20 Hz – 20 000 Hz
- appreciate that the loudness of a sound depends on the amplitude of vibration,
- describe how to measure the speed of sound in air by a simple direct method.

LAB 4.2 - Measuring the Speed of Sound

Aim: to measure the speed of sound in air.

Method:

Diagram:

Data: distance = …….. m

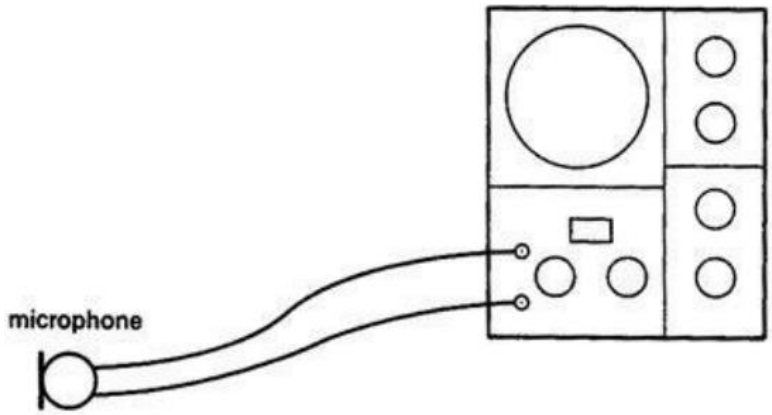
Test	Time (s)
1	
2	
3	
Average	

Analysis:

3 – Visualising Sound Waves

Objectives:

- understand how an oscilloscope and microphone can be used to display a sound wave,
- use an oscilloscope to determine the frequency of a sound wave and appreciate that the pitch of a sound depends on the frequency of vibration



LAB 4.3 - Using an Oscilloscope

Aim: To be able to measure the period and frequency of a sound wave using an oscilloscope.

Method 1:

- Hook up a speaker to a signal generator. Set the frequency to a value such as 250 or 300 Hz.
- Run the iPad Oscilloscope app – use the "run" function to freeze the image.
- Use the time base "TB" to determine the time interval between two crests – be as accurate as possible!
- Use f = 1 / T to determine the frequency, compare with the value from the signal generator.

Data:

Signal Generator frequency (Hz)	Measured Period (s)	Measured Frequency (Hz)

Conclusion and Evaluation:

Method 2:

- Repeat the experiment, but this time use a microphone connected to a real oscilloscope.
- Use the trigger function to try to stabilize the trace. This is very fiddly.

Data:

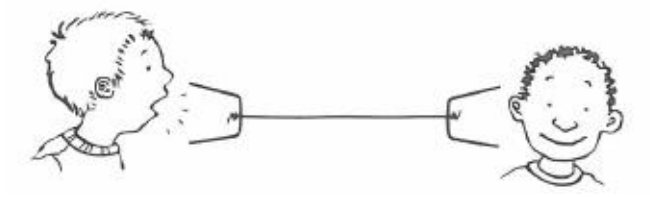
Signal Generator frequency (Hz)	Measured Period (s)	Measured Frequency (Hz)

Conclusion and Evaluation:

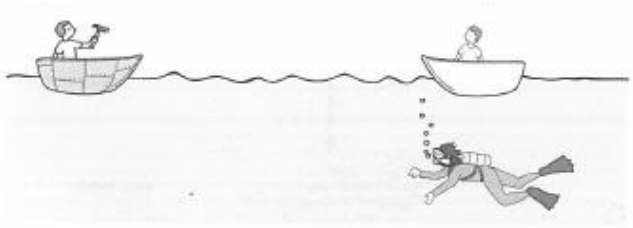
CW 4.4 - Sound Waves

1. Explain why the speed of sound in a vacuum is zero. (1)

2. An old-fashioned child's toy (before iphones…) was the string telephone. Explain how the sound is transmitted from one cup to the other. (1)



3. Two people are in boats. They are separated by 2000 m as shown in the diagram. How long does it take for sound to travel from one person to another? (2)

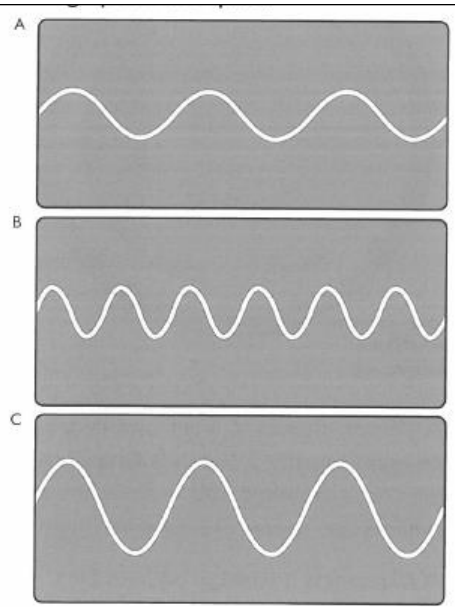


4. The diver is under the second boat. The speed of sound in water is 1500 m/s. How much sooner does he hear the sound? (2)

5. A bat sends out an ultrasound pulse as echo location towards a wall.
   a) What is ultrasound? (1)

   b) If the pulse returns 0.4 seconds after it was sent, how far is the bat from the wall? (2)

6. Three sound wave traces are shown. Caption each trace with a description of the sound (loud/quiet, high pitch/low pitch) (3)

4 – The Wave Equation

Objectives:

- recall and use the relationship between the speed, frequency and wavelength of a wave: wave speed = frequency × wavelength,

$$v = f \lambda$$

CW 4.5 - The Wave Equation

1. One day, swimming off South Shore it is noticed that the wavelength of the waves is 4.0 m. The swimmer bobs up and down every 2.0 seconds.

   a) Calculate the frequency of the waves (2)

   b) Use the wave equation to determine the speed of the waves. (2)

2. Sound travels at 340 m/s. If the frequency of middle C is 256 Hz, what is the wavelength? (2)

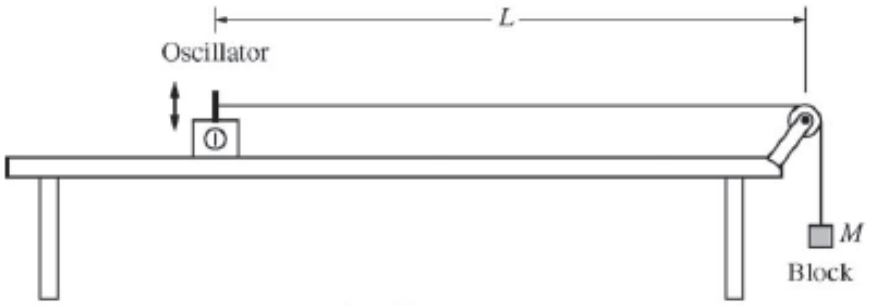
3. Upper C has a frequency of 512 Hz. What is the wavelength of this note? (2)

4. A medical ultrasound probe produces waves of a frequency of 25 kHz. What is the wavelength? (2)

5. HOTT FM has a frequency of 107.5 kHz. What is the wavelength of this wave given that radio waves travel at the speed of light, 3×10^8 m/s? (2)

LAB 4.6 - Measuring the Speed of Waves on String

Aim: to use the wave equation to determine the speed of waves on a vibrating string.



Method:

- Hang about 200 g on to the end of the string.
- Slowly change the frequency of the signal generator until you can see steady 'loops' in the string. These are called the harmonics. If there are two loops, you have got the second harmonic, three means the third harmonic etc. It is very difficult to find the first harmonic.
- Use a meter ruler to measure the wavelength (i.e. the length of two loops)
- Use the wave equation to determine the speed of the wave.

Data:

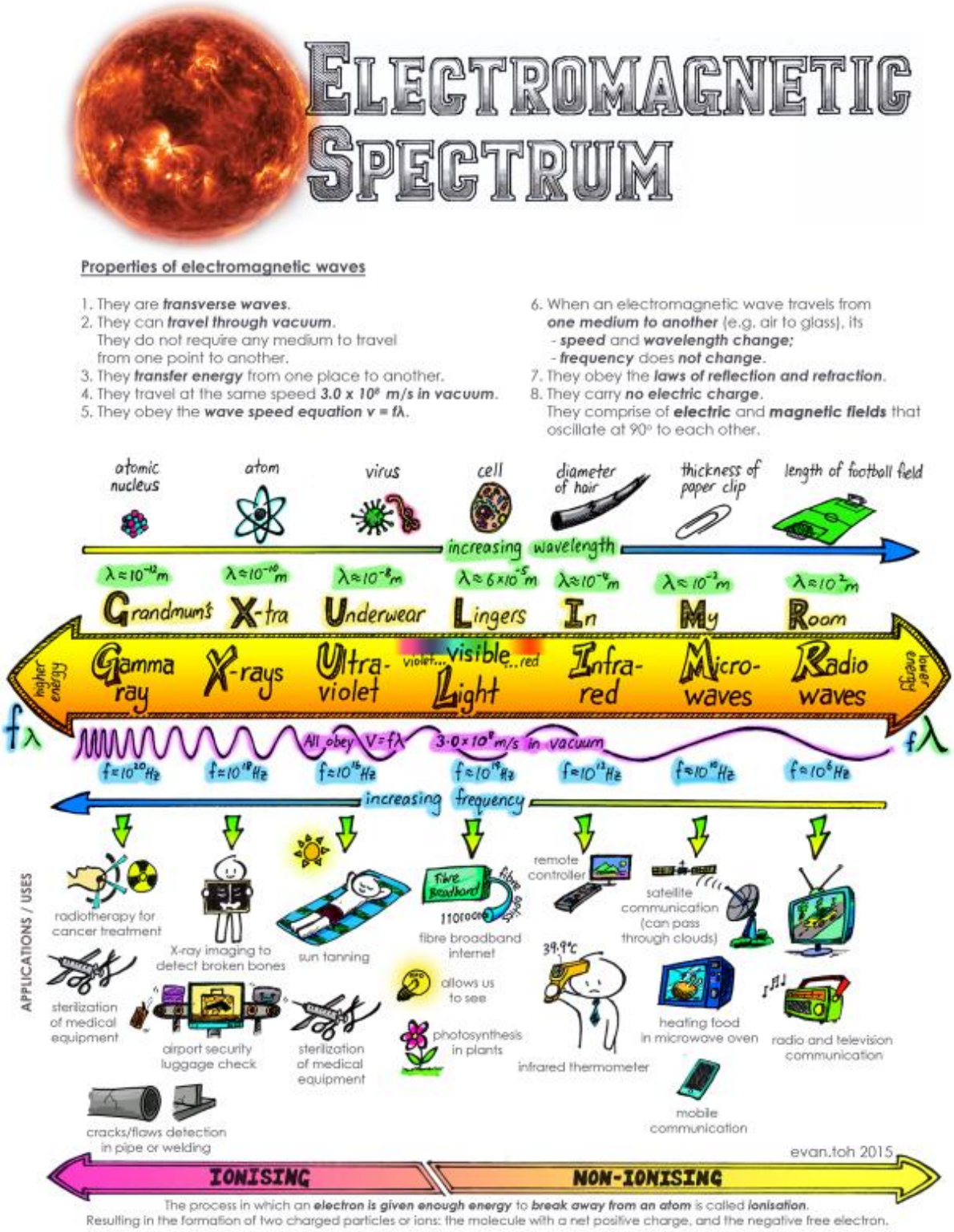
Frequency (Hz)	Wavelength (m)	Speed (m/s)

Evaluation:

5 – The EM Spectrum

Objectives:

- understand that light is part of a continuous electromagnetic spectrum.
- Recall the order of the EM spectrum – including the visible colours.
- Recall the uses of the various EM radiations.
- Recall the dangers of high frequency EM waves.


ELECTROMAGNETIC SPECTRUM
Properties of electromagnetic waves
1. They are transverse waves.
2. They can travel through vacuum. They do not require any medium to travel from one point to another.
3. They transfer energy from one place to another.
4. They travel at the same speed 3.0 x 10^8 m/s in vacuum.
5. They obey the wave speed equation v = fλ.
6. When an electromagnetic wave travels from one medium to another (e.g. air to glass), its - speed and wavelength change; - frequency does not change.
7. They obey the laws of reflection and refraction.
8. They carry no electric charge. They comprise of electric and magnetic fields that oscillate at 90° to each other.
atomic nucleus
atom
virus
cell
diameter of hair
thickness of paper clip
length of football field
increasing wavelength
λ≈10^-12 m
λ≈10^-10 m
λ≈10^-8 m
λ≈6×10^-5 m
λ≈10^-6 m
λ≈10^-2 m
λ≈10^2 m
Grandmum's X-tra Underwear Lingers In My Room
higher energy
Gamma ray
X-rays
Ultra-violet
violet... visible ...red
Light
Infra-red
Micro-waves
Radio waves
lower energy
fλ
All obey V=fλ
3.0×10^8 m/s in vacuum
f≈10^20 Hz
f≈10^18 Hz
f≈10^16 Hz
f≈10^14 Hz
f≈10^13 Hz
f≈10^10 Hz
f≈10^6 Hz
increasing frequency
APPLICATIONS / USES
radiotherapy for cancer treatment
X-ray imaging to detect broken bones
sun tanning
fibre broadband internet
remote controller
satellite communication (can pass through clouds)
sterilization of medical equipment
airport security luggage check
sterilization of medical equipment
allows us to see
photosynthesis in plants
infrared thermometer
heating food in microwave oven
radio and television communication
mobile communication
cracks/flaws detection in pipe or welding
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IONISING
NON-IONISING
The process in which an electron is given enough energy to break away from an atom is called ionisation.
Resulting in the formation of two charged particles or ions: the molecule with a net positive charge, and the negative free electron.
Ionisation is harmful to living cells. It results in mutation and destruction of the living cells, which might lead to cancer. (e.g. over-exposure to ultraviolet leads to skin cancer)
- Exposure to electromagnetic radiation primarily causes heating effects.
- Electromagnetic waves are characterised by their wavelength, frequency and energy. The waves consists of very small packets of energy called photons.
- The higher the frequency, the larger the amount of energy in each photon.

CW 4.7 - The EM Spectrum

1. Give 3 properties (features) that are common to ALL electromagnetic waves. (1)

2. Name a type of electromagnetic radiation that:

   a) Visible to the eye (1) .....
   b) Used by radar (1) .....
   c) Emitted by hot objects (1) .....
   d) Can cause sunburn/skin cancer (1)

      .....
   e) Can pass through dense materials (1)

      .....
   f) Used by wifi and cell phones (1)

      .....

3. A marine VHF radio produces waves of a Very High Frequency. Roughly 100 MHz.
   a) What is this frequency in Hertz? (use standard form) (1)

   b) What is the wavelength? (2)

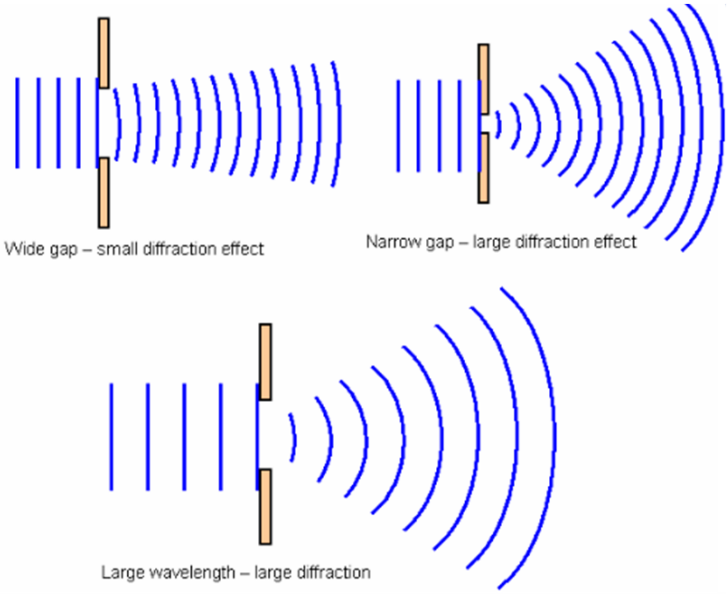
4. Gamma waves are emitted from the nucleus of the atom and have a wavelength comparable to the diameter of the nucleus. (1×10^{-14}m).
   a) Calculate the frequency. (2)

   b) How many times higher is this frequency than that of a VHF radio? (2)

6 – Diffraction

Objectives:

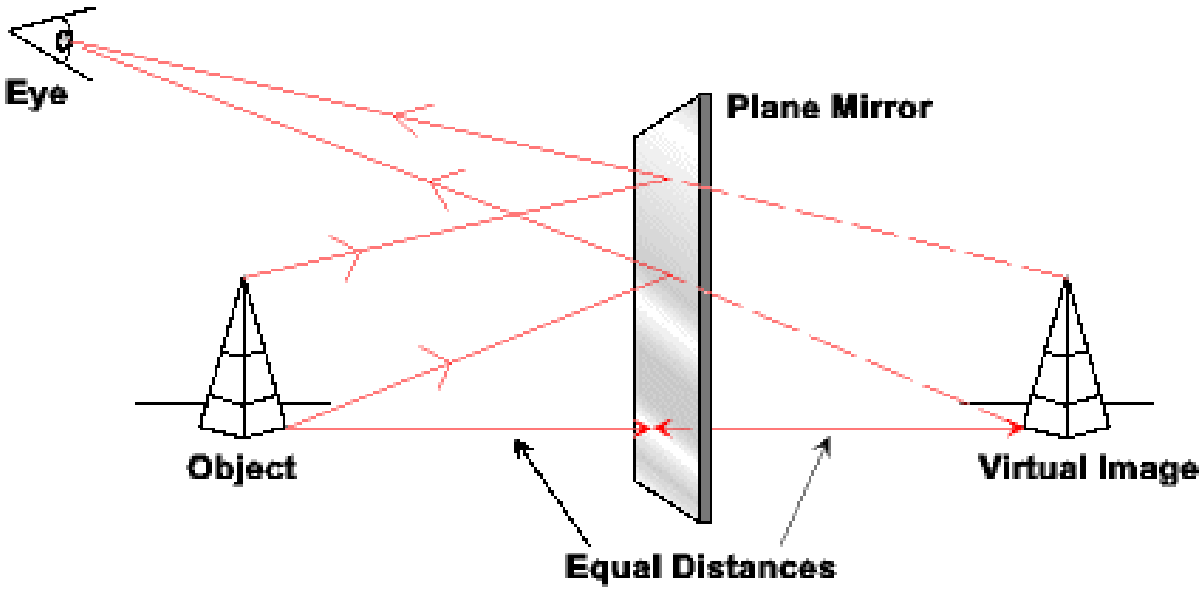
- understand that waves can be diffracted through gaps or when they pass an edge, and that the extent of diffraction depends on the wavelength and the physical dimension of the gap.



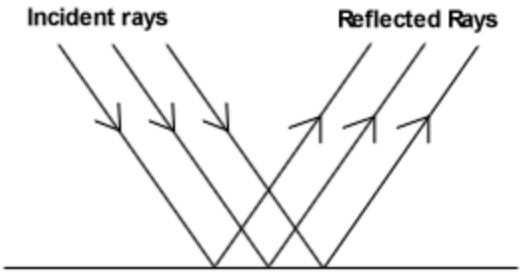
7 – Reflection

Objectives:

- recall that light waves are transverse waves which can be reflected.
- recall that the angle of incidence equals the angle of reflection.
- construct ray diagrams to illustrate the formation of a virtual image in a plane mirror.

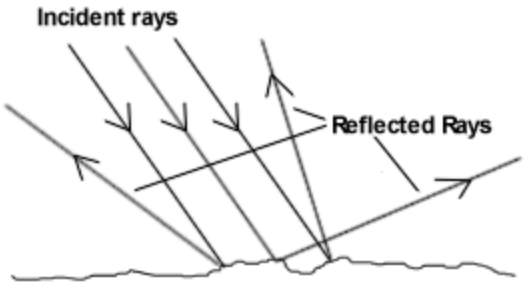


Regular Reflection



Eg. plane mirror or any other surface that produces a reflected image.

Diffuse Reflection



This is like any surface that we can see but does not reflect an image

CW 4.8 - Reflection

1. Give 2 examples of objects that are luminous (2)

2. Give 2 examples of objects in the sky that are only visible because they reflect light. (2)

3. Describe an experiment that demonstrates that light travels in a straight line. (a labeled diagram may be easier) (1)

4. The Moon is 384,000 km from Earth. How long does it take a laser pulse to travel from the Earth, reflect off the range finders placed by the Apollo astronauts on the Moon and return back to Earth? (3)

5. A man stands 10 m in front of a plane mirror. How far must he walk before he is 5 m from his image? (2)

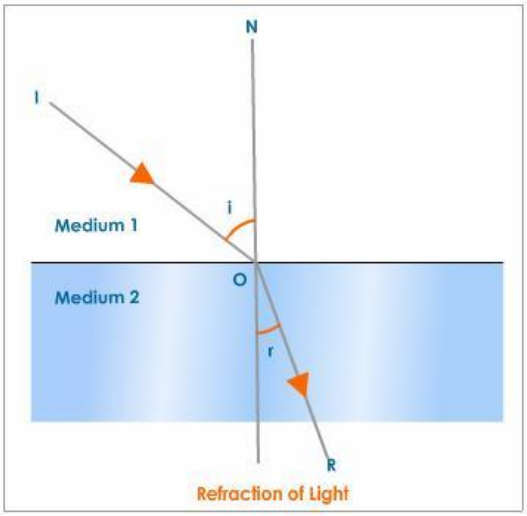
8 – Refraction

Objectives:

- describe experiments to investigate the refraction of light, using rectangular blocks, semicircular blocks and triangular prisms.
- recall and use the relationship between refractive index, angle of incidence and angle of refraction

$$n = \frac{\sin i}{\sin r}$$

- describe an experiment to determine the refractive index of glass, using a glass block.



AP Moment:

For future work at AP level we use the more correct equation:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

where $\theta_1 = i$ and $\theta_2 = r$. At IGCSE we approximate the refractive index of air, n_1, to be 1. This then simplifies the equation to:

$$\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2} \rightarrow n = \frac{\sin i}{\sin r}$$

LAB 4.9 - Refraction of Light

Aim: to determine the refractive index of glass or plastic.

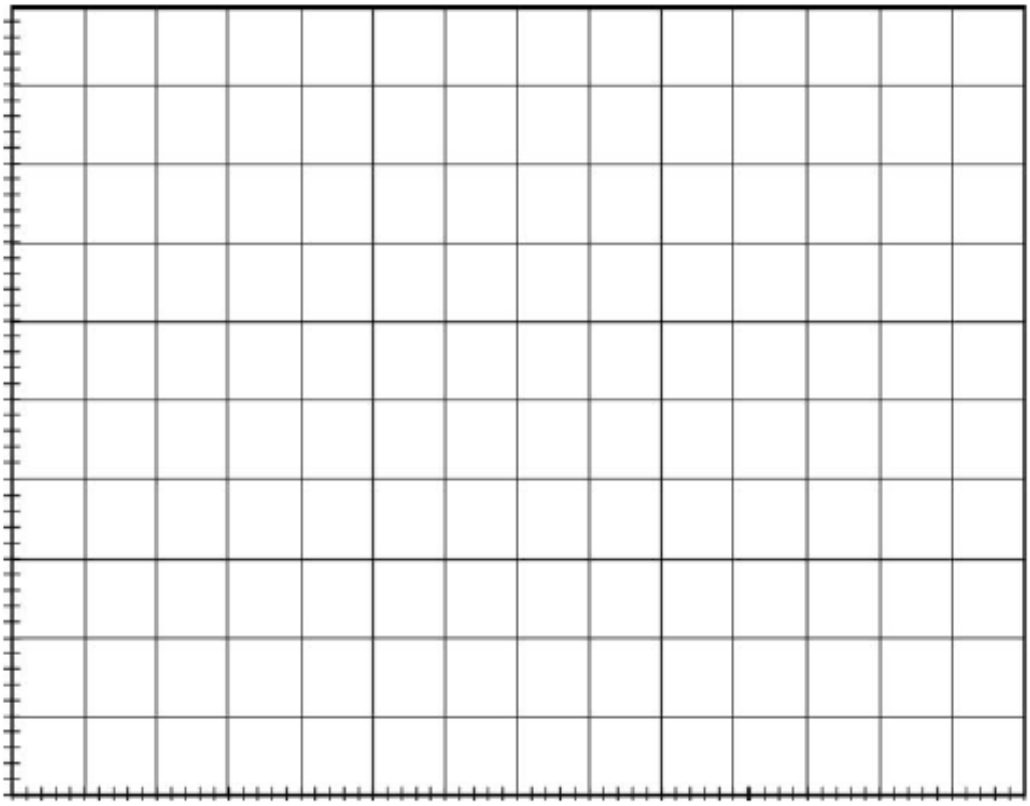
Method:

- Arrange a single slit to illuminate a glass or plastic semi-circular block with a thin beam of white light.
- Draw normal lines on the block at the interface with the light rays.
- Measure the angles on incidence and refraction.
- Calculate $sin\ \theta_i$ and $sin\ \theta_r$.
- Repeat the measurement for differing angles of incidence.

Diagram:

Results:

θ_1	θ_2	$sin\theta_1$	$sin\theta_2$
0			
10			
20			
30			
40			
50			
60			
70			
80			



Easier: Plot the angle of incidence against the angle of reflection.

Harder: Plot the sines of the angles (AP: linearization)

Conclusion:

Question: Why did we use a SEMI-CIRCULAR block?

CW 4.10 - Refraction of Light

1. Does light speed up or slow down when it goes from air to water? (1)

2. Does light speed up or slow down when it goes from water to glass? (1)

3. Why doesn't the refractive index have any units? (1)

4. An experiment is set up to determine the refractive index of a certain type of glass. Use the data below:

Angle of incidence	Angle of refraction	Refractive index
15°	10°	
45°	28°	
60°	35°	

5. The refractive index of water is 1.33. Calculate the angle of refraction is light strikes the water at an angle of 24°. (3)

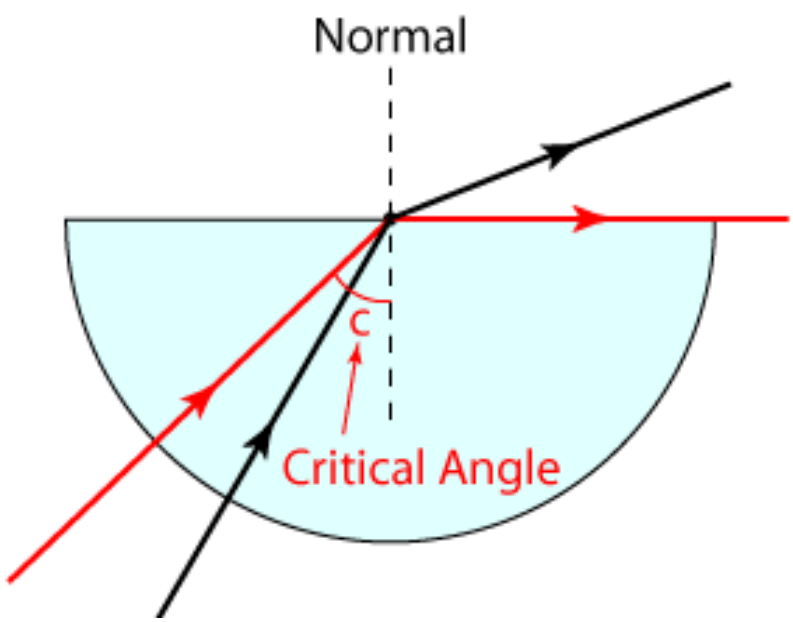
6. Diamond has a refractive index of 2.42. Calculate the angle of refraction if light strikes it at an angle of 60°. (3)

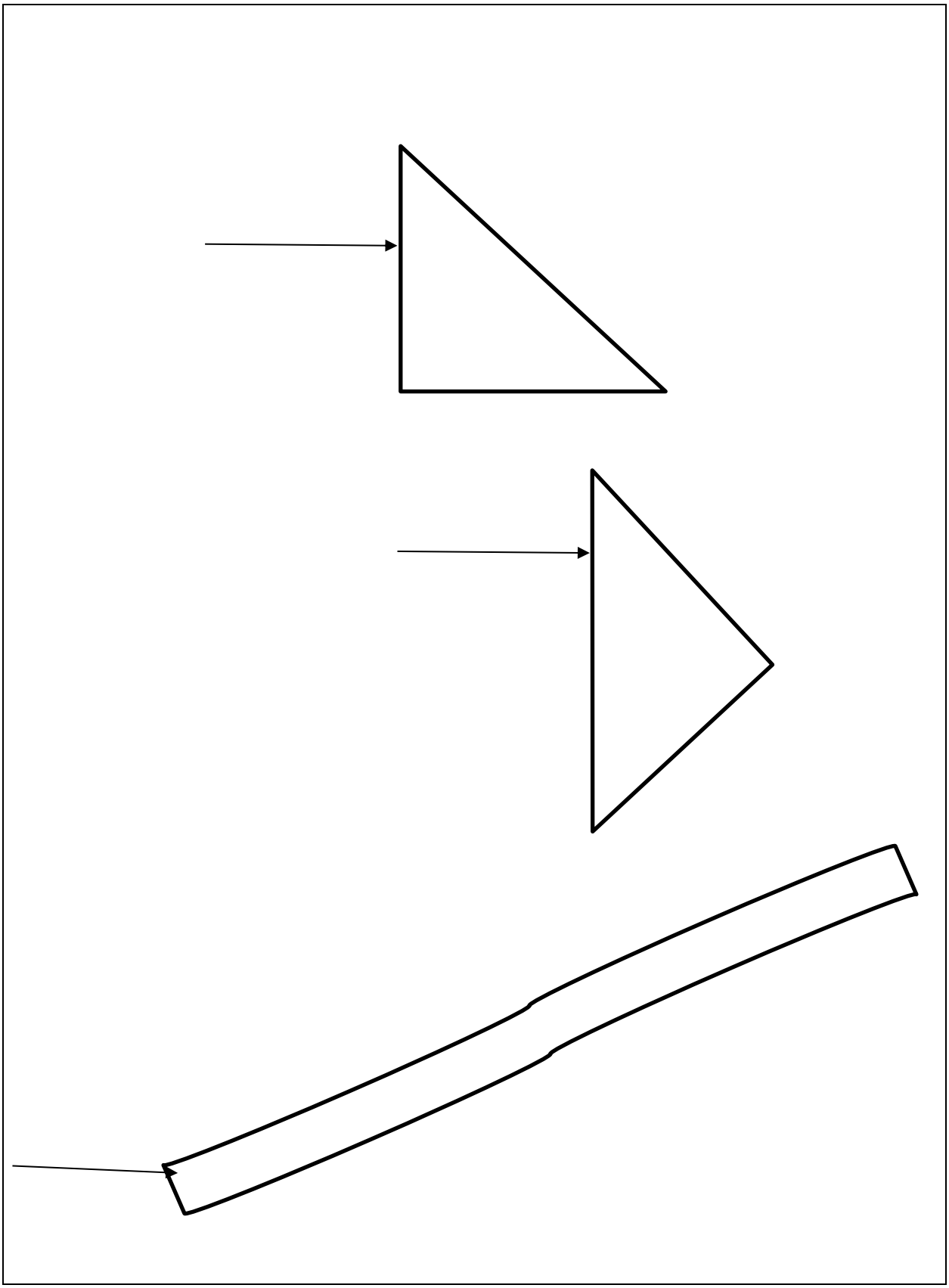
9 – Total Internal Reflection

Objectives:

- recall the meaning of critical angle *c*
- recall and use the relationship between critical angle and refractive index:

$$\sin c = \frac{1}{n}$$

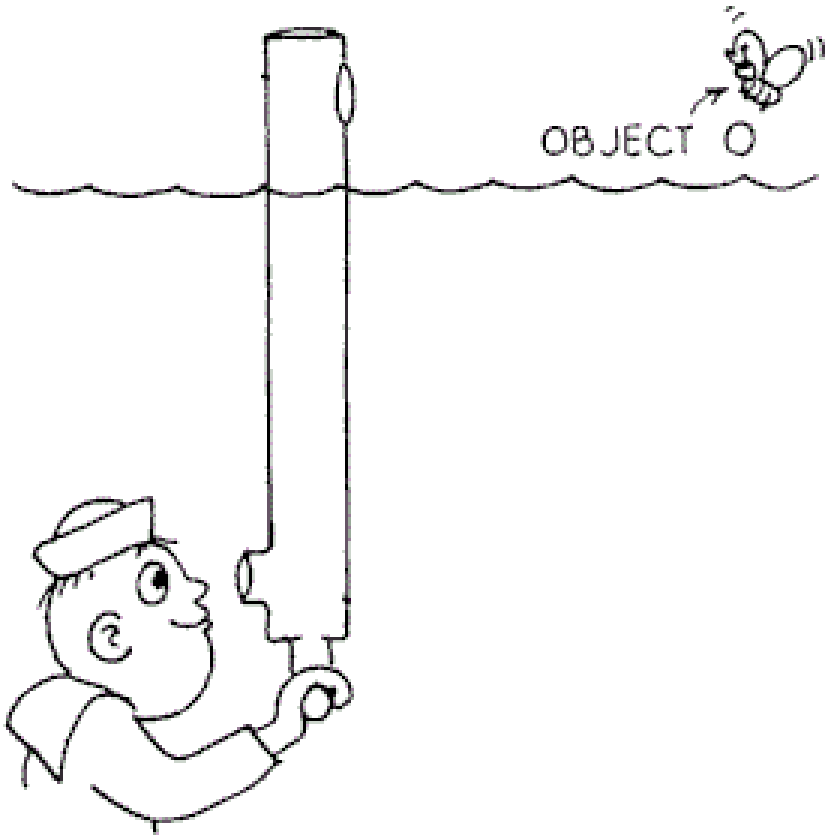




CW 4.11 – Total Internal Reflection

1. When snorkling or diving, sometimes the mask of your buddy appears to change into a mirror. Explain why. (2)

2. A periscope is usually made using 2 right-angled prisms instead of 2 mirrors. Add the prisms and the rays of light to the diagram to show this. (2)



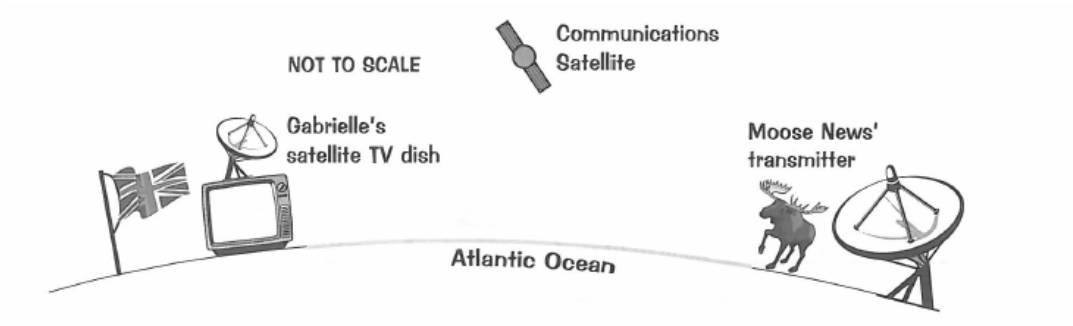
3. The refractive indices of various materials are shown below. Calculate their critical angles. (3)

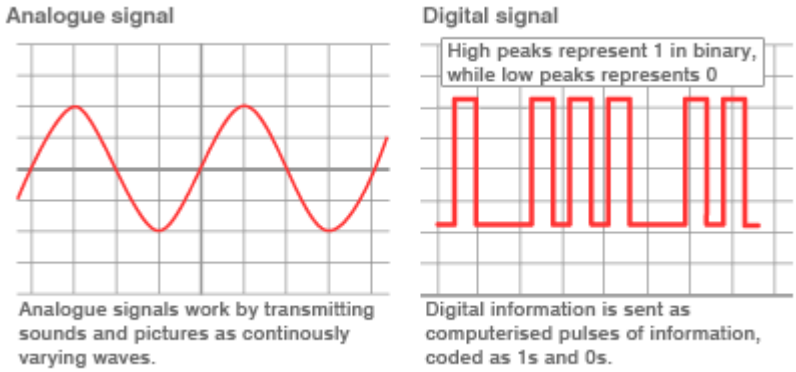
Material	Refractive Index	Critical Angle
water	1.33	
glass	1.50	
diamond	2.42	

10 – Communication Systems

Objectives:

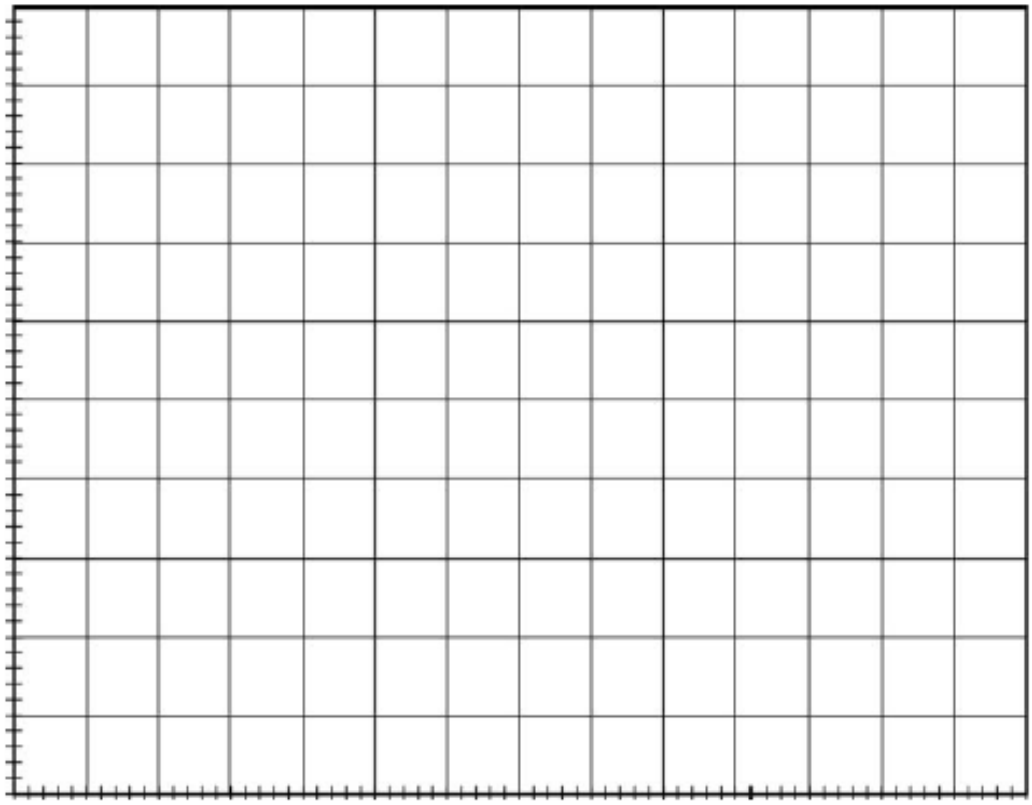
- describe the role of total internal reflection in transmitting information along optical fibres and in prisms
- understand the difference between analogue and digital signals.




Analogue signal
Digital signal
High peaks represent 1 in binary, while low peaks represents 0
Analogue signals work by transmitting sounds and pictures as continously varying waves.
Digital information is sent as computerised pulses of information, coded as 1s and 0s.

CW 4.12 - Making a Digital Signal

Aim: to demonstrate how to turn an analogue signal into a digital one.



- Label the x-axis 'Time (ms)' and the y-axis 'Voltage (mV)'
- Sketch a simple wave.
- Record the value of the Voltage in the table below – ignore decimal places.
- Use the table of binary code to convert the voltage into binary values.
- Write the binary code as a single line of digits with no gaps – this is the digital signal that is found in computer data, iPods etc etc!

Decimal	Binary	Decimal	Binary
0	0000	7	0111
1	0001	8	1000
2	0010	9	1001
3	0011	10	1010
4	0100	11	1011
5	0101	12	1100
6	0110	13	1101

Time (ms)	Voltage (mV)	Binary Code
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

Digital signal:

CW 4. 13 - PAST IGCSE QUESTIONS

4 A student is investigating refraction of light.

(a) What is **refraction**?

(1)

.....

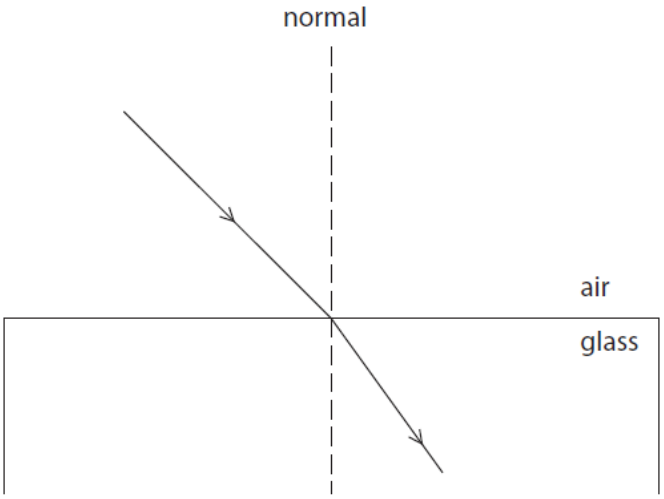
.....

.....

(b) The diagram shows a ray of light travelling from air to glass.

Add labels to show the angle of incidence, *i*, and the angle of refraction, *r*.

(2)

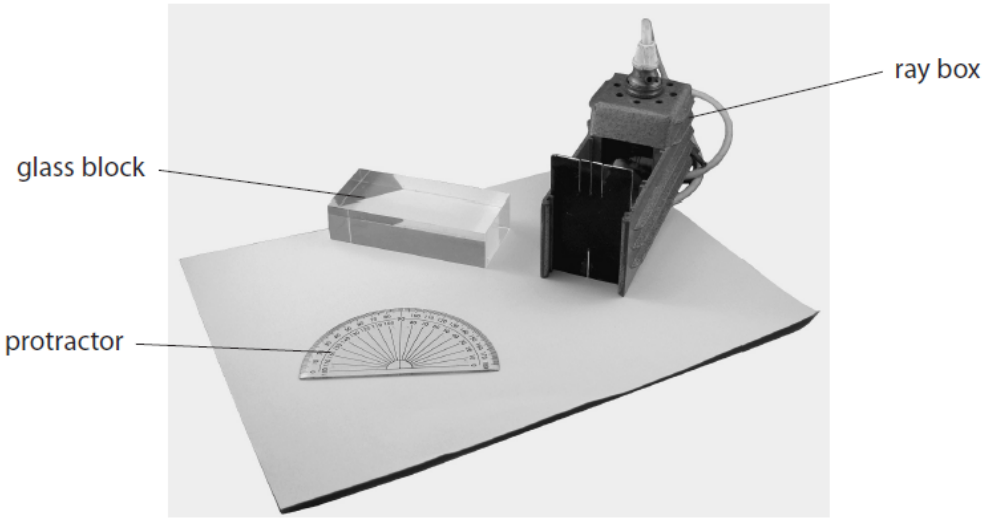


(c) The student wants to find the refractive index of the glass.

(i) State the equation linking refractive index, angle of incidence and angle of refraction.

(1)

(ii) The photograph shows the apparatus the student has available.



Describe how the student should carry out the experiment.

You should include:

- what the student should measure
- how the measurements should be made
- how the student should use a graph to find the refractive index.

(6)

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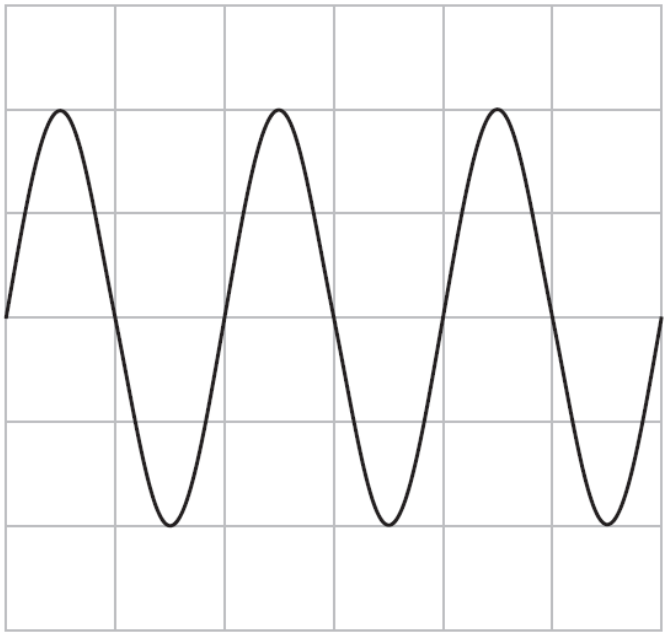
(Total for Question 4 = 10 marks)

2 A microphone is connected to an oscilloscope to display a sound wave.

The diagram shows the trace on the oscilloscope screen.



The oscilloscope settings are:

Y direction: 1 square = 1 V

X direction: 1 square = 0.001 s

(a) (i) How many time periods are shown on the trace?

(1)

.....

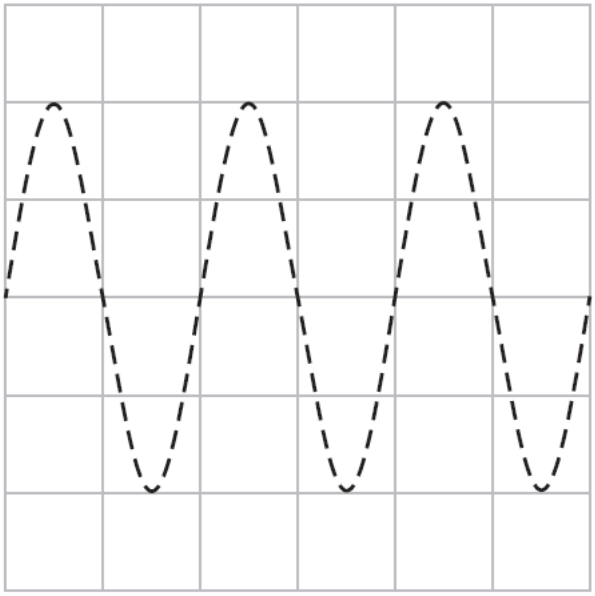
(ii) What is the frequency of the sound wave?

(2)

Frequency = ... Hz

(b) On the grid below, sketch the trace of a sound wave with a smaller amplitude and a higher frequency than the wave shown by the dotted line.

(2)



(Total for Question 2 = 5 marks)

11 A ray of light enters a glass block and is refracted as shown in Figure 1.

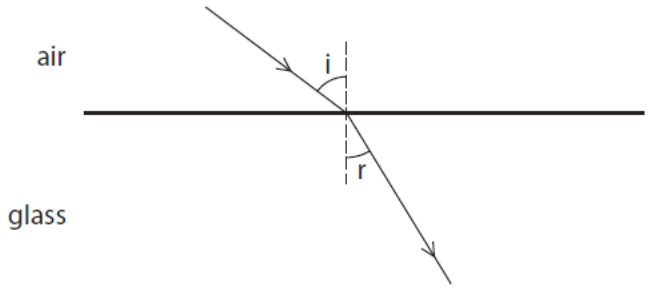


Figure 1

(a) Explain why the ray of light is refracted towards the normal.

(2)

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(b) Opals and diamonds are transparent stones used in jewellery.

Jewellers shape the stones so that light is reflected inside.

Figure 2 shows the path of a ray of light that enters and leaves a shaped piece of opal.

This ray of light is totally internally reflected.

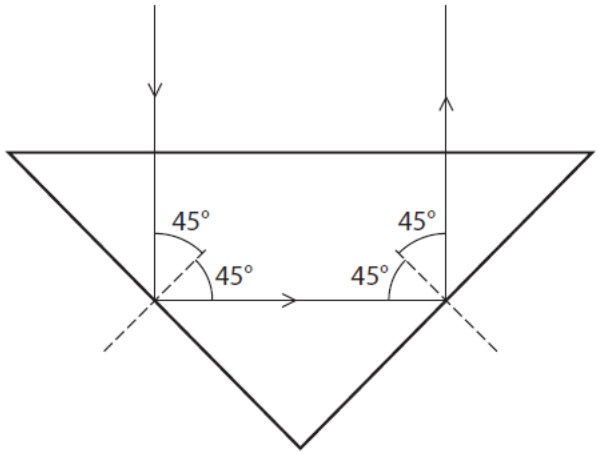

Figure 2

(i) State the equation linking refractive index and critical angle.

(1)

(ii) The critical angle of opal is 43°.

Show that the refractive index of opal is about 1.5.

(2)

(iii) The refractive index of diamond is 2.4.

Explain why rays of light inside a diamond are more likely to be totally internally reflected than those inside an opal.

(3)

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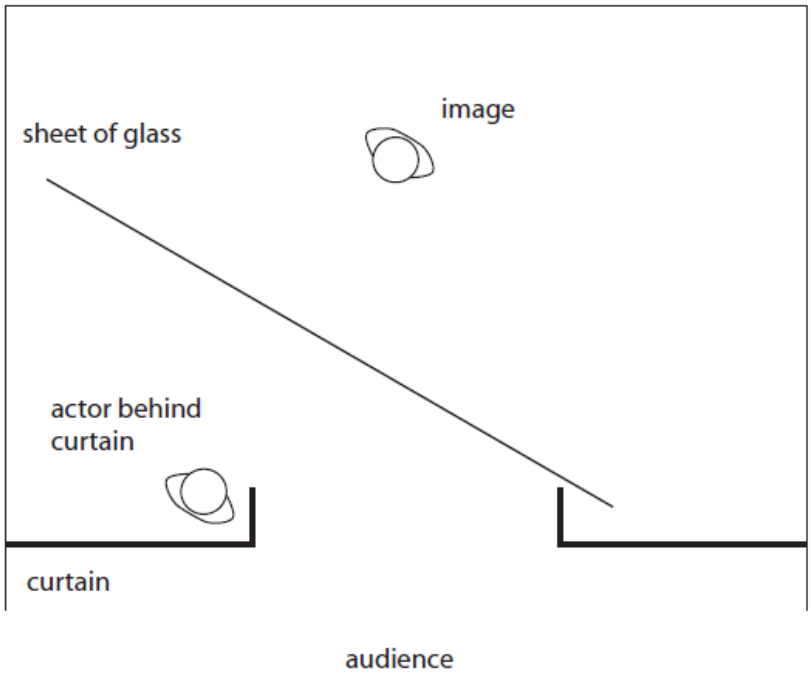
(Total for Question 11 = 8 marks)

2 Pepper's Ghost is a theatre effect used to make it appear that there is an image on stage.

The diagram shows a theatre viewed from above.

A sheet of glass is placed on the stage. A brightly lit actor stands behind a curtain at the side of the stage.

The audience sees the reflection of this actor in the glass.



(a) Add a ray diagram to show how light from the actor appears to come from the image. **(3)**

(b) The image formed by the glass is a virtual image.

State what is meant by the term **virtual image**. **(1)**

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(c) Light travels as a transverse wave.

Some waves travel as longitudinal waves.

(i) Give an example of a wave that travels as a longitudinal wave.

(1)

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(ii) Describe the difference between transverse waves and longitudinal waves.

You may draw diagrams to help your answer.

(3)

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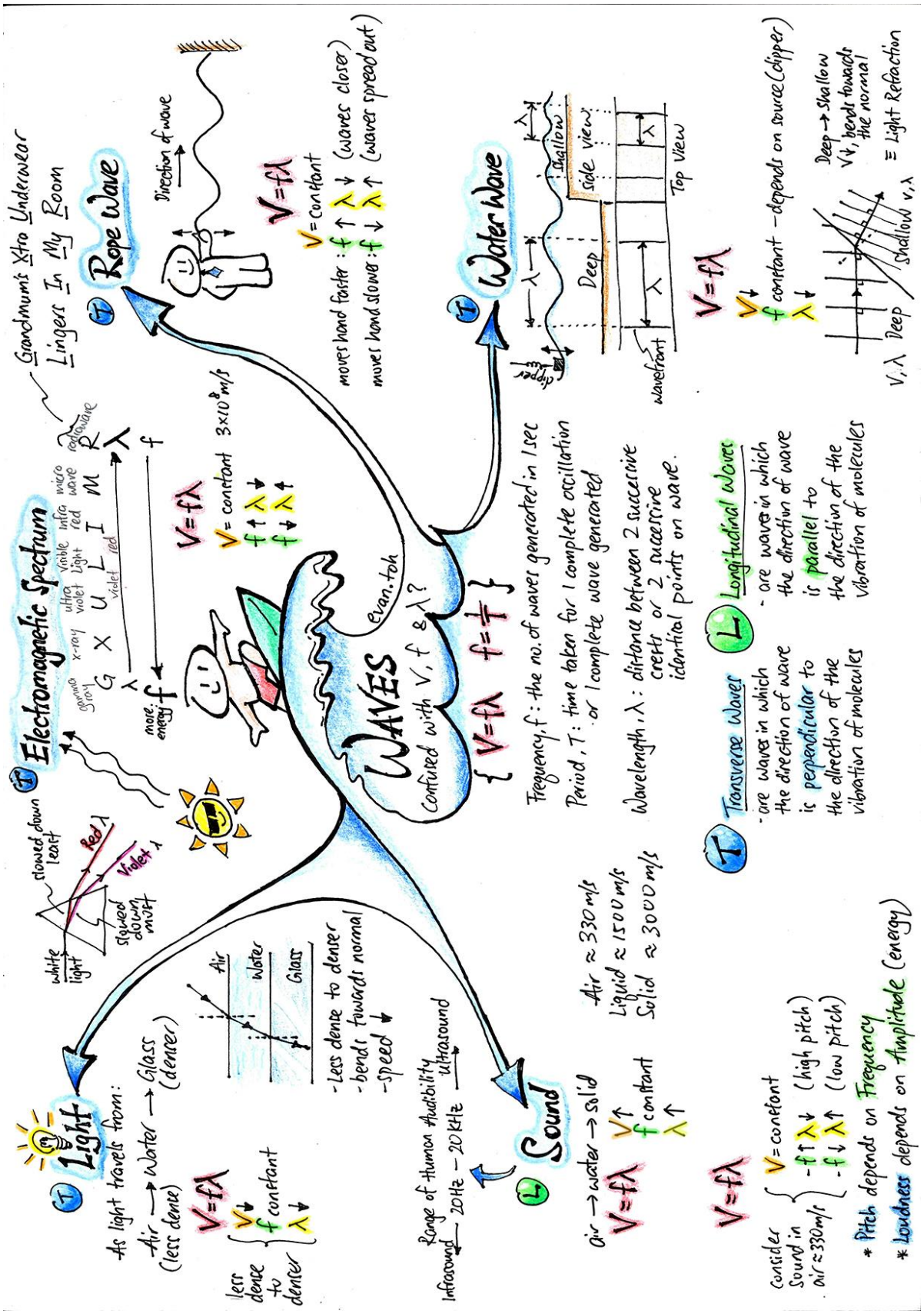
(Total for Question 2 = 8 marks)


WAVES
Confused with V, f & λ?
evan.toh
{ V=fλ f=1/T }
Frequency, f: the no. of waves generated in 1 sec
Period, T: time taken for 1 complete oscillation or 1 complete wave generated
Wavelength, λ: distance between 2 successive crests or 2 successive identical points on wave.
Electromagnetic Spectrum
Grandmum's Xtra Underwear Lingers In My Room
Gamma Gray
X-ray
ultra violet
visible light
infra red
micro wave
radiowave
G X U L I M R
violet red
more energy
V=fλ
V = constant 3×10⁸ m/s
f↑ λ↓
f↓ λ↑
Rope Wave
Direction of wave
V=fλ
V = constant
moves hand faster: f↑ λ↓ (waves closer)
moves hand slowly: f↓ λ↑ (waves spread out)
Water Wave
Deep
Shallow
Side view
Top View
wavefront
dipper
V=fλ
V↓
f constant – depends on source (dipper)
λ↓
Deep → Shallow
V↓, bends towards the normal
≡ Light Refraction
V, λ Deep
Shallow v, λ
Longitudinal Waves
- are waves in which the direction of wave is parallel to the direction of the vibration of molecules
Transverse Waves
- are waves in which the direction of wave is perpendicular to the direction of the vibration of molecules
Light
As light travels from:
Air → Water → Glass
(less dense) (denser)
V=fλ
V↓
f constant
λ↓
less dense to denser
white light
slowed down least
slowed down most
Red λ
Violet λ
Air
Water
Glass
- Less dense to denser
- bends towards normal
- speed ↓
Range of Human Audibility
Infrasound 20Hz – 20KHz Ultrasound
Sound
air → water → solid
V=fλ
V↑
f constant
λ↑
Air ≈ 330 m/s
Liquid ≈ 1500 m/s
Solid ≈ 3000 m/s
V=fλ
Consider Sound in air ≈ 330 m/s
V = constant
- f↑ λ↓ (high pitch)
- f↓ λ↑ (low pitch)
* Pitch depends on Frequency
* Loudness depends on Amplitude (energy)