Exit Routine – *make it sharp and purposeful*

1

Sort
Your equipment and pack it away

Stand
Behind your chair and wait to be dismissed

2

Single file
as you leave the room when dismissed

3

Straight
to your next lesson – no delays!

John Willmott School

Tuesday, 21 March 2023

In silence:

1. Format your desk
2. Complete the DNA in full sentences
3. Write the date, title and LQ

DNA:

1. Name two transverse waves and two longitudinal waves.
2. Describe the differences between transverse and longitudinal waves.

Stretch it:

State the equation that links waves speed, frequency and wavelength.

Title: Electromagnetic waves

LQ:

What are the electromagnetic waves?

Prior Learning	Current Learning	Future Learning
Vibrating string	Electromagnetic waves	

Name two transverse waves and two longitudinal waves. **Any correct answer e.g.**

- **Light – transverse**
- **Ripples in water - transverse**
- **Sound - longitudinal**
- **Ultrasound - longitudinal**

Describe the differences between transverse and longitudinal waves.

- **A transverse wave oscillates perpendicular (at 90°) to the direction in which the wave transfers energy.**
- **A longitudinal waves oscillates parallel to the direction in which the wave transfers energy**

State the equation that links waves speed, frequency and wavelength.

- **Wave speed (m/s) = frequency (Hz) x wavelength (m)**

Use the equation from Q3 to suggest what will happen to frequency if wave speed stays the same but wavelength increases. **If wave speed stays the same and wavelength increases then frequency must have decreased.**

Key Notes

1.

2.

3.

Key Notes The Colour Spectrum

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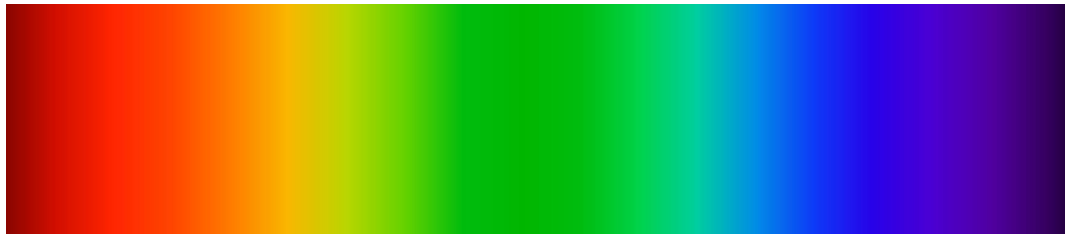
One of the most basic things that you already know about light is that there are different colours.
You can see that the different colours of light merge into each other.
This is called the **colour spectrum**.



Think, Pair, Share:

Why does some light look red to us, while other light looks blue or green or yellow etc?
What is the fundamental difference between the different colours of light?

Key Notes Wavelength and Frequency

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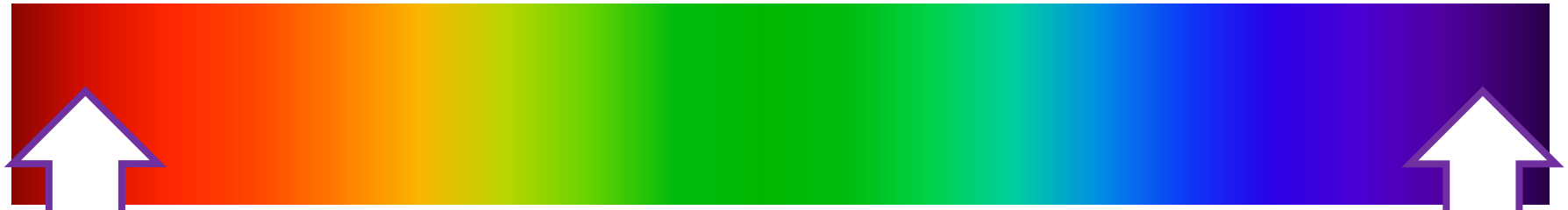
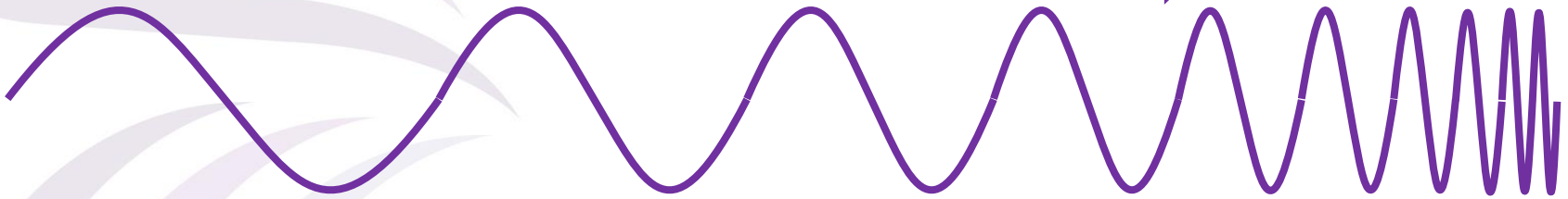
All colours of light travel at the same speed as each other in a vacuum or in air (we will look at this a little more in a moment).
The reason that some light appears as different colours to us is that **different colours of light have different wavelengths and frequencies.**



Red light has a **long wavelength** and a **low frequency**.

As we move along the spectrum from red light to violet light **wavelength decreases (gets shorter) and frequency increases.**

Violet light has a **short wavelength** and a **high frequency.**



Key Notes Wavelength and Frequency

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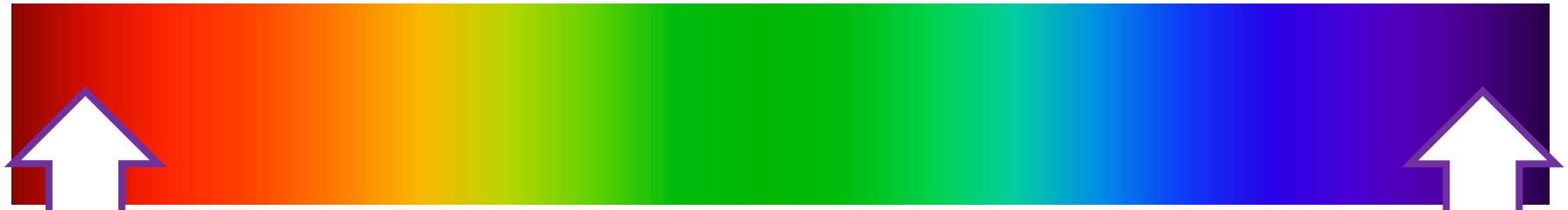
You will have noticed that wavelength and frequency have **an inverse relationship**:
As wavelength decreases (gets shorter) frequency increases.
This is because of the wave equation.



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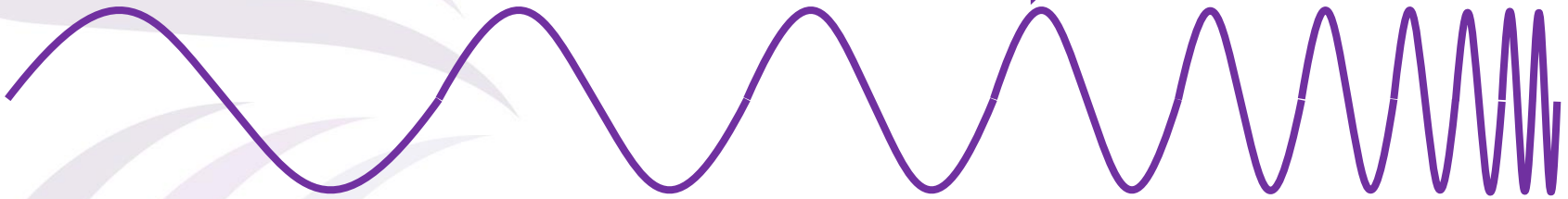

Key Notes

Wave Speed, Wavelength and Frequency

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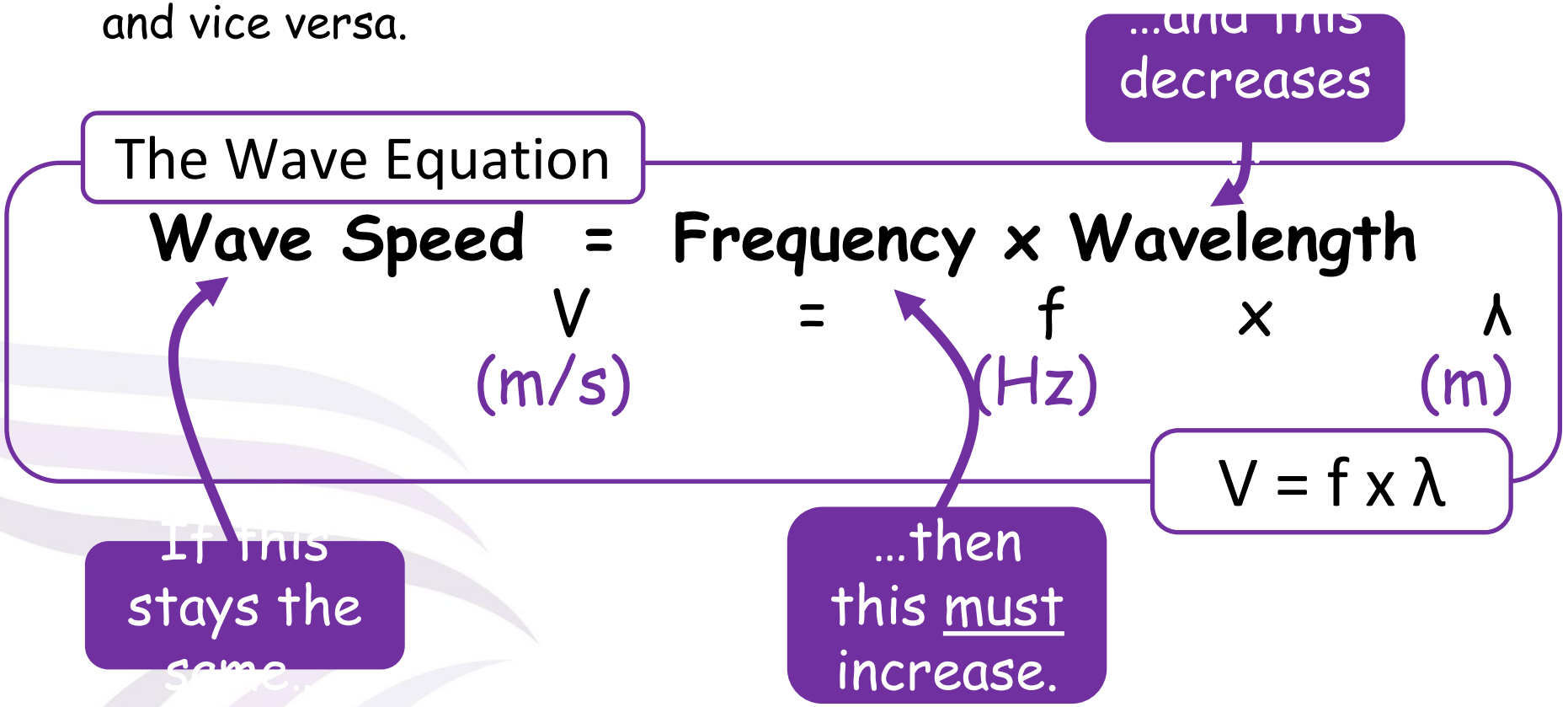
Because all colours of light travel at the same speed as each other in a vacuum or in air the wave speed is fixed.

Therefore if wavelength decreases, frequency *must* increase… and vice versa.



Key Notes

John Willmott School

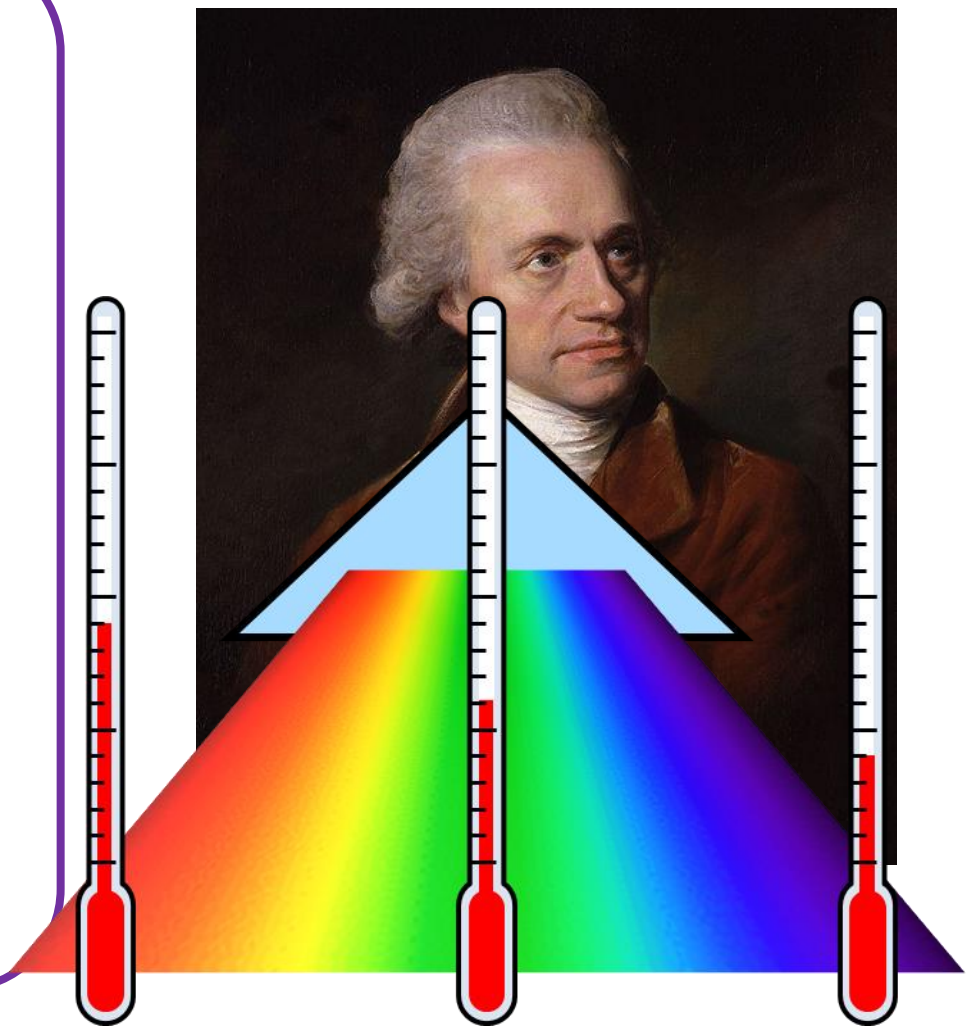
- Light is an electromagnetic wave.
- Like all electromagnetic waves, light is a transverse wave.
- Like all waves, light waves transfer energy.
- Different colours of light have different wavelengths and frequencies.
- The different colours of light form a spectrum – each colour merges with the next.
- All colours of light travel at the same speed as each other in a vacuum or in air.
- Because of this, wavelength and frequency have an inverse relationship – if one increases the other must decrease.

William Herschel

A British / German astronomer called William Herschel conducted experiments on light in 1800.

He used a prism to split white light into the different colours of the **spectrum** and placed a thermometer into each colour of light.

He found that different coloured light caused the temperature to increase more or less - as he moved along the colour spectrum from violet to red, the temperature increased more.



William Herschel

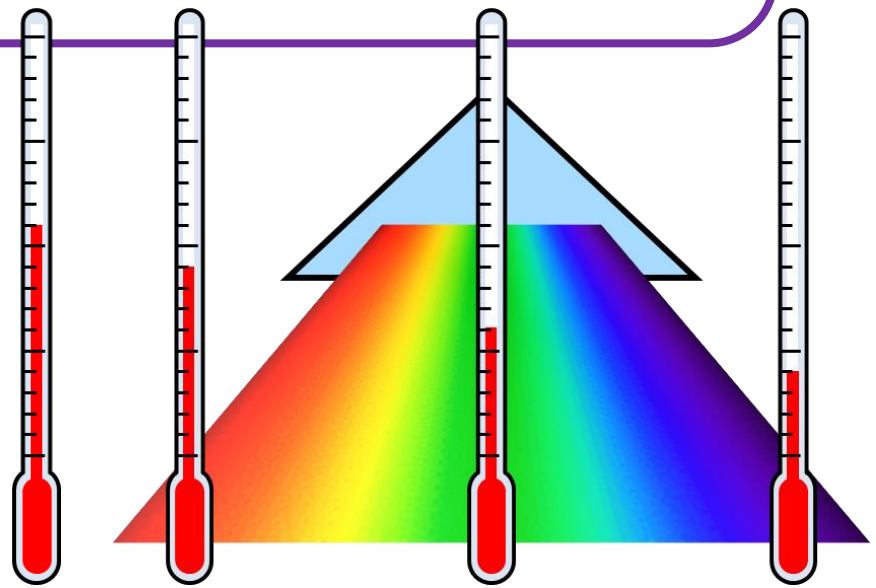
Herschel then placed a thermometer just past the red light.

He found that the pattern continued – the temperature of the thermometer placed just past the red light increased the most.

William Herschel had just discovered that there was an electromagnetic wave *that we can't see.*

As this electromagnetic wave was just past the red light it was called "infra red".

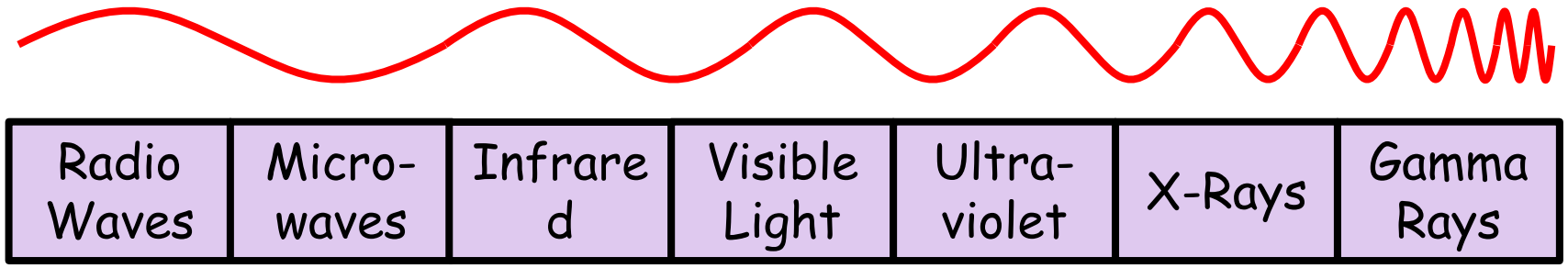
Other scientists built upon his work and found that **there are many more electromagnetic waves that we can't see.**



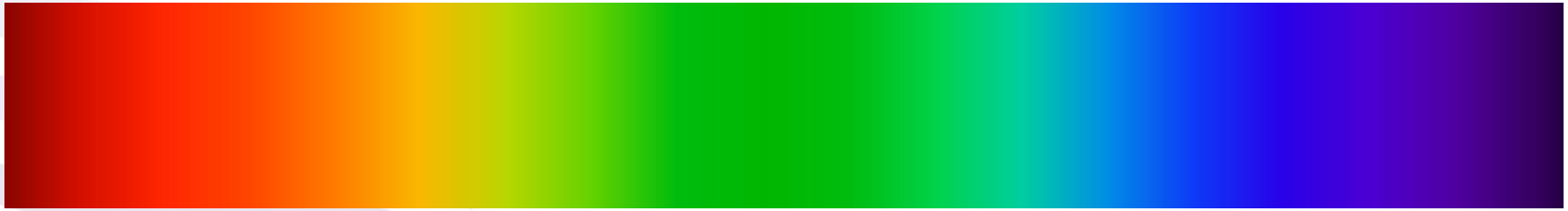
The Electromagnetic Spectrum

John Willmott School

Visible light – the spectrum of colours we can see – is just *one* part of a larger spectrum of electromagnetic waves. This is called the Electromagnetic Spectrum.



Radio Waves	Micro-waves	Infrared	Visible Light	Ultra-violet	X-Rays	Gamma Rays



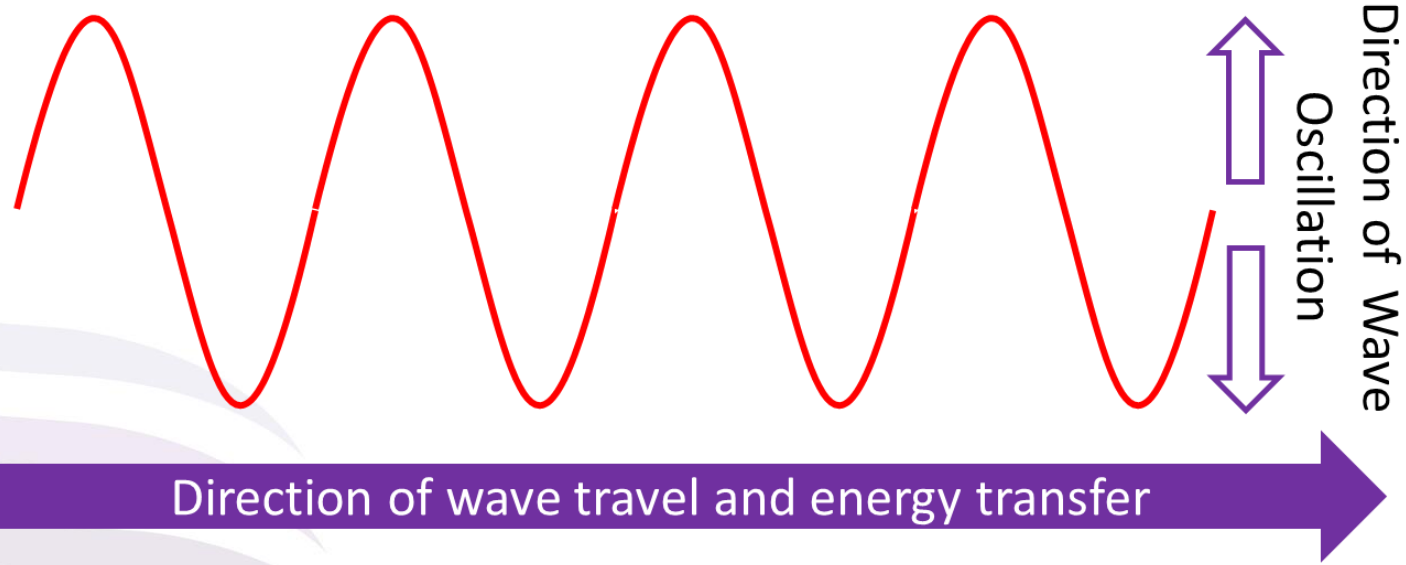
Visible Light

- Light is a no different to the other electromagnetic waves in the electromagnetic spectrum.
- It just happens to the part of the electromagnetic spectrum that we can detect (because we can see it with our eyes).
- Because we can see it we tend to call it “visible light”.

Electromagnetic Waves

Just like light, all the other electromagnetic waves in the electromagnetic spectrum:

- Are transverse waves
- Transfer energy from one place to another.
- Travel at same speed through a vacuum (such as space) or air

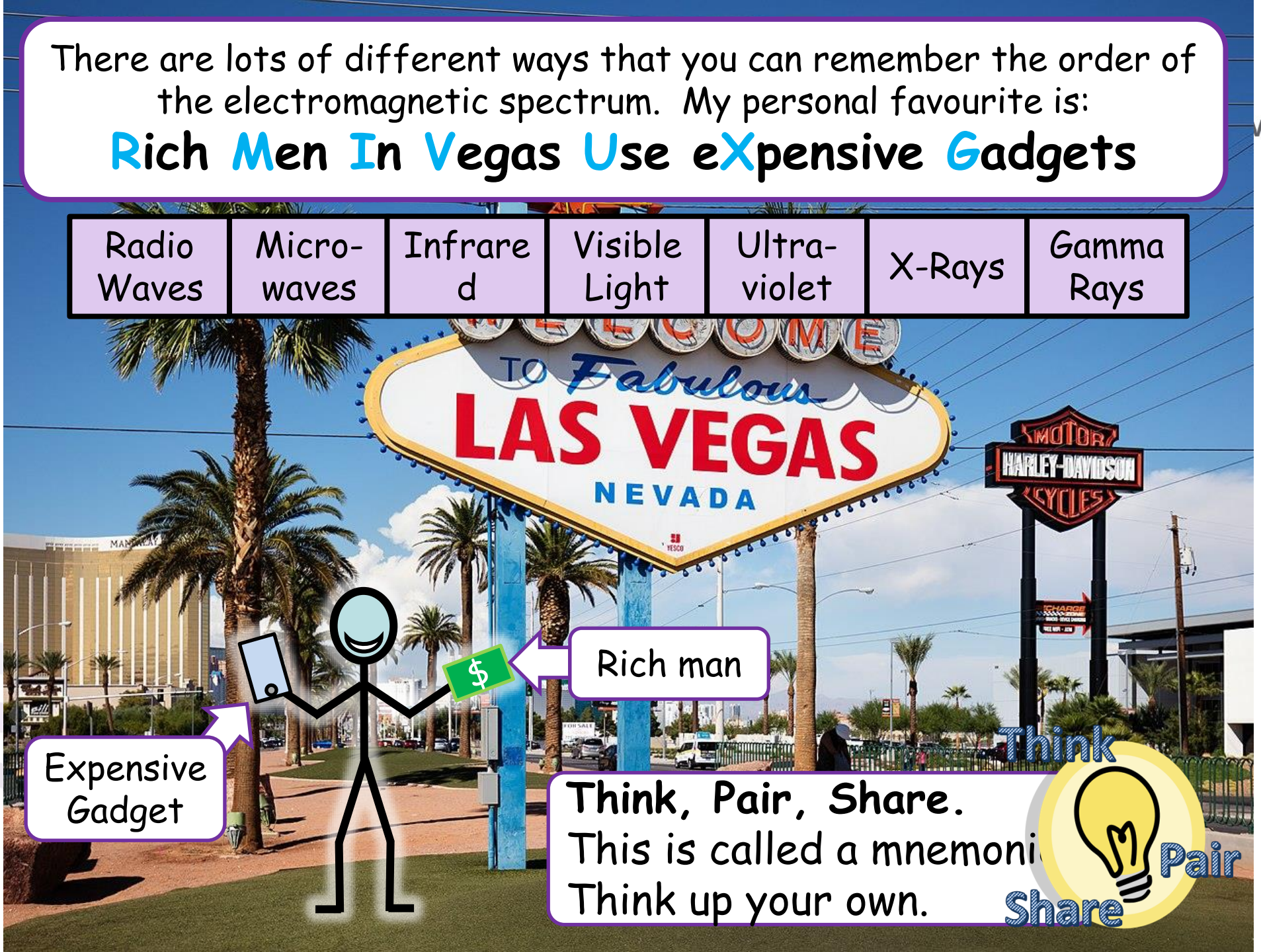


Key Idea: In transverse waves the oscillations are perpendicular (at 90°) to the direction in which the wave travels and transfers energy.

There are lots of different ways that you can remember the order of the electromagnetic spectrum. My personal favourite is:

Rich Men In Vegas Use eXpensive Gadgets

Radio Waves	Micro-waves	Infrared	Visible Light	Ultra-violet	X-Rays	Gamma Rays



Think, Pair, Share.
This is called a mnemoni
Think up your own.

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1 minute to discuss with the person next to you, before I choose people at random.

Learning Check: Quick Questions

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Light is the only part of the electromagnetic spectrum that we can detect with our eyes.	…wavelength and frequency.
…(continuous) spectrum.	Radio waves, microwaves, infrared, visible light, ultraviolet, x-rays, gamma rays.
Low frequency.	Transverse waves.

Visible Light and the EM Spectrum

John Willmott School

Tasks:

1. Name all of the electromagnetic waves in the electromagnetic spectrum in order (you can start at either end!).
2. Describe three similarities and one difference between visible light and all of the other electromagnetic waves.
3. Why do we see light as different colours?
4. Why are the different colours of visible light described as a "spectrum"?
5. Which colour of visible light has the shortest wavelength?

Extension 1: Note down a mnemonic (either the one you were taught or your own) to memorise the electromagnetic spectrum.

Challenge: The light waves from a red laser pointer has a wavelength of 6.4×10^{-7} metres. The speed of light in a vacuum is 3×10^{8} m/s.

a) calculate the frequency of the light

b) suggest how the wave speed, wavelength and frequency of light from a green laser would differ.

Answers

1. Name all of the electromagnetic waves in the electromagnetic spectrum in order (you can start at either end!). **Radio waves, microwaves, infrared, (visible) light, ultraviolet, X-rays, gamma rays (or in reverse order).**
2. Describe three similarities and one difference between visible light and all of the other electromagnetic waves.
   - **Similarities: Transverse waves, transfer energy, travel at same speed in a vacuum.**
   - **Difference: Visible light is the only EM wave we can see.**
3. Why do we see light as different colours? **Different colours of light have different wavelengths and frequencies.**
4. Why are the different colours of visible light described as a "spectrum"? **The colours merge into each other / there is no clear cut-off point between different colours.**
5. Which colour of visible light has the shortest wavelength? **Violet.**

Answers

Extension 1: Note down a mnemonic (either the one you were taught or your own) to memorise the electromagnetic spectrum. **Any suitable mnemonic.**

Challenge: The light waves from a red laser pointer has a wavelength of 6.4×10^{-7} metres. The speed of light in a vacuum is 3×10^{8} m/s.

a) calculate the frequency of the light. **4.6875×10^{14} Hz**

b) suggest how the wave speed, wavelength and frequency of light from a green laser would differ.

- **Wave speed would stay the same (assuming the light is travelling in air or a vacuum).**
- **Wavelength is shorter.**
- **Frequency is higher.**

The Electromagnetic Spectrum

John Willmott School

- It is easy for us to group the different wavelengths of visible light together (e.g. into “red” or “blue” light) because it is the part of the electromagnetic spectrum that we can see.
- **The other parts of the electromagnetic spectrum are also grouped together according to their wavelength and frequency**.
- You need to know the groups in the electromagnetic spectrum and the pattern in the wavelength and frequency of the whole spectrum.

Radio Waves	Micro-waves	Infrared	Visible Light	Ultra-violet	X-Rays	Gamma Rays

The Electromagnetic Spectrum

John Willmott School

You need to know the groups in the electromagnetic spectrum and the pattern in the wavelength and frequency of the whole spectrum.

Radio Waves	Micro-waves	Infrared	Visible Light	Ultra-violet	X-Rays	Gamma Rays

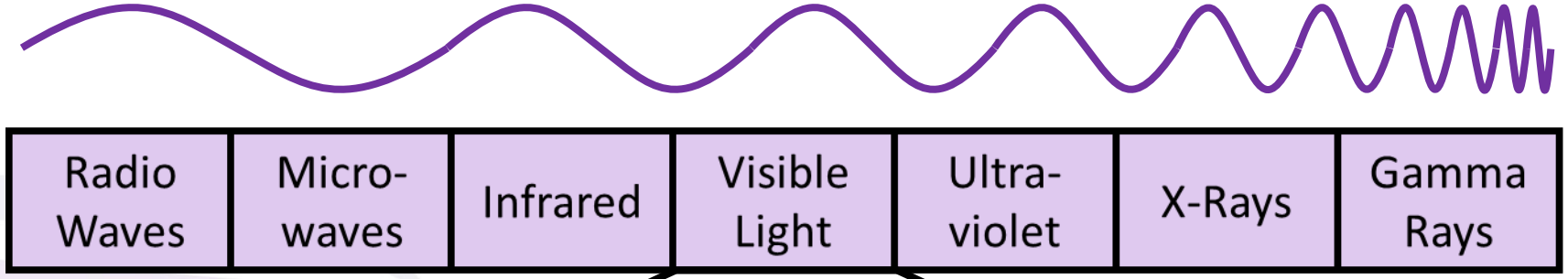
Long wavelength and low frequency. Low energy.

As we move from radio waves to gamma rays **wavelength decreases (gets shorter) and frequency increases.**

Short wavelength and high frequency. High energy.

What is a Spectrum?

- As you can see, the different colours of the colour spectrum merge into each other – there is no clear "cut off point" between yellow and green for example. This is why it is called a spectrum.
- This is the same with the other electromagnetic waves in the electromagnetic spectrum. We group together different parts of it into e.g. radio waves or microwaves but in reality they merge into each other.
- We call it a **continuous spectrum**.



The Electromagnetic Spectrum

- There are a range of wavelengths and frequencies within each group.
- For example red light has a longer wavelength and lower frequency than violet light (which has a shorter wavelength and higher frequency).

Radio Waves	Micro-waves	Infrared	Visible Light	Ultra-violet	X-Rays	Gamma Rays

As we move from radio waves to gamma rays wavelength decreases (gets shorter) and frequency increases

What *are* Electromagnetic Waves?

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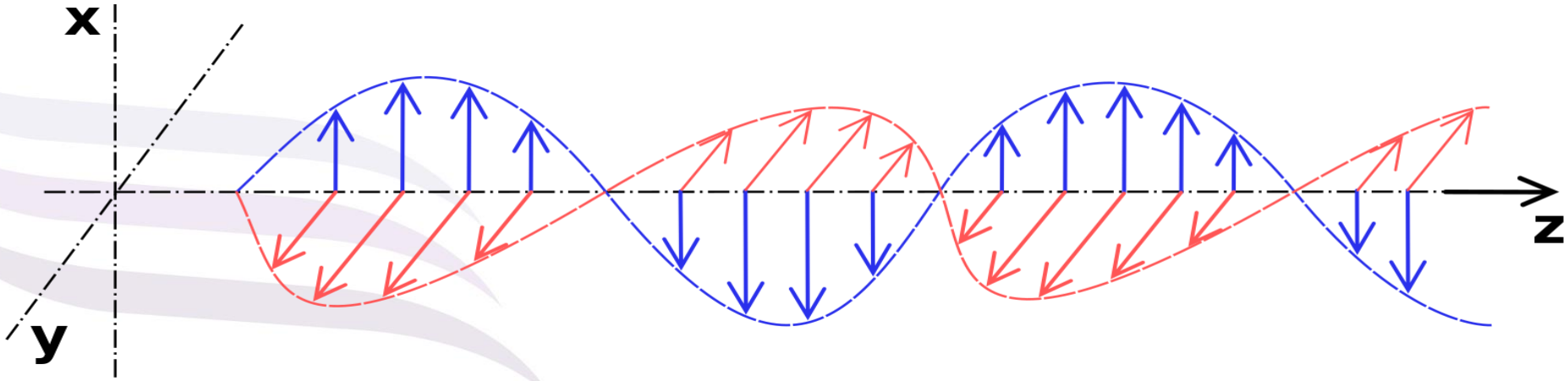
- All electromagnetic waves are **transverse waves** – the oscillations are perpendicular to the direction the wave travels (and transfers energy).
- Unlike ripples in water – which are also transverse waves but are oscillations in the water particles - the oscillations of an electromagnetic wave are changes in both the electric field and magnetic field.
- In this image the blue line shows the oscillation in the electric field and the red line shows the oscillation in the magnetic field. Both are perpendicular to the direction the wave travels.



What *are* Electromagnetic Waves?

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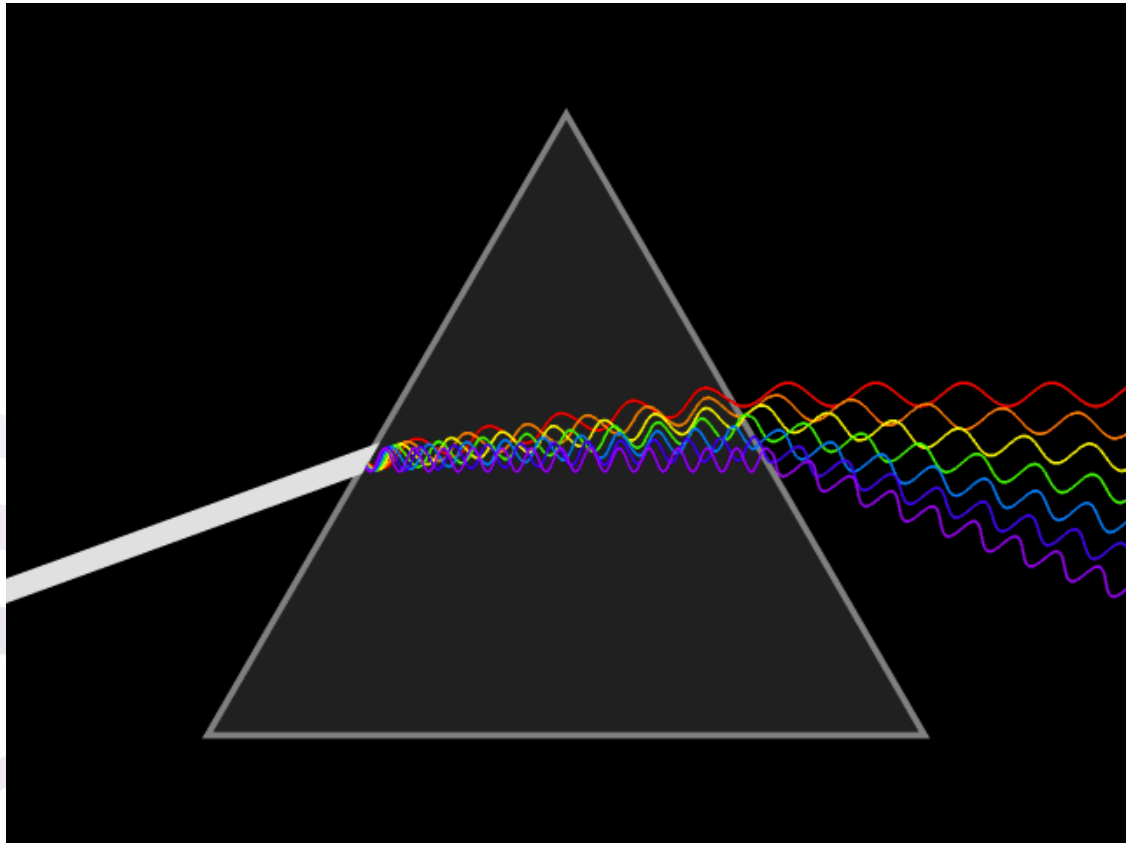
- You *don't* need to know that electromagnetic waves are oscillations in the electric and magnetic fields.
- However it does explain something that you *do* need to know: that **electromagnetic waves do <u>not</u> need a medium to travel through, and are able to travel through a vacuum** (such as space).
- The oscillations in these electric and magnetic fields can cause some particles to oscillate when the waves pass through a medium – this is why radio waves can transfer information.

Wave Speed

- All electromagnetic waves travel at the same speed as each other when in a vacuum or in air.
- The speed of electromagnetic waves in a vacuum is 3×10^8 m/s (300,000,000 or 300 *million* metres per second).
- The speed in air is *slightly* slower, but still the same for all the EM waves.
- This is often called the “speed of light” but it applies to all electromagnetic waves.

Wave Speed

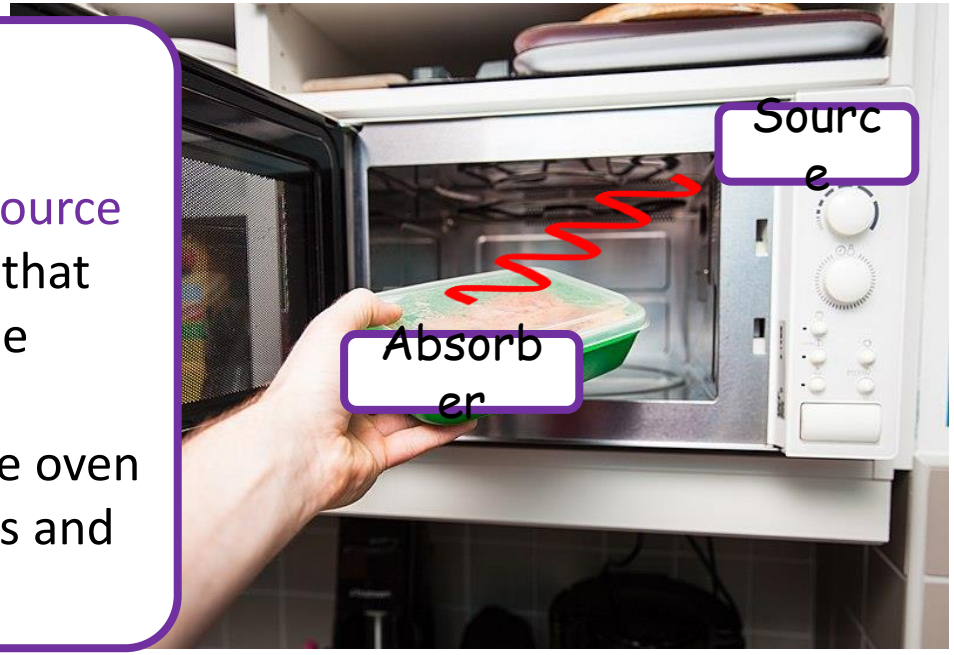
- Although electromagnetic waves travel at the same speed as each other in a vacuum, and in air (although slightly slower), they *don't* always travel at the same speed as each other in other substances such as glass.
- This is why a prism is able to split white light into the different colours of the colour spectrum.



Transferring Energy

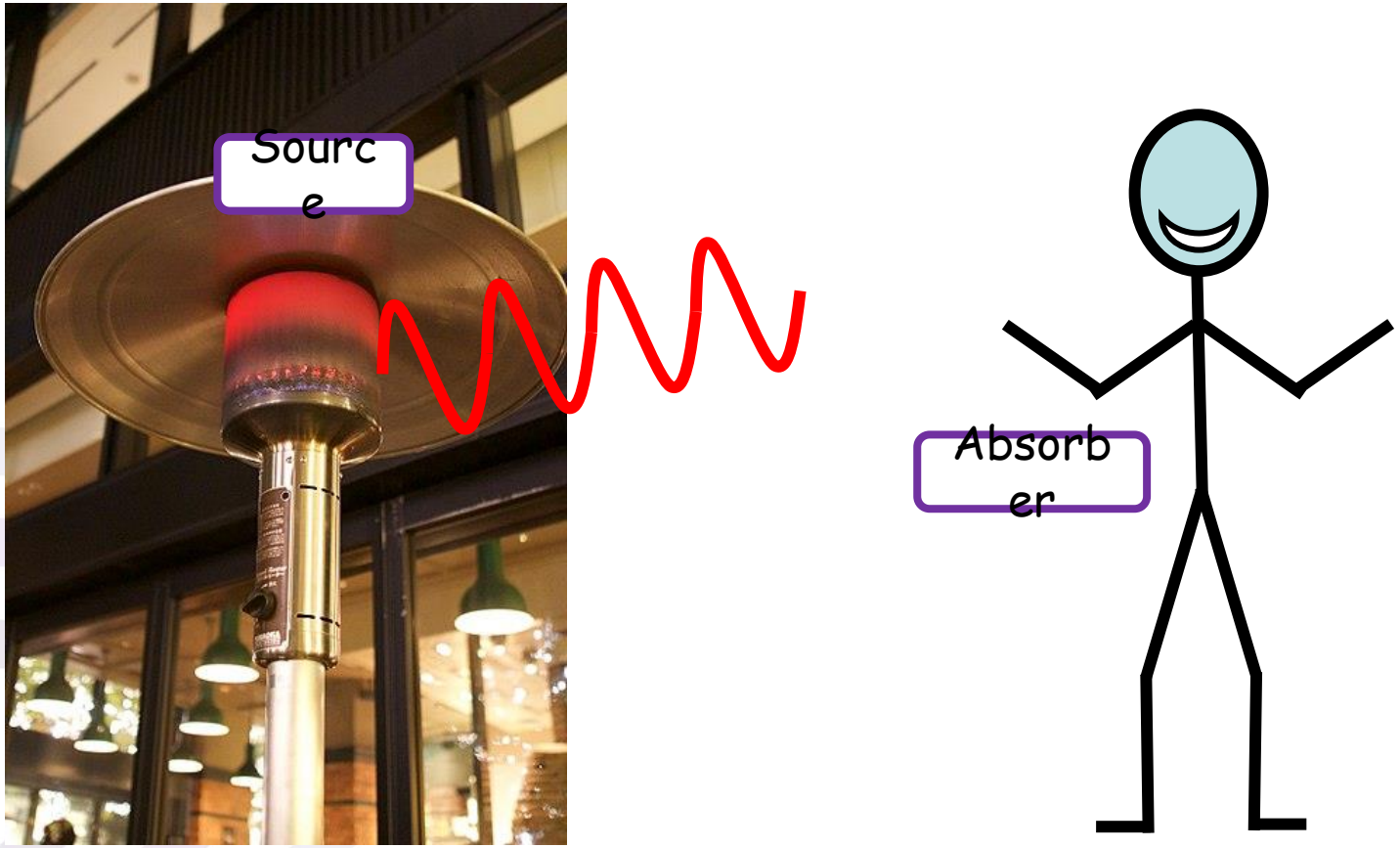
- Electromagnetic waves – like all waves - transfer energy from one place to another.
- In terms of energy transfer pathways, this is an example of the radiation pathway.
- More specifically they **transfer energy from a source to an absorber**.
- You will need to know some examples to illustrate this.

- A microwave *oven* produces microwaves.
- Energy is transferred from the source (the machinery inside the oven that produces the microwaves) to the absorber (the food).
- (The metal inside the microwave oven does not absorb the microwaves and instead reflects them).



Transferring Energy

- Infrared waves are produced by this outdoor heater – it is the source.
- The infrared waves then transfer energy to you – you are the absorber.
- This makes you feel warmer.

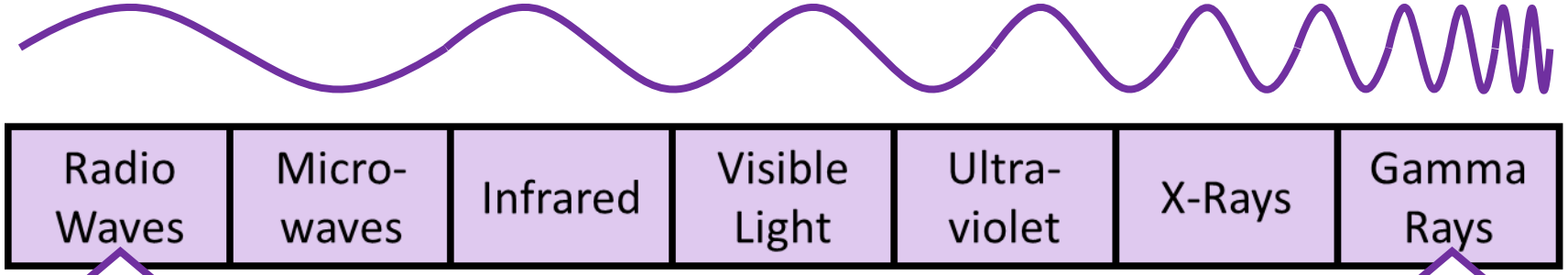


Energy Transfers or Pathways

Energy Transfer Pathway	Explanation
Mechanical	Energy is transferred mechanically when a force is used to move an object a certain distance. This is called the **work done** by the force.
Electrical	Energy is transferred electrically when a charge flows around a circuit. This is also described as the **work done** when an electrical current flows.
Heating	Energy is transferred by heating when there is a temperature difference, so energy flows from a hotter area to a colder area.
Radiation	Energy is transferred by radiation when it is transferred by **waves** (e.g. light, infra-red or sound waves) or **particles** (e.g. alpha particles).

Maths Skills

The wavelength and frequencies of electromagnetic waves range from incredibly small to incredibly large.
This means that you may be presented with wavelengths or frequencies in units such as nanometres or gigahertz.



Wavelength: 1×10^{8} m

Frequency: 3 Hz

Wavelength: 1×10^{-12} m

Frequency: 3×10^{20} Hz

Unit Prefixes in Science

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Prefix	Prefix Symbol	Multiple Size	Power of ten ($x10^x$)
tera-	T	1,000,000,000,000	12
giga-	G	1,000,000,000	9
mega-	M	1,000,000	6
kilo-	k	1,000	3
centi-	c	0.01	-2
milli-	m	0.001	-3
micro-	µ	0.000001	-6
nano-	n	0.000000001	-9

Example:

- 1 kilometre = 1000 metres
- The kilometre has the symbol km.
- 1 kilometre = 1.0×10^3 metres

Example:

- 1 millimetre = 0.001 metres
- The millimetre has the symbol mm.
- 1 millimetre = 1.0×10^{-3} metres

Tips:

1. The most common prefixes are kilo-, centi- and milli-
2. Do not confuse mega (M) and milli (m)
3. The prefix symbols are all the first letter of the prefix, except for micro (µ)

1 minute to discuss with the person next to you, before I choose people at random.

Learning Check: Quick Questions

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…decreases / gets shorter.

…increases (gets higher).

Electromagnetic waves transfer energy from a source to an absorber.

Violet coloured visible light.

The same time as all electromagnetic waves travel at the same speed in a vacuum.

A continuous spectrum.

Learning Check: In-Depth Questions

The Electromagnetic Spectrum

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Tasks:

1. Which electromagnetic wave has a) the highest frequency, b) the longest wavelength.
2. Describe the pattern in wavelength and frequency as we move along the electromagnetic spectrum from radio waves to gamma rays.
3. Describe the relationship between wavelength and frequency for electromagnetic waves.
4. Describe how the speed of microwaves and infrared waves will compare to each other in a) a vacuum and b) air.
5. State one similarity and one difference between gamma rays and water ripples.
6. Describe how a microwave oven heats food [3 marks]
7. Explain why the relationship between wavelength and frequency you described in Q3 is related to the wave equation.

Challenge: Radio waves have frequencies from 3 Hz to 30 MHz.
a) Convert 30 MHz to Hz. b) Show this as standard form. c) Calculate the period of a frequency of 30 MHz.

Answers

1. Which electromagnetic wave has
   a) the highest frequency. **Gamma rays**
   b) the longest wavelength. **Radio waves.**
2. Describe the pattern in wavelength and frequency as we move along the electromagnetic spectrum from radio waves to gamma rays. **Wavelength decreases (gets shorter) and frequency increases.**
3. Describe the relationship between wavelength and frequency for electromagnetic waves. **Inverse relationship. As wavelength decreases, frequency increases (or vice versa).**
4. Describe how the speed of microwaves and infrared waves will compare to each other in a) a vacuum and b) air. **Their speed will be the same as each other in both a vacuum and in air, but the speed is slightly slower in air.**
5. State one similarity and one difference between gamma rays and water ripples. **Similarity: both are transverse waves. Difference: water ripples require a medium to travel through. Any other correct answers are acceptable (e.g. gamma rays are electromagnetic waves but water ripples are not, or both transfer energy).**

Answers

6. Describe how a microwave oven heats food [3 marks].
   - **The microwave oven is a <u>source</u> of microwaves (1)**
   - **which transfer energy (1)**
   - **to food which <u>absorbs</u> them / is an <u>absorber (1)</u>**
7. Explain why the relationship between wavelength and frequency you described in Q3 is related to the wave equation. **Wave speed = frequency x wavelength. Because the speed of the wave is fixed, if wavelength increases then frequency must decrease (or vice versa).**

Challenge: Radio waves have frequencies from 3 Hz to 30 MHz.

a) Convert 30 MHz to Hz. **30,000,000**

b) Show this as standard form. **3×10^7 (remember $30 \times 10^6 = 3 \times 10^7$)**

c) Calculate the period of a frequency of 30 MHz. **3.3×10^{-8}**

Exam Style Questions

Please mark this in your book as "exam questions"

1 The diagram below shows the electromagnetic spectrum:

A	Micro-waves	B	C	Ultra-violet	X-Rays	D

a) Which letter shows the position of infrared in the electromagnetic s rum? [1 mark]

B

b) Which letter represents the electromagnetic wave that we are able to detect with our eyes? marks]

C

c) How do ultraviolet waves compare with X-Rays? Tick one box.

X-rays have a shorter wavelength and a higher fre cy ☑

X-rays have a shorter wavelength and a lower frequ cy ☐

X-rays have a longer wavelength and a higher frequ cy ☐

X-rays have a longer wavelength and a lower freque y ☐

1 d) Which two properties are the same for both Radio Waves and Gamma Rays? Tick two boxes [2 marks]

Both travel at the same speed through a vacu ☑

Both have the same amplitude ☐

Both have the same frequency ☐

Both have the same wavelength ☐

Both are transverse waves. ☑

e) The microwaves used to heat food in a microwave oven typically have a frequency of 2 450 000 000 Hz. Which of the numbers below is the same as 2 450 000 000 Hz?

2.45 kHz ☐

2.45 MHz ☐

2.45 GHz ☑

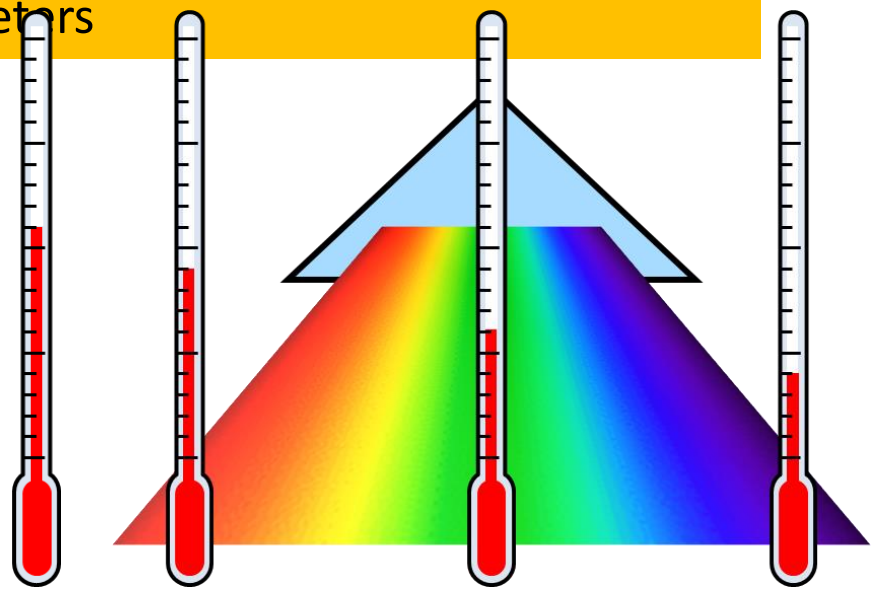
2.45 mHz ☐

2 A student used a prism to split white light into the colour spectrum. She then placed a thermometer into the violet light, green light, red light, and just beyond the red light. The temperature of each thermometer increased.

a) Which
experi

Visible Light
Infrared

- (Electromagnetic waves are) transferring energy
- From a source / the Sun
- These were absorbed by the thermometers



Exit Routine – *make it sharp and purposeful*

1

Sort
Your equipment and pack it away

Stand
Behind your chair and wait to be dismissed

2

Single file
as you leave the room when dismissed

3

Straight
to your next lesson – no delays!

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Exit Routine

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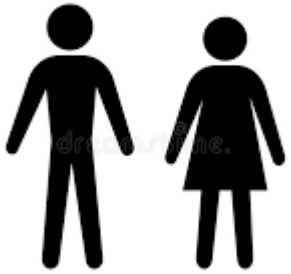
1

Sort your equipment and pass your books to the front

2

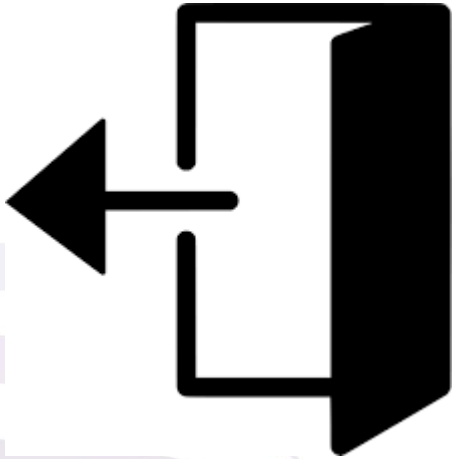
Stand behind your chair in silence and wait to be dismissed



3

Single file as you are dismissed

Straight to your next lesson. No delays!



Do It Now

Retrieval Task:

What is the definition of a gene?
What is polydactyl disorder?

Stretch it:

what can cause changes in DNA?

Complete in Silence Please

Do It Now

21 March, 2023

John Willmott School

Inheritance

LQ: Can I remember the beginning of the topic?

Complete in **Silence** Thank You