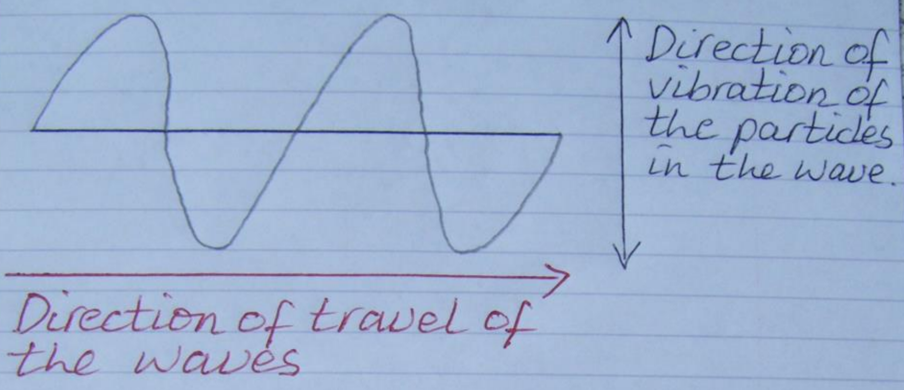
CfE Waves – B McMULLEN

Transverse Waves



In a transverse wave the direction of travel of the waves is perpendicular (at 90°) to the direction of vibration of particles in the wave.

Examples of transverse waves include the 8 types of wave in the electromagnetic spectrum and Water waves.

What is the em spectrum?

This is a group of waves that travel at the speed of light in air ie $3 \times 10^8 ms^{-1} = 300,000,000 ms^{-1}$.

Waves in the em spectrum

Type of Radiation	Detector
1) Gamma Rays	GM tube
2) X-Rays	Photographic Film
3) Ultraviolet (UV)	Photographic Film
4) Visible light (visible spectrum)	Eyes, solar cells
5) Infrared	Thermometer, skin
6) Microwaves	aerial or radio telescope
7) TV Waves	aerial or radio telescope
8) Radio Waves.	aerial or radio telescope.

* Gamma rays have the highest frequency.

* Radio waves have the longest wavelength.

* From 1) to 8) the wavelength of the waves increases and the frequency of the waves decreases.

* Rabbits Mambo In Very Unusual eXpensive Gardens. *.

Remembering the order of the waves.

The Visible Spectrum

This is the part of the em spectrum that contains all the colours visible to us. (ROYGBIV)

R	O	Y	G	B	I	V
E	R	E	R	L	N	I
D	A	L	E	U	D	O
	N	L	E	E	I	L
	G	O	N		G	E
	E	W			O	T

Red light has a wavelength $\approx 700nm = 700 \times 10^{-9}m = 7 \times 10^{-7}m$.

Violet light has a wavelength $\approx 400nm = 400 \times 10^{-9}m = 4 \times 10^{-7}m$.

Q How could we estimate the wavelength of green light?

A Green light lies between Red and violet light

$\therefore$ Wavelength of green light $\approx 550nm = 550 \times 10^{-9}m = 5.5 \times 10^{-7}m$.

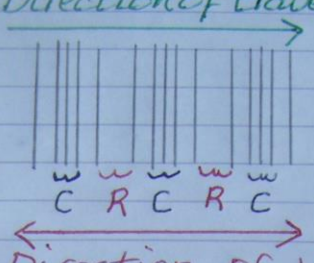
* Never mention the term Rainbow in Physics, always refer to this as a visible spectrum. *

The song should be 'Somewhere over the Visible Spectrum, way up high'.

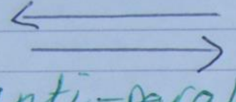
Longitudnal Waves

Direction of travel of the Waves

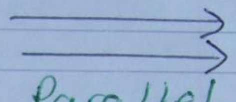
C – Compressions
R – Rarefactions



Direction of Vibration of the particles in the wave.



anti-parallel

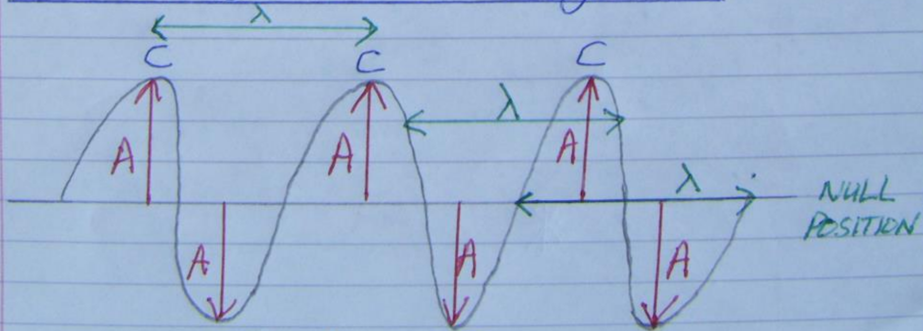


Parallel.

In a longitudnal wave the direction of travel of the waves is parallel or anti-parallel to the direction of vibration of the particles in the wave.

* Sound waves are longitudnal waves. *

Transverse Wave diagrams.



KEY

C → Crest (Top of the Wave)
T → Trough (Bottom of the wave)
A → Amplitude (height of Wave)
λ → Length of a wave, Wavelength.

NULL POSITION → POINT OF ZERO DISTURBANCE OF THE WAVE.

* The Amplitude A is measured from the NULL POSITION to the Crest or the NULL POSITION to the Trough. *

Definitions

1) Wavelength (λ) → This is the length of one wave or the distance over which a wave repeats itself.
(m)

2) Frequency (f) → The number of waves that pass a point per second.
(Hz)

3) Period (T) → The time taken to complete one wave.
(s)

4) Wavespeed (V) → The distance that a wave travels per second.
(ms^{-1})

Period (T)

From $f = \frac{N}{t}$ (from the Sound topic)

⇒ The time to complete 1 wave is called the Period (T).

⇒ N = 1 ∴ time t = T

⇒ $f = \frac{1}{T}$ ⇒ $T = \frac{1}{f}$ ⇐ In DB!!

Ex 1

Calculate the period of a wave with a frequency of 25Hz.

T = ?
f = 25Hz

$T = \frac{1}{f} = \frac{1}{25} = 0.04s$

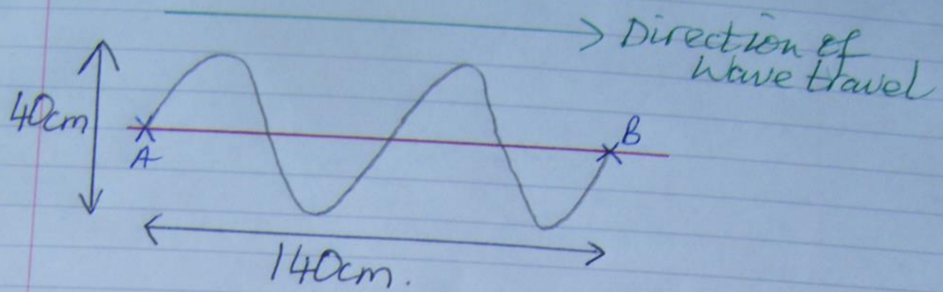
Ex 2

If 4 waves pass a point in 20 seconds then calculate the period of each wave.

f = ?
N = 4 waves
t = 20s

- $f = \frac{N}{t} = \frac{4}{20} = 0.20Hz$
- $T = \frac{1}{f} = \frac{1}{0.20} = 5s$

Ex3



If it takes 28 seconds for the wave to travel from A to B, then calculate or find:

Q

a) Amplitude of the waves

b) Wavelength of the waves

c) Speed of the waves

d) frequency of the waves

e) Use the answers in the calculations for b), c) and d) to produce an equation linking wavelength, wavespeed and frequency.

A

a) Amplitude $= \frac{0 \cdot 4m}{2} = \underline{0 \cdot 2m}$

b) Wavelength $= \frac{1 \cdot 4m}{2} = \underline{0 \cdot 7m}$

c) Speed, $v = \frac{d}{t} = \frac{1 \cdot 4}{28} = \underline{0 \cdot 05 ms^{-1}}$

d) frequency, $f = \frac{N}{t} = \frac{2}{28} = \underline{\underline{0.071\,Hz}}$

e) b) $\lambda = 0.7\,m$
c) $V = 0.05\,ms^{-1}$
d) $f = 0.071\,Hz$.

$\Rightarrow \quad v = f \times \lambda$

$\Rightarrow \quad 0.05 = 0.071 \times 0.7$

$\Rightarrow \quad 0.05 = 0.05$

$\Rightarrow$ This shows that $V = f \times \lambda$ ∴ QED

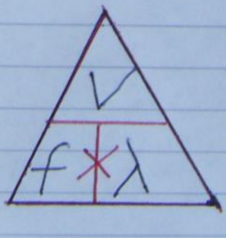
The wave Equation

In Ex3 we found the wavelength, speed and frequency of the wave.

It was then shown that we could combine the three quantities into an equation.

$$V = f \times \lambda$$

- V → Wavespeed (ms^{-1}) → OR wave velocity.
- f → frequency (Hz)
- λ → Wavelength (m)



1. $V = f \times \lambda$
2. $f = \frac{V}{\lambda}$
3. $\lambda = \frac{V}{f}$

Ex 4

Calculate the speed of a wave if it has a frequency of 40Hz and a wavelength of 15cm.

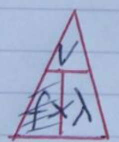
$V = ?$
$f = 40Hz$
$\lambda = 15cm = 0.15m$

$V = f \times \lambda$
$\Rightarrow V = 40 \times 0.15$
$\Rightarrow V = 6ms^{-1}$

Ex 5

Calculate the frequency of a water wave of 0.03m wavelength travelling at $120cms^{-1}$.

$V = 120cms^{-1} = 1.2ms^{-1}$
$f = ?$
$\lambda = 0.03m$



$f = \frac{V}{\lambda} = \frac{1.2}{0.03}$

$\Rightarrow f = 40Hz$

Ex 6

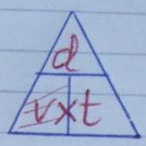
Water waves travel from one end of a swimming pool to the other.

The pool has a length of 25m with the waves taking 10 seconds to travel from one end to another.

If the distance between two successive wave crests is 12cm, then calculate or find:

Q a) Speed of the waves, v
b) Wavelength of the waves, λ
c) frequency of the waves, f
d) Period of the waves, T.

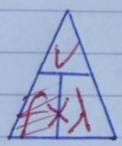
A a) $d = 25m$
$v = ?$
$t = 10s$



$v = \frac{d}{t} = \frac{25}{10} = 2.5ms^{-1}$

b) λ = distance between two successive wave crests
$\lambda = 12cm = 0.12m$

c) $v = 2.5ms^{-1}$
$f = ?$
$\lambda = 0.12m$



$f = \frac{v}{\lambda} = \frac{2.5}{0.12}$

$\Rightarrow f = 20.8Hz$

d) $T = ?$
$f = 20.8Hz$

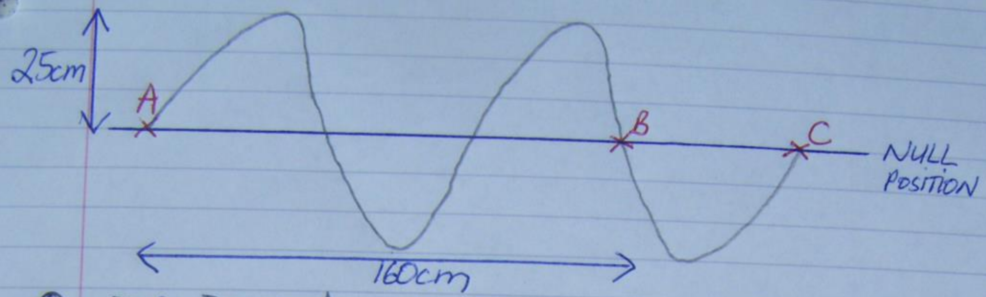
$T = \frac{1}{f} = \frac{1}{20.8}$

$\Rightarrow T = 0.048s$

* In parts c) and d) be careful with the significant figures.

As a rule of thumb do not go beyond 3 significant figures!! *

Ex 7



Q. If it takes 0·75 seconds for the wave to travel from A to B, then calculate or find:

a) Amplitude, A
b) frequency, f
c) wavelength, λ
d) Wavespeed, V
e) Period, T

A. a) Amplitude = 25cm = 0·25m

b) frequency, $f = \frac{N}{t} = \frac{1.5}{0.75} = 2Hz$

c) $1.5\lambda = 160cm = 1.6m$

$\Rightarrow \lambda = \frac{1.6}{1.5} = 1.07m$

d) $V = f\lambda = 2 \times 1.07 = 2.14ms^{-1}$

e) $T = \frac{1}{f} = \frac{1}{2} = 0.5s$

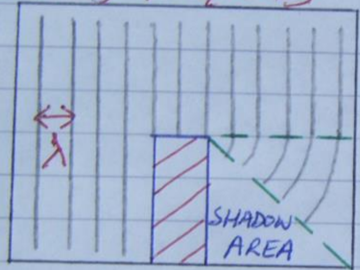
Diffraction

This is the bending (diffraction) of a wave around a barrier or an obstacle.

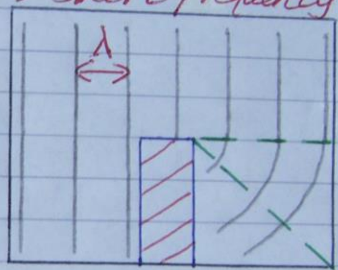
The longer the wavelength of a wave the greater the bending or diffraction.

eg water waves.

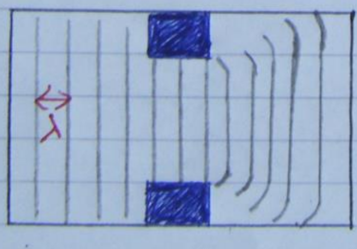
Short wavelength
⇒ Large frequency

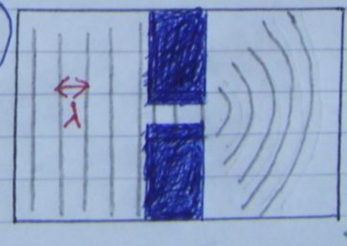
a) 

Long wavelength
⇒ Short frequency.

b) 

The shadow area found behind the obstacle in diagram a) means that no waves can be received here.

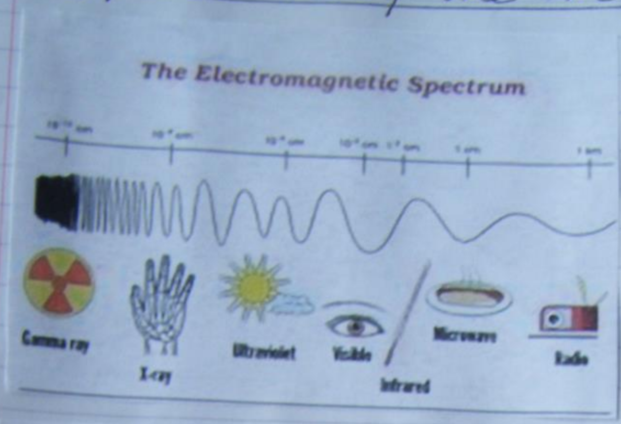
c) 

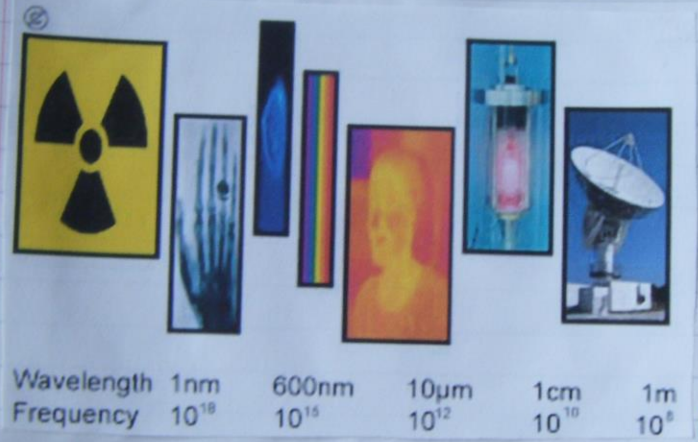
d) 

Waves diffracting through a gap wider than λ.

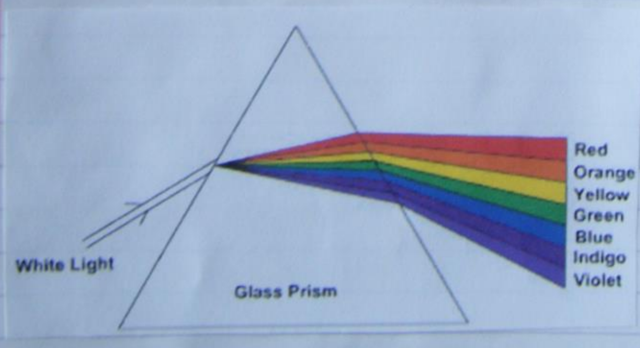
Waves diffracting through a gap narrower than λ.

Applications of the em spectrum





(Hz)



White light from the visible spectrum can be split into 7 colours using a glass prism.

ROYGBIV

	EM WAVE	RANGE	APPLICATION
1)	GAMMA RAYS	~ $\times 10^{-11}$m	Radioactive tracing within the body.
2)	X-RAYS	~ $\times 10^{-9}$m	X-Ray scanners at airports. Checking bones inside body
3)	Ultraviolet	~10nm to 400nm	Allows skin to tan and burn. Kills bacteria etc
4)	Visible light	400nm to 700nm	Only em radiation that can be viewed by the naked eye.
5)	Infrared	~1×10^{-5}m	Thermal imaging cameras. Physiotherapy muscle treatment
6)	Microwaves	~1cm to 10cm	Cooking food mobile phone transmissions
7)	TV Waves	~10cm to thousandths of metres.	Terrestial television signals
8)	Radio Waves		Radio telescopes DAB Radio signals.

Q. What is the difference between radio and TV waves?

A. They are basically the same, but TV uses higher frequency (shorter wavelength) in order to carry a higher information rate, ie greater bandwidth.

Q. Why are radio and TV waves not harmful?

A. Long wavelengths make them BENIGN. They diffract around objects rather than focus on them. This enables long distance communication.