CAMBRIDGE

Study & Master

Support Pack | Grade 10

CAPS

Physical Sciences

Waves, sound and light

This support pack for the **Waves, sound and light** strand of the **Physical Sciences Grade 10 CAPS curriculum** provides revision summaries on the topic to help prepare for the examinations. Learners can work through these individually at home or these could form the basis of a catch-up class or online lesson. You have permission to print or photocopy this document or distribute it electronically via email or WhatsApp.

Cambridge University Press Africa is a proudly South African publisher.

For more information on our *Study & Master* CAPS-approved textbooks and valuable resource materials, visit ***www.cambridge.org***

Brighter thinking | Better learning

www.cambridge.org

Unit 1: Transverse pulses on a string or spring

Summary

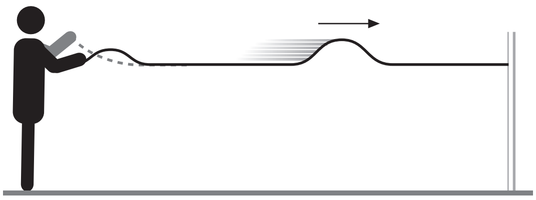
- A pulse is a single vibration travelling through a medium.
- The amplitude is the maximum displacement of particles in a medium.
- In a transverse pulse the particles move at right angles to the forward direction of the pulse.
- Superposition occurs when two pulses meet to occupy the same space at the same time. The pulses combine and the resultant displacement is the sum of the displacements of the individual pulses.
- Destructive interference occurs when two pulses move towards each other on opposite sides of a string. The crest of the one meets the trough of the other and the total amplitude is calculated by subtracting the two amplitudes.
- Constructive interference occurs when two pulses move towards each other and their crests troughs meet. They reinforce each other and the total amplitude is the sum of the individual waves.

Revision exercises: Unit 1 – Transverse pulses on a string or spring

1. Provide one term for each description.

a) The motion of the medium is perpendicular to the direction of the pulse
b) The maximum distance that matter is displaced from the resting position of a pulse
c) The displacement of a medium caused by two pulses is the algebraic sum of the displacements caused by the individual pulses.
d) When pulses come together, the resulting amplitude at that point is larger than the amplitude of an individual pulse.
e) The phenomenon that decreases amplitude when waves interact

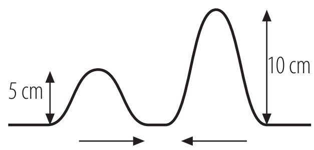
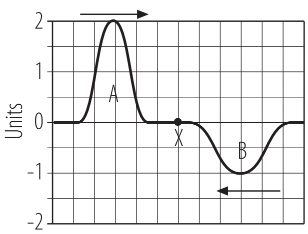
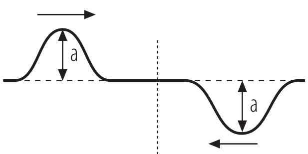
2. Sarah is generating pulses in a string as shown in the picture.



a) What is a pulse?
b) Is Sarah generating transverse or longitudinal pulses?
c) Describe the motion of the string particles.
d) What is the angle between the motion of the string particles and the direction in which the pulse is propagating?
e) Name the medium through which the pulses are propagated.
f) Redraw a single pulse and indicate the following on the sketch:
   i) pulse length
   ii) pulse amplitude
   iii) rest position.

3. When two or more waves meet at the same point, the resultant amplitude is determined by the principle of superposition.

a) Define this principle.
b) Each diagram in the table shows two pulses approaching each other in a uniform medium. Draw diagrams to show the pulses during superposition as well as after superposition. Indicate the amplitude and direction of propagation. Give the name of the phenomenon that occurs during superposition in each diagram.

Before superposition	During superposition	After superposition	Phenomenon
	i)	ii)	iii)
	iv)	v)	vi)
	vii)	viii)	ix)

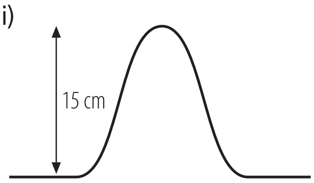
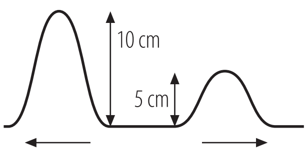
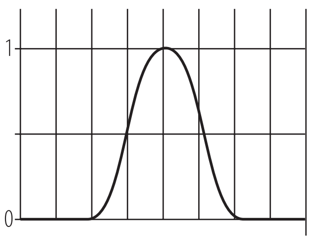
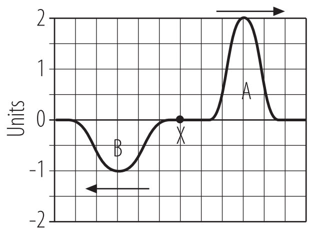
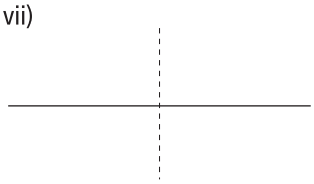
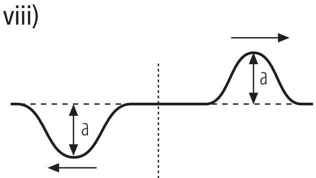
Unit 1: Answers

1. **a)** Transverse pulse
   b) Amplitude
   c) Superposition
   d) Constructive interference
   e) Destructive interference

2. **a)** A pulse is a single vibration travelling through a medium.
   b) Transverse pulses
   c) The string particles vibrate from their rest position upwards to a maximum displacement, and then back to their original rest position.

3. **a)** When two pulses meet to occupy the same space at the same time, they combine and the resultant displacement is the sum of the displacements of the individual pulses.

   b)

<table>
<tr><th>During superposition</th><th>After superposition</th><th>Phenomenon</th></tr>
<tr><td>i)

</td><td>ii)

</td><td>iii) Constructive interference</td></tr>
<tr><td>iv)

</td><td>v)

</td><td>vi) Destructive interference</td></tr>
<tr><td>vii)
</td><td>viii)

</td><td>ix) Destructive interference</td></tr>
</table>

Unit 2: Transverse waves

Summary

- A wave is an oscillation or disturbance in which energy is transferred away from the point of disturbance.
- A transverse wave is a succession of transverse pulses. Each particle moves up and down as the wave passes it.
- The rest or equilibrium position is the position of the undisturbed string or spring.
- The crests are the highest points of the waves.
- The troughs are the lowest points of the wave.

Revision exercises: Unit 2 – Transverse waves

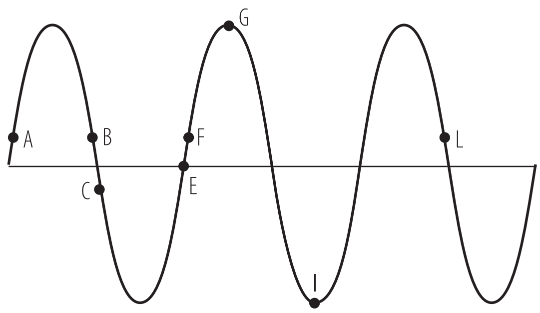
1. Provide one term for each description.

a) The number of waves per unit of time
b) Waves that occur when the motion of the medium is at right angles to the direction of the wave
c) The distance between two consecutive points in phase
d) The time taken for one complete wave to pass a fixed point
e) The lowest points in a transverse wave

2. Storms in the deep see can create waves that travel to the coast. If the waves travel at 16 $m \cdot s^{-1}$ towards the coast, which is 3 000 km away, how long does it take them to reach the coast? Give your answer in days and hours.

3. A seismic wave has a frequency of 0,2 Hz. It travels 12 km in 6 seconds. Determine the wavelength of the wave.

4. Study the wave diagram and answer the questions. Letters A to L represent points in the medium.



a) Write down letters that represent points in phase.
b) Which points are $2\frac{1}{2}$ wavelengths apart?
c) Give a point that lies on a trough.
d) Which point represents zero displacement?
e) If the wavelength is 6×10^{-3} m and the frequency is 5×10^{10} Hz, calculate the speed of the wave.
f) Is this an electromagnetic wave? Explain your answer.

Unit 2: Answers

1. **a)** Frequency
   b) Transverse waves
   c) Wavelength
   d) Period
   e) Troughs

2. $\Delta t = \frac{\Delta x}{v}$

   $= \frac{3 \times 10^6 \text{ m}}{16 \text{ m·s}^{-1}}$

   $= 187\,500 \text{ s} = 52{,}08 \text{ h}$

   $= 2$ days and $4{,}08$ h

3. $v = \frac{\Delta x}{\Delta t}$

   $= \frac{12 \text{ km}}{6 \text{ s}} = 2 \text{ km·s}^{-1}$

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

   $= \frac{2 \text{ km·s}^{-1}}{0{,}2 \text{ Hz}} = 10 \text{ km}$

4. **a)** A and F; B and L
   b) A and L
   c) I
   d) E
   e) $v = f \times \lambda$
   $= 5 \times 10^{10} \text{ Hz} \times 6 \times 10^{-3} \text{ m}$
   $= 3 \times 10^8 \text{ m·s}^{-1}$
   f) Yes; the speed corresponds to the speed of electromagnetic waves.

Unit 3: Longitudinal waves

Summary

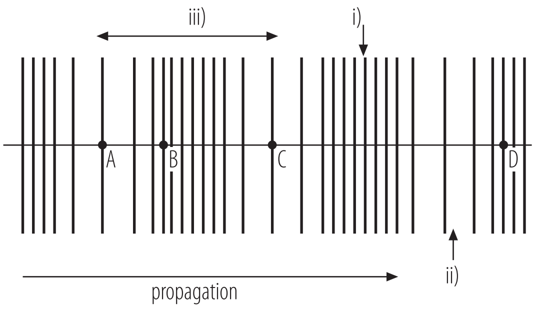
- In a longitudinal wave the particles move forwards and backwards and then return to their original positions. So, the particles in the coil oscillate in the same direction in which the wave is travelling.
- Compressions are the regions where the coils of the spring are closer together.
- Rarefactions are the regions where the coils of the spring are further apart.
- The amplitude (r) is the maximum displacement of the particles from their rest position.
- The wavelength (λ) is the distance between the centres of two consecutive compressions or two consecutive rarefactions.
- The frequency (f) is the number of compressions that pass a given point in one second.
- The period (T) is the time taken for one complete wavelength to pass a given point.
- $T = 1/f$ or $f = 1/T$
- The wave speed is the speed at which each compression appears to move: $v = f\lambda$

Revision exercises: Unit 3 – Longitudinal waves

1. Provide one term for the following.

a) The distance between two successive crests or two successive troughs
b) The amount of time it takes for one complete wavelength to pass a point in the medium
c) The name given to the regions where the coils of a spring are pulled apart when a longitudinal wave moves through

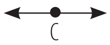
2. Study the diagram of a longitudinal wave and answer the questions.



a) Provide labels for i) to iii).
b) Describe the motion of the particle at position C as the wave moves to the right.
c) How many wavelengths are shown in the diagram?
d) If point A makes 336 oscillations in 1,75 seconds, what is the frequency of the wave?
e) Explain why points B and D are in phase.

Unit 3: Answers

1. **a)** Wavelength
b) Period
c) Rarefactions

2. **a)** **i)** Compression
ii) Rarefaction
iii) Wavelength
b) The particle moves to the left and right. 
c) 3
d) Frequency = number of oscillations per second

Therefore $f = \frac{336}{1{,}75\ \text{s}} = 192$ Hz

e) They perform the same movement at the same time and they are separated by a whole number of wavelengths.

Unit 4: Sound

Summary

- Sound waves are longitudinal waves that result from vibrations in a medium that cause the particles of the medium to be compressed and rarefied in the direction of propagation.
- The movement of the particles causes regular pressure changes in the medium. Sound waves are pressure waves and transmit energy.
- Sound waves travel well through gas (air), but better through a liquid and best through a solid. The pressure waves of sound are propagated better when the molecules of the medium are more closely spaced.
- The speed of sound increases with an increase in temperature.
- When a sound wave strikes an obstruction, it is reflected according to the laws of reflection (angle of incidence = angle of reflection).
- We hear sound that is reflected off a solid surface as an echo.
- The degree of highness or lowness of a sound is called its pitch and depends on its frequency −an increase in frequency causes the pitch to rise.
- Loudness depends on both the amplitude of a sound wave and its frequency – louder sounds produce waves with larger amplitudes; frequencies between 1 000 and 5 000 Hz sound louder to humans.
- Our brains interpret regular vibrations as musical sounds and a sound with a great number of different frequencies as a discordant noise.
- Ultrasound has frequencies above 20 kHz and humans cannot hear it.
- When an ultrasound wave travels inside an object with materials of different density, part of the wave is reflected and part is refracted at each boundary. The reflected rays can be detected by a probe and a computer displays an image on a monitor.
- Doctors use ultrasound to check on the health of babies before they are born, and to detect and examine blockages and other problems in internal organs.

Revision exercises: Unit 4 – Sound

1. Provide one term for each description.

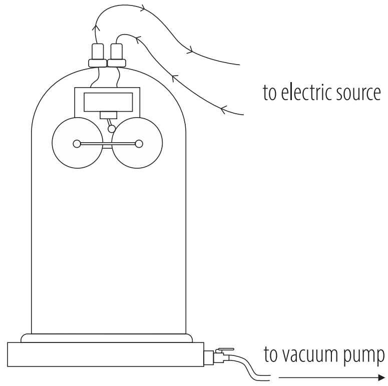
- **a)** Sound waves with frequencies above 20 kHz
- **b)** A bunched up area on a sound wave that corresponds to the crest of a transverse wave
- **c)** This property of a wave is a measure of the amount of energy it carries.
- **d)** The pitch of a sound wave depends on this property.

2. Before modern communication methods church bells were used as timekeepers and to mark the hour for prayer. Church bells today often ring to commemorate occasions and events. To ring the bell, the bell ringer pulls on a rope, swinging the clapper. The motion causes the clapper to hit the inside rim of the bell, making the sound.

a) Replace the words in brackets with a single term.

When the bell rings the sides of the bell i) (*flex inwards and outwards very rapidly*). This creates ii) (*regions of low pressure*) and iii) (*high pressure*) in the air next to the bell that are propagated out from the bell as waves. This is a typical iv) (*air molecules vibrate parallel to the direction of wave propagation*) wave.

b) Suppose an electric ringing bell is placed inside a sealed bell jar filled with air.



If air is gradually pumped out of the jar to create a vacuum, describe what a person nearby will hear before, while and after the air is removed from the jar. Explain your answer.

c) The outside temperature on a hot summer's day is almost 40 °C. The clock of the local church chimes at 13:00. Andile sits in the classroom and hears the sound 1,2 s later. The speed of the sound in the air is 351,88 $m \cdot s^{-1}$.

- **i)** Determine the distance between the church and the classroom.
- **ii)** If the frequency of the sound wave is 280 Hz, calculate the distance between two consecutive compressions in the sound wave travelling through air.
- **iii)** How will the time that it takes the sound to reach Andile's classroom differ if the church bell chimes early in the morning when the air temperature is much lower? Explain your answer.

3. Bats are one of humanity's most valuable allies in the fight against unwanted insects. Bats eat a large number of flying insects and are the main night-time predator of mosquitoes. A single little bat can consume hundreds of mosquitoes every night.

- **a)** How do bats catch their prey in the dark?
- **b)** A bat emits sound waves with frequency 10^5 Hz and wavelength 3,4 mm. The sound waves reflect against a tree 8,5 m in front of the bat.

i) Determine the speed of the sound waves.

ii How long before the bat hears the echo?

c) Determine the frequency and wavelength of the sound made by a mosquito if it vibrates its wings at 600 times per second. Take the speed of sound in air as $340\ m{\cdot}s^{-1}$.

Unit 4: Answers

1. **a)** Ultrasound
b) Compression
c) Amplitude
d) Frequency

2. **a)** **i)** Vibrate
ii) Rarefactions
iii) Compressions
iv) Longitudinal

b) The person will hear the bell ringing when the jar is filled with air. As the air becomes less dense, the sound becomes fainter. When the air is removed, the person will not be able to hear the sound. Sound waves are transmitted through waves of pressure variations. This method of transmission requires a material to compress and expand. In a vacuum, all air molecules are removed, thus there is no medium through which the sound can travel.

c) **i)** $\Delta x = v\Delta t$
$= 351{,}88 \text{ m·s}^{-1} \times 1{,}2 \text{ s} = 422{,}26 \text{ m}$

ii) $\lambda = \frac{v}{f}$
$= \frac{351{,}88 \text{ m·s}^{-1}}{280 \text{ Hz}}$
$= 1{,}26 \text{ m}$

iii) If the air temperature is lower, the speed of sound is lower. According to $t = \frac{\Delta x}{v}$: If Δx is constant and v decreases, then t will increase. It will take the sound longer to reach the class room.

3. **a)** Bats are not blind, but at night their ears are more important than their eyes. As they fly, they make high frequency shouting sounds. The returning echoes give the bats information about anything that is ahead of them, including the size and shape of an insect and which way it is going. This system of finding prey is called echolocation - locating things by their echoes.

b) **i)** $v = f \times \lambda$
$= 10^5 \text{ Hz} \times 3{,}4 \times 10^{-3} \text{ m}$
$= 340 \text{ m·s}^{-1}$

ii) $\Delta t = \frac{\Delta x}{v}$
$= \frac{17 \text{ m}}{340 \text{ m·s}^{-1}}$
$= 0{,}05 \text{ s}$

c) $f = 600 \text{ Hz}$
$\lambda = \frac{v}{f}$
$= \frac{340 \text{ m·s}^{-1}}{600 \text{ Hz}}$
$= 5{,}67 \times 10^{-1} \text{ m}$

Unit 5: Electromagnetic radiation

Summary

- Electromagnetic (EM) radiation exhibits both wave and particle properties. This is called the wave-particle duality.
- EM radiation originates from charges that accelerate and give off energy.
- EM radiation consists of electric and magnetic fields that oscillate perpendicularly to one another and the direction of propagation. It has the same shape as transverse waves.
- All electromagnetic waves travel through space at a constant speed of $c = 3 \times 10^8\ m{\cdot}s^{-1}$
- The seven different types of EM waves have different frequencies, wavelengths and energy. We use the wave equation ($c = f\lambda$) to calculate the frequencies and wavelengths.
- Electromagnetic waves are grouped according to wavelength.
- Gamma rays have the shortest wavelength and can pass through most substances. They are emitted from radioactive substances such as uranium and radium. Gamma rays are used to kill cancer cells in tumours and to sterilise surgical instruments.
- X-rays have wavelengths between that of ultraviolet light and gamma rays. They are produced when fast-moving electrons are brought to a sudden stop when they hit a metal target. X-rays are used by doctors and dentists to see what is going on inside our bodies. Security checks at airports use X-ray machines to identify objects in handbags, briefcases and luggage.
- Ultraviolet (UV) waves have wavelengths between X-rays and violet in the visible spectrum. The surface of the sun emits UV rays that cause the skin to tan and form vitamin D that helps to strengthen our bones. UV rays kill microbes in hospitals. Forensic scientists use UV light to look for clues at a crime scene.
- The visible spectrum is that part of the spectrum that we can see and contains the seven colours in order: violet, indigo, blue, green, yellow, orange and red. Red has the longest and violet the shortest wavelength.
- Infrared waves have longer wavelengths than red. Near infrared waves are not hot and are used in the remote control of a television set. Far infrared waves are also called thermal waves because they carry heat. They radiate from all objects that are warmer than their surroundings. The heating element in a conventional oven gives off infrared waves to cook food.
- Microwaves are electromagnetic waves with wavelengths between that of infrared and radio waves. The sun emits microwave radiation. A microwave oven produces microwaves that cause water molecules in food to rotate and cook food through friction.
- Radio waves have the longest wavelengths. Natural radio waves are made by lightning and stars. Man-made radio waves are used for radio communication, broadcasting, radar and other navigation systems.
- Gamma rays have the highest frequency and, therefore, carry the most energy. They are the most penetrative and can pass through most substances. X-rays have lower energy and pass through soft tissues. The lower frequency waves cannot penetrate solids.

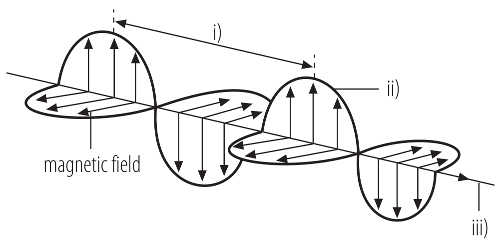
- A photon is a discrete amount (packet) of energy and is the basic particle of all EM radiation.
- Higher frequency waves carry more energy: $E = hf$ where E is the energy of the photon, f is the frequency of the photon and h is the Planck constant $= 6{,}63 \times 10^{-34}$ J·s.
- $E = \frac{hc}{\lambda}$ where $c = 3 \times 10^{8}$ m·s^{-1} and λ the wavelength.

Revision exercises: Unit 5 – Electromagnetic radiation

1. Provide one term for each description.

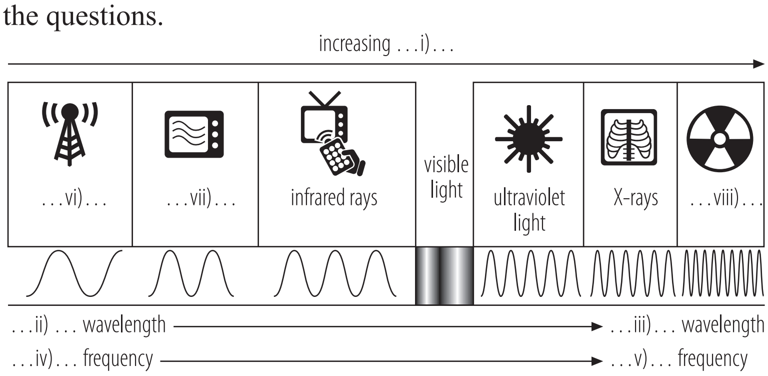
- **a)** All electromagnetic waves travel at this speed in a vacuum
- **b)** The type of electromagnetic waves used in heat lamps
- **c)** Electromagnetic waves with the shortest wavelength and the highest frequency
- **d)** The very narrow range of waves in the electromagnetic spectrum that humans can see
- **e)** A discrete packet of energy associated with electromagnetic radiation
- **f)** Electromagnetic waves exhibit both particle and wave-like properties
- **g)** The angle between the magnetic and electric fields of an electromagnetic wave
- **h)** This model describes a beam of light as a stream of photons, each carrying a discrete amount of energy

2. The diagram shows a typical electromagnetic wave.



- **a)** Provide labels for i) to iii).
- **b)** How are electromagnetic waves created?
- **c)** List four characteristics of electromagnetic waves.

3. The diagram shows the electromagnetic spectrum. Use the diagram to answer the questions.



- **a)** Complete the missing terms i) to viii).
- **b)** An X-ray has a wavelength of 5 nanometers. Calculate the energy carried by an X-ray photon.
- **c)** State one main difference between X-rays and sound waves.
- **d)** Why can ultraviolet light cause skin cancer but ordinary visible light not?
- **e)** Why is it possible for an electromagnetic wave to travel through a vacuum?
- **f)** Explain how a microwave cooks food.
- **g)** Name the electromagnetic wave that fits each description.
  - **i)** This electromagnetic wave is used in airport security scanners.
  - **ii)** This electromagnetic wave is used in night-vision cameras.
  - **iii)** This electromagnetic wave is emitted from the nuclei of radioactive atoms.
  - **iv)** This electromagnetic wave is needed for the production of vitamin D in the body.

Unit 5: Answers

1. **a)** 3×10^8 m·s^{-1}
   b) Infrared
   c) Gamma rays
   d) Visible light / spectrum
   e) Photon
   f) Wave–particle duality
   g) 90°
   h) Particle model

2. **a)** **i)** Wavelength **ii)** Electric field
   iii) Direction of propagation
   b) Electromagnetic waves are produced because of the accelerated motion of electric charges. When electrons are accelerated within atoms, they produce changing electric fields. These changing electric fields generate changing magnetic fields in a plane perpendicular to the electric field plane.
   c) They can travel through a vacuum.
   They travel at speeds of 3×10^8 m·s^{-1} in a vacuum.
   They consist of oscillating electric and magnetic fields.
   They have wave and particle nature.
   They transfer energy.
   They can be reflected, diffracted and can interfere.

3. **a)** **i)** Energy **ii)** Long
   iii) Short **iv)** Low
   v) High **vi)** Radio waves
   vii) Microwaves **viii)** Gamma rays
   b) $E = \frac{hc}{\lambda}$
   $= \frac{6{,}63 \times 10^{-34}\ \text{J·s} \times 3 \times 10^8\ \text{m·s}^{-1}}{5 \times 10^{-9}\ \text{m}}$
   $= 3{,}98 \times 10^{-17}$ J
   c) X-rays are transverse waves (electromagnetic waves). Sound waves are longitudinal waves.
   d) UV light has a shorter wavelength than visible light, so it has more energy ($E = \frac{hc}{\lambda}$).
   This means that it penetrates deeper into our skin than visible light and is more likely to cause damage to the cells.
   e) Electromagnetic waves are composed of oscillating electric and magnetic fields. These fields do not require a medium and thus can travel through a vacuum. In fact, air and other mediums slow light down.
   f) In a microwave oven, the electromagnetic waves generated are tuned to frequencies that can be absorbed by water molecules. As water molecules absorb energy, they vibrate faster and faster and the temperature of the water increases, so food containing water molecules gets hot.
   g) **i)** X-rays **ii)** Infrared rays
   iii) Gamma rays **iv)** Ultraviolet rays