



14

ELECTROMAGNETIC SPECTRUM

- 14.1** Properties of electromagnetic waves
- 14.2** Applications of electromagnetic waves
- 14.3** Effects of electromagnetic waves on cells and tissue

Learning Outcomes

Candidates should be able to:

- (a) state that all electromagnetic waves are transverse waves that travel with the same speed in vacuum and state the magnitude of this speed
- (b) describe the main components of the electromagnetic spectrum
- (c) state examples of the use of the following components:
 - (i) radiowaves (e.g. radio and television communication)
 - (ii) microwaves (e.g. microwave oven and satellite television)
 - (iii) infra-red (e.g. infra-red remote controllers and intruder alarms)
 - (iv) light (e.g. optical fibres for medical uses and telecommunications)
 - (v) ultra-violet (e.g. sunbeds and sterilisation)
 - (vi) X-rays (e.g. radiological and engineering applications)
 - (vii) gamma rays (e.g. medical treatment)
- (d) describe the effects of absorbing electromagnetic waves, e.g. heating, ionisation and damage to living cells and tissue

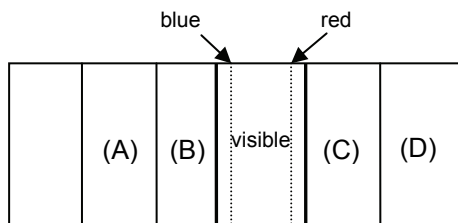
14•1

Properties of electromagnetic waves

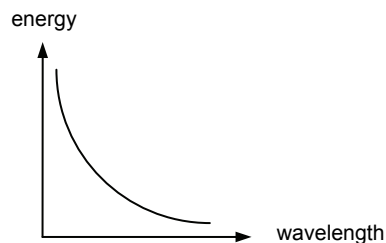
MCQs

- Which of the following statements about electromagnetic waves is correct?
 - Radio waves propagates as both transverse and longitudinal waves
 - The frequency of the electromagnetic waves decreases from micro wave to γ -radiation
 - All electromagnetic waves travel at the same speed in vacuum
 - Infra red radiation has more energy than ultra-violet light
- What could be used to detect the radiation just outside the red end of the visible spectrum?
 - fluorescent paper
 - sensitive thermometer
 - radio receiver
 - Geiger-Muller counter
- Which of the following waves will best penetrate fog or low cloud?
 - infra-red
 - radio
 - red light
 - ultra-violet
- A copper plate is heated to 100°C . It cools by emitting
 - electrons.
 - γ - radiation.
 - infra-red radiation.
 - ultraviolet radiation.

- The diagram shows the electromagnet spectrum, with the blue end and red end of the visible spectrum marked. Which section of the spectrum has waves which have a long wavelength and can be produced by electrical oscillations in a circuit?



- The diagram shows the relationship between the energy of electromagnetic radiation and the wavelength of the waves.



Which of the following has the highest energy?

- infra-red
 - X-rays
 - ultra-violet
 - microwaves
- Which one of the following groups of electromagnetic waves is in order of increasing frequency?
 - microwaves, ultraviolet rays, X-rays
 - gamma ray, visible light, ultraviolet rays
 - radio waves, visible light, infra-red radiation
 - gamma ray, ultra-violet rays, radio waves

8. Which of the following is not true about electromagnetic waves? They all
- (A) travel through vacuum at a speed of $3 \times 10^8 \text{ m s}^{-1}$.
- (B) require a transparent medium to transverse.
- (C) slow down if they pass through a denser medium.
- (D) are transverse waves.



9. X and Y are different wave motions. X travels much faster than Y but has a much shorter wavelength. What could X and Y be?

X	Y
(A) radio waves	sound waves
(B) red light	infrared radiation
(C) sound waves	ultraviolet radiation
(D) ultraviolet radiation	radio waves



10. On a sunny day, a lady parks her car with all its windows closed. When she returns, she is surprised at how unpleasantly hot it is inside. The reason for this is

- (A) infra-red rays from the sun are high energy rays and can easily pass through the glass windows.
- (B) ultra-violet rays from the sun have become trapped inside the car.
- (C) infra-red rays emitted from the inside of the car have been trapped in the car.
- (D) the sun has warmed up the metal surface of the car.



11. The following pieces of instruments are used on a ship. Which of the following produces waves that are not electromagnetic?

- (A) Navigation lights (B) Radar
(C) Radio Transmitter (D) Fog horn



12. How do the wavelength, frequency and speed of ultraviolet light in vacuum compare with those of visible light?

Wavelength	Frequency	Speed
(A) Longer	Higher	Slower
(B) Longer	Lower	Same
(C) Same	Lower	Slower
(D) Shorter	Higher	Same

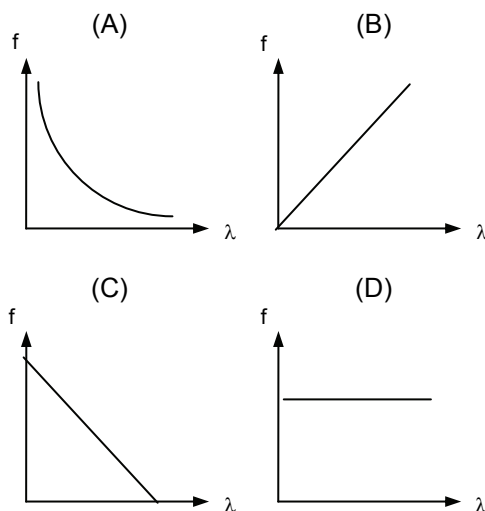


13. Which of the statements below is true of electromagnetic waves?

- (A) Radio waves are longitudinal waves.
- (B) The wavelength of infra-red radiation is longer than ultraviolet radiation.
- (C) All electromagnetic waves travel at the same speed in water.
- (D) Ultrasound has a higher frequency than radio waves.



14. Which one of the following graphs shows the correct relationship between the frequency f of an electromagnetic wave and its wavelength, λ ?



15. Which of the following statements about waves is incorrect?

- (A) Visible light rays can travel through a vacuum.
- (B) Infra-red rays are emitted by hot objects.
- (C) Ultra-violet rays can produce sunburn.
- (D) Radio waves can travel through thick sheet of concrete.



16. The diagram represents some of the main parts of the electromagnetic spectrum.

1	Infra-red	2	3	4	Gamma rays
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What are the numbered parts?

- | | 1 | 2 | 3 | 4 |
|-----|---------------|---------------|---------------|-------------|
| (A) | radio waves | ultraviolet | visible light | X-rays |
| (B) | radio waves | visible light | ultraviolet | X-rays |
| (C) | visible light | ultraviolet | X-rays | radio waves |
| (D) | visible light | ultraviolet | radio waves | X-rays |



Questions – 14.1

1. In a determination of the speed of light passing from the Sun to the Earth, which of the following values is most likely to be recorded?

- 3×10^3
- 3×10^8
- 3×10^{13}
- 3×10^{18}

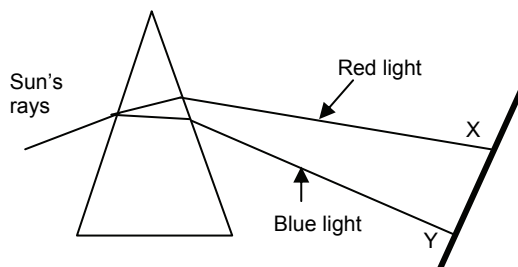
When determining the speed of ultra-violet radiation from the Sun to the Earth, state the value you would expect and give a reason for your answer.



2. (a) Assuming that the speed of electromagnetic radiation is $3 \times 10^8 \text{ m s}^{-1}$, calculate the wavelength of ultra-violet radiation which has frequency of $2.5 \times 10^{15} \text{ Hz}$.
- (b) Indicate how you would attempt to detect the presence of ultra-violet radiation.
- (c) Describe how you would show that ultra-violet radiation may be reflected.



3. The diagram shows the paths of two colours in the visible part of the radiation from the sun as it passes through the prism.



- (a) At X and Y there are small amounts of radiation which have passed through the prism but cannot be seen.
- Name the type of radiation at (i) X and (ii) Y.
- (b) Describe one method by which the radiation at Y may be detected.



Applications of electromagnetic waves

1 4 • 2

4. (a) Describe a simple test which can be used to distinguish between a beam of infra-red radiation and a beam of ultra-violet radiation.
- (b) Draw a labelled diagram of an experiment to show that a filament lamp emits radiation beyond the red end of the visible spectrum.



MCQs

- Which of the following about ultraviolet rays is not correct?
 - They produce fluorescence in fluorescent material.
 - They may be used for sterilization.
 - They are widely employed for burglar alarm.
 - They are absorbed by plants to perform photosynthesis.
- Which of the following electromagnetic waves is usually employed in industrial heating and drying?

(A) Microwaves	(B) Infra-red rays
(C) Visible light	(D) X-rays
- Which of the following waves is the most suitable for healing cancer?

(A) X-rays	(B) Gamma-rays
(C) Ultrasonic	(D) Ultraviolet rays
- An electromagnetic radiation used to make satellite photographs of the weather in the daytime and at night is

(A) infra-red	(B) microwaves
(C) visible light	(D) ultraviolet
- Which type of wave passes through fog and low cloud with the least difficulty?
 - Monochrome blue light
 - Radio
 - Ultraviolet
 - Infra-red

6. Which of the following does not make use of electromagnetic waves in its operation?

- (A) A camera (B) A radio set
(C) A microphone (D) A television set



7. Infra-red is used in communication. Which one of the following is the correct explanation?

- (A) IR is used in lasers that shine through the air.
(B) IR is used in optical fibres which can make it go round bends.
(C) IR is beamed down from satellites to receivers on the ground.
(D) IR is useful to those who can see infra-red.



Questions – 14.2

1. (a) Describe briefly what happens when
- ultra-violet radiation
 - visible light and
 - infra-red radiation
- contained in sunlight fall on a window pane.
- (b) Describe one method of detecting infra-red radiation.



2. Explain why, when viewed through a thick piece of blue glass, a lamp emitting white light appears less bright to the observer.



3. Very short wavelength radio waves can be used to determine the distance of the Moon from the Earth, by measuring the time taken for radio-waves to travel from the Earth to the Moon and back again. Calculate the delay between the transmission and reception of the signal when the Moon is 3.9×10^8 m from the Earth.



4. A satellite passing the planet Neptune communicates with its controller on the Earth using a microwave transmitter with output power 22.0 W and wavelength $79600 \mu\text{m}$. Neptune is 4.35×10^{12} m from the Earth at the time when the communication takes place.

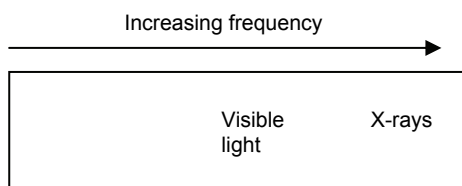
- (a) State two main properties of microwave.
(b) Calculate the time taken for a signal to travel from the satellite to the Earth.



5. (a) Draw a labeled diagram to show how you would detect a beam of infra-red radiation.
(b) State clearly the effect which the radiation has when it reaches your arrangement and the observation which you make.



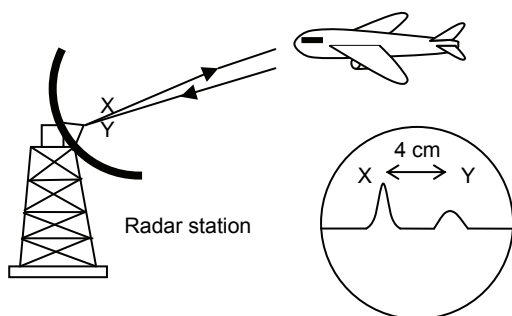
6. (a) Name three regions of the electromagnetic spectrum other than X-rays and visible light.
- (b) Copy the figure below and on it show the position of the here regions of the electromagnetic spectrum that you have chosen in (a).



- (c) Write one or two sentences about each region of the spectrum that you have chosen, describing how the electromagnetic waves are used or how they affect people.
- (d) State one property that all parts of the electromagnetic spectrum have in common.



7. The two peaks, X and Y, shown in the figure above were produced on the screen of a cathode ray oscilloscope when high frequency radio waves (radar) were sent out (X) and returned (Y) after bouncing off an aeroplane. The time-base was set at 2 cm per ms and the distance XY is 4 cm apart.



- (a) Why is the amplitude of the graph at Y lower than that X?
- (b) What is the time taken for the radio wave from the radar station to reach the aeroplane?
- (c) Calculate the distance between the radar station and the aeroplane at the instant when the measurement was taken. Explain your answers carefully. (Speed of light in air is $3.0 \times 10^8 \text{ m s}^{-1}$)



8. The table below gives information about the wavelength and output power of some types of laser.

Type of laser	Wavelength /m	Output power /W
Excer	3.2×10^{-7}	20.0
Neon	4.9×10^{-7}	2.0
Diee	5.5×10^{-7}	0.5
Hee-lee	6.3×10^{-7}	0.005
Yak	10.6×10^{-7}	50.0

The visible spectrum has wavelengths ranging from $4.0 \times 10^{-7} \text{ m}$ to $7.0 \times 10^{-7} \text{ m}$.

- (a) Which laser emits infra-red radiation?
- (b) Name one medical use of infra-red radiation.
- (c) Calculate the frequency of light from the Hee-lee laser.
- (d) Light from a Neon laser is used to treat a patient's eye. During the treatment, the laser fires 20 short pulses of light. Each pulse lasts 0.2 s.

Calculate the energy given out by the laser during treatment.



9. Fill up the blanks in the table below.

Wave	Wavelength	Use
Long Wave Radio	1500 m	
Medium Wave Radio	300 m	
Short Wave Radio	25 m	
FM Radio	3 m	
UHF Radio	30 cm	
Microwaves	3 cm	
Infra red	3 mm	
Light	200 - 600 nm	
Ultra violet	100 nm	
X-ray	5 nm	
Gamma rays	<0.01 nm	



①④③

Effects of electromagnetic waves on cells and tissue

Questions – 14.3

1. (a) A nuclear explosion occurs as a result of the rapid release of energy from an uncontrolled nuclear reaction. The energy of a nuclear explosion is initially released in the form of gamma rays.

Briefly explain why people near the location mostly suffer severe burns?

- (b) Despite the harmful effects of gamma rays as stated above, gamma rays has contributed much to man's medical as well as food preservation developments.

Briefly describe and give an example for each of the developments.



Answer keys:**1 4 • 1****MCQs**

1. C
2. B
3. B
4. C
5. D
6. B
7. A
8. B
9. A
10. C
11. D
12. D
13. B
14. A
15. D
16. B

Questions

1. 3×10^8
 3×10^8 m/s
2. (a) 1.2×10^{-7} m
3. (a)(i) infra-red
(a)(ii) ultraviolet

1 4 • 2**MCQs**

1. C
2. B
3. B
4. A
5. B
6. C
7. B

Questions

3. 2.6 s
4. (b) 1.45×10^4 s

7. (b) 1 ms
(c) 3×10^5 m
8. (a) Excer
(c) 4.76×10^{14} Hz
(d) 8 J