A-Level Physics

Longitudinal and Transverse Waves

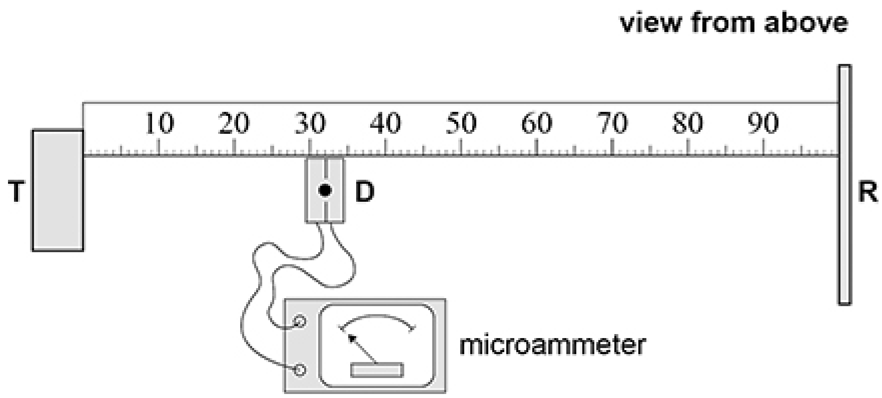
Question Paper

Time available: 65 minutes
Marks available: 48 marks

1. A student investigates stationary waves using microwaves.

Figure 1 shows a metre ruler fixed to a bench. The student places a microwave transmitter **T** at one end of the ruler and a vertical metal reflector **R** at the other end. **R** is at a right angle to the ruler.

Figure 1



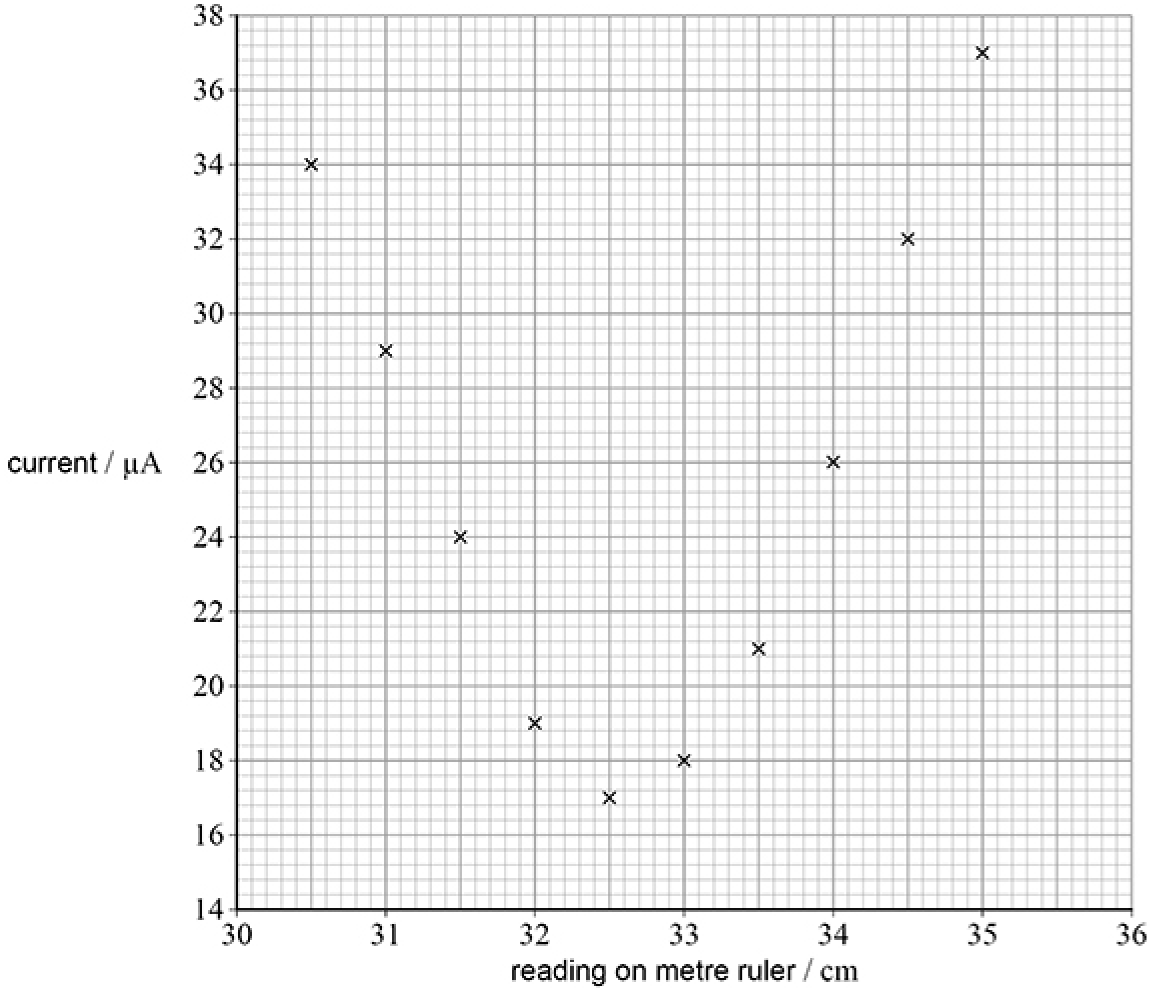
The student places a microwave detector **D** approximately one-third of the distance from **T** to **R**. When **T** is switched off, the microammeter connected to **D** reads zero.

When **T** is switched on, stationary waves are produced between **T** and **R**, and the microammeter registers a current. When the student moves **D** along the ruler, the size of the current changes between maximum and minimum values.

The student measures the current at different positions of **D** along the ruler to identify a position **P** of the minimum current.

Figure 2 is a plot of the measurements taken near **P**.

Figure 2



(a) Draw a line of best fit for these data.

(2)

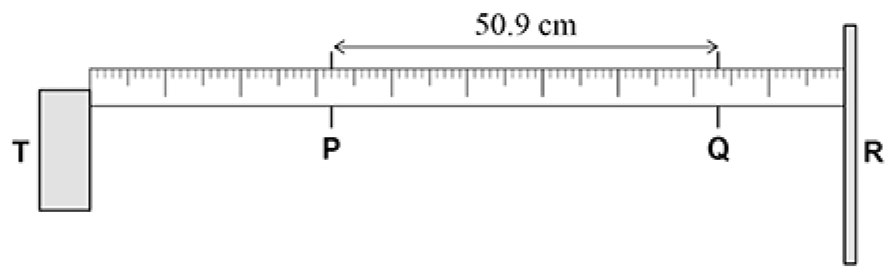
(b) State a value for the position of **P**.

position of **P** = _______________ cm

(1)

The student moves **D** along the metre ruler towards **R** and observes a series of maximum and minimum readings on the microammeter. He identifies **Q** as the position of the **8th minimum** current from **P**. He measures the distance **PQ** to be 50.9 cm, as shown in **Figure 3**.

Figure 3



(c) The absolute uncertainty in identifying any minimum current is ± 0.2 cm.

Determine the percentage uncertainty in the distance **PQ**.

percentage uncertainty in **PQ** = _______________ %

(2)

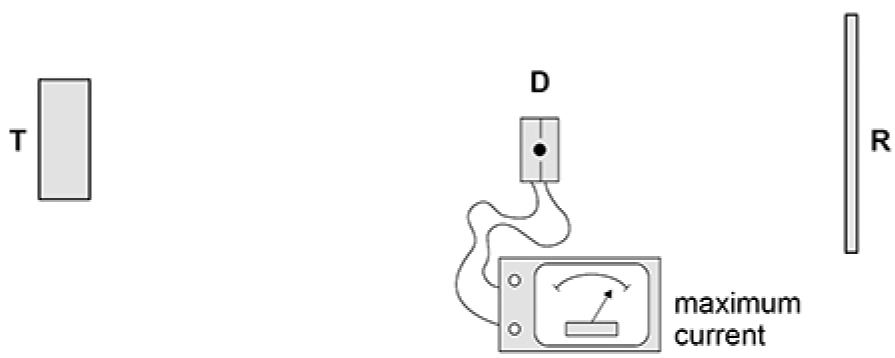
(d) Deduce the frequency of the microwaves produced by **T**.

frequency = _______________ Hz

(3)

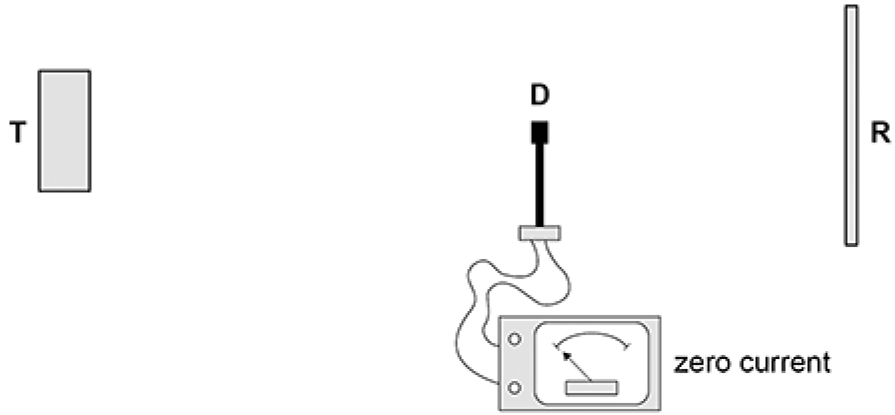
(e) **Figure 4** shows **D** placed at a position where the current is a maximum.

Figure 4



The student rotates **D** by 90°, without changing its distance from **T**, to the position shown in **Figure 5**. The current is now zero.

Figure 5



State the property of microwaves that is shown by this change in current.

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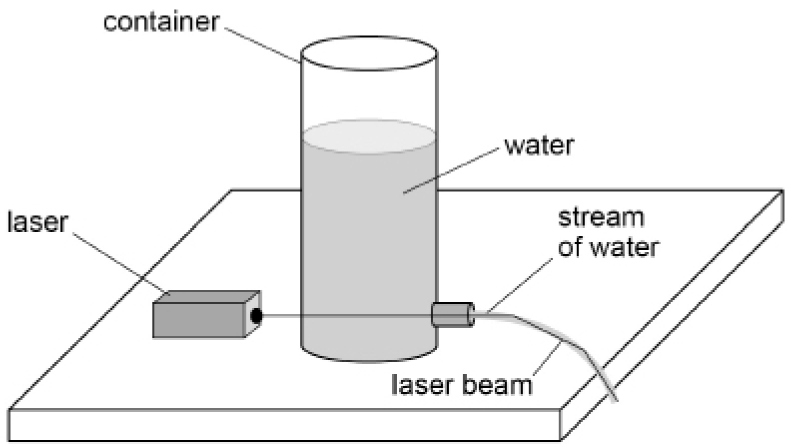
(1)
(Total 9 marks)

2. In 1870 John Tyndall sent a beam of light along a stream of water.
Figure 1 shows a modern version of Tyndall's experiment using a laser beam.
Water has a refractive index of 1.33

Figure 1



(a) Explain why the laser beam stays inside the stream of water.

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(2)

(b) Calculate the speed of the laser light in the water.
Give your answer to an appropriate number of significant figures.

speed = ____________________ $m\ s^{-1}$

(3)

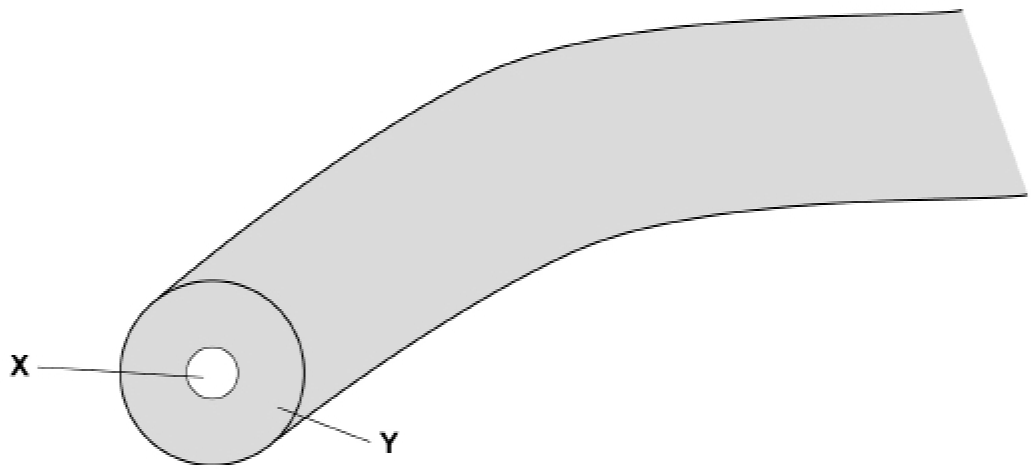
(c) Calculate the critical angle for the water−air boundary.

critical angle = ____________________ degrees

(1)

(d) Tyndall's experiment led to the development of optical fibres.
Figure 2 shows a step-index optical fibre.

Figure 2



Discuss the properties of a step-index optical fibre.

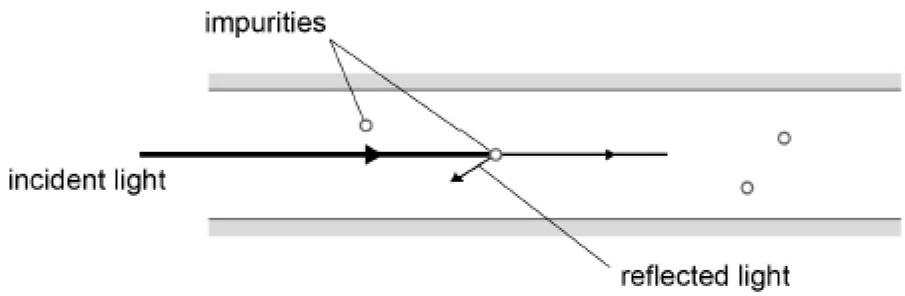
Your answer should include:

- the names of part **X** and part **Y**
- a description of the functions of **X** and **Y**
- a discussion of the problems caused by material dispersion and modal dispersion and how these problems can be overcome.

(6)

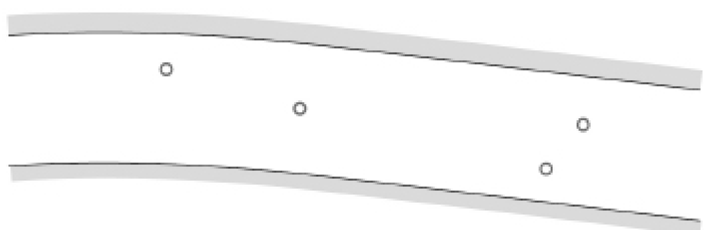
(e) Scientists use optical fibres to monitor earthquakes. Light travelling through an optical fibre can be reflected by impurities in the fibre, as shown in **Figure 3**.

Figure 3



Earthquakes bend the optical fibre slightly, as shown in **Figure 4**. This changes the amount of reflected light.

Figure 4



Suggest why the amount of reflected light changes as the fibre bends.
You may draw on **Figure 4** as part of your answer.

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(2)

(f) The waves caused by earthquakes can be longitudinal or transverse.

Describe the difference between longitudinal waves and transverse waves.

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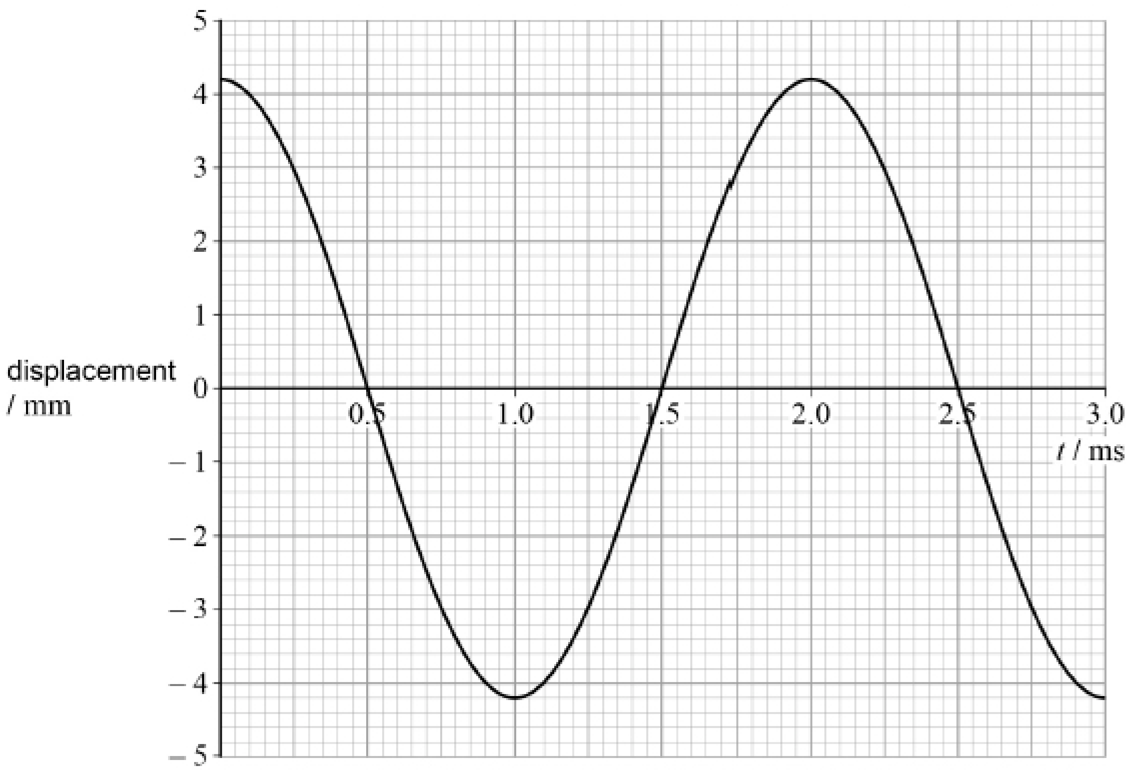
(2)

(Total 16 marks)

3. A loudspeaker cone is driven by a signal generator (oscillator).

The graph shows the variation of displacement with time *t* for a point **P** at the centre of the cone.

P is oscillating with simple harmonic motion.



(a) State the time, in milliseconds, when **P** is moving at its maximum positive velocity.

time = ____________________ ms

(1)

(b) Calculate the maximum acceleration of **P**.

acceleration = ____________________ m s^{-2}

(3)

(c) The loudspeaker creates variations in pressure and produces a sound wave in the air around it.

State the type of wave produced and describe the motion of the particles in this type of wave.

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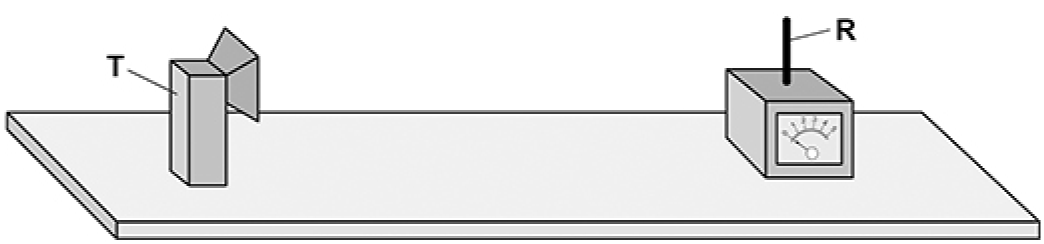
(1)

(Total 5 marks)

4. **Figure 1** shows apparatus used to investigate the properties of microwaves.
The microwaves from the transmitter **T** are vertically polarised and have a wavelength of about 3 cm.
The microwaves are detected at the receiver by a vertical metal rod **R**.

Figure 1



(a) Explain how the apparatus can be used to demonstrate that the waves from **T** are vertically polarised.

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(3)

Figures 2a and **2b** show **T** and **R** and two different positions of a metal plate **M** that reflects microwaves. **M** is vertical and parallel to the direct transmission from **T** to **R**.

Figure 2a

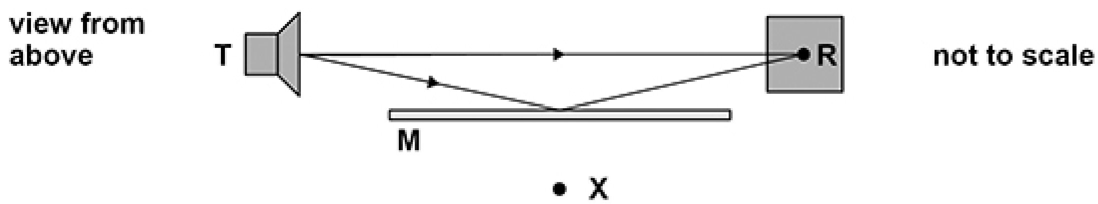
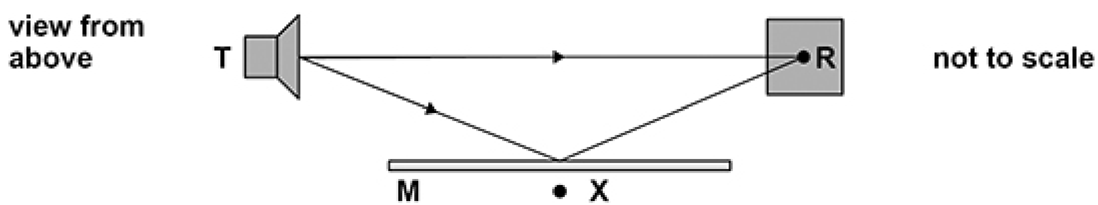


Figure 2b



In an experiment, **T** and **R** are about two metres apart. **M** is moved slowly towards **X**.
Figure 2a shows the initial position of **M**.
Figure 2b shows **M** when it has been moved a few centimetres.

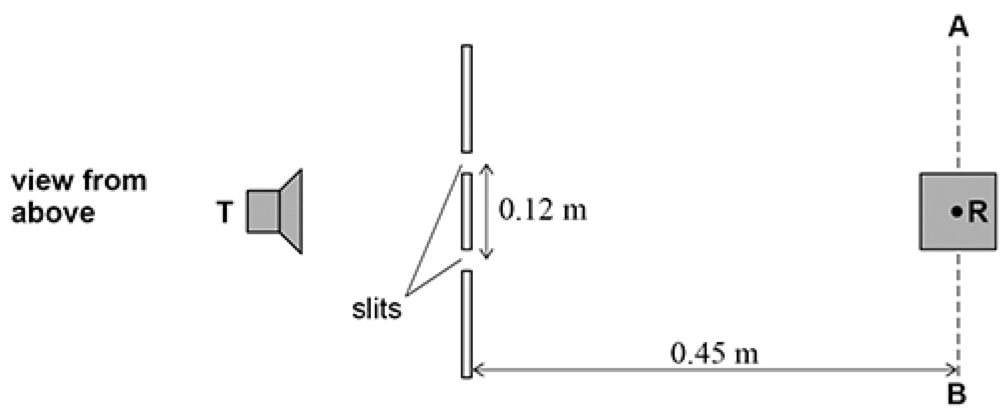
The arrowed lines show the path of waves that reach **R** directly and the path of waves that reach **R** by reflection from **M**.

(b) Explain what happens to the signal detected by **R** as **M** is moved slowly towards **X**.

(4)

Figure 3 shows an arrangement used in a different experiment to try to determine the wavelength of the microwaves.

Figure 3



A double-slit arrangement is placed between **T** and **R**.

The initial position of **R** is the same distance from each slit and is 0.45 m from the midpoint of the two slits.
AB is a line perpendicular to the line between **T** and the initial position of **R**.
R can be moved 0.25 m towards **A** and 0.25 m towards **B** along **AB**.

The two slits act as two coherent sources with a separation of 0.12 m.

(c) Suggest why Young's double-slit equation should **not** be used to determine the wavelength.

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(1)

(d) The wavelength is known to be about 3 cm.

Deduce whether this practical arrangement is suitable for a determination of a value for the wavelength.

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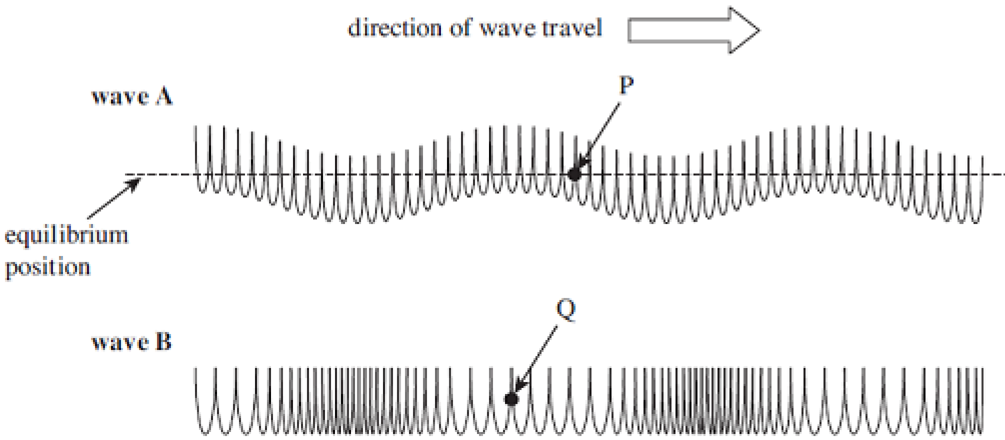
(3)

(Total 11 marks)

5. The figure below shows two ways in which a wave can travel along a slinky spring.



(a) State and explain which wave is longitudinal.

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(2)

(b) On the figure above,

(i) clearly indicate and label the wavelength of **wave B**

(1)

(ii) use arrows to show the direction in which the points **P** and **Q** are about to move as each wave moves to the right.

(2)

(c) Electromagnetic waves are similar in nature to **wave A**.

Explain why it is important to correctly align the aerial of a TV in order to receive the strongest signal.

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(2)

(Total 7 marks)