IB · DP · Physics

2 hours | 14 questions

Structured Questions

4.3 Wave Characteristics

4.3.1 Wavefronts / 4.3.2 Amplitude & Intensity / 4.3.3 Superposition / 4.3.4 Polarisation / 4.3.5 Malus's Law

Easy (5 questions)	/43
Medium (5 questions)	/59
Hard (4 questions)	/39
Total Marks	**/141**

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Easy Questions

1 (a) Outline what is meant by the terms

(i) Wavefront

[2]

(ii) Ray

[1]

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(3 marks)

(b) Complete the following sentence by placing a tick (✓) next to the correct answer:

The distance between two consecutive wavefronts is equal to the:

	wavelength
	frequency
	amplitude

.....

(1 mark)

(c) On the grid below, draw scale diagrams showing the wavefronts for

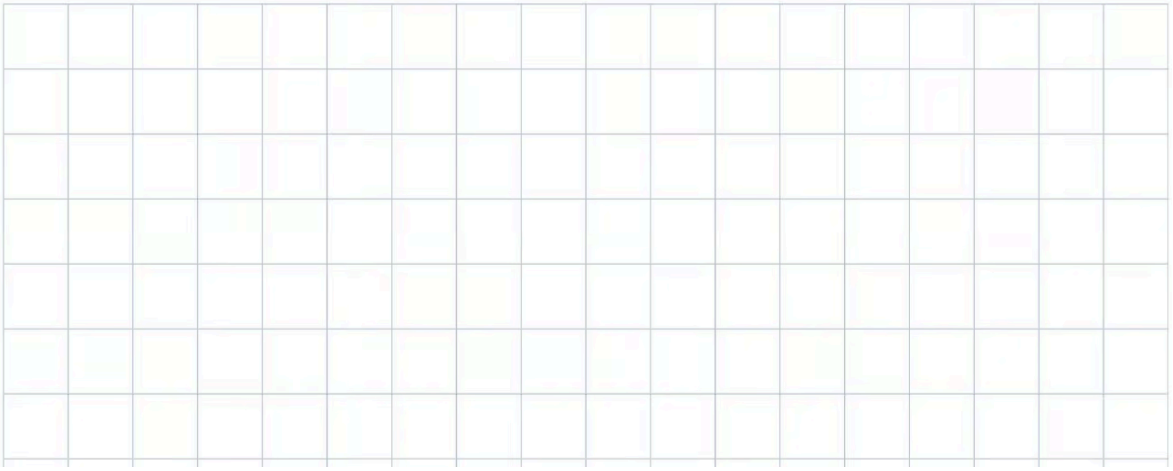
(i) A plane wave with a wavelength of 1 cm.

[2]

(ii) A circular wave with a wavelength of 1 cm.

[2]

On both diagrams, show with arrows, the direction of propagation.



(4 marks)

(d) Complete the following sentences by circling the correct word:

The higher the frequency of an oscillation, the **longer / shorter** the wavelength and the **closer / further apart** the wavefronts are **to / from** one another.

The lower the frequency of the oscillation, the **longer / shorter** the wavelength and the **closer / further apart** the wavefronts are **to / from** one another.

(2 marks)

2 (a) Match the terms power and intensity to their correct definitions and SI units.

Power	
Intensity	

The rate of energy transfer per unit area
$J\ s^{-1}$
$J\ s^{-1}\ m^{-2}$
The rate of energy transfer

.....

.....

(2 marks)

(b) A point source radiates light waves in all directions. The intensity, *I*, of the waves is related to the power, *P*, by the equation:

$$I = \frac{P}{4\pi r^2}$$

The relationship between the distance from the point source, *r*, and the intensity of the wave are shown to follow an inverse square law.

Describe what is meant by the term inverse square law in this context.

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(2 marks)

(c) Describe the relationship between intensity, *I*, and amplitude, *A*.

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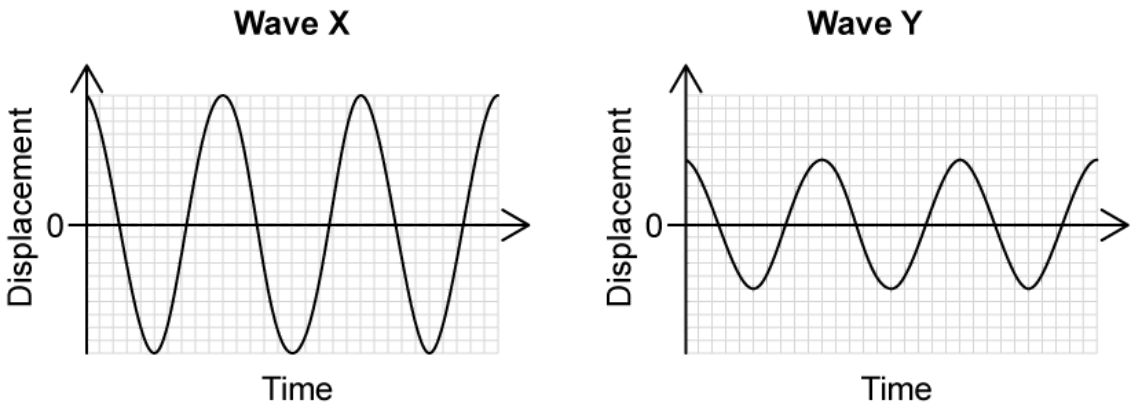
(2 marks)

(d) Two students are investigating the relationship between intensity and amplitude. The graphs below show the variation of the displacement of a particle with time when two progressive waves X and Y pass separately through a medium.



The intensity of wave X is I_0. Student 1 says that the intensity of wave Y must be $\frac{I_0}{2}$ but Student 2 thinks it must be $\frac{I_0}{4}$.

Determine, using the relationship from part (c), which student is correct.

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(2 marks)

3 (a) Outline what is meant by the principle of superposition.

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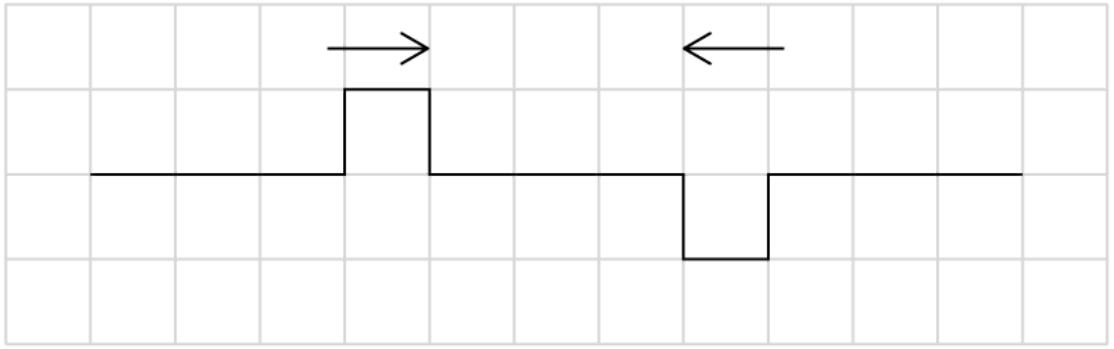
(2 marks)

(b) Two pulses travel toward one another as shown in the diagram.



Sketch the resultant displacement as the pulses superpose.

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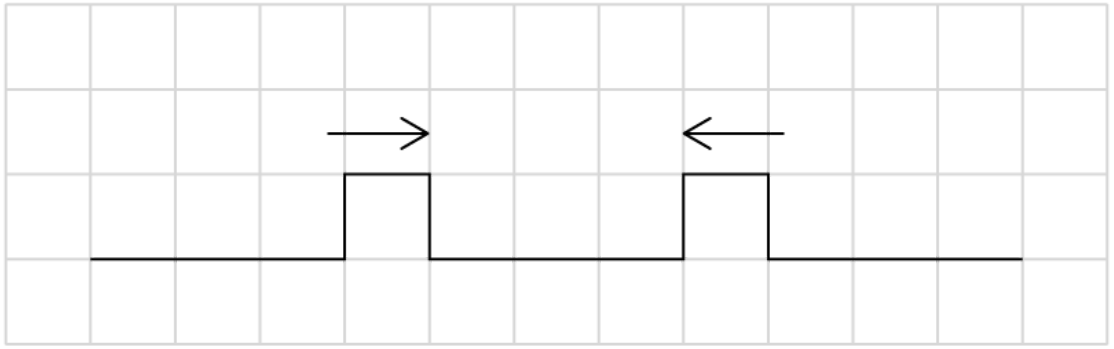
(1 mark)

(c) Two pulses travel in opposing directions as shown in the diagram. When the pulses meet, they superpose.



Draw the resultant peak as the pulses superpose.

(1 mark)

(d) Distinguish between the terms constructive interference and destructive interference.

(4 marks)

4 (a) Distinguish between the terms polarised and unpolarised light.

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(2 marks)

(b) Outline the reason why a sound wave cannot be polarised.

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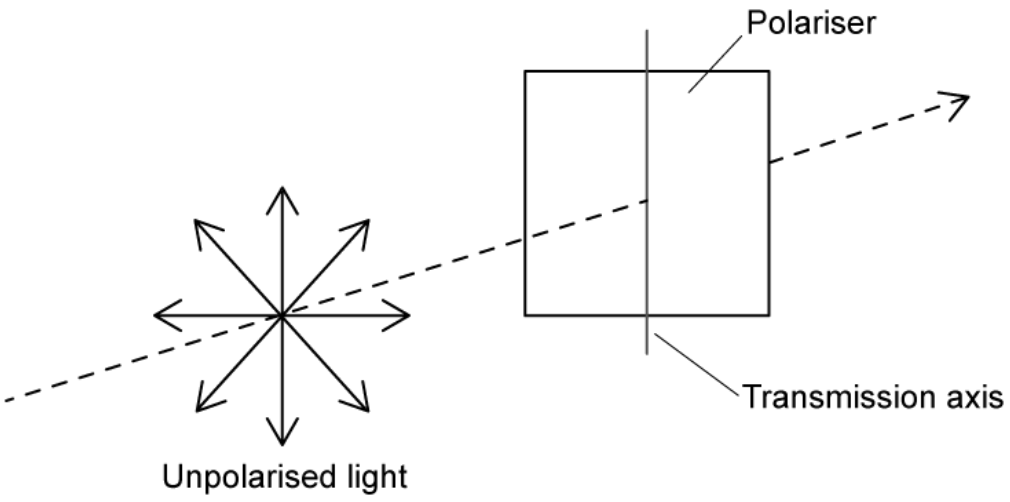
(2 marks)

(c) Unpolarised light is passed through a polariser as shown in the diagram.



Draw a double-headed arrow to indicate the resultant orientation of the polarised light.

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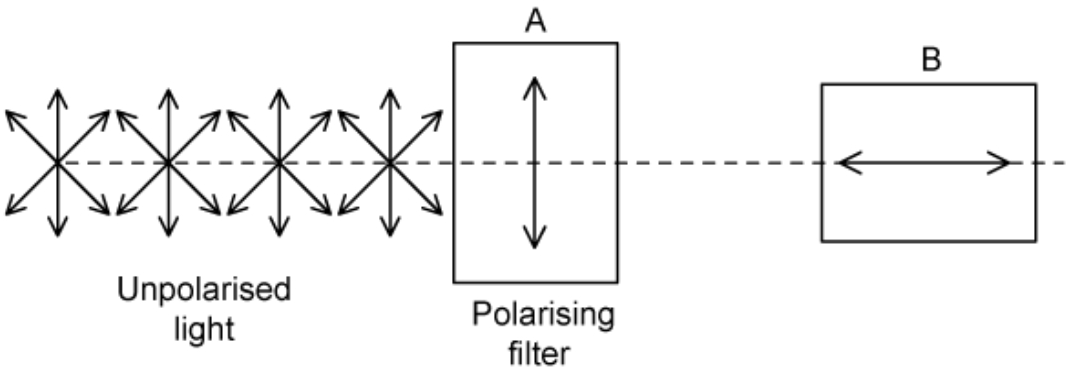
(1 mark)

(d) Polarised light is passed through polarising filter A as shown in the diagram.



An identical polarising filter B is placed directly after A at 90°.

State and explain what happens to the intensity of the light after it is incident on polarising filter B.

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(3 marks)

5 (a) Outline the change in intensity of the incident unpolarised light as it passes through a polariser.

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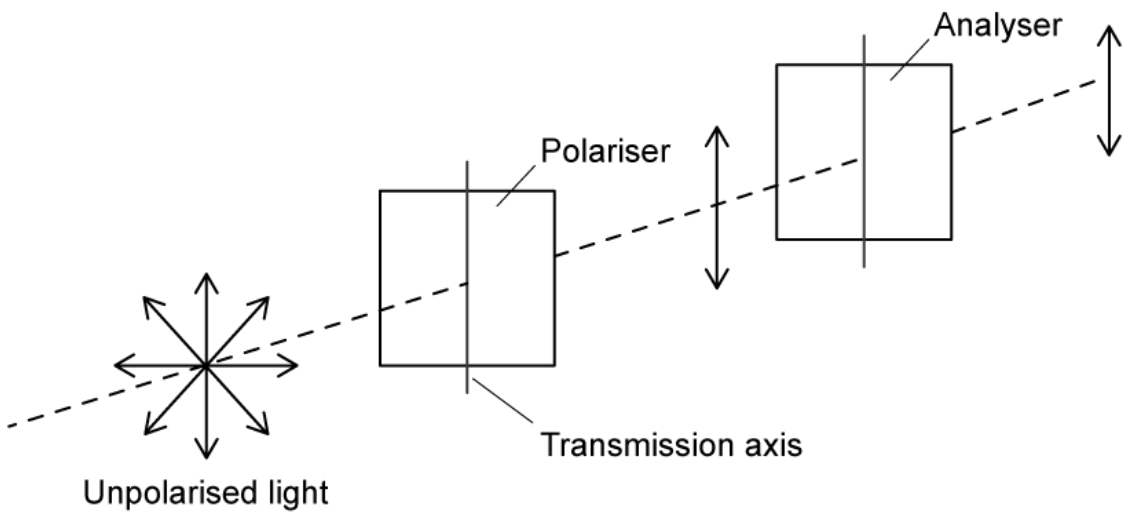
(1 mark)

(b) Unpolarised light is passed through a polarising filter as shown in the diagram. A second polarising filter called an analyser is placed in sequence.



Compare the intensity of the analysed light to the intensity of the unpolarised light.

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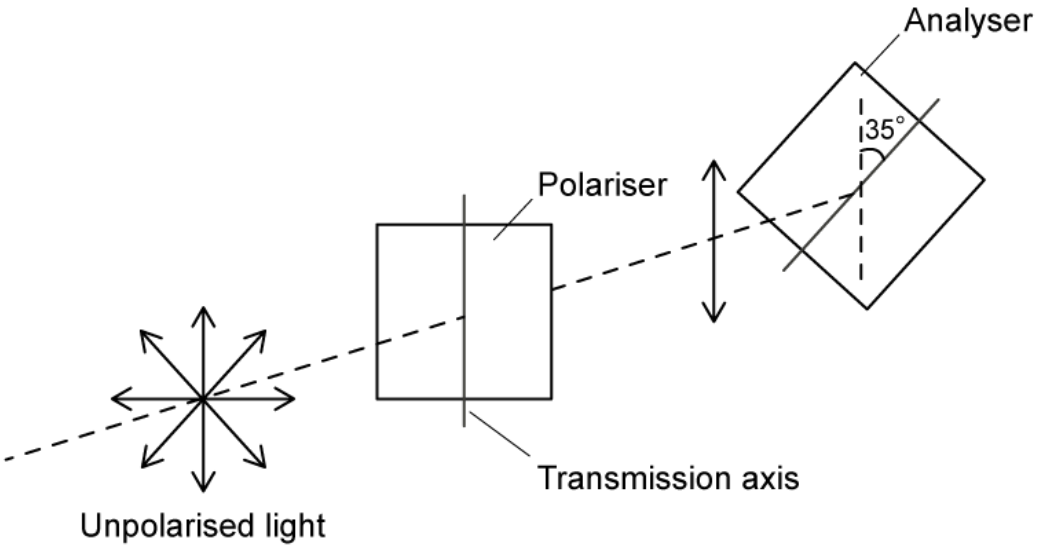
(1 mark)

(c) Unpolarised light with intensity I_0 = 20 W m^{-2} is incident on the polariser. The analyser is rotated so that the transmission axis is at an angle of 35° compared to the vertical axis of the polariser.



Calculate the intensity of the analysed light.

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(3 marks)

(d) Polaroid sunglasses use polarisation to reduce glare.

Choose suitable words and phrases to complete the following passage:

When unpolarised light is **reflected / refracted** from smooth non-metallic surfaces, **partial / total** plane polarisation occurs. Light is then polarised in a plane **perpendicular / parallel** to that surface.

Most surfaces around us are horizontal, therefore, most of the **reflected / refracted** light is polarised in the **vertical / horizontal** plane.

Polaroid sunglasses have a vertical transmission axis, which means that only light oscillating in the **vertical / horizontal** plane will be transmitted.

This greatly reduces the glare from **reflective / refractive** surfaces, such as water, allowing the wearer to see objects beneath the surface of the water more clearly.

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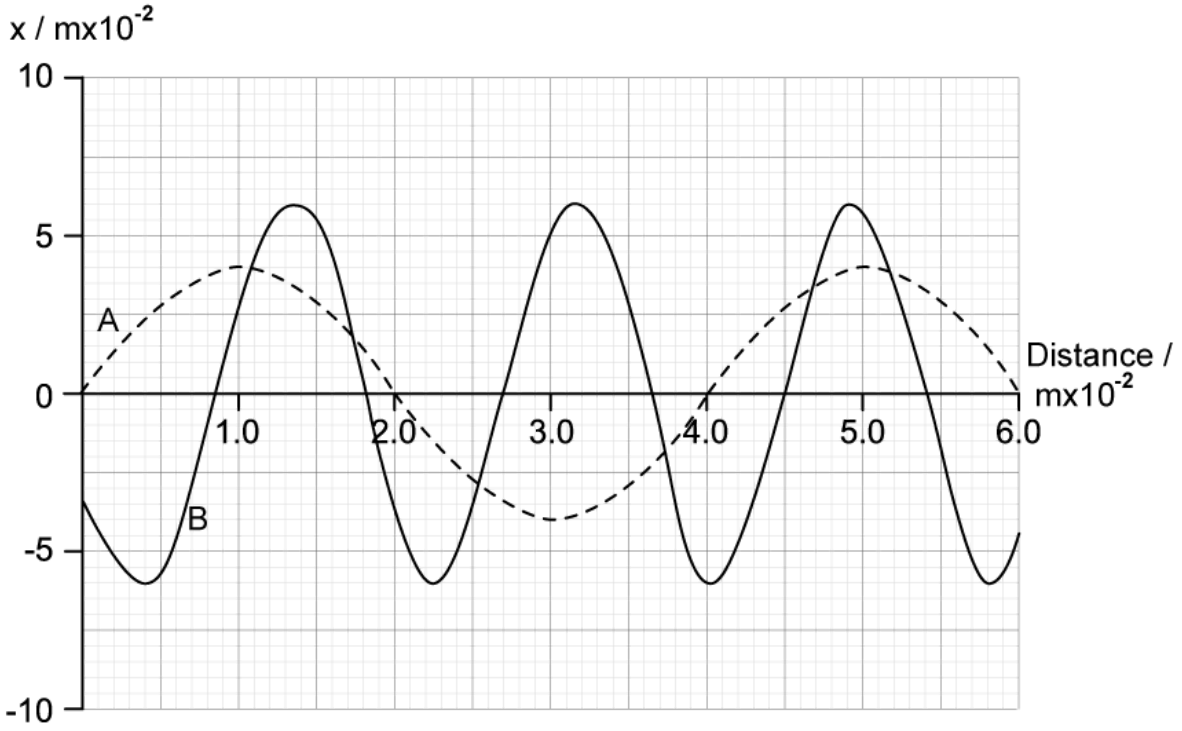
(4 marks)

Medium Questions

1 (a) A large water tank is set up so that a wave can be generated at each end of the tank. The two waves, A and B, travel towards each other at the same speed.

The graph shows the variation of displacement of the water surface with distance travelled at a particular instant.



Deduce how many times greater the amplitude of B is to the amplitude of A.

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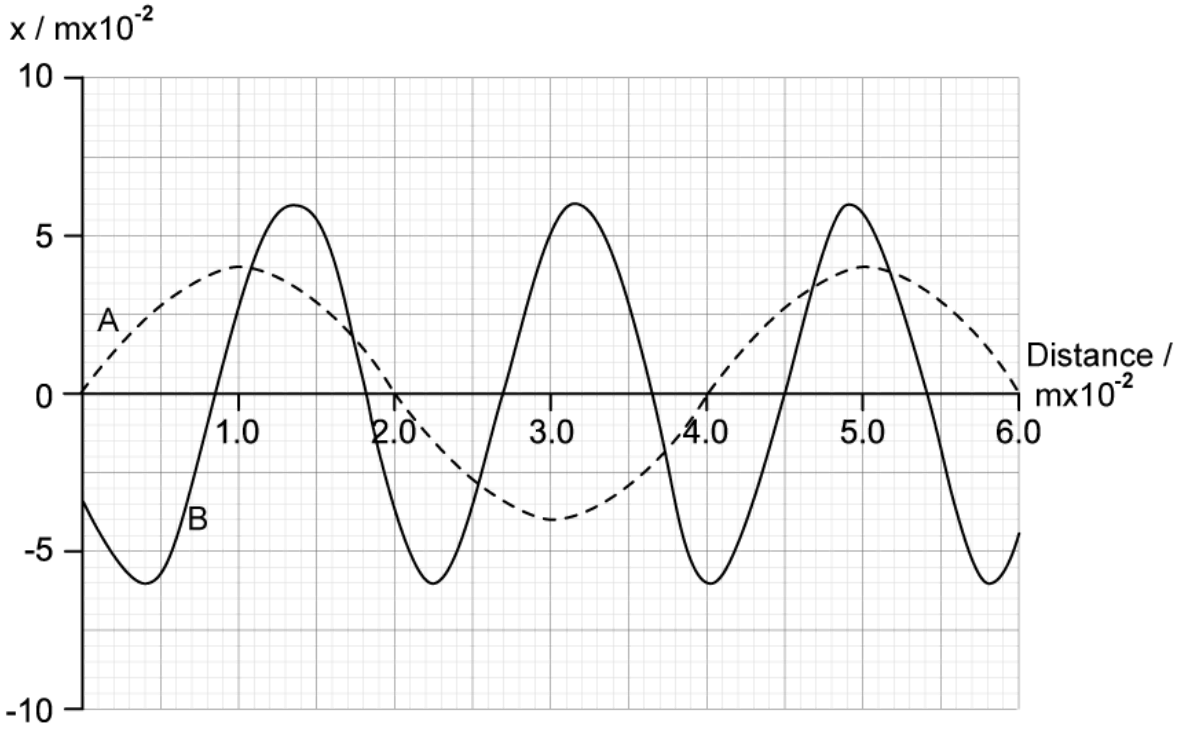
(2 marks)

(b) Wave A has a frequency of 9.0 Hz.



(i) Calculate the velocity of wave A

[2]

(ii) Determine the frequency of wave B

[2]

(4 marks)

(c) Explain how the stationary wave is generated in the tank.

(3 marks)

(d) Sketch a graph to represent the wave which would result from the superposition of wave A and wave B.

(4 marks)

2 (a) Superposition occurs when two or more waves interfere with each other.

(I) Explain the conditions required for a consistent stationary interference pattern to form during superposition.

[2]

(ii) Sketch a diagram to support your answer to part (i).

[2]

(4 marks)

(b) Superposition is often demonstrated using water waves which are transverse and clearly show increases and decreases in amplitude.

Describe how sound waves can also undergo superposition.

(3 marks)

(c) Two microwave transmitters are placed 15 cm apart and connected to the same source. A receiver is placed 70 cm away and moved along a line parallel to the transmitters. The receiver detects and alternating pattern of maxima and minima.

Explain how the maxima and minima are formed.

(3 marks)

(d) One transmitter is removed and a metal grille is placed between the transmitter and the receiver. The grille is rotated through 180^{o} and back round again. The signal at the receiver is heard to rise and fall as the grill rotates.

(i) Explain what causes the rising and falling signal.

[2]

(ii) Sketch a graph to show the pattern of rising and falling signal.

[2]

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(4 marks)

3 (a) Distinguish between light which is polarised and unpolarised.

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(2 marks)

(b) Outline the function of an analyser when investigating polarised light.

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(2 marks)

(c) The analyser is used to investigate polarised light. Light with intensity 11.94 W m^{-2} is incident on a polarising filter. The transmission axis of the analyser is fixed at an angle of 35° to the electric field of the polarised light.

(i) Write down the intensity of the light transmitted by the polarising filte

[1]

(ii) Calculate the intensity of the light transmitted by the analyser

[2]

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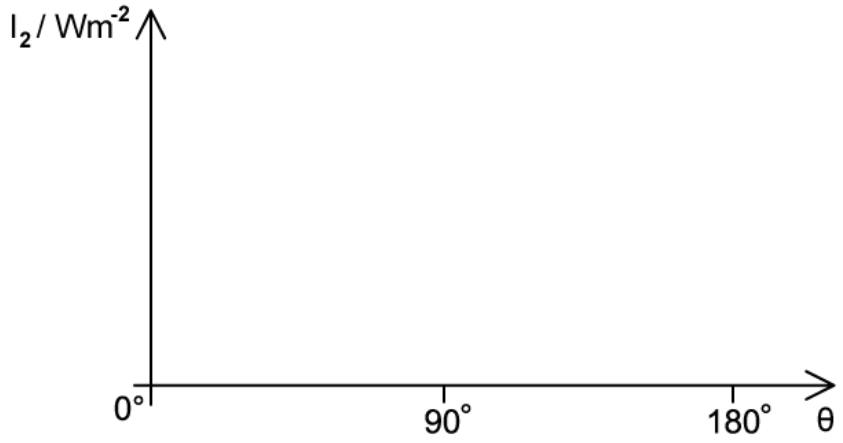
(3 marks)

(d) The analyser is rotated through 180°.

Sketch a graph to show the variation of intensity I_2 with angle θ of the light leaving the analyser.



(2 marks)

4 (a) A microwave transmitter is set up 75 cm away from a receiver which is connected to an oscilloscope so that the intensity of the wave incident on the receiver can be determined.

Initially the intensity is found to be 32 mW m^{-2}. The receiver is moved to a new position 125 cm from the transmitter. The new intensity is found to be 11.6 mW m^{-2}.

Show that these results support the theory that intensity is related to distance according to an inverse square law.

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(3 marks)

(b) The transmitter remains at 125 cm and the energy of the signal is increased. The new intensity is found to be 46.4 mW m^{-2}.

Determine the factor by which the energy was increased.

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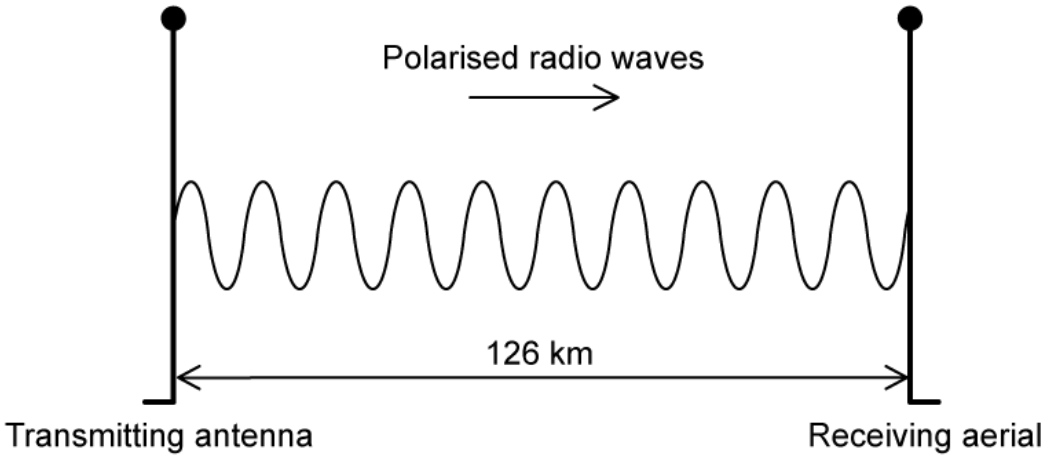
(2 marks)

(c) Radio waves are emitted from a straight conducting rod antenna such that the plane of polarisation of the waves is parallel to the rod. An identical metal conducting rod, known as an aerial, is used for reception.



Suggest why the receiving aerial must be set up parallel to the transmitting antenna.

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(2 marks)

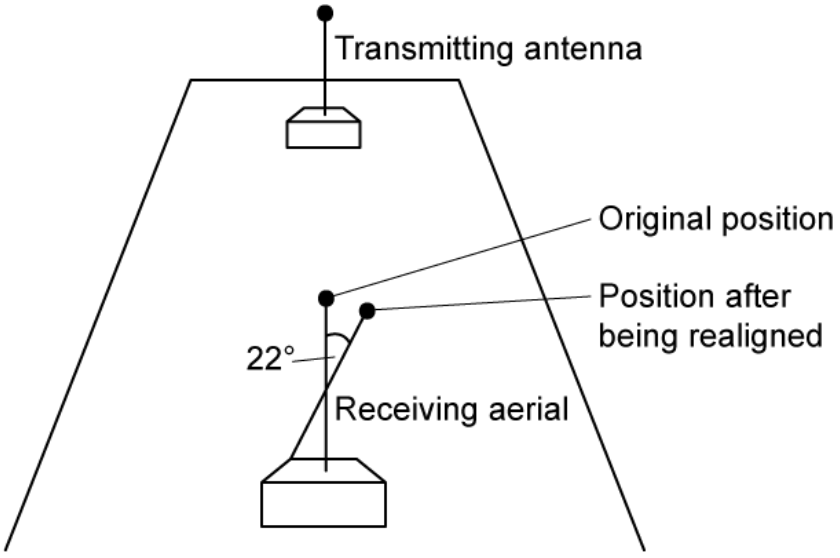
(d) The receiving aerial is moved so that it leans 22^{o} from its original position. The power of the received signal in the new position is 15 μW.

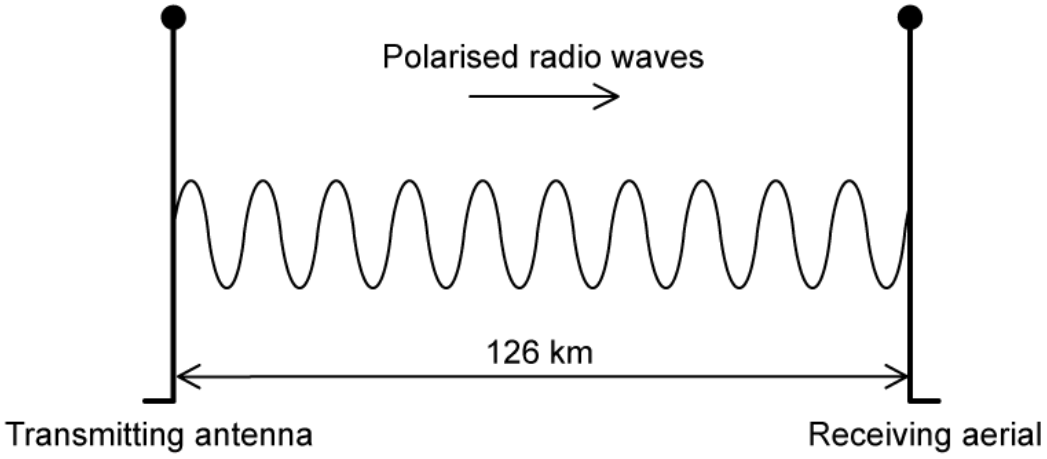
(i) Calculate the power that was received in the first position.

[2]

(ii) Calculate the minimum time between the wave leaving the transmitting antenna and being received at the receiving aerial.

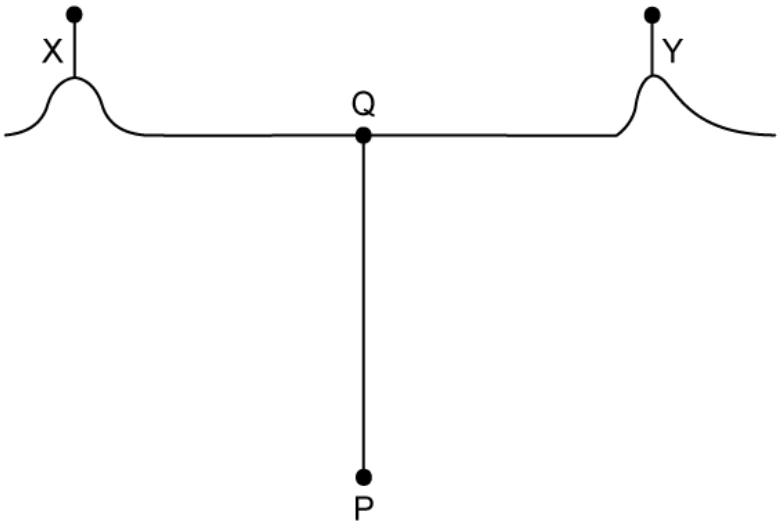
[1]





(3 marks)

5 (a) A group of hikers are exactly equidistant between two radio transmitters, X and Y. The transmitters are set to an operating wavelength of 200 m and have the same power outputs.



The hikers at point P receive a signal with zero amplitude. Outline what information about the signal you can assume from this.

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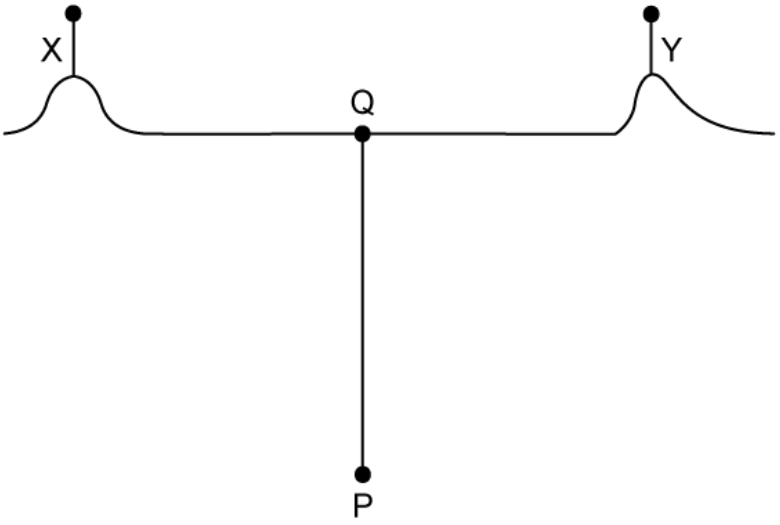
(3 marks)

(b) The hikers walk towards point Q on the line shown and continue to receive a signal of zero amplitude.

Once at Q they turn and walk towards Y, continuing until they receive a signal with amplitude double that emitted from either transmitter.



(i) Explain why there is no increase in amplitude detected on the walk from P to Q

[2]

(ii) Calculate the distance they walked along the line from Q to Y

[2]

(4 marks)

(c) The hikers continue moving from Q towards the transmitter at Y where the distance QY is 20 km. The signal continues to rise and fall as they walk.

Calculate how many times they will hear the signal fall in intensity as they walk.

(2 marks)

(d) The hikers are wearing polarising glasses to protect their eyes from glare.

(i) Describe how glare is caused.

[2]

(II) Explain how polarising glasses reduce glare from the surface of a road without reducing the amount of light entering the eye from above.

[2]

(4 marks)

Hard Questions

1 (a) When electromagnetic waves are reflected from a shiny surface, such as a road sign, they often become polarised.

Suggest how to determine experimentally if visible light reflected from a road sign is polarised.

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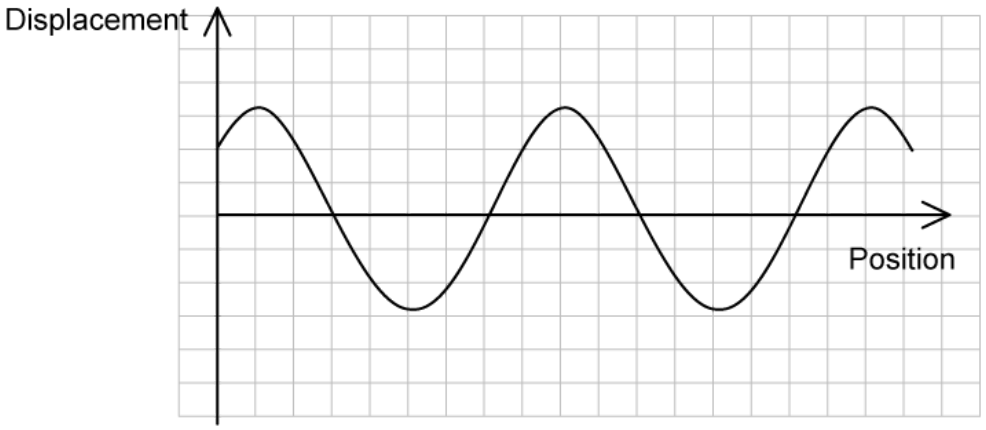
(2 marks)

(b) Changes in phase can occur when electromagnetic waves are reflected from a surface.

If an electromagnetic wave is reflected at the boundary between a medium with a higher refractive index than the medium it is travelling in, the oscillating electric field undergoes a phase change of π radians.

Light is incident on an air-water boundary. A displacement-position sketch of the amplitude of the incident electric field is shown. The origin represents the boundary.



Sketch the amplitude of the reflected electric field on the graph.

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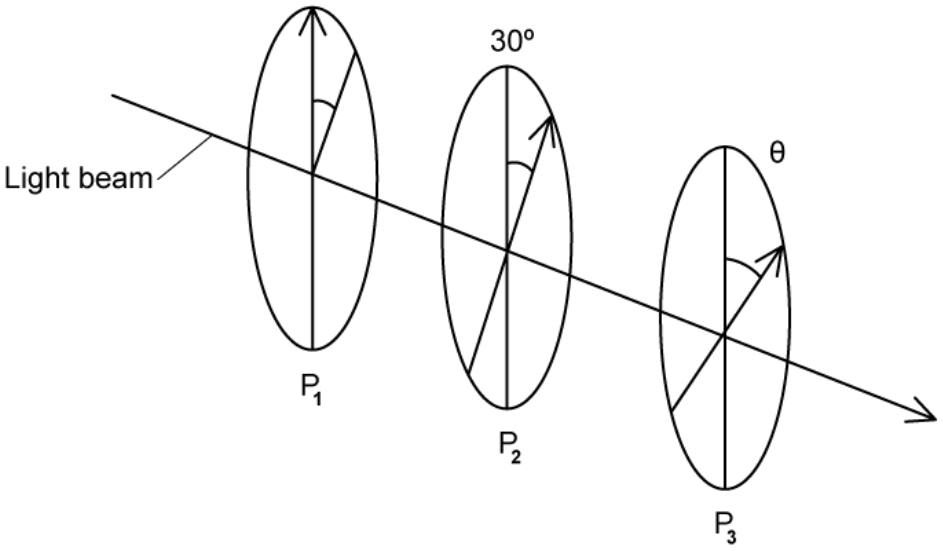
(2 marks)

(c) Three polaroid filters P_1, P_2 and P_3 are aligned as follows:



Unpolarised light is incident on P_1 and subsequently passes through each of the three polaroid filters. P_1 and P_2 are in fixed positions, but P_3 can be rotated to any angle θ to P_1.

Determine the angles of θ at which minima and maxima of emergent light intensity occur.

(3 marks)

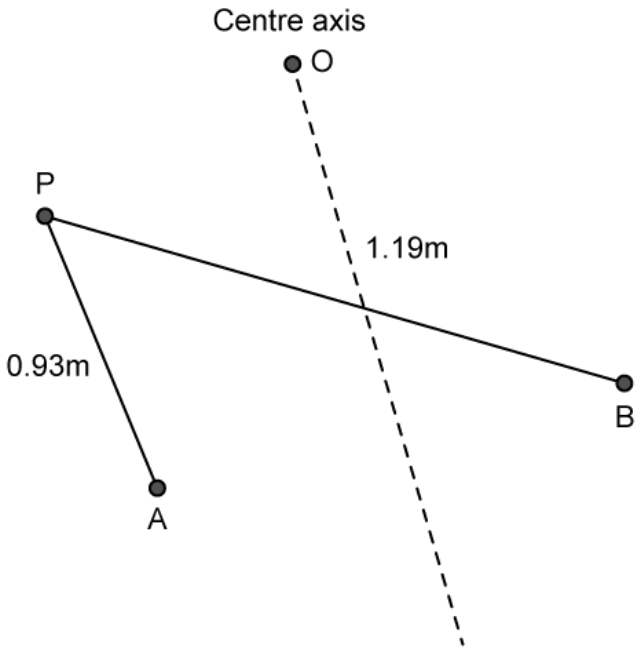
(d) Complete the missing spaces in the table to show whether the waves listed are polarised or unpolarised, and to give a reason for your answer.

Wave	Polarised or unpolarised	Reason
Light from the sun		
Compression waves caused by an earthquake	Unpolarised	Longitudinal waves cannot be polarised
Electromagnetic waves emitted from a dipole aerial		
Ultrasonic waves from an echo sounder		

(3 marks)

2 (a) Two coherent sources, A and B, which are in phase with each other, emit microwaves of wavelength 40.0 mm. The amplitude of waves from source B is twice that of source A.

A detector is placed at the point P where it is 0.93 m from A and 1.19 m from B. The centre axis is normal and a bisector to the straight line joining A and B.



With reference to the phase of the microwaves, deduce the magnitude of the detected signal at P and explain your reasoning.

(3 marks)

(b) Determine the ratio of the intensity at P to the intensity at O.

(3 marks)

(c) Discuss, with suitable calculations, what happens to the detected signal as the detector is moved from P to O.

(5 marks)

(d) The source B is altered such that it emits waves that are 180° out of phase with source A.

Deduce the type of interference that now occurs at point P and explain your reasoning.

(2 marks)

3 (a) Transverse, sinusoidal progressive waves of wavelength λ have points P and Q which are $\frac{5\lambda}{4}$ apart. The waves travel from P to Q.

With an appropriate sketch, discuss the motion of Q at the instant when P is displaced upwards but is moving downwards.

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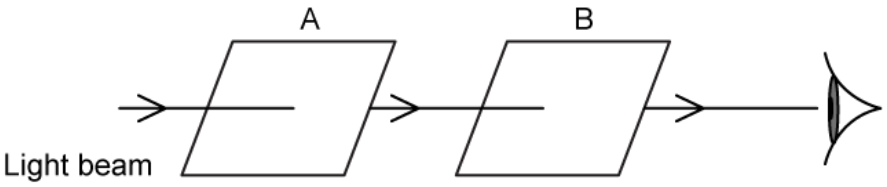
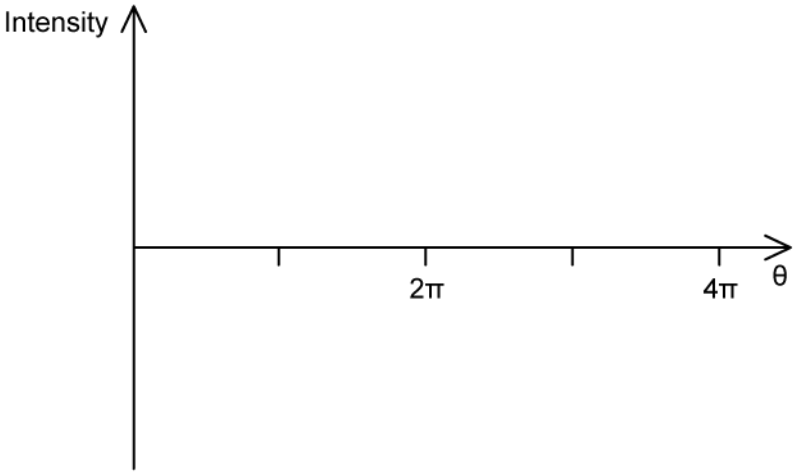
(3 marks)

(b) Electromagnetic waves, being transverse, can be polarised. A light source is viewed through two pieces of polarisers, A and B, with their axes initially at $\frac{\pi}{2}$ radians from each other:

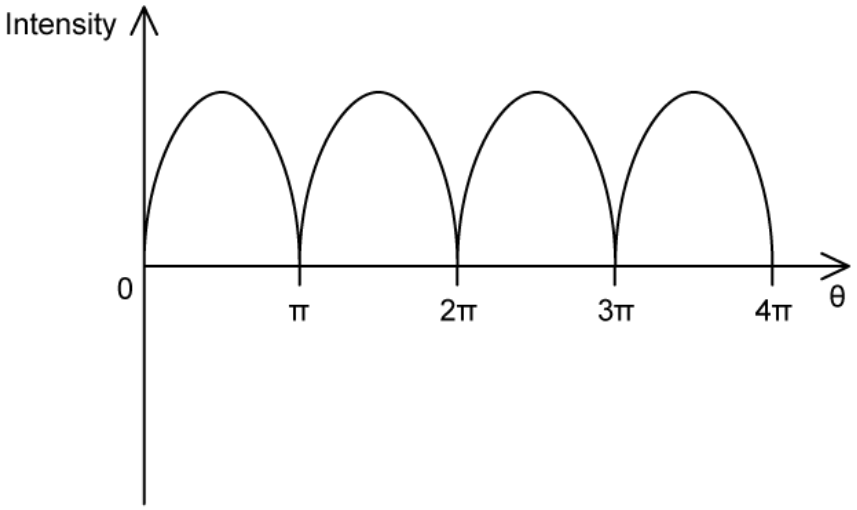


Using the axes below, sketch the variation of intensity of light reaching the eye with angular displacement of B with respect to A when polariser B is rotated.



(4 marks)

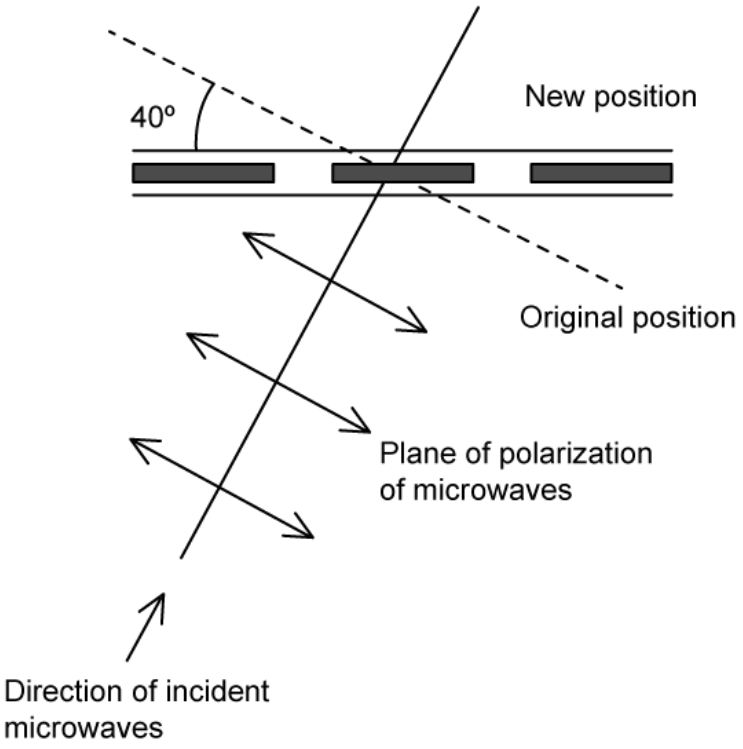
(c) A common incorrect way of drawing this graph is as:



State the differences between the correct graph in part b, and then, through derivation of Malus' Law, explain why the graph above is incorrect.

(3 marks)

4 (a) Plane polarised electromagnetic waves are incident on an aerial positioned to give a maximum response. High winds cause the aerial to rotate about the direction of the incident wave until it makes and angle of 40° to the plane of polarisation.



Calculate the percentage reduction in the amplitude of the signal received by the aerial following the high winds.

(3 marks)

(b) The intensity of incident radiation is 0.05 mW m^{-2}. When the aerial is repaired, it is found to have a maximum vibration amplitude of 6.3 mm.

Determine the angle at which the aerial has been set.

(3 marks)