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|  | |  |  | | --- | --- | | **Waves Part 1 Practise Paper**  50 marks |  | | Please note that you may see slight differences between this paper and the original.  Candidates answer on the Question paper.  **OCR supplied materials:** Additional resources may be supplied with this paper.  **Other materials required:** •   Pencil •   Ruler (cm/mm) | **Duration:** 60 mins | |  | | |  |

## INSTRUCTIONS TO CANDIDATES

•   Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.  
•   Use black ink. HB pencil may be used for graphs and diagrams only.  
•   Answer **all** the questions, unless your teacher tells you otherwise.  
•   Read each question carefully. Make sure you know what you have to do before starting your answer.  
•   Where space is provided below the question, please write your answer there.  
•   You may use additional paper, or a specific Answer sheet if one is provided, but you must clearly show your candidate number, centre number  
    and question number(s).

## INFORMATION FOR CANDIDATES

•   The quality of written communication is assessed in questions marked with either a pencil or an asterisk. In History and Geography   
    a *Quality of extended response* question is marked with an asterisk, while a pencil is used for questions in which *Spelling, punctuation and  
    grammar and the use of specialist terminology* is assessed.  
•   The number of marks is given in brackets **[ ]** at the end of each question or part question.  
•   The total number of marks for this paper is **50**.  
•   The total number of marks may take into account some 'either/or' question choices.

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|  | |  |  | | --- | --- | |  |  | | **1.** | The diagram below shows the displacement-time graph of an air particle as a sound wave passes.    The speed of the sound wave is 340 m s−1. What is the wavelength of the sound wave?   1. 0.68 m 2. 1.7 m 3. 170 m 4. 680 m   Your answer       |  | | --- | | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **2.** | The figure shows part of a transverse progressive wave which is travelling to the right along a string. The horizontal dotted line shows the position of the string when there is no wave present. In which direction is the string at the point **P** moving at the instant shown?     1. upwards 2. downwards 3. to the right 4. it is at rest   Your answer       |  | | --- | | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **3.** | A student views the display of a laptop screen through a polarising filter. The intensity of the light changes when the filter is rotated.  Which property of light is demonstrated in this experiment?     |  |  | | --- | --- | | **A** | It has wavelength of about 5 × 10−7 m. | | **B** | It travels at the speed of light. | | **C** | It is a transverse wave. | | **D** | It is a longitudinal wave. |   Your answer    **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **4.** | In which region of the electromagnetic spectrum is radiation of wavelength 50 μm?     |  |  | | --- | --- | | **A** | visible | | **B** | infra-red | | **C** | microwave | | **D** | radio |   Your answer    **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **5.** | In which region of the electromagnetic spectrum is radiation of frequency 300 MHz?     |  |  | | --- | --- | | **A** | radio wave | | **B** | microwave | | **C** | visible | | **D** | X-ray |   Your answer    **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **6.** | A ray of monochromatic light is incident at the boundary between two transparent materials of refractive index n1 and n2. The critical angle θ is equal to 80°.    What is the ratio     |  |  | | --- | --- | | **A** | 0.17 | | **B** | 0.98 | | **C** | 1.02 | | **D** | 5.76 |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **7.** | Which of the following statements is/are correct about electromagnetic waves?     |  |  |  | | --- | --- | --- | |  | 1 | They can be plane polarised. | |  | 2 | They can be refracted and diffracted. | |  | 3 | They have the same speed in a vacuum and in glass. |      |  |  | | --- | --- | | **A** | Only 1 | | **B** | Only 3 | | **C** | Only 1 and 2 | | **D** | 1, 2 and 3 |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **8.** | The diagram below shows the oscilloscope trace for an electrical signal.     |  | | --- | |  |   The frequency of the signal is 250 Hz.  What is the time-base setting of the oscilloscope?     |  |  | | --- | --- | | **A** | 1 ms cm−1 | | **B** | 2 ms cm−1 | | **C** | 4 ms cm−1 | | **D** | 8 ms cm−1 |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **9.** | A small loudspeaker emits sound uniformly in all directions. The amplitude of the sound is 12 μm at a distance of 1.5 m from the loudspeaker.  What is the amplitude of the sound at a distance of 4.5 m from the loudspeaker?     |  |  | | --- | --- | | **A** | 1.3 μm | | **B** | 4.0 μm | | **C** | 6.9 μm | | **D** | 12 μm |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **10(a).** | The table shows the refractive index n of air and glass for blue light. It also shows the speed v and the wavelength λ of blue light in air.     |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | |  |  |  | | --- | --- | --- | |  | **air** | **glass** | | refractive index n | 1.00 | 1.53 | | speed of light v / m s−1 | 3.00 × 108 |  | | wavelength λ/m | 4.69 × 10−7 |  | |  |   A semi-circular block of glass is placed in air. **Fig. 2.1** shows the path of blue light through the air and the semi-circular glass block.     |  | | --- | |  |      |  |  | | --- | --- | | **Fig. 2.1** (not to scale) |  |  1. The angle i is 30°. 1. Determine angle p.   p = ............................................................ ° **[1]**  2. Determine angle q, using the information from the table in **(a)**.  q = ............................................................ ° **[2]**   1. The angle i is increased from 30° to 60°. Describe and explain how angles p and q will change. In your answer, include the term **critical angle**.             **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | **Fig. 2.2** shows a semi-circular glass block with the blue light replaced by red light.     |  |  | | --- | --- | |  |  |      |  |  | | --- | --- | | **Fig. 2.2** (not to scale) |  |   The dashed lines show the original paths of the blue light.     |  |  | | --- | --- | | Draw on **Fig. 2.2** the path of the red light in the glass block and out of the glass block. | **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **11.** | A sound wave is an example of a longitudinal wave.   1. State what is meant by the term **longitudinal** wave.     **[1]**   1. A microphone is connected to an oscilloscope. Sound of frequency 500 Hz is incident on the microphone. The oscilloscope time-base is set to 0.5 ms cm−1 and the y-gain set to 1.0 mV cm−1. The signal displayed on the oscilloscope screen has an amplitude of 2.0 mV. The oscilloscope grid is shown below.      |  | | --- | |  |      |  |  | | --- | --- | | Sketch the oscilloscope trace on the grid above. | **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **12(a).** | \*The speed v of surface water waves in shallow water of depth d is given by the equation , where g is the acceleration of free fall.  The speed v is about 1 ms–1 for a depth of about 10 cm.  You are provided with a rectangular plastic tray, supply of water and other equipment available in the laboratory.  Describe how an experiment can be conducted in the laboratory to test the validity of the equation above and how the data can be analysed to determine a value for g.                                                      **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | This question is about waves.  The **period** of a progressive wave can be determined from Fig. 16.1. Add a correct label to the horizontal axis so that the period can be found.     |  | | --- | | **Fig. 16.1** | | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | A progressive wave has wavelength λ, frequency f and period T.  Show that the speed v of the wave is given by the equation v = fλ.     |  | | --- | | **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(d).** | A scientist is investigating the interference of light using very thin transparent material. A sample of the transparent material is placed in a vacuum. Fig. 16.2 shows the path of two identical rays of light **L** and **M** from a laser.     |  | | --- | | **Fig. 16.2** |   The refractive index of the material is 1.20. The thickness of the material is 1.5 × 10–6 m. The wavelength of the light in vacuum is 6.0 × 10–7 m.   1. Show that the difference in time t for the two rays to travel between the dashed lines **X** and **Y** is 1.0 × 10–15 s.      |  | | --- | | t = ...................................................... s **[3]** |  1. Calculate the period T of the light wave.      |  | | --- | | t = ...................................................... s **[2]** |  1. The rays of light are in phase at the dashed line **X**.  Use your two answers above to state the phase difference φ in degrees between the light rays at **Y**.      |  | | --- | | φ = ...................................................... ° **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **13.** | You are provided with a rectangular block of plastic.  Describe how you can use a ray-box (or a laser beam), together with other equipment available in the laboratory, to accurately determine the refractive index of the plastic block.              **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **14.** | In an experiment using microwaves, a metal grille **G** consisting of a series of long metal rods is placed between a transmitter **T** and a detector **D** as shown in Fig. 7.2.  **Fig. 7.2**  The grille is slowly rotated through 180° about the line joining **T** and **D**. The detected signal at **D** varies from zero to maximum and back to zero again.  Explain why the detected signal behaves in this way.            **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **15(a).** | A student investigates the path of a light ray through ethanol. Fig. 8.1 shows ethanol in a rectangular glass container. Light of wavelength 5.2 × 10−7 m is incident on the container as shown.     |  | | --- | |  | | **Fig. 8.1 (not to scale)** |   The table below shows the refractive indices n and speeds of light v in various transparent media.     |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | **medium** | **n** | **v / m s−1** |  | |  | air | 1.00 | 3.00 × 108 |  | |  | ethanol |  | 2.20 × 108 |  | |  | glass | 1.52 |  |  | |  | vacuum | 1.00 | 3.00 × 108 |  |      |  |  |  | | --- | --- | --- | | (i) | Complete the table by calculating the missing values of n and v. | **[2]** |      |  |  | | --- | --- | | (ii) | Determine the wavelength λ of the light in glass. |        |  |  |  | | --- | --- | --- | | λ = |  | m **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Fig. 8.2 shows an enlarged version of a section of the left hand side of the glass container.     |  | | --- | | **Fig. 8.2 (not to scale)** |      |  |  | | --- | --- | | (i) | The light is incident on the glass at an angle of 37°. Determine the angle of refraction θ in the glass. |        |  |  |  | | --- | --- | --- | | θ = |  | ° **[2]** |      |  |  |  | | --- | --- | --- | | (ii) | Without any further calculation, sketch the ray of light as it passes through the glass into the ethanol. | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **16.** | Light travels from air to water. The refractive index of water is greater than the refractive index of air. Compare the speed, frequency and wavelength of light in air and in water.          **[3]** | |

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|  | |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  | |  |  | | --- | --- | | **Waves Part 1 and 2 Practise Paper**  50 marks |  | | Please note that you may see slight differences between this paper and the original.  Candidates answer on the Question paper.  **OCR supplied materials:** Additional resources may be supplied with this paper.  **Other materials required:** •   Pencil •   Ruler (cm/mm) | **Duration:** 60 mins | |  | | |  |  INSTRUCTIONS TO CANDIDATES •   Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters. •   Use black ink. HB pencil may be used for graphs and diagrams only. •   Answer **all** the questions, unless your teacher tells you otherwise. •   Read each question carefully. Make sure you know what you have to do before starting your answer. •   Where space is provided below the question, please write your answer there. •   You may use additional paper, or a specific Answer sheet if one is provided, but you must clearly show your candidate number, centre number     and question number(s). INFORMATION FOR CANDIDATES •   The quality of written communication is assessed in questions marked with either a pencil or an asterisk. In History and Geography      a *Quality of extended response* question is marked with an asterisk, while a pencil is used for questions in which *Spelling, punctuation and     grammar and the use of specialist terminology* is assessed. •   The number of marks is given in brackets **[ ]** at the end of each question or part question. •   The total number of marks for this paper is **50**. •   The total number of marks may take into account some 'either/or' question choices.   |  |  | | --- | --- | |  |  | | **17.** | A stationary sound wave, of fundamental mode of vibration, is formed in a tube closed at one end.     |  | | --- | |  |   The length of the tube is 0.17 m. The speed of sound in air is 340 m s−1.  What is the fundamental frequency of the stationary wave?     |  |  | | --- | --- | | **A** | 500 Hz | | **B** | 1000 Hz | | **C** | 2000 Hz | | **D** | 4000 Hz |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **18.** | This question is about progressive waves and stationary waves.  Which statement is **not** correct?     |  |  | | --- | --- | | **A** | A progressive wave transports energy through space. | | **B** | A stationary wave must have at least one node. | | **C** | For both waves, the amplitude of the oscillation is the same everywhere along the wave. | | **D** | In the stationary wave, the oscillations of the particles at two adjacent antinodes are out of phase by 180°. |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **19.** | A stationary sound wave, in its fundamental mode of vibration, is formed in a tube open at both ends.     |  | | --- | |  |   The length of the tube is 0.17 m. The speed of sound in air is 340 m s−1.  Which row for this stationary wave is correct?     |  |  |  |  | | --- | --- | --- | --- | |  | **Number of nodes** | **Frequency of stationary wave / Hz** |  | | **A** | 1 | 500 |  | | **B** | 1 | 1000 |  | | **C** | 2 | 1000 |  | | **D** | 2 | 2000 |  |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **20.** | The diagram below shows the oscilloscope trace for an electrical signal.     |  | | --- | |  |   The time-base setting of the oscilloscope is 2 μs cm−1. What is the frequency of the signal?     |  |  | | --- | --- | | A | 125 Hz | | B | 250 Hz | | C | 125 kHz | | D | 250 kHz |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **21.** | The waves emitted from two sources are coherent. Which quantity must be constant for these emitted waves?     |  |  | | --- | --- | | **A** | amplitude | | **B** | frequency | | **C** | intensity | | **D** | phase difference |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **22.** | A progressive wave of amplitude a has intensity I. This wave combines with another wave of amplitude 0.6a at a point in space. The phase difference between the waves is 180°.  What is the resultant intensity of the combined waves in terms of I?     |  |  | | --- | --- | | **A** | 0.16 I | | **B** | 0.4 I | | **C** | 1.6 I | | **D** | 2.6 I |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **23.** | A narrow beam of light in air is directed at the surface of a triangular glass prism.  Which is the correct diagram for the light refracted by the prism?     |  |  | | --- | --- | | **A** |  | | **B** |  | | **C** |  | | **D** |  |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **24.** | A ray of monochromatic light is incident at a boundary between medium 1 and medium 2. The ray is both refracted and reflected at the boundary.    Which of the following statements is / are true?   1. The refracted light and incident light have the same wavelength. 2. The speed of light in medium 2 is greater than the speed of light in medium 1. 3. The angle θ is the critical angle. 4. 1, 2 and 3 5. Only 1 and 2 6. Only 1 7. Only 2   Your answer       |  | | --- | | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **25(a).** | Fig. 5.1 shows two microwave transmitters **A** and **B** 0.20 m apart. The transmitters emit microwaves of frequency 10 GHz, of equal amplitude and in phase. A microwave detector is placed at **O** a distance of 4.0 m from **AB**.    Interference of the waves from the two transmitters is detected only when the transmitters are coherent. Explain the meaning of   * 1. interference       **[2]**   * 1. coherent.     **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | The length of the detector aerial is half a wavelength. Calculate the length of the aerial.  Show your working.     |  | | --- | | aerial length = ........................................................... m **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | * 1. Explain why the amplitude of the detected signal changes when the detector is moved in the direction **OP**.         **[2]**   * 1. Calculate the distance between adjacent **maximum** and **minimum** signals.      |  | | --- | | distance = ........................................................... m **[2]** |  1. Explain why the amplitude of the detected signal changes when the detector is moved in the direction **OQ**.         **[2]**   1. Explain why the amplitude of the detected signal decreases to a minimum before increasing again as transmitter **A** is moved a small distance in the direction **AR** with the detector fixed at **O**. Calculate the distance **A** is moved to cause this minimum signal at **O**.                  |  | | --- | | distance = ........................................................... m **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(d).** | State, with a reason, the effect on the intensity of the signal detected at **O** when each of the following changes is made.   1. The amplitude of the waves emitted from **A** and **B** is doubled.       **[2]**   1. The detector **O** is rotated 90° about the axis through **OQ**.           **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **26(a).** | Fig. 4.1 shows a section of a uniform string under tension at one instant of time. A progressive wave of wavelength 80 cm is moving along the string from left to right. At the instant shown, the displacement of the string is zero at the point opposite the zero mark on the scale beneath the string.    Four points **P**, **Q**, **R** and **S** at 10, 30, 40 and 60 cm respectively, are marked on the string. The oscillatory motion of each point can be described in terms of amplitude, frequency and phase difference from **O**.   1. State the meaning of each of the terms    1. amplitude        * 1. frequency        * 1. phase difference.          |  | | --- | | **[3]** |  1. Describe using these three terms how the motion of points **P**, **Q**, **R** and **S**    1. is similar,        * 1. is different.          |  | | --- | | **[2]** | | |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **(b).** | Fig. 4.2 shows the same section of string now held under tension between a clamp and a pulley, 80 cm apart. A mechanical oscillator is attached to the string close to the clamped end. The frequency of the mechanical oscillator is varied until the stationary wave shown is set up between the clamp and the pulley. The same four points as in Fig. 4.1 are marked on the string.     1. Describe how a stationary wave is different from a progressive wave.           **[2]**   1. Explain how the stationary wave is formed on this string.             **[3]**   1. Describe, using the terms amplitude, frequency and phase difference, how the motions of the points **P**, **Q** and **S**    1. are similar,        * 1. are different.          |  | | --- | | **[3]** |  1. In Fig. 4.2 the frequency of oscillation is 30 Hz. State, with a reason, the lowest frequency of oscillation of the string at which the motions of all of the points **P**, **Q**, **R** and **S** are    1. in phase,        * 1. all at rest.          |  | | --- | | **[4]** | | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **27(a).** | \* Students are given a glass block and a ray box to determine the refractive index of glass. The students measure the angle of incidence i and the angle of refraction r. The table shows the results collected by the students.     |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | i / ° + 0.5° | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | | r / ° ± 0.5° | 6 | 13 | 20 | 25 | 31 | 35 | 39 | 41 |   The refractive index of air is 1.00.  Describe, with the help of a labelled diagram, how the students may have conducted the experiments in the laboratory.  Discuss how you could use the data from the table to graphically determine a value for the refractive index of glass.                      **[6]** | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **(b).** | Fig.17 shows a ray of light at the boundary between glass and water.    Use Fig. 17 to describe and explain how the wavelength of the light changes as light travels from glass to water.          **[3]** | |

**END OF QUESTION PAPER**

# Mark scheme for both papers

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Question** | | | **Answer/Indicative content** | **Marks** | **Guidance** |
| 1 |  |  | A | 1 |  |
|  |  |  | **Total** | **1** |  |
| 2 |  |  | B | 1 |  |
|  |  |  | **Total** | **1** |  |
| 3 |  |  | C | 1 | **Examiner's Comments**  All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions.  The candidates to demonstrate their knowledge and understanding of physics. |
|  |  |  | **Total** | **1** |  |
| 4 |  |  | B | 1 | **Examiner's Comments**  All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions. |
|  |  |  | **Total** | **1** |  |
| 5 |  |  | **A** | 1 |  |
|  |  |  | **Total** | **1** |  |
| 6 |  |  | **B** | **1** |  |
|  |  |  | **Total** | **1** |  |
| 7 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 8 |  |  | **A** | 1 |  |
|  |  |  | **Total** | **1** |  |
| 9 |  |  | **B** | 1 | **Examiner’s Comments**  The emission of sound ‘uniformly in all direction’ was the clue that the intensity of the wave followed an inverse square law relationship with distance from the source. The intensity is also directly proportional to amplitude2. This meant that amplitude of the wave is inversely proportional to the distance from the source. The correct answer (key) for this question is **B**. The most popular distractor was **C**, where 12 μm was divided by √3.  **Exemplar 1**    This exemplar illustrates the sensible strategy from a top-end candidate.  The key ideas are jotted down and analysis completed: I ∝ 1/r2 and I ∝ A2, therefore A ∝ 1/r.  The distance r increases by a factor of 3, therefore the amplitude will decrease by a factor of 3. This makes the answer 4.0 μm. The final sum being done either in the head or calculator – this is of little significance. What is important here is that all the important ideas have been extracted competently from the question. A commendable technique. |
|  |  |  | **Total** | **1** |  |
| 10 | a | i | **1.** p = 30° **2.** sin q = 0.5 × 1.53 or 0.765 q = 50° | B1 C1 A1 | **Allow** 49.9° **Note** 19 ° does not score |
|  |  | ii | p always equals i or p increases with i / when i = 60°, p = 60°   Any three from:   as i increases, q increases (until i equals the critical angle)   when i = critical angle, q = 90°   critical angle = 41°   when i is greater than critical angle, total internal reflection occurs   when i = 60°, there is no angle q or no refracted ray | B1    B1 ×3 | **Not** q = 0 |
|  | b |  | Straight line to centre of block and reflects along original ray P   Straight line to centre of block and refracts with angle q less than 49.9° but greater than 30° | B1    B1 |  |
|  |  |  | **Total** | **9** |  |
| 11 |  | i | Vibrations or oscillations parallel to direction of travel of the wave / direction of energy transfer | B1 |  |
|  |  | ii | Amplitude of 2 cm (in each direction)  Sinusoidal shape (by eye) with period of 4 cm – at least two waves | B1  B1 | Check peak, equilibrium and trough positions   **Examiner’s Comments** In this question (a)(ii), candidates were required to sketch the trace. While perfect drawings are not expected, since the grid is given, candidates should try to use it effectively. The amplitude should be two squares above and two squares below for the peaks and troughs respectively. Similarly, for the period (4cm) using the grid, candidates should be able to make sure that the drawing is consistent at the peak, trough and zero lines. |
|  |  |  | **Total** | **3** |  |
| 12 | a |  | **Level 3 (5–6 marks)** Clear description **and** clear analysis  *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*  **Level 2 (3–4 marks)** Clear description **or** Clear analysis **or** Some description **and** some analysis  *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.*  **Level 1 (1–2 marks)** Limited description **or** Limited analysis  *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*  **0 marks** No response or no response worthy of credit. | B1× 6 | Use level of response annotations in RM Assessor  **Indicative scientific points may include:** **Description**   * Method for creating wave / pulse, e.g. lifting and releasing tray, dropping a ball into the water, ripple-tank arrangement, etc. (Details not expected) * speed = distance ÷ time **or** *v = x ÷ t* **or** *v = fλ* * Measure distance travelled using a ruler * Use a stopwatch / timer/ video technique / strobe to measure time / frequency * Measure the depth of water using a ruler etc * Record / measure / determine *v* for different *d* * Repeat to find average *v*   **Analysis**   * Plotting a graph, e.g. *v* against √*d* **or** *v2* against *d* **or** lg*v* against lg*d* etc. * Correct determination of *g* from straight-line graph **or** * Table with *v* and √*d* **or** *v2* and *d* * Correct calculation of average value of *g* from the table   **Examiner’s Comments**  This level of response (LoR) question was designed to assess practical skills of planning, implementation, analysis and evaluation from module 1 of the specification, together with the mathematical skills of graphs from Section M3. The context of the question was waves and the relationship between wave speed *v* and depth *d* of the water.  A holistic approach to marking is used, with marks given according answers matching the descriptors for the various levels. There is no one perfect answer for this question, examiners were expecting an eclectic approach. The key things examiners were looking for were:  - A plausible technique for creating the waves on the surface of the water.  - Method for determining the speed of the waves.  - Instruments used for measurements.  - Techniques used to produce reliable results.  - The graph plotted, and how the acceleration of free fall *g* is determined from the data.  On occasions, the methods used for determining the speed of the waves and creating the waves were a bit creative, but perhaps plausible in the hands of very competent physicists. For examples, light-gates were often used to determine the speed of the waves. The intricacies of this method were often omitted, but given lots of time, the technique could be made to work. There were some interesting suggestions about using a motion-sensor above a floating ball to determine the frequency of the waves. Examiners were not looking for perfection. Most candidates either dropped objects into the water or struck the side of the tray to create the waves. The speed was often determined by dividing the distance travelled by the wave by the time it took to travel a known distance.  Candidates either plotted *v*2 against *d* or *v* against √*d* to determine *g*. Across the ability range, the analysis sections of the answers were generally better than the descriptions.  The exemplar 5 shows a response that scored Level 3 (L3) and exemplar 6 shows a response that missed out on a top score because of lack of detail in the description.  **Exemplar 5**    This exemplar shows that examiners are not expecting perfection with the practical skills or the analysis. The description here is clear, as is the analysis. This response met all the requirements of a Level 3 score.             **Exemplar 6**    This exemplar shows a Level 2 response. You will notice that the description is not as robust at that shown in exemplar 5. The analysis in both is similar. There are small margins between the levels. |
|  | b |  | time | B1 | **Allow** *t* but **not** *T* **Ignore** any correct unit given with the correct label **Not** a wrong unit with the correct label, e.g *t* / m (CON) **Not** just a unit of time, e.g. second  **Examiner’s Comments**  Almost all candidates did well here by correctly labelling the horizontal axis. Most answers also included the unit, e.g. time / s. A very small number of candidates had *distance, time period, frequency* and *velocity* for the label. |
|  | c |  | |  |  | | --- | --- | | (v = distance/time) |  |      |  |  | | --- | --- | |  | and v = fλ |   **or**  There are f wavelengths per unit time  v = distance travelled per unit time and v = f×λ | M1   A1    M1  A1 | **Allow** ‘(distance travelled is) λ in one period / T  **Not** t for T    **Allow** ‘…in 1 s’ instead of ‘per unit time’  **Allow** λ / ‘waves’; **not** cycles / oscillations instead of wavelengths  **Examiner’s Comments**  For maximum marks, it was important for candidates to clearly show all the steps leading to the wave equation. Supportive text always helps with the clarity of answers. The vast majority of the candidates produced flawless answers in terms of λ, f and T. A significant number of candidates used t or d, which made their working ambiguous. Some tried their luck with 4.0 s from **Fig. 16.1**, which led to no marks.  The exemplar 3 below shows a model response supported by equations and text and exemplar 4 shows that even top end candidates make mistakes.      **Exemplar 3**    This is a model response for a show-type question. The text provides continuity and supports the derivation of the wave equation. A perfect solution.  **Exemplar 4**    This was a high scoring candidate overall who misunderstood the question here. The focus is on S.I. units of the various quantities and not on a derivation of v = fλ from first principles. |
|  | d | i | |  |  |  | | --- | --- | --- | | (speed in material =) |  | **or** 2.5 × 108 (ms-1) |      |  |  | | --- | --- | |  | **or**   5.0 × 10-15 (s) | |  | **or**   6.0 × 10-15 (s) |   t = [6.0 – 5.0] × 10-15 = 1.0 × 10-15 (s) | C1  C1  C1   A0 | **Allow other correct methods**  **Note** omitting or incorrect use of 1.2 is XP  **Allow** 1 SF answer 5 × 10-15  **Allow** 1 SF answer 6 × 10-15 **Note** this also scores the first C1 mark **Note** omitting or incorrect use of 1.2 is XP  **Examiner’s Comments**  Generally, candidates answered this question extremely well and most scoring full marks  In **(c)(i)**, the solutions ranged from being well-structured to an assortment of equations and substitutions filling the entire answer space. Equations for refractive index and speed were easily used to show the answer to be 1.0 × 10-15 s.  In **(c)(ii)**, candidates either calculated the frequency of 5.0 × 1014 Hz and then used T = f-1 or calculated T directly using = 2.0 × 10−15 s.  **(c)(iii)** provided some discrimination with middle and top candidates getting the correct answer of 180°. As always, error carried forward (ECF) rules apply in calculations. This helped those candidates who got an incorrect answer of 2.4 × 10-15 s in **(c)(ii)** to score a mark for 150°.     |  |  | | --- | --- | |  | **Misconception** |   There were some missed opportunities, with some candidates making the following mistakes.   * In **(c)(i)** calculating the difference in the time for the two rays by halving the period of 2.0 × 10-15 s. * In **(c)(ii)** using the wavelength in vacuum of 6.0 × 10-7 m but the incorrect speed of 2.5 × 108 ms-1 to calculate the period. This gave an answer of 2.4 × 10-15 s; examiners allowed 1 mark for this method. * In **(c)(iii)**, a small number of candidates, mainly at the low-end, confused the symbol φ for phase difference to be work function. This produced some bizarre answers. |
|  |  | ii | |  |  |  | | --- | --- | --- | |  | **or** 5.0 × 1014 (Hz) **or** |  |   T = 2.0 × 10-15 (s) | C1   A1 | **Allow** 1 SF of 2 × 10-15 **Allow** 1 mark for 2.4 × 10-15 (s); 2.5 × 108 ms-1 used |
|  |  | iii | φ = 180° | B1 | Possible ECF from **(i)** and **(ii)** **Note** answer must be φ = **(c)(i)** × 360°/**(c)(ii)** **Not** an answer in rad, e.g. π rad |
|  |  |  | **Total** | **15** |  |
| 13 |  |  | Clear indication that angles of incidence and refraction are being measured relative to the normals    refractive index = sini/sinr    Any one from:   * Measure angle(s) using a protractor * Plot sini against sinr graph or average sini /sinr value**s** * Use narrow beam of light (for ray box) / draw thin pencil lines * Conduct experiment in a dark room | B1      B1    B1 | Note this can be scored from a clear diagram. The angles must have sensible labels, e.g. i, r, θ1, ***θ***2, etc Ignore angle of refraction > angle of incidence  **Allow** n for refractive index **Allow** n1sinθ1 = n2sinθ2, as long as all labels have been correctly identified and the refractive index for air/vacuum is taken as 1 **Not** n = c/v   **Examiner’s Comments**  This question produced a wide spectrum of marks, with only the upper quartile of the candidates generally securing 2 or 3 marks. Candidates are reminded that if a diagram is drawn to support an answer, it must be adequately annotated. On many scripts, the normal was missed out and the angles of incidence and refraction were marked incorrectly (often between the light beam and the straight edge of the rectangular block). A significant number of candidates decided to change the block to a semi-circular one, and focused erroneously on determining the refractive index n using the critical angle equation sinC = 1/n. |
|  |  |  | **Total** | **3** |  |
| 14 |  |  | Microwaves from **T** are transverse/polarised wtte   At 0° or 180° the grille blocks (all) the (polarised) waves and at 90° the grille allows all the microwaves to pass. | **B1    B1** | **Allow** E field perpendicular to direction of motion   **Allow** explanation in terms of I = I0 cos2 θ     **Examiner’s Comments**  Candidates found this question difficult. Candidates often did not state that the microwaves were polarised or mistakenly thought that the grille caused the microwaves to become polarised.  Candidates also did not appear to read the question carefully often thinking that the detected signal varied from a maximum initially. Some candidates quoted I = I0 cos2 θ to help explain their answer. |
|  |  |  | **Total** | **2** |  |
| 15 | a | i | 1.36  1.97 × 108 | **B1  B1** | **Not** 1.3 or 1.4  **Not** 1.9 or 2.0  **Examiner’s Comments**  This question was generally well answered. Some lower ability candidates were careless in the calculation of the speed of light in glass and gave their answers as either 1.9 or 2.0 as opposed to 1.97. There were also some candidates who gave an answer of 4.56 × 108 m s−1 – this is where candidates should check the pattern in the table. |
|  |  | ii |  | **B1** | **Allow** 3.41 × 10−7 (m)  **Not** ECF from (a)(i)  **Examiner’s Comments**  Surprisingly, this question did not score highly – many candidates did not realise that the wavelength of light in the glass would be the wavelength of light in air divided by the refractive index of glass. |
|  | b | i | θ = 23(.3)° | **C1**    **A1** | **Examiner’s Comments**  Many candidates correctly applied Snell’s law. Common mistakes were either using the wrong refractive index or inverting the answer. |
|  |  | ii | Ray in glass bends towards normal and ray in ethanol bends away from normal but at a smaller angle than 37°  Rays are straight by eye | **B1** | **Note** Ray should not be parallel to incoming ray.   **Not** angle of refraction is zero in glass  **Examiner’s Comments**  This question required candidates to apply the previous answers to this question to draw an appropriate ray diagram. Candidates do need to use a ruler. A common error was for the emergent ray in the ethanol to be parallel to the incident ray in the air. This question required candidates to think through their diagram stage by stage using information from the previous part and the table given earlier in the question.  **Exemplar 8**    This candidate has used a ruler and drawn straight rays. The candidate has marked on the normal and indicated the angle of refraction in the glass. It is clear that the ray in the ethanol is not parallel to the original ray. |
|  |  |  | **Total** | **6** |  |
| 16 |  |  | Speed of light is less in water (ORA)    Frequency is the same (in both)   Wavelength is smaller in water (ORA) | **B1    B1   B1** | **Allow** calculated values for air **and** water **Allow** speed decreases (from air to water) **Not** v or c  **Allow** f is the same   **Allow** wavelength / λ decreases (from air to water)  **Examiner’s Comments**  Most candidates gained two or more marks. Many candidates were aware that the speed of light was less in water than in air. A significant number of candidates also knew that the frequency of light remains constant and successfully argued the fate of the wavelength using the wave equation v = fλ.  **Exemplar 12**   This exemplar illustrates a flawless answer from a top–end candidate. It had all the main ingredients for scoring 3 marks. The answers matched well with the marking points – the examiner had no issues with following the text. |
|  |  |  | **Total** | **3** |  |
| 17 |  |  | **A** | 1 |  |
|  |  |  | **Total** | **1** |  |
| 18 |  |  | **C** | 1 |  |
|  |  |  | **Total** | **1** |  |
| 19 |  |  | A | 1 |  |
|  |  |  | **Total** | **1** |  |
| 20 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 21 |  |  | **D** | 1 |  |
|  |  |  | **Total** | **1** |  |
| 22 |  |  | **A** | **1** |  |
|  |  |  | **Total** | **1** |  |
| 23 |  |  | **C** | **1** |  |
|  |  |  | **Total** | **1** |  |
| 24 |  |  | D | 1 |  |
|  |  |  | **Total** | **1** |  |
| 25 | a | i | when two (or more) waves meet / superpose / overlap (at a point) | M1 | **NOT** interact, combine, join, connect, collide, hit, |
|  |  | i | there is a change in overall displacement | A1 | intersect, pass through, etc. **allow** the resultant displacement equals the sum of the individual displacements |
|  |  | ii | constant phase difference / relationship (between the waves) | B1 | **allow** fixed **not** same   **Examiner's Comments**  More than half of the candidates are aware that coherence requires a constant phase difference. Interference is related to the principle of superposition of waves and the sum of displacements at the point(s) where the waves meet. Many candidates refer to amplitudes and to the waves colliding, etc. There is only a small selection of words that are accepted to describe the word interference. |
|  | b |  | λ = c/f = 3.0 × 108/1.0 × 1010 | M1 |  |
|  |  |  | λ = 3.0 × 10−2 so aerial length = 1.5 × 10−2 (m) | A1 | **accept** 1.5 c(m)   **Examiner's Comments**  Well answered by most. The common error was to insert MHz for GHz in the calculation. |
|  | c | i | the path difference between the signals (from the two transmitters) changes (along OP) | B1 | **give** 1 mark out of 2 for maxima and minima occur (because of interference) |
|  |  | i | causing the detected signal to vary between maximum and minimum values / AW **or** when signals (at the point on OP) are in phase there is a maximum when (π) out of phase there is a minimum | B1 |  |
|  |  | i | x = λD/a = 3.0 × 10−2 × 4.0/0.20 (= 0.60) | C1 | **ecf (b)** 20 times answer to **(b)** |
|  |  | i | so distance = x/2 = 0.30 (m) | A1 | **allow** 1 SF answer here |
|  |  | ii | amplitude of signal decreases (inversely) with distance | B1 | **allow** intensity; **no mark if** any suspicion of decrease being caused by interference effect |
|  |  | ii | because energy emitted by the transmitters spreads out (so less is collected by the receiver the further away it is) | B1 | **accept** any statement which conveys the idea of energy spreading correctly, e.g. I α 1/d2 |
|  |  | ii | when AO - BO = λ/2 a minimum occurs / AW **or** phase difference of π (180°) between detected signals from A and B | B1 | idea that movement of λ/2 will change maximum to minimum or vice versa |
|  |  | ii | so distance = λ/2 = 1.5 × 10−2 m | B1 | **ecf (b)** same answer as **(b); accept** 1.5 c(m)   **Examiner's Comments**  The meanings of phase and path length and their role in interference were often not well understood leading to confusion when movements of the detector or transmitter were made. Many failed to realise in part (ii) that the distances of the detector from the two transmitters remain equal. Energy was often lost rather than spreading out. Few seemed to be aware of the inverse square law. Most answered part (iii) well especially those in terms of path length rather than phase difference. |
|  | d | i | intensity increases by factor of 4 | B1 |  |
|  |  | i | as intensity α (amplitude)2 | B1 | Enter text here. |
|  |  | ii | intensity falls to zero | B1 | Enter text here. |
|  |  | ii | (emitted) signal is (vertically) polarised | B1 | Enter text here. |
|  |  | ii | receiver in position only to detect horizontally polarised signal | B1 | **allow** transmitter and detector act like ‘crossed polarisers’ or quoting Malus' law correctly   **Examiner's Comments**  There were many good answers to part (i). In part (ii) some students failed to recognise that the question related to polarisation but most scored some marks. |
|  |  |  | **Total** | **16** |  |
| 26 | a | i | the maximum displacement from equilibrium or rest position | B1 | **allow** zero or undisturbed for equilibrium |
|  |  | i | number of oscillations / vibrations (at a point) per unit time | B1 | number of wavelengths passing a point or produced by the wave source per unit time **allow** per second **NOT** amount for number |
|  |  | i | how far ‘out of step’ (out of sync) the oscillations at two points on the wave / string are / AW | B1 | **alt e.g.** the fraction of a cycle between the oscillations at the two points |
|  |  | ii | all have same frequency **or** same amplitude | B1 | **N.B.** withhold mark if extra incorrect answers given |
|  |  | ii | all have different phases / phase differences | B1 | **allow** not in phase or all out of phase   **Examiner's Comments**  The basic definitions on waves in part (i) were often imprecise. A typical example for frequency is the amount of waves in a second. For phase difference most compared two different waves rather than referring to two points on the same wave. In part (ii) many confused a progressive wave with a stationary wave so only about one third of the candidates scored both marks. |
|  | b | i | progressive a wave which transfers energy | B1 | **accept** phase relationship descriptions between |
|  |  | i | stationary a wave which traps / stores energy (in pockets) **or** progressive : transfers shape / information from one place to another stationary where the shape does not move along / which has nodes and antinodes / AW | B1 | different points on wave;  must be a comparison for same property to score both marks |
|  |  | i | the wave reflected (at the fixed end of the wire) | B1 |  |
|  |  | i | interferes / superposes with the incident wave to produce a resultant wave with nodes and antinodes / no | B1 |  |
|  |  | i | energy transfer | B1 |  |
|  |  | ii | **(all** points have) same frequency | B1 |  |
|  |  | ii | **P** and **Q** have same amplitude and (are in) phase | B1 | **allow** same phase difference here |
|  |  | ii | **S** has larger amplitude than **P** and **Q** | B1 | **allow** different to |
|  |  | ii | **S** has a phase difference of Φ / in antiphase to **P** and **Q** | B1 | **or** 180° **max** any 3 out of 4 marking points |
|  |  | iii | 15 Hz | B1 |  |
|  |  | iii | as all points in the fundamental / first harmonic mode move in phase | B1 | **accept** string is 1/2 λ long / between ends |
|  |  | iii | 120 Hz | B1 |  |
|  |  | iii | for every 10 cm to be at rest ? = 20 cm (so 4 × frequency of Fig. 4.2) | B1 | **accept** as all points are nodes **or** f = 8f0 **or** is 8th harmonic   **Examiner's Comments**  In part (i) many candidates gave only the characteristics of a stationary wave failing to give the comparison property for a progressive wave. Part (ii) was answered well by all. In part (iii) most candidates were aware that all points oscillated with the same frequency but failed to give enough detail to score further marks. In part (iv) many candidates did not notice the request for frequency values . It was apparent that few candidates had an understanding of harmonics. About half of the candidates gave at least one correct frequency but the explanation for the choice was often not convincing. |
|  |  |  | **Total** | **17** |  |
| 27 | a |  | **Level 3 (5–6 marks)** Clearly labelled diagram. Procedure is correct including appropriate measurements Analysis is correct and includes A5. (6 marks) Any point omitted or incorrect (5 marks). There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.  **Level 2 (3–4 marks)** Good diagram. Most measurements made Some analysis. (4 marks) Any point omitted or incorrect (3 marks). There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.  **Level 1 (1–2 marks)** Basic diagram with incomplete labels. Some measurements. Limited analysis. (Maximum 2 marks) The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.  **0 marks** No response or no response worthy of credit. | B1 x 6 | **Diagram**  1. Labelled diagram of glass block & ray box  2. Incident and refracted rays shown  3. Normal shown and correct i and r  **Procedure**  1. Block placed on paper  2. Incident and refracted rays marked  3. Angles measured using a protractor  **Analysis**  1. sin i and sin r calculated  2. sin i against sin r graph plotted  3. Straight line of best fit drawn  4. gradient = refractive index (n)  5. Error bars drawn to find the gradient |
|  | b |  | The ray is refracted away from the normal, therefore the refractive index of water is less than the refractive index of glass or speed of light in water is greater than the speed of light in glass. | B1 |  |
|  |  |  | The frequency remains constant. | B1 |  |
|  |  |  | *v* = *fλ* and therefore the wavelength of light increases as it travels from glass to water. | B1 |  |
|  |  |  | **Total** | **9** |  |