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HIGHER

P6H Waves: Higher Tier Practice

AQA 8463 · Calculator allowed · about 95 minutes

Total Marks

Name: ________________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 A loudspeaker cone vibrates back and forth, producing sound waves of frequency 250 Hz that travel through air at a speed of 340 m/s.

(a) State whether the sound wave produced is transverse or longitudinal, and explain how the vibration of the particles relates to the direction the wave travels. **(2)**

(b) Calculate the wavelength of this sound wave. Give your answer to 3 significant figures. **(3)**

....

(Total for Question 1 is 5 marks)

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2 A technician is testing a signal generator connected to a loudspeaker. She uses an oscilloscope to display the sound wave produced, and measures a time period of 4.0 milliseconds (ms) between successive wave peaks on the screen.

(a) Calculate the frequency of the sound wave, in Hz. Give your answer to 3 significant figures. **(3)**

....

(b) The speed of sound in the air in the room is 344 m/s. Calculate the wavelength of this sound wave. **(2)**

....

(Total for Question 2 is 5 marks)

3 A group of students carried out the required practical to investigate the frequency, wavelength and speed of waves in a solid, using a length of string stretched between a vibration generator and a fixed point, with the frequency of the vibration generator varied to produce a clear stationary wave pattern. They repeated the wavelength measurement three times for one frequency setting. Results (wavelength, in cm): 24.2, 24.6, 31.0, 24.4.

(a) Identify the anomalous (outlier) result in the data, and suggest one likely cause of it. **(2)**

(b) Calculate the mean wavelength, excluding the anomalous result. **(2)**

....

(c) The vibration generator was set to a frequency of 35 Hz. Use your answer to part (b) to calculate the speed of the wave on the string, in m/s. **(2)**

....

(d) Suggest one improvement to this method that would increase the precision of the wavelength measurement. **(1)**

(Total for Question 3 is 7 marks)

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4 A hospital ultrasound scanner sends a pulse of ultrasound into a patient's abdomen. The pulse travels through soft tissue at a speed of 1540 m/s. The reflected pulse returns to the detector 0.052 ms after it was sent, having reflected off a boundary between two types of tissue.

(a) Calculate the total distance travelled by the pulse (there and back). **(2)**

....

(b) Calculate the depth of the tissue boundary below the surface of the skin. **(1)**

....

(Total for Question 4 is 3 marks)

5 Radio waves used for a particular broadcast have a frequency of 1.20×10^8 Hz. Electromagnetic waves travel at 3.00×10^8 m/s in a vacuum (and approximately this speed in air).

(a) Calculate the wavelength of this radio wave. **(2)**

....

(b) A different electromagnetic wave has a much shorter wavelength of 5.00×10^{-7} m. Calculate its frequency. **(2)**

....

(Total for Question 5 is 4 marks)

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6 When a wave meets the boundary between two different materials, it can be absorbed, transmitted or reflected, and often some combination of all three happens at once.

(a) Explain what happens to a wave that is absorbed at a boundary, in terms of energy transfer, and give one example of a practical use of this. **(2)**

(b) Explain what happens to a wave that is transmitted at a boundary, and state what may happen to its direction of travel as it does so. **(2)**

(Total for Question 6 is 4 marks)

7 A ray of light travels from air into a rectangular glass block, hitting the flat surface at an angle to the normal, then exits the glass block through the opposite parallel face back into the air.

(a) Describe, in terms of the direction of the ray and its wave speed, what happens as the ray enters the glass block. **(2)**

(b) Describe and explain what happens to the direction of the ray as it exits the glass block back into the air, given that the two surfaces of the block are parallel. **(2)**

(Total for Question 7 is 4 marks)

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8 Earthquakes produce seismic waves that travel through the Earth. Seismologists detect these waves at monitoring stations around the world using seismometers.

(a) State whether P-waves are transverse or longitudinal, and state which types of material (solid, liquid, gas) they can travel through. **(2)**

(b) State whether S-waves are transverse or longitudinal, and state which types of material they can travel through. **(2)**

(Total for Question 8 is 4 marks)

9 Seismologists around the world detect the seismic waves produced by a large earthquake. On the opposite side of the Earth from the earthquake, S-waves are not detected at all, and this 'S-wave shadow zone' provides evidence about the structure of the Earth's interior.

(a) Explain what the absence of S-waves in this shadow zone tells scientists about the outer core of the Earth. **(2)**

(b) P-waves are detected on the far side of the Earth, but their paths are refracted (bent), producing a P-wave shadow zone in a different location to the S-wave shadow zone. Suggest what this refraction of P-waves tells scientists about the core. **(1)**

(Total for Question 9 is 3 marks)

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10 A student generates water waves of different amplitudes in a ripple tank and measures the energy transferred to a small floating cork placed in the path of the waves, using a simple sensor. Her results are shown below.

Amplitude (mm) -- Energy transferred to cork per second (arbitrary units)
2 -- 4
4 -- 16
6 -- 36
8 -- 64

(a) Describe the relationship between the amplitude of the waves and the energy transferred per second, as shown by the data. **(2)**

(b) Predict the energy transferred per second for a wave amplitude of 10 mm, based on the pattern in the data. **(1)**

(Total for Question 10 is 3 marks)

11 Explain how P-waves and S-waves, detected at seismometers around the world after a large earthquake, provide evidence that the Earth's outer core is liquid while its mantle and inner core are solid. Your answer should refer to the properties of P-waves and S-waves and to the pattern of shadow zones observed.

(Total for Question 11 is 6 marks)

Mark scheme · P6H Waves: Higher Tier Practice

Question 1

- (a) **B1** longitudinal
- (a) **B1** the air particles vibrate parallel to (in the same direction as) the direction the wave travels/energy is transferred, oe
- **(a) Answer: Longitudinal: the air particles vibrate parallel to (along) the direction the wave travels.**
- (b) **M1** rearranges v = f x wavelength to wavelength = v / f
- (b) **M1** substitutes: wavelength = 340 / 250
- (b) **A1** 1.36 m cao (3 s.f.)
- **(b) Answer: 1.36 m**

Question 2

- (a) **M1** converts 4.0 ms to seconds: 4.0 x 10^{-3} s
- (a) **M1** f = 1 / (4.0 x 10^{-3})
- (a) **A1** 250 Hz cao
- **(a) Answer: 250 Hz**
- (b) **M1** wavelength = 344 / 250, ft from (a)
- (b) **A1** 1.38 m cao (3 s.f.)
- **(b) Answer: 1.38 m**

Question 3

- (a) **B1** 31.0 cm is the anomalous result
- (a) **B1** a likely cause, e.g. a measurement/reading error, the string was not vibrating in a clear stable pattern at that instant, or the ruler was misaligned, oe
- **(a) Answer: 31.0 cm is anomalous, likely caused by a misread measurement or the string pattern not being stable at that instant.**
- (b) **M1** (24.2 + 24.6 + 24.4) / 3
- (b) **A1** 24.4 cm cao
- **(b) Answer: 24.4 cm**
- (c) **M1** converts 24.4 cm to 0.244 m and substitutes: v = 35 x 0.244, ft from (b)
- (c) **A1** 8.54 m/s cao (3 s.f.)
- **(c) Answer: 8.54 m/s**
- (d) **B1** e.g. measure the distance across several wavelengths and divide by the number of wavelengths, rather than measuring a single wavelength, oe
- **(d) Answer: Measure the distance across several wavelengths and divide by the number of wavelengths, rather than measuring just one.**

Question 4

- (a) **M1** converts 0.052 ms to 5.2 x 10^{-5} s and substitutes: distance = 1540 x 5.2 x 10^{-5}
- (a) **A1** 0.0801 m cao (3 s.f.)
- **(a) Answer: 0.0801 m**
- (b) **B1** 0.0400 m (unrounded 0.08008 / 2 = 0.04004), ft from (a), cao
- **(b) Answer: 0.0400 m (40.0 mm)**

Question 5

- (a) **M1** rearranges and substitutes: wavelength = (3.00 x 10^{8}) / (1.20 x 10^{8})
- (a) **A1** 2.50 m cao
- **(a) Answer: 2.50 m**
- (b) **M1** rearranges and substitutes: f = (3.00 x 10^{8}) / (5.00 x 10^{-7})
- (b) **A1** 6.00 x 10^{14} Hz cao
- **(b) Answer: 6.00 x 10^{14} Hz**

Question 6

- (a) **B1** the wave's energy is transferred to the energy store of the material (e.g. as an increase in its internal/thermal energy), and the wave does not continue beyond the boundary, oe
- (a) **B1** example use, e.g. a solar panel absorbing light to generate electricity, or a black surface absorbing infrared radiation to heat up, oe
- **(a) Answer: The wave's energy is transferred into the material, for example increasing its internal (thermal) energy, and the wave does not continue past the boundary. Example: a solar panel absorbs light to generate electricity.**
- (b) **B1** the wave continues travelling through the second material (into the new medium), oe
- (b) **B1** if it meets the boundary at an angle, the change in wave speed in the new medium causes it to change direction (refract), oe
- **(b) Answer: The wave continues travelling into the second material. If it meets the boundary at an angle, it will refract (change direction) because its speed changes in the new material.**

Question 7

- (a) **B1** the ray slows down as it enters the glass (light travels more slowly in glass than in air), oe
- (a) **B1** the ray bends towards the normal, because it is entering a denser (optically) medium, oe
- **(a) Answer: The ray slows down as it enters the glass, because light travels more slowly in glass than in air, and it bends towards the normal because it is entering an optically denser medium.**
- (b) **B1** the ray speeds up again and bends away from the normal, oe
- (b) **B1** because the two surfaces are parallel, the ray emerges parallel to its original direction before it entered the glass (it is laterally displaced, but not deviated overall), oe
- **(b) Answer: The ray speeds up again and bends away from the normal as it leaves the glass. Because the two surfaces are parallel, the emerging ray travels in a direction parallel to the original ray, just shifted sideways slightly.**

Question 8

- (a) **B1** P-waves are longitudinal
- (a) **B1** P-waves can travel through solids and liquids (and gases), oe
- **(a) Answer: P-waves are longitudinal, and can travel through solids and liquids (and gases).**
- (b) **B1** S-waves are transverse
- (b) **B1** S-waves can only travel through solids, not through liquids or gases, oe
- **(b) Answer: S-waves are transverse, and can only travel through solids, not through liquids or gases.**

Question 9

- (a) **B1** S-waves cannot travel through liquids, oe
- (a) **B1** so the absence of S-waves on the far side of the Earth shows that they have been blocked by a region that must be liquid; this shows that the outer core of the Earth is liquid, oe
- **(a) Answer: Because S-waves cannot travel through liquids, the fact that they are not detected on the far side of the Earth shows that they have been blocked by a liquid region; this is evidence that the Earth's outer core is liquid.**
- (b) **B1** the P-waves change speed suddenly as they cross the boundary into (and out of) the core, showing that the core has a different density/composition from the mantle around it, oe
- **(b) Answer: The sudden change in P-wave speed as they cross into and out of the core shows that the core has a different density (and composition) from the surrounding mantle.**

Question 10

- (a) **B1** as amplitude increases, the energy transferred per second increases, oe
- (a) **B1** the relationship is not linear/proportional; the energy increases much faster than the amplitude (e.g. doubling the amplitude from 2 to 4 mm roughly quadruples the energy, from 4 to 16), oe
- **(a) Answer: As amplitude increases, the energy transferred per second increases, but not in direct proportion; the energy increases much faster than the amplitude (for example, doubling the amplitude from 2 mm to 4 mm quadruples the energy transferred, from 4 to 16 units).**
- (b) **B1** 100 (units), following the pattern that energy = amplitude^2, oe; accept a reasonable extrapolated value with correct reasoning shown
- **(b) Answer: 100 units, since the pattern in the table shows that the energy transferred is equal to the amplitude squared (energy = amplitude^2).**

Question 11

- **Level 3** (5-6): A clear, logically structured explanation that correctly states the properties of P-waves and S-waves (type of wave and which materials they travel through), and links the observed S-wave shadow zone directly to evidence that the outer core is liquid, and the detection of P-waves (with refraction) on the far side of the Earth to evidence that the mantle is solid throughout and that the core has a different density from the mantle.
- **Level 2** (3-4): A mostly correct explanation. The properties of P-waves and/or S-waves are described accurately, and there is some correct link to the shadow zone evidence, but the reasoning may be incomplete or only partly linked to the conclusion about the state of the core.
- **Level 1** (1-2): A simple, partial answer, for example stating that S-waves do not reach the far side of the Earth, with little or no explanation of why this shows the core is liquid.
- **Indicative content:**
  - P-waves are longitudinal and can travel through solids and liquids; S-waves are transverse and can only travel through solids.
  - S-waves are detected all around the world except in a shadow zone on the opposite side of the Earth from the earthquake.
  - Because S-waves cannot travel through liquids, this shadow zone shows that S-waves have been blocked by a liquid layer inside the Earth; this liquid layer is the outer core.
  - P-waves are detected everywhere, including on the far side of the Earth, showing that they can pass all the way through the Earth, including through the outer core, which is consistent with P-waves being able to travel through both solids and liquids.
  - P-waves refract (change direction) as they enter and leave the core, because their speed changes suddenly at this boundary; this produces a P-wave shadow zone in a different location from the S-wave shadow zone, and shows that the core has a different density from the surrounding mantle.
  - Because seismic waves (both P- and S-waves) travel through the mantle in all directions without being blocked, this shows that the mantle (and, from further analysis, the inner core) must be solid.
  - Taken together, the presence of an S-wave shadow zone (showing a liquid outer core) and the pattern of P-wave refraction (showing a density change at the core boundary) provide strong evidence for a liquid outer core surrounded by a solid mantle, with a solid inner core at the centre.