

## **Questions**

Q1.

**Answer the question with a cross in the box you think is correct ☐ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐ .**

Ultrasound has a number of different uses in medicine.

Which of the following is the main reason why ultrasound is not used to perform scans of the chest and lungs?

- ☐ **A** The air in the lungs causes most of the ultrasound to be reflected back.
- ☐ **B** The duration of the pulses of ultrasound limits the amount of detail that can be seen.
- ☐ **C** The wavelength of the ultrasound is too long.
- ☐ **D** Ultrasound can damage the lungs.

**(Total for question = 1 mark)**

Q2.

**Answer the question with a cross in the box you think is correct ☐ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐ .**

Ultrasound scans can be used to create an image of a patient's kidneys.

For each ultrasound pulse sent into the body, a number of pulses are detected.

Which of the following explains why a number of pulses are detected?

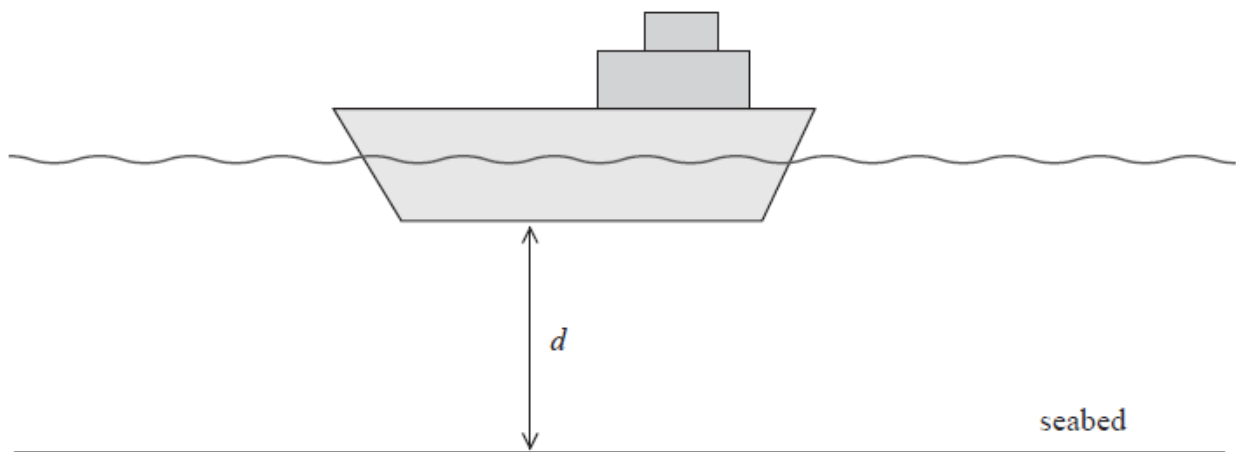
- ☐ **A** Interference occurs when the pulse is in the body.
- ☐ **B** The ultrasound reflects off different layers within the body.
- ☐ **C** The ultrasound has a very high frequency.
- ☐ **D** The ultrasound has a very large wavelength.

(Total for question = 1 mark)

Q3.

Answer the question with a cross in the box you think is correct ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.

A pulse of ultrasound is emitted from the bottom of a boat. The ultrasound reflects from the seabed and is detected at the bottom of the boat after time  $t$ . The depth  $d$  of water under the boat is shown.



The ultrasound has a frequency  $f$  and travels at a speed  $v$  in the seawater.

Which of the following can be used to calculate  $d$ ?

☒ A  $d = vt$

☐ B  $d = \frac{v}{f}$

☐ C  $d = \frac{vt}{2}$

☐ D  $d = \frac{v}{2f}$

(Total for question = 1 mark)

Q4.

**Answer the question with a cross in the box you think is correct ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.**

Which of the following would increase the detail in an ultrasound scan?

- ☐ **A** increasing the duration of the pulses
- ☐ **B** increasing the frequency of the ultrasound
- ☐ **C** increasing the intensity of the ultrasound
- ☐ **D** increasing the wavelength of the ultrasound

**(Total for question = 1 mark)**

Q5.

**Answer the question with a cross in the box you think is correct (☐). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☐.**

A student stands a distance  $d$  from a wall. She makes a loud sound. She hears the echo of the sound from the wall after a time  $t$ .

Which of the following expressions gives the speed of the sound wave?

- ☐ **A**  $\frac{2d}{t}$
- ☐ **B**  $\frac{d}{t}$
- ☐ **C**  $\frac{d}{2t}$
- ☐ **D**  $\frac{2t}{d}$

**(Total for question = 1 mark)**

Q6.

**Answer the question with a cross in the box you think is correct ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.**

A car has a distance sensor that uses a pulse-echo technique to determine the distance between the car and a nearby object.

The sensor emits a pulse of sound and then detects the echo after time  $t$ .  
The speed of sound is  $v$ .

Which of the following gives the distance between the car and the object?

☐ **A**  $2vt$

☐ **B**  $2vt^{-1}$

☐ **C**  $0.5vt$

☐ **D**  $0.5vt^{-1}$

**(Total for question = 1 mark)**

Q7.

**Answer the question with a cross in the box you think is correct (☐). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☐).**

A bat is an animal that locates objects using a pulse-echo technique. A bat emits a pulse of sound waves that travel to an object. The bat detects the reflected pulse 4 ms later.

speed of sound =  $340 \text{ ms}^{-1}$

Which of the following expressions gives the distance, in metres, between the bat and the object?

- ☐ **A**  $2 \times 340 \times 4 \times 10^{-3}$
- ☐ **B**  $\frac{340}{2 \times 4 \times 10^{-3}}$
- ☐ **C**  $340 \times 4 \times 10^{-3}$
- ☐ **D**  $\frac{340 \times 4 \times 10^{-3}}{2}$

**(Total for question = 1 mark)**

Q8.

Ultrasound can be used to investigate organs inside the human body.

Which of the following statements about ultrasound is correct?

- ☐ **A** All of the ultrasound is reflected at a boundary between different tissues.
- ☐ **B** Ultrasound travels faster in air than inside the body.
- ☐ **C** Ultrasound with a greater wavelength gives an image with a higher resolution.
- ☐ **D** Ultrasound with a shorter pulse duration gives an image with a higher resolution.

**(Total for question = 1 mark)**

Q9.

**Answer the question with a cross in the box you think is correct ☐. If you change your mind about an answer, put a line through the box ☐ and then mark your new answer with a cross ☐.**

A bat is an animal that locates objects using a pulse-echo technique.

A bat emits a pulse of sound waves that travel to an object. The bat detects the reflected pulse 6.0 ms later.

speed of sound =  $340 \text{ m s}^{-1}$

Which of the following gives the distance, in metres, of the object from the bat?

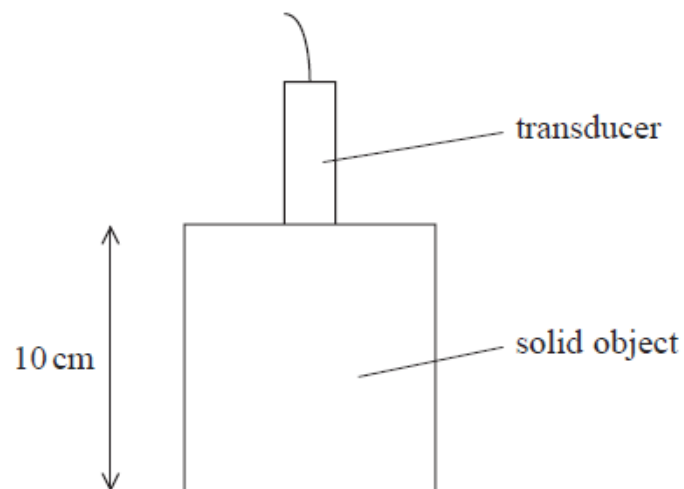
- ☐ **A**  $340 \times 3.0$
- ☐ **B**  $340 \times 6.0$
- ☐ **C**  $340 \times 0.0030$
- ☐ **D**  $340 \times 0.0060$

(Total for question = 1 mark)

Q10.

**Answer the question with a cross in the box you think is correct ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.**

An ultrasound transducer is placed on the surface of a solid object as shown.



A pulse of ultrasound is transmitted into the object. The pulse is received at the transducer  $50 \mu\text{s}$  after it is emitted.

Which of the following can be used to calculate the speed of sound in this object?

☐ **A**  $\frac{0.10}{50 \times 10^{-6}}$

☐ **B**  $\frac{0.10}{25 \times 10^{-6}}$

☐ **C**  $\frac{0.10}{100 \times 10^{-6}}$

☐ **D**  $\frac{0.20}{25 \times 10^{-6}}$

**(Total for question = 1 mark)**

Q11.

Some animals use a pulse-echo technique to collect information about their surroundings.

Describe how this technique provides information about the surroundings.

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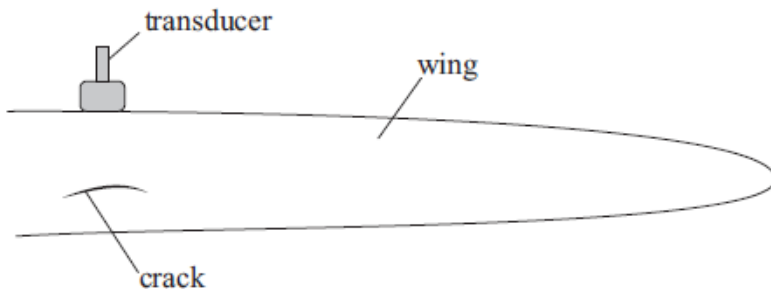
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**(Total for question = 3 marks)**

Q12.

\* Ultrasound can be used to detect cracks in the wing of an aeroplane, as shown.



A transducer that emits and receives ultrasound is used to scan the wing.

Explain how ultrasound can be used to determine the depth of a crack.

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**(Total for question = 6 marks)**

Q13.

A pulse-echo technique, using ultrasound, can be used to produce images of an unborn baby as shown.



Explain how the ultrasound scan of the unborn baby is produced.

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**(Total for question = 6 marks)**

Q14.

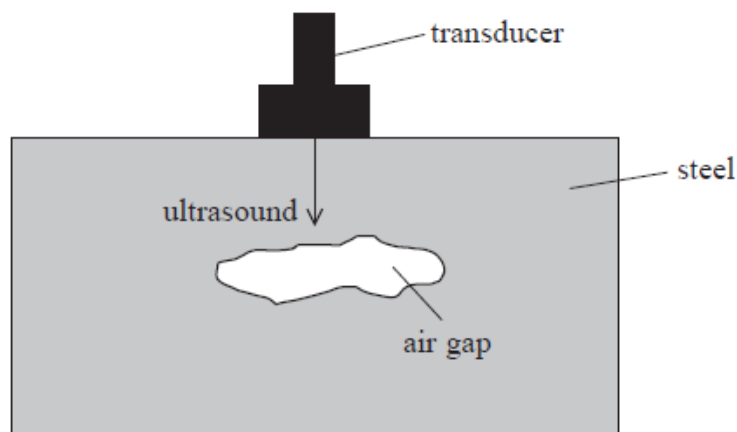
Rolled steel joists (RSJs) are used in the construction of buildings, as shown.



(Source: © Jon Kempner / Shutterstock)

The strength of an RSJ is greatly reduced if there are air gaps within the steel. Ultrasound is used to detect any air gaps in the RSJ.

Pulses of ultrasound are sent by a transducer into an RSJ as shown. Any returning ultrasound is detected by the transducer.



(a) Explain how this arrangement can be used to show whether the RSJ contains an air gap.

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(b) Ultrasound is a sound wave with a frequency greater than 20 kHz. The frequency of ultrasound used by the transducer in this method is 5 MHz.

Explain why a much higher frequency than 20 kHz is needed in this method.

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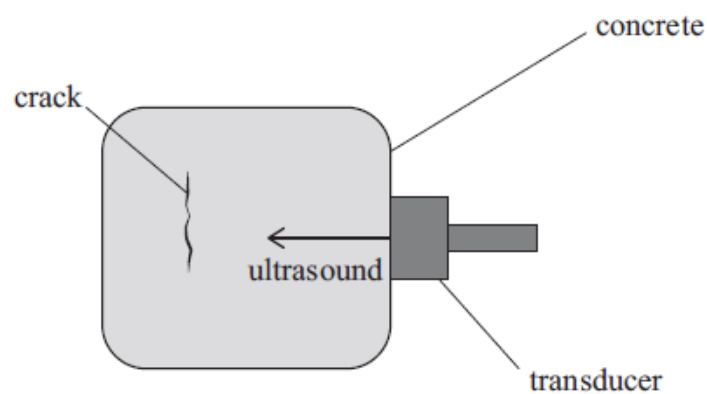
**(Total for question = 7 marks)**

Q15.

Concrete is often used in building construction.

After several years, concrete may develop cracks. Ultrasound can be used to find these cracks.

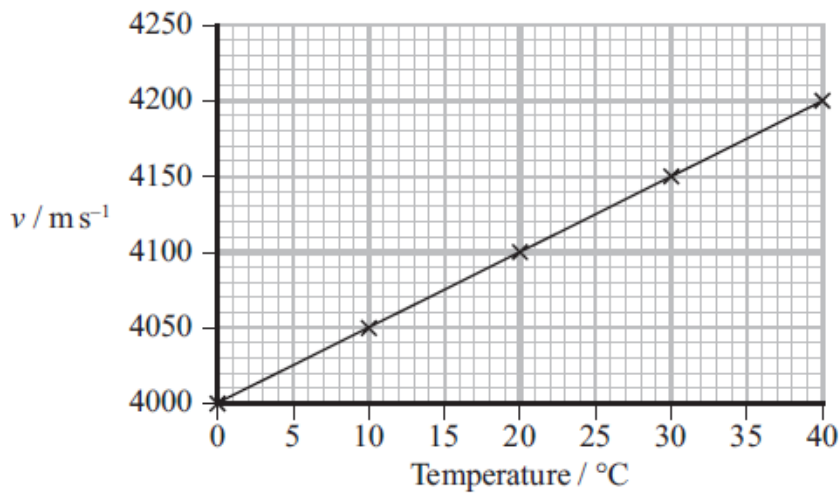
A transducer sends pulses of ultrasound into a piece of concrete, as shown.



The transducer detects pulses of ultrasound reflected from the crack.

To be detected, the reflected pulse must not overlap with the pulse emitted by the transducer.

(a) In this piece of concrete, the speed  $v$  of ultrasound varies with temperature, as shown.



A pulse of ultrasound is incident on a crack in this piece of concrete. The crack is a distance of 4.0 cm from the transducer.

The temperature of the concrete is 23 °C.

Deduce whether the transducer can detect ultrasound reflected from this crack.

duration of ultrasound pulse = 200  $\mu\text{s}$

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(b) Pulses of ultrasound with a higher frequency can be used to find cracks of shorter length.

Explain why a higher frequency is used.

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Q16.

A fishing boat uses a pulse-echo technique to determine the depth of fish under the water surface.

The boat has a transducer which emits pulses of sound into the water and detects returning pulses of sound.

(a) The transducer emits a pulse of sound and detects an echo from a fish after a time of 37 ms.

speed of sound in water =  $1500 \text{ ms}^{-1}$

Calculate the distance between the transducer and the fish.

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Distance = .....

(b) After each pulse is emitted by the transducer, there is a fixed time  $T$  before the next pulse is emitted.

Explain how  $T$  affects the maximum distance at which a fish can be detected.

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(c) The transducer can emit pulses of sound waves of different frequency.

Explain how the frequency should be adjusted to improve the accuracy when detecting the location of a fish.

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**(Total for question = 7 marks)**

Q17.

The rails of a railway track are usually made from steel, which can withstand the high stress of heavy trains. However, steel can develop cracks over time, leading to accidents if not repaired. Large cracks in a rail, such as the one shown in the photograph, are easy to observe.



(Source: [virginiabeach.legalexaminer.com](http://virginiabeach.legalexaminer.com))

Ultrasound is commonly used to detect cracks that are too small to be seen. An ultrasound transducer transmits a pulse of ultrasound into the top of the rail and records the time taken for the pulse to return. If this time is less than the time expected for the pulse to return from the bottom of the rail, a crack is present.

(a) State why an ultrasound pulse would be reflected by a crack in a rail.

**(1)**

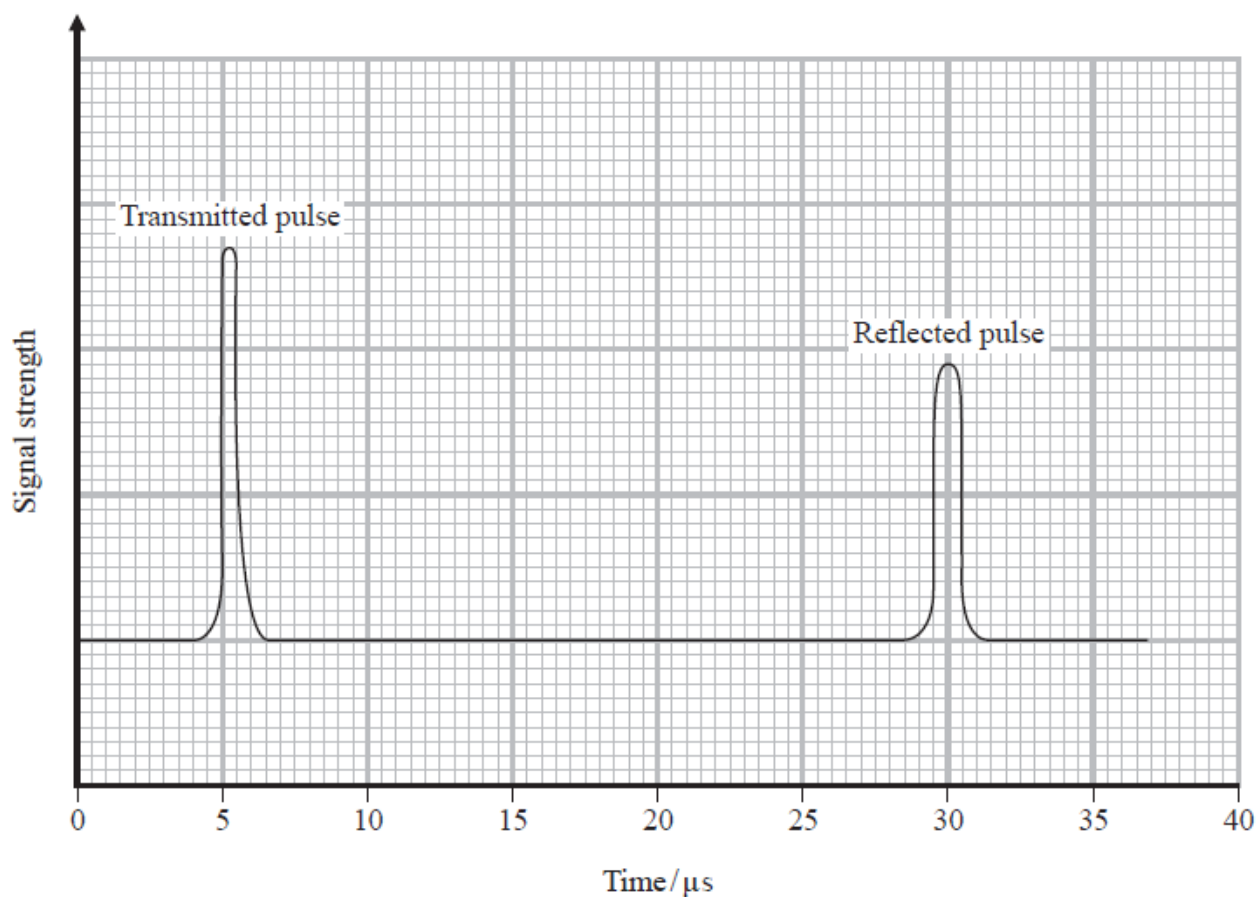
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(b) A data logger connected to the transducer produces a graph of ultrasound signal strength against time.



Determine whether the reflected pulse is from a crack in the rail or from the bottom of the rail.

depth of rail = 15 cm

speed of ultrasound in steel =  $5800 \text{ m s}^{-1}$

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(c) Suggest why this ultrasound method may not detect multiple cracks in a piece of rail.

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(d) To detect cracks, transducers are attached to the wheels of special trains.

Explain why these trains must travel much more slowly than passenger trains.

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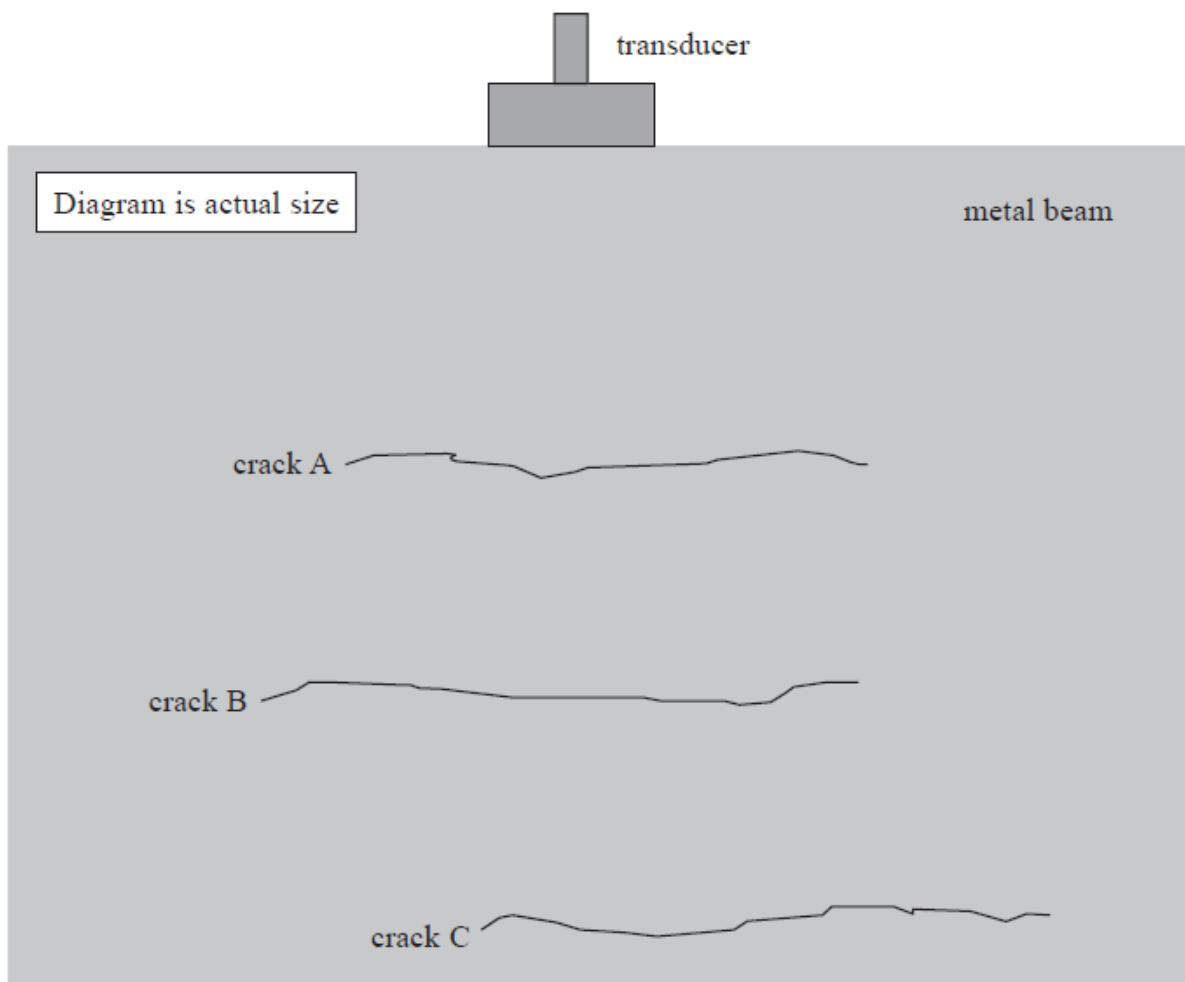
**(Total for question = 8 marks)**

Q18.

Ultrasound can be used to check for cracks in metal beams.

A transducer emits a pulse of ultrasound into a metal beam. The same transducer detects the returning pulses.

Part of a metal beam is shown. The beam contains three cracks, A, B and C.



The transducer detects a returning pulse from each crack.

(a) Explain why there is a returning pulse from crack B.

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(b) One pulse returns  $1.4 \times 10^{-5}$  s after being emitted by the transducer.

Deduce whether the pulse has returned from crack A, crack B or crack C.

You should take measurements from the diagram.

speed of ultrasound in metal =  $5900 \text{ m s}^{-1}$

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(c) Explain why ultrasound used to detect cracks in metal beams usually has frequencies of MHz, rather than kHz.

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**(Total for question = 8 marks)**

Q19.

ICESat-2 is a satellite launched into space by NASA in 2018. One purpose of the satellite is to measure the thickness of ice on the Earth's surface. The satellite is powered using solar panels. A laser in the satellite produces a beam of photons, which travel to the Earth and back.

(a) Calculate the intensity of solar radiation as it reaches ICESat-2.

distance from the Sun to ICESat-2 =  $1.50 \times 10^{11}$  m  
power of the Sun =  $3.83 \times 10^{26}$  W

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Intensity of solar radiation = .....

(b) The laser emits light with a wavelength of 532 nm. Calculate the energy, in J, of each photon.

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Energy of photon = ..... J

(c) The photons released by the laser are directed towards the Earth. The mean time for these photons to return to the satellite is 3.20 ms.

(i) Calculate the height that ICESat-2 orbits above the surface of the Earth.

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Height above Earth = .....

(ii) When photons arriving at the satellite are detected, only those with a wavelength of exactly 532 nm are used in the analysis of the results.

Suggest why.

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(d) At one point, ICESat-2 passes over a flat ice sheet. The ice sheet is 1000 m above sea level.

Explain how the measurements taken by ICESat-2 can be used to show that the ice sheet has a flat surface and is higher than sea level.

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**(Total for question = 11 marks)**