Q1.(a)   When ultrasound is incident at an interface between two different media some energy is transmitted and some is reflected. The ratio of the reflected energy intensity I_r to the incident energy intensity I_i depends on the relative acoustic impedances of the two substances.

Acoustic impedance Z is a property of the substance and is given by $Z = \rho v$

where ρ is the density of the substance and v is the velocity of the ultrasound wave. The ratio is given by

$$\frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$$

Z_1 is the acoustic impedance of the substance into which the wave is reflected.
Z_2 is the acoustic impedance of the substance into which the wave is transmitted.

The table below shows the density and velocity of waves in two different substances.

Substance	Density / kg m^{-3}	Velocity / m s^{-1}
1	1050	1540
2	925	1450

(i)   Calculate the percentage of incident energy that is reflected when ultrasound is incident on a surface while travelling from substance 1 into substance 2.

percentage reflected .... %

(3)

(ii)   An ultrasound wave of frequency 2.00 MHz travels in substance 1.

Calculate the wavelength of the ultrasound in metres.

wavelength .... m

(2)

(b) Describe how ultrasound is used to produce an image of different tissues within the body.

Your answer should include:
- an explanation of how the image is produced
- an explanation of how the differences in acoustic impedance of body tissues affect the quality of the image produced.

The quality of your written communication will be assessed in your answer.

(6)

(c) The resolution of an image is an important factor in the design of ultrasound equipment.

State what is meant by **resolution** and explain why the wavelength of the ultrasound determines the resolution of the image.

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(2)
(Total 13 marks)

Q2.(a) During a magnetic resonance (MR) brain scan, the head of the patient is exposed to short pulses of radio frequency electromagnetic waves while in a strong magnetic field. Outline the basic principles of an MR scanner used to perform this scan.

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(3)

(b)   Ultrasound is thought to be more suitable than X-rays for scanning an unborn fetus.

State **two** reasons why ultrasound is used for this application.

reason 1..

....

reason 2..

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(2)
(Total 5 marks)

Q3.(a)   The diagram below shows an ultrasound transducer used in an A-scan.
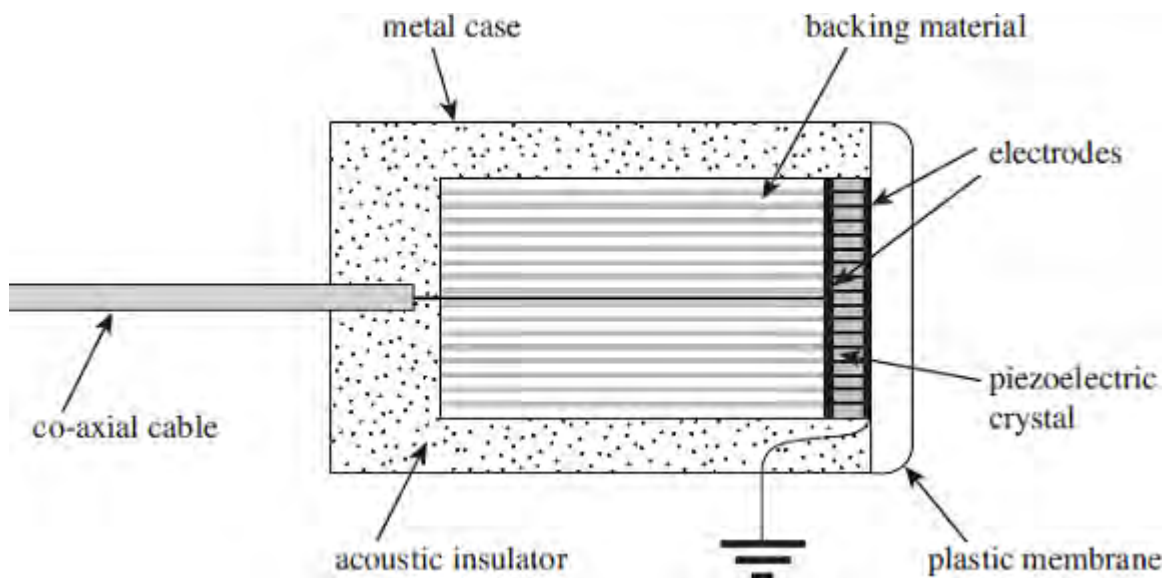
Outline, with reference to the diagram, the process by which the transducer produces a short pulse of ultrasound.

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(4)

(b)   Ultrasound is incident on the boundary between two materials. Some of the ultrasound is reflected at the boundary and the remainder is transmitted across the boundary. The ratio of the intensity of the reflected ultrasound, I_r, to the intensity of the incident ultrasound, I_i, is given by the equation

$$\frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$$

where Z_1 and Z_2 are the acoustic impedances of the two materials.

(i)   Calculate the percentage of the incident ultrasound which would be transmitted into the skin when incident on an air-skin boundary.

acoustic impedance of air = 4.29×10^2 kg m^{-2} s^{-1}
acoustic impedance of skin = 1.65×10^6 kg m^{-2} s^{-1}

transmitted percentage .... %

(2)

(ii)   When obtaining the ultrasound image of an unborn foetus, a coupling gel is used. Explain why a coupling gel is needed and state the property of the gel that ensures a good quality image.

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(2)
(Total 8 marks)

Q4.   (i)   State the **two** physical properties of a material which determine its acoustic impedance.

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(ii)   Under what condition is ultrasound strongly reflected at a boundary between two types of material?

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(iii)   State where a coupling medium or gel is used in an ultrasound scan and explain why it is necessary.

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(Total 6 marks)

Q5. The figure below shows a transducer used in an ultrasound A scan.
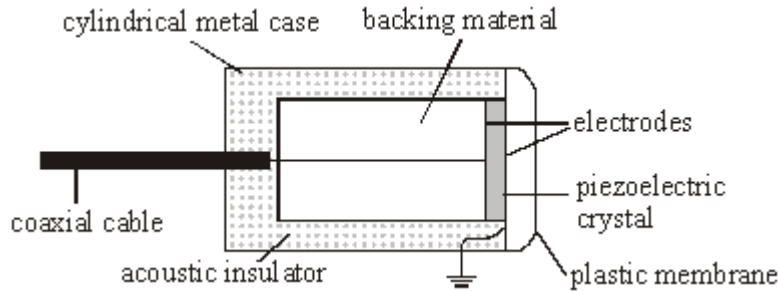
(a) Describe how pulses of ultrasound are produced by the transducer.

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(3)

(b) In an ultrasound A scan

(i) explain how the received signals are detected,

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(ii) state why it is essential to use short pulses of ultrasound.

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(3)
(Total 6 marks)

Q6.   In the course of diagnosis and treatment of a child's broken arm, several images of the arm are required. Similarly, to check the progress of a woman's pregnancy, several images of the foetus are required. **In each case,** state which imaging technique would probably be used and give **two** reasons for the choice.

Broken arm:

technique used ....

reason 1 ....

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reason 2 ....

....

Foetus:

technique used ....

reason 1 ....

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reason 2 ....

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(Total 4 marks)