MEDICAL PHYSICS

4-1 Ultrasound imaging

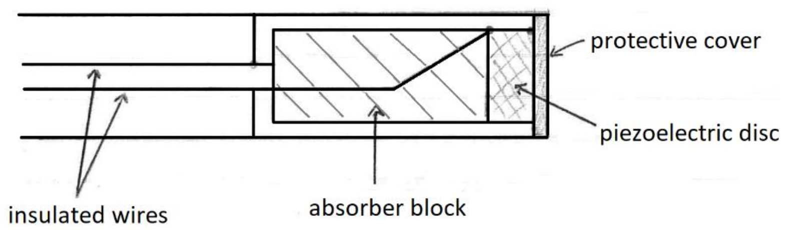
1. f = 2.5 MHz = 2.5×10^6 Hz

(a) (i) c_{AIR} = 340 ms^{-1} c = fλ so $\lambda = \frac{c}{f} = \frac{340}{2.5 \times 10^6}$ = 1.36×10^{-4} m = 1.4×10^{-4} m to 2 sf

(ii) $c_{SOFT\ TISSUE}$ = 1550 ms^{-1} $\lambda = \frac{c}{f} = \frac{1550}{2.5 \times 10^6}$ = 6.2×10^{-4} m to 2 sf

(b) Waves of a much lower frequency are not suitable for imaging as they would diffract and spread out too much.

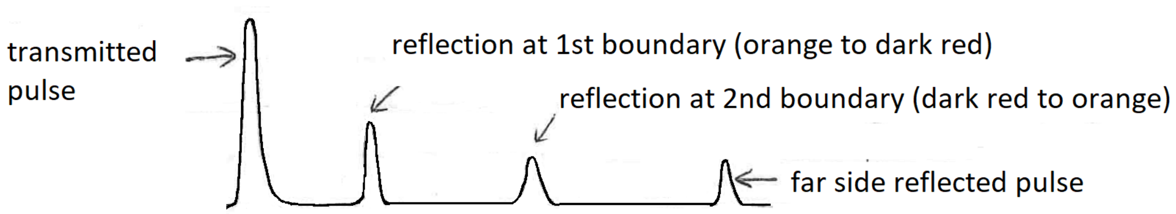
2. (a) (i)

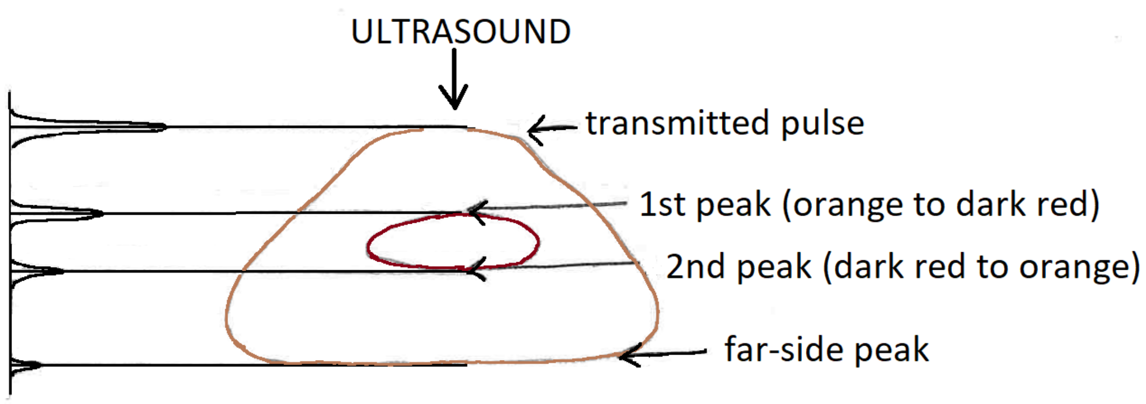


The wires are used to apply an alternating p.d. across the piezoelectric disc. When the applied frequency is the same as the natural frequency of vibration of the disc, it vibrates at the resonant frequency creating sound waves of that frequency in the surrounding medium.

(ii) The backing block is designed to prevent waves being generated at the back (as well as the front) of the disc which would cancel those from the front. It also damps the disc vibrations rapidly between the end of one pulse and the production of the next.

(b) (i)





(ii) X = 0.60 m

$x = \frac{d}{D}X$

Screen distance d = 6 mm to 1st pulse (allow 6/7 mm) and d= 12 mm to 2nd pulse (allow 12/13 mm)

So difference = 6 mm

$x = \frac{6}{25}$ x 0.60 = 0.144 m = 0.14 m to 2 sf (if 7 mm used then $x = \frac{7}{25}$ x 0.60 = 0.168 m = 0.17 m)

Across the organ distance d is between 6 mm and 7 mm
Average value = 0.156 m = 0.16 m

3. (a) (i) Z_{AIR} = 410 $kgm^{-2}s^{-1}$
Z_{SKIN} = 1.6 x 10^6 $kgm^{-2}s^{-1}$

$R = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2} = \frac{(1.6 \times 10^6 - 410)^2}{(1.6 \times 10^6 + 410)^2}$ = 0.999…. = 1.0 to 2 sf

(ii) Z_{WATER} = 1.6 x 10^5 $kgm^{-2}s^{-1}$
Z_{SKIN} = 1.6 x 10^6 $kgm^{-2}s^{-1}$

$R = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2} = \frac{(1.6 \times 10^6 - 1.5 \times 10^6)^2}{(1.6 \times 10^6 + 1.5 \times 10^6)^2}$ = 0.00104…. = 1.0 X 10^{-3} to 2 sf

(b) Nearly all the ultrasound is reflected at an air-skin boundary (R = 1.0) whereas nearly all of it is transmitted at a water-skin boundary (R = 1.0 X 10^{-3}). A gel, which is mostly water, is therefore applied between the probe and the skin so that the ultrasound will enter the body rather than being reflected.

(c) (i) ρ = 1040 kgm^{-2} c = 1580 ms^{-1}

Z = ρc = 1040 x 1580 = 1.6432 x 10^6 = 1.64 x 10^6 $kgm^{-2}s^{-1}$ to 3 sf

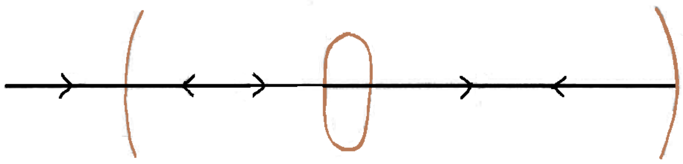
(ii) Z_{ORGAN} = 1.64 x 10^5 $kgm^{-2}s^{-1}$
$Z_{SOFT\ TISSUE}$ = 1.6 x 10^6 $kgm^{-2}s^{-1}$

$R = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2} = \frac{(1.64 \times 10^6 - 1.6 \times 10^6)^2}{(1.64 \times 10^6 + 1.6 \times 10^6)^2}$ = 1.524…. X 10^{-4} = 1.5 X 10^{-4} to 2 sf

4. (a) An A-scan sends a pulse into the body and records the reflected pulse from each of the interfaces between the different tissues. These are then used to measure the precise locations of the internal boundaries.

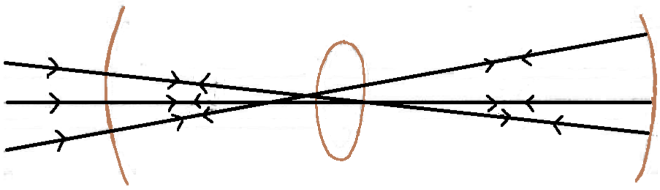
A B-scan sends several pulses into the body simultaneously and the strength of the received pulses controls the beam current and intensity of the image. A 2-D image of the patient is built up.

A



single pulse sent out and reflected

B



multiple pulses sent out and reflected to build up a 2-D image

(b) An ultrasound scan is used to scan a baby in the womb because image resolution is not crucial and ultrasound is non-ionising and will thus cause no damage to the baby. Ultrasound will also distinguish different soft tissues.

An X-ray is used to scan an air-filled organ such as the lungs because X-rays will penetrate the boundary whereas nearly all the ultrasound will be reflected back and not pass into the lungs. Hence to obtain information beyond the tissue-air boundary X-rays must be used.