Hull University Teaching Hospitals NHS Trust

The Physics of Diagnostic Ultrasound

FRCR Physics Lectures

Revision Session

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Revision Questions

Regarding Ultrasound:

Clinically the range 3-15 MHz is commonly used

True

Remember the rate of attenuation increases with frequency

3 MHz might be used on an abdominal probe

15 MHz might be used for examining an eye

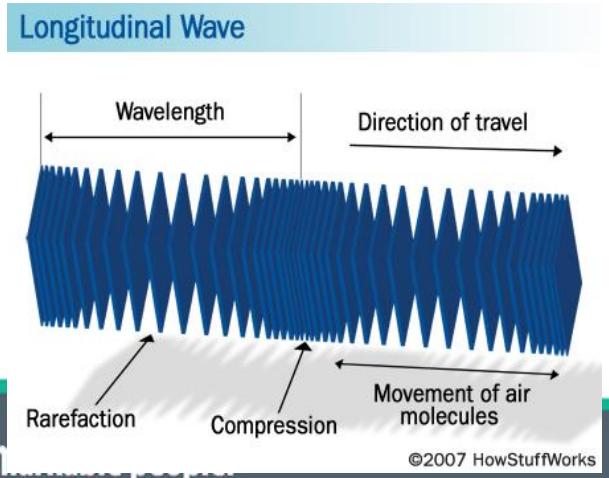
Revision Questions

Regarding Ultrasound:

Sound waves move through tissue as a zone of compression followed by a zone of rarefraction

True

The total length of these two zones is equal to the wavelength of the sound



Revision Questions

Regarding Ultrasound:

It travels through tissue at 154 m/s

False

Ultrasound travels through tissue at approximately 1540 m/s

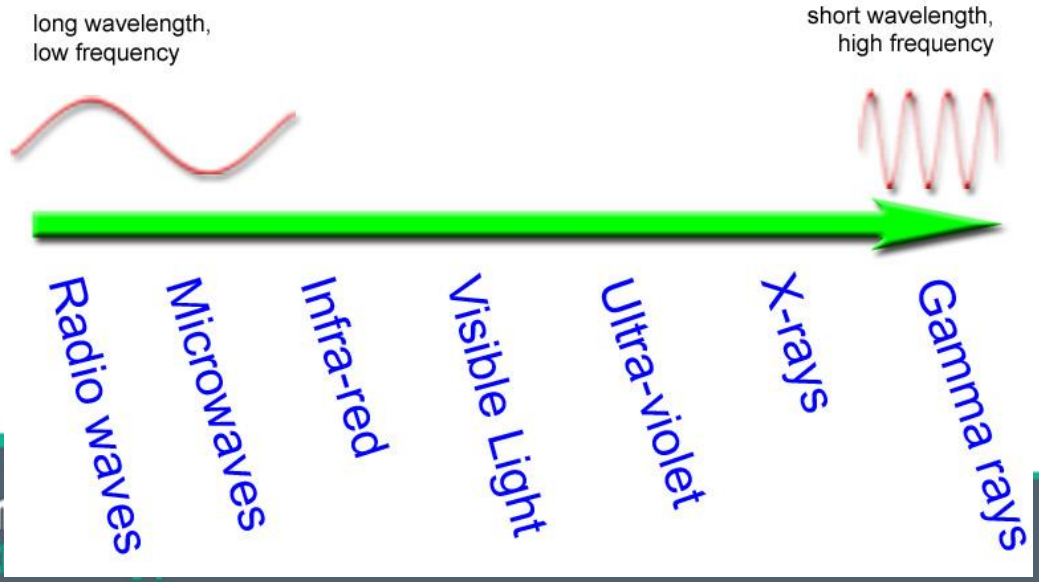
Revision Questions

Regarding Ultrasound:

It is at the lower energy end of the electromagnetic spectrum

False

Ultrasound is not a form of electromagnetic radiation



Revision Questions

Regarding Ultrasound:

Intensity is proportional to the square of the amplitude

True

Intensity is the power per unit area

Knowing the intensity of the beam is important for issues of safety

Revision Questions

Regarding Ultrasound:

30 decibels (dB) is a common intensity used clinically

False

No universal reference intensity exists for ultrasound.

Decibels are used to indicate a change in intensity

Decibel, dB = 10 $\log_{10}$ (I_2 / I_1)

Revision Questions

Regarding Diagnostic Ultrasound:

The reflective properties at the interface between tissues are ultilised in image acquisition

True

Reflection occurs due to differences in acoustic impedance

Revision Questions

Regarding Diagnostic Ultrasound:

Sound waves require a medium to travel in

True

Sound waves can not travel through a vacuum

Revision Questions

Regarding Diagnostic Ultrasound:

The velocity is proportional to the atomic number of the material through which it travels

False

Velocity depends on the density and elasticity (compressibility) of the material

$$c = \sqrt{k\,I\,\rho}$$

Revision Questions

Regarding Diagnostic Ultrasound:

Damage to tissues from ultrasound causes a stochastic risk of cancer

False

No link between cancer and ultrasound exposure has been made

Revision Questions

Regarding Diagnostic Ultrasound:

M-Mode ultrasound is the term used for mobile ultrasound units which ultilise a single multifunctional transducer

False

M-Mode ultrasound is used to visualise rapidly moving structures (e.g. heart valve)

Image shows motion (y-axis) vs time (x-axis)

Revision Questions

Regarding Diagnostic Ultrasound:

Ultrasound is a high frequency form of electromagnetic radiation

False

Ultrasound waves are not electromagnetic waves

Ultrasound waves are longitudinal mechanical waves

Revision Questions

Regarding Ultrasound in Tissue:

A large difference in acoustic impedance between tissues means more sound is reflected and less is transmitted at their boundary

True

This is clinically important where the ultrasound beam meets a narrow air gap between the probe and the skin as there is a large mismatch between the two – acoustic coupling is therefore required

Revision Questions

Regarding Ultrasound in Tissue:

All tissues attenuate ultrasound equally

False

Each tissue has its own ultrasonic attenuation coefficient

Soft tissues – 0.5-1.0 dB/cm

Bone – 20 dB/cm

Revision Questions

Regarding Ultrasound in Tissue:

An ultrasound beam is attenuated linearly in soft tissue

False

The attenuation of an ultrasound beam in soft tissue is exponential

Revision Questions

Regarding Ultrasound in Tissue:

Over 99% of an ultrasound beam will be reflected at a gas-soft tissue interface

True

Typical reflection proportions would be 99.9% air-tissue, 30% bone-muscle, 1% fat-muscle

Revision Questions

The piezoelectric effect:

The piezoelectric effect describes the interconversion of electric and mechanical energy in some materials

True

If a voltage is applied to a piezoelectric material, the material with expand or contract, and if a force is applied to a piezoelectric material which causes it to expand or contract a voltage will be induced in the material

Revision Questions

The piezoelectric effect:

The resonant frequency of a transducer depends on the piezoelectric material used

True

The resonant frequency is that at which a piezoelectric element would naturally reverberate at. This is determined by both the composition and dimensions of the element

Revision Questions

The ultrasound beam:

Maintains its dimensions indefinitely

False

The ultrasound beam diverges at distances beyond the near field zone

Revision Questions

The ultrasound beam:

The near field is longer with a higher frequency

True

The near field length is proportional to: frequency x beam diameter^2

Revision Questions

The ultrasound beam:

There is less near field divergence with an increasing transducer diameter

False

There is less far field divergence with a larger transducer diameter

Revision Questions

With real-time ultrasound imaging, if all other factors are kept constant:

A higher PRF allows a higher number of lines per frame

True

PRF = lines per frame x frame rate

Revision Questions

With real-time ultrasound imaging, if all other factors are kept constant:

To view an object further from the probe the PRF must be increased

False

The further the object from the probe, the greater the time for an echo to return, and therefore the PRF needs to be lower

Revision Questions

With real-time ultrasound imaging, if all other factors are kept constant:

A typical abdominal ultrasound scan at 20 cm maximum depth might allow 100 lines per frame at 30 frames per second

True

Minimum time for 1 line = 2D / c

N lines per frame gives Time for 1 frame = 2ND / c

Frame rate = c / 2ND

N = c / (frame rate x 2D) = 1540 / (30 x 2 x 0.2)

N = 128 lines per frame

Revision Questions

Contrast and harmonic imaging:

Contrast agents used in ultrasound include microbubbles up to 1 mm diameter

False

Microbubbles are normally less than 4 μm

Revision Questions

Artefacts in ultrasound:

Speckle occurs because there is nothing for the sound waves to reflect back from

False

Speckle occurs because the constituents of solid organs are too small to fully reflect the sound. Instead, beam energy is scattered in all directions and some of this is detected giving a characteristic speckled appearance

Revision Questions

Artefacts in ultrasound:

Shadowing occurs behind objects with a high attenuation coefficient

True

TGC will under-compensate making distal objects seem less echogenic

Revision Questions

Artefacts in ultrasound:

Fluid filled structures often cause acoustic enhancement

True

Fluid is weakly attenuating and thus allows the beam to pass through and a better signal to be received from objects on the far side

Revision Questions

Artefacts in ultrasound:

Refraction can cause objects to appear in a different location

True

When ultrasound is transmitted across a tissue boundary it will undergo some refraction. Ultrasound scanners assume travel in straight lines.

Revision Questions

Doppler ultrasound:

The Doppler effect is the change in sound wave frequency caused by reflection from a moving surface

True

Reflection of an ultrasound wave from an object moving towards the wave effectively shortens the wavelength and increases the frequency. Reflection from an object moving away from the wave has the opposite effect

Revision Questions

Doppler ultrasound:

The Doppler effect is at a maximum when imaging blood vessels parallel to the beam

True

The Doppler shift is proportional to cosθ. At θ = 0 (parallel to beam) cosθ = 1 and the Doppler shift will be at a maximum.

Revision Questions

Doppler ultrasound:

Aliasing only occurs in continuous wave Doppler

False

Continuous wave Doppler does not use pulses and therefore the sampling rate is not limited by the pulse repetition frequency.

Aliasing is only a concern for pulsed wave Doppler.

Revision Questions

Doppler ultrasound:

Range gating is used for depth localisation

True

If detected, Doppler shift could be occurring anywhere along the line of the ultrasound beam. Range gating means the detector will only accept signal in a short window of time corresponding to a specific depth.

Revision Questions

Ultrasound Safety:

Staff using ultrasound should be mindful of the ionising radiation regulations 1999 (IRR 99)

False

Ultrasound does not use ionising radiation and therefore, does not fall under IRR 99

There is no legislation relating to diagnostic ultrasound. However, the BMUS produce guidelines for safe use and good practice.

Revision Questions

Ultrasound Safety:

Thermal Index (TI) is the ratio of the power output divided by the power required to raise the temperature of the tissue by 1^{o}C

True

Guidelines exist on maximum length scan times depending on TI and patient core temperature

Revision Questions

Ultrasound Safety:

A Mechanical Index (MI) >0.7 indicates a potential risk of cavitation

True

This is a theoretical risk but 0.7 is the figure published by BMUS

The risk is considered to be greater if using contrast media

The End