PIPADOR REVISION

MRCOG Part 1 Revision Notes

Ultrasound

MEDICAL PHYSICS • LECTURE 505

VISUAL EXAMINATION REVISION NOTES

2026 Edition

505

MRCOG PART 1 REVISION NOTES | MEDICAL PHYSICS

Ultrasound

Physics of ultrasound imaging, transducers, modes, artefacts, safety and O&G applications

1,540 m/s	2–15 MHz	Z = ρc	TI / MI
Speed in soft tissue	Diagnostic range	Acoustic impedance	Safety indices

■ KEY FACTS: Learning objectives

- Define ultrasound, frequency, wavelength, acoustic impedance, attenuation and resolution.
- Explain how ultrasound images are produced (piezoelectric effect, pulse–echo principle) and the trade-offs in transducer choice.
- Describe imaging modes, artefacts, bioeffects and safety (thermal and mechanical indices, ALARA, BMUS guidance) and O&G applications.

505.1 Key definitions

Term	Definition
Ultrasound	• Sound waves with frequency above human hearing (> 20 kHz) • Medical imaging uses ≈ 2–15 MHz
Frequency (f)	Number of cycles per second (Hz)
Wavelength (λ)	Distance of one cycle; λ = c ÷ f (≈ 0.3 mm at 5 MHz in tissue)
Propagation speed (c)	Depends on the medium — assumed 1,540 m/s in soft tissue (air ≈ 330, bone ≈ 4,080 m/s)
Acoustic impedance (Z)	• Z = density × speed • Differences in Z between tissues create reflections (echoes)
Attenuation	Loss of energy with depth by absorption (heat), scattering and reflection — ≈ 0.5–1 dB/cm/MHz
Piezoelectric effect	Crystals (e.g. lead zirconate titanate, PZT) deform when voltage is applied (transmit) and produce voltage when struck by echoes (receive)
Resolution	Ability to separate two structures: axial (along beam), lateral (across beam), temporal (frame rate)

■ IN PLAIN ENGLISH: Ultrasound

An ultrasound probe works like a bat: it sends a short burst of sound, then **listens for echoes**. The time taken for each echo tells the machine how deep the reflecting structure is; the strength of the echo sets its brightness on the screen.

505.2 Physics of image formation

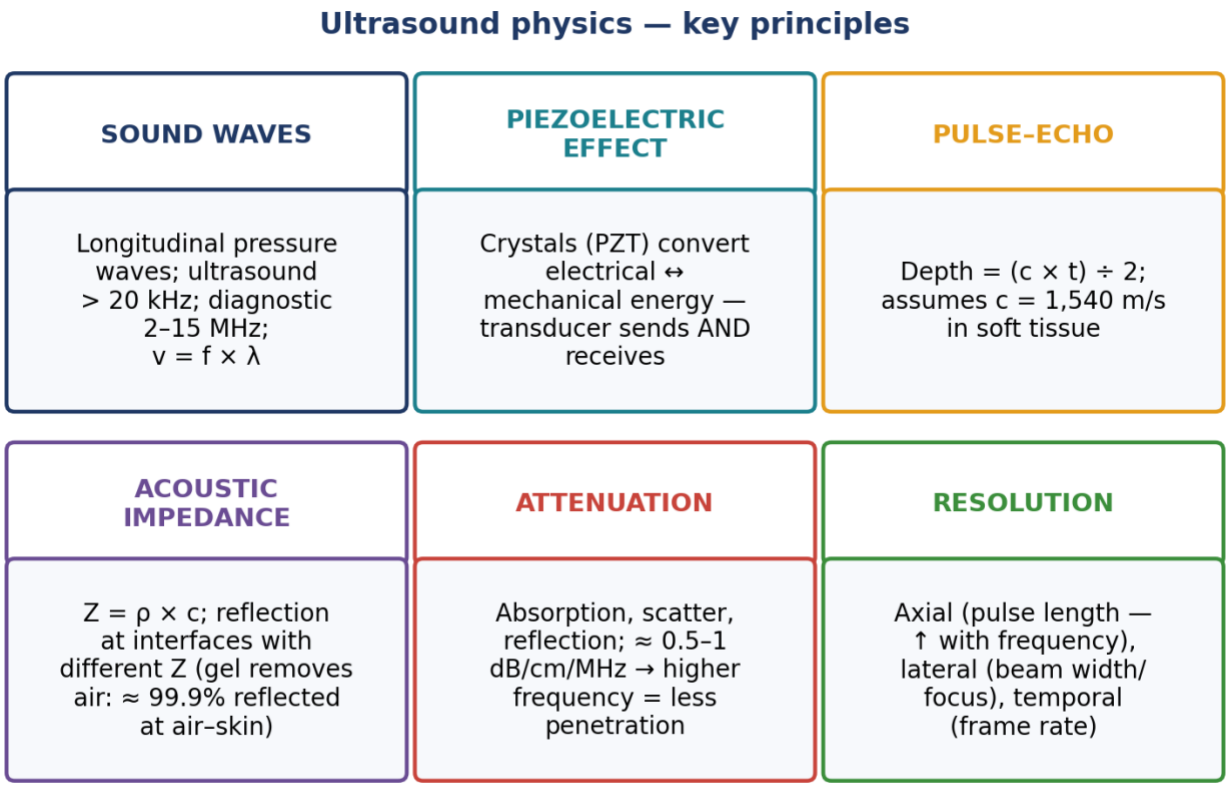


Figure 505.1 — Key physical principles

■ KEY EQUATIONS

Wave equation: $c = f \times \lambda$

Depth of reflector = (c × round-trip time) ÷ 2

Acoustic impedance: $Z = \rho \times c$

Intensity reflection coefficient $R = [(Z_2 - Z_1) \div (Z_2 + Z_1)]^2$ — large Z mismatch (air, bone) → almost total reflection

Attenuation (dB) ≈ coefficient × frequency (MHz) × path length (cm)

- **Coupling gel** eliminates air between probe and skin (otherwise ≈ 99.9% of the beam is reflected).
- Echoes from deeper structures are weaker — **time-gain compensation (TGC)** amplifies later echoes.
- **Axial resolution** = half the spatial pulse length — improved by higher frequency and shorter pulses
  - **Lateral resolution** depends on beam width — best at the focal zone (adjust focus to the area of interest).

505.3 Frequency, penetration and transducers

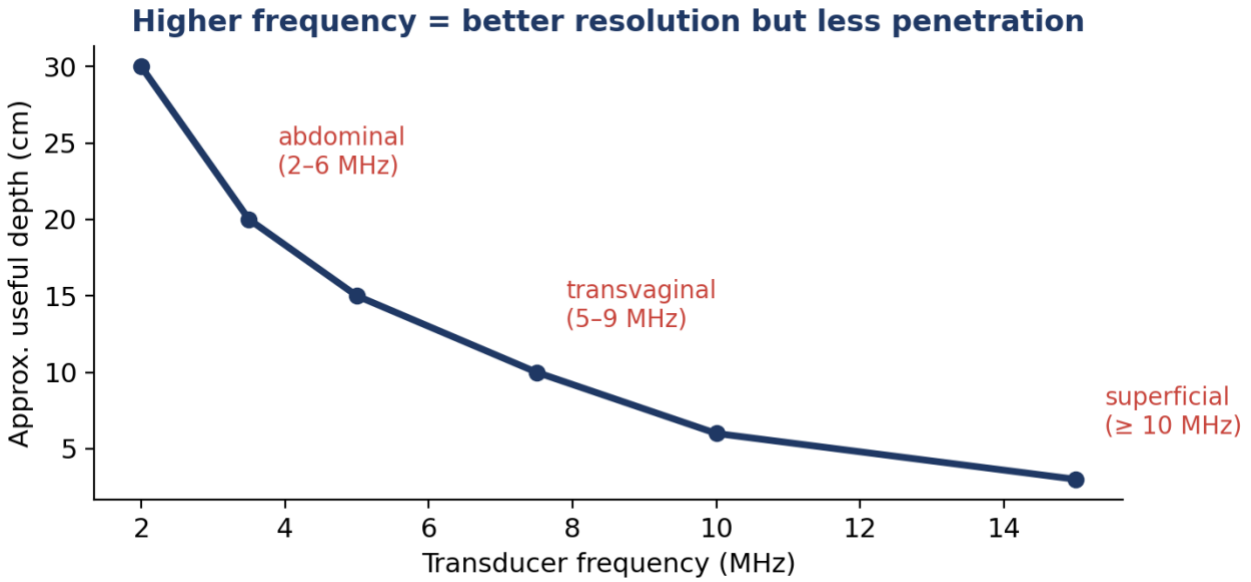


Figure 505.2 — Frequency vs penetration

Transducer	Frequency / use
Curvilinear (convex)	2–6 MHz — transabdominal obstetric and gynaecological scanning (wide field of view)
Endocavity (transvaginal)	5–9 MHz — close to pelvic organs → high resolution: early pregnancy, ovaries, endometrium, cervical length
Linear array	7–15 MHz — superficial structures (breast, vessels, line insertion, groin nodes)
Phased array	1–5 MHz — small footprint, cardiac/fetal echocardiography
3D/4D volume probes	Volume acquisition — uterine anomalies (septate vs bicornuate), fetal face/skeleton

505.4 Imaging modes

Mode	Description
A-mode (amplitude)	Echo amplitude vs depth — historical (ophthalmology)
B-mode (brightness)	2-D grey-scale image — standard real-time imaging
M-mode (motion)	Movement of structures along one line over time — fetal heart rate, valve motion
Doppler	Blood flow velocity and direction (Lecture 506)
3D/4D	Reconstructed volume imaging (4D = real-time 3D)
Harmonic imaging	Uses returning harmonic frequencies — reduces artefact, improves contrast in obese patients
Elastography / contrast ultrasound	Tissue stiffness; microbubble contrast (not routine in pregnancy)

505.5 Artefacts

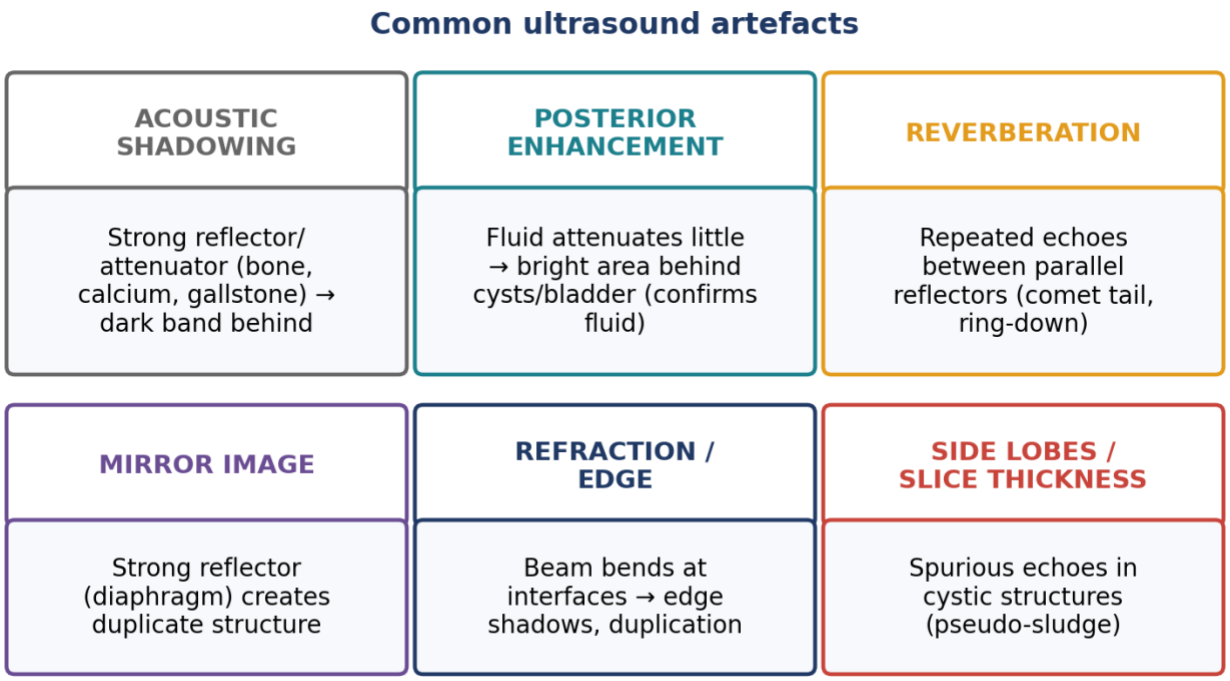


Figure 505.3 — Common artefacts

505.6 Bioeffects and safety

Topic	Details
Thermal effects	• Absorption → heating • Greatest with Doppler (especially pulsed) and near bone (fetal bone from 2nd trimester) • Measured by THERMAL INDEX (TI): TIs (soft tissue), TIb (bone at focus), TIc (cranial bone)
Mechanical effects	• Cavitation and radiation force — risk where gas present (lung, bowel) • Measured by MECHANICAL INDEX (MI)
ALARA	• As Low As Reasonably Achievable — minimise output and exposure time • Avoid non-medical 'keepsake' scanning
BMUS guidance	• Monitor TI/MI displays • In obstetric scanning keep TI ≤ 0.7 where possible (time limits for higher TI) • Avoid routine pulsed/colour Doppler in the 1st trimester unless clinically indicated (e.g. NT screening ductus venosus with low TI and short duration)
No proven harm	No confirmed adverse fetal effects from diagnostic ultrasound at normal outputs
Infection control	• High-level disinfection of endocavity probes between patients • Probe covers

505.7 O&G applications

- Early pregnancy (viability, location, dating — CRL)
  - Screening (NT, anomaly scan), growth and liquor
  - Placental localisation, cervical length

  - Fetal echocardiography
  - Guided procedures (CVS, amniocentesis, FBS, IUT).
- Gynaecology: endometrial thickness (PMB)
  - Fibroids/adenomyosis (MUSA)
  - Ovarian masses (IOTA), IUD location, follicle tracking, oocyte retrieval
  - Bladder scanning (PVR)
  - Pelvic floor imaging
  - Endoanal ultrasound (OASI).

■ COMMON PITFALLS

Using a high-frequency probe for deep structures (poor penetration).

Misinterpreting posterior enhancement or shadowing as pathology.

Prolonged Doppler insonation of the embryo in the 1st trimester.

Forgetting to adjust focus and TGC.

505.8 Must-know summary

■ EXAM TIP

- Ultrasound > 20 kHz; diagnostic 2–15 MHz; $c = f\lambda$; tissue speed 1,540 m/s; depth = $c\,t \div 2$.
- Piezoelectric crystals transmit and receive; reflection depends on impedance mismatch ($Z = \rho c$) — gel removes air.
- Higher frequency → better resolution, less penetration (TVS 5–9 MHz vs abdominal 2–6 MHz).
- Safety: TI (heating) and MI (cavitation); ALARA; BMUS — caution with Doppler in early pregnancy.

■ MNEMONIC / MEMORY AID

Image quality knobs — 'FFTG': Frequency, Focus, TGC, Gain.