

3.10 Medical physics (A-level only)

Students with an interest in biological and medical topics are offered the opportunity to study some of the applications of physical principles and techniques in medicine. The physics of the eye and ear as sensory organs is discussed. The important and developing field of medical imaging, with both non-ionising and ionising radiations is considered. Further uses of ionising radiation are developed in a section on radiation therapy.

3.10.1 Physics of the eye (A-level only)

3.10.1.1 Physics of vision (A-level only)

Content

The eye as an optical refracting system, including ray diagrams of image formation.

Sensitivity of the eye; spectral response as a photodetector.

Spatial resolution of the eye; explanation in terms of the behaviour of rods and cones.

3.10.1.2 Defects of vision and their correction using lenses (A-level only)

Content

Properties of converging and diverging lenses; principal focus, focal length and power,

$$power = \frac{1}{f}; \frac{1}{u} + \frac{1}{v} = \frac{1}{f}; m = \frac{v}{u}$$

Myopia, hypermetropia, astigmatism.

Ray diagrams and calculations of powers (in dioptres) of correcting lenses for myopia and hypermetropia.

The format of prescriptions for astigmatism.

3.10.2 Physics of the ear (A-level only)

3.10.2.1 Ear as a sound detection system (A-level only)

Content

Simple structure of the ear, transmission processes.

3.10.2.2 Sensitivity and frequency response (A-level only)

Content

Production and interpretation of equal loudness curves.

Human perception of relative intensity levels and the need for a logarithmic scale to reflect this.

Definition of intensity.

Intensity level = $10 \log \frac{I}{I_0}$ where the threshold of hearing $I_0 = 1.0 \times 10^{-12} \text{ W m}^{-2}$

Measurement of sound intensity levels and the use of dB and dBA scales; relative intensity levels of sounds.

3.10.2.3 Defects of hearing (A-level only)

Content

The effect on equal loudness curves and the changes experienced in terms of hearing loss due to injury resulting from exposure to excessive noise or deterioration with age (excluding physiological changes).

3.10.3 Biological measurement (A-level only)

3.10.3.1 Simple ECG machines and the normal ECG waveform (A-level only)

Content

Principles of operation for obtaining the ECG waveform; explanation of the characteristic shape of a normal ECG waveform.

3.10.4 Non-ionising imaging (A-level only)

3.10.4.1 Ultrasound imaging (A-level only)

Content

Reflection and transmission characteristics of sound waves at tissue boundaries, acoustic impedance, Z , and attenuation.

Advantages and disadvantages of ultrasound imaging in comparison with alternatives including safety issues and resolution.

Piezoelectric devices

Principles of generation and detection of ultrasound pulses.

A-scans and B-scans.

Examples of applications.

Use of the equations $Z = \rho c$ and $\frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$

3.10.4.2 Fibre optics and endoscopy (A-level only)

Content

Properties of fibre optics and applications in medical physics; including total internal reflection at the core-cladding interface.

Physical principles of the optical system of a flexible endoscope; the use of coherent and non-coherent fibre bundles; examples of use for internal imaging and related advantages.

3.10.4.3 Magnetic resonance (MR) scanner (A-level only)

Content

Basic principles of MR scanner:

- cross-section of patient scanned using magnetic fields
- protons initially aligned with spins parallel
- spinning hydrogen nuclei (protons) precess about the magnetic field lines of a superconducting magnet
- 'gradient' field coils used to scan cross-section
- short radio frequency (RF) pulses cause excitation and change of spin state in successive small regions
- protons excited during the scan emit RF signals as they de-excite
- RF signals detected and the resulting signals are processed by a computer to produce a visual image.

Students will not be asked about the production of magnetic fields used in an MR scanner, or about de-excitation relaxation times.

3.10.5 X-ray imaging (A-level only)

3.10.5.1 The physics of diagnostic X-rays (A-level only)

Content

Physical principles of the production of X-rays; maximum photon energy, energy spectrum; continuous spectrum and characteristic spectrum.

Rotating-anode X-ray tube; methods of controlling the beam intensity, the photon energy, the image sharpness and contrast, and the patient dose.

3.10.5.2 Image detection and enhancement (A-level only)

Content

Flat panel (FTP) detector including X-ray scintillator, photodiode pixels, electronic scanning.

Advantages of FTP detector compared with photographic detection.

Contrast enhancement; use of X-ray opaque material as illustrated by the barium meal technique.

Photographic detection with intensifying screen and fluoroscopic image intensification; reasons for using these.

3.10.5.3 Absorption of X-rays (A-level only)

Content

Exponential attenuation.

Linear coefficient μ , mass attenuation coefficient μ_m , half-value thickness

$$I = I_0 e^{-\mu x} \quad \mu_m = \frac{\mu}{\rho}$$

Differential tissue absorption of X-rays excluding details of the absorption processes.

3.10.5.4 CT scanner (A-level only)

Content

Basic principles of CT scanner:

- movement of X-ray tube
- narrow, monochromatic X-ray beam
- array of detectors
- computer used to process the signals and produce a visual image.

Comparisons will be limited to advantages and disadvantages of image resolution, cost and safety issues. Students will not be asked about the construction or operation of the detectors.

3.10.6 Radionuclide imaging and therapy (A-level only)

3.10.6.1 Imaging techniques (A-level only)

Content

Use of a gamma-emitting radioisotope as a tracer; technetium- 99m , iodine-131 and indium-111 and their relevant properties.

The properties should include the radiation emitted, the half-life, the energy of the gamma radiation, the ability for it to be labelled with a compound with an affinity for a particular organ.

The Molybdenum-Technetium generator, its basic use and importance.

PET scans.

3.10.6.2 Half-life (A-level only)

Content

Physical, biological and effective half-lives; $\frac{1}{T_E} = \frac{1}{T_B} + \frac{1}{T_P}$; definitions of each term.

3.10.6.3 Gamma camera (A-level only)

Content

Basic structure and workings of a photomultiplier tube and gamma camera.

3.10.6.4 Use of high-energy X-rays (A-level only)

Content

External treatment using high-energy X-rays. Methods used to limit exposure to healthy cells.

3.10.6.5 Use of radioactive implants (A-level only)

Content

Internal treatment using beta emitting implants.

3.10.6.6 Imaging comparisons (A-level only)

Content

Students will be required to make comparisons between imaging techniques. Questions will be limited to consideration of image resolution, convenience and safety issues.