OCR (A) Physics A-level

Module 6 - Particles and Medical Physics

Definitions and Concepts

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6.1: Capacitors

Capacitance: The charge stored per unit pd in a capacitor.

Capacitor: An electrical component that stores charge. A parallel-plate capacitor is made of two parallel conducting plates with an insulator between them (dielectric).

Capacitors in Parallel: When capacitors are connected in parallel, their individual capacitances are summed to give the total capacitance.

Capacitors in Series: When capacitors are connected in series, the total capacitance is equal to the inverse of the sum of the inverses of the individual capacitances.

Energy Stored by a Capacitor: Equal to half the product of the charge stored and the capacitance. This can be found from the area under a charge-voltage graph.

Farad: The unit of capacitance.

Time Constant: The product of the circuit resistance and capacitance. It is the time taken for the voltage to discharge to 1/e (or 36.8%) of its initial charge.

6.2: Electric Fields

Coulomb's Law: The size of the force that acts between two point charges is proportional to the product of their charges and inversely proportional to the square of their separation. It is attractive for opposite charges and repulsive for like charges.

Electric Field Strength: The force per unit positive charge exerted on a charged object placed at that point in the field. This is a vector acting in the same direction as the force on a positive charge.

Electric Field: A region surrounding a charged object which causes a force to be exerted on any charged object placed within the field.

Electric Potential Energy: The work done on a positive charge in bringing it from infinity to that point in the field. It is proportional to the product of the two charges and inversely proportional to their separation.

Electric Potential: The work done per unit charge on a positive test charge in bringing it from infinity to that point in the field.

Field Lines: Lines that demonstrate the direction in which a positive charge would feel if placed at that point in the field.

Parallel Plate Capacitor: A capacitor made up of two parallel conducting plates with an insulator between them (dielectric).

Permittivity: A property of an electric field. It relates electric flux density and the electric field strength.

6.3: Electromagnetism

Faraday's Law: The magnitude of the induced EMF is directly proportional to the rate of change of magnetic flux linkage.

Field Lines: Lines that show the direction in which a magnetic North monopole would experience a force if placed at that point in a field. Magnetic field lines point from North to South.

Fleming's Left-Hand Rule: The relative direction of motion, field direction and current direction in the motor effect can be represented by the thumb, first finger and second finger of the left hand respectively. For the motion of a charged particle in a magnetic field, its direction replaces the current direction.

Force on a Charge Particle: A charged particle moving through a magnetic field will experience force equal to the product of the charge, its velocity and the magnetic flux density.

Force on a Current-Carrying Conductor: A current-carrying conductor will experience a force when placed in a magnetic field. The direction of the force can be determined using Fleming's left-hand rule.

Lenz's Law: The direction of an induced current is such that it opposes the current that created it.

Magnetic Field: A region of space in which magnetic materials and moving electric charges feel a force.

Magnetic Flux Density: The force per unit current per unit length on a current-carrying wire placed at 90º to the field lines. Sometimes also referred to as the magnetic field strength.

Magnetic Flux Linkage: The magnetic flux multiplied by the number of turns, N, of the coil.

Magnetic Flux: A value which describes the magnetic field or field lines passing through an area. It is the product of magnetic flux density and the perpendicular area it passes through.

Tesla: The unit of magnetic flux density.

Transformer: A device used to increase or decrease the voltage with two sets of coils with different numbers of turns wrapped around a magnetic core. The transformer is step-up if the number of coils on the secondary coil is greater than the number on the primary coil. The transformer is step-down if the number of coils on the secondary coil is fewer than the number on the primary coil.

Velocity Selector: A combination of a magnetic field and an electric field, which results in charges passing through and leaving with a specific velocity.

Weber: The unit of magnetic flux.

6.4: Nuclear and Particle Physics

Activity: The rate of decay of the radioactive nuclei in a given isotope. It is proportional to the total number of nuclei in the sample and is measured in Becquerels.

Alpha Particles: A type of particle consisting of two protons and two neutrons. Alpha particles are emitted in alpha decay and are strongly ionising, but weakly penetrating.

Alpha-Scattering: An experiment that involved firing alpha particles at a thin gold foil and detecting their subsequent motion. It provided evidence for the currently accepted model of the atom.

Annihilation: The process of a particle and its antiparticle colliding and being converted into energy. The energy is released in two photons to conserve momentum.

Antiparticles: All particles have a corresponding antiparticle with the same mass but opposite charge and conservation numbers.

Beta Particles: An electron or positron. Beta particles are emitted during beta decay and have medium ionising and penetrating capabilities.

Beta-Minus Decay: The process of a proton inside a nucleus turning into a neutron, and emitting a beta-minus particle (an electron) and a neutrino.

Beta-Plus Decay: The process of a neutron inside a nucleus turning into a protron, and emitting a beta-plus particle (a positron) and a neutrino.

Binding Energy: The amount of energy required to split a nucleus into all its separate constituent nucleons. It is equivalent to the mass defect.

Chain Reaction: The process of the neutrons released by a fission reaction inducing further fissile nuclei to undergo fission.

Control Rods: Rods found in nuclear reactors to absorb neutrons and control the rate of reaction. They can be raised or lowered depending on the rate required.

Decay Constant: The probability of decay in a unit time.

Einstein's Mass-Energy Equivalence: Mass and energy are equivalent, with the energy equivalent of a given mass being equal to the product of the mass and the speed of light squared.

Electron: A negatively charged fundamental particle that is found in energy levels surrounding a nucleus.

Gamma Rays: A type of radiation emitted in gamma decay. Gamma rays are weakly ionising but very strongly penetrating.

Hadrons: A class of subatomic particle that experiences the strong nuclear interaction.

Half-Life: The average time it takes for the number of radioactive nuclei in a sample of an isotope to halve.

Isotopes: A form of an element with the same number of protons but different numbers of neutrons.

Leptons: A group of elementary subatomic particles, consisting of electrons, muons and neutrinos.

Mass Defect: The difference in mass between a nucleus and the sum of the masses of its constituent nucleons.

Moderator: A material in nuclear reactors that absorbs energy from fast moving neutrons, to slow them down to speeds that can be absorbed by fissile neutrons to induce fission.

Neutron: A neutrally charged nucleon, found in the nucleus of an atom. Neutrons are a form of hadron.

Nuclear Fission: The splitting a nucleus, to form two smaller daughter nuclei, neutrons and energy.

Nuclear Fusion: The joining of two smaller nuclei to form a larger nucleus and to release energy.

Nucleon Number: The sum of the number of protons and neutrons in a given nucleus.

Positron: A positively charged particle that is the antiparticle of an electron.

Proton Number: The number of protons present in the nucleus of a given element.

Proton: A positively charged nucleon, found in the nucleus of an atom. Protons are a form of hadron.

Quarks: Fundamental particle that interacts with other quarks via the strong interaction. They change flavour via the weak interaction and annihilate with antiquarks to form photons via the electromagnetic interaction.

Radioactive Dating: The use of radioactive isotopes with known half-lives to date objects. The isotope that is usually used is Carbon-14.

Random Nature of Decay: Radioactive decay is random - you cannot predict when a nucleus will decay or which nucleus will decay next.

Strong Nuclear Force: A force that acts between nucleons in a nucleus to keep it stable. It is attractive at distances of up to 3fm and repulsive at separations less than 0.5fm.

6.5: Medical Imaging

A-Scan: A method of scanning tissue that involves placing an ultrasound emitting transducer on the surface of the body, and then measuring reflections of emitted pulses. A-Scans are used to measure the foetal head size during pregnancy.

Acoustic Impedance: The product of the speed of sound through a given medium, and the density of the medium.

Anode: A positively charged electrode.

Attenuation of X-Rays: The reduction of X-ray intensity as they pass through matter.

B-Scan: A method of scanning tissue, used for more complex structures than A-scans. Instead of the echo signals controlling the y-gain (as in A-scans), they control the brightness of the oscilloscope spot. B-scans are used to determine the placenta's position during pregnancy.

Cathode: A negatively charged electrode.

Compton Effect: The decrease in a photon's energy when it is scattered by a charged particle. This results in a decrease in the photon's frequency and therefore an increase in its wavelength.

Computerised Axial Tomography Scanning: A scanning method that produces a cross section of the body by rotating a monochromatic x-ray beam around it, in combination with a series of detectors. Whilst it produces higher resolution images that ultrasound and is non-invasive, it is highly ionising and costly.

Contrast Media: A contrast medium is a substance that ensures that there is a significant difference between the density of the area being scanned and the rest of the body. Barium is often chosen due to its high proton number. It is consumed by the patient.

Gamma Camera: A type of detector used in PET scanners, consisting of photomultiplier tubes that convert gamma photons into electrical pulses.

Medical Tracers: Gamma emitters that have suitably short half-lives to be ingested into the body, and be detected externally for the duration of a medical process.

Pair Production: The production of a particle and antiparticle pair from a sufficiently high energy photon.

Photoelectric Effect: The emission of electrons from a metal surface when light above a certain frequency is shone on it.

Piezoelectric Effect: An effect shown by crystals like quartz. When a potential difference is applied, the crystal will mechanically deform. Likewise, when the crystal is deformed, a potential difference is produced.

Positron Emission Tomography Scans: A scanning technique that produces cross-sectional and 3D images. It involves a radionuclide being injected into the body, which then releases gamma photons that are detected by the scanning machine.

Simple Scatter: The process of low energy photons scattering off a particle without a change of momentum.

Ultrasound: Sound waves with a frequency higher than the upper-frequency audible to the human ear (20kHz).

X-Ray Tube: An evacuated tube which converts electrical signals into X-rays.