# Topic 8: Nuclear & Particle Physics

## **0.8 Specification notice:**

Mathematical skills that could be developed in this topic include using appropriate units in calculations.

## **8.Q Exam questions**

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| Explain how an electron is accelerated in a linac? (6) | * Set of tubes in a line * Electrons accelerated by electric field * Acceleration takes place in the gaps between tubes * Adjacent tubes connected to thermals of a power supply with opposite polarity * Power supply is alternating (so that as electron emerges from one tube the next tube is positive) * Time spent in each tube must be the same so as the electrons travel faster the tubes must be longer |
| Explain how the cyclotron produces the high-energy proton beam (6)? | * There is an alternating E-field * E-field accelerates protons between dees * Magnetic field perpendicular to plane of dees * Proton path curved by magnetic field which causes a centripetal force * As velocity of protons increases radius of path in dees increases * The time for which a proton is in a dee remains constant |
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|  | * **Fundamental - quarks and leptons** * **Baryons made of 3 quarks** * **Mesons made of quark and antiquark** * **Each particle has an antiparticle** * **There are 6 quarks and 6 leptons** |

## **8.130 Understand what is meant by nucleon number ( mass number ) and *proton number (atomic number)***

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| What is the nucleon number? | The same as the mass number and is the total number of protons and neutrons in the nucleus (also is the number of baryons)  *This is not the same as the relative atomic mass number as they take into account isotopes* |
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## **8.131 Understand how large-angle alpha particle scattering gives evidence for a nuclear model of the atom and how our understanding of atomic structure has changed over time**

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| **What was the order in which the model of the atom was developed and by who?** | * Dalton model - John dalton (1803) * Plum pudding - J.J thomson (1897) * Nucleus - Geiger & mardsen (Rutherford as well) [1909-1911] * Shells - Niels bohr (1913) * Quantum mechanical model - Erwin schrodinger (kinda) [1926] * Neutrons - James chadwick (1932) |
| What are the results of the results of the Rutherford alpha scattering Gold Foil Experiment? What does these mean? + Mnemonic | * Most 𝛼 particles pass through undeflected -> most of the atom is empty space. * A very small number are deflected through an angle greater than 90° -> This suggests the nucleus is very small and is where the mass and charge of the atom is concentrated therefore the atom consists of a **small dense charged nucleus** * Some a-particles deflected through small angles of less than 10° -> This suggests there is a charged nucleus in the centre with a small diameter * Some 𝛼 particles **deflected marginally** and even fewer **bounced back ->** most of the mass of the atom is concentrated in the nucleus rather than throughout the atom * This backscattering couldn’t be explained by the plum pudding model.   *MASS - Mr Adams Sees Stars*  *Its advised to say charged instead of positively charged as the deflection of the alpha particle could have been caused by the positive charge of the nucleus or the attraction of an electron in the atom* |
| What conclusion from the observation would be made using an aluminium foil (Al) instead of gold foil (Au) for the alpha scattering experiment? | * The fraction of alpha scattering is less for Al so the force of repulsion from Al nucleus is less * Therefore the charge on an Al nucleus is less than Au * The KE is less for scattered alpha for Al so recoiling nucleus must have more KE * The mass of an Al nucleus is less than mass of Au nucleus |
| Explain, with reference to the properties of the alpha particle, why a relatively large force is needed to deflect alpha particles through a large angle? | * Due to the large mass and speed and therefore large momentum * The alpha particle would have a large change in momentum when deflected through large angles which requires a large force |
| Describe how the model of the atom changed, as a consequence of the alpha scattering experiments? | * Before scattering experiment was the plum pudding model where the atom mass was distributed equally * After experiment it was discovered that there is a very small nucleus containing most of the mass of the atom * The atom was mostly empty space * The nucleus was charged |

## **8.132 Understand that electrons are released in the process of thermionic emission and how they can be accelerated by electric and magnetic fields**

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| Describe thermionic emission ? | This is the emission of charged particles from a metal surface due to thermal energy overcoming the electrostatic forces holding electrons in the atom |
| **Which equations is commonly equated in thermionic emissions questions?** | * 1mv2=KE * V=W/Q -> VQ=W -> W=eV * 1mv2=eV |

## **8.133 Understand the role of electric and magnetic fields in particle accelerators (linac and cyclotron) and detectors (general principles of ionisation and deflection only)**

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| How does a cyclotron work? | The electric field flips frequently is such that each time a particle reaches the next ‘dee’ it is accelerated |

## **8.134 Be able to derive and use the equation for a charged particle in a magnetic field**

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| What is the derivation for r = p/BQ | * F = mv2/r * F = Bqv * p = mv * mv2/r=Bqv * mv/r = Bq * r = mv/Bq * r = p/Bq |
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## **8.135 Be able to apply conservation of charge, energy and momentum to interactions between particles and interpret particle tracks**

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| Explain how **observations and measurements** from a photograph of a bubble chamber or any modern detector can be used to establish information about particles | * A track being shown means the particle is either positively or negatively charged * The track having a radius of curvature means the particle has momentum via p=Bqr  1. A smaller radius means the particle has a smaller momentum and vice versa  * If the radius of a track is decreasing (i.e spiralling closer inwards) the particles momentum is decreasing via p=Bqr therefore the velocity of the particle is decreasing therefore the KE of the particle is also decreasing due to it ionising other particles in its path * Depending on the question via FLHR you can find out the charge of the particle as the B field would be perpendicular to the velocity of the particle via F=Bqv   *For questions like this make sure you remember charge, energy and momentum has to be conserved so mention observations for all 3*  *Don’t mention about lepton or baryon number as you cannot deduct from observation* |

## **8.136 Understand why high energies are required to investigate the structure of nucleons**

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| What is required for an electron to collide with nucleons and what is the equation for the diameter of a nucleon | * High energy electrons and because of it their de Broglie wavelength becomes smaller * λ = h/p ≈ nucleon diameter   *In particle physics you will likely be asked to explain effects based on the de broglie wavelength to which the wavelength is inversely proportional to a particle momentum and velocity* |
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## **8.137 Be able to use the equation ∆E = c2∆m in situations involving the creation and annihilation of matter and antimatter particles**

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| What is pair production (creation)? | When a photon interacts with a nucleus or atom and has enough energy to produce a particle and its antiparticle    The path of the particle-antiparticle is in opposite directions as they are oppositely charged and hence the B force is oppositely direction. However they have the same radius as they each have the same mass and hence same momentum  *It should be stressed that: any extra energy becomes kinetic energy and the photon has to interact with something as it’s massless* |
| What is annihilation? | When a particle meets its equivalent anti-particle they both are destroyed and their mass is converted into energy in the form of two gamma ray photons    *These particles are moving in opposite directions to conserve momentum* |
| What is the equation used for annihilation and why? | As two particles make two photons |
| What is the minimum energy required of a photon to undergo pair production?  What happen above this energy? | The total rest energies of the particles involved. For a particle-antiparticle pair, it would be:    Above this, excess energy goes into kinetic energy. |

## **8.138 Be able to use MeV and GeV (energy) and MeV/c2, GeV/c2 (mass) and convert between these and SI units**

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## **8.139 Understand situations in which the relativistic increase in particle lifetime is significant (use of relativistic equations not required)**

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| What is the script for proving special relativity using pions from Mr Adams? | * Pions decay rapidly * due to their high speed special relativity predicts that time runs more slowly * Therefore pions from the upper atmosphere have a longer lifetime than stationary pions * Therefore more pions reach the Earth’s surface before decaying than expected |

## **8.140 Know that in the standard quark-lepton model particles can be classified as:**

## **● baryons (e.g. neutrons and protons) which are made from three quarks**

## **● mesons (e.g. pions,** kaon**) which are made from a quark and an antiquark**

## **● leptons (e.g. electrons and neutrinos) which are fundamental particles**

## **● photons and that the symmetry of the model predicted the top quark**

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| Sketch the family tree of particles and give examples for end branches | * Leptons - electrons,muon,tau,neutrino * Quarks - up, down,strange, charm, top, bottom * Hadrons are baryons and mesons * Baryons - proton, neutron made up of 3 quarks * Mesons - pion, kaon made up of a quark and antiquark * There are particles which don’t take part which are photons, bozons, gluon and higgs |

## **8.141 Know that every particle has a corresponding antiparticle and be able to use the properties of a particle to deduce the properties of its antiparticle and vice versa**

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| What are the similarities and differences between a particle and its antiparticle | Similarities:   * Same mass (same rest mass) * -> Same energy via E=mc2   Usually same momentum  Differences:   * Opposite charge * Opposite lepton or baryon number |
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## **8.142 Understand how to use laws of conservation of charge, baryon number and lepton number to determine whether a particle interaction is possible**

| Which particles have a positive,negative and neutral baryon number (B)? | * Baryon number = +1 for Proton, neutron etc * Baryon number = -1 for antiproton, antineutron etc * Baryon number = 0 for mesons, leptons |
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| Which particles have a positive, negative and neutral charge (Q) ? | * Charge = +1 for protons, positrons * Charge = -1 for electrons * Charge = 0 for neutrons,photons, neutrinos * The charge on quarks is partial so like an up is +⅔ and down is -⅓ and the opposite applies to its anti particle |
| Which particles have a positive,negative and neutral lepton number (L)? | * Lepton number = +1 for all leptons i.e electrons, muon, tau, neutrino * Lepton number = -1 for all anti-leptons i.e positron, antielectron neutrino/electron antineutrino * Lepton number = 0 for all particles that are not leptons i.e hadrons   *Try not to make the mistake that an electron lepton number is -1 as its charge is negative because its L is +1 and a positron is -1* |

## **8.143 Be able to write and interpret particle equations given the relevant particle symbols.**

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| What 5 properties are conserved in particle physics edexcel? | * Momentum (P) * Mass-energy [E] * Charge (Q) * Baryon number (B) * Lepton number (L) |
| When writing or interpreting particle equations with relevant symbols should you be aware of? | * Always remember that Lepton (L), Baryon (B) and Charge (Q) properties need to be conserved for a reaction to occur |
| What are most of the general symbols that a particle equation question could give you? Including: Electron,positron,kaon,pion,proton,neutron,neutrino,electron neutrino, anti-electron neutrino, up quark, down quark and photons | * e- = electron * e+ = positron * k = kaon * π = pion * p+ = proton * n = neutron * v = neutrino * ve- = electron neutrino * e- = anti electron neutrino /electron antineutrino * u = up quark * d = down quark * 𝛌 = photons   *Mesons such as kaons or pions would have a +, - or 0 above them to indicate charge as most are unstable*  *Most antiparticles would have a bar above their symbol e.g e- anti-electron neutrino* |

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