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**Knowledge Rich Curriculum Plan**

Science – Physics

Year 13



| **Science** **Year 13 Physics**  | **Unit: Nuclear Physics** |  |  |
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| **Lesson/Learning Sequence**  | **Intended Knowledge:***Students will know that…* | **Tiered Vocabulary**  | **Prior Knowledge:***In order to know this students, need to already know that…* |
| **Lesson:** **Rutherford Scattering** | * Students will know that Rutherford and Marsden fired a beam of alpha particles at thin gold foil
* Students will know that a circular detector screen surrounded the gold foil and the alpha source was used to detect alpha particles deflected by any angle
* Students will know that the expected observations were that alpha particles would be deflected by a very small amount
* Students will know that instead most of the alpha particles went straight through the foil, and a small number were deflected by a large angle (some even by more than 90 degrees)
* Students will know how the model of the atom changed due to Rutherford's experiment
* Students will know that you can estimate the closest approach of a scattered particle as you know its initial kinetic energy
* Students will learn about this in more detail when looking at Coulomb's law as part of the field’s topic
 |  | * ***Students need to already know how the ideas of the atom have changed throughout time***
* ***Students need to already know that the plum pudding model was the idea that atoms were spheres of positive charge with tiny negative electrons stuck in them***
* ***Students need to already know that alpha particles are positively charged***
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| **Lesson:** **Nuclear Radius and Density** | * Students will know that electron diffraction can be used to estimate nuclear radius
* Students will know that the de Broglie wavelength of the beam of electrons used in electron diffraction must be tiny, so electrons must have a very high energy
* Students will know that a diffraction pattern will be seen when electron diffraction is used on an atom
* Students will know how diffraction grating provided evidence for the nuclear radius being very small
* Students will know that the radius of the smallest nucleus is about 1 fm
* Students need to know that nuclear radius is proportional to the cube root of the nucleon number
* Students will know that the relationship between Radius and nucleon number can be written as:

R = R0A^1/3, where R0 is roughly 1.1 fm* Students will know that the volume that each nucleon takes up is about the same
* Students will know that because protons and neutrons have nearly the same mass, all nuclei have similar density
* Students will know that nuclear matter is very dense
 |  | * ***Students need to already know that electrons have associated de Broglie wavelength***
* ***Students need to already know that electrons have wave-particle duality***
* ***Students need to already know that nucleons are protons and neutronss, and are found in the nucleus***
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| **Lesson:** **Radioactive Emissions** | * Students will know that if a nucleus is unstable it will break down to become more stable
* Students will know that instability of a nucleus is linked to number of neutrons or amount of energy
* Students will know that radioactive decay is random
* Students will know that a beta-plus particle is a positron, has negligible mass and a relative charge of +1
* Students will know that when a nucleus decays it releases particles and/ or energy
* Students will know that when creating sheets of material, like paper foil or steel, ionising radiation is used to control its thickness
* Students will know that thickness of sheet material is controlled by:

1) The material is flattened as its fed through rollers2) A radioactive source is placed on one side of the material, and a radioactive detector on the other. The thicker the material, the more radiation it absorbs3) If too much radiation is being absorbed, the rollers move closer together, if too little radiation is being absorbed, they move further apart* Students will know that as alpha particles are strongly positive, they can easily pull electrons off atoms.
* Students will know that ionising atoms transfers energy from the alpha particle to the atom, and that as the alpha particle quickly ionises many atoms it loses its energy.
* Students will know that a use of alpha radiation is in smoke alarms.
* Students will know that alpha sources are dangerous if they are ingested
* Students will know that beta particles ionise atoms by knocking electrons off them due to their high speed.
* Students will know that beta radiation is used for controlling thickness of a material.
* Students will know that gamma radiation is used in medicine.
* Students will know that radioactive tracers are used to help diagnose patients.
* Students will know that radioactive tracers work by the patient being injected with a source with a short half-life (preventing prolonged exposure) and a detector is used to detect the emitted gamma rays
* Students will know that gamma rays are used in the treatment of cancerous tumours, damaging cells and sometimes curing patients of cancer
* Students will know that radiation damages all cells, and so a rotating beam of gamma is used
* Students will know that exposer to gamma radiation can also cause long term side effects like infertility
* Students will know that risks to workers as well as patients are managed when it comes to using gamma rays.
 |  | * ***Students need to already know that:***

***- an alpha particle is 2 protons and 2 neutrons, has a relative mass of 4 and a relative charge of +2******- a beta-minus particle is an electron, has negligible mass and a relative charge of -1******- Gamma radiation is an electromagnetic wave with no mass and no charge**** ***Students need to know that alpha is strongly ionising and weakly penetrating, beta-minus is moderately ionising and penetrating and gamma radiation is strongly penetrating and weakly ionising***
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| **Lesson:** **More Radioactive Emissions** | * Students will know that background radiation is caused by:

1) Radioactive radon gas in the air2) The ground and buildings3) Cosmis radiation4) Living things5) Man-made radiation* Students will know that background radiation is all around us, and not harmful
* Students will know that when you take a reading from a radioactive source, you need to measure the background radiation separately and subtract it from your measurement
* Students will know that the intensity of gamma radiation obeys the inverse square law
* Students will know that a gamma source emits gamma radiation in all directions
* Students will know that the inverse square law means that as you increase the distance away from the source, the intensity will decrease by the square of the distance
* Students will know that the inverse square law can be proved by measuring the intensity at different distances using a Geiger counter
* Students will know that the inverse square law is considered when working with radioactive sources.
 |  | * ***Students need to already know that gamma radiation is weakly ionising and strongly penetrating***
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| **Lesson:** **Required Practical 12** | * Students will know how to investigate the inverse-square law for gamma radiation
 |  | * ***Students need to already know that the intensity of gamma radiation obeys the inverse square law***
* ***Students need to already know that a gamma source emits gamma radiation in all directions***
* ***Students need to already know that the inverse square law means that as you increase the distance away from the source, the intensity will decrease by the square of the distance***
* ***Students need to already know that the inverse square law can be proved by measuring the intensity at different distances using a Geiger counter***
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| **Lesson:** **Exponential Law of Decay** | * Students will know that if you have a very large number of nuclei, the overall decay behaviour shows a pattern
* Students will know that any sample of a particular isotope has the same rate of decay
* Students will know that the activity of a same is the number of nuclei (N) that decay each second
* Students will know that the decay constant (lambda) is the probability for a given nucleus decaying per second
* Students will know that activity can be calculated using:
* activity = decay constant x number of nuclei
* Students will know that activity is the rat of change of N, so can be calculated using
* change in the number of nuclei / changes in time
* Students will know that half-life is measured by measuring the time it takes for its activity to half
* Students will know how to use graphs to determine half-life
* Students will know that half life can be calculated using an equation found in the data booklet
* Students will know that the number of unstable nuclei remaining after half-life depends on the number originally present.
* Students will know how to complete calculations in terms of half life, decay constant, number of unstable nuclei,
* Students will know that half-lives are used in a variety of situations:
* - Radioactive dating of objects
* - Medical diagnosis
* Students will know that long half-lives can be dangerous, as the substance will remain radioactive for a long time.
 |  | * ***Students need to already know that radioactive decay is random***
* ***Students need to already know that the half life of an isotope is the average time it takes for the number of unstable nuclei to halve***
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| **Lesson:** **Nuclear Decay** | * Students will know that some nuclei are more stable than others
* Students will know that the nucleus is under the influence of the strong nuclear force holding it together and the electromagnetic force pushing the protons apart.
* Students will know that there is a very delicate balanced between strong nuclear force and electromagnetic force, and it's easy for a nucleus to become unstable
* Students will know that a nucleus can be unstable if it has:

1) too many neutrons2) too few neutrons3) too many nucleons4) too much energy* Students will know that alpha emissions happen in heavy nuclei
* Students will know how to represent alpha decay using nuclear equations
* Students will know that beta minus emissions happen in neutron rich nuclei
* Students will know how to represent beta minus decay with nuclear equations
* Students will know that beta-plus emission happens in nuclei with too few neutrons
* Students will know that gamma radiation is emitted from nuclei with too much energy
* Students will know that during gamma radiation there is no change to the nuclear constituents
* Students will know that gamma radiation can also be produced during electron capture, which is where a nucleus captures one of the orbiting electrons, causing a proton to change into a neutron
* Students will know how to draw energy level diagrams for nuclear reactions
* Students will know that during nuclear reactions energy, momentum, charge and nucleon number are conserved
 |  | * ***Students need to already know how to use standard notation to represent atomic structure***
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| **Lesson:** **Binding Energy** | * Students will know that the mass defect is the difference between the mass of the nucleus and the mass of its constituent parts
* Students will know that, according to Einstein's equation, mass and energy are equivalent
* Students will know that as nucleons join together the total mass decreases, and the lost mass is converted into energy and released
* Students will know that the amount of energy released is equivalent to the mass defect
* Students will know that the energy needed to separate all of the nucleons in a nucleus is called the binding energy (measured in MeV)
* Students will know how to complete calculations involving binding energy and Einstein's equation
* Students will know that a graph of average binding energy per nucleon against nucleon number:

- shows a curve- The most stable nuclei occur around the maximum point of the graph (nucleon number 56, iron)* Students will know that a high average binding energy per nucleon means that more energy is needed to remove nucleons
* Students will know that nuclear fusion involves combining small nuclei together, that increases the average binding energy per nucleon dramatically meaning a lot of energy is released during nuclear fusion
* Students will know that nuclear fission is when a large nuclei is split in two, which means the nucleon numbers of the two new nuclei are smaller causing an increase in the average binding energy per nucleon
* Students will know that the change in average binding energy gives the energy released
* Students will know how to estimate the energy released from nuclear fusion/ fission
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| **Lesson:** **Fusion and Fission** | * Students will know that nuclear fission is when a nucleus splits into two smaller nuclei
* Students will know that induced fission is where slow moving neutrons are fired at nuclei, which then absorb the neutron to form two lighter nuclei, releasing energy and any left over neutrons
* Students will know that induced fission often results in a chain reaction
* Students will know that critical mass is the minimum mass needed to make a chain reaction happen
* Students will know that nuclear fusion is where two nuclei join together to form a bigger nucleus
* Students will know that for nuclear fusion to occur the two nuclei must have very high energies to be moving fast enough to overcome the electrostatic repulsion of the protons
* Students will know that nuclei that are lighter than iron will undergo fusion
* Students will know that nuclei heavier than iron will undergo fission
 | Nuclear fission: a nucleus splits into two smaller nucleiNuclear fusion: two smaller nuclei fuse to form a larger nucleus | * ***Students need to already know how to interpret the average binding energy against nucleon number graph***
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| **Lesson:** **Nuclear Reactors** | * Students will know that the components of a nuclear reactor are as follows:

- Fuel Rods: contain the fuel, this is where nuclear fission happens. The uranium that is used in fuel rods has a higher percentage of the U-235 isotope, which means it is enriched- Moderator: slows the neutrons down that are given out from nuclear fission. The neutrons collide with the atoms of the moderator which turns the kinetic energy into heat. Typically, the moderator is made of graphite or water- Coolant: Carries the heat from the moderator to the heat exchanger. Typically made of carbon dioxide or water- Control rods: Absorbs neutrons to reduce the amount of nuclear fission taking place and control the reaction. Typically, the control rods are made of boron and cadmium.* Students will know that thermal neutrons are neutrons that are travelling slow enough to cause a fission process.
 | Moderator: Substance used in nuclear reactors that slows neutrons down | * ***Students need to already know that nuclear fission is when a nucleus splits into two smaller nuclei***
* ***Students need to already know that induced fission is where slow moving neutrons are fired at nuclei, which then absorb the neutron to form two lighter nuclei, releasing energy and any left over neutrons***
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| **Lesson:** **Nuclear Safety Aspects** | * Students will know that safety features involved with nuclear power plants are:

- Solid fuel being used rather than liquids avoids dangers of leaks or spillages- Shielding of the reactor core, which is made to withstand high temperatures and pressures- Emergency shut down which will make it impossible for a nuclear disaster to take place* Students will know that there are three levels of waste:

- High-level radioactive waste. This comes from the fuel rods, and is disposed of by storing them in cooling ponds and splitting the unused plutonium and uranium from the waste powder- Intermediate-level Radioactive waste: this includes the fuel cladding, sludge from treatment processes, contaminated equipment, hospital radioisotopes and containers of radioactive materials. It is removed by sealing in drums and encasing into concrete- Low-level waste: This includes worn-out lab equipment, protective clothing, wrapping material and cooling pond water. It is removed by sealing in metal drums and burying deep underground. |  |  |