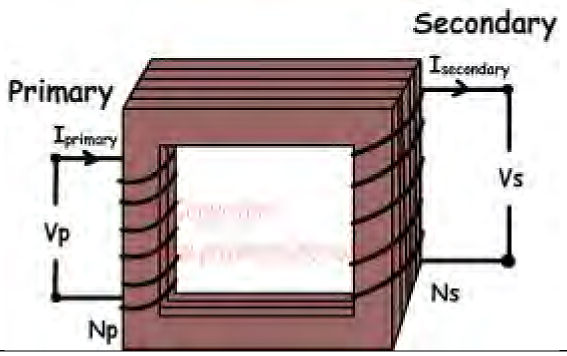
Unit G485: *Fields, Particles and Frontiers of Physics*

Define Electric Field Strength	Electric field strength at a point in space is the force per unit (positive) charge
Define Magnetic Flux Density	a measure of the strength of a magnetic field at a given point, expressed by the force per unit length on a conductor carrying unit current at that point. F=BQv
Define Tesla	One Tesla is the uniform magnetic flux density which, acting normally to a long straight wire carrying a current of 1 ampere, causes a force per unit length of $1nm^{-1}$ on the conductor
Define Magnetic flux	magnetic flux = magnetic flux density x (cross-sectional) area (perpendicular to field direction) B x A (normal to B). Magnetic flux=magnetic field x Area
Define The Weber	One Weber is equal to one Tesla metre^2
Define Magnetic Flux Linkage	The change of magnetic flux linkage is equal to the product of the change in magnetic flux and the number of turns N of a conductor involved in the change in flux
Define Capacitance	Capacitance = charge per (unit) potential differences Ratio of charge to potential for a conductor
Define The Farad	coulomb per (unit) volt
Define The Time Constant of a Circuit	Time for the charge to have decreased to $\frac{1}{e}$ of its initial charge
Define Proton Number	The number of protons found in the nucleus of an atom
Define Nucleon Number	The mass number, the sum of the number of neutrons and protons in an atomic nucleus
Define Isotopes	Isotopes are different forms of the same element which have the same number of protons but different numbers of neutrons in their nuclei
Define Activity (Radioactivity)	Spontaneous emission of a stream of particles or electromagnetic rays in nuclear decay
Define The Decay Constant	The probability of decay of a nucleus per unit time Reciprocal of decay time
Define Half Life	The half-life of a radioactive nuclide is the time taken for the number of un-decayed nuclei to be reduced to half its original number
Define Binding Energy	The energy equivalent of the mass defect of a nucleus. It is the energy required to separate to infinity all the nucleons of a nucleus
Define Binding Energy Per Nucleon	Binding energy per nucleon is defined as the total (minimum) energy needed to completely separate all the nucleons / protons and neutrons in a nucleus divided by the number of nucleons in the nucleus
Define Intensity	Power per unit area(W/m^2)
Define The Distance Measured In Astronomical Units (AU)	The astronomical unit is defined as the radius of the circular path round the sun followed by a body in 365.25 days
Define The Distance Measured In Parsecs (pc)	Distance from a base length of 1 AU that subtends an angle of 1 (arc) second
Define The Distance Measured In Light-Years (ly)	The distance travelled by electromagnetic radiation (light) in one year

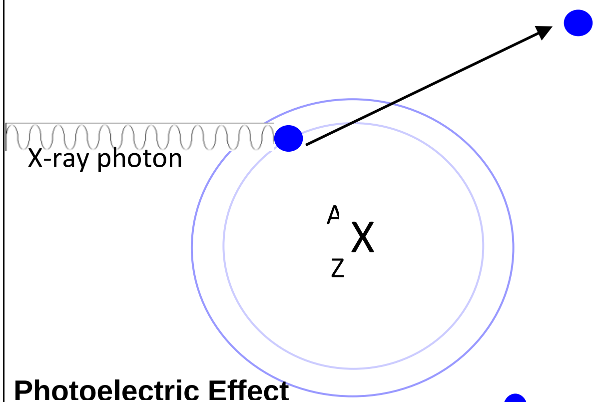
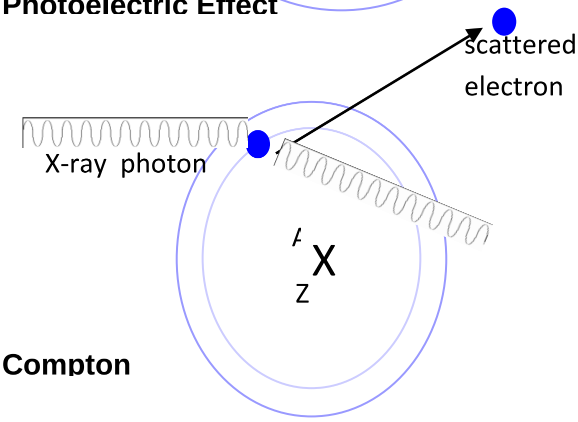
Define Critical Density	The density above which it is believed the expansion of the universe will slow down and reverse
State that electric fields are created by electric charges	Electric charges exert forces on each other when they are a distant apart. An electric field is a region of space where a stationary charge experiences a force
State and use Fleming's left-hand rule to determine the force on a current conductor places at right angles to a magnetic field.	If the first two fingers and thumb of the left hands are placed at right angles then the first finger is in the direction of the field, the second in the direction of the current and the thumb in the direction of motion
State and use Faradays Law of electromagnetic induction	Induced e.m.f is proportional to the rate of change of (magnetic) flux
State and use Lenz's law	The direction of the induced e.m.f is such as to cause effects to oppose the change producing it
State and use the equation for the total capacitance of two or more capacitors in parallel	$C = C_1 + C_2 + C_3 + \cdots$
State and use the equation for the total capacitance of two or more capacitors in series	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$ for two capacitors in series you can use the equation $C = \frac{C_1.C_2}{C_1+C_2}$
State and use the notation ^A_ZX for the representation of nuclides	$^A_ZX = {}^{nucleon\ number}_{Proton\ number}X$
State the quantities conserved in a nuclear decay	The charge, the total number of neutrons and protons, total energy, the total momentum of the system and the total lepton number.
State that there are two types of β decay	
State that (electron) neutrinos and (electron) antineutrinos are produced during β^+ and β^- decays respectively	β^- decay plus antineutrino β^+ decay plus neutrino
State that a β^- particle is an electron and a β^+ particle is a positron	
State that electrons and neutrinos are members of a group of particles known as leptons	
State the approximate magnitudes in meters of the parsec	$3.1 \times 10^{16}\ m$
State the approximate value in meters of the light-year	$10 \times 10^{15}\ m$
State Olbers' paradox	Based on: the universe being static / homogeneous and infinite / infinite number of stars
State and interpret Hubble's law	The speed of recession of a galaxy is proportional to its distance (from Earth / observer)
State the cosmological principle	Universe is isotropic /same in all directions Homogeneous / evenly distributed
Explain the effect of a uniform electric field on the motion of a charged particle	If E is uniform, then the acceleration of the charged particle is constant. If the particle has a positive charge, then its acceleration is in the direction of the electric field. If the particle has negative charge, then its acceleration is in the direction opposite the electric field
Explain the use of deflection of charged particles in the magnetic and electric fields of a mass spectrometer	Depending on the strength of the magnetic and electric fields the mass of charged [articles detected can be changed. E.g: the smaller the electric field the larger massed particles can be detected
Explain that the area under a potential difference against charge graph is equal to the	

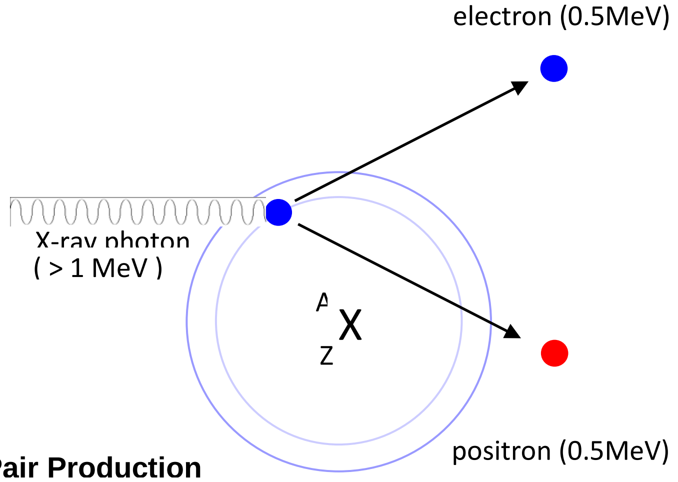
energy stored by a capacitor	
Explain exponential decays as having a constant ratio property	
Explain that since protons and neutrons contain charged constituents called quarks they are therefore not fundamental particles	
Explain how soft tissues like the intestines can be images using barium meal	In order to make soft tissue more visible, contrast media, such as barium, are used. The patient swallows a liquid rich in barium as it will readily absorb X-rays. The barium meal coats the wall of the tract enabling its outline to be seen in X-rays.
Explain what is meant by the Doppler effect	Doppler effect is a change in frequency and wavelength of a wave. It is caused by the change in distance between the thing creating the wave and whatever is measuring, seeing or hearing the wave.
Explain qualitatively how the Doppler effect can be used to determine the speed of blood	Doppler effect uses ultrasound waves. Sound waves are reflected by the moving blood cells. Change in frequency/wavelength enables the speed of blood flow or rate of flow of blood to be found
Explain how ultrasound transducers emit and receive high frequency sound	Transducer is the name given to any device that converts energy from one form to another. In this case electrical energy is converted into ultrasound energy by means of a piezo-electric crystal such as a quartz
Explain that the standard model of the universe implies a finite age for the universe (hot big bang)	galaxies are moving apart / universe is expanding if galaxies have always been moving apart then at some stage they must have been closer together / or started from a point evidence in red shift either optical / microwave further away the galaxy the faster the speed of recession the existence of a (2.7 K) microwave background radiation there is more helium in the universe than expected
Explain that the universe can be 'open', 'flat' or 'closed', depending on its density	Open: Universe expands for all time Flat: expands to a limit (but never reaches it) Closed: Universe contracts / collapses back
Explain that the ultimate fate of the universe depends on its density	if average density of the Universe is less than critical then it will be too small to stop it expanding / it goes on forever if the average density of the Universe is greater than the critical value it will cause the contraction (and produce a big crunch) close to critical value and therefore a universe expands that will go towards a limit / expands at an ever decreasing rate asymptotic
Explain that it is currently believed that the density of the universe is close to, and possibly exactly equal to, the critical density needed for a 'flat' cosmology	$\rho_0 = \frac{3H_0^2}{8\pi G}$ Estimates give values of 1 or 2 orders of magnitude less than critical. But rotation of galaxies show they have more mass than we can see, and the inflationary expansion theory suggests that the density is exactly equal to critical
Describe the difference between A-scan and B-scan	A-scan in one direction only / range or distance or depth finding B-scan uses a number of sensors or a sensor in different positions / angles (to build up a 2D/3D image)
Describe the importance of impedance matching	The greater the mismatch, the more ultrasound is reflected
Describe the principle contents	There are at least 10^{10} galaxies in the universe. From a

of the universe, including stars, galaxies and radiation	side view there is a disc shaped conglomeration of stars with a bulging central nucleus
Describe the solar system in terms of the Sun, planets, planetary satellites and comets	Solar system contains 9 well known planets and their satellites; it also contains a number of small or dwarf planets. These planets all orbit the sun. Comets have an elliptical orbit, which means that they return regularly often passing close enough to the earth to be visible
Describe the formation of a star, such as our Sun, from interstellar dust and gas.	Gas / dust (cloud) / nebula / (hydrogen) gas drawn together by gravitational forces Gravitational collapse Temperature of (dust) cloud increases / KE (of cloud) increases / (cloud) heats up (Loss in (gravitational) PE / KE increases / PE changes KE / temperature increase) Fusion occurs (when temperature is about 10^7K Protons / hydrogen nuclei combine to make helium (nuclei) (Fusion of protons / hydrogen nuclei (produces helium nuclei and energy)) Stable sized star is produced when thermal / radiation pressure is equal to gravitational pressure
Describe the Sun's probable evolution into a red giant and white dwarf	When hydrogen runs out the outer layers of the star expands / core shrinks Red giant formed / eventually (the core becomes) a white dwarf [A white dwarf is: A very dense star Hot star / high surface temperature / low luminosity No fusion reactions take place / leaks away photons (from earlier fusion reactions) Its collapse is prevented by Fermi pressure / mass less than 1.4 solar masses]
Describe how a star much more massive than our Sun will evolve into a super red giant and then either a neutron star or black hole.	(When hydrogen / helium runs out) the outer layers of the start expands / a (super) red giant is formed The core (of the star) collapses (rapidly) / a supernova is formed (Depending on the initial mass of the star, a supernova is) followed by neutron star / black hole
Describe and interpret Hubble's red shift observations	Observations that the wavelengths of identifiable spectral lines in the spectra of light from distant galaxies did not correspond with wavelength measured on earth. Column of light seemed to be shifted towards the red end of the spectrum. This was interpreted as a continuous expansion of the universe
Describe and explain the significance of the 3K microwave background radiation	Leftover radiation (stretched over time) from events in the Big Bang.
Describe qualitatively the evolution of universe $10^{-43}s$ after the big bang to the present	(At the start it was) very hot / extremely dense / singularity All forces were unified Expansion led to cooling Quarks / leptons soup More matter than antimatter Quarks combine to form hadrons / protons / neutrons Imbalance of neutrons and protons / (primordial) helium

	produced. Atoms formed Ideas of gravitational force responsible for formation of stars / galaxies Temperature becomes 2.7K / 3K or (the Universe is saturated with cosmic) microwave background radiation
Describe how electric field lines represent an electric field	The direction of the electric field is defined as the direction in which a positive charge would move if it were free to do so. So the lines of force can be drawn with arrows that go from positive to negative
Describe the similarities and differences between the gravitational fields of point masses and the electric fields of point charges	
Describe the magnetic field patterns of a long straight current-carrying conductor and a long solenoid	Magnetic field patterns due to a long straight wire are concentric circles centred on the middle of the wire. The separation of the line increases with distance from the wire. A solenoid may be thought to be made up of many flat coils placed side by side. The field lines are parallel and equally spaced over the centre section of the solenoid indicating the field is uniform
Describe the function of a simple ac generator	An electric generator converts mechanical energy in the form of the rotation energy of a coil of wire into electrical energy
Describe the function of a simple transformer	A simple transformer is two coil of insulated wire wound on to a laminated soft iron core. And alternating e.m.f is applied across the primary coil and an e.m.f is induced in the secondary 
Describe the function of step-up and step-down transformers	Step up- when V_s is greater than V_p there are more turns in the secondary coil than the primary. Low to high voltage Step down- when V_s is less than V_p there are more turns in the primary coil than the secondary. High to low voltage
Describe the uses of capacitors for the storage of energy in applications such as flash photography, lasers used in nuclear fusion and as back-up power supplies for computers	Capacitor takes a few seconds to charge then it is either discharged rapidly when connected to the flash bulb to give a short but intense flash, or it can be released slowly, when being used as a back up battery
Describe qualitatively the alpha-particle scattering experiment and the evidence this provides	α - particle scattering suitable diagram with source, foil, moveable detector

for the existence, charge and small size of the nucleus	2 or more trajectories shown vacuum most particles have little if any deflection large deflection of very few reference to Coulomb's law /elastic scattering alphas repelled by nucleus (positive charges) monoenergetic OR electron scattering High energy diagram with source sample, moveable detector / film Vacuum Electron accelerator or other detail Most have zero deflection Characteristic angular distribution with minimum Minimum not zero De Broglie wavelength Wavelength comparable to nuclear size hence high energy
Describe the basic atomic structure of the atom and the relative sizes of the atom and the nucleus	Protons are in the nucleus they have a mass u and charge +e Neutrons are also in the nucleus they do not have a charge and have a mass u Electrons orbit the nucleus and have mass u/2000 and a charge -e
Describe how the strong nuclear force between nucleons is attractive and very short-ranged	Due to a strong force that binds quarks together to form neutrons and protons. Must be short range as it does not influence beyond the nuclear surface and strong enough to overcome the repulsive force of the protons.
Describe a simple quark model of hadrons in terms of up, down and strange quarks and their respective antiquarks, taking into account their charge, baryon number and strangeness.	There are three quarks with corresponding antiquarks. They have a fractional charge of either 1 or 2 thirds. Baryons are made up of three quarks Mesons are small and made of a quark and antiquark
Describe how the quark model may be extended to include the properties of charm topness and bottomness	3 more quarks called charmed, bottom and top. Charmed quarks have a charge +2e/3 and a baryon number of 1/3 Bottom quarks have a charge of –e/3 and a baryon number of 1/3 Top quarks have a charge of +we/3 and a baryon number of 1/3
Describe the properties of neutrons and protons in terms of a simple quark model	Neutrons- No charge, mass u, made of 1 up and 2 down quarks Protons-+1 charge, mass u, made of 2 up and 1 down quark
Describe how there is weak interactions between quarks and that this is responsible for β decay	Because of weak interactions between quarks a down quark is able to become an up quark turning a neutron into a proton and emitting an electron
Describe the two types of β decay in terms of a simple	β- decay a neutron turns into a proton and emits an electron

quark model	β+ decay a proton turns into a neutron and a positron is emitted
Describe the spontaneous and random nature of radioactive decay of unstable nuclei	**Spontaneous**: the decay cannot be induced / occurs without external influence **Random**: cannot predict when / which (nucleus) will decay next
Describe the nature, penetration and range of α particles, *β* particles and γ rays	Alpha particles have a charge +2e and can travel through a few cm of air Beta emissions has a charge of –e and can penetrate a few mm of aluminium Gamma rays have no charge and penetrate a few cm of lead
Describe the use of radioactive isotopes in smoke alarms	Ionisation of air caused by a small alpha particle emitter with a long half-life, the alpha particles pass between electrons producing a current. If there is more than a certain concentration of smoke alpha particles are absorbed and the current is then reduced, this then triggers the alarm
Describe the nature of x-rays	Electromagnetic waves Travel at speed of light / $3x10^{8}$ m/s (in a vacuum) Travel in a vacuum Can cause ionisation Wavelength about 10^{-10}m (X-rays are) high energy photons
Describe in simple terms how x-rays are produced	Electrons are accelerated through high voltage (High speed) electron(s) hit metal Kinetic energy of electron(s) 'produces' X-ray (photons)
Describe how x-rays interact with matter (limited to the photoelectric effect, Compton effect and pair production)	 **Photoelectric Effect**  **Compton** (X-ray) photon interacts / collides with an (orbital) electron The (scattered) photon has a longer wavelength / lower frequency / lower energy AND

	The electron is ejected (from the atom at high speed)  **Pair Production** Incoming photon (disappear and) produces electron-positron pair.
Describe the use of x-rays in imaging internal body structures including the use of image intensifiers and of contrast media	Intensifier used as X-ray would pass through film Intensifier converts X-ray photon to many visible (light) photons (which are absorbed by film) Lower exposure / fewer X-rays needed Iodine / barium (used as contrast material) High Z number / large attenuation coefficient / large absorption coefficient / large atomic number (easily absorbs x-rays / used to improve image contrast) Contrast media are ingested / injected into the body. Used to reveal tissues. Absorption of X-rays by (silver halide molecules) by a photographic film Uses of fluorescent / scintillator/ phosphor Photon releases electron (that is accelerated onto a fluorescent screen) number of electrons increased /multiplied Different soft body tissue produce little difference in contrast/attenuation (Contrast media with) high atomic number / Z used / iodine or barium (used to give greater contrast)
Describe the operation of a computerised axial topography (CAT) scanner	
Describe the advantages of a CAT scan compared with an x-ray image	Differences: Simple X-ray is one directional / produces single image Simple X-ray is one directional / produces single image Computer processes data / image constructed from many slices Advantages: X-ray image is 2D / CT scan produces 3D image Greater detail / definition / contrast with CT scan / ‘soft tissues can be seen’ Image can be rotated
Describe the use of medical	Radioactive substance that is ingested / injected (into

tracers like technetium-99m to diagnose the function of organs	patient) Technetium(-99) / Iodine(-131)Tracer administered will be giving off radiation so the path can be followed. It will not interfere with any functions of the body. And it must emit detectable radiation so that the image of the organs can be observed
Describe the main components of a gamma camera	Collimator – gamma (ray photons) travel along the axis of lead tubes or allows parallel gamma (ray photons travel to the scintillator) Having thin / long / narrow (lead) tubes makes the image sharper / less blurred Scintillator – gamma ray photon produces many / thousands of photons of (visible) light Photomultiplier – An electrical pulse is / electrons are produced from the light (photons) Computer – signals (from photomultiplier tubes) are used to produce an image
Describe the principles of positron emission tomography (PET)	Uses radioactive substance / uses positron-emitting substance / uses F(F-18) Can reveal the 'function' of the brain. 3D
Describe the main components of an MRI scanner	Strong electromagnet, radio frequency transmitting coils, radio frequency receiving coils, gradient coils and a computer.
(Outline the principle of MRI)	Protons / nuclei have spin / behave like tiny magnets Protons / nuclei precess about the magnetic field (provided by the strong electromagnet) Transmitting coild provide (pulses of) radio waves of frequency equal to the Larmor frequency The protons / nuclei absorb energy / radio waves / resonate and flip into a higher energy state When protons / nuclei flip back to a lower energy state they emit (photons of) radio waves The relaxation time of the (protons / nuclei) depends on the (surrounding) tissues The radio waves are picked up by the receiving coils The gradient coils alter the magnetic flux density (through the body) The Larmor frequency (of the protons / nuclei) varies throughout the body The computer (processes all the signals from the receiving coils and) generates the image
Describe the advantages and disadvantages of MRI	Advantage: not ionising radiation (as with X-rays) / better soft tissue contrast Disadvantage: heating effect of metal objects /effect on cardiac pacemakers / takes a long time to perform MRI scan Method does not use ionising radiation hence no radiation hazard to patient or staff Gives better soft tissue contrast than CT scans Generates data from a 3D volume simultaneously Information can be displayed on a screen as a section in any direction There are no moving mechanisms involved in MRI

	There is no sensation, after effects at the field strengths used for routine diagnosis Strong magnetic field could draw steel objects into the magnet Metallic objects may become heated Cardiac pacemakers may be affected by the magnetic fields CT scanners better for viewing bony structures
Describe the need for non invasive techniques in diagnosis	No entry into body / no cutting / incision of patient / no surgery. Lower risk of infection / less trauma
Describe the properties of ultrasound	The gel allows maximum transmission of ultrasound (into the body)
Describe the piezoelectric effect	The application of a p.d. across a material / crystal causes an expansion / contraction / vibration
Describe the principles of ultrasound scanning	Pulses of ultrasound (sent into the body) Wave / ultrasound / pulse / signal is reflected (at boundary of tissue) Time of delay used to determine depth / thickness The fraction of reflected signal is used to identify the tissue Small wavelength used which means finer detail can be seen / greater resolution Blood – Ultrasound is reflected by (moving) blood (cells) The frequency / wavelength (of ultrasound) is changed The change of frequency is related to speed of blood / change of wavelength is related to speed of blood / ‘frequency is proportional to speed of blood’
Describe the process of induced nuclear fission	The splitting of a heavy nucleus into two lighter nuclei of approximately the same mass
Describe the techniques of radioactive dating	Living plants / animals absorb carbon(-14) Once dead, the plant does not take in any more carbon(-14) The fraction of C-14 to C-12 (nuclei) or number of C-14 (nuclei) or activity of C-14 (nuclei) measured in dead and living (sample) $x = x_0 e^{-\lambda t}$ used with data above to estimate the age
Describe and explain the process of nuclear chain reaction	Occurs when one nuclear reaction causes an average of one of more nuclear reactions, thus leading to a self-propagating series of reactions Controlled chain reaction: The control rods are inserted into the reactor so as to allow (on average) one neutron from previous reaction to cause subsequent fission.
Describe the basic construction of a fission reactor and explain the role of the fuel rods, control rods and the moderator	Fuel rods: contain the uranium (nuclei) / fissile material Control rods: Absorb (some of the) neutrons. Moderator: Slows down the (fast moving) neutrons / lowers the KE of (fast moving) neutrons / makes (fast moving) neutrons into thermal neutrons. Slow moving neutrons have a greater chance of causing fission / being absorbed (by U-235) / sustaining chain reaction
Describe the use of nuclear	Advantages-does not produce acid rain or waste gases

fission as an energy source	which cause pollution -provides energy for nuclear power and can provide electricity Disadvantages-problems with the reaction getting out of control -risks from radiation -long half life of waste -can be used to drive nuclear weapons
Describe the peaceful and destructive uses of nuclear fission	Peaceful-Create Energy Destructive-Nuclear Weapons
Describe the environmental effects of nuclear waste	Nuclear waste is (radio)active for a long time Causes ionisation
Describe the process of nuclear fusion	Joining / fusing together of ('lighter') nuclei / protons (to make 'heavier' nuclei.) Mass decreases in the reaction and this is transformed into energy OR the products have a greater binding energy. High temperature / approx. 10^7K needed for fusion High pressure / density (required in the core). The protons / nuclei repel (each other because of their positive charge) The strong (nuclear) force comes into play when the protons / nuclei are close to each other.
Describe the conditions in the core of stars	Fusion in the core of the sun: Protons / hydrogen nuclei to produce Helium nuclei (positrons and neutrinos) There is electrostatic repulsion (between the protons) / The protons repel (each other because of their positive charge) High temperatures / 107 K needed (for fusion (At high temperatures some of the fast moving) protons come close enough to each other for the strong (nu-clear) force (to overcome the electrostatic repulsion) High density / pressure (in the core of the Sun) There is a decrease in mass, hence energy is released / products have greater binding energy
Analyse the circular orbits of charged particles moving in a plane perpendicular to a uniform magnetic field by relating the magnetic force to the centripetal acceleration it causes	Consider positively charged particle of mass m carrying charge q and moving with velocity v, when it enters the magnetic field which is normal to the direction of motion of the particle it will experience a force normal to its direction. This does not affect speed but will change the direction of motion so the body moves in a circular motion
Analyse the motion of charged particles in both electric and magnetic fields	The force on a particle of charge q moving at speed v and an angle θ to a uniform magnetic field of flux density B is given by $F=BqvSin\theta$