Spec reference	Spec point	Extra details
6.1.1 Capacitors	(a) capacitance; C= Q/V; the unit farad (b) charging and discharging of a capacitor or capacitor plates with reference to the flow of electrons (c) total capacitance of two or more capacitors in series; $1/C_T = 1/C_1 + 1/C_2 + ...$ (d) total capacitance of two or more capacitors in parallel; $C = C_1 + C_2 + ...$ (e) (i) analysis of circuits containing capacitors, including resistors (ii) techniques and procedures used to investigate capacitors in both series and parallel combinations using ammeters and voltmeters.	Q α V with C as the constant of proportionality: C is the charge per Unit p.d (Volt) $1\ F = 1CV^{-1}$ Total loss of electrons from positive plate = total gain of electrons by negative plate. Derived using the fact that: $Q_{Total} = Q_1 = Q_2 = Q_3$ $V_{Supply} = V_1 + V_2 + V_3$ .... Derived using the fact that: $V_{Supply} = V_1 = V_2 = V_3$ .... and $Q_{Total} = Q_1 + Q_2 + Q_3$ to calculate the total charge on the capacitor array. To calculate the potential difference across individual capacitors (in series).
6.1.2 Energy	(a) p.d. – charge graph for a capacitor; energy stored is area under graph (b) energy stored by capacitor; $W = \frac{1}{2}QV,\ W = \frac{1}{2}\frac{Q^2}{C}$ and $W = \frac{1}{2}V^2C$ (c) uses of capacitors as storage of energy.	Area under graph = energy stored. Gradient = capacitance
6.1.3 Charging and		

discharging capacitors	(a) (i) charging and discharging capacitor through a resistor (ii) techniques and procedures to investigate the charge and the discharge of a capacitor using both meters and data-loggers	 HSW4 Investigating the charge and discharge of capacitors in the laboratory (PAG)
	(b) time constant of a capacitor–resistor circuit; $\tau = CR$	Time for the values of Q/V/I to fall to 1/e/0.37/37% of its original value.
	(c) equations of the form $x = x_0 e^{-\frac{t}{CR}}$ and $x = x_0(1 - e^{-\frac{t}{CR}})$ for capacitor–resistor circuits.	This form for discharging capacitors. This form for values involving a charging capacitor (Q and V), V across capacitor.
	(d) graphical methods and spreadsheet modelling of the equation $\frac{\Delta Q}{\Delta t} = -\frac{Q}{CR}$ for a discharging capacitor	Iterative processes. HSW3 Using spreadsheets to model the discharge of a capacitor.
	(e) exponential decay graph; constant-ratio property of such a graph.	Idea that if a quantity decays exponentially, its value will decrease by the same <u>fraction</u> periodically if with respect to time. .

6.2.1 Point and spherical charges	(a) electric fields are due to charges. (b) modelling a uniformly charged sphere as a point charge at its centre. HSW1 (c) electric field lines to map electric fields (d) electric field strength $$E = \frac{F}{Q}.$$	A region surrounding a charge where if a second charge was introduced, it would experience a force. Direction of fields lines = direction of force acting on **positive** charge. Force per unit **positive** charge. F = Eq a = Fq/m
6.2.2 Coulomb's law	(a) Coulomb's law for the force between two point charges; $$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$$ (b) electric field strength for a point charge: $$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$ (c) similarities and differences between the gravitational field of a point mass and the electric field of a point charge. (d) the concept of electric fields as being one of a number of forms of field giving rise to a force.	Analogous to Gravitational fields. Force per unit **positive** charge. Similarity of equations – radial fields - inverse square law, the fact that gravitational force is always attractive whereas electric force is attractive and repulsive depending on the charges. Magnitude of electric force much larger.
6.2.3 Uniform electric field	(a) uniform electric field strength. $$E = \frac{V}{d}$$	Uniform field between 2 parallel plates with a pd V across them and a distance d apart. Idea of the field strength = magnitude of the potential gradient (as met in gravitational fields).

	(b) parallel plate capacitor; permittivity. $C = \frac{\varepsilon_0 A}{d}$; $C = \frac{\varepsilon A}{d}$; $\varepsilon = \varepsilon_r \varepsilon_0$ (c) motion of charged particles in a uniform electric field.	This will be covered when we discuss capacitors. Proportionality relationships. Dielectric materials: an understanding of permittivity and relative permittivity of free space is not required. Charge moving at rest accelerating in a uniform field can be treated in terms of the field equations and ***suvats*** or using the equation: $qV = ½ mv^2$ Idea that the force acting on a charge entering at 90° uniform electric field is analogous to a mass projected into a uniform gravitational field – ***suvats*** and projectile motion.
6.2.4 Electric potential and energy	(a) electric potential at a point as the work done in bringing unit **<u>positive</u>** charge from infinity to the point; electric potential is zero at infinity: $V = \frac{Q}{4\pi\varepsilon_0 r}$ (b) electric potential at a distance r from a point charge; changes in electric potential.	Analogous to gravitational potential. The +/- nature of electric potential depends on the sign of the charge.

	(c) capacitance $C = 4\pi\varepsilon_0 R$ for an isolated sphere	Derivation expected from equation for electric potential and Q = VC. This will be covered in the capacitors unit.
6.3.1 Magnetic fields	(a) magnetic fields are due to moving charges or permanent magnets. (b) magnetic field lines to map magnetic fields. (c) magnetic field patterns for a long straight current-carrying conductor, a flat coil and a long solenoid. (d) Fleming's left-hand rule. (e) (i) force on a current-carrying conductor; $F = BIL\sin\theta$ (ii) techniques and procedures used to determine the uniform magnetic flux density between	Region of space surrounding a current (or permanent magnet) where if another current (or magnet) were introduced, it would experience a force. Direction of force on a normal current or North pole of a magnet. Concentric circles. Right hand corkscrew/thumb rule. Right hand grip rule. Force acting on current normal to a magnetic field. Field: N to S Current: + to – Force due to interaction between an external field and field due to the current. If θ is the angle between a current and field lines, sin θ component is norm to the lines and cosθ component is parallel to the field (hence no force). PAG –

	the poles of a magnet using a current-carrying wire and digital Balance. (f) magnetic flux density; the unit tesla.	 1Telsa is flux density where a force of = 1N acting on a current of 1A of length 1m perpendicular to the field.
6.3.2 Motion of charged particles	(a) force on a charged particle travelling at right angles to a uniform magnetic field; F = BQv (b) charged particles moving in a uniform magnetic field; circular orbits of charged particles in a uniform magnetic field (c) charged particles moving in a region occupied by both electric and magnetic fields; velocity selector.	Fleming's left-hand rule to predict direction of force – current direction of positive charge – opposite to direction of negative charge. Force always acts at 90° to the velocity. No work done on charged particles hence no change in speed. Balancing the electric force (F = Eq) with the magnetic force (F = Bqv)
6.3.3 Electromagnetism	(a) magnetic flux ϕ; the unit weber; ϕ = BAcosθ (b) magnetic flux linkage **ϕ** (c) Faraday's law of electromagnetic induction and Lenz's law. (d) (i) e.m.f. = − rate of change of magnetic flux linkage;	B – flux density (T) A = area (m2) θ = angle between the field lines and an arrow normal to the area. **ϕ** = BANcosθ Magnetic flux linked to N turns of the coil. Emf: E α rate of change of flux linkage $\mathcal{E} = -\frac{\Delta(N\phi)}{\Delta t}$ Minus sign indicates the direction of induced EMF.

	$$\mathcal{E} = -\frac{\Delta(N\phi)}{\Delta t}$$ (ii) techniques and procedures used to investigate magnetic flux using search coils. (e) simple a.c. generator (f) (i) simple laminated iron-cored transformer for an ideal transformer; $\frac{n_s}{n_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$ (ii) techniques and procedures used to investigate transformers.	The direction of an induced current is such as to produce a magnetic effect that seeks to oppose the change that brought it about. In accordance with the conservation of energy. e.g. induced poles with falling magnets. Deducing EMF from graphs of flux(linkage) against time (magnitude = gradient). Tracing EMF induced with time from Flux linkage graph. Use in calculations. Use to explain transmission voltages/currents and efficiency.
6.4 Nuclear and partcle physics	(a) alpha-particle scattering experiment; evidence of a small charged nucleus HSW7 (b) simple nuclear model of the atom; protons, neutrons and electrons (c) relative sizes of atom and nucleus	10^{-10}m – atomic diameter 10^{-14}m – nuclear diameter

	(d) proton number; nucleon number; isotopes; notation $^{A}_{Z}X$ for the representation of nuclei (e) strong nuclear force; short-range nature of the force; attractive to about 3 fm and repulsive below about 0.5 fm (f) radius of nuclei; $R = r_0 A^{1/3}$ = where r_0 is a constant and A is the nucleon number (g) mean densities of atoms and nuclei.	1 fm = 10^{-15} m Graph and logarithm graphs. All nuclei have (nearly) the same density as Mass α A Volume α A (see equation above).
6.4.2 Fundamental partcles	(a) particles and antiparticles; electron–positron, proton-antiproton, neutron-antineutron and neutrino-antineutrino (b) particle and its corresponding antiparticle have same mass; electron and positron have opposite charge; proton and antiproton have opposite charge (c) classification of hadrons; proton and neutron as examples of hadrons; all hadrons are subject to both the strong nuclear force and the weak nuclear force	Strong interactions in collisions and approach. Weak interactions are involved in decay situations.

	(d) classification of leptons; electron and neutrino as examples of leptons; all leptons are subject to the weak nuclear force but not the strong nuclear force. (e) simple quark model of hadrons in terms of up (u), down (d) and strange (s) quarks and their respective anti-quarks (f) quark model of the proton (uud) and the neutron (udd) (g) charges of the up (u), down (d), strange (s), anti-up ($\bar{u}$), anti-down($\bar{d}$) and the anti-strange ($\bar{s}$) quarks as fractions of the elementary charge e. (h) beta-minus (β^-) decay; beta-plus (β^+) decay. (i) β^- decay in terms of a quark model; $d \rightarrow u + {}^{0}_{-1}e + \bar{\nu}$ (j) β^+ decay in terms of a quark model; $u \rightarrow d + {}^{0}_{+1}e + \nu$ (k) balancing of quark transformation equations in terms of charge (l) decay of particles in terms of the quark model.	Information about charge etc. on data sheet. You need to recall this. You need to recall this. Data sheet again.

6.4.3 Radioactivity	(a) radioactive decay; spontaneous and random nature of decay (b) (i) α-particles, β-particles and γ-rays; nature, penetration and range of these radiations (ii) techniques and procedures used to investigate the absorption of α-particles, β-particles and γ-rays by appropriate materials (c) nuclear decay equation for alpha, beta minus and beta-plus decays; balancing nuclear transformation equations (d) activity of a source; decay constant λ of an isotope; $A = \lambda N$ (e) (i) half-life of an isotope; $\lambda t_{1/2} = \ln(2)$ (ii) techniques and procedures used to determine the half-life of an isotope such as protactinium (f) (i) the equations $A = A_0 e^{-\lambda t}$ and $N = N_0 e^{-\lambda t}$ where A is the activity and N is the number of undecayed nuclei. (ii) simulation of radioactive decay using dice (g) graphical methods and spreadsheet modelling of the equation: $\frac{\Delta N}{\Delta t} = -\lambda N$	Spontaneous – cannot be influenced by external events. Random – cannot predict when an individual nucleus will decay. GCSE knowledge expected here. Activity as the rate of decay of nuclei. λ - the probability a nucleus will decay in unit time. Use in conjunction with half life equation. Analogous with capacitor decay.

	(h) radioactive dating, e.g. carbon-dating.	
6.4.4 Nuclear fission and fusion	(a) Einstein's mass–energy equation; $\Delta E = \Delta mc^2$ (b) energy released (or absorbed) in simple nuclear reactions (c) creation and annihilation of particle–antiparticle pairs (d) mass defect; binding energy; binding energy per nucleon (e) binding energy per nucleon against nucleon number curve; energy changes in reactions (f) binding energy of nuclei using $\Delta E = \Delta mc^2$ and masses of nuclei (g) induced nuclear fission; chain reaction (h) basic structure of a fission reactor; components – fuel rods, control rods and moderator (i) environmental impact of nuclear waste, Decision making process when building new nuclear power stations. (j) nuclear fusion; fusion reactions and temperature. Learners will also require knowledge of 5.1.4	Binding energy = the energy required to separate the nucleons in a nucleus. (change in) Binding energy = Δmc^2 Idea that increased binding energy per nucleon relates to energy released and a reduction in mass. Analysis of equation. Fusion reactions require close confinement of nuclei and high temperatures to overcome the coulombic repulsion between nuclei – strong nuclear force. Boltzmann distributions to explain temperature of reactions. Stars and nuclear fusion.

	(k) balancing nuclear transformation equations.	
6.5 Medical imaging		
6.5.1 Using X-rays	(a) basic structure of an X-ray tube; components – heater (cathode), anode, target metal and high voltage supply (b) production of X-ray photons from an X-ray tube. (c) X-ray attenuation mechanisms; simple scatter, photoelectric effect, Compton effect and pair production (d) attenuation of X-rays; $I = I_0 e^{-\mu x}$ where I is the intensity of radiation transmitted, μ is the attenuation (absorption) coefficient. (e) diagnosis using PET scanning.	HSW10, HSW12 Issues raised when equipping a hospital with an expensive scanner.
6.5.3 Using ultrasound	(a) ultrasound; longitudinal wave with frequency greater than 20 kHz (b) piezoelectric effect; ultrasound transducer as a device that emits and receives ultrasound	

	(c) ultrasound A-scan and B-scan (d) acoustic impedance of a medium; $Z = \rho c$ (e) reflection of ultrasound at a boundary $\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ (g) Doppler effect in ultrasound; speed of blood in the patient; $\frac{\Delta f}{f} = \frac{2v\cos\theta}{c}$	