U2 - Particles and radiation

<table>
<tr><td>What affects the stability of the isotope and why?</td><td>No. of neutrons (i.e., the more neutrons, the less stable) ∵ the strong nuclear force can no longer hold the nucleus together.</td></tr>
<tr><td>How do you find specific charge?</td><td>Divide the charge (C) of the object by its mass (kg).</td></tr>
<tr><td>What does the strong nuclear force / strong interaction do and what is it carried by?</td><td>

- Holds electrostatically repelling nucleons together.
- Carried by gluons.

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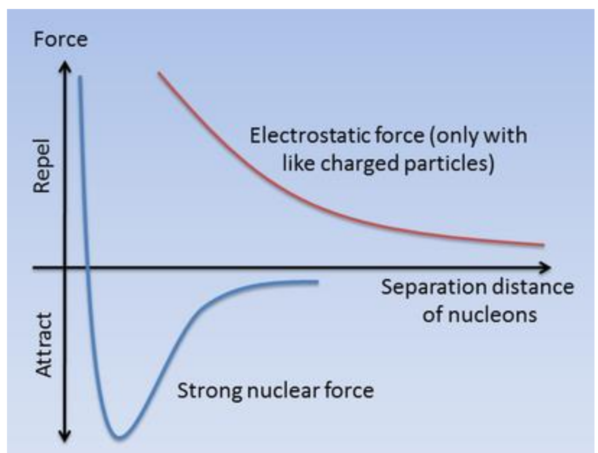
<tr><td>What does strong nuclear force give rise to, to what, at which distances, and why?</td><td>

- Very short range attraction up to 3 fm.
- Balanced attraction between the strong nuclear force and electrostatic force at 1.5 fm.
- Very short range repulsion under 0.5 fm.
- This is all between individual nucleons.



The very short range repulsion prevents nucleons collapsing into singularities.

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<tr><td colspan="2">Above 3 fm, the strength of the strong nuclear force drops and the strength of the electrostatic force takes over ∴ decreased stability.</td></tr>
<tr><td>Give 4 properties of alpha particles</td><td>Highly ionising due to size; low penetration due to size; charge of +2; amu of ≃4.</td></tr>
<tr><td>Why were neutrinos hypothesised?</td><td>To account for conservation of energy and momentum in beta decay.</td></tr>
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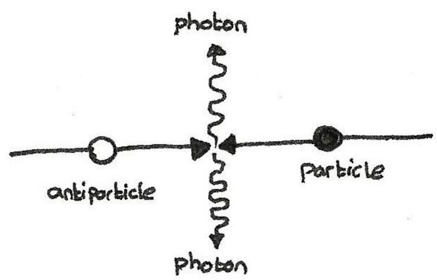
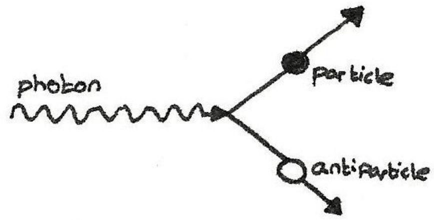
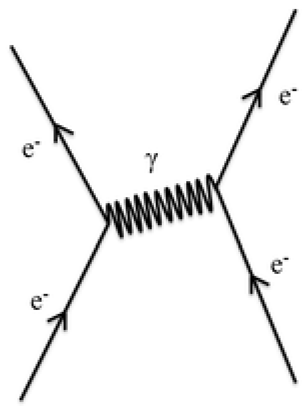
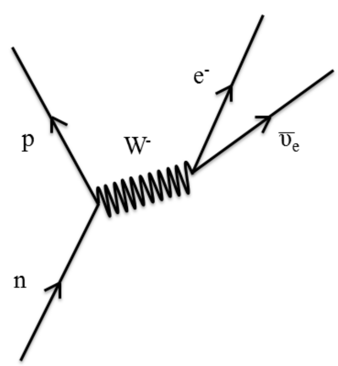
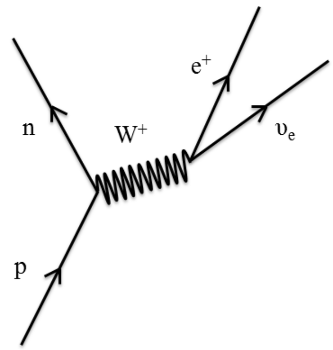
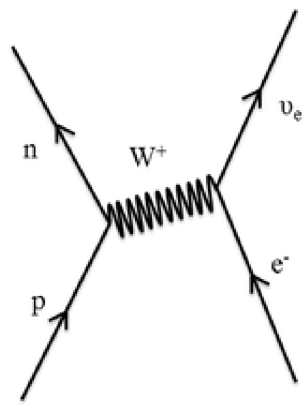
What happens on the quark-level of beta minus decay?	• A down quark in the nuclide decays into up quark whilst emitting a W^- boson (1). • The W^- boson decays into a beta minus particle and anti electron neutrino (1).
What problems do beta minus and beta plus decay solve?	• Beta minus decays solves too many neutrons. • Beta plus decay solves too many protons.
Give 3 properties of gamma rays	High frequency; very penetrating; not so ionising.
What is ionisation energy defined as?	The minimum energy required to remove an electron from its **GROUND STATE** to form an ion.
What is an electron volt defined as?	The energy of an electron when accelerated through a p.d. of 1 V.
How do particles and their antiparticles differ?	In all their properties (i.e., charge, lepton number, baryon number, and strangeness) except for rest mass.
What is annihilation?	When a particle and its antiparticle meet and annihilate converting their mass into energy in the form of photons.  *These particles are moving in opposite directions to conserve momentum.*
What is the equation used for annihilation and why?	$2hf_{min} = 2E_0 = 2mc^2$ As two particles make two photons.
What is pair production?	When a photon interacts with an atom (1) and has enough energy to produce a particle and its antiparticle.

	 *It should be stressed that: any surplus energy becomes kinetic energy and the photon has to interact with something as it's massless*
What is the minimum energy required of a photon to undergo pair production? What happens above this?	The total rest energies of the particles involved. For a particle-antiparticle pair, it would be: $$hf_{min} = 2E_0 = 2mc^2$$ Above this, excess energy goes into kinetic energy.
What particles are usually produced from pair production and why?	Electron-positron pairs due to their relatively low rest mass.
How does the mass of a gauge boson affect the range of its force?	The greater its mass, the short the range of the force. *W bosons have a mass 100x of a proton ∴ require a lot of energy ∴ can only exist for little time ∴ cannot travel far. Whereas photons with zero mass have infinite range.*
What are the roles of exchange particles?	Transfer force, transfer energy, transfer charge (sometimes).
What are the 4 fundamental forces?	Gravity, electromagnetic force, strong nuclear force, weak nuclear force.
What is gravity and its force carrier?	The mechanism by which particles with mass attract each other by exchanging gravitons.
What is the electromagnetic force and its force carrier?	When charged particles repel or attract each other by exchanging virtual photons.
What does the weak force / weak interaction act between, lead to, and what is it carried by?	● Quarks (∴ all hadrons) and leptons. ● Leads to particle decay. ● Carried by $W^+/W^-/Z^0$ bosons. *This is according to the AQA Physics A Unit 1 2015 Paper.*

What are the 3 key points of Feynman Diagrams?	● The only axis is time. ● Momentum is preserved at each vertex. ● The gauge boson must be drawn as a wiggly line.
What is the Feynman Diagram for the repulsion between electrons?	 $e^- + e^- \rightarrow e^- + e^-$ Two electrons exchange a virtual photon as they repel.
What is the Feynman Diagram for beta minus decay?	 $n \rightarrow p + e^- + \overline{\upsilon}_e$

What is the Feynman Diagram for beta plus decay?	 $p \rightarrow n + e^+ + \upsilon_e$
What is the Feynman Diagram for electron capture?	 $p + e^- \rightarrow n + \upsilon_e$ An electron from an inner shell is captured by the nucleus and exchanges a W^- boson with a proton to form a neutron and an electron neutrino. *This happens because the nucleus has too many protons yet not enough neutrons.*

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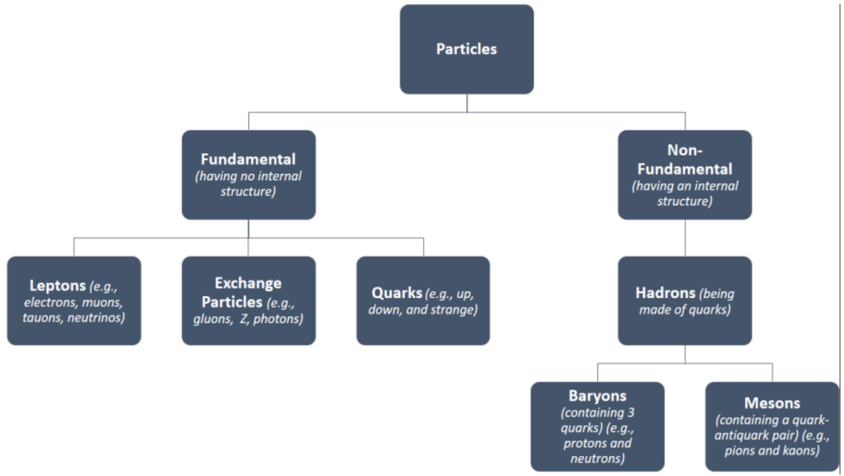
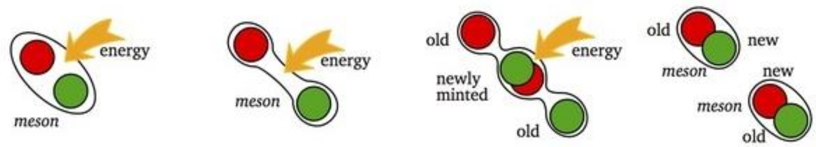
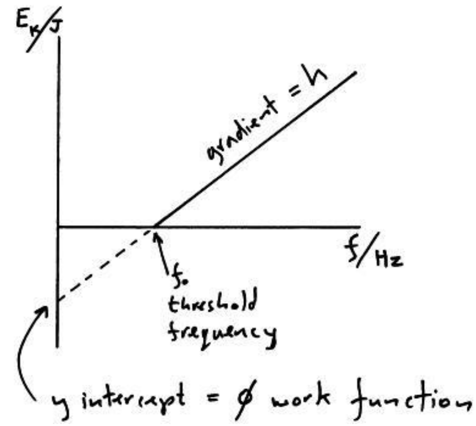
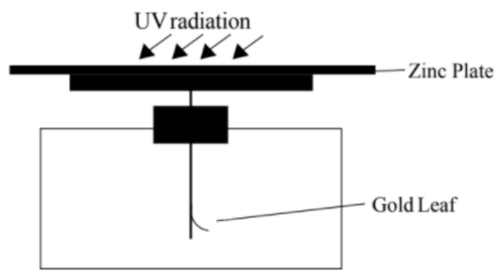
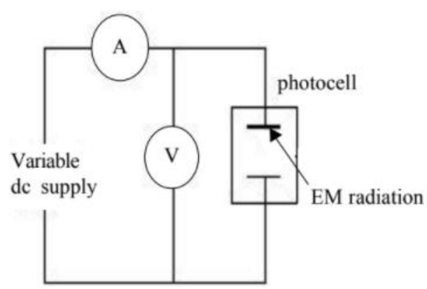
<tr><td>Sketch the family tree of particles</td><td>
</td></tr>
<tr><td>What does the strong force / strong interaction act between?</td><td>Quarks (∴ all hadrons).</td></tr>
<tr><td>What is quark confinement?</td><td>Applying enough energy to quarks to “separate” them yet producing a quark-antiquark pair instead.

</td></tr>
<tr><td>What are the 6 leptons?</td><td>Electrons, muons, tauons, electron neutrino, muon neutrino, and tauon neutrino.</td></tr>
<tr><td>What are muons and what can they decay into?</td><td>Heavy electrons which decay into electrons, some electron neutrinos, and some muon neutrinos as shown below:
$$\mu^- \longrightarrow e^- + \bar{\nu}_e + \nu_\mu$$
$$\mu^+ \longrightarrow e^+ + \nu_e + \bar{\nu}_\mu$$</td></tr>
<tr><td>What is a hadron?</td><td>A particle that <u>IS</u> subject to strong interaction.</td></tr>
<tr><td>What hadrons and leptons don't decay and why?</td><td>Protons, electrons, and neutrinos ∵ they're the most stable with the least rest energy.</td></tr>
<tr><td>Define baryon and give the structure of 2 baryons</td><td>A hadron consisting of 3 quarks.
Proton with uud and neutron with udd.</td></tr>
<tr><td>What is a meson?</td><td>A hadron consisting of a quark and an antiquark.</td></tr>
</table>

Give 2 examples of mesons	● Pions (π^+, π^-, and π^0). ● Kaons (k^+, k^-, and k^0).
Give an example of a strange particle	A kaon.
What 3 things are unusual about strange particles?	1. Produced by strong interaction (∴ strangeness **IS** conserved) **YET** decay by weak interaction (∴ strangeness **IS NOT** conserved). 2. They are always produced in particle-antiparticle pairs (∴ strangeness of 0 is conserved in strong interaction). 3. They have relatively long half-lives.
What do kaons decay into and by what?	Pions by weak interaction.
What is a lepton?	A particle that **<u>ISN'T</u>** subject to strong interaction.
What 4 properties are usually conserved in particle physics?	Charge, baryon number, lepton number **OF EACH FAMILY**, and strangeness (only for the strong interaction). *This is alongside energy and momentum.*
How should it like when working out which particle should be used?	$\overline{\nu_\mu} + p \rightarrow n + e^+$ L: $(-1) + 0 = 0 + (-1)$ no problem L_μ: $(-1) + 0 = 0 + 0$ problem L_e: $0 + 0 = 0 + (-1)$ problem *Total lepton number, muon and electron lepton number.*
Define threshold frequency (f_0) under the photoelectric effect	Minimum energy required to overcome the work function
What is the work function?	The minimum energy required to remove an electron from the surface of a specific metal.
What 4 observations made under the Photoelectric Effect support the particle theory over the wave theory?	● Electrons are only emitted above a threshold frequency (f_0); irrespective of intensity. ● The $K_{E\ (max)}$ of emitted electrons depends on the frequency of EM radiation. ● The no. of photoelectrons emitted per second depends on the intensity of EM radiation.

	• Low intensity EM radiation (above f_0) results in the immediate emissions of electrons.
Why does 'electrons being emitted above f_0 despite intensity' support the particle theory over the wave theory?	• Wave theory - light consists of waves with energy ∝ intensity ∴ greater intensity should cause emission of photoelectrons regardless of frequency. • Particle theory - light consists of photons with energy $E = hf$ and the metal emits photoelectrons when $f \geq f_0$. *For the wave theory, imagine shining a lot of light onto one square metre.*
Why is '$K_{E\ (max)}$ depending on the frequency of EM' support the particle theory over the wave theory?	• Wave theory - energy ∝ intensity ∴ greater intensity ⇒ higher K_E electrons. • Particle theory - the $K_{E\ (max)}$ depends on frequency and work function as defined by $K_{E\ (max)} = hf - \varphi$.
Why does 'the no. of photoelectrons per second depends on the intensity of the EM radiation' support the particle theory over the wave theory?	• Wave theory - greater frequency ⇒ more waves arriving per second ∴ intensity should have no effect. • Particle theory - the no. of photons arriving per second depends on intensity ∵ each photon has a fixed energy and one electron absorbs a photon in a one-to-one interaction.
Why does 'low intensity EM radiation (above f_0) resulting in immediate emission of electrons' support the particle theory over the wave theory?	• Wave theory - energy ∝ intensity ∴ lower intensity means it must take time for energy to accumulate to free an electron. • Particle theory - no. of electrons emitted ∝ intensity ∴ whilst few arrive for low intensity, they still have sufficient energy ⇒ immediate electron emission.
Why do photoelectron kinetic energies vary to a maximum?	• $E_{k\ (max)} = hf - \varphi$. • Each photon's energy is the same (due to frequency) ∴ more energy is required to remove electrons further from the surface due to more attraction.

How does the photoelectric effect equation look when plotted as a line?	 The y-intercept being the work function and the x-intercept being the threshold frequency.
What happens during the gold leaf experiment?	 The zinc rod/plate is negatively charged ∴ gold leaf hangs tilted. Shining UV light causes it to discharge ∴ leaf falls down.
What is the stopping potential?	Minimum p.d. required on a metal plate to attract all photoelectrons emitted from the surface back.
Describe the vacuum photocell	 ● The metal surface is the anode (∴ positively charged so can attract e^-'s back). ● Light with frequency > f_0 is shone on the anode so that photoelectrons are emitted. ● Applying a sufficient p.d will cause electrons to be attracted back ∴ current flows ● The photocell is evacuated to prevent photoelectrons colliding with air molecules.

What is the equation linking $E_{k\ (max)}$ to stopping potential?	$$E_{k(max)} = e \cdot V_s$$ *As V = E/Q, multiplying it by the charge of an electron gives J.*
What's the difference between excitation with electrons and photons?	● An **electron** can **deliver more energy** (e.g., a 5.3 eV electron colliding with and moving another electron up by 4.9 eV before mar carrying on with 0.4 eV). ● A **photon** has to **deliver** the **exact amount** (e.g., exactly 4.9 eV) as it's absorbed.
What is de-excitation?	When an electron moves from a higher energy level to a lower energy level whilst emitting a photon of fixed frequency.
What is the excitation/de-excitation amount determined by?	$$hf = E_1 - E_2$$
What happens in fluorescent lights?	1. Electrons are accelerated via a tube of mercury vapour atoms using a voltage, collide the electrons, transferring energy and thus exciting them. 2. Upon de-exciting, they emit UV photons of energy = difference in energy levels. 3. Fluorescent coating absorbs the UV photons, causes electrons to excite which upon de-exciting indirectly, emit visible photons. *The coating has to be on the inside of the glass as glass can absorb UV too.*
Why must mercury gas be at a low pressure in fluorescent lights?	● Electrons must be able to travel a sufficient distance to gain sufficient energy required for excitations (1). ● Electrons need to be able to pass through.
What can you view an the spectrum of a light source using?	A diffraction grating and spectrometer.
What is a continuous spectrum?	An emission spectrum that consists of a continuum of wavelengths.
What is an emission spectrum and an absorption spectrum?	● An emission spectrum is a spectrum of electromagnetic radiation emitted from electrons de-exciting:

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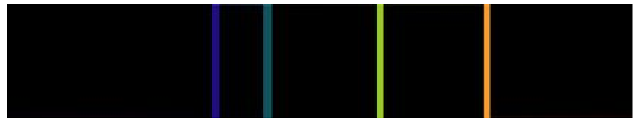

- An absorption spectrum is a spectrum of electromagnetic radiation transmitted via a substance with dark vertical lines corresponding to waves absorbed.


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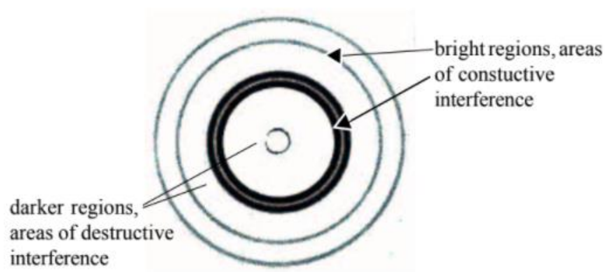
<tr><td>What wave-like and particle-like properties do electrons exhibit?</td><td>

- Wave-like - electrons diffract and interfere when passing through a small enough gap.
- Particle-like - electrons are deflected in electric and magnetic fields.
</td></tr>
<tr><td>How can the wave-like nature of electrons be observed?</td><td>

1. Fire electrons via a crystalline structure causing them to diffract onto a fluorescent screen.
2. An illuminated pattern of concentric bright and dark circles is formed corresponding to areas of constructive and destructive interference respectively.



These are fired by accelerating them through a potential difference. A larger potential difference would mean they're accelerated more and gain more kinetic energy leading to a smaller wavelength and thus less diffraction so closer rings.
</td></tr>
<tr><td>What structure is required for electron diffraction and why?</td><td>

- Crystalline structure.
- The gaps between atoms ≅ De Broglie wavelength of electron for maximum diffraction to occur.
</td></tr>
<tr><td>Why is light both a wave and particle?</td><td>

- It undergoes things such as refraction, diffraction, and dispersion.
- Yet, also undergoes the photoelectric effect.
</td></tr>
<tr><td>What is the De Broglie wavelength?</td><td>The wavelength of matter.</td></tr>
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