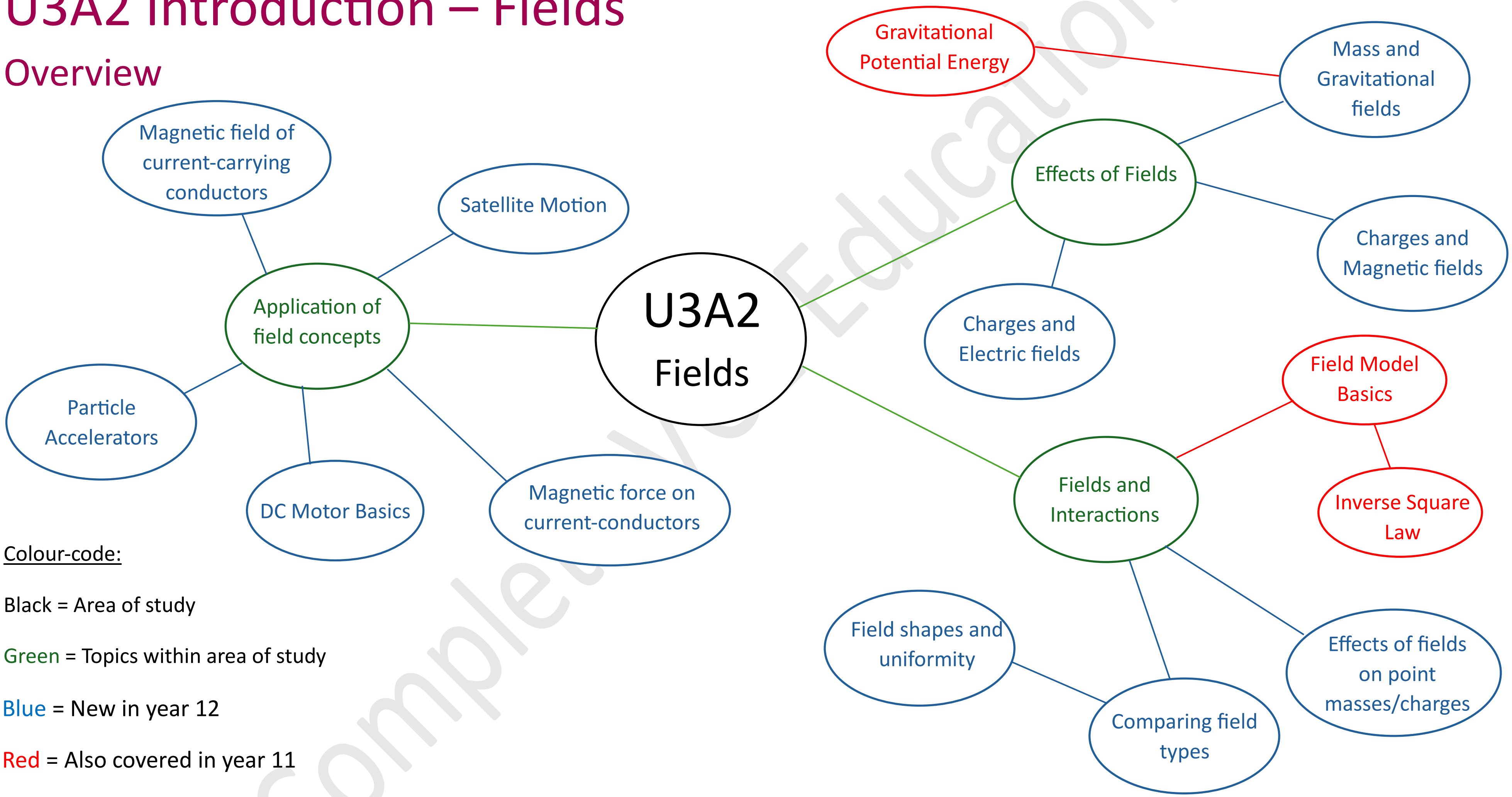
U3A2 Introduction – Fields

Overview



<u>Colour-code:</u>

Black = Area of study

Green = Topics within area of study

Blue = New in year 12

Red = Also covered in year 11

Topic 1 – Fields and Interactions

Subtopic	Elaboration	Relevant Year 11 Knowledge	Formulas and Concepts	SAC/Exam Tips	Example Questions
The Field model	The basics of how the field model explains non-contact forces in three major categories: gravitational, magnetic and electrical. While different in certain properties, all three can be explained in the same model of lines and arrows.	• Drawing basic Physics diagrams (such as force diagrams) • Inverse square law (may have been learnt alongside thermodynamics) • Gravity (as a concept) • Electric charges	• **Inverse Square Law:** Describes the distribution of a field's strength as a proportion to the distance from its centre. As the name suggests, it follows an *inverse square* relationship with distance. • **Field lines:** A graphical depiction of the direction, *uniformity, shape* and *strength* of a field at various points.	• Questions under this subtopic typically fall under two main categories; recollection of theory, or drawing of field lines. • There is little helpful information on the formula sheet for field model questions. • These questions are usually not worth many marks and should be completed quickly to save time.	• 'Draw 10 field lines around this bar magnet' • 'How much weaker is the gravitational field strength of Mars at an altitude of two radii compared to at its surface?'
The nature of field types	Goes into more detail about each of the field types and how they differ from each other.		• **Field directions:** Whether it be poles or dipoles, outwards or toward the centre, or anything in between, all three field types have slightly different properties that make them unique. The magnetic field direction of straight wires and solenoids can be found using the right-hand grip rule, and right-hand coil rule respectively. • **Magnetic Phenomena:** Generation of magnetic fields from current-carrying conductors, solenoids, bar magnets and other ways such a field type is generated.	• These kinds of questions fall under a similar banner to the previous subtopic, involving mostly theory and remembering key portions of information – such as there being no such thing as a magnetic monopole.	• 'Compare and contrast the shape and directions of gravitational and magnetic fields.' • 'Is a magnetic field produced by a solenoid an example of a uniform or non-uniform field?'

Topic 2 – Field Effects

Subtopic	Elaboration	Relevant Year 11 Knowledge	Formulas and Concepts	SAC/Exam Tips	Example Questions
Electric Fields	Focuses on how electric fields affect the motion of point charges with regards to different field subtypes, such as uniform electric fields.	Familiarity with units and concepts relating to electricity would be useful, such as charge, voltage, current, etc.	• **Coulomb's Law:** Describes the magnitude of force between two electrical charges. $F = k\frac{q_1 q_2}{r^2}$ • **Electric field due to a point charge:** $E = k\frac{Q}{r^2}$ • **Energy changes in an electrical field:** $W = qV, E = \frac{V}{d}$ • **Force on a charged particle due to a uniform electrical field:** $F = qE$	• Questions are heavy on calculations rather than theory, though these calculations are not particularly long (beyond the base formulas). • Fortunately most formulas are present on the VCAA formula sheet, though it may be useful to have rearranged formulas on your own cheat sheet.	• Finding force due to electrical fields between two point charges. • Finding the field strength between two plates at a particular potential difference.
Magnetic Fields	Focuses on how magnetic fields affect the motion of point charges with regards to variations in velocity, charge magnitude, etc.		• **Force on a charge by a magnetic field:** $F = qvB$ Can only be used if the charge is travelling perpendicular to the magnetic field. If 'v' is parallel to B in direction, then F = 0 always. • **Direction of magnetic force on a moving charge** Using the right hand slap rule, you can find this direction. The direction of force needs to be reversed for a negative charge. • **Radius of path followed by a point charge in a magnetic field:** $qvB = \frac{mv^2}{r}$ or $r = \frac{mv}{qB}$	• Once again mostly calculation questions involving a set of given variables (or diagram). • All relevant formulas are on the VCAA formula sheet. • VCAA place a particular importance on radius questions – they are rather common!	• Finding the initial velocity of an electron travelling through a magnetic field of a particular strength with a certain radius. • Amount of force on an electron travelling perpendicular to a magnetic field.

Gravitational Fields	Expands on the initial content of gravitational fields with more advanced gravitational field strength and force formulas, with a strong emphasis on finding changes in gravitational potential energy – particularly under a curve.	• Gravitational Potential energy calculations $E_g = mg\Delta h$ • Kinetic energy calculations $E_k = \frac{1}{2}mv^2$	• **Gravitational field strength:** $g = G\frac{M}{r^2}$ • **Force due to gravitational field:** $F_g = G\frac{m_1 m_2}{r^2}$ • **Area under gravitational force/field strength curve** The area under gravitational force graphs correlates to the change in gravitational potential energy between two distances from the planet's centre.	• More calculations using variables. • A trick questions VCAA always seems to ask is how much energy it would take to put a rocket into orbit. The pitfall here is forgetting that **kinetic energy is also required** on top of GPE to put it at a speed suitable for orbit! • Keep an eye on the axes of gravitational force/field graphs – if it's a field strength graph, the final area still needs to be multiplied by the mass of the object.	• 'How much energy would it take to put a satellite into orbit at a certain orbit velocity?' • The magnitude of gravitational force between two bodies of mass.

Topic 3 – Application of Field Concepts

Subtopic	Elaboration	Relevant Year 11 Knowledge	Formulas and Concepts	SAC/Exam Tips	Example Questions
Satellite Motion	Delves further into gravitational fields through the lens of satellites and orbital motion. Links heavily back to circular motion from the previous AOS in terms of understanding and formulas.	• Gravitational force calculations $F = mg$ • Normal force (as a concept) • Labelling force diagrams	• **Circular motion:** Akin to AOS 1 with an additional formula for use with scenarios involving orbits. $a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$ • **Kepler's Third Law:** Used for comparing the orbits of different satellites – derivation is not on formula sheet! The latter proportionality must only be used for satellites of the same planet. $\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ or $\frac{{r_1}^3}{{T_1}^2} = \frac{{r_2}^3}{{T_2}^2}$ • **Types of satellites:** Geosynchronous: Have orbital period of 24 hours Geostationary (commonly asked on exams): Type of geosynchronous satellite which is always above same point on Earth. Must be above Equator.	• Questions are heavy on calculations rather than theory, however these questions can be quite mark-heavy (often 3-5 marks). • No derived formulas are on the formula sheet so efficient cheat-sheet use is critical, especially for Kepler's Third Law questions. • Always check whether the question is giving or asking you for the radius or altitude of orbit.	• Solving for any one variable in Kepler's Third Law for a given satellite. • Finding orbital velocity of a moon, for example.
Applications of Magnetic Fields	Focuses on the effects of magnetic fields on the motion of current-carrying conductors in particular rather than just point charges. A major practical focus is placed on the operation of DC motors, which transform electrical energy to mechanical energy.	• Familiarity with electricity calculations (Voltage, Current, Resistance, etc.)	• **Magnetic force on a current-carrying conductor:** $F = nIlB$ Once again can only be used if the direction of 'I' is perpendicular to 'B'. If they are parallel, F = 0. • **Principles of DC motor function:** Understanding all of the components of a DC motor and how they function together to work. A particular emphasis is placed on understanding why split-ring commutators are needed. • **Magnetic force of a free current-carrying wire:** A straight wire can also create its own magnetic field if an electrical current passes through it. This is typically in a circular field shape around the wire.	• This subtopic has a mix of calculation and theory questions, with the calculations not straying too far from VCAA supplied formulas, and the theory mostly relating to DC motors. • All relevant formulas are on the VCAA formula sheet. • Always make sure the direction of the current is perpendicular to the magnetic field. Refer to the right-hand slap rule for verification.	• Amount of force a current-carrying wire experiences when placed perpendicular to a particular magnetic field. • Whether two wires will attract or push away from each other depending on the direction of current.

Applications of Electrical fields	Whilst not as far as the magnetic and gravitational fields, electrical field concepts are further expanded on with an introduction to particle accelerators. Further electricity details are to follow in AOS 3, which is almost completely dedicated to it.	• Familiarity with electricity calculations (Voltage, Current, Resistance, etc.) • Energy transformations	• **How does a particle accelerator work?** Particle accelerators can be modelled simply as cases of circular motion in the case of appliances such as the synchrotron. It is important to remember that acceleration is performed by the electrical field, but the magnetic field controls direction. Basic particle accelerators such as two charged plate 'rings' can also be used as a basis for **electrical work** to **kinetic energy** transformations on electrons for example.	• This topic isn't completely fleshed out as it is saved for AOS 3 – hence it's small size compared to the rest of the subtopics. • As mentioned in the concepts section, this topic heavily borrows concepts from energy transformations and circular motion (as a model).	• 'Explain how the magnetic and electrical forces contribute to the workings of the Australian Synchrotron.' • Determining acceleration voltage from final speed between two charged plates (or vice-versa).