## Mapping guide: Legacy AS and A2 Units 7892 to H245

## Content of Pure Core (Mandatory papers Y540 and Y541)

| **OCR Reference.** | **Content Description**  (unshaded content is AS content) | **Legacy Unit and Reference** | **Notes** |
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| **4.01a** | a) Be able to construct proofs using mathematical induction.  *This topic may be tested using any relevant content including divisibility, powers of matrices and results on powers, exponentials and factorials.*  *e.g.*  *Prove that  for  .*  *Prove that  is divisible by 4 for  .*  *Prove that  for  .* | 4725 FP1 – Proof by Induction (a) | (a) use the method of mathematical induction to establish a given result (not restricted to summation of series)  Excluding summation of series. |

***DISCLAIMER***

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| **4.01b** | b) Be able to construct proofs of a more demanding nature, including conjecture followed by proof.  *This topic may be tested using any relevant content including sums of series.*  *e.g. Prove that*  *for all*  .  *Prove that  for .*  *Prove that  for .*  *Prove that  for any real number  and  .*  *Prove that the n*th *derivative of  is  .* | 4725 FP1 – Proof by Induction (a) & (b) | (a) use the method of mathematical induction to establish a given result (not restricted to summation of series)  (b) recognise situations where conjecture based on a limited trial followed by inductive proof is a useful strategy, and carry this out in simple cases, e.g. to find the *n*th power of the matrix |
| **4.02a** | a) Understand the language of complex numbers.  *Know the meaning of “real part”, “imaginary part”, “conjugate”, “modulus” and “argument” of a complex number.* | 4725 FP1 – Complex Numbers (a) | (a) understand the idea of a complex number, recall the meaning of the terms ‘real part’, ‘imaginary part’, ‘modulus’, ‘argument’, ‘conjugate’, … |
| **4.02b** | b) Be able to express a complex number *z* in either the cartesian form , where , or modulus-argument form , where  is the modulus of *z* and *θ,* measured in radians, is the argument of *z*. | 4725 FP1 – Complex Numbers (a) | Modulus-argument form not explicitly included in 4725, although the terms modulus and argument are included. |
| **4.02d** | d) Understand and be able to use the exponential form, , of a complex number. | 4727 FP3 – Complex Numbers (d) | (d) use expressions for and  in terms of , e.g. in expressing powers of  and  in terms of multiple angles or in summing series |
| **4.02c** | c) Understand and be able to use the notation:  *z*, , , , , .  *Includes knowing that a complex number is zero if and only if both the real and imaginary parts are zero.*  *The principal argument of a complex number, for uniqueness, will be taken to lie in either of the intervals  or . Learners may use either as appropriate unless the interval is specified.*  *In stage 1 knowledge of radians is assumed: see H240 section 1.05d.* | 4725 FP1 – Complex Numbers (a) | Notation , , , ,  is not explicitly included in 4725 although the terms conjugate, real part, imaginary part, argument and modulus are included. |
| **4.02e** | e) Be able to carry out basic arithmetic operations  of complex numbers in both cartesian and modulus-argument forms.  *In stage 1 knowledge of radians and compound angle formulae is assumed: see H240 sections 1.05d and 1.05l.*  *Learners may use the results*  *and .* | 4725 FP1 – Complex Numbers (b) | *(*b) carry out operations of addition, subtraction, multiplication and division of two complex numbers expressed in cartesian form  Calculations using modulus argument form are not explicitly included in 4725. |
| **4.02f** | f) Convert between cartesian and modulus-argument forms. | 4726 FP2 – Polar Coordinates (a) | (a) understand the relations between cartesian and polar coordinates (using the convention), and convert equations of curves from cartesian to polar form and vice versa  Converting between cartesian and modulus-argument forms is not explicitly included in 4725. |
| **4.02g** | g) Know that, for a polynomial equation with real coefficients, complex roots occur in conjugate pairs. | 4725FP1 – Complex Numbers (c) | (c) use the result that, for a polynomial equation with real coefficients, any non-real roots occur in conjugate pairs |
| **4.02h** | h) Be able to find algebraically the two square roots of a complex number.  *e.g. By squaring and comparing real and imaginary parts.* | 4725 FP1 – Complex Numbers (e) | (e) find the two square roots of a complex number |
| **4.02i** | i) Be able to solve quadratic equations with real coefficients and complex roots. |  | Solving a quadratic equation with complex roots is not explicitly included in 4725. |
| **4.02j** | j) Be able to use conjugate pairs, and the factor theorem, to solve or factorise cubic or quartic equations with real coefficients.  *Where necessary, sufficient information will be given to deduce at least one root for cubics or at least one complex root or quadratic factor for quartics.* |  | Using conjugate pairs and the factor theorem to solve cubic and quartic equations is not explicitly included in 4725. |
| **4.02k** | k) Be able to represent and interpret Argand diagrams.  *e.g. To represent and interpret complex numbers geometrically.*  *Understand and use the terms “real axis” and “imaginary axis”.* | 4725 FP1 – Complex Numbers (d) | (d) represent complex numbers geometrically by means of an Argand diagram, …  4.02k and 4.02l cover 4725 Complex Numbers (d) between them. |
| **4.02m** | m) Understand the geometrical effects of multiplying and dividing two complex numbers.  *Includes raising complex numbers to positive integer powers.* | 4727 FP3 – Complex Numbers (a) | (a) carry out operations of multiplication and division of two complex numbers expressed in polar form, and interpret these operations in geometrical terms |
| **4.02l** | l) Understand the geometrical effects of taking the conjugate a complex number, and adding and subtracting two complex numbers. | 4725 FP1 – Complex Numbers (d) | (d) … and understand the geometrical effects of conjugating a complex number and of adding and subtracting two complex numbers  4.02k and 4.02l cover 4725 Complex Numbers (d) between them. |
| **4.02n** | n) Know and be able to use Euler’s formula  .  *e.g. To express, and work with, complex numbers in the forms* . | 4727 FP3 – Complex Numbers (d) | (d) use expressions for  and  in terms of , e.g. in expressing powers of  and  in terms of multiple angles or in summing series |
| **4.02o** | o) Be able to illustrate equations and inequalities involving complex numbers by means of loci in an Argand diagram.  *i.e. Circle of the form , half-lines of the form , lines of the form , and ,*  *and regions defined by inequalities in these forms.*  *To include the convention of dashed and solid lines to show exclusion and inclusion respectively.*  *No shading convention will be assumed. If not directed, learners should indicate clearly which regions are included.*  *In stage 1 knowledge of radians is assumed: see H240 section 1.05d.* | 4725 FP1 – Complex Numbers (f) | (f) illustrate simple equations and inequalities involving complex numbers by means of loci in an Argand diagram, e.g.*, ,*  *,* is new content in thereformed specification. |
| **4.02p** | p) Understand and be able to use set notation in the context of loci.  *e.g. The region  where ,  and  may be represented by the set .*  *In stage 1 knowledge of radians is assumed: see H240 section 1.05d.* |  | Use of set notation is new content in thereformed specification. |
| **4.02q** | q) Understand de Moivre’s theorem and use it to find multiple-angle formulae and sums of series of involving trigonometric and/or exponential terms.  *Express trigonometrical ratios of multiple angles in terms of powers of trigonometrical ratios of the fundamental angle.*  *e.g.  .*  *Use expressions for  and  in terms of  or equivalent relationships.*  *e.g.*  *Express powers of  and  in terms of series of trigonometric ratios of multiples of the fundamental angle.*  *e.g. .* | 4727 FP3 – Complex Numbers (b), (c) & (d) | (b) understand de Moivre’s theorem, for positive and negative integer exponent, in terms of the geometrical effect of multiplication and division of complex numbers  (c) use de Moivre’s theorem to express trigonometrical ratios of multiple angles in terms of powers of trigonometrical ratios of the fundamental angle  (d) use expressions for and in terms of, e.g. in expressing powers of and in terms of multiple angles or in summing series |
| **4.02r** | r) Be able to find the *n* distinct *n*th roots of  for  and know that they form the vertices of a regular *n*-gon on an Argand diagram.  *Answers may be asked for in either cartesian or modulus-argument form.* | 4727 FP3 – Complex Numbers (e) | (e) find and use the *n*th roots of unity, e.g. to solve an equation of the form  Knowing that the *n*throots of  form the vertices of a regular *n*-gon on an Argand diagram is new content in the reformed specification. |
| **4.02s** | s) Be able to use complex roots of unity to solve geometric problems.  *e.g. To locate the roots of unity on an Argand diagram or to prove results about sums of roots of unity.* | 4727 FP3 – Complex Numbers (e) | (e) find and use the *n*th roots of unity, e.g. to solve an equation of the form  Use in solving geometric problems is new content in the reformed specification. |
| **4.03a** | a) Understand the language of matrices.  *Understand the meaning of “conformable”, “equal”, “square”, “rectangular”, “m by n”, “determinant”, “zero” and “null”, ”transpose” and “identity” when applied to matrices.*  *Learners should be familiar with real matrices and complex matrices.* | 4725 FP1 – Matrices (a) & (b) | (a) … and recognise the terms null (or zero) matrix and identity (or unit) matrix  (b) … evaluate determinants of matrices  The terms conformable, equal, square and rectangular are new content in the reformed specification. |
| **4.03b** | b) Be able to add, subtract and multiply conformable matrices; multiply a matrix by a scalar.  *Learners may perform any operations involving entirely numerical matrices by calculator.*  *Includes raising square matrices to positive integer powers.*  *Learners should understand the effects on a matrix of adding the zero matrix to it, multiplying it by the zero matrix and multiplying it by the identity matrix.* | 4725 FP1 – Matrices (a) | (a) carry out operations of matrix addition, subtraction and multiplication, …  Multiplication by a scalar is implied. |
| **4.03c** | c) Understand that matrix multiplication is associative but not commutative.  *Understand the terms “associative” and “commutative”.* |  | The terms associative and commutative are new content in the reformed specification. |
| **4.03d** | d) Be able to find and use matrices to represent linear transformations in 2-D.  *Includes:*   * *reflection in either coordinate axis and in the lines* * *rotation about the origin*   *(defined by the angle of rotation , where the direction of positive rotation is taken to be anticlockwise)*   * *enlargement centre the origin*   *(defined by the scale factor)*   * *stretch parallel to either coordinate axis*   *(defined by the invarient axis and scale factor)*   * *shear parallel to either coordinate axis*   *(defined by the invarient axis and the image of a tranformed point).*  *Includes the terms “object” and “image”.* | 4725 FP1 – Matrices (d)(iii) | (d) understand the use of  matrices to represent certain geometrical transformations in the plane, and in particular  (iii) find the matrix that represents a given transformation or sequence of transformations (understanding of the terms ‘rotation’, ‘reflection’, ‘enlargement’, ‘stretch’ and ‘shear’ will be required) |
| **4.03e** | e) Be able to find and use matrices to represent successive transformations.  *Includes understanding and being able to use the result that the matrix product* **AB** *represents the transformation that results from the transformations represented by* **B** *followed by the transformation represented by* **A***.* | 4725 FP1 – Matrices (d)(i) | (d) understand the use of  matrices to represent certain geometrical transformations in the plane, and in particular  (i) recognise that the matrix product **AB** represents the transformation that results from the transformation represented by **B** followed by the transformation represented by **A** |
| **4.03f** | f) Be able to use matrices to represent single linear transformations in 3-D.  *3-D transformations will be confined to reflection in one of the planes    or rotation about one of the coordinate axes. The direction of positive rotation is taken to be anticlockwise when looking towards the origin from the positive side of the axis of rotation.*  *Includes the terms “plane of reflection” and “axis of rotation”.*  *In stage 1, knowledge of 3-D vectors is assumed: see H240 section 1.10b.* |  | Matrix transformations in 3 dimensions are new content in the reformed specification. |
| **4.03g** | g) Be able to find invariant points and lines for a linear transformation.  *Includes the distinction between invariant lines and lines of invariant points.*  [*The 3-D transformations in section 4.03f are excluded.*] |  | Invariant points and lines are new content in the reformed specification. |
| **4.03h** | h) Be able to find the determinant of a  matrix with and without a calculator.  *Use and understand the notation*  *or  or* . | 4725 FP1 – Matrices (b) | (b) … evaluate determinants of matrices |
| **4.03i** | i) Know that the determinant of a  matrix is the area scale factor of the transformation defined by that matrix, including the effect on the orientation of the image.  *Learners should know that a transformation preserves the orientation of the object if the determinant of the matrix which represents it is positive and that the transformation reverses orientation if the determinant is negative, and be able to interpret this geometrically.* | 4725 FP1 – Matrices (d)(ii) | (d) understand the use of  matrices to represent certain geometrical transformations in the plane, and in particular  (ii) recall how the area scale factor of a transformation is related to the determinant of the corresponding matrix |
| **4.03j** | j) Be able to calculate the determinant of a  matrix with or without a calculator. | 4725 FP1 – Matrices (b) | (b) … evaluate determinants of matrices |
| **4.03k** | k) Know that the determinant of a  matrix is the volume scale factor of the transformation defined by that matrix, including the effect on the preservation of the orientation of the image.  *Learners should know that the sign of the determinant determines whether or not the corresponding transformation preserves orientation, but do not need to understand the geometric interpretation of this in 3-D.* |  | Geometric interpretation of  determinants is new content in the reformed specification. |
| **4.03l** | l) Understand and be able to use singular and non-singular matrices.  *Includes understanding the significance of a zero determinant.* |  | Understand and use singular and non-singular matrices are new content in the reformed specification. |
| **4.03m** | m) Know and be able to use the result that . |  | This is implied in 4725. |
| **4.03n** | n) Be able to find and use the inverse of a non-singular  matrix with and without a calculator. | 4725 FP1 – Matrices (b) | (b) … find inverses of non-singular matrices |
| **4.03o** | o) Be able to find and use the inverse of a non-singular  matrix with and without a calculator. | 4725 FP1 – Matrices (b) | (b) … find inverses of non-singular matrices |
| **4.03p** | p) Understand and be able to use simple properties of inverse matrices.  *e.g. The result that .* | 4725 FP1 – Matrices (c) | (c) understand and use the result, for non-singular matrices, that |
| **4.03q** | q) Understand and be able to use the connection between inverse matrices and inverse transformations. |  | The connection between inverse matrices and inverse transformations is new content in the reformed specification. |
| **4.03r** | r) Be able to solve two or three linear simultaneous equations in two or three variables by the use of an inverse matrix, where a unique solution exists. | 4725 FP1 – Matrices (e) | (e) formulate a problem involving the solution of 2 linear simultaneous equations in 2 unknowns, or 3 equations in 3 unknowns, as a problem involving the solution of a matrix equation, and vice versa |
| **4.03s** | s) Be able to determine, for two or three linear simultaneous equations where no unique solution exists, whether the equations have an infinite set of solutions (the equations are consistent) or no solutions (the equations are inconsistent).  [*Finding the solution set in the infinite case is excluded.*] | 4725 FP1 – Matrices (f) | (f) understand the cases that may arise concerning the consistency or inconsistency of 2 or 3 linear simultaneous equations, relate them to the singularity or otherwise of the corresponding square matrix, and solve consistent systems  Use of a calculator is new content in the reformed specification. |
| **4.03t** | t) Be able to interpret the solution or failure of solution of three simultaneous linear equations in terms of the geometrical arrangement of three planes.  *Learners should know and be able to identify the different ways in which two or three distinct planes can intersect in 3-D space, including cases where two or three of the planes are parallel.*  *Learners should understand and be able to apply the geometric significance of the singularity of a matrix in relation to the solution(s) or non-existence of them.*  *[Finding the line of intersection of two or more planes is excluded.]* | 4725 FP1 – Matrices (f) | (f) understand the cases that may arise concerning the consistency or inconsistency of 2 or 3 linear simultaneous equations, relate them to the singularity or otherwise of the corresponding square matrix, and solve consistent systems  The geometric aspect of this in terms of planes is new content in the reformed specification. |
| **4.04a** | a) Understand and be able to use the equation of a straight line in 2-D and 3-D, in cartesian and vector form.  *Learners should know and be able to use the forms:*  *,  and , in 2-D, and  and  in 3-D.*  *Includes being able to convert from one form to another.* | 4721 C1 – Coordinate Geometry and Graphs (d)  4724 C4 – Vectors (f)  4727 FP3 – Vectors (a) | (d) interpret and use linear equations, particularly the forms*,and*  (f) understand the significance of all the symbols used when the equation of a straight line is expressed in the form  *(*a) understand the significance of all the symbols used when the equation of a line is expressed in the form |
| **4.04b** | b) Understand and be able to use the equation of a plane in cartesian and vector form.  *Learners should know and be able to use the forms:*  *, ,* *and .*  *Includes being able to convert from one form to another.* | 4727 FP3 – Vectors (b) | (b) understand the significance of all the symbols used when the equation of a plane is expressed in any of the forms *or* or  is implied in 4727. |
| **4.04c** | c) Be able to calculate the scalar product and use it both to calculate the angles between vectors and/or lines, and also as a test for perpendicularity.  *Includes the notation* . | 4724 C4 – Vectors (e) & (h) | (e) calculate the scalar product of two vectors (in either two or three dimensions), and use the scalar product to determine the angle between two directions and to solve problems concerning perpendicularity of vectors  (h) find the angle between two lines  4.04c and 4.04e cover 4724 Vectors (h) between them. |
| **4.04d** | d) Be able to find the angle between two planes and the angle between a line and a plane. | 4727 FP3 – Vectors (d)(iv) | (d) use equations of lines and planes to solve problems concerning distances, angles and intersections, and in particular  (iv) find the angle between a line and a plane, and the angle between two planes |
| **4.04e** | e) Be able to find, where it exists, the point of intersection between two lines.  *Includes determining whether or not lines intersect, are parallel or are skew.* | 4724 C4 – Vectors (e) & (h) | (e) … and use the scalar product to determine the angle between two directions and to solve problems concerning perpendicularity of vectors  (h) find the point of intersection of two lines when it exists  4.04c and 4.04e cover 4724 Vectors (h) between them. |
| **4.04f** | f) Be able to find the intersection of a line and a plane. | 4727 FP3 – Vectors (d)(i) | (d) use equations of lines and planes to solve problems concerning distances, angles and intersections, and in particular  (i) … and find the point of intersection of a line and a plane when it exists |
| **4.04g** | g) Be able to use the vector product to find a vector perpendicular to two given vectors.  *Includes the notation* .  *When the vector product is required, either a calculator or a formula may be used. The formula below will be given:*  .  *[The magnitude of the vector product is excluded.]* | 4737 FP3 – Vectors (c) | (c) recall the definition, in geometrical terms, of the vector product of two vectors, and, in cases whereandare expressed in component form, calculatein component form |
| **4.04h** | h) Be able to find the distance between two parallel lines and the shortest distance between two skew lines.  *For skew lines, the formula, where* **a** *and* **b** *are the position vectors of points on each line and  is a mutual perpendicular to both lines, will be given. Either will be given, or it must be established from given information including by use of the vector product.* | 4727 FP3 – Vectors (d)(v) | (d) use equations of lines and planes to solve problems concerning distances, angles and intersections, and in particular  (v) find the shortest distance between two skew lines  Finding the distance between parallel lines is new content in the reformed specification.  The formula being given is new content in the reformed specification. |
| **4.04i** | i) Be able to find the shortest distance between a point and a line.  *The formula*  *where the coordinates of the point are*  *and the equation of the line is given by* , *will be given.* | 4727 FP3 – Vectors (d)(iii) | (d) use equations of lines and planes to solve problems concerning distances, angles and intersections, and in particular  (iii) find the perpendicular distance from … a point to a line  4.04i and 4.04j cover 4727 vectors (d)(iii) between them.  The formula being given is new content in the reformed specification. |
| **4.04j** | j) Be able to find the shortest distances between a point and a plane.  *The formula* *where* **b** *is the position vector of the point and the plane is given by , will be given.* | 4727 FP3 – Vectors (d)(iii) | (d) use equations of lines and planes to solve problems concerning distances, angles and intersections, and in particular  (iii) find the perpendicular distance from a point to a plane  4.04i and 4.04j cover 4727 vectors (d)(iii) between them. |
| **4.05a** | a) Understand and be able to use the relationships between the symmetric functions of the roots of polynomial equations and the coefficients.  *Up to, and including, quartic equations.*  *e.g. For the quadratic equation  with roots  and  ,  and  .* | 4725 FP1 – Roots of Polynomial Equations (a) | (a) use the relations between the symmetric functions of the roots of polynomial equations and the coefficients (for equations of degree 2 or 3 only)  Quartic equations are new content in the reformed specification. |
| **4.05b** | b) Be able to use a substitution to obtain an equation whose roots are related to those of the original equation.  *Equations will be of at least cubic degree.* | 4725 FP1 – Roots of Polynomial Equations (b) | (b) use a given simple substitution to obtain an equation whose roots are related in a simple way to those of the original equation |
| **4.05c** | c) Extend their knowledge of partial fractions up to rational functions in which the denominator may include quadratic factors of the form  for , and in which the degree of the numerator may exceed the degree of the denominator.  *See H240 section 1.02y.* | 4726 FP2 – Rational Functions and Graphs (a) | (a) express in partial fractions a rational function in which the denominator may include a factor of the form in addition to linear factors as specified in section 5.4, and in which the degree of the numerator may exceed the degree of the denominator |
| **4.06a** | a) Understand and be able to use formulae for the sums of integers, squares and cubes and use these to sum related series.  *Formulae for  and  will be given, but learners may be asked to prove them.* | 4725 FP1 – Summation of Series (a) | (a) use the standard results for , ,  to find related sums |
| **4.06b** | b) Understand and be able to use the method of differences to find the sum of a (finite or infinite) series.  *Including the use of partial fractions.*  *e.g. Find* | 4725 FP1 – Summation of Series (b) | (b) use the method of differences to obtain the sum of a finite series |
| **4.07a** | a) Understand and be able to use the definitions of the hyperbolic functions   and  in terms of exponentials.  *Including the domain and range of each function.* | 4726 FP2 – Hyperbolic Functions (a) | (a) recall definitions of the six hyperbolic functions in terms of exponentials  , ,  excluded. |
| **4.07b** | b) Know and be able to sketch the graphs of the hyperbolic functions. | 4726 FP2 – Hyperbolic Functions (a) | (a) … and sketch the graphs of simple hyperbolic functions  , ,  excluded. |
| **4.07c** | c) Know and be able to use the identity .  *Learners may be asked to derive or use other identities, but no prior knowledge of them is assumed.*  [*Prior knowledge of other identities is excluded.*] | 4726 FP2 – Hyperbolic Functions (b) | (b) derive and use identities such as  Knowledge of  is not assumed. |
| **4.07d** | d) Be able to differentiate and integrate hyperbolic functions. | 4726 FP2 – Differentiation and Integration (b) | (b) derive and use the derivatives of,,  Integrating hyperbolic functions is implied in 4726. |
| **4.07e** | e) Understand and be able to use the definitions of the inverse hyperbolic functions and their domains and ranges. | 4726 FP2 – Hyperbolic Functions (c) | (c) use the notations ,, to denote the principal values of the inverse hyperbolic relations |
| **4.07f** | f) Be able to derive and use expressions in terms of logarithms for the inverse hyperbolic functions.  *Includes the* *notation: , ,  and , , .* | 4726 FP2 – Hyperbolic Functions (c) | (c) derive and use expressions in terms of logarithms for these  The notation *, ,* is new content in the reformed specification. |
| **4.08a** | a) Be able to find the Maclaurin series of a function, including the general term. | 4726 FP2 – Differentiation and Integration (c) | (c) use the first few terms of the Maclaurin series of , , , and |
| **4.08b** | b) Recognise and be able to use the Maclaurin series for  , , ,  and , and functions based on these.  *The interval of validity should be understood.*  [*Proof of the interval of validity and use of non-real values of x are excluded.*] | 4726 FP2 – Differentiation and Integration (d) | (d) derive and use the first few terms of the Maclaurin series of simple functions, e.g., ,  ,  (derivation of a general term is not included)  Understanding the interval of validity is new content in the reformed specification. |
| **4.08c** | c) Be able to evaluate improper integrals where either the integrand is undefined at a value in the range of integration or where the range of integration is infinite.  *e.g.*  *or* |  | Evaluating improper integrals where the integrand is undefined at a value or the range of integration is infinite is new content in the reformed specification. |
| **4.08d** | d) Be able to derive formulae for and calculate volumes of solids of revolution.  *To include solids generated using either coordinate axis as the axis of rotation, and the volume of a solid formed by rotation of a region between two curves.*  *This includes curves defined parametrically.* | 4723 C3 – Differentiation and Integration (h) | (h) use definite integration to find a volume of revolution about one of the coordinate axes (including, for example, the region between the curves and, rotated about the *x*-axis.) |
| **4.08e** | e) Understand and be able to evaluate the mean value of a function.  *Includes the use of: mean value .* |  | Understanding and evaluating the mean value of a function is new content in the reformed specification. |
| **4.08f** | f) Be able to integrate using partial fractions.  *See Further Algebra section 4.05c and H240 section 1.02y for permitted forms.* | 4724 C4 – Differentiation and Integration (e) | (e) integrate rational functions by means of decomposition into partial fractions |
| **4.08g** | g) Be able to derive and use the derivatives of ,  and , ,  and . | 4726 FP2 – Differentiation and Integration (a) & (b) | (a) derive and use the derivatives of,,  (b) derive and use the derivatives of,, |
| **4.08h** | h) Be able to integrate functions of the form: , ,  and  and use an appropriate inverse trigonometric or hyperbolic substitution for the evaluation of associated definite or indefinite integrals. | 4726 FP2 – Differentiation and Integration (e) | (e) integrate , , and , and use appropriate trigonometric or hyperbolic substitutions for the evaluation of definite or indefinite integrals (the substitution  is included)  4.08h and 8.06c cover 4726 Differentiation and Integration (e) between them. |
| **4.09a** | a) Understand and be able to use polar coordinates (using the convention ) and be able to convert between polar and cartesian coordinates. | 4726 FP2 – Polar Coordinates (a) | (a) understand the relations between cartesian and polar coordinates (using the convention), and convert equations of curves from cartesian to polar form and vice versa |
| **4.09b** | b) Be able to sketch polar curves, with *r* given as a function of  *Identify significant features of polar curves such as symmetry, and least and greatest values of r.*  *Includes use of trigonometric functions.* | 4726 FP2 – Polar Coordinates (b) | (b) sketch simple polar curves, for or or a subset of either of these intervals, and identify significant features of polar curves such as symmetry, least/greatest values of *r* |
| **4.09c** | c) Be able to find the area enclosed by a polar curve.  *Be able to use the formula .* | 4726 FP2 – Polar Coordinates (c) | (c) use the formula  for the area of a sector in simple cases |
| **4.10a** | a) Understand the difference between, and be able to find, general and particular solutions to differential equations.  *Includes understanding that the general solution will include arbitrary constant(s) and that the particular solution may be found from initial or boundary conditions.* | 4724 C4 – First Order Differential Equations (c)  4727 FP3 – Differential Equations (f) | (c) use an initial condition to find a particular solution of a differential equation  (f) use initial conditions to find a particular solution to a differential equation, and interpret the solution in the context of a problem modelled by the differential equation |
| **4.10b** | b) Be able to use differential equations in modelling in kinematics and in other contexts.  *Includes use of Newton’s second law of motion and the language of kinematics including the notation  and* .  *Includes problems involving variable force.*  *Problems may include formulating differential equations which leaners cannot solve analytically.*  [*Problems involving either variable mass or the form  are excluded.*] | 4724 C4 – First Order Differential Equations (a)  4730 M3 – Linear Motion under a Variable Force (a) & (b)  4730 M3 – Simple Harmonic Motion (b) | (a) formulate a simple statement involving a rate of change as a differential equation, including the introduction if necessary of a constant of proportionality  (a) use for velocity, and for acceleration, as appropriate  (b) solve problems which can be modelled as the linear motion of a particle under the action of a variable force, by setting up and solving an appropriate differential equation (restricted to equations in which the variables are separable)  (b) Set up the differential equation of motion in problems leading to SHM, quote appropriate forms of solution, and identify the period and amplitude of the motion |
| **4.10c** | c) Be able to find and use an integrating factor  to solve differential equations of the form  .  *Includes recognising when it is appropriate to do so, rearranging into the given form when necessary.* | 4727 FP3 – Differential Equations (a) | (a) find an integrating factor for a first-order linear differential equation, and use an integrating factor to find the general solution |
| **4.10d** | d) Be able to solve differential equations of the form , where *a* and *b* are constants, by using the auxiliary equation.  *Include rearranging into the given form when necessary.*  *Learners should be able to interpret the sign of the discriminant of the auxiliary equation and how it determines the form of the complementary function.*  *Including the cases when the roots of the auxiliary equation are:*  *(i) distinct and real,*  *(ii) repeated,*  *(iii) complex.* | 4727 FP3 – Differential Equations (d) | (d) find the complementary function for a first or second order linear differential equation with constant coefficients  The term auxiliary equation is new content in the reformed specification. |
| **4.10e** | e) Be able to solve differential equations of form , where *a* and *b* are constants, by solving the homogeneous case and adding a particular integral to the complementary function (in cases where  is a polynomial, exponential or trigonometric function).  *Includes cases where the form of the complementary function affects the choice of trial integral for the particular integral.*  *Includes cases where the form of the particular integral is given.* | 4727 FP3 – Differential Equations (c), (d) & (e) | (c) recall the meaning of the terms ‘complementary function’ and ‘particular integral’ in the context of linear differential equations, and use the fact that the general solution is the sum of the complementary function and a particular integral  (d) find the complementary function for a first or second order linear differential equation with constant coefficients  (e) recall the form of, and find, a particular integral for a first or second order linear differential equation in the cases where  or  or  is a suitable form, and in other cases find the appropriate coefficient(s) given a suitable form of particular integral;  The term homogeneous is new content in the reformed specification. |
| **4.10f** | f) Be able to solve the equation for simple harmonic motion (SHM)  and relate the solution to the motion.  *Includes use of the formula*  *and in*  *modelling situations.*  *Learners may quote these formulae without proof when not asked to derive it or to solve the SHM equation.* | 4730 M3 – Simple Harmonic Motion (b) | (b) Set up the differential equation of motion in problems leading to SHM, quote appropriate forms of solution, and identify the period and amplitude of the motion |
| **4.10g** | g) Be able to model damped oscillations using second order differential equations and interpret their solutions.  *The terms “underdamping”, “overdamping” and “critical damping” should be known and understood informally.* |  | Damped oscillations are new content in the reformed specification. |
| **4.10h** | h) Be able to analyse and interpret models of situations with one independent variable and two dependent variables as a pair of coupled, simultaneous, first order differential equations, and be able to solve them.  *e.g. Predator-prey models, continuous population models, industrial processes.*  *Includes solution by eliminating one variable to produce a single second order equation.*  *Systems will be of the form:*  ,  *or easily reducible to this form.* |  | Coupled, simultaneous, first order differential equations are new content in the reformed specification. |

### Content of Statistics (Optional paper Y542)

| **OCR Reference** | **Content Description**  (unshaded content is AS content) | **Legacy Unit and Reference** | **Notes** |
| --- | --- | --- | --- |
| **5.01a** | a) Be able to evaluate probabilities by calculation using permutations and combinations.  *Includes the terms permutation and combination*.  *Includes the notation  and  .*  *For underlying content on probability see H240 section 2.03.* | 4732 S1 – Probability (a) | (a) understand the terms permutation and combination |
| **5.01b** | b) Be able to evaluate probabilities by calculation in contexts involving selections and arrangements.  *Selection problems include, for example, finding the probability that 3 vowels and 2 consonants are chosen when 5 letters are chosen at random from the word ‘CALCULATOR’.*  *Arrangement problems only involve arrangement of objects in a line and include*  *1. repetition, e.g. the probability that the word*  *‘ARTIST’ is formed when the letters of the word*  *‘STRAIT’ are chosen at random.*  *2. restriction, e.g. the probability that two consonants*  *are (or are not) next to each other when the letters*  *of the word ‘TRAITS’ are placed in a random order.* | 4732 S1 – Probability (b), (c) & (d) | (b) solve problems about selections, e.g. finding the number of ways in which a team of 3 men and 2 women can be selected from a group of 6 men and 5 women  (c) solve problems about arrangements of objects in a line, including those involving  (i) repetition (e.g. the number of ways of arranging the letters of the word ‘NEEDLESS’)  (ii) restriction (e.g. the number of ways several people can stand in a line if 2 particular people must — or must not — stand next to each other)  (d) evaluate probabilities in simple cases by means of enumeration of elementary events (e.g. for the total score when two fair dice are thrown) or by calculation using permutations and combinations |
| **5.02a** | a) Understand and be able to use discrete probability distributions.  *Includes using and constructing probability distribution tables and functions relating to a given situation involving a discrete random variable.*  *Any defined non-standard distribution will be finite.* | 4732 S1 – Discrete Random Variables (b)  4733 S2 – The Poisson Distribution (c) | (b) use formulae for probabilities for the binomial and geometric distributions, and model given situations by one of these, as appropriate (the notations  and  are included)  (c) understand informally the relevance of the Poisson distribution to the distribution of random events, and use the Poisson distribution as a model  Discrete uniform distribution is new content in the reformed specification. |
| **5.02b** | b) Understand and be able to calculate the expectation and variance of a discrete random variable.  *Includes knowing and be able to use the formulae*      [*Proof of these results is excluded.*] | 4732 S1 – Discrete Random Variables (a) | (a) construct a probability distribution table relating to a given situation involving a discrete random variable, and calculate the expectation, variance and standard deviation of (the notationsfor expectation (also referred to as expected value or mean) and for variance, are included) |
| **5.02c** | c) Know and be able to use the effects of linear coding on the mean and variance of a random variable. | 4734 S3 – Linear Combinations (a)(i) | (a) Use, in the course of solving problems, the results that  (i)and |
| **5.02d** | d) Know and be able to use the formulae and  for a binomial distribution.  *[Proof of these results is excluded.]*  *For the underlying content on binomial distributions, see H240 sections 2.04b and 2.04c.* | 4732 S1 – Discrete Random Variables (d) | (d) use formulae for the expectation and variance of the binomial distribution…  5.05d and 5.02h cover 4732 Discrete Random Variables (d) between them. |
| **5.02e** | e) Know and be able to use the conditions under which a random variable will have a discrete uniform distribution, and be able to calculate probabilities and the mean and variance for a given discrete uniform distribution.  *Includes use of the notation for the uniform distribution over the interval* . |  | Discrete uniform distribution is new content in the reformed specification. |
| **5.02f** | f) Know and be able to use the conditions under which a random variable will have a geometric distribution.  *Includes use of the notation , where X is the number of trials up to and including the first success.* | 4732 S1 – Discrete Random Variables (b) | (b) … and model given situations by (the geometric distribution), as appropriate (the notation is included)  (The binomial distribution is covered in H240.) |
| **5.02g** | g) Be able to calculate probabilities using the geometric distribution.  *Learners may use the formulae  and .* | 4732 S1 – Discrete Random Variables (b) | (b) use formulae for probabilities for the… and geometric distribution  (The binomial distribution is covered in H240.) |
| **5.02h** | h) Know and be able to use the formulae and  for a geometric distribution.  [*Proof of these results is excluded.*] | 4732 S1 – Discrete Random Variables (d) | (d) use formulae for the … and for the expectation of the geometric distribution  Variance of the geometric distribution is new content in the reformed specification.  5.05d and 5.02h cover 4732 Discrete Random Variables (d) between them. |
| **5.02i** | i) Understand informally the relevance of the Poisson distribution to the distribution of random events, and be able to use the Poisson distribution as a model.  *Includes use of notation  , where X is the number of events in a given interval.* | 4733 S2 – The Poisson Distribution (c) | (c) understand informally the relevance of the Poisson distribution to the distribution of random events, and use the Poisson distribution as a model |
| **5.02j** | j) Understand and be able to use the formula . | 4733 S2 – The Poisson Distribution (a) | (a) calculate probabilities for the distribution, directly from the formula…  5.02j and 5.03k cover 4733 Poisson Distribution (a) between them. |
| **5.02k** | k) Be able to calculate probabilities using the Poisson distribution, using appropriate calculator functions.  *Learners are expected to have a calculator with the ability to access probabilities from the Poisson distribution.*  [*Use of the Poisson distribution to calculate numerical approximations for a binomial distribution is excluded.*] | 4733 S2 – The Poisson Distribution (a) | (a) calculate probabilities for the distribution, … and also by using tables of cumulative Poisson probabilities (or equivalent calculator functions)  Using tables of cumulative Poisson probabilities is not required in the reformed specification.  Note that it is expected that calculators available in the assessment will be able to access probabilities from the Poisson distribution. |
| **5.02l** | l) Know and be able to use the conditions under which a random variable will have a Poisson distribution.  *Learners will be expected to identify which of the modelling conditions [assumptions] is/are relevant to a given scenario and to explain them in context.* | 4733 S2 – The Poisson Distribution (c) | (c) understand informally the relevance of the Poisson distribution to the distribution of random events  Modelling conditions [assumptions] are implied in 4733. |
| **5.02m** | m) Be able to use the result that if  then the mean and variance of *X* are each equal to . | 4733 S2 – The Poisson Distribution (b) | (b) use the result that if  then the mean and variance of are each equal to |
| **5.02n** | n) Know and be able to use the result that the sum of independent Poisson variables has a Poisson distribution. | 4734 S3 – Linear Combinations (a)(vi) | (a) Use, in the course of solving problems, the results that  (vi) if  and have independent Poisson distributions then has a Poisson distribution |
| **5.03a** | a) Understand and be able to use the concept of a continuous random variable, a probability density function (p.d.f.) and a cumulative distribution function (c.d.f).  *Includes the normal, continuous uniform and exponential distributions.*  *Includes understanding informally the link between the exponential and Poisson distributions.*  *Includes knowing and being able to use the formula for the mean and variance of the continuous uniform and exponential distribution.*  *For the underlying content on normal distributions, see H240 sections 2.04e, 2.04f and 2.04g.* | 4733 S2 – Continuous Random Variables (a)  4734 S3 – Continuous Random Variables (a) | (a) understand the concept of a continuous random variable, and recall and use properties of a probability density function (restricted to functions defined over a single interval)  (a) use probability density functions which may be defined ‘piecewise’ |
| **5.03b** | b) Be able to use a probability density function (including where defined piecewise) to solve problems involving probabilities.  *Includes knowing and being able to use* . | 4733 S2 – Continuous Random Variables (b)  4734 S3 – Continuous Random Variables (a) | (b) use a probability density function to solve problems involving probabilities, …  (a) use probability density functions which may be defined ‘piecewise’  5.03b and 5.03c cover 4733 Continuous Random Variables (b) between them. |
| **5.03c** | c) Be able to calculate the mean and/or variance of a distribution using the formulae  and . | 4733 S2 – Continuous Random Variables (b) | (b) use a probability density function … and to calculate the mean and variance of a distribution  5.03b and 5.03c cover 4733 Continuous Random Variables (b) between them. |
| **5.03d** | d) Be able to use the general result , where  is the probability density function of the continuous random variable *X* and  is a function of *X*. | 4734 S3 – Continuous Random Variables (b) | (b) use, in simple cases, the general result, where is the probability density function of the continuous random variable  and  is a function of |
| **5.03e** | e) Be able to find and use a cumulative distribution function (including where defined piecewise) to solve problems involving probabilities.  *Includes being able to use* | 4734 S3 – Continuous Random Variables (c) | (c) understand and use the relationship between the probability density function and the (cumulative) distribution function, and use either to evaluate the median, quartiles and other percentiles |
| **5.03f** | f) Know and be able to use the relationship between the probability density function, , and the cumulative distribution function, , and use either to evaluate the median, quartiles and other percentiles. | 4734 S3 – Continuous Random Variables (c) | (c) understand and use the relationship between the probability density function and the (cumulative) distribution function, and use either to evaluate the median, quartiles and other percentiles |
| **5.03g** | g) Be able to find and use the cumulative distribution functions of related variables.  *e.g. Given the c.d.f. of X, find the c.d.f. of Y and hence the p.d.f. of Y where .* | 4734 S3 – Continuous Random Variables (d) | (d) use (cumulative) distribution functions of related variables in simple cases, e.g. given the c.d.f. of a variable , to find the c.d.f. and hence the p.d.f. of, where |
| **5.04a** | a) Be able to use the following results, including the cases where  and/or :  1. ,  2. if *X* and *Y* are independent then  . | 4734 S3 – Linear Combinations of Random Variables (a)(i), (ii), (iii) | (a) Use, in the course of solving problems, the results that  (i) and  (ii)  (iii)  for independent  and |
| **5.04b** | b) Be able to use the following results:  1. If *X* has a normal distribution then  has a  normal distribution.  2. If *X* and *Y* have independent normal distributions  then has a normal distribution. | 4734 S3 – Linear Combinations of Random Variables (a)(iv), (v) | (a) Use, in the course of solving problems, the results that  (iv) if has a normal distribution then so does  (v) if and  have independent normal distributions then has a normal distribution |
| **5.05a** | a) Know that for any randomly and independently selected sample, , of size  taken from a population, then for the sample mean :  1. ,  2.  and  3.  is approximately normally distributed when *n* is  large (approximately ).  [*Proof of these results is excluded.*] | 4733 S2 – Sampling and Hypothesis Tests (c) & (e) | (c) recognise that a sample mean can be regarded as a random variable, and use the facts that  and that  (e) use the Central Limit Theorem where appropriate |
| **5.05b** | b) Know that unbiased estimates of the population mean and variance are given by  and  respectively.  [*Proof of these results is excluded.*]  *Only an informal understanding of “unbiased” is required.* | 4733 S2 – Sampling and Hypothesis Tests (f) | (f) calculate unbiased estimates of the population mean and variance from a sample, using either raw or summarised data (only a simple understanding of the term ‘unbiased’ is required) |
| **5.05c** | c) Be able to use a normal distribution to carry out a hypothesis test for a population mean in the following cases.  1. A sample drawn from a normal population of  known, given or assumed variance,  2. A large sample drawn from any population with  known, given or assumed variance,  3. A large sample, drawn from any population with  unknown variance. | 4733 S2 – Sampling and Hypothesis Tests (i)(i) & (i)(ii) | (i) Formulate hypotheses and carry out a hypothesis test of a population mean in the following cases:  (i) a sample drawn from a normal distribution of known variance  (ii) a large sample, using the Central Limit Theorem and an unbiased variance estimate derived from the sample |
| **5.05d** | d) Be able to use a normal distribution to find a confidence interval for a population mean in each of the above cases. | 4734 S3 – Confidence Intervals; the *t* Distribution (a) | (a) determine a confidence interval for a population mean, using a normal distribution, in the context of  (i) a sample drawn from a normal population of known variance  (ii) a large sample, using the Central Limit Theorem and an unbiased variance estimate derived from the sample |
| **5.06a** | a) Be able to use a chi-squared ( ) test with the appropriate number of degrees of freedom to test for independence in a contingency table and interpret the results of such a test.  *Rows or columns, as appropriate, should be combined so that each expected frequency is at least 5, and Yates’ correction should be used in the special case of a  table.*  *A table of critical values of the  distribution will be provided*.  *Includes calculation of expected frequencies and contributions to the test statistic.*  *Questions may require candidates to calculate some expected frequencies and contributions to the test statistic, but will not involve lengthy calculations.* | 4734 S3 –  tests (c) | (c) use a test with the appropriate number of degrees of freedom to test for independence in a contingency table (rows or columns, as appropriate, should be combined so that each expected frequency is at least 5, and Yates’ correction should be used in the special case of a table) |
| **5.06b** | b) Be able to fit a theoretical distribution, as prescribed by a given hypothesis involving a given ratio, proportion or discrete uniform distribution, to given data.  Q*uestions may require candidates to calculate some expected frequencies, but will not involve lengthy calculations*. | 4734 S3 –  tests (a) | (a) fit a theoretical distribution, as prescribed by a given hypothesis, to given data (questions set will not involve lengthy calculations) |
| **5.06c** | c) Extend their knowledge of fitting distributions to other known or given discrete and continuous distributions.  Q*uestions may require candidates to calculate some expected frequencies, but will not involve lengthy calculations*. | 4734 S3 –  tests (a) | (a) fit a theoretical distribution, as prescribed by a given hypothesis, to given data (questions set will not involve lengthy calculations) |
| **5.06d** | c) Be able to use a  test with the appropriate number of degrees of freedom to carry out the corresponding goodness of fit test.  *Where necessary, adjacent classes should be combined so that each expected frequency is at least 5.*  *A table of critical values of the distribution will be provided*. | 4734 S3 –  tests (b) | (b) use a test with the appropriate number of degrees of freedom to carry out the corresponding goodness of fit test (classes should be combined so that each expected frequency is at least 5) |
| **5.07a** | a) Understand what is meant by a non-parametric hypothesis test, appreciate situations where such tests are useful and be able to select an appropriate test. | 4735 S4 – Non-parametric Tests (a) | (a) understand what is meant by a non-parametric significance test, appreciate situations where such tests are useful, and select an appropriate test |
| **5.07b** | b) Understand the basis of sign tests, the Wilcoxon signed-rank test and the Wilcoxon rank-sum test (also known as the Mann-Whitney U test).  *Tables of critical values of T and W will be provided*. *Learners should know the notation  and .* | 4735 S4 – Non-parametric Tests (b) | (b) understand, in simple terms, the basis of sign tests, Wilcoxon signed-rank tests and the Wilcoxon rank-sum test, …  5.07b and 5.07f cover 4735 Non-parametric Tests (b) between them. |
| **5.07c** | c) Be able to test a hypothesis concerning a population median using a single-sample sign test and a single-sample Wilcoxon signed-rank test.  [*Problems in which observations coincide with the hypothetical population median are excluded.*] | 4735 S4 – Non-parametric Tests (c) | (c) test a hypothesis concerning a population median using a single-sample sign test and a single-sample Wilcoxon signed-rank test (problems in which observations coincide with the hypothetical population median will not be set) |
| **5.07d** | d) Understand the difference between a paired-sample test and a two-sample test, and be able to select the appropriate form of test when solving problems. | 4734 S3 – Difference of Population Means and Proportions (a) | (a) understand the difference between a two-sample test and a paired-sample test, and select the appropriate form of test in solving problems |
| **5.07e** | e) Be able to test for identity of populations using a paired-sample sign test, a Wilcoxon matched-pairs signed-rank test and (for unpaired samples) a Wilcoxon rank-sum test.  [*Problems involving tied ranks are excluded.*] | 4735 S4 – Non-parametric Tests (d) | (d) test for identity of populations using a paired-sample sign test, a Wilcoxon matched-pairs signed-rank test and (for unpaired samples) a Wilcoxon rank-sum test (problems involving tied ranks will not be set) |
| **5.07f** | f) Be able to carry out tests using the Wilcoxon signed-rank test and the Wilcoxon rank-sum test for large samples using the approximations:  Wilcoxon signed-rank test    Wilcoxon rank-sum test (samples of size  and  , with  )  .  *Includes the use of continuity corrections.* | 4735 S4 – Non-parametric Tests (b) | (b) understand, in simple terms, the basis of sign tests, Wilcoxon signed-rank tests and the Wilcoxon rank-sum test, and use normal approximations where appropriate in these tests  5.07b and 5.07f cover 4735 Non-parametric Tests (b) between them. |
| **5.08a** | a) Be able to calculate the product-moment correlation coefficient (pmcc) for a set of bivariate data; raw data or summarised data may be given.  *Use of appropriate calculator functions is expected.*  *Learners will not be required to enter large amounts of data into a calculator during the examination.* | 4732 S1 – Bivariate Data (a) | (a) calculate, both from simple raw data and from summarised data, the product-moment correlation coefficient for a set of bivariate data |
| **5.08b** | b) Understand that the value of a correlation coefficient is unaffected by linear coding of the variables. | 4732 S1 – Bivariate Data (d) | (d) understand that the value of a correlation coefficient is unaffected by linear transformations (coding) of the variables |
| **5.08c** | c) Understand Pearson's product-moment correlation coefficient as a measure of how close data points lie to a straight line. |  | Understanding Pearson’s product-moment correlation coefficient as measuring fit to a straight line is implied in 4732. |
| **5.08d** | d) Use and be able to interpret Pearson's product-moment correlation coefficient in hypothesis tests, using either a given critical value or a *p-*value and a table of critical values.  *When using Pearson’s coefficient in a hypothesis test, the data may be assumed to come from a bivariate normal distribution.*  *A table of critical values of Pearson’s coefficient will be provided.* |  | Using Pearson’s product-moment correlation coefficient in hypothesis tests is new content in the reformed specification. |
| **5.08e** | e) Be able to calculate Spearman’s rank correlation coefficient for a maximum of 10 pairs of data values or ranks.  *Includes being able to draw basic conclusions about the meaning of a value of the coefficient in relation to the ranks before, or without, carrying out a hypothesis test.*  *Includes understanding the conditions under which the use of rank correlation may be appropriate.*  *[Tied ranks are excluded.]* | 4732 S1 – Bivariate Data (b) | (b) understand the basis of Spearman’s coefficient of rank correlation, and calculate its value (questions will not involve tied ranks)  Interpreting the meaning of a value of Spearman’s rank correlation coefficient is implied in 4732.  Understanding the conditions for using rank correlation is new content in the reformed specification. |
| **5.08f** | f) Be able to carry out a hypothesis test for association in a population.  *Includes understanding that this is a non-parametric test, as it makes no assumptions about the population.*  *Tables of critical values of Spearman’s coefficient will be provided.* |  | Using Spearman coefficient of rank correlation in hypothesis tests is new content in the reformed specification. |
| **5.08g** | g) Be able to choose between Pearson's product-moment correlation coefficient and Spearman’s rank correlation coefficient for a given context.  *Includes interpreting a scatter diagram and distinguishing between linear correlation and association.* | 4732 S1 – Bivariate Data (c) | (c) interpret the value of a product-moment correlation coefficient or of Spearman’s rank correlation coefficient in relation to the appearance of a scatter diagram, with particular reference to values close to –1, 0, 1  Choosing between Pearson's product-moment correlation coefficient and Spearman’s rank correlation coefficient is new content in the reformed specification. |
| **5.09a** | a) Understand the difference between an independent (or controlled) variable and a dependent (or response) variable.  *Includes appreciating that, in a given situation, neither parameter may be independent.* | 4732 S1 – Bivariate Data (e) | (e) understand the difference between an independent (or controlled) variable and a dependent variable  The term response variable is new content in the reformed specification. |
| **5.09b** | b) Understand the concepts of least squares and regression lines in the context of a scatter diagram. | 4732 S1 – Bivariate Data (f) | (f) understand the concepts of least squares and regression lines in the context of a scatter diagram |
| **5.09c** | c) Be able to calculate, both from raw data and from summarised data, the equation of the regression line of *y* on *x*, where the independent variable (if any) is *x*.  [*The regression line of x on y is excluded.*] | 4732 S1 – Bivariate Data (g) | (g) calculate, both from simple raw data and from summarised data, the equation of a regression line, understand the distinction between the regression line of on and that of on, and use the fact that both regression lines pass through the mean centre  The reformed specification implies knowing that the regression line passes through the mean point. |
| **5.09d** | d) Understand the effect on a regression line of linear coding on one or both variables. |  | The effect of linear coding on a regression line is new content in the reformed specification. |
| **5.09e** | e) Be able to use, in the context of a problem, the regression line of *y* on *x* to estimate a value of *y*, and be able to interpret in context the uncertainties of such an estimate. | 4732 S1 – Bivariate Data (h) | (h) select and use, in the context of a problem, the appropriate regression line to estimate a value, and be able to interpret in context the uncertainties of such estimations |

## Content of Mechanics (Optional paper Y543)

| **OCR Reference** | **Content Description**  (unshaded content is AS content) | **Legacy Unit and Reference** | **Notes** |
| --- | --- | --- | --- |
| **6.01a** | a) Be able to find the dimensions of a quantity in terms of M, L and T, and understand that some quantities are dimensionless.  *Includes understanding and using the notation* [*d*] *for the dimension of the quantity d.*  *Learners are expected to know or be able to derive the dimensions of any quantity for which they know the units. Dimensions of other quantities will be given, or their derivation will be the focus of assessment.* |  | Finding the dimensions of a quantity in terms of M, L and T is new content in the reformed specification. |
| **6.01b** | b) Understand and be able to use the relationship between the units of a quantity and its dimensions. |  | Using dimensions to determine units is new content in the reformed specification. |
| **6.01c** | c) Be able to use dimensional analysis as an error check.  *e.g. Verify the relationship that power is proportional to the product of the driving force and the velocity.* |  | Using dimensional analysis as an error check is new content in the reformed specification. |
| **6.01d** | d) Be able to use dimensional analysis to determine unknown indices in a proposed formulation.  *e.g. Determine the period of oscillation of a simple pendulum in terms of its length, mass and the acceleration due to gravity, g.* |  | Using dimensional analysis to determine unknown indices is new content in the reformed specification. |
| **6.01e** | e) Be able to formulate models and derive equations of motion using a dimensional argument. |  | Formulating models and deriving equations of motions using dimensional argument is new content in the reformed specification. |
| **6.02a** | a) Understand the concept of work done by a force. | 4729 M2 – Energy, Work and Power (a) | (a) understand the concept of the work done by a force …  6.02a and 6.02b cover 4729 Energy, Work and Power (a) between them. |
| **6.02c** | c) Be able to calculate the work done by a constant force in two dimensions using vectors  or by a variable force  in one dimension only. | 4730 M3 – Linear Motion Under a Variable Force (b) | (b) solve problems which can be modelled as the linear motion of a particle under the action of a variable force …  Calculating the work done by a constant force in two dimensions () is new content in the reformed specification. |
| **6.02b** | b) Be able to calculate the work done by a constant force.  *The force may not act in the direction of motion of the body and so learners will be expected to resolve forces in two dimensions*. | 4729 M2 – Energy, Work and Power (a) | (a) … and calculate the work done by a constant force when its point of application undergoes a displacement not necessarily parallel to the force (use of the scalar product is not required)  6.02a and 6.02b cover 4729 Energy, Work and Power (a) between them. |
| **6.02d** | d) Understand the concept of the mechanical energy of a body.  *i.e. the kinetic and potential energy.* | 4729 M2 – Energy, Work and Power (b) | (b) understand the concepts of gravitational potential energy and kinetic energy …  4729 refers to kinetic energy and gravitational potential energy only.  6.02d and 6.02e cover 4729 Energy, Work and Power (b) between them. |
| **6.02f** | f) Be able to calculate the kinetic energy of a body using the scalar product .  *Learners may be expected to use the formula , in solving a variety of problems, for example in calculating the kinetic energy of a body.* |  | Calculating kinetic energy using  and using the vector forms of the suvat equations is new content in the reformed specification. |
| **6.02e** | e) Be able to calculate the gravitational potential energy  and kinetic energy  of a body. | 4729 M2 – Energy, Work and Power (b) | (b) understand the concepts of gravitational potential energy and kinetic energy, and use appropriate formulae  6.02d and 6.02e cover 4729 Energy, Work and Power (b) between them. |
| **6.02g** | g) Understand and be able to use Hooke’s law, in the form , for elastic strings and springs.  *Includes an informal understanding of when Hooke’s Law does not apply.* | 4730 M3 – Elastic Strings and Springs (a) | (a) use Hooke’s law as a model relating the force in an elastic string or spring to the extension or compression …  Understanding the term ‘modulus of elasticity’ is not required in the reformed specification. |
| **6.02h** | h) Be able to calculate the elastic potential energy  stored in a string or spring.  *Learners will be expected to state the formula for the elastic potential energy stored in a string or spring unless they are explicitly asked to derive it*. | 4730 M3 – Elastic Strings and Springs (b) | (b) use the formula for the elastic potential energy stored in a string or spring |
| **6.02i** | i) Understand and be able to use the principle of the conservation of mechanical energy and the work-energy principle for dynamic systems, including consideration of energy loss.  *Learners will only need to consider kinetic and gravitational potential energy.* | 4729 M2 – Energy, Work and Power (c) | (c) understand and use the relationship between the change in energy of a system and the work done by the external forces, and use in appropriate cases the principle of conservation of energy |
| **6.02j** | j) Extend their knowledge of the principle of the conservation of mechanical energy and the work-energy principle to systems which include elastic strings or springs. | 4730 M3 – Elastic Strings and Springs (c) | (c) solve problems involving forces due to elastic strings or springs, including those where considerations of work and energy are needed |
| **6.02k** | k) Understand and be able to use the definition of power (the rate at which a force does work).  *Includes  .* | 4729 M2 – Energy, Work and Power (d) | (d) use the definition of power as the rate at which a force does work …  6.02k and 6.02l cover 4729 Energy, Work and Power (d) between them. |
| **6.02l** | l) Be able to use the relationship between power, the tractive force and velocity  to solve problems.  *e.g. Motion on an inclined plane*.  *Includes maximum velocity and speed.*  *Learners will be required to resolve forces in two dimensions.* | 4729 M2 – Energy, Work and Power (d) & (e) | (d) … and use the relationship between power, force and velocity for a force acting in the direction of motion  (e) solve problems involving, for example, the instantaneous acceleration of a car moving on a hill with resistance  6.02k and 6.02l cover 4729 Energy, Work and Power (d) between them. |
| **6.02m** | m) Be able to calculate the power associated with a variable force in two dimensions using the scalar product . |  | Calculating power using the scalar product, , is new content in the reformed specification. |
| **6.03a** | a) Recall and be able to use the definition of linear momentum in one dimension. | 4728 M1 – Linear Momentum (a) | (a) recall and use the definition of linear momentum and show understanding of its vector nature (in one dimension only) |
| **6.03c** | c) Recall and be able touse the definition of momentum in two dimensions including the vector form . | 4730 M3 – Impulse and Momentum in Two Dimensions (a) | (a) understand the vector nature of … and momentum, …  6.03c, 6.03d and 6.03g cover 4730 Impulse and Momentum in Two Dimensions (a) between them. |
| **6.03b** | b) Understand and be able to apply the principle of conservation of linear momentum in one dimension applied to two particles.  *Includes using the formula .* | 4728 M1 – Linear Momentum (b) | (b) understand and use conservation of linear momentum in simple applications involving the direct collision of two bodies moving in the same straight line before and after impact, including the case where the bodies coalesce (knowledge of impulse and of the coefficient of restitution is not required) |
| **6.03d** | d) Understand and be able to apply the principle of conservation of linear momentum in two dimensions applied to two particles.  *Includes using the vector form .* | 4730 M3 – Impulse and Momentum in Two Dimensions (a) | (a) understand the vector nature of impulse and momentum, and solve problems concerning impulse and momentum for motion in two dimensions  6.03c, 6.03d and 6.03g cover 4730 Impulse and Momentum in Two Dimensions (a) between them. |
| **6.03e** | e) Understand and be able to use the concept of the impulse imparted by a force. | 4729 M2 – Coefficient of Restitution; Impulse (c) | (c) recall and use the definition of impulse as change of momentum (in one dimension only, restricted to ‘instantaneous’ events, so that calculations involving force and time are not included)  Problems involving time are new content in the reformed specification. |
| **6.03f** | f) Be able to use the relationship between the instantaneous impulse of a force and the change in momentum .  *The instantaneous impulse is the impulse associated with an instantaneous change in velocity.*  *Learners will only be required to apply this to instantaneous events in one dimension.*  *e.g.*  *The direct impact of two smooth spheres.*  *An impulsive force acting in the direction of an inelastic string*.  *Questions involving collisions(s) between particles may include multiple collisions and the conditions under which further collisions occur.* | 4729 M2 – Coefficient of Restitution; Impulse (c) | (c) recall and use the definition of impulse as change of momentum (in one dimension only, restricted to ‘instantaneous’ events, so that calculations involving force and time are not included) |
| **6.03g** | g) Understand and be able to apply the impulse - momentum principle in two dimensions including the vector form .  *e.g.*  *The oblique impact of two smooth spheres.*  *A smooth sphere with a fixed plane surface*.  *An impulsive force acting at an angle to an inelastic string.* | 4730 M3 – Impulse and Momentum in Two Dimensions (a) | (a) understand the vector nature of impulse and momentum, and solve problems concerning impulse and momentum for motion in two dimensions  6.03c, 6.03d and 6.03g cover 4730 Impulse and Momentum in Two Dimensions (a) between them. |
| **6.03h** | h) Understand and be able to apply the impulse - momentum principle for a constant force expressed as force  time or for a variable force in one dimension only as . | 4729 M2 – Coefficient of Restitution; Impulse (c) | (c) recall and use the definition of impulse as change of momentum …  Calculations involving force and time are new content in the reformed specification. |
| **6.03i** | i) Recall and be able to use the definition of the coefficient of restitution, including .  *[Superelastic collisions are excluded.]* | 4729 M2 – Coefficient of Restitution; Impulse (a) | (a) recall and use Newton’s experimental law and the definition of coefficient of restitution, the property  , …  6.03i and 6.03j cover 4729 Coefficient of Restitution; Impulse (a) between them. |
| **6.03j** | j) Understand and be able to use the terms “perfectly elastic”  and “inelastic”  for describing collisions.  *Learners should know that for perfectly elastic collisions there will be no loss of kinetic energy and for inelastic collisions the bodies coalesce and there is maximum loss of kinetic energy.* | 4729 M2 – Coefficient of Restitution; Impulse (a) | (a) … and the meaning of the terms ‘perfectly elastic’  and ‘inelastic’  6.03i and 6.03j cover 4729 Coefficient of Restitution; Impulse (a) between them. |
| **6.03k** | k) Recall and be able to use Newton’s experimental law in one dimension for problems of direct impact.  e.g. *Between two smooth spheres  and a smooth sphere with a fixed plane surface , where  and  are the velocities before and after impact.* | 4729 M2 – Coefficient of Restitution; Impulse (b) | (b) use Newton’s experimental law in the course of solving problems that may be modelled as the direct impact of two smooth spheres or as the direct impact of a smooth sphere with a fixed plane surface |
| **6.03l** | l) Extend their knowledge to problems involving Newton’s experimental law in two dimensions.  *e.g. The oblique impacts of two smooth spheres and a smooth sphere with a fixed plane surface.*  *Questions may involve the velocity expressed as a two dimensional vector.* | 4730 M3 – Impulse and Momentum in Two Dimensions (b) | (b) solve problems that may be modelled as the oblique impact of two smooth spheres or as the oblique impact of a smooth sphere with a fixed surface (the appropriate use of Newton’s experimental law is included) |
| **6.04a** | a) Understand and be able to apply the principle that the effect of gravity is equivalent to a single force acting at the body’s centre of mass.  *Includes understanding that, in terms of linear motion, a rigid body may be modelled by a particle of the same mass at its centre of mass.* | 4729 M2 – Centre of Mass (a) | (a) use the result that the effect of gravity on a rigid body is equivalent to a single force acting at the centre of mass of the body |
| **6.04b** | b) Be able to find the position of the centre of mass of a uniform rigid body using symmetry, for example a rectangular lamina. | 4729 M2 – Centre of Mass (b) | (b) identify the position of the centre of mass of a uniform body using considerations of symmetry |
| **6.04c** | c) Be able to determine the centre of mass of a system of particles or the centre of mass of a composite rigid body.  *Questions may involve any of the rigid bodies listed in the Formulae Booklet, but will be limited to compound shapes such as a uniform L-shaped lamina or a hemisphere abutting a cylinder with a common axis*.  *Includes composition by addition or subtraction, for example a rectangular lamina with a semicircle attached to one side, or a rectangular lamina with a semicircle removed.* | 4729 M2 – Centre of Mass (c) & (d) | (c) use given information about the position of the centre of mass of a triangular lamina and other simple shapes (including those listed in the List of Formulae)  (d) determine the position of the centre of mass of a composite rigid body by considering an equivalent system of particles (in simple cases only, e.g. a uniform L-shaped lamina or a hemisphere abutting a cylinder) |
| **6.04d** | d) Be able to use integration to determine the position of the centre of mass of a uniform lamina or a uniform solid of revolution. | 4731 M4 – Centre of Mass (a)(ii) & (a)(iii) | (a) use integration to determine the position of the centre of mass of  (i) …  (ii) a uniform lamina  (iii) a uniform solid of revolution |
| **6.04e** | e) Be able to solve problems involving the equilibrium of a single rigid body under the action of coplanar forces.  *e.g. Suspension of a rigid body from a given point or problems involving the toppling or sliding of a rigid body placed on an inclined plane*.  *May include rigid bodies which are hinged to a surface.*  *[Hinged bodies are excluded.]* | 4729 M2 – Equilibrium of a Rigid Body (c) | (c) solve problems involving the equilibrium of a single rigid body under the action of coplanar forces, including those involving toppling or sliding (problems set will not involve complicated trigonometry) |
| **6.05a** | a) Understand and be able to use the definitions of angular velocity, velocity, speed and acceleration in relation to a particle moving in a circular path, or a point rotating in a circle, with constant speed.  *Includes the use of bothand* | 4729 M2 – Uniform Motion in a Circle (a) & (b) | (a) understand the concept of angular speed for a particle moving in a circle, …  (b) understand that the acceleration of a particle moving in a circle with constant speed is directed towards the centre of the circle  6.05a and 6.05b cover 4729 Uniform Motion in a Circle (a) and (b) between them. |
| **6.05b** | b) Be able to use and apply the relationships , , for motion in a circle with constant speed. | 4729 M2 – Uniform Motion in a Circle (a) & (b) | (a) … and use the relation  (b) … and use the formulae  and  6.05a and 6.05b cover 4729 Uniform Motion in a Circle (a) and (b) between them. |
| **6.05c** | c) Be able to solve problems regarding motion in a horizontal circle.  *e.g.*  *Motion of a conical pendulum.*  *Motion on a banked track*.  *Problems will be restricted to those involving constant forces but learners will be required to resolve forces in two dimensions*. | 4729 M2 – Uniform Motion in a Circle (c) | (c) solve problems which can be modelled by the motion of a particle moving in a horizontal circle with constant speed |
| **6.05d** | d) Understand the motion of a particle in a circle with variable speed.  *In ‘Stage 1’ Learners will be expected to use energy considerations to calculate the speed of a particle at a given point on a circular path.* | 4730 M3 – Motion in a Vertical Circle (a) | (a) use formulae for the radial and transverse components of acceleration for a particle moving in a circle with variable speed  Variable speed (unless the circle is vertical) is new content in the reformed specification. |
| **6.05e** | e) Extend their understanding of the motion of a particle in a circle with variable speed to include the radial and tangential components of the acceleration. | 4730 M3 – Motion in a Vertical Circle (a) | (a) use formulae for the radial and transverse components of acceleration for a particle moving in a circle with variable speed  Variable speed (unless the circle is vertical) is new content in the reformed specification. |
| **6.05f** | f) Be able to solve problems involving motion round a vertical circle including motion which is not restricted to a circular path.  *This is restricted to a combination of motion in a circle and free fall.*  *e.g. The subsequent motion of a particle moving on the outside of a smooth circular surface*.  *The motion of a particle on a string moving in a vertical circle and then as a projectile.* | 4730 M3 – Motion in a Vertical Circle (a) & (b) | (a) use formulae for the radial and transverse components of acceleration for a particle moving in a circle with variable speed  (b) solve problems which can be modelled as that of a particle, or a pair of connected particles, moving without loss of energy in a vertical circle (including the determination of points where circular motion breaks down, e.g. through loss of contact with a surface or a string becoming slack) |
| **6.06a** | a) Be able to use  or  to model the linear motion of a particle under the action of a variable force in one dimension only.  *Learners will be required to solve problems in which the corresponding differential equation can be solved by either the method of separation of variables or an integrating factor*. | 4730 M3 – Linear Motion under a Variable Force (a) | (a) use  for velocity, and  or  for acceleration, as appropriate |

## Content of Discrete Mathematics (Optional paper Y544)

| **OCR Reference** | **Content Description**  (unshaded content is AS content) | **Legacy Unit and Reference** | **Notes** |
| --- | --- | --- | --- |
| **7.01a** | a) Understand and be able to use the terms “existence”, “construction”, “enumeration” and “optimisation” in the context of problem solving.  *Includes classifying a given problem into one or more of these categories.* |  | The classification of problems is new content in the reformed specification. |
| **7.01b** | b) Understand and be able to use the basic language and notation of sets.  *Including the term “partition” and counting the number of partitions of a set including with constraints.* |  | The language and notation of sets, including partitions, is new content in the reformed specification. |
| **7.01c** | c) Be able to use the pigeonhole principle in solving problems. |  | The pigeonhole principle is new content in the reformed specification. |
| **7.01d** | d) Understand and use the multiplicative principle.  Includes knowing that the number of arrangements of *n* distinct objects is . | 4732 S1 –  Probability (c) | (c) solve problems about arrangements of objects in a line, …  The multiplicative principle is implied in 4732. |
| **7.01e** | e) Be able to enumerate the number of ways of obtaining an ordered subset (permutation) of *r* elements from a set of *n* distinct elements.  *Includes using the notation* . | 4732 S1 –  Probability (a) | (a) understand the terms permutation …  7.01e and 7.01f cover 4732 Probability (a) between them. |
| **7.01f** | f) Be able to enumerate the number of ways of obtaining an unordered subset (combination) of *r* elements from a set of *n* distinct elements.  *Includes using the notation .* | 4732 S1 –  Probability (a) | (a) understand the terms … and combination  7.01e and 7.01f cover 4732 Probability (a) between them. |
| **7.01g** | g) Be able to solve problems about enumerating the number of arrangements of objects in a line, including those involving:    1. repetition, *e.g. how many different eight digit*  *numbers can be made from the digits of*  *12333210?*  2. restriction, *e.g. how many different eight digit*  *numbers can be made from the digits of*  *12333210 if the two 2s cannot be next to each*  *other?* | 4732 S1 –  Probability (c) | (c) solve problems about arrangements of objects in a line, including those involving  (i) repetition (e.g. the number of ways of arranging the letters of the word ‘NEEDLESS’)  (ii) restriction (e.g. the number of ways several people can stand in a line if 2 particular people must — or must not — stand next to each other) |
| **7.01h** | h) Be able to solve problems about enumerating the number of arrangements of only some of a group of objects.  *e.g. how many different four digit numbers can be made from the digits of 12333210?*  *e.g. how many different numbers greater than 20 000 can be made from the digits of 12333210?* |  | Enumerating arrangements of subsets is new content in the reformed specification. |
| **7.01i** | i) Be able to solve problems about selections, including with constraints.  *e.g. Find the number of ways in which a team of 3 men and 2 women can be selected from a group of 6 men and 5 women.* | 4732 S1 – Probability (b) | (b) solve problems about selections, e.g. finding the number of ways in which a team of 3 men and 2 women can be selected from a group of 6 men and 5 women |
| **7.01j** | j) Be able to solve problems with several constraints.  *e.g. Given a graph showing who dislikes who, find the number of ways of choosing 3 men and 2 women from a group of 4 men and 4 women so that no two people chosen dislike each other.* |  | Enumerating selections with constraints is new content in the reformed specification. |
| **7.01k** | k) Be able to use the inclusion-exclusion principle for two sets in solving problems.  *e.g.*  *Venn diagrams may be used.*  *e.g. How many integers in are not divisible by 2, 3 or 5?* |  | The inclusion-exclusion principle is new content in the reformed specification. |
| **7.01l** | l) Be able to extend the inclusion-exclusion principle to more than two sets.  *e.g.*  *Venn diagrams may be used.*  *e.g. How many integers in are not divisible by 2, 3 or 5?* |  | The inclusion-exclusion principle is new content in the reformed specification. |
| **7.01m** | m) Be able to find derangements.  *Includes enumeration of the number of derangements of  objects, , by ad hoc methods only.* |  | Finding derangements is new content in the reformed specification. |
| **7.02a** | a) Understand the meaning of the terms vertex (or node) and arc (or edge).  *Includes the concept of the “degree” of a vertex as the number of arcs “incident” to the vertex.*  *Includes the term “adjacent” for pairs of vertices or edges.* | 4736 D1 – Graph Theory (a) | (a) understand the meaning of the terms ‘arc’ (or ‘edge’), ‘node’ (or ‘vertex’), …  7.02a, 7.02b and 7.02c cover 4736 Graph Theory (a) between them.  The degree of a vertex is the same as the order or valency of that vertex. |
| **7.02b** | b) Understand the meaning of the terms “tree”, “simple”, “connected” and “simply connected” as they refer to graphs.  *Includes understanding and using the restrictions on the vertex degrees implied by these conditions.* | 4736 D1 – Graph Theory (a) | (a) understand the meaning of the terms …’tree’ …  7.02a, 7.02b and 7.02c cover 4736 Graph Theory (a) between them.  The terms simple, connected and simply connected are new content in the reformed specification. |
| **7.02c** | c) Understand the meaning of the terms “walk”, “trail”, “path”, “cycle” and “route”.  *A “walk” is a set of arcs where the end vertex of one is the start vertex of the next.*  *A “trail” is a walk in which no arcs are repeated.*  *A “path” is a trail in which no nodes are repeated.*  *A “cycle” is a closed path.*  *A “route” can be a walk, a trail or a path, or may be a closed walk, trail or path.* | 4736 D1 – Graph Theory (a) | (a) understand the meaning of the terms …’path’ … and ‘cycle’  7.02a, 7.02b and 7.02c cover 4736 Graph Theory (a) between them.  The terms walk, trail and route are new content in the reformed specification. |
| **7.02d** | d) Understand and be able to use the term “complete” and the notation  for a complete graph on *n* vertices.  *Includes knowing that  has*  *arcs.* | 4736 D1 – Graph Theory (c) | (c) solve simple problems involving planar graphs, both directed and undirected  The notation  for a complete graph is new content in the reformed specification |
| **7.02e** | e) Understand and be able to use bipartite graphs and the notation  for a complete bipartite graph connecting *m* vertices to *n* vertices.  *Includes knowing that  has mn arcs.* | 4736 D1 – Graph Theory (c) | (c) solve simple problems involving planar graphs, both directed and undirected  The notation  for a complete bipartite graph is new content in the reformed specification. |
| **7.02f** | f) Use a colouring argument to show that a given graph is, or is not, bipartite. |  | Using a colouring argument to show bipartite is new content in the reformed specification. |
| **7.02g** | g) Use the degrees of vertices to determine whether a given graph is Eulerian, semi-Eulerian or neither. Understand what these terms mean in terms of traversing the graph. | 4736 D1 – Graph Theory (b) | (b) use the orders of the nodes in a graph to determine whether the graph is Eulerian or semi-Eulerian or neither |
| **7.02h** | h) Understand and be able to use the definition of a Hamiltonian path, a Hamiltonian cycle and a Hamiltonian graph. |  | A Hamiltonian cycle is new content in the reformed specification. |
| **7.02i** | i) Know and use Ore’s theorem.  *i.e. For a simple graph  with  vertices, if  for every pair of distinct non-adjacent vertices  and , then  is Hamiltonian.*  *Includes understanding that Ore’s theorem gives a sufficient but not necessary condition for a graph to be Hamiltonian.* |  | Ore’s theorem is new content in the reformed specification. |
| **7.02j** | j) Understand what it means to say that two graphs are isomorphic. Construct an isomorphism either by a reasoned argument or by explicit labelling of vertices.  *Includes understanding that having the same degree sequence (ordered list of vertex degrees) is necessary but not sufficient to show isomorphism.*  *Includes the term non-isomorphic.* |  | Isomorphism is new content in the reformed specification. |
| **7.02k** | k) Understand and be able to use digraphs.  *Includes the terms “indegree” and “outdegree”.* | 4736 D1 – Graph Theory (c) | (c) solve simple problems involving planar graphs, both directed and undirected  The terms indegree and outdegree are new content in the reformed specification. |
| **7.02l** | l) Understand and be able to apply the concepts of planarity, subdivision and contraction.  *i.e. Subdivision is inserting a vertex of degree 2 into an arc. Contraction is contracting two vertices into one so that any arc incident with the original two vertices is incident with the contracted vertex.*  *Includes the notation  for the vertex created by the contraction of the arc AB.*  *Includes drawing planar representations.* | 4736 D1 – Graph Theory (c) | (c) solve simple problems involving planar graphs, both directed and undirected  The concepts of planarity, subdivision and contraction are new content in the reformed specification. |
| **7.02m** | m) Know, understand and use Euler’s formula . |  | Euler’s formula  is new content in the reformed specification. |
| **7.02n** | n) Know and use Kuratowski’s theorem.  *i.e. A finite graph is planar if and only if it does not contain a subgraph that is a subdivision of  or  .* |  | Kuratowski’s theorem is new content in the reformed specification. |
| **7.02o** | o) Understand and be able to use the concept of thickness.  [*Calculation of thickness  is excluded.*] |  | The concept of the thickness of a graph is new content in the reformed specification. |
| **7.02p** | p) Understand that a network is a weighted graph. Use graphs and networks to model the connections between objects.  *Graphs and networks may be directed or undirected.* | 4736 D1 – Networks (a) | (a) recall that a network is a graph in which each arc is assigned a ‘weight’, and use networks as mathematical models |
| **7.02q** | q) Use an adjacency matrix representation of a graph and a weighted matrix representation of a network. |  | The terms adjacency matrix and weighted matrix are new content in the reformed specification. |
| **7.02r** | r) Be able to model problems using graphs or networks, and solve them. | 4736 D1 –  Graph Theory (c)  4736 D1 –  Networks (a) | (c) solve simple problems involving planar graphs, both directed and undirected  (a) recall that a network is a graph in which each arc is assigned a ‘weight’, and use networks as mathematical models |
| **7.03a** | a) Understand that an algorithm has an input and an output, is deterministic and finite.  *Includes the use of a counter and the use of a stopping condition in an algorithm.*  *Be familiar with the terms greedy, heuristic and recursive in the context of algorithms.* | 4736 D1 –  Algorithms (a) | (a) understand the definition of an algorithm  The terms input, output, deterministic, finite, use of counter and stopping condition are implied but not explicit in 4736. |
| **7.03b** | b) Appreciate why an algorithmic approach to problem solving is generally preferable to ad hoc methods, and understand the limitations of algorithmic methods.  *Includes understanding that algorithmic methods are used by computers for solving large scale problems and that small scale problems are only being used to demonstrate how a given algorithm works.* | 4736 D1 –  Algorithms (b) | (b) appreciate why an algorithmic approach to problem solving is generally preferable to ad hoc methods, and understand the limitations of algorithmic methods |
| **7.03c** | c) Trace through an algorithm and interpret what the algorithm has achieved. Algorithms may be presented as flow diagrams, listed in words, or written in simple pseudo-code.  *Includes understanding and being able to use the functions  and  Learners may find it useful to have a calculator with these functions, but large numbers of repeated applications will not be required in the assessment.*  *Includes adapting or altering an algorithm to achieve a given purpose, and adjusting a short set of instructions to create an algorithm.*  [*Programming skills will not be required*.] | 4736 D1 –  Algorithms (d) | (d) interpret and apply simple algorithms defined by flow diagrams or given as a listing in words  The terms trace through an algorithm and pseudo-code, and the functions and are implied but not explicit in 4736. |
| **7.03d** | d) Use the order of an algorithm to calculate an approximate run-time for a large problem by scaling up a given run-time.  *Includes understanding that when the “maximum run-time” of an algorithm is represented as a function of the “size” of the problem, the order of the algorithm, for very large sized problems, is given by the dominant term.*  *Learners should know that the sum of the first n positive integers is* .  *Learners should be familiar with the notation  and the concept of dominance in an informal sense only.* | 4736 D1 –  Algorithms (c) | (c) understand the meaning of the order of an algorithm, and determine the order of a given algorithm in simple cases, including the algorithms for standard network problems  The term run-time is new content in the reformed specification. |
| **7.03e** | e) Compare the efficiency of two algorithms that achieve the same end result by considering a given aspect of the run-time in a specific case.  *e.g. The number of swaps or comparisons to sort a given list*. |  | Comparing efficiency is new content in the reformed specification. |
| **7.03f** | f) Calculate worst case time complexity, the “maximum run-time” , as a function of the size of a problem by considering the worst case for a specific problem.  *Includes cases of the algorithms for sorting and standard network problems studied in this specification*.  *Includes an informal understanding that, for example*  *is* order  , or equivalently . |  | Calculating the worst case time complexity and the “maximum run-time”  are new content in the reformed specification. |
| **7.03h** | h) Calculate the run-time as a function of the size of a problem by considering the best case, the worst case or a typical case.  *Includes c*o*nsidering all cases and averaging where appropriate*. |  | Calculating the run-time using best case, worst case, a typical case or average case is new content in the reformed specification. |
| **7.03g** | g) Be familiar with , where *n* is a measure of the size of the problems and  or . |  | for  is new content in the reformed specification. |
| **7.03i** | i) Be familiar with:  for ,  for ,  where *n* is a measure of the size of the problem.  *Know the hierarchy of orders and what this means in terms of efficiency. Learners should be aware that:*  , *which is given in the Formulae Booklet.* |  | for ,  for ,  and hierarchy of orders are new content in the reformed specification. |
| **7.03j** | j) Be able to sort a list using bubble sort and using shuttle sort.  *Bubble sort and shuttle sort will start at the left-hand end of the list, unless specified otherwise in the question.*  *Includes knowing that, in general, sorting algorithms have quadratic order as a function of the length of the list.* | 4736 D1 –  Algorithms (e)(i) | (e) show familiarity with simple algorithms concerning sorting and packing, including  (i) bubble and shuttle sorts  (ii) ... |
| **7.03k** | k) Be able to sort a list using quick sort.  *Quick sort will pivot on the first value, unless specified otherwise in a question.*  *Includes knowing that quick sort is only*  *in the worst case.*  *Questions may be set that interrogate the application of the method, for example whether the choice of pivot affects the efficiency of quicksort.* |  | Quick sort is new content in the reformed specification. |
| **7.03l** | l) Be familiar with the next-fit, first-fit, first-fit decreasing and full bin methods for one-dimensional packing problems.  *Includes knowing that these are heuristic algorithms.*  *Includes the terms “online” and “offline”.* | 4736 D1 –  Algorithms (e)(ii) | (e) show familiarity with simple algorithms concerning sorting and packing, including  (i) …  (ii) first-fit methods (first-fit and first-fit decreasing)  The full bin method is new content in the reformed specification. |
| **7.03m** | m) Extend their knowledge of packing methods.  *e.g. Packing problems in two or three dimensions.*  *e.g. Knapsack problems: given a set of items, each with a mass and a profit, determine which to include so that the total mass does not exceed some given limit and the total profit is as large as possible.* |  | Extending packing methods and knapsack problems are new content in the reformed specification. |
| **7.04a** | a) Be able to use examples to demonstrate understanding and use of Dijkstra’s algorithm to find the length and route of a least weight (shortest) path.  *Solve problems that require a least weight (shortest) path as part of their solution.*  *Know that Dijkstra’s algorithm has quadratic order (as a function of the number of vertices).* | 4736 D1 – Networks (d)  4736 D1 –  Algorithms (c) | (d) use Dijkstra’s algorithm to determine the shortest path between two nodes  (c) understand the meaning of the order of an algorithm, and determine the order of a given algorithm in simple cases, including the algorithms for standard network problems |
| **7.04b** | b) Be able to use examples to demonstrate understanding and use of Prim’s algorithm (both in graphical and tabular/matrix form) and Kruskal’s algorithm to find a minimum connector (minimum spanning tree) for a network.  *Solve problems that require a minimum spanning tree as part of their solution.*  *Includes adapting a solution to deal with practical issues.*  *Know that Prim’s algorithm and Kruskal’s algorithm have cubic order (as a function of the number of vertices).* | 4736 D1 – Networks (b)  4736 D1 – Algorithms (c) | (b) apply Prim’s and Kruskal’s algorithms in solving the minimum connector problem to find a minimum spanning tree (including the use of a matrix representation for Prim’s algorithm)  (c) understand the meaning of the order of an algorithm, and determine the order of a given algorithm in simple cases, including the algorithms for standard network problems |
| **7.04c** | c) Be able to use the nearest neighbour method on a network formed by weighting a complete graph to find an upper bound for the travelling salesperson problem.  *Understand that when the nearest neighbour method is used on a network formed by weighting a graph that is not complete it may stall before reaching every vertex or it may reach every vertex but to close the route may need a path that is not a direct connection from the end back to the start vertex.*  *Includes choosing between two, or more, upper bounds to find the best (least) upper bound.*  *Includes using short-cuts where possible to improve an upper bound.* | 4736 D1 – Networks (c)(i) | (c) find a solution to the travelling salesperson problem in simple cases, and in other cases  (i) determine an upper bound by using the nearest neighbour method  Understanding that the nearest neighbour method may stall when applied to an incomplete network is new content in the reformed specification. |
| **7.04d** | d) Be able to use a minimum spanning tree on a reduced network to calculate a lower bound for the travelling salesperson problem on a complete graph and understand why this method gives a lower bound.  *Understand that for a graph that is not complete this method can give a value that is not a lower bound.*  *Includes choosing between two or more lower bounds to find the best (greatest) lower bound.* | 4736 D1 – Networks (c)(iii) | (c) find a solution to the travelling salesperson problem in simple cases, and in other cases  (iii) use minimum connector methods on a reduced network to determine a lower bound |
| **7.04e** | e) Be able to solve the route inspection problem by consideration of all possible pairings of up to six odd nodes.  *If a problem has more than six odd nodes additional restrictions will reduce the number of pairings that need to be considered.*  *Problems may be set that require an understanding of how the number of pairings increases as the number of odd nodes increases. For  odd nodes the number of pairings is* . | 4736 D1 – Networks (e) | (e) solve simple cases of the route inspection problem for at most six odd nodes by consideration of all possible pairings of the odd nodes |
| **7.04f** | f) Be able to choose an appropriate algorithm to solve a practical problem.  *Includes adapting an algorithm or a solution to deal with practical issues.* | 4736 D1 – Networks (a) | (a) recall that a network is a graph in which each arc is assigned a ‘weight’, and use networks as mathematical models |
| **7.05a** | a) Be able to construct and interpret activity networks using activity onarc.  *Appreciate that a path of critical activities (a critical path) is a longest path in a directed network.* | 4737 D2 – Critical Path Analysis (e) | (e) construct and interpret activity networks, using activity on arc |
| **7.05b** | b) Be able to carry out a forward pass to determine earliest start times and find the minimum project completion time, and to carry out a backward pass to determine latest finish times and find the critical activities.  *Includes understanding and using the terms burst and merge.* | 4737 D2 – Critical Path Analysis (f) & (g) | (f) carry out forward and reverse passes to determine earliest and latest start times and finish times, or early and late event times  (g) identify critical activities and find a critical path |
| **7.05c** | c) Understand, and be able to calculate, (total) float. | 4737 D2 – Critical Path Analysis (h) | (h) construct and interpret cascade charts and resource histograms, and carry out resource levelling  Calculating float is new content in the reformed specification. |
| **7.05d** | d) Be able to find latest start times and earliest finish times for activities. Calculate and interpret independent and interfering float. | 4737 D2 – Critical Path Analysis (h) | (h) construct and interpret cascade charts and resource histograms, and carry out resource levelling  The terms independent and interfering float are new content in the reformed specification. |
| **7.05e** | e) Be able to use an activity network to construct a cascade chart and use a cascade chart to determine the effect on the minimum project completion time of a delay to one or more activities, or other scheduling restrictions.  *Cascade charts may be constructed either with one activity on each row or with the critical activities together in one row and a row for each non-critical activity.*  *Float may be shown using dashed lines.*  *Includes constructing a schedule to show how a given number of workers can complete a project subject to given constraints.* | 4737 D2 – Critical Path Analysis (h) | (h) construct and interpret cascade charts and resource histograms, and carry out resource levelling  Scheduling (timetabling) restrictions are implied in 4736. |
| **7.06a** | a) Be able to set up a linear programming formulation in the form “maximise (or minimise) objective subject to inequality constraints, and trivial constraints of the form variable”.  *Includes:*  *1. identifying relevant variables, including units*  *when appropriate,*  *2. formulating constraints in these variables,*  *including when the information is given in ratio*  *form,*  *3. writing down an objective function and stating*  *whether it is to be maximised or minimised.* | 4736 D1 – Linear Programming (a) & (b) | (a) formulate in algebraic terms a real-world problem posed in words, including the identification of relevant variables, constraints and objective function  (b) set up a linear programming formulation in the form ‘maximise (or minimise) objective, subject to inequality constraints and trivial constraints of the form *variable* ’, and use slack variables to convert inequality constraints into equations together with trivial constraints  7.06a and 7.06b cover 4736 Linear Programming (b) between them. |
| **7.06b** | b) Be able to use slack variables to convert inequality constraints, each being  a non-negative constant, into equations, together with further trivial constraints of the form variable . | 4736 D1 – Linear Programming (b) | (b) set up a linear programming formulation in the form ‘maximise (or minimise) objective, subject to inequality constraints and trivial constraints of the form *variable* ’, and use slack variables to convert inequality constraints into equations together with trivial constraints  7.06a and 7.06b cover 4736 Linear Programming (b) between them. |
| **7.06c** | c) Be able to investigate constraints and objectives in numerical cases using algebra and ad hoc methods. |  | Investigating constraints and objectives numerically and algebraically is new content in the reformed specification. |
| **7.06d** | d) Be able to carry out and interpret a graphical solution for problems where the objective is a function of two variables, including cases where integer solutions are required.  *The region where each inequality is not satisfied will be shaded, leaving the feasible region as the unshaded part of the graph.* | 4736 D1 – Linear Programming (c) | (c) carry out a graphical solution for 2-variable problems, including cases where integer solutions are required |
| **7.06e** | e) Be able to discuss the effect of making a change to one or two of the coefficients and how this will change the solution. |  | Graphically investigating changes to coefficients is new content in the reformed specification. |
| **7.06f** | f) Be able to carry out integer programming, including using the branch-and-bound method. |  | Integer programming using the branch-and-bound method is new content in the reformed specification. |
| **7.07a** | a) Be able to set up an initial simplex tableau in standard format.  *Rows to show objective to be maximised, followed by constraints. Columns to represent objective, variables and then slack variables, with the column representing the right-hand side as the last column*. | 4736 D1 – Linear Programming (d) | (d) use the Simplex method for maximising an objective function, interpret the values of the variables and the objective function at any stage in the Simplex method  7.07a, 7.07b and 7.07c cover 4736 Linear Programming (d) between them. |
| **7.07b** | b) Be able to perform an iteration of a simplex tableau, including the choice of the pivot.  *The column with the most negative value in the objective row should be chosen, unless other specific instruction is given.* | 4736 D1 – Linear Programming (d) | (d) use the Simplex method for maximising an objective function, interpret the values of the variables and the objective function at any stage in the Simplex method  7.07a, 7.07b and 7.07c cover 4736 Linear Programming (d) between them. |
| **7.07c** | c) Be able to interpret the values of the variables, slack variables and objective at any stage and know when the optimum has been achieved.  *Includes discussing the effect of changes to the coefficients.* | 4736 D1 – Linear Programming (d) | (d) use the Simplex method for maximising an objective function, interpret the values of the variables and the objective function at any stage in the Simplex method  7.07a, 7.07b and 7.07c cover 4736 Linear Programming (d) between them. |
| **7.07d** | d) Be able to use the terms “basic feasible solution”, “basic variable” and “non-basic variable” appropriately.  *Basic variables correspond to columns consisting of zeroes together with a single 1*, *the other variables are non-basic.* |  | The terms basic feasible solution, basic variable and non-basic variable are new content in the reformed specification. |
| **7.07e** | e) Understand what an iteration of the simplex algorithm achieves, in terms of moving along edges of a multi-dimensional convex polygon, usually in two or three dimensions, and be able to apply this to problems. |  | Interpreting simplex iterations geometrically is new content in the reformed specification. |
| **7.07f** | f) Be able to explain, algebraically, some of the calculations used in the simplex algorithm. |  | Explaining simplex calculations algebraically is new content in the reformed specification. |
| **7.08a** | a) Understand the idea of a zero-sum game and its representation by means of a pay-off matrix.  *Includes converting a game to a zero-sum form, where appropriate.* | 4737 D2 – Game Theory (a) | (a) understand the idea of a zero-sum game and its representation by means of a pay-off matrix |
| **7.08b** | b) Be able to reduce a matrix using a dominance argument. | 4737 D2 – Game Theory (c) | (c) reduce a matrix by using a dominance argument |
| **7.08c** | c) Be able to identify play-safe strategies and stable solutions and understand what they represent. | 4737 D2 – Game Theory (b) | (b) identify play-safe strategies and stable solutions  Understanding what stable solutions represent is implied in 4736. |
| **7.08d** | d) Be able to identify a Nash Equilibrium solution and understand what it represents. |  | Nash Equilibrium is new content in the reformed specification. |
| **7.08e** | e) Be able to determine an optimal mixed strategy for a game with no stable solution by reducing to two variables and using simultaneous equations or a graphical method, where possible.  *Includes knowing that the optimum may occur at an extreme value  or .* | 4737 D2 – Game Theory (d)(i) | (d) determine an optimal mixed strategy for a game with no stable solution  (i) by using a graphical method for  or  games, where  or |
| **7.08f** | f) Be able to determine an optimal mixed strategy for a game with no stable solution by reformulating the problem as a linear programming problem that could be solved using the simplex algorithm. | 4737 D2 – Game Theory (d)(ii) | (d) determine an optimal mixed strategy for a game with no stable solution  (ii) by converting higher order games to linear programming problems that could then be solved using the Simplex method |

## Content of Additional Pure Mathematics (Optional paper Y545)

| **OCR Reference.** | **Content Description**  (unshaded content is AS content) | **Legacy Unit and Reference** | **Notes** |
| --- | --- | --- | --- |
| **8.01a** | a) Be able to work with general sequences given either as recurrence relations or by position-to-term (closed form) formulae .  *The notation  for sequences, which may or may not include a zeroth term, should be recognised.* | 4722 C2 – Sequences and Series (a) | (a) understand the idea of a sequence of terms, and use definitions such as  and relations such as  to calculate successive terms and deduce simple properties |
| **8.01b** | b) Use induction to prove results relating to both sequences and series. | 4725 FP1 – Proof by Induction (a) | (a) use the method of mathematical induction to establish a given result … |
| **8.01c** | c) Understand and be able to describe various possibilities for the behaviour of sequences.  *Learners are expected to be able to use the terms “periodic”, “convergence”, “divergence”, “oscillating”, “monotonic”.*  *Note that a periodic sequence with period two may be referred to as “oscillating”, but that both convergent and divergent sequences can oscillate. “Divergence” can refer to sequences that are bounded or unbounded.* |  | Describing the behaviour of sequences is implied in 4722. |
| **8.01d** | d) Identify and be able to use the limit of the *n*th term of a sequence as , including steady-states.  *Includes forming sequences from other sequences, for example, finding differences or ratios of successive terms of a sequence.*  [*Rates of convergence are excluded.*] | 4725 FP1 – Summation of Series (c) | (c) recognise, by direct consideration of the sum to  terms, when a series is convergent, and find the sum to infinity in such cases  The term steady-state is new content in the reformed specification. |
| **8.01e** | e) Be able to work with the Fibonacci Numbers (and other Fibonacci-like sequences, such as the Lucas Numbers), and understand their properties.  *Includes recognising and using the properties of , both numerical and algebraic, and its role in the Fibonacci sequence.* |  | The properties of Fibonacci and Lucas numbers are new content in the reformed specification. |
| **8.01f** | f) Be able to solve a first-order linear recurrence relation with constant coefficients, using the associated auxiliary equation and complementary function.  *Includes finding both general and particular solutions.*  *Includes homogeneous and non-homogeneous recurrence relations of the form , where may be a polynomial function or of the form*  *Includes knowing the terms, “closed form” and “position-to-term”.*  *Includes understanding that a “recurrence system” consists of a “recurrence relation”, an “initial condition” and the range of the variable n*. |  | The general solution of first-order linear recurrence relations is new content in the reformed specification. [Although the same ideas are in 4727 FP3 Differential Equations (c) and (d).] |
| **8.01g** | g) Be able to solve a second order linear recurrence relation with constant coefficients, using the associated auxiliary equation and complementary function.  *Includes finding both general and particular solutions.*  *Includes the cases when the roots of the auxiliary equation are:*  *(i) distinct and real,*  *(ii) repeated,*  *(iii) complex.*  *Includes homogeneous and non-homogeneous recurrence relations of the form , where may be a polynomial function or of the form*  *Learners should be aware that this topic is the discrete analogue of the work on differential equations in H245 section 4.10.* |  | Finding the general solution of second order linear recurrence relations is new content in the reformed specification. [Although the same ideas are in 4727 FP3 Differential Equations (c) and (d).] |
| **8.01h** | h) Be able to apply their knowledge of recurrence relations to modelling.  *Includes birth- and/or death-rates and the use of the  function for discrete models. Learners may find it useful to have a calculator with this function, but large numbers of repeated applications will not be required in the assessment.* |  | Modelling with recurrence relations is new content in the reformed specification. |
| **8.01i** | i) Be able to extend their knowledge of modelling to second order recurrence relations. |  | Modelling with recurrence relations is new content in the reformed specification. |
| **8.02a** | a) Understand and be able to work with numbers written in base *n*, where *n* is a positive integer.  *The standard notation for number bases will be used.*  *i.e.  will denote the number  (with  in this example) and the letters A-F will be used to represent the integers 10-15 respectively when .* |  | Number bases are new content in the reformed specification. |
| **8.02b** | b) Be able to use (without proof) the standard tests for divisibility by 2, 3, 4, 5, 8, 9 and 11.  *Includes knowing that repeated tests can be used to establish divisibility by composite numbers.* |  | Divisibility tests are new content in the reformed specification. |
| **8.02c** | c) Be able to establish suitable (algorithmic) tests for divisibility by other primes less than 50.  *For integers a and b, the notation*  will be used for *“a divides exactly into b” (“a is a factor of b”, “b is a multiple of a”, etc.).* |  | Tests for divisibility by small primes are new content in the reformed specification. |
| **8.02d** | d) Appreciate that, for any pair of positive integers *a*, *b* with , we can uniquely express *a* as where *q* (the quotient) and *r* (the residue, or remainder, when *a* is divided by *b*) are both positive integers and  . |  | The division algorithm is new content in the reformed specification. |
| **8.02e** | e) Understand and be able to use finite arithmetics (the arithmetic of integers modulo *n* for ). |  | Finite (modular) arithmetic is new content in the reformed specification. |
| **8.02g** | g) Be able to calculate quadratic residues and solve, or prove insoluble, equations involving them. |  | Quadratic and cubic residues are new content in the reformed specification. |
| **8.02f** | f) Be able to solve single linear congruences of the form . |  | Solving linear congruences of the form  is new content in the reformed specification. |
| **8.02h** | h) Be able to solve simultaneous linear congruences of the form .  *No more than three simultaneous linear congruences will be used. Use of the Chinese remainder theorem will be allowed but not required.* |  | Solving simultaneous linear congruences of the form  is new content in the reformed specification. |
| **8.02i** | i) Understand the concepts of prime numbers, composite numbers, highest common factors (hcf), and coprimality (relative primeness).  *Knowledge of the fundamental theorem of arithmetic will be expected, but proof of the result will not be required.* |  | The term coprimality is new content in the reformed specification. |
| **8.02j** | j) Know and be able to apply the result that  and  for any integers *x* and *y*.  *Includes using this result, for example to test for common factors or coprimality.* |  | The result  and  for any integers *x* and *y* and using this result to test for common factors or coprimality is new content in the reformed specification. |
| **8.02k** | k) Know and be able to use Euclid’s lemma: if  and  then  . |  | Euclid’s lemma is new content in the reformed specification. |
| **8.02l** | l) Know and be able to use Fermat’s little theorem in both forms:  1. If *p* is prime and hcf , then  ;  2. If *p* is prime .  *Includes recognising that if p is prime then Fermat’s little theorem holds, but that the converse is not true (that is, be aware of the existence of “pseudo-primes” to base p).*  [*The proof is excluded.*]  [*Carmichael numbers are excluded.*] |  | Using Fermat’s little theorem is new content in the reformed specification. |
| **8.02m** | m) Know and be able to use the fact that  is not necessarily the least positive integer *n* for which . |  | is not necessarily the least positive integer *n* for which  is new content in the reformed specification. |
| **8.02n** | n) Know that the *n* with this property, called “the order of *a* modulo *p*”, is a factor of  and be able to find it in specific cases. |  | The order of *a* modulo *p*, is a factor of  and finding an order in specific cases is new content in the reformed specification. |
| **8.02o** | o) Be able to use the binomial theorem to show that  for prime *p*, and use this result. |  | is new content in the reformed specification. |
| **8.03a** | a) Be able to work with binary operations and their properties when defined on given sets.  *Includes knowing and understanding the terms “associativity” and “commutativity”.* | 4727 FP3 – Groups (a) | (a) recall that a group consists of a set of elements together with a binary operation which is closed and associative, for which an identity exists in the set, and for which every element has an inverse in the set  8.03a and 8.03c cover 4727 Groups (a) between them. |
| **8.03b** | b) Be able to construct Cayley tables for given finite sets under the action of a given binary operation.  *Multiplicative notation and/or terminology will generally be used, when appropriate.* |  | Constructing Cayley tables is implied in 4727. |
| **8.03c** | c) Recall and be able to use the definition of a group, for example to show that a given structure is, or is not, a group.  *e.g. Questions may be set on groups of integers modulo n (for ), functions, matrices, transformations, the symmetries of given geometrical shapes and complex numbers.*  *Groups may be referred to in either of the forms:*  *1. by the given set and associated binary operation*  *,*  *2. as “G”, where the operation is understood, or*  *3. as “the set* G *with the operation ”.*  *To include knowing the meaning of the terms “identity” and “closed”, and that in an abelian group the operation is commutative.* | 4727 FP3 – Groups (a) & (b) | (a) recall that a group consists of a set of elements together with a binary operation which is closed and associative, for which an identity exists in the set, and for which every element has an inverse in the set  (b) use the basic group properties to show that a given structure is, or is not, a group (questions may be set on, for example, groups of matrices, transformations, integers modulo *)*  8.03a and 8.03c cover 4727 Groups (a) between them. |
| **8.03d** | d) Recognise and be able to use the Latin square property for group tables. |  | The Latin square property for group tables is new content in the reformed specification. |
| **8.03e** | e) Recall the meaning of the term “order”, as applied both to groups and to elements of a group, and be able to determine the orders of elements in a given group.  *Includes knowing and being able to use the fact that the order of an element is a factor of the order of the group.* | 4727 FP3 – Groups (d) | (d) recall the meaning of the term ‘order’, as applied both to groups and to elements of a group, and determine the order of elements in a given group |
| **8.03f** | f) Understand and be able to use the definition of a subgroup, find subgroups and show that given subsets are, or are not, proper subgroups. | 4727 FP3 – Groups (e) | (e) understand the idea of a subgroup of a group, find subgroups in simple cases, and show that given subsets are, or are not, (proper) subgroups |
| **8.03g** | g) Recall the meaning of the term “cyclic” as applied to groups. | 4727 FP3 – Groups (g) | (g) recall the meaning of the term ‘cyclic’ as applied to groups, and show familiarity with the structure of finite groups up to order 7 (questions on groups of higher order are not excluded, but no particular prior knowledge of such groups is expected)  8.03g, 8.03i and 8.03j (in A level) cover 4727 Groups (g) between them. |
| **8.03h** | h) Understand that a cyclic group is generated by “powers” of a single element (generator), that there may be more than one such element within a group, and that other (non-cyclic) groups may be generated by two or more elements along with their “powers” and “products”. |  | Powers and generators are implied in 4727. |
| **8.03i** | i) Be familiar with the structure of finite groups up to, and including, order seven, and able to apply this knowledge in solving problems. | 4727 FP3 – Groups (g) | (g) recall the meaning of the term ‘cyclic’ as applied to groups, and show familiarity with the structure of finite groups up to order 7 (questions on groups of higher order are not excluded, but no particular prior knowledge of such groups is expected)  8.03g, 8.03i and 8.03j (in A level) cover 4727 Groups (g) between them. |
| **8.03j** | j) Be able to work with groups of higher finite order, or of infinite order.  *No particular prior knowledge of such groups, or their structures, will be expected.* | 4727 FP3 – Groups (g) |
| **8.03k** | k) Recall and be able to apply Lagrange’s theoremconcerning the order of a subgroup of a finite group.  *The proof of the theorem is not required, but a clear statement of the result may be expected.* | 4727 FP3 – Groups (f) | (f) recall and apply Lagrange’s theorem concerning the order of a subgroup of a finite group (the proof of the theorem is not required) |
| **8.03l** | l) Be able to determine whether two given groups are, or are not, isomorphic using informal methods.  *e.g. By noting disparities between the orders of elements.* | 4727 FP3 – Groups (h) | (h) understand the idea of isomorphism between groups, and determine whether given finite groups are, or are not, isomorphic |
| **8.03m** | m) Be able to work with groups defined by their algebraic properties.  *Includes using algebraic methods to establish properties in abstract groups.*  *e.g. To show that any group in which every element is self-inverse is abelian, to establish an identity or complete a Cayley table.* | 4727 FP3 – Groups (c) | (c) use algebraic methods to establish properties in abstract groups in easy cases, e.g. to show that any group in which every element is self-inverse is commutative |
| **8.04a** | a) Understand and be able to use the definition, in geometrical terms, of the vector product and be able to form the vector product in magnitude and direction, and in component form.  *Includes use of the formula  , where  in that order (and the vectors  in that order) form a right-handed triple.* | 4727 FP3 – Vectors (c) | (c) recall the definition, in geometrical terms, of the vector product of two vectors, and, in cases whereandare expressed in component form, calculatein component form |
| **8.04b** | b) Understand the anti-commutative and distributive properties of the vector product. |  | These properties of the vector product are new content in the reformed specification. |
| **8.04c** | c) Be able to use the vector product to calculate areas of triangles and parallelograms. | 4727 FP3 – Vectors (c) | This is implied in 4727. |
| **8.04d** | d) Understand the significance of .  *e.g. The equation of a line in the form .* |  | The cross product equation of a line  is new content in the reformed specification. |
| **8.04e** | e) Understand and be able to use the definition of the scalar product, and be able to use it to calculate volumes of tetrahedra and parallelepipeds.  *Includes the notation .*  *Includes understanding the significance of .* |  | The scalar triple product  is new content in the reformed specification. |
| **8.05a** | a) Be able to work with functions of two variables, given either explicitly in the form  or implicitly in the form , and understand and use the fact that this equation, and its partial derivatives, relate to a 3-D surface.  *An informal understanding only of how the partial derivatives relate to the surface is required.*  *Functions  will involve sums and products of powers of x and y only. Issues relating to domains and ranges will not be considered beyond the appreciation that, for example the surface  has no point at which.* |  | Surfaces are new content in the reformed specification. |
| **8.05b** | b) Extend their knowledge of surfaces to those defined by functions of more than two variables, and incorporating trigonometric functions, logarithms and exponentials. |  | Surfaces are new content in the reformed specification. |
| **8.05c** | c) Be able to sketch sections and contours, and know how these are related to the surface.  *i.e. Sections of the form  or  and contours of the form* . |  | Sections and contours are new content in the reformed specification. |
| **8.05d** | d) Be able to find first and second derivatives, including mixed derivatives.  *Learners will be expected to recognise and use both notations for first- and second order partial derivatives, including mixed ones.*  *e g.* ,  and , .  *Includes the Mixed derivative theorem; namely, that  or  for suitably well-defined, continuous functions* f*.* |  | Partial differentiation is new content in the reformed specification. |
| **8.05e** | e) Understand and be able to apply the concept that stationary points of *z* arise when  (or ) and that these can be maxima, minima or saddle-points.  *Learners should know and understand the basic properties of these stationary points.*  *Learners will only be required to find stationary points, but will not be required to determine their natures.* |  | Stationary points and saddle-points are new content in the reformed specification. |
| **8.05f** | f) Be able to determine, for 3-D surfaces given in the form , the nature of maxima, minima and saddle-points by means of the sign of the determinant of the matrix of second partial derivatives (the Hessian Matrix),  ;  namely, that:  1. if  and , there is a (local) minimum;  2. if  and , there is a (local) maximum;  3. if  there is a saddle-point;  4. if  then the nature of the stationary point  cannot be determined by this test. |  | The Hessian matrix is new content in the reformed specification. |
| **8.05g** | g) Be able to determine, for 3-D surfaces given in the form , the equation of a tangent plane to the curve at a given point  using the formula  . |  | Tangent planes are new content in the reformed specification. |
| **8.06a** | a) Be able to establish and use given reduction formulae, and employ them to evaluate integrals using recursive techniques. | 4726 FP2 – Differentiation and Integration (f) | (f) derive and use reduction formulae for the evaluation of definite integrals in simple cases |
| **8.06b** | b) Be able to find arc lengths and areas of surface of revolution for curves defined in cartesian or parametric form. |  | Arc length and areas of surface of revolution are new content in the reformed specification. |

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| **Content from Legacy Units (FP1, FP2, FP3) which does not appear in the reformed A level specification (H245):**  FP2 – Rational Functions and Graphs (b): determine the salient features of the graph of a rational function for which the numerator and denominator are of degree 2 at most, including in particular (i) asymptotic behaviour and (ii) any restrictions on the values taken by the function.  FP2 – Rational Functions and Graphs (c): understand and use the relationship between the graphs of  and  FP2 – Hyperbolic Functions (a): recall definitions of , ,  and sketch their graphs  FP2 – Differentiation and Integration (g): understand how the area under a curve may be approximated by areas of rectangles, and use rectangles to estimate or set bounds for the area under a curve or to derive inequalities concerning sums  FP2 – Numerical Methods: entire section (content statements a, b, c & d)  FP3 – Differential Equations (b): use a given substitution to reduce a first-order differential equation to linear form or to a form in which the variables are separable  FP3 – Vectors (d): (ii) find the line of intersection of two non-parallel planes |

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