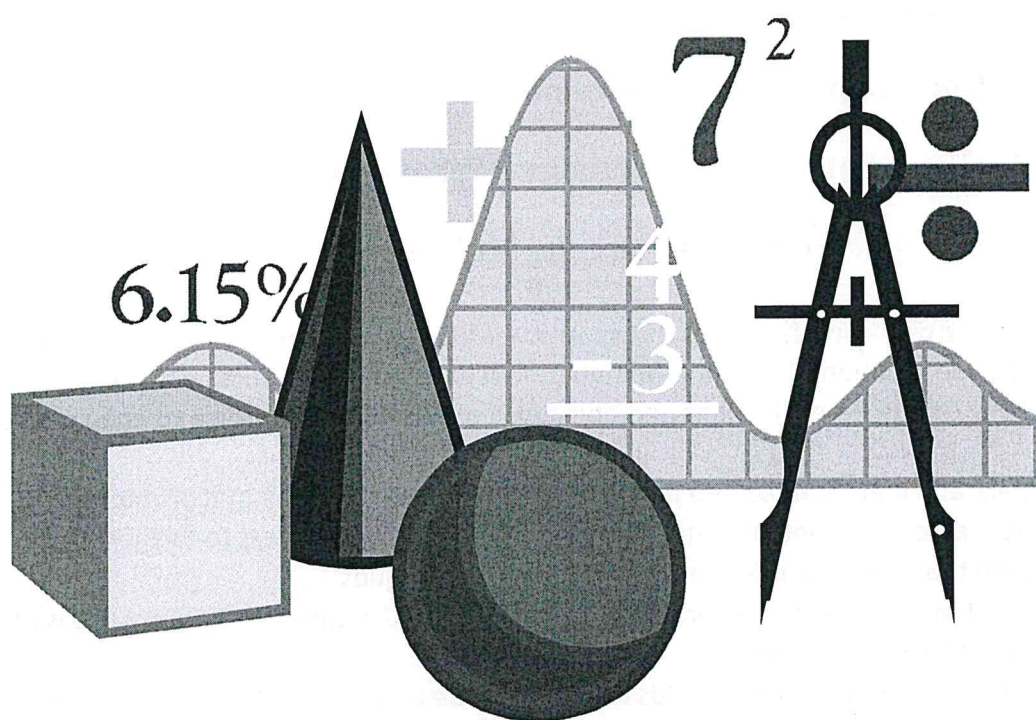




A Level Mathematics
INDUCTION BOOKLET

De Lisle College

2022

INTRODUCTION TO A LEVEL MATHS AT DE LISLE COLLEGE

Thank you for choosing to study Mathematics in the sixth form at De Lisle College. The Mathematics Department is committed to ensuring that you make good progress throughout your A level and in order that you make the best possible start to the course, we have prepared this booklet.

Contents of Induction booklet

Section 1: Course/specification overview – What does this course involve?

Section 2: Our department expectations – What do we expect of our students?

Section 3: Review/revise – What are the fundamental skills you need?

Section 1: Course/specification overview – What does this course involve?

You will study combination of Pure mathematics, Mechanics and Statistics, with two thirds of the course focusing on the Pure. The aims and objectives of this qualification are to enable students to:

- understand mathematics and mathematical processes in a way that promotes confidence, fosters enjoyment and provides a strong foundation for progress to further study
- extend their range of mathematical skills and techniques
- understand coherence and progression in mathematics and how different areas of mathematics are connected
- apply mathematics in other fields of study and be aware of the relevance of mathematics to the world of work and to situations in society in general
- use their mathematical knowledge to make logical and reasoned decisions in solving problems both within pure mathematics and in a variety of contexts, and communicate the mathematical rationale for these decisions clearly
- reason logically and recognise incorrect reasoning
- generalise mathematically
- construct mathematical proofs
- use their mathematical skills and techniques to solve challenging problems that require them to decide on the solution strategy
- recognise when mathematics can be used to analyse and solve a problem in context
- represent situations mathematically and understand the relationship between problems in context and mathematical models that may be applied to solve them
- draw diagrams and sketch graphs to help explore mathematical situations and interpret solutions
- make deductions and inferences and draw conclusions by using mathematical reasoning
- interpret solutions and communicate their interpretation effectively in context
- read and comprehend mathematical arguments, including justifications of methods and formulae, and communicate their understanding
- read and comprehend articles concerning applications of mathematics and communicate their understanding
- use technology such as calculators and computers effectively and recognise when their use may be inappropriate
- take increasing responsibility for their own learning and the evaluation of their own mathematical development.

The topics you will be covering include:

Pure: Proof and algebraic methods, Trigonometry, Coordinate geometry, The Binomial Expansion, Vectors, Integration, Differentiation, Exponentials and logarithms, Numerical methods, Functions, Sequences and Parametric Equations.

Mechanics: Kinematics, Forces, Dynamics, Statics, Moments, Variable acceleration and Vectors.

Statistics: Data Collection, Measuring and Representing data, Correlation, Hypothesis Testing, Linear regressions, Conditional Probability, Probability Distributions, The Binomial Distribution and The Normal Distribution.

Section 2: Our department expectations

Maths A level is very hard work. I mean it! It will take a lot of effort from you to reach your potential in this subject. However, a good qualification in this subject is valued very highly by Universities and employers. It can also be very rewarding and enjoyable. A minimum grade of a 7 is required for this course. However, this is no guarantee that you will do well on the course! (The same is true of an 8/9)

We will need to push on at quite a pace to get through the work. You will have homework set regularly during the week which will need to be completed before the next lesson. There will be a lot of work to complete. You will need to get yourself organised quickly. There will be regular tests on work covered. There will be a baseline test at the start of the year to ensure that you have mastered essential algebra skills.

The staff in De Lisle Maths Department love maths and are keen to help. We will always endeavour to find time for anyone who comes to see us with problems.

Section 3: Review/revise

It is **vitaly important** that you spend some time working through the questions in this booklet - you will need to have a good knowledge of these topics **before** you commence your course in September. You should have met all the topics before at GCSE. These skills should be secure and automatic as they form the foundation on which the rest of the course will be built.

Work through the introduction to each chapter, making sure that you understand the examples. Then tackle the exercise – not necessarily every question, but enough to ensure you understand the topic thoroughly. The answers are given at the back of the booklet. It is a requirement of the course that this preparatory work is completed.

We will test you in August to check how well you understand these topics, so it is essential that you have worked through the booklet before then. If you do not pass this test, you will be placed on a support contract and will be expected to attend support sessions and complete extra work until you have achieved the required standard. You will then be re-tested in October. A mock test is provided at the back of this booklet. **You must bring your answers to this AND evidence of completion of each of the preceding exercises to your first lesson in August.** If you fail to complete this work your continuation on the course will be reconsidered.

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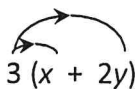
Chapter 1	Removing brackets
Chapter 2	Linear equations
Chapter 3	Simultaneous equations
Chapter 4	Factorising
Chapter 5	Change the subject of the formula
Chapter 6	Solving quadratic equations
Chapter 7	Indices
Chapter 8	Surds

Chapter 1: REMOVING BRACKETS

To remove a single bracket, we multiply every term in the bracket by the number or the expression on the outside:

Examples

1) $3(x + 2y) = 3x + 6y$



2) $-2(2x - 3) = (-2)(2x) + (-2)(-3)$
 $= -4x + 6$



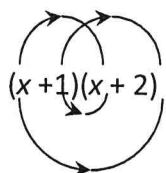
To expand two brackets, we must multiply everything in the first bracket by everything in the second bracket. We can do this in a variety of ways, including

- * the smiley face method
- * FOIL (Fronts Outers Inners Lasts)
- * using a grid.

Examples:

1) $(x + 1)(x + 2) = x(x + 2) + 1(x + 2)$

or



$$(x + 1)(x + 2) = x^2 + 2 + 2x + x$$

$$= x^2 + 3x + 2$$

or

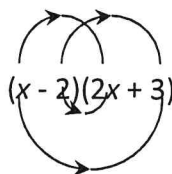
	x	1
x	x^2	x
2	$2x$	2

$$(x + 1)(x + 2) = x^2 + 2x + x + 2$$

$$= x^2 + 3x + 2$$

2) $(x - 2)(2x + 3) = x(2x + 3) - 2(2x + 3)$
 $= 2x^2 + 3x - 4x - 6$
 $= 2x^2 - x - 6$

or



$$(x - 2)(2x + 3) = 2x^2 - 6 + 3x - 4x = 2x^2 - x - 6$$

or

	x	-2
$2x$	$2x^2$	$-4x$
3	$3x$	-6

$$(2x + 3)(x - 2) = 2x^2 + 3x - 4x - 6$$

$$= 2x^2 - x - 6$$

EXERCISE A

Multiply out the following brackets and simplify.

1. $7(4x + 5)$
2. $-3(5x - 7)$
3. $5a - 4(3a - 1)$
4. $4y + y(2 + 3y)$
5. $-3x - (x + 4)$
6. $5(2x - 1) - (3x - 4)$
7. $(x + 2)(x + 3)$
8. $(t - 5)(t - 2)$
9. $(2x + 3y)(3x - 4y)$
10. $4(x - 2)(x + 3)$
11. $(2y - 1)(2y + 1)$
12. $(3 + 5x)(4 - x)$

Two Special Cases**Perfect Square:**

$$(x + a)^2 = (x + a)(x + a) = x^2 + 2ax + a^2$$

$$(2x - 3)^2 = (2x - 3)(2x - 3) = 4x^2 - 12x + 9$$

Difference of two squares:

$$(x - a)(x + a) = x^2 - a^2$$

$$(x - 3)(x + 3) = x^2 - 3^2 \\ = x^2 - 9$$

EXERCISE B Multiply out

1. $(x - 1)^2$
2. $(3x + 5)^2$
3. $(7x - 2)^2$
4. $(x + 2)(x - 2)$
5. $(3x + 1)(3x - 1)$
6. $(5y - 3)(5y + 3)$

Chapter 2: LINEAR EQUATIONS

When solving an equation, you must remember that whatever you do to one side must also be done to the other. You are therefore allowed to

- add the same amount to both side
- subtract the same amount from each side
- multiply the whole of each side by the same amount
- divide the whole of each side by the same amount.

If the equation has unknowns on both sides, you should collect all the letters onto the same side of the equation.

If the equation contains brackets, you should start by expanding the brackets.

A linear equation is an equation that contains numbers and terms in x . A linear equation does not contain any x^2 or x^3 terms.

More help on solving equations can be obtained by downloading the leaflet available at this website: <http://www.mathcentre.ac.uk/resources/workbooks/mathcentre/web-simplelinear.pdf>

Example 1: Solve the equation $64 - 3x = 25$

Solution: There are various ways to solve this equation. One approach is as follows:

Step 1: Add $3x$ to both sides (so that the x term is positive): $64 = 3x + 25$

Step 2: Subtract 25 from both sides: $39 = 3x$

Step 3: Divide both sides by 3: $13 = x$

So the solution is $x = 13$.

Example 2: Solve the equation $6x + 7 = 5 - 2x$.

Solution:

Step 1: Begin by adding $2x$ to both sides
(to ensure that the x terms are together on the same side) $8x + 7 = 5$

Step 2: Subtract 7 from each side: $8x = -2$

Step 3: Divide each side by 8: $x = -\frac{1}{4}$

Exercise A: Solve the following equations, showing each step in your working:

1) $2x + 5 = 19$

2) $5x - 2 = 13$

3) $11 - 4x = 5$

4) $5 - 7x = -9$

5) $11 + 3x = 8 - 2x$

6) $7x + 2 = 4x - 5$

Example 3: Solve the equation $2(3x - 2) = 20 - 3(x + 2)$

Step 1: Multiply out the brackets: $6x - 4 = 20 - 3x - 6$
(taking care of the negative signs)

Step 2: Simplify the right hand side: $6x - 4 = 14 - 3x$

Step 3: Add $3x$ to each side: $9x - 4 = 14$

Step 4: Add 4: $9x = 18$

Step 5: Divide by 9: $x = 2$

Exercise B: Solve the following equations.

1) $5(2x - 4) = 4$

2) $4(2 - x) = 3(x - 9)$

3) $8 - (x + 3) = 4$

4) $14 - 3(2x + 3) = 2$

EQUATIONS CONTAINING FRACTIONS

When an equation contains a fraction, the first step is usually to multiply through by the denominator of the fraction. This ensures that there are no fractions in the equation.

Example 4: Solve the equation $\frac{y}{2} + 5 = 11$

Solution:

Step 1: Multiply through by 2 (the denominator in the fraction): $y + 10 = 22$

Step 2: Subtract 10: $y = 12$

Example 5: Solve the equation $\frac{1}{3}(2x + 1) = 5$

Solution:

Step 1: Multiply by 3 (to remove the fraction) $2x + 1 = 15$

Step 2: Subtract 1 from each side $2x = 14$

Step 3: Divide by 2 $x = 7$

When an equation contains two fractions, you need to multiply by the lowest common denominator.

This will then remove both fractions.

Example 6: Solve the equation $\frac{x+1}{4} + \frac{x+2}{5} = 2$

Solution:

Step 1: Find the lowest common denominator:

4

The smallest number that both and 5 divide into is 20.

Step 2: Multiply both sides by the lowest common denominator

$$\frac{20(x+1)}{4} + \frac{20(x+2)}{5} = 40$$

Step 3: Simplify the left hand side:

$$\frac{\overset{5}{\cancel{20}}(x+1)}{\cancel{4}} + \frac{\overset{4}{\cancel{20}}(x+2)}{\cancel{5}} = 40$$

$$5(x+1) + 4(x+2) = 40$$

Step 4: Multiply out the brackets:

$$5x + 5 + 4x + 8 = 40$$

Step 5: Simplify the equation:

$$9x + 13 = 40$$

Step 6: Subtract 13

$$9x = 27$$

Step 7: Divide by 9:

$$x = 3$$

Example 7: Solve the equation $x + \frac{x-2}{4} = 2 - \frac{3-5x}{6}$

Solution: The lowest number that 4 and 6 go into is 12. So we multiply every term by 12:

$$12x + \frac{12(x-2)}{4} = 24 - \frac{12(3-5x)}{6}$$

Simplify

$$12x + 3(x-2) = 24 - 2(3-5x)$$

Expand brackets

$$12x + 3x - 6 = 24 - 6 + 10x$$

Simplify

$$15x - 6 = 18 + 10x$$

Subtract 10x

$$5x - 6 = 18$$

Add 6

$$5x = 24$$

Divide by 5

$$x = 4.8$$

Exercise C: Solve these equations

1) $\frac{1}{2}(x+3) = 5$

2) $\frac{2x}{3} - 1 = \frac{x}{3} + 4$

3) $\frac{y}{4} + 3 = 5 - \frac{y}{3}$

4) $\frac{x-2}{7} = 2 + \frac{3-x}{14}$

Exercise C (continued)

5) $\frac{7x-1}{2} = 13 - x$

6) $\frac{y-1}{2} + \frac{y+1}{3} = \frac{2y+5}{6}$

7) $2x + \frac{x-1}{2} = \frac{5x+3}{3}$

8) $2 - \frac{5}{x} = \frac{10}{x} - 1$

FORMING EQUATIONS

Example 8: Find three consecutive numbers so that their sum is 96.

Solution: Let the first number be n , then the second is $n + 1$ and the third is $n + 2$.

Therefore $n + (n + 1) + (n + 2) = 96$

$$3n + 3 = 96$$

$$3n = 93$$

$$n = 31$$

So the numbers are 31, 32 and 33.

Exercise D:

1) Find 3 consecutive even numbers so that their sum is 108.

2) The perimeter of a rectangle is 79 cm. One side is three times the length of the other.
Form an equation and hence find the length of each side.

3) Two girls have 72 photographs of celebrities between them. One gives 11 to the other and finds that she now has half the number her friend has.
Form an equation, letting n be the number of photographs one girl had at the **beginning**.
Hence find how many each has **now**.

Chapter 3: SIMULTANEOUS EQUATIONS

An example of a pair of simultaneous equations is $3x + 2y = 8$ ○
 $5x + y = 11$ ○

In these equations, x and y stand for two numbers. We can solve these equations in order to find the values of x and y by eliminating one of the letters from the equations.

In these equations it is simplest to eliminate y . We do this by making the coefficients of y the same in both equations. This can be achieved by multiplying equation ○ by 2, so that both equations contain $2y$:

$$\begin{array}{rcl} 3x + 2y & = & 8 \quad \text{○} \\ 10x + 2y & = & 22 \quad 2 \times \text{○} = \text{○} \end{array}$$

To eliminate the y terms, we subtract equation ○ from equation ○. We get: $7x = 14$
i.e. $x = 2$

To find y , we substitute $x = 2$ into one of the original equations. For example if we put it into ○:

$$\begin{array}{rcl} 10 + y & = & 11 \\ y & = & 1 \end{array}$$

Therefore the solution is $x = 2, y = 1$.

Remember: You can check your solutions by substituting both x and y into the original equations.

Example: Solve $2x + 5y = 16$ ○
 $3x - 4y = 1$ ○

Solution: We begin by getting the same number of x or y appearing in both equation. We can get $20y$ in both equations if we multiply the top equation by 4 and the bottom equation by 5:

$$\begin{array}{rcl} 8x + 20y & = & 64 \quad \text{○} \\ 15x - 20y & = & 5 \quad \text{○} \end{array}$$

As the SIGNS in front of $20y$ are DIFFERENT, we can eliminate the y terms from the equations by ADDING:

$$\begin{array}{rcl} 23x & = & 69 \quad \text{○} + \text{○} \\ \text{i.e. } x & = & 3 \end{array}$$

Substituting this into equation ○ gives:

$$\begin{array}{rcl} 6 + 5y & = & 16 \\ 5y & = & 10 \\ \text{So... } y & = & 2 \end{array}$$

The solution is $x = 3, y = 2$.

If you need **more help** on solving simultaneous equations, you can download a booklet from the following website:

<http://www.mathcentre.ac.uk/resources/workbooks/mathcentre/web-simultaneous1.pdf>

Exercise:

Solve the pairs of simultaneous equations in the following questions:

1) $x + 2y = 7$
 $3x + 2y = 9$

2) $x + 3y = 0$
 $3x + 2y = -7$

3) $3x - 2y = 4$
 $2x + 3y = -6$

4) $9x - 2y = 25$
 $4x - 5y = 7$

5) $4a + 3b = 22$
 $5a - 4b = 43$

6) $3p + 3q = 15$
 $2p + 5q = 14$

Chapter 4: FACTORISING

Common factors

We can factorise some expressions by taking out a common factor.

Example 1: Factorise $12x - 30$

Solution: 6 is a common factor to both 12 and 30. We can therefore factorise by taking 6 outside a bracket:

$$12x - 30 = 6(2x - 5)$$

Example 2: Factorise $6x^2 - 2xy$

Solution: 2 is a common factor to both 6 and 2. Both terms also contain an x . So we factorise by taking $2x$ outside a bracket.

$$6x^2 - 2xy = 2x(3x - y)$$

Example 3: Factorise $9x^3y^2 - 18x^2y$

Solution: 9 is a common factor to both 9 and 18.
The highest power of x that is present in both expressions is x^2 .
There is also a y present in both parts.
So we factorise by taking $9x^2y$ outside a bracket:

$$9x^3y^2 - 18x^2y = 9x^2y(xy - 2)$$

Example 4: Factorise $3x(2x - 1) - 4(2x - 1)$

Solution: There is a common bracket as a factor.
So we factorise by taking $(2x - 1)$ out as a factor.
The expression factorises to $(2x - 1)(3x - 4)$

Exercise A

Factorise each of the following

1) $3x + xy$

2) $4x^2 - 2xy$

3) $pq^2 - p^2q$

4) $3pq - 9q^2$

5) $2x^3 - 6x^2$

6) $8a^5b^2 - 12a^3b^4$

7) $5y(y - 1) + 3(y - 1)$

Factorising quadratics

Simple quadratics: Factorising quadratics of the form $x^2 + bx + c$

The method is:

Step 1: Form two brackets $(x \dots)(x \dots)$

Step 2: Find two numbers that multiply to give c and add to make b . These two numbers get written at the other end of the brackets.

Example 1: Factorise $x^2 - 9x - 10$.

Solution: We need to find two numbers that multiply to make -10 and add to make -9. These numbers are -10 and 1.

Therefore $x^2 - 9x - 10 = (x - 10)(x + 1)$.

General quadratics: Factorising quadratics of the form $ax^2 + bx + c$

The method is:

Step 1: Find two numbers that multiply together to make ac and add to make b .

Step 2: Split up the bx term using the numbers found in step 1.

Step 3: Factorise the front and back pair of expressions as fully as possible.

Step 4: There should be a common bracket. Take this out as a common factor.

Example 2: Factorise $6x^2 + x - 12$.

Solution: We need to find two numbers that multiply to make $6 \times -12 = -72$ and add to make 1. These two numbers are -8 and 9.

$$\begin{aligned}\text{Therefore, } 6x^2 + x - 12 &= 6x^2 - 8x + 9x - 12 \\ &= 2x(3x - 4) + 3(3x - 4) && \text{(the two brackets must be identical)} \\ &= (3x - 4)(2x + 3)\end{aligned}$$

Difference of two squares: Factorising quadratics of the form $x^2 - a^2$

Remember that $x^2 - a^2 = (x + a)(x - a)$.

$$\begin{aligned}\text{Therefore: } x^2 - 9 &= x^2 - 3^2 = (x + 3)(x - 3) \\ 16x^2 - 25 &= (2x)^2 - 5^2 = (2x + 5)(2x - 5)\end{aligned}$$

$$\text{Also notice that: } 2x^2 - 8 = 2(x^2 - 4) = 2(x + 4)(x - 4)$$

$$\text{and } 3x^3 - 48xy^2 = 3x(x^2 - 16y^2) = 3x(x + 4y)(x - 4y)$$

Factorising by pairing

We can factorise expressions like $2x^2 + xy - 2x - y$ using the method of factorising by pairing:

$$\begin{aligned}2x^2 + xy - 2x - y &= x(2x + y) - 1(2x + y) && \text{(factorise front and back pairs, ensuring both} \\ & && \text{brackets are identical)} \\ &= (2x + y)(x - 1)\end{aligned}$$

If you need **more help** with factorising, you can download a booklet from this website
<http://www.mathcentre.ac.uk/resources/workbooks/mathcentre/web-factorisingquadratics.pdf>

Exercise B

Factorise

1) $x^2 - x - 6$

2) $x^2 + 6x - 16$

3) $2x^2 + 5x + 2$

4) $2x^2 - 3x$ (factorise by taking out a common factor)

5) $3x^2 + 5x - 2$

6) $2y^2 + 17y + 21$

7) $7y^2 - 10y + 3$

8) $10x^2 + 5x - 30$

9) $4x^2 - 25$

10) $x^2 - 3x - xy + 3y^2$

11) $4x^2 - 12x + 8$

12) $16m^2 - 81n^2$

13) $4y^3 - 9a^2y$

14) $8(x+1)^2 - 2(x+1) - 10$

Chapter 5: CHANGING THE SUBJECT OF A FORMULA

We can use algebra to change the subject of a formula. Rearranging a formula is similar to solving an equation – we must do the same to both sides in order to keep the equation balanced.

Example 1: Make x the subject of the formula $y = 4x + 3$.

Solution:
Subtract 3 from both sides: $y = 4x + 3$
 $y - 3 = 4x$
Divide both sides by 4; $\frac{y-3}{4} = x$

So $x = \frac{y-3}{4}$ is the same equation but with x the subject.

Example 2: Make x the subject of $y = 2 - 5x$

Solution: Notice that in this formula the x term is negative.
 $y = 2 - 5x$
Add $5x$ to both sides $y + 5x = 2$ (the x term is now positive)
Subtract y from both sides $5x = 2 - y$
Divide both sides by 5 $x = \frac{2-y}{5}$

Example 3: The formula $C = \frac{5(F-32)}{9}$ is used to convert between ° Fahrenheit and ° Celsius.

We can rearrange to make F the subject.

$C = \frac{5(F-32)}{9}$
Multiply by 9 $9C = 5(F-32)$ (this removes the fraction)
Expand the brackets $9C = 5F - 160$
Add 160 to both sides $9C + 160 = 5F$
Divide both sides by 5 $\frac{9C+160}{5} = F$
Therefore the required rearrangement is $F = \frac{9C+160}{5}$.

Exercise A

Make x the subject of each of these formulae:

1) $y = 7x - 1$

2) $y = \frac{x+5}{4}$

3) $4y = \frac{x}{3} - 2$

4) $y = \frac{4(3x-5)}{9}$

Rearranging equations involving squares and square roots

Example 4: Make x the subject of $x^2 + y^2 = w^2$

Solution:

$$x^2 + y^2 = w^2$$

Subtract y^2 from both sides:

$$x^2 = w^2 - y^2 \quad (\text{this isolates the term involving } x)$$

Square root both sides:

$$x = \pm\sqrt{w^2 - y^2}$$

Remember that you can have a positive or a negative square root. We cannot simplify the answer any more.

Example 5: Make a the subject of the formula $t = \frac{1}{4}\sqrt{\frac{5a}{h}}$

Solution:

$$t = \frac{1}{4}\sqrt{\frac{5a}{h}}$$

Multiply by 4

$$4t = \sqrt{\frac{5a}{h}}$$

Square both sides

$$16t^2 = \frac{5a}{h}$$

Multiply by h :

$$16t^2h = 5a$$

Divide by 5:

$$\frac{16t^2h}{5} = a$$

Exercise B:

Make t the subject of each of the following

1) $P = \frac{wt}{32r}$

2) $P = \frac{wt^2}{32r}$

3) $V = \frac{1}{3}\pi t^2h$

4) $P = \sqrt{\frac{2t}{g}}$

5) $Pa = \frac{w(v-t)}{g}$

6) $r = a + bt^2$

More difficult examples

Sometimes the variable that we wish to make the subject occurs in more than one place in the formula. In these questions, we collect the terms involving this variable on one side of the equation, and we put the other terms on the opposite side.

Example 6: Make t the subject of the formula $a - xt = b + yt$

Solution: $a - xt = b + yt$

Start by collecting all the t terms on the right hand side:

Add xt to both sides: $a = b + yt + xt$

Now put the terms without a t on the left hand side:

Subtract b from both sides: $a - b = yt + xt$

Factorise the RHS: $a - b = t(y + x)$

Divide by $(y + x)$: $\frac{a - b}{y + x} = t$

So the required equation is $t = \frac{a - b}{y + x}$

Example 7: Make W the subject of the formula $T - W = \frac{Wa}{2b}$

Solution: This formula is complicated by the fractional term. We begin by removing the fraction:

Multiply by $2b$: $2bT - 2bW = Wa$

Add $2bW$ to both sides: $2bT = Wa + 2bW$ (this collects the W 's together)

Factorise the RHS: $2bT = W(a + 2b)$

Divide both sides by $a + 2b$: $W = \frac{2bT}{a + 2b}$

If you need more help you can download an information booklet on rearranging equations from the following website:

<http://www.mathcentre.ac.uk/resources/workbooks/mathcentre/web-formulae2-tom.pdf>

Exercise C

Make x the subject of these formulae:

1) $ax + 3 = bx + c$

2) $3(x + a) = k(x - 2)$

3) $y = \frac{2x + 3}{5x - 2}$

4) $\frac{x}{a} = 1 + \frac{x}{b}$

Chapter 6: SOLVING QUADRATIC EQUATIONS

A quadratic equation has the form $ax^2 + bx + c = 0$.

There are two methods that are commonly used for solving quadratic equations:

- * factorising
- * the quadratic formula

Note that not all quadratic equations can be solved by factorising. The quadratic formula can always be used however.

Method 1: Factorising

Make sure that the equation is rearranged so that the right hand side is 0. It usually makes it easier if the coefficient of x^2 is positive.

Example 1 : Solve $x^2 - 3x + 2 = 0$

Factorise $(x-1)(x-2) = 0$

Either $(x-1) = 0$ or $(x-2) = 0$

So the solutions are $x = 1$ or $x = 2$

Note: The individual values $x = 1$ and $x = 2$ are called the **roots** of the equation.

Example 2: Solve $x^2 - 2x = 0$

Factorise: $x(x-2) = 0$

Either $x = 0$ or $(x-2) = 0$

So $x = 0$ or $x = 2$

Method 2: Using the formula

Recall that the roots of the quadratic equation $ax^2 + bx + c = 0$ are given by the formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Example 3: Solve the equation $2x^2 - 5 = 7 - 3x$

Solution: First we rearrange so that the right hand side is 0. We get $2x^2 + 3x - 12 = 0$

We can then tell that $a = 2$, $b = 3$ and $c = -12$.

Substituting these into the quadratic formula gives:

$$x = \frac{-3 \pm \sqrt{3^2 - 4 \times 2 \times (-12)}}{2 \times 2} = \frac{-3 \pm \sqrt{105}}{4} \quad (\text{this is the surd form for the solutions})$$

If we have a calculator, we can evaluate these roots to get: $x = 1.81$ or $x = -3.31$

If you need more help with the work in this chapter, there is an information booklet downloadable from this web site: <http://www.mathcentre.ac.uk/resources/workbooks/mathcentre/web-quadratic-equations.pdf>

EXERCISE

1) Use factorisation to solve the following equations:

a) $x^2 + 3x + 2 = 0$

b) $x^2 - 3x - 4 = 0$

c) $x^2 = 15 - 2x$

2) Find the roots of the following equations:

a) $x^2 + 3x = 0$

b) $x^2 - 4x = 0$

c) $4 - x^2 = 0$

3) Solve the following equations either by factorising or by using the formula:

a) $6x^2 - 5x - 4 = 0$

b) $8x^2 - 24x + 10 = 0$

4) Use the formula to solve the following equations to 3 significant figures. Some of the equations can't be solved.

a) $x^2 + 7x + 9 = 0$

b) $6 + 3x = 8x^2$

c) $4x^2 - x - 7 = 0$

d) $x^2 - 3x + 18 = 0$

e) $3x^2 + 4x + 4 = 0$

f) $3x^2 = 13x - 16$

Chapter 7: INDICES

Basic rules of indices

y^4 means $y \times y \times y \times y$.

4 is called the **index** (plural: indices), **power** or **exponent** of y .

There are 3 basic rules of indices:

- | | | | |
|----|----------------------------|------|------------------------|
| 1) | $a^m \times a^n = a^{m+n}$ | e.g. | $3^4 \times 3^5 = 3^9$ |
| 2) | $a^m \div a^n = a^{m-n}$ | e.g. | $3^8 \div 3^6 = 3^2$ |
| 3) | $(a^m)^n = a^{mn}$ | e.g. | $(3^2)^5 = 3^{10}$ |

Further examples

$$y^4 \times 5y^3 = 5y^7$$

$$4a^3 \times 6a^2 = 24a^5$$

$$2c^2 \times (-3c^6) = -6c^8$$

(multiply the numbers and multiply the a 's)

(multiply the numbers and multiply the c 's)

$$24d^7 \div 3d^2 = \frac{24d^7}{3d^2} = 8d^5$$

(divide the numbers and divide the d terms i.e. by subtracting the powers)

Exercise A

Simplify the following:

1) $b \times 5b^5 =$

(Remember that $b = b^1$)

2) $3c^2 \times 2c^5 =$

3) $b^2c \times bc^3 =$

4) $2n^6 \times (-6n^2) =$

5) $8n^8 \div 2n^3 =$

6) $d^{11} \div d^9 =$

7) $(a^3)^2 =$

8) $(-d^4)^3 =$

More complex powers

Zero index:

Recall from GCSE that

$$a^0 = 1.$$

This result is true for any non-zero number a .

Therefore $5^0 = 1$ $\left(\frac{3}{4}\right)^0 = 1$ $(-5.2304)^0 = 1$

Negative powers

A power of -1 corresponds to the reciprocal of a number, i.e. $a^{-1} = \frac{1}{a}$

Therefore $5^{-1} = \frac{1}{5}$

$$0.25^{-1} = \frac{1}{0.25} = 4$$

$$\left(\frac{4}{5}\right)^{-1} = \frac{5}{4}$$

(you find the reciprocal of a fraction by swapping the top and bottom over)

This result can be extended to more general negative powers: $a^{-n} = \frac{1}{a^n}$.

This means:

$$3^{-2} = \frac{1}{3^2} = \frac{1}{9}$$

$$2^{-4} = \frac{1}{2^4} = \frac{1}{16}$$

$$\left(\frac{1}{4}\right)^{-2} = \left(\left(\frac{1}{4}\right)^{-1}\right)^2 = \left(\frac{4}{1}\right)^2 = 16$$

Fractional powers:

Fractional powers correspond to roots:

$$a^{1/2} = \sqrt{a}$$

$$a^{1/3} = \sqrt[3]{a}$$

$$a^{1/4} = \sqrt[4]{a}$$

In general:

$$a^{1/n} = \sqrt[n]{a}$$

Therefore:

$$8^{1/3} = \sqrt[3]{8} = 2$$

$$25^{1/2} = \sqrt{25} = 5$$

$$10000^{1/4} = \sqrt[4]{10000} = 10$$

A more general fractional power can be dealt with in the following way: $a^{m/n} = (a^{1/n})^m$

So $4^{3/2} = (\sqrt{4})^3 = 2^3 = 8$

$$\left(\frac{8}{27}\right)^{2/3} = \left(\left(\frac{8}{27}\right)^{1/3}\right)^2 = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$$

$$\left(\frac{25}{36}\right)^{-3/2} = \left(\frac{36}{25}\right)^{3/2} = \left(\sqrt{\frac{36}{25}}\right)^3 = \left(\frac{6}{5}\right)^3 = \frac{216}{125}$$

Exercise B:

Find the value of:

1) $4^{1/2}$

2) $27^{1/3}$

3) $\left(\frac{1}{9}\right)^{1/2}$

4) 5^{-2}

5) 18^0

6) 7^{-1}

7) $27^{2/3}$

8) $\left(\frac{2}{3}\right)^{-2}$

9) $8^{-2/3}$

10) $(0.04)^{1/2}$

11) $\left(\frac{8}{27}\right)^{2/3}$

12) $\left(\frac{1}{16}\right)^{-3/2}$

Simplify each of the following:

13) $2a^{1/2} \times 3a^{5/2}$

14) $x^3 \times x^{-2}$

15) $(x^2y^4)^{1/2}$

Chapter 8: SURDS

A surd is a root of a number that cannot be expressed as an integer. Surds are part of the set of irrational numbers.

Example:

$\sqrt{3}$ and $\sqrt{8}$ are surds but $\sqrt{4}$ is not as it equals 2.

Simplifying Surds

Start to simplify surds by using two rules:

$$\sqrt{ab} = \sqrt{a} \times \sqrt{b} \text{ and } \sqrt{\frac{a}{b}} = \frac{\sqrt{a}}{\sqrt{b}}$$

By using the multiplication rule, simplify surds by finding a factor of the number you are taking a root of which is a square number. Always try to find the largest square number factor, otherwise you will have to simplify further.

Example:

$$\begin{aligned}\sqrt{8} &= \sqrt{4} \times \sqrt{2} \\ &= 2\sqrt{2}\end{aligned}$$

$$\begin{aligned}3\sqrt{12} &= 3 \times \sqrt{4} \times \sqrt{3} \\ &= 3 \times 2 \times \sqrt{3} \\ &= 6\sqrt{3}\end{aligned}$$

$$\begin{aligned}\frac{\sqrt{600}}{\sqrt{2}} &= \sqrt{\frac{600}{2}} \\ &= \sqrt{300} \\ &= \sqrt{100} \times \sqrt{3} \\ &= 10\sqrt{3}\end{aligned}$$

EXERCISE A

Simplify

1) $\sqrt{50}$

2) $\sqrt{72}$

3) $\sqrt{27}$

4) $\sqrt{80}$

5) $\sqrt{360}$

6) $\frac{\sqrt{900}}{\sqrt{3}}$

Multiplying and Dividing with Surds

The rules of algebra are true for any numeric value; these include surds. To multiply and divide expressions with surds, deal with any integers together and then deal with any surds.

Examples:

$$2\sqrt{3} \times \sqrt{2} = 2\sqrt{6}$$

$$3\sqrt{5} \times 6\sqrt{2} = 18\sqrt{10}$$

$$\begin{aligned} 2\sqrt{5} \times 7\sqrt{8} &= 14\sqrt{40} \\ &= 14 \times \sqrt{4} \times \sqrt{10} \\ &= 28\sqrt{10} \end{aligned}$$

$$\sqrt{2}(5 + 2\sqrt{3}) = 5\sqrt{2} + 2\sqrt{6}$$

$$\frac{8\sqrt{14}}{2\sqrt{7}} = 4\sqrt{2}$$

$$(1 + \sqrt{3})(2 - \sqrt{2}) = 2 - 2\sqrt{2} + 2\sqrt{3} - \sqrt{6}$$

$$\begin{aligned} (3 + \sqrt{2})(3 - \sqrt{2}) &= 3^2 - (\sqrt{2})^2 \\ &= 1 \end{aligned}$$

In this example, you could expand as usual but this is an example of the difference of two squares.

EXERCISE B

Simplify

1) $\sqrt{3} \times \sqrt{7}$

2) $5\sqrt{2} \times 4\sqrt{5}$

3) $3\sqrt{3} \times 2\sqrt{6}$

4) $\sqrt{8} \times \sqrt{27}$

5) $\frac{5\sqrt{20}}{6\sqrt{5}}$

6) $\frac{8\sqrt{18}}{4\sqrt{2}}$

7) $(\sqrt{2} + 1)(\sqrt{2} + 5)$

8) $(5 - \sqrt{3})(\sqrt{2} - 8)$

Addition and Subtraction with Surds

You can only add or subtract with surds if the surd is the same; sometimes if they are not the same, you may be able to simplify them so that the same surd is present.

Example:

$$2\sqrt{3} + 4\sqrt{3} + 6\sqrt{5} = 6\sqrt{3} + 6\sqrt{5}$$

Here add the $2\sqrt{3}$ and $4\sqrt{3}$ as the same surd is present but you cannot add the $6\sqrt{5}$.

$$\begin{aligned} 2\sqrt{5} + \sqrt{45} &= 2\sqrt{5} + 3\sqrt{5} \\ &= 5\sqrt{5} \end{aligned}$$

By simplifying $\sqrt{45}$ to $3\sqrt{5}$, you can add the two surds together.

These methods also work for subtraction of surds.

Exercise C

Simplify

1) $\sqrt{3} + \sqrt{7}$

2) $5\sqrt{2} + 4\sqrt{2}$

3) $3\sqrt{6} + \sqrt{24}$

4) $\sqrt{50} + \sqrt{8}$

5) $\sqrt{27} + \sqrt{75}$

6) $2\sqrt{5} - \sqrt{5}$

7) $\sqrt{72} - \sqrt{50}$

8) $6\sqrt{3} - \sqrt{12} + \sqrt{27}$

9) $\sqrt{200} + \sqrt{90} - \sqrt{98}$

10) $\sqrt{72} - \sqrt{75} + \sqrt{108}$

Rationalising the Denominator

It is far easier to calculate with a fraction if the surd in the denominator is a rational number (i.e. not a surd). The process of this is known as *rationalising the denominator*. To do this, multiply by the surd in the denominator, doing so makes use of the fact that $\sqrt{a} \times \sqrt{a} = (\sqrt{a})^2 = a$

Example:

$$\frac{1}{\sqrt{3}}$$

Multiply the denominator by $\sqrt{3}$ to rationalise it and so multiply the numerator by $\sqrt{3}$ also:

$$\frac{1}{\sqrt{3}} \times \frac{\sqrt{3}}{\sqrt{3}} = \frac{\sqrt{3}}{3}$$

Example 2:

$$\begin{aligned}\frac{4}{\sqrt{2}} &= \frac{4}{\sqrt{2}} \times \frac{\sqrt{2}}{\sqrt{2}} \\ &= \frac{4\sqrt{2}}{2} \\ &= 2\sqrt{2}\end{aligned}$$

Example 3:

$$\begin{aligned}\frac{2 + \sqrt{3}}{\sqrt{5}} &= \frac{2 + \sqrt{3}}{\sqrt{5}} \times \frac{\sqrt{5}}{\sqrt{5}} \\ &= \frac{\sqrt{5}(2 + \sqrt{3})}{5} \\ &= \frac{2\sqrt{5} + \sqrt{15}}{5}\end{aligned}$$

If there is more than just a surd in the denominator, we make use of the difference of two squares by multiplying by its conjugate.

Example:

Rationalise $\frac{2}{3 - \sqrt{7}}$

We multiply the numerator and denominator by its conjugate: $3 + \sqrt{7}$

It's a difference of two squares so expand as usual

$$\begin{aligned}\frac{2}{3 - \sqrt{7}} \times \frac{3 + \sqrt{7}}{3 + \sqrt{7}} &= \frac{2(3 + \sqrt{7})}{(3 - \sqrt{7})(3 + \sqrt{7})} \\ &= \frac{2(3 + \sqrt{7})}{3^2 - (\sqrt{7})^2} \\ &= \frac{2(3 + \sqrt{7})}{9 - 7} \\ &= \frac{2(3 + \sqrt{7})}{2} \\ &= 3 + \sqrt{7}\end{aligned}$$

Exercise D

Rationalise the following:

1

a) $\frac{1}{\sqrt{2}}$

d) $\frac{5}{2\sqrt{7}}$

g) $\frac{4+\sqrt{7}}{\sqrt{3}}$

b) $\frac{3}{\sqrt{5}}$

e) $\frac{\sqrt{3}}{\sqrt{2}}$

h) $\frac{6+8\sqrt{5}}{\sqrt{2}}$

c) $\frac{10}{\sqrt{5}}$

f) $\frac{10}{\sqrt{10}}$

i) $\frac{6-\sqrt{5}}{\sqrt{5}}$

2

a) $\frac{1}{\sqrt{2}-1}$

d) $\frac{1}{3+\sqrt{5}}$

b) $\frac{2}{\sqrt{6}-2}$

e) $\frac{1}{\sqrt{6}-\sqrt{5}}$

c) $\frac{6}{\sqrt{7}+2}$

Practice Booklet Test

This is the review test that you must complete and bring full worked solutions to your first lesson in August. A similar skills test will be given early in August. Students should be aware that if they underperform in this test they will be required to attend additional afterschool sessions until they have mastered all of the fundamental skills which are covered in this booklet.

You may NOT use a calculator

If $ax^2 + bx + c = 0$ then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

1. Expand and simplify

(a) $(2x + 3)(2x - 1)$

(b) $(a + 3)^2$

(c) $4x(3x - 2) - x(2x + 5)$

2. Factorise

(a) $x^2 - 7x$

(b) $y^2 - 64$

(c) $2x^2 + 5x - 3$

(d) $6t^2 - 13t + 5$

3. Simplify

(a) $\frac{4x^3y}{8x^2y^3}$

(b) $\frac{3x+2}{3} + \frac{4x-1}{6}$

4. Solve the following equations

(a) $\frac{h-1}{4} + \frac{3h}{5} = 4$

(b) $x^2 - 8x = 0$

(c) $p^2 + 4p = 12$

5. Write each of the following as single powers of x and y

(a) $\frac{1}{x^4}$

(b) $(x^2y)^3$

(c) $\frac{x^5}{x^{-2}}$

6. Work out the values of the following, giving your answers as fractions

(a) 4^{-2}

(b) 10^0

(c) $\left(\frac{8}{27}\right)^{\frac{1}{3}}$

7. Solve the simultaneous equations

$$3x - 5y = -11$$

$$5x - 2y = 7$$

8. Rearrange the following equations to make x the subject

(a) $v^2 = u^2 + 2ax$

(b) $V = \frac{1}{3}\pi x^2h$

(c) $y = \frac{x+2}{x+1}$

9. Solve $5x^2 - x - 1 = 0$ giving your solutions in surd form

10. Simplify the following:-

a) $\sqrt{200}$

b) $\frac{21}{\sqrt{7}}$

c) $(7 - \sqrt{5})(3 + \sqrt{5})$

d) $\sqrt{48} + \sqrt{147} - \sqrt{75}$

e) $\frac{3}{\sqrt{5}+2}$

SOLUTIONS TO THE EXERCISES

CHAPTER 1:

Ex A

- 1) $28x + 35$ 2) $-15x + 21$ 3) $-7a + 4$ 4) $6y + 3y^2$ 5) $-4x - 4$
 6) $7x - 1$ 7) $x^2 + 5x + 6$ 8) $t^2 - 7t + 10$ 9) $6x^2 + xy - 12y^2$
 10) $4x^2 + 4x - 24$ 11) $4y^2 - 1$ 12) $12 + 17x - 5x^2$

Ex B

- 1) $x^2 - 2x + 1$ 2) $9x^2 + 30x + 25$ 3) $49x^2 - 28x + 4$ 4) $x^2 - 4$
 5) $9x^2 - 1$ 6) $25y^2 - 9$

CHAPTER 2

Ex A

- 1) 7 2) 3 3) $1\frac{1}{2}$ 4) 2 5) $-3/5$ 6) $-7/3$

Ex B

- 1) 2.4 2) 5 3) 1 4) $\frac{1}{2}$

Ex C

- 1) 7 2) 15 3) $24/7$ 4) $35/3$ 5) 3 6) 2 7) $9/5$ 8) 5

Ex D

- 1) 34, 36, 38 2) 9.875, 29.625 3) 24, 48

CHAPTER 3

- 1) $x = 1, y = 3$ 2) $x = -3, y = 1$ 3) $x = 0, y = -2$ 4) $x = 3, y = 1$
 5) $a = 7, b = -2$ 6) $p = 11/3, q = 4/3$

CHAPTER 4

Ex A

- 1) $x(3 + y)$ 2) $2x(2x - y)$ 3) $pq(q - p)$ 4) $3q(p - 3q)$ 5) $2x^2(x - 3)$ 6) $4a^3b^2(2a^2 - 3b^2)$
 7) $(y - 1)(5y + 3)$

Ex B

- 1) $(x - 3)(x + 2)$ 2) $(x + 8)(x - 2)$ 3) $(2x + 1)(x + 2)$ 4) $x(2x - 3)$ 5) $(3x - 1)(x + 2)$
 6) $(2y + 3)(y + 7)$ 7) $(7y - 3)(y - 1)$ 8) $5(2x - 3)(x + 2)$ 9) $(2x + 5)(2x - 5)$ 10) $(x - 3)(x - y)$
 11) $4(x - 2)(x - 1)$ 12) $(4m - 9n)(4m + 9n)$ 13) $y(2y - 3a)(2y + 3a)$ 14) $2(4x + 5)(x - 4)$

CHAPTER 5

Ex A

- 1) $x = \frac{y+1}{7}$ 2) $x = 4y - 5$ 3) $x = 3(4y + 2)$ 4) $x = \frac{9y+20}{12}$

Ex B

- 1) $t = \frac{32rP}{w}$ 2) $t = \pm \sqrt{\frac{32rP}{w}}$ 3) $t = \pm \sqrt{\frac{3V}{\pi h}}$ 4) $t = \frac{P^2 g}{2}$ 5) $t = v - \frac{Pag}{w}$ 6) $t = \pm \sqrt{\frac{r-a}{b}}$

Ex C

- 1) $x = \frac{c-3}{a-b}$ 2) $x = \frac{3a+2k}{k-3}$ 3) $x = \frac{2y+3}{5y-2}$ 4) $x = \frac{ab}{b-a}$

CHAPTER 6

- 1) a) -1, -2 b) -1, 4 c) -5, 3 2) a) 0, -3 b) 0, 4 c) 2, -2
 3) a) $-1/2, 4/3$ b) 0.5, 2.5 4) a) -5.30, -1.70 b) 1.07, -0.699 c) -1.20, 1.45
 d) no solutions e) no solutions f) no solutions

CHAPTER 7

Ex A

- 1) $5b^6$ 2) $6c^7$ 3) b^3c^4 4) $-12n^8$ 5) $4n^5$ 6) d^2 7) a^6 8) $-d^{12}$

Ex B

- 1) 2 2) 3 3) $1/3$ 4) $1/25$ 5) 1 6) $1/7$ 7) 9 8) $9/4$ 9) $\frac{1}{4}$ 10) 0.2 11) $4/9$ 12) 64
 13) $6a^3$ 14) x 15) xy^2

CHAPTER 8

Ex A

- 1) $2\sqrt{5}$ 2) $6\sqrt{2}$ 3) $3\sqrt{3}$ 4) $4\sqrt{5}$ 5) $6\sqrt{10}$ 6) $10\sqrt{3}$

Ex B

- 1) $\sqrt{21}$ 2) $20\sqrt{10}$ 3) $18\sqrt{2}$ 4) $6\sqrt{6}$ 5) $5/3$ 6) 6 7) $7 + 6\sqrt{2}$ 8) $5\sqrt{2} - \sqrt{6} + 8\sqrt{3} - 40$

Ex C

- 1) $\sqrt{3} + \sqrt{7}$ 2) $9\sqrt{2}$ 3) $5\sqrt{6}$ 4) $7\sqrt{2}$ 5) $8\sqrt{3}$ 6) $\sqrt{5}$ 7) $\sqrt{2}$ 8) $7\sqrt{3}$
9) $3\sqrt{2} + 3\sqrt{10}$ 10) $6\sqrt{2} + \sqrt{3}$

Ex D

- 1) a) $\frac{\sqrt{2}}{2}$ b) $\frac{3}{5}\sqrt{5}$ c) $2\sqrt{5}$ d) $\frac{5\sqrt{7}}{14}$ e) $\frac{\sqrt{6}}{2}$

f) $\sqrt{10}$ g) $\frac{4\sqrt{3} + \sqrt{21}}{3}$ h) $3\sqrt{2} + 4\sqrt{10}$ i) $\frac{6\sqrt{5} - 5}{5}$

- 2) a) $\sqrt{2} + 1$ b) $2 + \sqrt{6}$ c) $2\sqrt{7} - 4$ d) $\frac{3 - \sqrt{5}}{4}$ e) $\sqrt{6} + \sqrt{5}$

Answers to Practice Booklet Test

1. a) $4x^2 + 4x - 3$ b) $a^2 + 6a + 9$ c) $10x^2 - 13x$

2. a) $x(x - 7)$ b) $(y - 8)(y + 8)$ c) $(2x - 1)(x + 3)$ d) $(3t - 5)(2t - 1)$

3. a) $\frac{x}{2y^2}$ b) $\frac{10x + 3}{6}$ 4. a) $h = 5$ b) $p = -6$ and 2

7. a) x^4 b) x^6y^3 c) x^7 6. a) $\frac{1}{16}$ b) 1 c) $\frac{2}{3}$ 7. $x = 3, y = 4$

8. a) $x = \frac{v^2 - u^2}{2a}$ b) $x = \sqrt{\frac{3v}{\pi h}}$ c) $x = \frac{2 - y}{y - 1}$

9. $x = \frac{1 \pm \sqrt{21}}{10}$

10. a) $10\sqrt{2}$ b) $3\sqrt{7}$ c) $16 + 4\sqrt{5}$ d) $6\sqrt{3}$ e) $3\sqrt{5} - 6$