Chapter 10

Algebra (Expansion and Factorisation)

Contents:

A The distributive law
B Simplifying algebraic expressions
C Brackets with negative coefficients
D The product \((a + b)(c + d)\)
E Geometric applications
F Factorisation of algebraic expressions
A rectangle has length \((2x + 3)\) cm and width \((x + 4)\) cm. We let its perimeter be \(P\) and its area be \(A\).

**Things to think about:**

1. How can we quickly write down formulae for \(P\) and \(A\) in terms of \(x\)?
2. How can we simplify the formulae so they do not contain brackets?

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**THE DISTRIBUTIVE LAW**

The perimeter of a rectangle can be found by either:
- adding all four side lengths, or
- doubling the sum of length and width.

For example, the perimeter of the rectangle alongside is \(7 + 3 + 7 + 3 = 20\) cm or \(2 \times (7 + 3) = 20\) cm.

If we apply these methods to a rectangle with sides in terms of a variable or variables we discover a useful algebraic result.

**What to do:**

1. For the following rectangles, find the perimeter by:
   - i. adding all four side lengths
   - ii. doubling the sum of the length and width.

   ![Rectangle A](image1.png)
   ![Rectangle B](image2.png)
   ![Rectangle C](image3.png)

2. Use the results of 1 to suggest an expression equal to \(2(a + b)\) which does not involve brackets.

3. We can also find the area of a partitioned rectangle by two different ways.
   - a. Write an expression for the area of the overall rectangle.
   - b. Write an expression for the area of (1) plus the area of (2).
   - c. Copy and complete: \(x(x + 2) = \ldots\)
Consider the diagram alongside.

The total number of squares
\[ = 5 \times (4 + 3) \]
\[ = 5(4 + 3) \]

However, it is also \( 5 \times 4 + 5 \times 3 \) as there are \( 5 \times 4 \) squares to the left of the red line and \( 5 \times 3 \) squares to the right of it.

So, \( 5(4 + 3) = 5 \times 4 + 5 \times 3 \).

Now consider the rectangle alongside, which has length \( b + c \) and width \( a \).

The area of the rectangle is \( a(b + c) \) \{length \times width\} but it is also area \( A \) + area \( B = ab + ac \).

So, \( a(b + c) = ab + ac \).

This is true for all values of \( a \), \( b \) and \( c \), and we call this result the **distributive law**.

\[ a(b + c) = ab + ac \]

So, to remove a set of brackets from an expression we multiply each term inside the brackets by the term in front of them. The resulting terms are then added.

**Example 1**

Expand:

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>(4(3x + 1))</td>
<td>(5(7 + 2x))</td>
<td>(2(3y + 4z))</td>
</tr>
<tr>
<td></td>
<td>(4 \times 3x + 4 \times 1)</td>
<td>(5 \times 7 + 5 \times 2x)</td>
<td>(2 \times 3y + 2 \times 4z)</td>
</tr>
<tr>
<td></td>
<td>(12x + 4)</td>
<td>(35 + 10x)</td>
<td>(6y + 8z)</td>
</tr>
</tbody>
</table>
**EXERCISE 10A**

1. Complete these expansions:
   - a. \(2(x + 5) = 2x + \ldots\)
   - b. \(5(y + 3) = \ldots + 15\)
   - c. \(6(3 + a) = \ldots + 6a\)
   - d. \(7(4 + b) = 28 + \ldots\)
   - e. \(3(z + 4) = 3z + \ldots\)
   - f. \(8(a + 3) = \ldots + 24\)

2. Expand these expressions:
   - a. \(3(a + 2)\)
   - b. \(2(x + 5)\)
   - c. \(5(a + 4)\)
   - d. \(7(2x + 3)\)
   - e. \(3(2y + 1)\)
   - f. \(4(4c + 7)\)
   - g. \(3(10 + y)\)
   - h. \(5(2 + x)\)
   - i. \(2(2 + b)\)
   - j. \(4(m + n)\)
   - k. \(4(2a + b)\)
   - l. \(3(2x + 3y)\)

### Example 2

<table>
<thead>
<tr>
<th></th>
<th>(a) Expand: 2x(3x - 2)</th>
<th>(b) ((2a - 1)b)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a</strong></td>
<td>(2x(3x - 2))</td>
<td>((2a - 1)b)</td>
</tr>
<tr>
<td><strong>b</strong></td>
<td>(2x(3x - 2))</td>
<td>((2a - 1)b)</td>
</tr>
<tr>
<td><strong>c</strong></td>
<td>(2x(3x - 2))</td>
<td>((2a - 1)b)</td>
</tr>
<tr>
<td><strong>d</strong></td>
<td>(2x(3x - 2))</td>
<td>((2a - 1)b)</td>
</tr>
</tbody>
</table>

3. Expand:
   - a. \(a(a - 4)\)
   - b. \(2a(a - 3)\)
   - c. \(a(a - 6)\)
   - d. \(y(4y - 10)\)
   - e. \(3p(2p - 6)\)
   - f. \(r(r - 2)\)
   - g. \(z(5 - z)\)
   - h. \(k(k - 1)\)
   - i. \(y(1 - y)\)
   - j. \(5x(3x - 2)\)
   - k. \(7p(2p - 4)\)
   - l. \(q(q - 1)\)

4. Expand:
   - a. \((x + 2)3\)
   - b. \((x + y)4\)
   - c. \((2 + y)3\)
   - d. \((a + b)c\)
   - e. \((m + n)d\)
   - f. \((k + 7)7\)
   - g. \((k + 7)k\)
   - h. \((p + 4)p\)

5. Expand:
   - a. \(k(l + 3)\)
   - b. \(k(l - 1)\)
   - c. \(k(l + 5)\)
   - d. \(x(y - 2)\)
   - e. \((a - 2)b\)
   - f. \((x + 6)y\)
   - g. \((k + 7)l\)
   - h. \((z - 1)p\)
   - i. \(5x(2y - 3)\)
   - j. \(2a(a + c)\)
   - k. \(4k(k - 2f)\)
   - l. \(2x(3x - 4y)\)

6. Use the distributive law to expand:
   - a. \(3(z + 2)\)
   - b. \(3(3z - 2)\)
   - c. \(10(2z - 3y)\)
   - d. \(7(x + 3z + 1)\)
   - e. \(6(2 - 3a - 5b)\)
   - f. \(4(5z - 2x + 3y)\)
   - g. \(2a(3x - 4y + 7)\)
   - h. \(x(5 - 2x + 3y)\)
   - i. \(2p(3 + x - 2q)\)
   - j. \(4(2x - 5y - 2)\)
   - k. \(6(m + 2n + 8)\)
   - l. \(7x(x + 3y + 4)\)
   - m. \(5x(x + 3y + 7z)\)
   - n. \(8x(a - 3b + c)\)
   - o. \(10x(x + 5) + 1\)
   - p. \(9y(x - z + p)\)
   - q. \(6a(a + 5b + 2c)\)
   - r. \(3x(x^2 + 3x + 9)\)
We have already seen that like terms are terms with exactly the same variable form. They contain the same variables, to the same powers or indices.

For example, \(xy\) and \(3xy\) are like terms, and \(2x^2y\) and \(10yz^2\) are like terms, but \(5x\) and \(3x^2\) are not like terms, and \(5xy\) and \(7yz\) are not like terms.

We can now simplify expressions involving brackets by expanding the brackets and then collecting like terms.

Expand the brackets and then simplify by collecting like terms:

\[
\begin{align*}
a) & \quad 6y + 2(y – 4) \\
& = 6y + 2y – 8 \\
& = 8y – 8 \\
b) & \quad 2(2x + 1) + 3(x – 2) \\
& = 4x + 2 + 3x – 6 \\
& = 7x – 4
\end{align*}
\]

EXERCISE 10B

1. Expand and then simplify by collecting like terms:
   \[
   \begin{align*}
a) & \quad 2 + 3(x + 2) \\
b) & \quad 2 + 5(a + 7) \\
c) & \quad 3(n + 1) + 2(n + 3) \\
d) & \quad 3n + 2(n + 3) \\
e) & \quad 2(x – 6) + 5(x – 1) \\
f) & \quad 8(y – 2) + 3(y + 6) \\
g) & \quad 3(x + 4) + 6(5 + x) \\
h) & \quad 6(2 + y) + 8(y + 1) \\
i) & \quad 4(x + 7) + 11(2 + x) \\
j) & \quad 12(y + 3) + 3(3 + y) \\
k) & \quad 2(x – 4) + (x – 4)x
\end{align*}
\]

Example 4

Expand and then simplify by collecting like terms:

\[
2a(a + 5) + 3(a + 4)
\]

\[
\begin{align*}
& = 2a \times a + 2a \times 5 + 3 \times a + 3 \times 4 \\
& = 2a^2 + 10a + 3a + 12 \quad \{\text{10a and 3a are like terms}\} \\
& = 2a^2 + 13a + 12
\end{align*}
\]

2. Expand and then simplify by collecting like terms:
   \[
   \begin{align*}
a) & \quad m(m + 2) + m(2m + 1) \\
b) & \quad x(x + 2) – x^2 \\
c) & \quad 3a(a + 2) – 2a^2 \\
d) & \quad 5x(x + 2) – 2 \\
e) & \quad 3a(a + 2) + 5a(a + 1) \\
f) & \quad 4(p + 3q) + 2(p + 2q) \\
g) & \quad x(x + 3y) + 2x(x + y) \\
h) & \quad 4(3 + 2x) + 4x(x + 1)
\end{align*}
\]
When the number or term in front of a set of brackets is negative, we say it has a negative coefficient. When we expand the brackets we use the distributive law as before. We place the negative coefficient in brackets to make sure we get the signs correct.

**Example 5**

Expand:  
\[
\begin{align*}
a & \quad -3(x + 4) \\
b & \quad -(5 - x)
\end{align*}
\]

\[
\begin{align*}
a & = (-3) \times x + (-3) \times 4 \\
& = -3x + (-12) \\
& = -3x - 12 \\
b & = -(1) \times 5 + (-1) \times (-x) \\
& = -5 + x \\
& = x - 5
\end{align*}
\]

**Self Tutor**

With practice you should not need all the middle steps.

**EXERCISE 10C**

1. Complete the following expansions:
   \[
   \begin{align*}
a & = -2(x + 5) = -2x - .... \\
b & = -2(x - 5) = -2x + .... \\
c & = -3(y + 2) = -3y - .... \\
d & = -3(y - 2) = -3y + .... \\
e & = -(b + 3) = -b - .... \\
f & = -(b - 3) = -b + .... \\
g & = -4(2m + 3) = .... - 12 \\
h & = -4(2m - 3) = .... + 12
\end{align*}
\]

2. Expand:
   \[
   \begin{align*}
a & = -2(x + 5) \\
b & = -3(2x + 1) \\
c & = -3(4 - x) \\
d & = -6(a + b) \\
e & = -(x + 6) \\
f & = -(x - 3) \\
g & = -(5 + x) \\
h & = -(8 - x) \\
i & = -5(x + 1) \\
j & = -4(3 + x) \\
k & = -(3b - 2) \\
l & = -2(5 - c)
\end{align*}
\]

**Example 6**

Expand and simplify:

\[
\begin{align*}
a & \quad 3(x + 2) - 5(3 - x) \\
b & \quad x(3x - 4) - 2x(x + 1)
\end{align*}
\]

\[
\begin{align*}
a & = 3 \times x + 3 \times 2 + (-5) \times 3 + (-5) \times (-x) \\
& = 3x + 6 - 15 + 5x \\
& = 8x - 9 \\
b & = x \times 3x + x \times (-4) + (-2x) \times x + (-2x) \times 1 \\
& = 3x^2 - 4x - 2x^2 - 2x \\
& = x^2 - 6x
\end{align*}
\]
3 Expand and simplify:
  a $3(x + 2) - 2(x + 1)$
  b $4(x - 7) - 2(3 - x)$
  c $3(x - 2) - 2(x + 2)$
  d $3(y - 4) - 2(y + 3)$
  e $5(y + 2) - 2(y - 3)$
  f $6(b - 3) - 3(b - 1)$

4 Expand and simplify:
  a $x(x + 4) - x(x + 2)$
  b $x(2x - 1) - x(7 - x)$
  c $-(x + 6) - 2(x + 1)$
  d $-2(x - 1) - 3(5 - x)$
  e $-a(a + 2) - 2a(1 - a)$
  f $-(11 - a) - 2(a + 6)$

D THE PRODUCT $(a + b)(c + d)$

The expression $(a + b)(c + d)$ can be expanded by using the distributive law three times.

$$(a + b)(c + d) = (a + b)c + (a + b)d$$

{compare $(c + d) = b + c + d$}

$$c(a + b) + d(a + b) = ac + bc + ad + bd$$

Example 7

Expand and simplify:

<table>
<thead>
<tr>
<th></th>
<th>Expand and simplify:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>$(x + y)(p + q)$</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>$(x + y)p + (x + y)q$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$px + py + qx + qy$</td>
<td></td>
</tr>
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<td></td>
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</tr>
</tbody>
</table>

**SELF TUTOR**

Always look for like terms to collect.

EXERCISE 10D

1 Expand and simplify:

<table>
<thead>
<tr>
<th></th>
<th>Expand and simplify:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>$(a + b)(m + n)$</td>
<td>b</td>
</tr>
<tr>
<td>d</td>
<td>$(a - b)(c + d)$</td>
<td>e</td>
</tr>
<tr>
<td>g</td>
<td>$(a + b)(m - n)$</td>
<td>h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>i</td>
</tr>
</tbody>
</table>

2 Expand and simplify:

<table>
<thead>
<tr>
<th></th>
<th>Expand and simplify:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>$(x + 2)(x + 3)$</td>
<td>b</td>
</tr>
<tr>
<td>d</td>
<td>$(2x + 1)(x + 2)$</td>
<td>e</td>
</tr>
<tr>
<td>g</td>
<td>$(x - 1)(x + 5)$</td>
<td>h</td>
</tr>
<tr>
<td>j</td>
<td>$(x - y)(x + 3)$</td>
<td>k</td>
</tr>
<tr>
<td>m</td>
<td>$(x - 4)(x - 3)$</td>
<td>n</td>
</tr>
<tr>
<td>p</td>
<td>$(a + 2)^2$</td>
<td>q</td>
</tr>
<tr>
<td>s</td>
<td>$(x - 1)^2$</td>
<td>t</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Now that we have the distributive law, we can often simplify expressions for the perimeter and area of geometric figures.

**Example 8**

For the given rectangle, find in simplest form expressions for:

- **a** its perimeter $P$
- **b** its area $A$

**a** Perimeter $= 2(\text{length} + \text{width})$

$\therefore \quad P = 2[(x + 5) + x] \text{ cm}$

$\therefore \quad P = 2(2x + 5) \text{ cm}$

$\therefore \quad P = 4x + 10 \text{ cm}$

**b** Area $= \text{length} \times \text{width}$

$\therefore \quad A = x(x + 5) \text{ cm}^2$

$\therefore \quad A = x^2 + 5x \text{ cm}^2$

**EXERCISE 10E**

1. Find, in simplest form, an expression for the perimeter $P$ of:

   - **a**
   - **b**
   - **c**

2. Find, in simplest form, an expression for the perimeter $P$ of:

   - **a**
   - **b**
   - **c**

3. Find in simplest form, an expression for the area $A$ of:

   - **a**
   - **b**
   - **c**
4 Find, in simplest form, expressions for the perimeter $P$ and area $A$ in the Opening Problem on page 200.

**Factorisation of Algebraic Expressions**

Factorisation is the reverse process of expansion.

For example: $3(x + 2) = 3x + 6$ is *expansion*  
$(3x + 6) = 3(x + 2)$ is *factorisation*.

To factorise an algebraic expression we need to insert brackets.

We find the HCF (highest common factor) of all terms in the expression then place it before the brackets being inserted.

**Example 9**

Find the HCF of:

<table>
<thead>
<tr>
<th></th>
<th>a $3a$ and 9</th>
<th>b $4ab$ and $2b$</th>
<th>c $5x^2$ and $10x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>$3a = 3 \times a$</td>
<td>$4ab = 2 \times 2 \times a \times b$</td>
<td>$5x^2 = 5 \times x \times x$</td>
</tr>
<tr>
<td></td>
<td>$9 = 3 \times 3$</td>
<td>$2b = 2 \times b$</td>
<td>$10x = 2 \times 5 \times x$</td>
</tr>
<tr>
<td></td>
<td>$\therefore$ HCF = 3</td>
<td>$\therefore$ HCF = $2b$</td>
<td>$\therefore$ HCF = $5x$</td>
</tr>
</tbody>
</table>

**Example 10**

Factorise:

<table>
<thead>
<tr>
<th></th>
<th>a $2a + 6$</th>
<th>b $ab - bd$</th>
</tr>
</thead>
</table>
| a  | The HCF of $2a$ and 6 is 2.  
    | $\therefore 2a + 6 = 2 \times a + 2 \times 3 = 2(a + 3)$ | The HCF of $ab$ and $-bd$ is $b$.  
    | $\therefore ab - bd = a \times b - b \times d = b(a - d)$ |
EXERCISE 10F

1 Find the missing factor:
   a. $3 \times \square = 3x$
   b. $3 \times \square = 12b$
   c. $5 \times \square = 10xy$
   d. $\square \times 4x = 4x^2$
   e. $\square \times 5y = 10y^2$
   f. $\square \times 3a = 3a^2$
   g. $x \times \square = 2xy$
   h. $\square \times 2x = 6x^2$
   i. $6y \times \square = 12y^2$

2 Find the HCF of:
   a. $4x$ and $12$
   b. $3x$ and $6$
   c. $4y$ and $14$
   d. $3ab$ and $6b$
   e. $4y$ and $4xy$
   f. $5ad$ and $10a$
   g. $6x^2$ and $2x$
   h. $3y$ and $9y^2$
   i. $12a$ and $3a^2$
   j. $2(x - 1)$ and $3(x - 1)$
   k. $4(x + 2)$ and $x + 2$
   l. $2(x + 3)$ and $2x + 6$

3 Factorise:
   a. $5a + 10$
   b. $6a + 8$
   c. $6a + 12b$
   d. $4 + 8x$
   e. $11a + 22b$
   f. $16x + 8$
   g. $4a + 8$
   h. $10 + 15y$
   i. $25x + 20$
   j. $x + ax$
   k. $3x + mx$
   l. $ac + an$

4 Factorise:
   a. $2a - 10$
   b. $4y - 20$
   c. $3b - 12$
   d. $6x - 24$
   e. $6x - 14$
   f. $14y - 7$
   g. $5a - 15$
   h. $10 - 15b$
   i. $20b - 25$
   j. $16b - 24$
   k. $x - xy$
   l. $ab - ac$

5 Factorise:
   a. $x^2 + 3x$
   b. $2x^2 + 8x$
   c. $3x^2 - 12x$
   d. $6x - x^2$
   e. $8x - 4x^2$
   f. $15x - 6x^2$
   g. $2x^3 + 4x^2$
   h. $2x^3 + 5x^2$

Example 11

Factorise: a. $3x^2 + 12x$

\[
3x^2 + 12x = 3 \times x \times x + 4 \times 3 \times x = 3x(x + 4)
\]

b. $4y^2 - 2y$

\[
4y^2 - 2y = 2 \times 2 \times y - 2 \times y \times y = 2y(2 - y)
\]

Example 12

Factorise: $3(a + b) + x(a + b)$

$3(a + b) + x(a + b)$ has common factor $(a + b)$

$\therefore 3(a + b) + x(a + b) = (a + b)(3 + x)$
Factorise:
\[ a \quad 2x^3 + 2x^2 + 4x \]
\[ d \quad ax^2 + 2ax + a^2x \]
\[ b \quad x^4 + 2x^3 + 3x^2 \]
\[ e \quad 3my^2 + 3my + 6m^2y \]
\[ c \quad 6x^3 - 3x^2 + 5x \]
\[ f \quad 4x^2a + 6x^2a^2 + x^4a^3 \]

Factorise:
\[ a \quad 2(x + a) + p(x + a) \]
\[ d \quad 3(x + 4) - x(x + 4) \]
\[ b \quad n(x - 2) + p(x - 2) \]
\[ e \quad a(7 - x) - b(7 - x) \]
\[ c \quad r(y + 5) + 4(y + 5) \]
\[ f \quad 4(x + 11) + y(x + 11) \]
\[ g \quad x(x + 2) + x + 2 \]
\[ h \quad x(x + 2) - x - 2 \]
\[ i \quad x(x + 3) + 2x + 6 \]
\[ j \quad x(x - 1) + 2x - 2 \]
\[ k \quad x(x + 5) + 3x + 15 \]
\[ l \quad x(x - 4) - 2x + 8 \]

**KEY WORDS USED IN THIS CHAPTER**
- distributive law
- highest common factor
- expansion
- like terms
- factorisation
- negative coefficient

**REVIEW SET 10A**

1. Copy and complete:
   Using the area of rectangles, the diagram alongside shows that
   \[ a(... + ... + ...) = \]

2. Expand:
   \[ a \quad x(y + z) \quad b \quad 3(2x - 5) \quad c \quad -x(3 - x) \quad d \quad (x + 5)d \]

3. Expand:
   \[ a \quad 3(x^2 - 6x + 4) \quad b \quad -2(x^2 - x + 1) \]

4. Expand and simplify by collecting like terms:
   \[ a \quad 2(x + 5) + 3(2x + 1) \quad b \quad 3(x - 2) + 4(3 - x) \]
   \[ c \quad 3(x - 4) - 2(x + 3) \quad d \quad x(x + 3) + 5(x + 6) \]
   \[ e \quad x(x - 2) - (x - 1) \quad f \quad y(2 + y) - 3y(2 - y) \]

5. Find, in simplest form, an expression for the perimeter \( P \) of:
   \[ a \quad \]
   \[ b \quad (3x - 4) \text{cm} \]
   \[ c \quad (x - 2) \text{cm} \]

6. Find, in simplest form, an expression for the area \( A \) of:
   \[ a \quad 3x \text{cm} \]
   \[ b \quad (x + 1) \text{cm} \]
   \[ c \quad x \text{mm} \]

\[ \]
Expand and simplify:

7. a \((x + 3)(x + 4)\)  
   b \((x - 3)(2x + 1)\)  
   c \((2x - 1)(x - 7)\)

8. Factorise:
   a \(3x + 12\)  
   b \(x^2 - 3x\)  
   c \(ab + bc - 2b\)  
   d \(a(x - 2) + 3(x - 2)\)  
   e \(x(x + 3) + 2x + 6\)

**REVIEW SET 10B**

1. Expand and simplify:
   a \(3(2 - y)\)  
   b \(4(3t + 2)\)  
   c \(-a(a + 2)\)  
   d \((x + 6)n\)

2. Expand and simplify:
   a \(x + 2(x + 1)\)  
   b \(x - 2(x - 4)\)

3. Expand:
   a \(2x(x + y - 3)\)  
   b \(-2x(3 - x)\)

4. Expand and simplify:
   a \(3(x + 5) + 2(x - 3)\)  
   b \(4(y + 5) + 3(2 + x)\)  
   c \(5(x - 2) - 2(x - 1)\)  
   d \(2x(x + 2) + x(x - 3)\)  
   e \(3x(x + 5) - (x - 5)\)  
   f \(n(n + 2) - 2n(1 - n)\)

5. Find, in simplest form, an expression for the perimeter \(P\) of:
   a
   b
   c

6. Find, in simplest form, an expression for the area \(A\) of:
   a
   b
   c

7. Expand and simplify:
   a \((x + 2)(x + 9)\)  
   b \((x + 3)(x - 2)\)  
   c \((x - 7)(x - 4)\)

8. Factorise:
   a \(4x + 24y\)  
   b \(2x^2 - 8x\)  
   c \(3a + 6ab + 9a^2\)  
   d \(3(x - 6) + d(x - 6)\)  
   e \(2x(x + 4) + 3x + 12\)