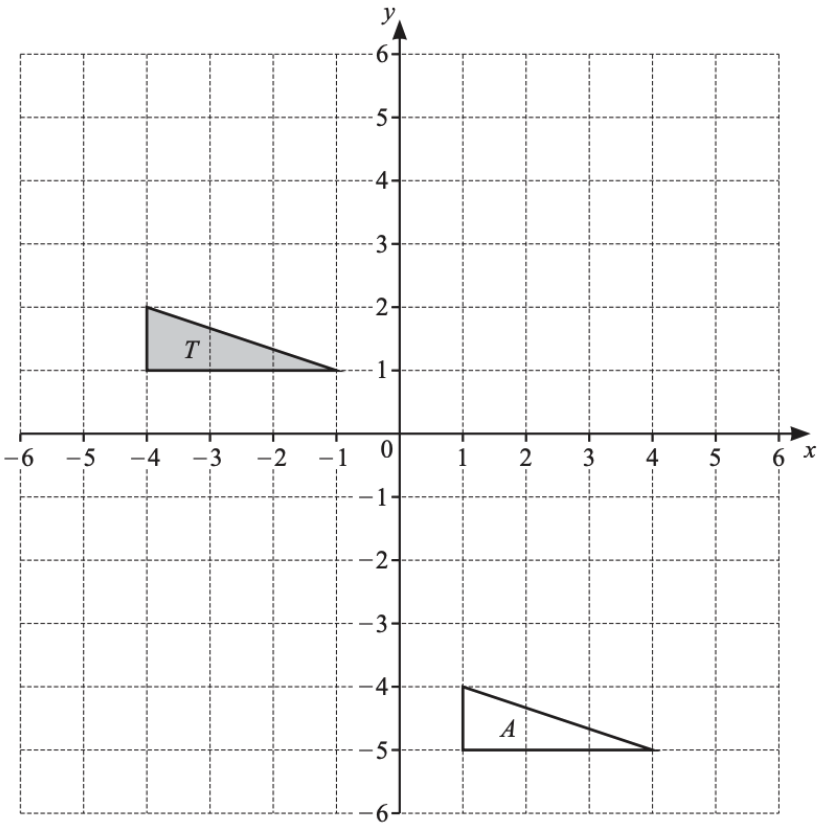
Mathematics

Paper 4

Vectors

4



(a) Draw the image of triangle T after a reflection in the line $y = -1$. [2]

(b) Draw the image of triangle T after a rotation through 90° clockwise about (0, 0). [2]

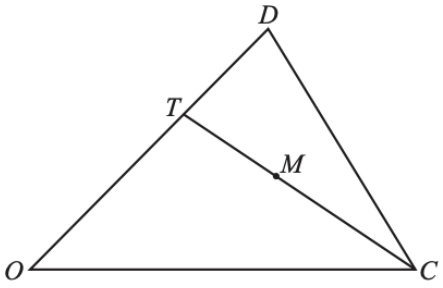
(c) Describe fully the **single** transformation that maps triangle T onto triangle A.

.....

..... [2]

2.

(d)



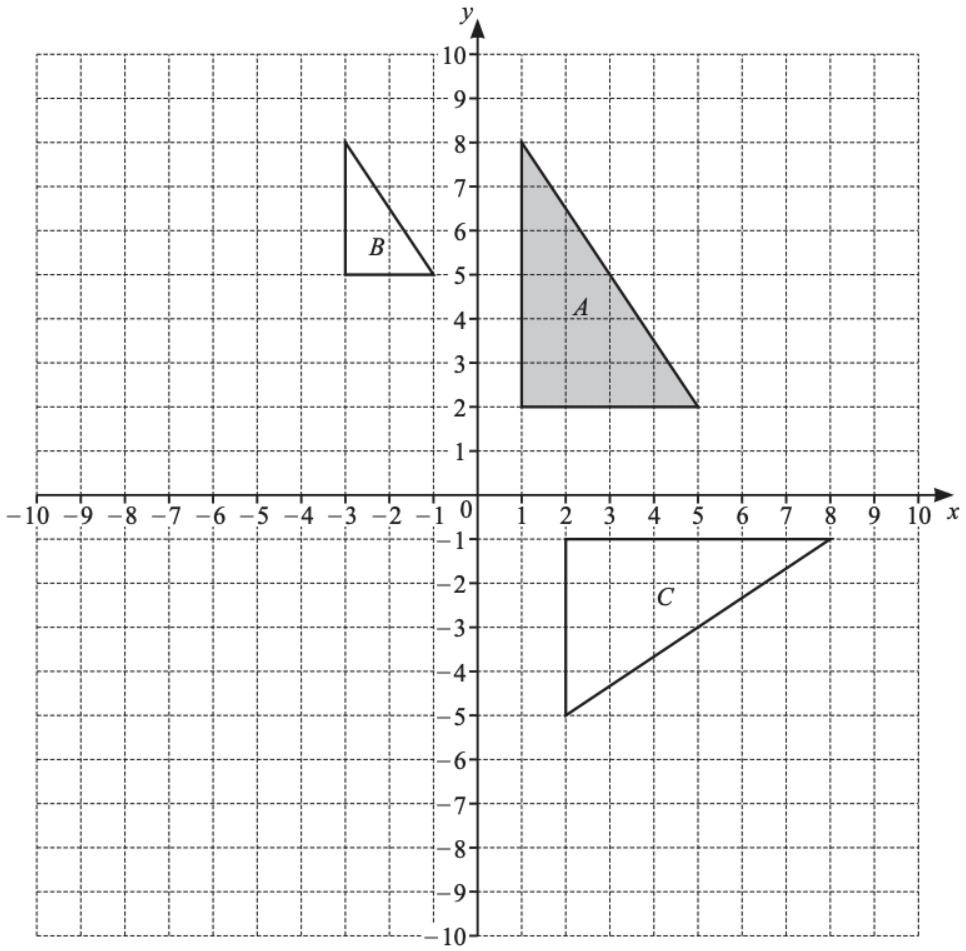
NOT TO SCALE

In the diagram, O is the origin, $OT = 2TD$ and M is the midpoint of TC.
$\overrightarrow{OC} = \mathbf{c}$ and $\overrightarrow{OD} = \mathbf{d}$.

Find the position vector of M.
Give your answer in terms of **c** and **d** in its simplest form.

..... [3]

2



(a) **(i)** Draw the image of triangle A after a reflection in the line $y = -x$. [2]

(ii) Draw the image of triangle A after a translation by the vector $\begin{pmatrix} -2 \\ -9 \end{pmatrix}$. [2]

(b) Describe fully the **single** transformation that maps

(i) triangle A onto triangle B,

.....

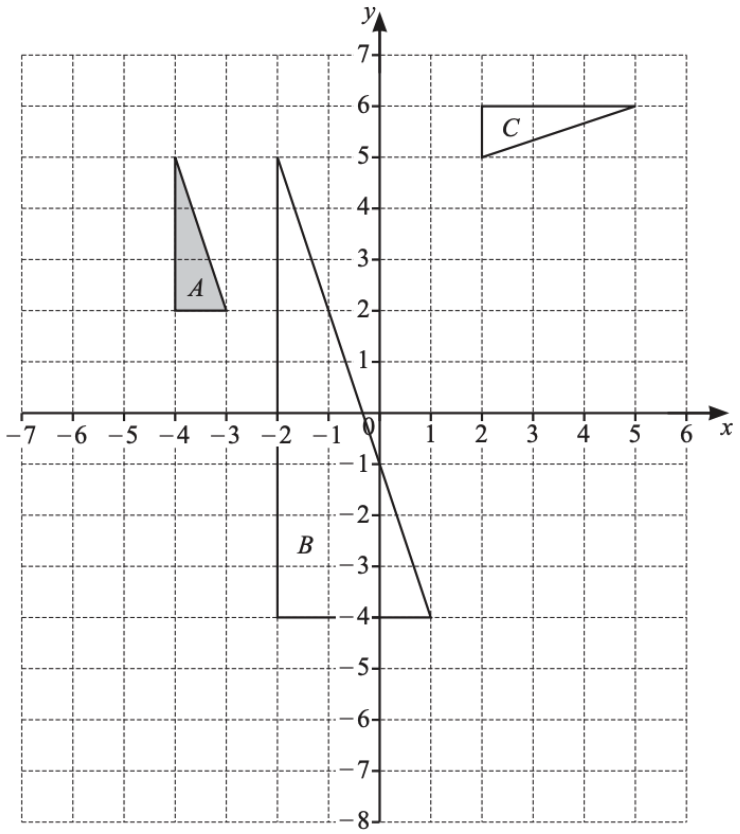
..... [3]

(ii) triangle A onto triangle C.

.....

..... [3]

1



(a) Draw the image of shape A after a translation by the vector $\begin{pmatrix} 8 \\ -6 \end{pmatrix}$. [2]

(b) Draw the image of shape A after a reflection in the line $y = -1$. [2]

(c) Describe fully the **single** transformation that maps shape A onto shape B.

.....

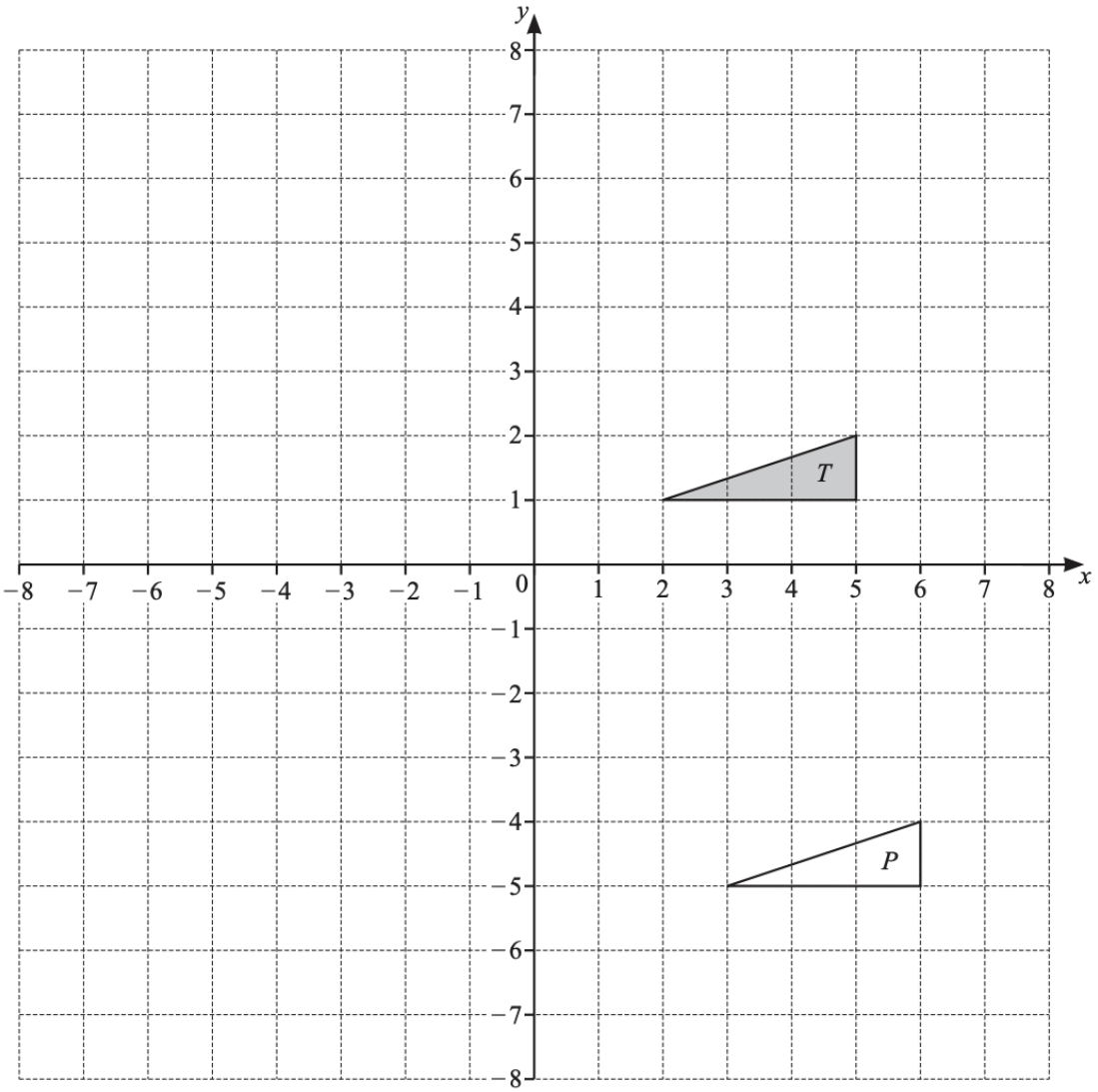
..... [3]

(d) Describe fully the **single** transformation that maps shape A onto shape C.

.....

..... [3]

2



(a) Describe fully the **single** transformation that maps triangle T onto triangle P.

.....

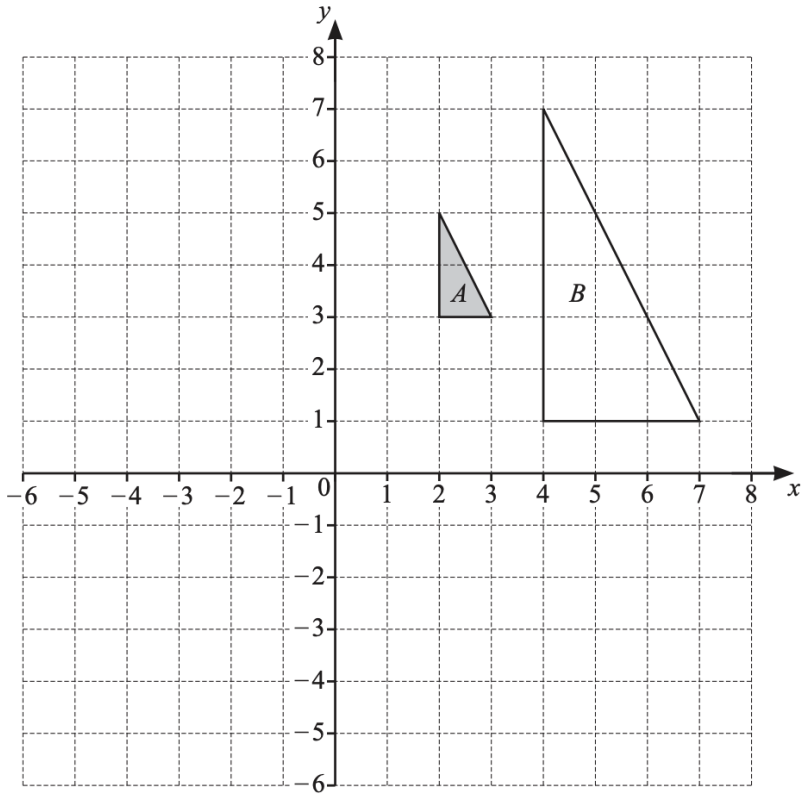
..... [2]

(b) **(i)** Reflect triangle T in the line $x = 1$. [2]

(ii) Rotate triangle T through 90° anticlockwise about (6, 0). [2]

(iii) Enlarge triangle T by a scale factor of −2, centre (1, 0). [2]

2



(a) On the grid, draw the image of

(i) triangle A after a rotation of 90° anticlockwise about (0, 0), [2]

(ii) triangle A after a translation by the vector $\begin{pmatrix} 3 \\ -5 \end{pmatrix}$. [2]

(b) Describe fully the **single** transformation that maps triangle A onto triangle B.

.....

..... [3]

8 **(a)** $\overrightarrow{AB} = \begin{pmatrix} 6 \\ -1 \end{pmatrix}$ $\overrightarrow{BC} = \begin{pmatrix} -2 \\ 5 \end{pmatrix}$ $\overrightarrow{DC} = \begin{pmatrix} 2 \\ -3 \end{pmatrix}$

Find

(i) $\overrightarrow{AC}$,

$\overrightarrow{AC} = \begin{pmatrix} \quad \\ \quad \end{pmatrix}$ [2]

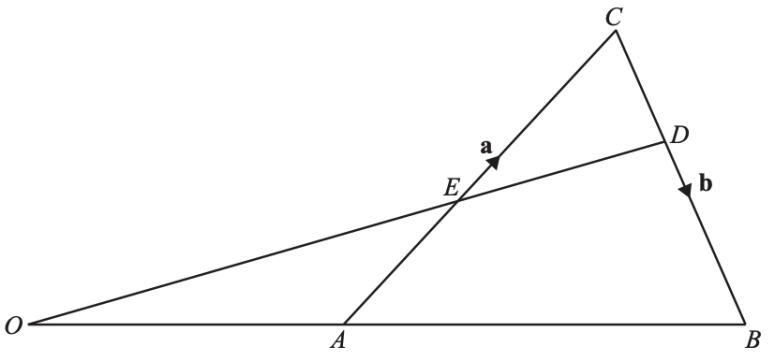
(ii) $\overrightarrow{BD}$,

$\overrightarrow{BD} = \begin{pmatrix} \quad \\ \quad \end{pmatrix}$ [2]

(iii) $\left|\overrightarrow{BC}\right|$.

..... [2]

(b)



NOT TO SCALE

In the diagram, OAB and OED are straight lines.
O is the origin, A is the midpoint of OB and E is the midpoint of AC.
$\overrightarrow{AC} = \mathbf{a}$ and $\overrightarrow{CB} = \mathbf{b}$.

Find, in terms of **a** and **b**, in its simplest form

(i) $\overrightarrow{AB}$,

$\overrightarrow{AB} =$ ..... [1]

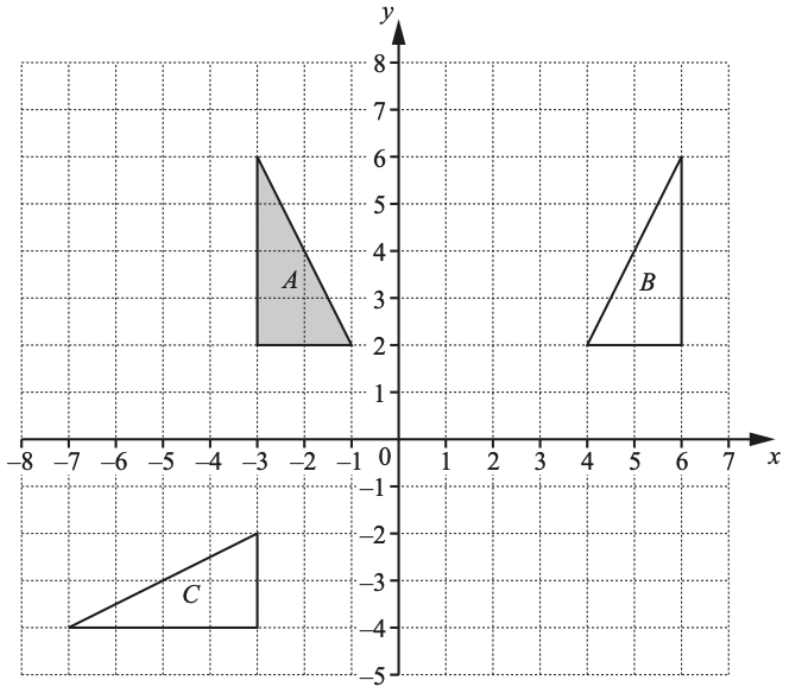
(ii) $\overrightarrow{OE}$,

$\overrightarrow{OE} =$ ..... [2]

(iii) the position vector of D.

..... [3]

2



(a) Describe fully the **single** transformation that maps

(i) triangle A onto triangle B,

.....

..... [2]

(ii) triangle A onto triangle C.

.....

..... [3]

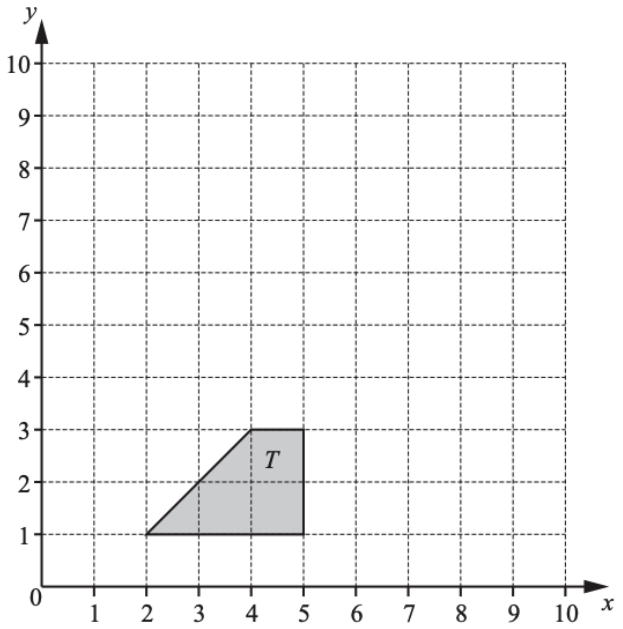
(b) On the grid, draw the image of

(i) triangle A after an enlargement, scale factor $-\frac{1}{2}$, centre (3, 0), [2]

(ii) triangle A after a translation by the vector $\begin{pmatrix} -3 \\ 1 \end{pmatrix}$, [2]

(iii) triangle A after the transformation that is represented by the matrix $\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$.

1



(a) (i) Translate shape T by the vector $\begin{pmatrix} -1 \\ 6 \end{pmatrix}$.

Label the image A. [2]

(ii) Rotate shape T about the point (5, 3) through 180°.
Label the image B. [2]

(iii) Describe fully the **single** transformation that maps shape A onto shape B.

.....

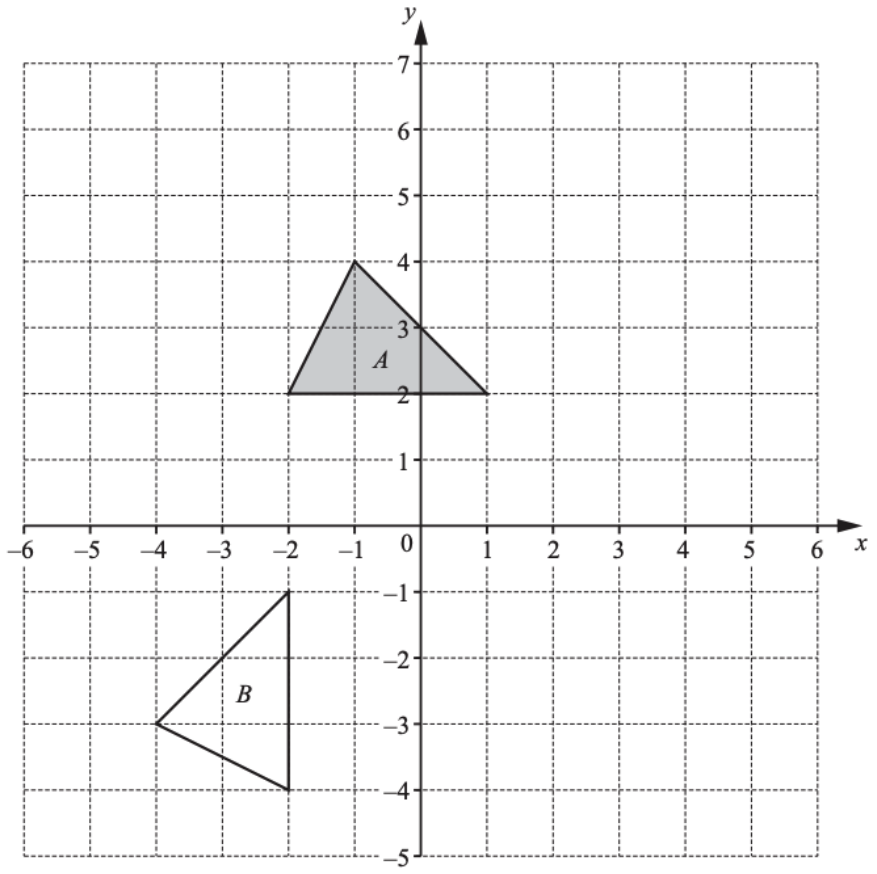
..... [3]

(b) (i) Reflect shape T in the line $y = x$. [2]

(ii) Find the matrix that represents the transformation in **part (b)(i)**.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

3



(a) On the grid, draw the image of

(i) triangle A after a translation by the vector $\begin{pmatrix} -3 \\ 2 \end{pmatrix}$, [2]

(ii) triangle A after a reflection in the line $y = x$. [2]

(b) Describe fully the **single** transformation that maps triangle A onto triangle B.

.....

..... [3]

(c) **(i)** Find the matrix that represents an enlargement, scale factor -2, centre $(0, 0)$.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

(ii) Calculate the determinant of the matrix in **part (c)(i)**.

..... [1]

3 A line joins A (1, 3) to B (5, 8).

(a) **(i)** Find the midpoint of AB.

(..... , ...) [2]

(ii) Find the equation of the line AB.
Give your answer in the form $y = mx + c$.

$y =$ ..... [3]

(b) The line AB is transformed to the line PQ.

Find the co-ordinates of P and the co-ordinates of Q after AB is transformed by

(i) a translation by the vector $\begin{pmatrix} 5 \\ -2 \end{pmatrix}$,

P (..... , ...)

Q (..... , ...) [2]

(ii) a rotation through 90° anticlockwise about the origin,

P (..... , ...)

Q (..... , ...) [2]

(iii) a reflection in the line $x = 2$,

P (..... , ...)

Q (..... , ...) [2]

(iv) a transformation by the matrix $\begin{pmatrix} -1 & 2 \\ 0 & -1 \end{pmatrix}$.

P (..... , ...)

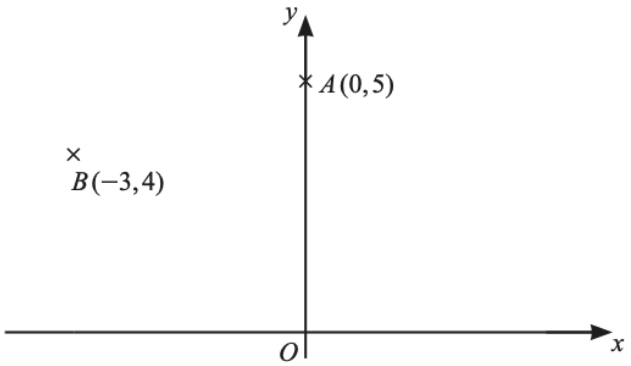
Q (..... , ...) [2]

(c) Describe fully the **single** transformation that maps the line AB onto the line PQ where P is the point $(-2, -6)$ and Q is the point $(-10, -16)$.

.....

..... [3]

(b)



NOT TO SCALE

(i) Write $\overrightarrow{OA}$ as a column vector.

$\overrightarrow{OA} = \begin{pmatrix} \quad \\ \quad \end{pmatrix}$ [1]

(ii) Write $\overrightarrow{AB}$ as a column vector.

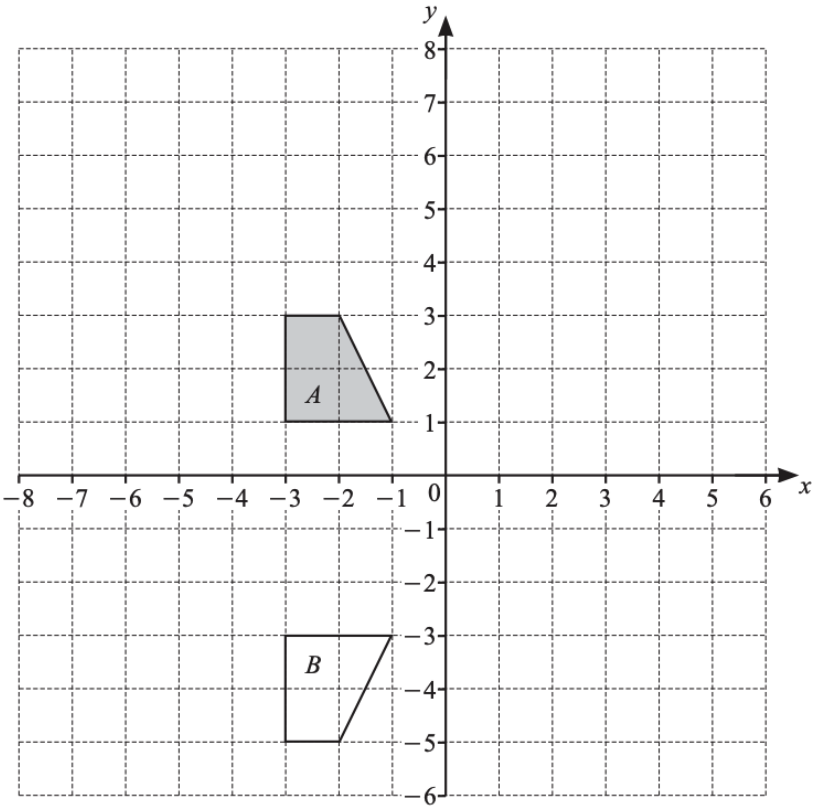
$\overrightarrow{AB} = \begin{pmatrix} \quad \\ \quad \end{pmatrix}$ [1]

(iii) A and B lie on a circle, centre O.

Calculate the length of the arc AB.

..... [6]

7



(a) Describe fully the **single** transformation that maps shape *A* onto shape *B*.

.....

..... [2]

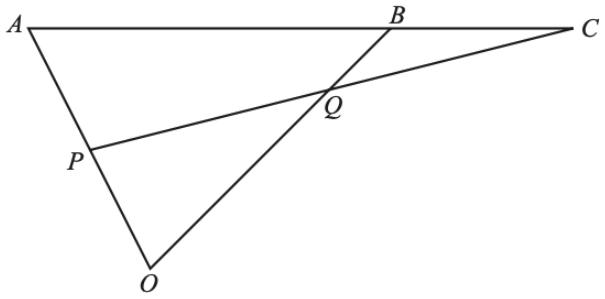
(b) On the grid, draw the image of

(i) shape *A* after a translation by the vector $\begin{pmatrix} -3 \\ 4 \end{pmatrix}$, [2]

(ii) shape *A* after a rotation through 180° about (0, 0), [2]

(iii) shape *A* after an enlargement, scale factor 2, centre (−7, 0). [2]

11



NOT TO SCALE

OAB is a triangle and ABC and PQC are straight lines.
P is the midpoint of OA, Q is the midpoint of PC and $OQ : QB = 3 : 1$.
$\overrightarrow{OA} = 4\mathbf{a}$ and $\overrightarrow{OB} = 8\mathbf{b}$.

(a) Find, in terms of **a** and/or **b**, in its simplest form

(i) $\overrightarrow{AB}$,

$\overrightarrow{AB} =$ ..... [1]

(ii) $\overrightarrow{OQ}$,

$\overrightarrow{OQ} =$ ..... [1]

(iii) $\overrightarrow{PQ}$.

$\overrightarrow{PQ} =$ ..... [1]

(b) By using vectors, find the ratio $AB : BC$.

..... : ..... [3]

9 **(a)** Find the magnitude of the vector $\begin{pmatrix} -1 \\ 7 \end{pmatrix}$.

..... [2]

(b) The determinant of the matrix $\begin{pmatrix} 6 & 2m \\ 5 & m \end{pmatrix}$ is 24.

Find the value of m.

$m =$ ..... [2]

(c) $\mathbf{L} = \begin{pmatrix} 2 & 5 \\ 3 & 9 \end{pmatrix}$ $\mathbf{M} = \begin{pmatrix} -4 \\ 2 \end{pmatrix}$ $\mathbf{N} = \begin{pmatrix} 1 & 7 \end{pmatrix}$

Work out the following.

(i) **NM**

..... [2]

(ii) **LM**

..... [2]

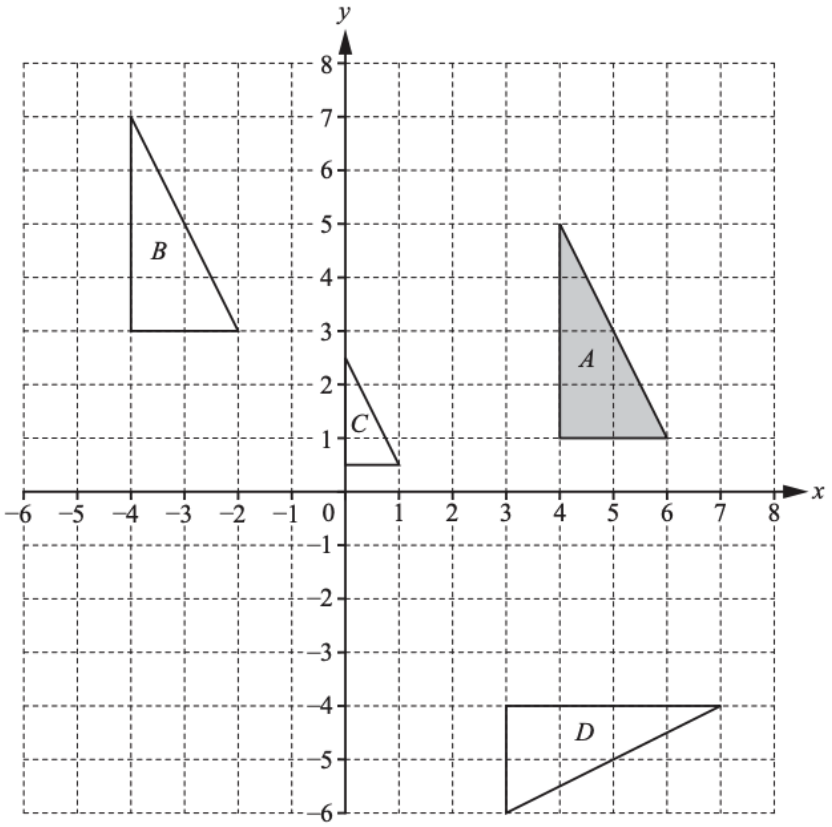
(iii) $\mathbf{L}^2$

..... [2]

(iv) $\mathbf{L}^{-1}$

..... [2]

4



(a) Describe fully the **single** transformation that maps

(i) triangle A onto triangle B,

.....

..... [2]

(ii) triangle A onto triangle C,

.....

..... [3]

(iii) triangle A onto triangle D.

.....

..... [3]

(b) On the grid, draw the image of triangle A after an enlargement by scale factor 2, centre $(7, 3)$. [2]

11 **(a)** $\overrightarrow{OA} = \begin{pmatrix} 4 \\ 3 \end{pmatrix}$ $\overrightarrow{AB} = \begin{pmatrix} 8 \\ -7 \end{pmatrix}$ $\overrightarrow{AC} = \begin{pmatrix} -3 \\ 6 \end{pmatrix}$

Find

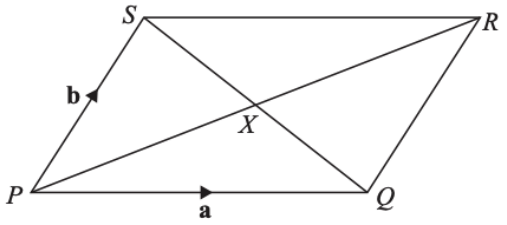
(i) $|\overrightarrow{OB}|$,

$|\overrightarrow{OB}| =$ ..... [3]

(ii) $\overrightarrow{BC}$.

$\overrightarrow{BC} =$ $\begin{pmatrix} \quad \\ \quad \end{pmatrix}$ [2]

(b)



NOT TO SCALE

$PQRS$ is a parallelogram with diagonals PR and SQ intersecting at X.
$\overrightarrow{PQ} = \mathbf{a}$ and $\overrightarrow{PS} = \mathbf{b}$.

Find $\overrightarrow{QX}$ in terms of $\mathbf{a}$ and $\mathbf{b}$.
Give your answer in its simplest form.

$\overrightarrow{QX} =$ ..... [2]

(c) $\mathbf{M} = \begin{pmatrix} 2 & 5 \\ 1 & 8 \end{pmatrix}$

Calculate

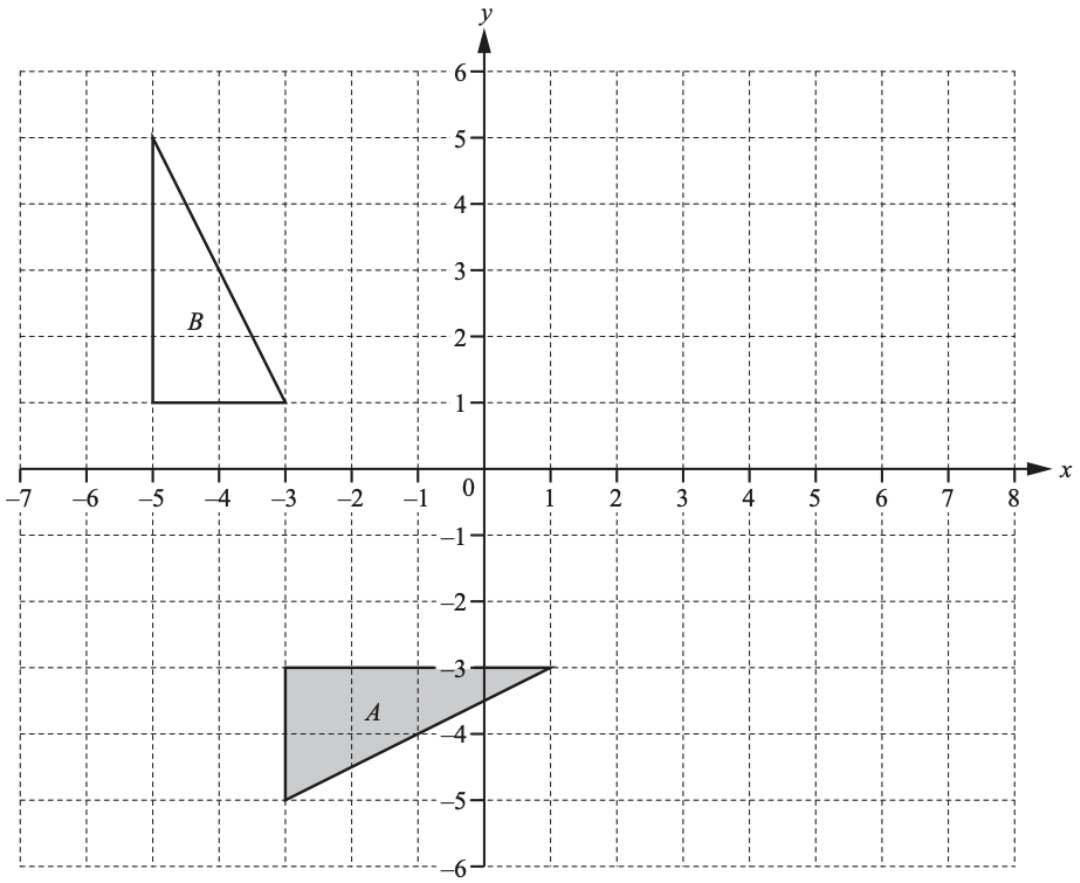
(i) $\mathbf{M}^2$,

$\mathbf{M}^2 =$ $\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

(ii) $\mathbf{M}^{-1}$.

$\mathbf{M}^{-1} =$ $\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

3



(a) **(i)** Draw the image of triangle A after a reflection in the line $x = 2$. [2]

(ii) Draw the image of triangle A after a translation by the vector $\begin{pmatrix} -2 \\ 4 \end{pmatrix}$. [2]

(iii) Draw the image of triangle A after an enlargement by scale factor $-\frac{1}{2}$, centre (3, 1). [3]

(b) Describe fully the **single** transformation that maps triangle A onto triangle B.

.....

..... [3]

(c) Describe fully the **single** transformation represented by the matrix $\begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix}$.

.....

..... [2]

8 **(a)** $\mathbf{M} = \begin{pmatrix} 2 & 1 \\ 4 & 3 \end{pmatrix}$ $\mathbf{N} = \begin{pmatrix} 1 & 2 \end{pmatrix}$ $\mathbf{P} = \begin{pmatrix} 4 \\ 1 \end{pmatrix}$

(i) For the following calculations, put a tick (✓) if it is possible or put a cross (✗) if it is not possible. There is no need to carry out any of the calculations.

Calculation	✓ or ✗
$\mathbf{N} + \mathbf{P}$	
$\mathbf{NP}$	
$\mathbf{M}^2$	
$\mathbf{N}^2$	
$\mathbf{MN}$	
$\mathbf{NM}$	

[4]

(ii) Work out $\begin{pmatrix} 1 \\ 2 \end{pmatrix} + \mathbf{P}$.

..... [1]

(iii) Work out $\mathbf{PN}$.

..... [2]

(iv) Work out $\mathbf{M}^{-1}$.

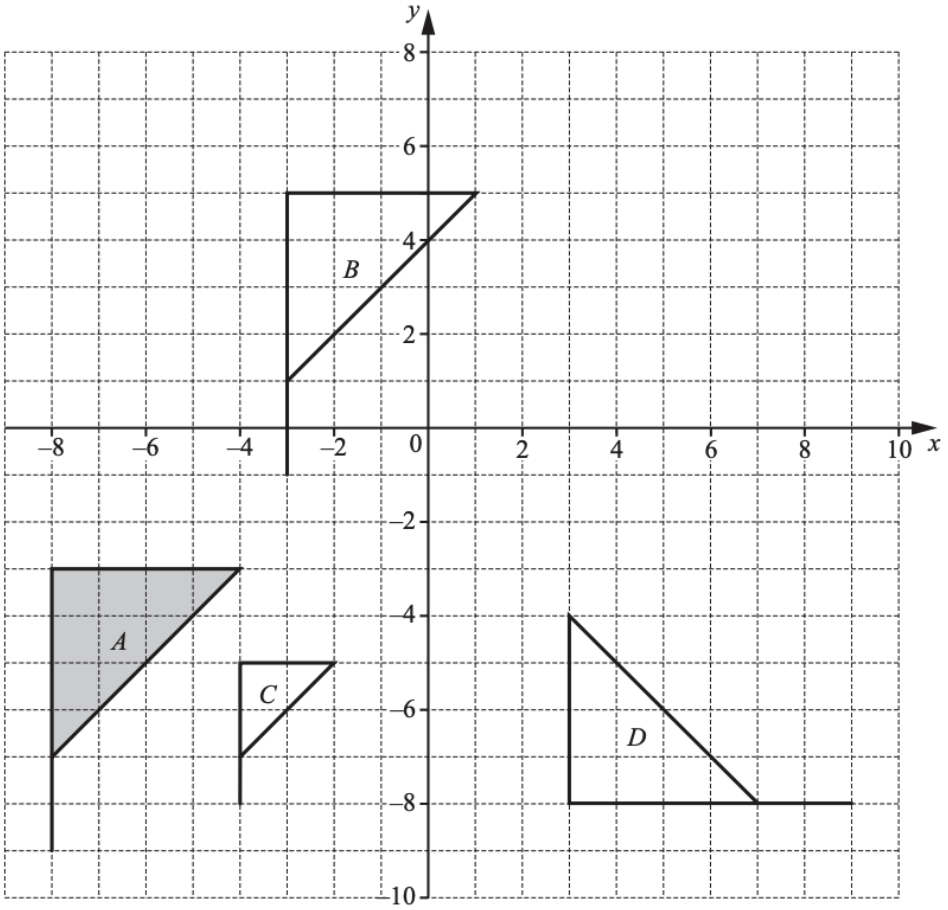
..... [2]

(b) Describe fully the **single** transformation represented by the matrix $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}$.

.....

..... [3]

2



(a) Describe fully the **single** transformation that maps

(i) flag *A* onto flag *B*,

.....

..... [2]

(ii) flag *A* onto flag *C*,

.....

..... [3]

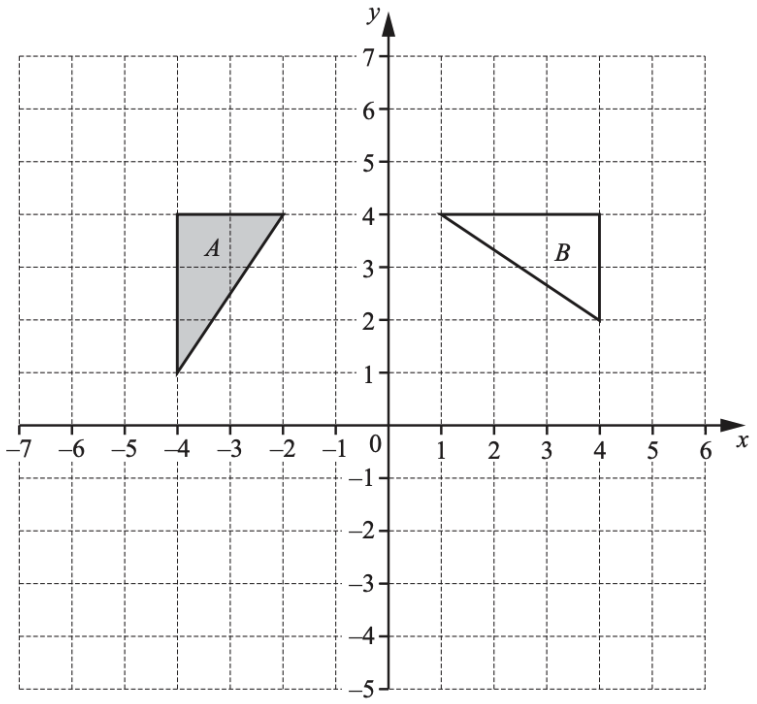
(iii) flag *A* onto flag *D*.

.....

..... [3]

(b) Draw the reflection of flag *A* in the line $y = -1$. [2]

3



(a) Describe fully the **single** transformation that maps triangle A onto triangle B.

.....

..... [3]

(b) On the grid, draw the image of

(i) triangle A after a reflection in the x-axis, [1]

(ii) triangle A after a translation by the vector $\begin{pmatrix} 7 \\ -5 \end{pmatrix}$, [2]

(iii) triangle A after the transformation represented by the matrix $\begin{pmatrix} 0.5 & 0 \\ 0 & 0.5 \end{pmatrix}$. [3]

11 **(a)** $\mathbf{a} = \begin{pmatrix} -3 \\ 2 \end{pmatrix}$ $\mathbf{b} = \begin{pmatrix} 5 \\ 4 \end{pmatrix}$ $\mathbf{c} = \begin{pmatrix} 14 \\ 9 \end{pmatrix}$

(i) Find $3\mathbf{a} - 2\mathbf{b}$.

$\begin{pmatrix} \quad \\ \quad \end{pmatrix}$ [2]

(ii) Find $|\mathbf{a}|$.

..... [2]

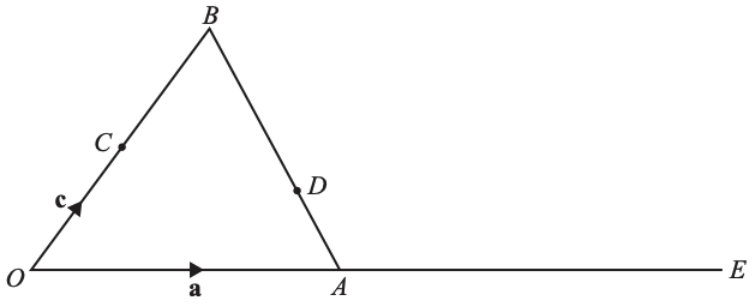
(iii) $m\mathbf{a} + n\mathbf{b} = \mathbf{c}$

Write down two simultaneous equations and solve them to find the value of m and the value of n. Show all your working.

$m =$ .....

$n =$ ..... [5]

(b)



NOT TO SCALE

OAB is a triangle and C is the mid-point of OB.
D is on AB such that $AD : DB = 3 : 5$.
OAE is a straight line such that $OA : AE = 2 : 3$.
$\overrightarrow{OA} = \mathbf{a}$ and $\overrightarrow{OC} = \mathbf{c}$.

(i) Find, in terms of **a** and **c**, in its simplest form,

(a) $\overrightarrow{AB}$,

$\overrightarrow{AB} =$ ..... [1]

(b) $\overrightarrow{AD}$,

$\overrightarrow{AD} =$ ..... [1]

(c) $\overrightarrow{CE}$,

$\overrightarrow{CE} =$ ..... [1]

(d) $\overrightarrow{CD}$.

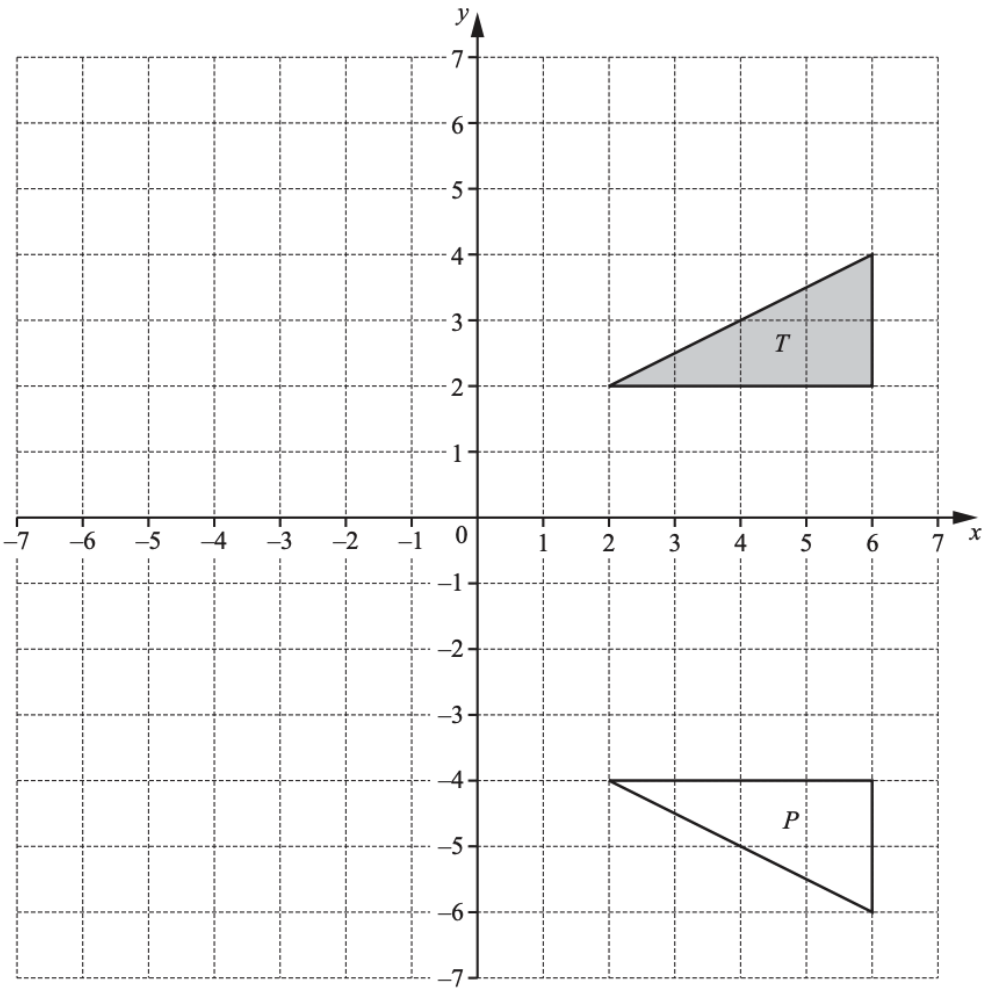
$\overrightarrow{CD} =$ ..... [2]

(ii) $\overrightarrow{CE} = k\overrightarrow{CD}$

Find the value of k.

$k =$ ..... [1]

1 (a)



(i) Describe fully the **single** transformation that maps triangle T onto triangle P.

.....

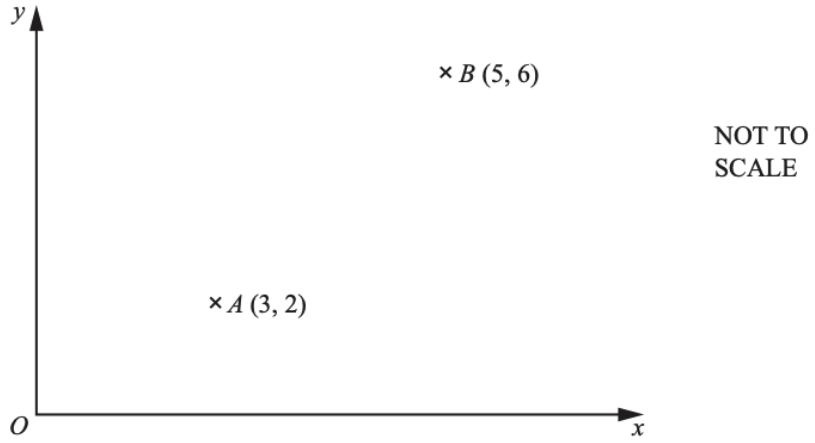
..... [2]

(ii) Translate triangle T by the vector $\begin{pmatrix} -2 \\ -5 \end{pmatrix}$. [2]

(iii) Rotate triangle T through 90° anticlockwise about (0, 0). [2]

(iv) Enlarge triangle T by scale factor $-\frac{1}{2}$ with centre (0, 0). [2]

(b)



(i) Find the column vector $\overrightarrow{AB}$.

$\overrightarrow{AB} = \begin{pmatrix} \quad \\ \quad \end{pmatrix}$ [1]

(ii) Find $\left|\overrightarrow{AB}\right|$.

$\left|\overrightarrow{AB}\right|$ = ... [2]

(iii) B is the mid-point of the line AC.

Find the co-ordinates of C.

(..... , ...) [2]

(iv) Find the equation of the straight line that passes through A and B.

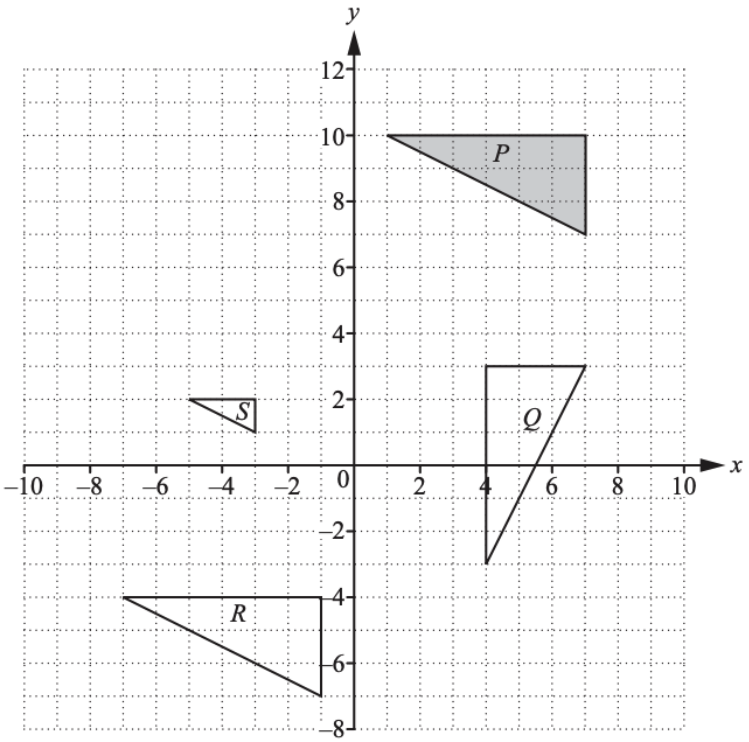
..... [3]

(v) The straight line that passes through A and B cuts the y-axis at D.

Write down the co-ordinates of D.

(..... , ...) [1]

2



(a) Describe fully the **single** transformation that maps

(i) shape P onto shape Q,

.....

..... [3]

(ii) shape P onto shape R,

.....

..... [2]

(iii) shape P onto shape S.

.....

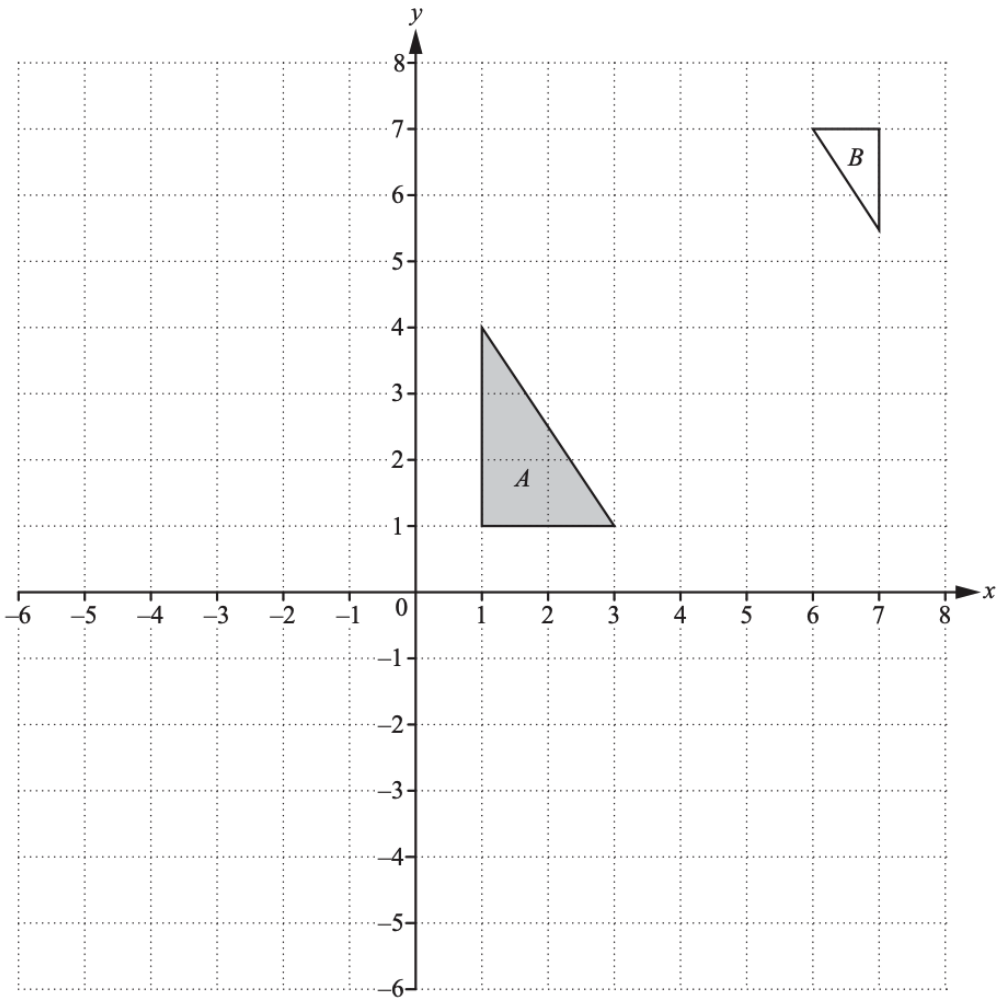
..... [3]

(b) **(i)** Draw the reflection of **shape *S*** in the line $y = x$. [2]

(ii) Write down the matrix that represents the transformation in **part (b)(i)**.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

3



(a) **(i)** Draw the image of triangle A after reflection in the line $x = 4$. [2]

(ii) Draw the image of triangle A after rotation of 90° anticlockwise about (0, 0). [2]

(iii) Draw the image of triangle A after translation by the vector $\begin{pmatrix} 1 \\ -5 \end{pmatrix}$. [2]

(b) Describe fully the **single** transformation that maps triangle A onto triangle B.

.....

..... [3]

(c) Find the matrix that represents the transformation in **part (a)(ii)**.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

(d) Point P has co-ordinates (4, 1).

$\mathbf{F} = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}$ and $\mathbf{G} = \begin{pmatrix} 1 & 0 \\ 0 & 2 \end{pmatrix}$ represent transformations.

(i) Find $\mathbf{G}(P)$, the image of P after the transformation represented by $\mathbf{G}$.

(..... , ...) [2]

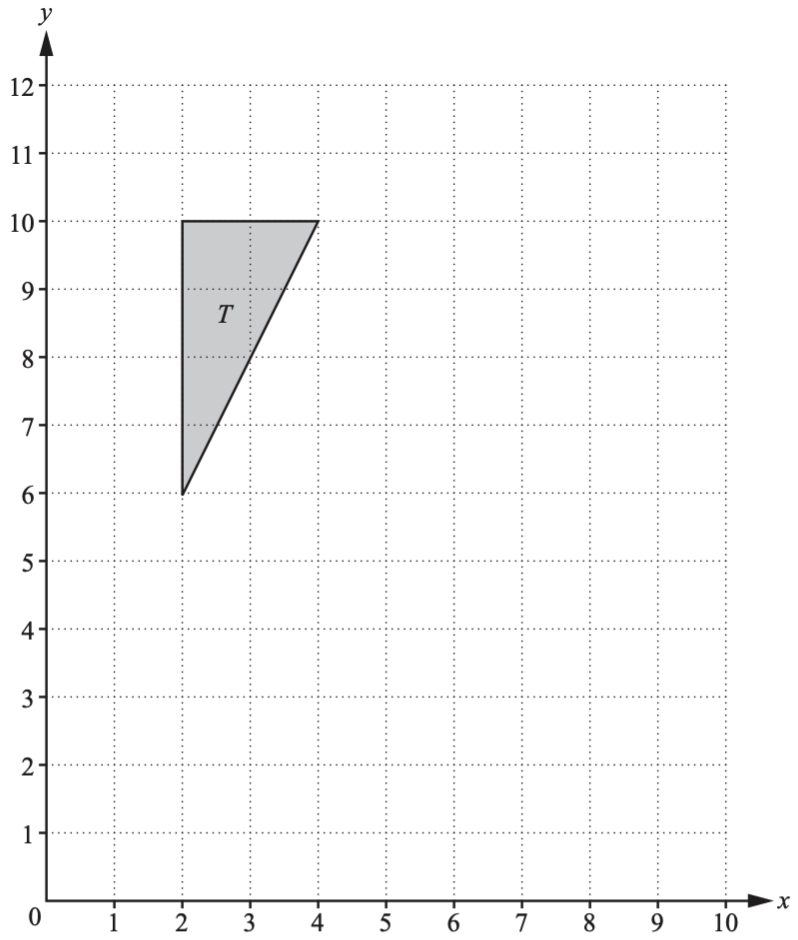
(ii) Find $\mathbf{GF}(P)$.

(..... , ...) [3]

(iii) Find the matrix $\mathbf{Q}$ such that $\mathbf{GQ}(P) = P$.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [3]

2 **(a)**



On the grid, draw the image of

(i) triangle T after translation by the vector $\begin{pmatrix} 6 \\ -5 \end{pmatrix}$, [2]

(ii) triangle T after rotation through 90° anticlockwise with centre (4, 10), [2]

(iii) triangle T after enlargement with scale factor $\frac{1}{2}$, centre (10, 0). [2]

(b) Describe fully the **single** transformation that is represented by the matrix $\begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix}$.

.....

..... [2]

(c) $\mathbf{M} = \begin{pmatrix} 2 & 3 \\ 2 & 4 \end{pmatrix}$ $\mathbf{N} = \begin{pmatrix} 2 \\ 3 \end{pmatrix}$ $\mathbf{P} = (1 \;\; 5)$

(i) Find

(a) **MN**,

$\mathbf{MN} =$ [2]

(b) **NP**,

$\mathbf{NP} =$ [2]

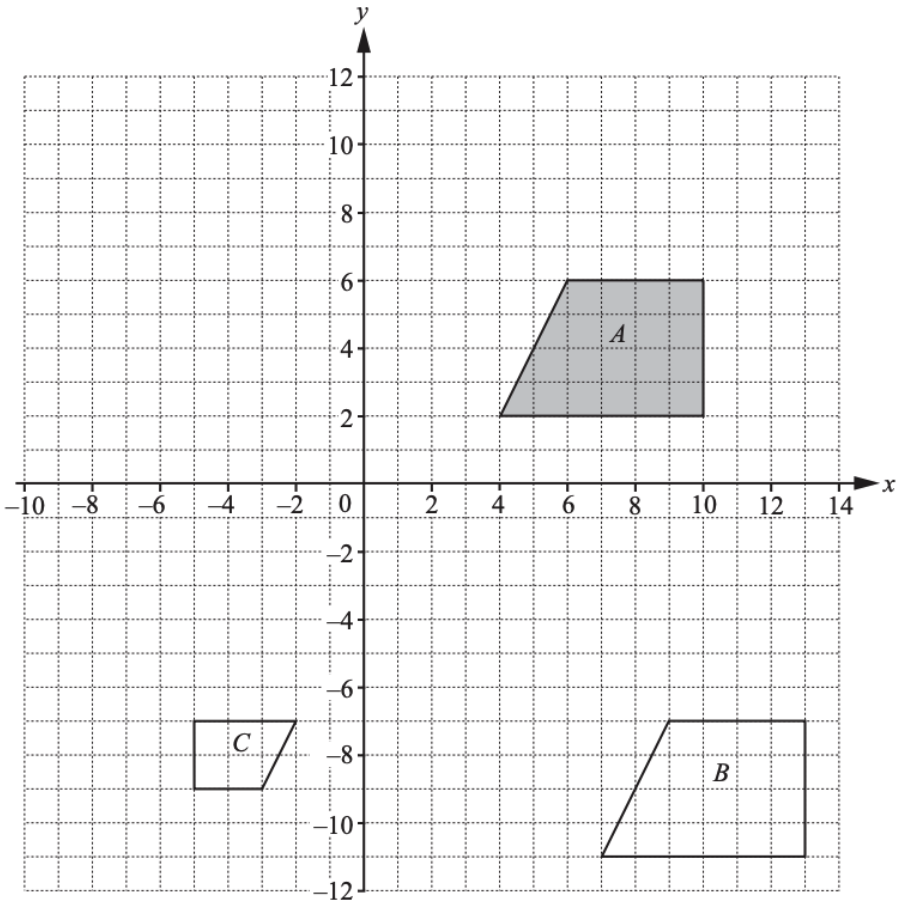
(c) $\mathbf{M}^{-1}$.

$\mathbf{M}^{-1} =$ $\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

(ii) Write down a product of two of the matrices **M**, **N** and **P** which it is not possible to work out.

..... [1]

6



(a) Describe fully the **single** transformation that maps shape *A* onto

(i) shape *B*,

.....

..... [2]

(ii) shape *C*.

.....

..... [3]

(b) Draw the image of shape *A* after rotation through 90° anticlockwise about the point (3, −1). [2]

(c) Draw the image of shape *A* after reflection in $y = 1$. [2]

(d) Describe fully the **single** transformation represented by the matrix $\begin{pmatrix} 3 & 0 \\ 0 & 3 \end{pmatrix}$.

.....

..... [3]

11 **(a)** $\mathbf{A} = \begin{pmatrix} 2 & -3 \\ 1 & 4 \end{pmatrix}$

Find

(i) $\mathbf{A}^2$,

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

(ii) $\mathbf{A}^{-1}$, the inverse of $\mathbf{A}$.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

(b) Describe fully the **single** transformation represented by the matrix $\begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}$.

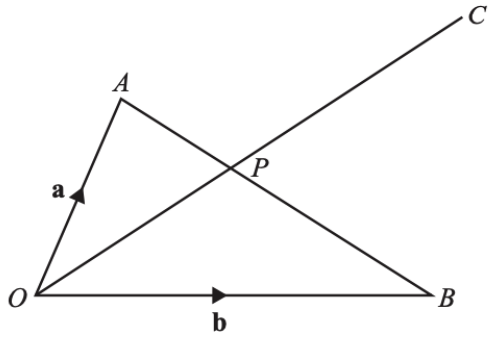
.....

..... [2]

(c) Find the matrix that represents a clockwise rotation of 90° about the origin.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

(d)



NOT TO SCALE

In the diagram, O is the origin and P lies on AB such that $AP : PB = 3 : 4$.
$\overrightarrow{OA} = \mathbf{a}$ and $\overrightarrow{OB} = \mathbf{b}$.

(i) Find $\overrightarrow{OP}$, in terms of **a** and **b**, in its simplest form.

$\overrightarrow{OP}$ = ... [3]

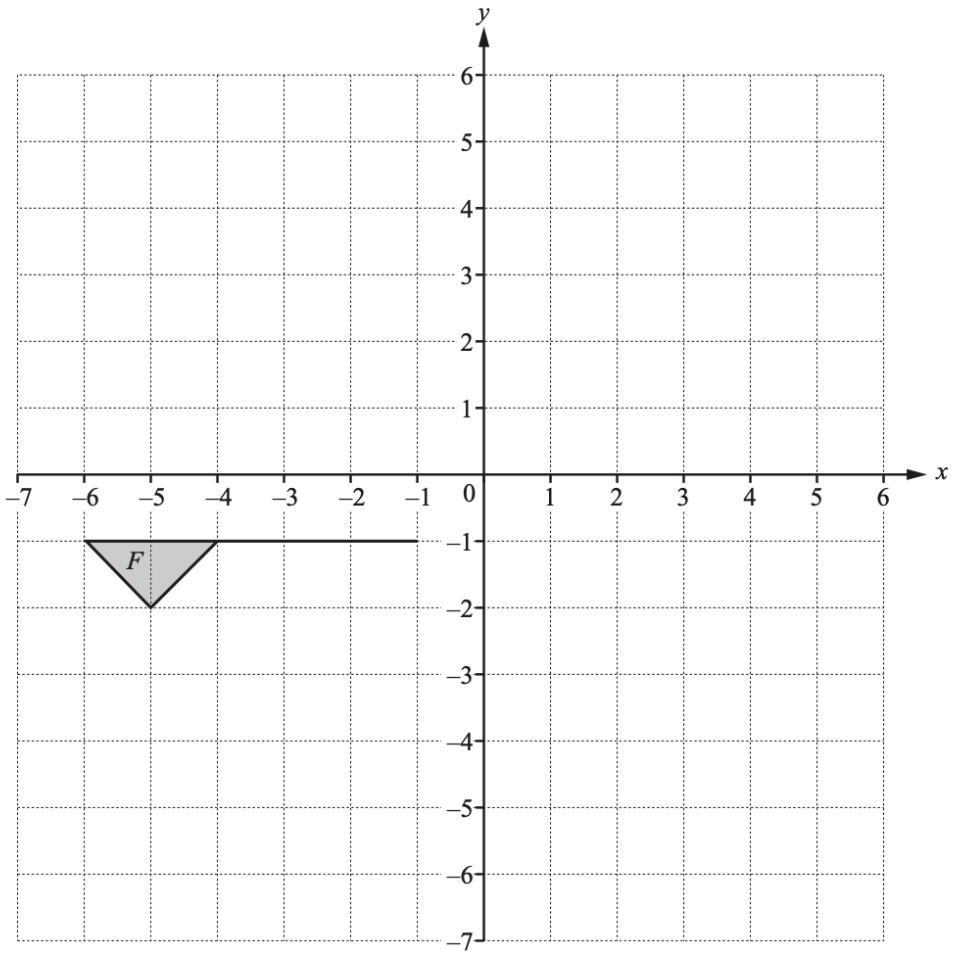
(ii) The line OP is extended to C such that $\overrightarrow{OC} = m\overrightarrow{OP}$ and $\overrightarrow{BC} = k\mathbf{a}$.

Find the value of m and the value of k.

m = ...

k = ... [2]

4 (a)



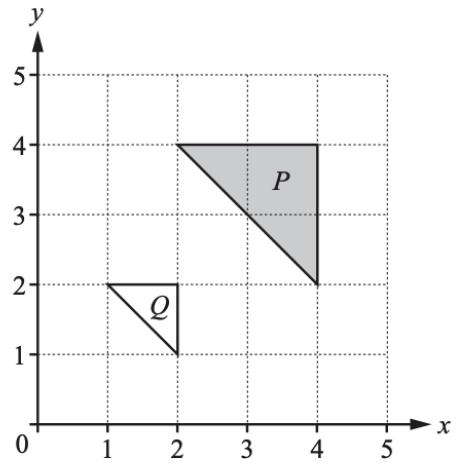
Draw the image of

(i) flag F after translation by the vector $\begin{pmatrix} 6 \\ -2 \end{pmatrix}$, [2]

(ii) flag F after rotation through 180° about $(-2, 0)$, [2]

(iii) flag F after reflection in the line $y = x$. [2]

(b)



(i) Describe fully the **single** transformation that maps triangle P onto triangle Q.

.....

..... [3]

(ii) Find the matrix that represents this transformation.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

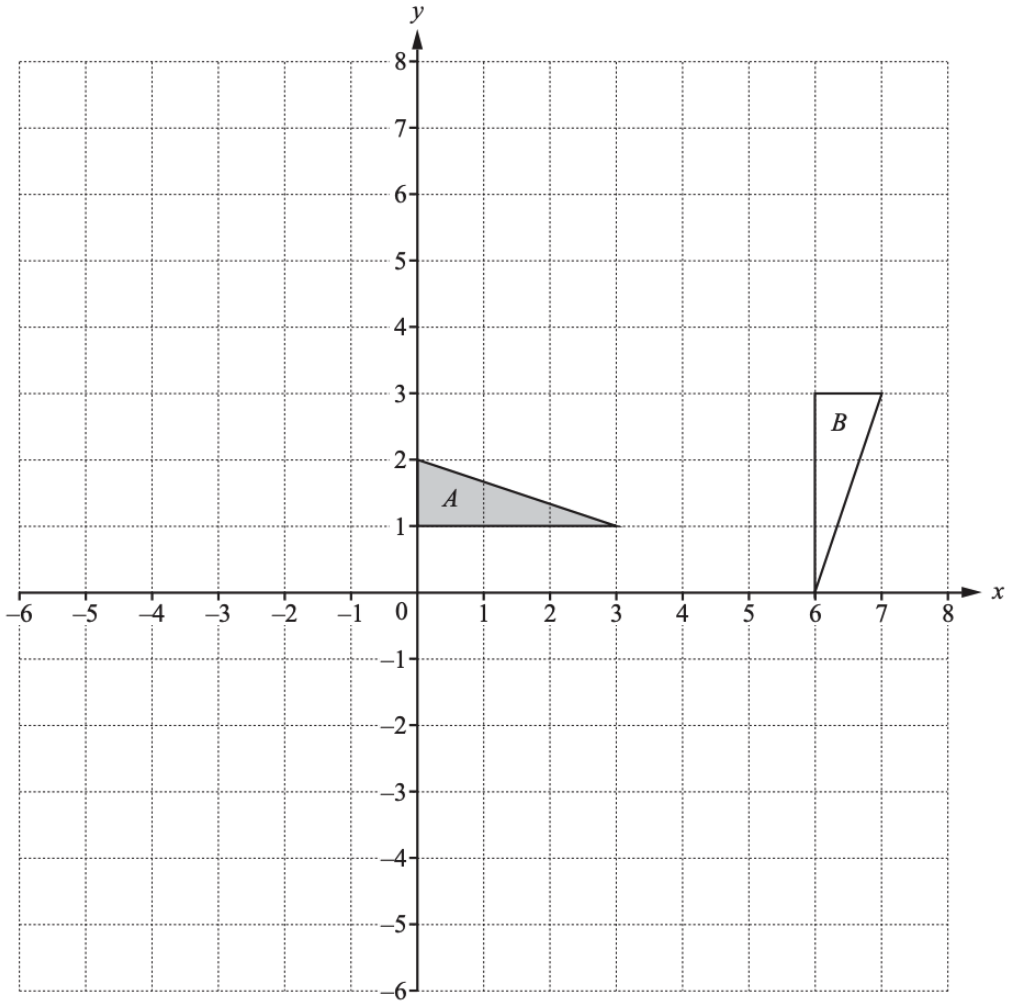
(c) The point A is translated to the point B by the vector $\begin{pmatrix} 4u \\ 3u \end{pmatrix}$.

$|\overrightarrow{AB}| = 12.5$

Find u.

$u =$ ..... [3]

5



(a) Draw the image of

(i) triangle A after a reflection in the line $x = 0$, [2]

(ii) triangle A after an enlargement, scale factor 2, centre (0, 4), [2]

(iii) triangle A after a translation by the vector $\begin{pmatrix} -5 \\ 3 \end{pmatrix}$. [2]

(b) Describe fully the **single** transformation that maps triangle A onto triangle B.

.....

..... [3]

(c) $\mathbf{T} = \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}$ $\mathbf{U} = \begin{pmatrix} 3 & 1 \\ 0 & 2 \end{pmatrix}$

Point P has co-ordinates $(1, -4)$.

(i) Find $\mathbf{T}(P)$.

(....., ...) [2]

(ii) Find $\mathbf{TU}(P)$.

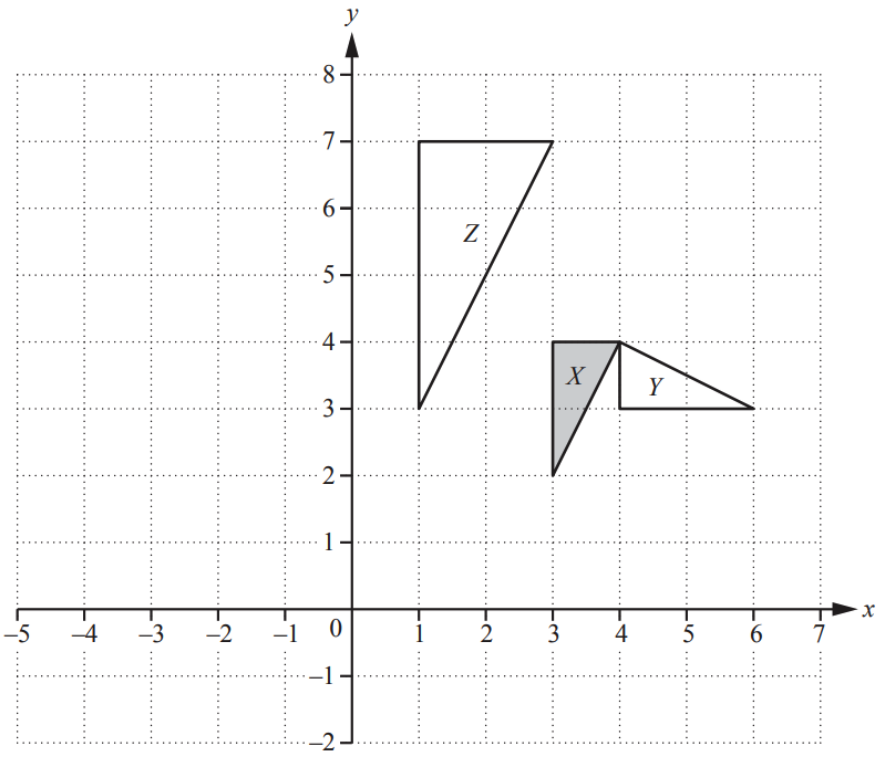
(....., ...) [2]

(iii) Describe the **single** transformation represented by the matrix **T**.

.....

..... [3]

6



(a) Describe fully the **single** transformation that maps

(i) triangle X onto triangle Y,

.....

..... [3]

(ii) triangle X onto triangle Z.

.....

..... [3]

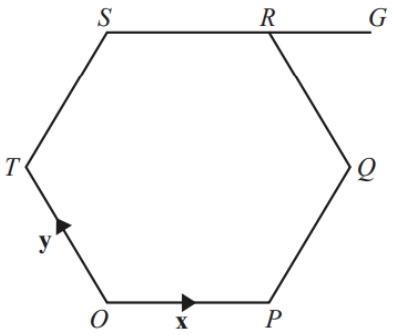
(b) **(i)** Draw the image of triangle X after a translation by the vector $\begin{pmatrix} -5 \\ 3 \end{pmatrix}$.

Label this triangle P. [2]

(ii) Draw the reflection of triangle P in the line $y = 3$. [2]

(c) Draw the image of triangle X after the transformation represented by the matrix $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}$. [3]

9



NOT TO SCALE

O is the origin and $OPQRST$ is a regular hexagon.

$\overrightarrow{OP} = \mathbf{x}$ and $\overrightarrow{OT} = \mathbf{y}$.

(a) Write down, in terms of **x** and/or **y**, in its simplest form,

(i) $\overrightarrow{QR}$,

$\overrightarrow{QR}$ = ... [1]

(ii) $\overrightarrow{PQ}$,

$\overrightarrow{PQ}$ = ... [1]

(iii) the position vector of S.

..... [2]

(b) The line SR is extended to G so that $SR : RG = 2 : 1$.

Find $\overrightarrow{GQ}$, in terms of **x** and **y**, in its simplest form.

$\overrightarrow{GQ}$ = ... [2]

(c) M is the midpoint of OP.

(i) Find $\overrightarrow{MG}$, in terms of **x** and **y**, in its simplest form.

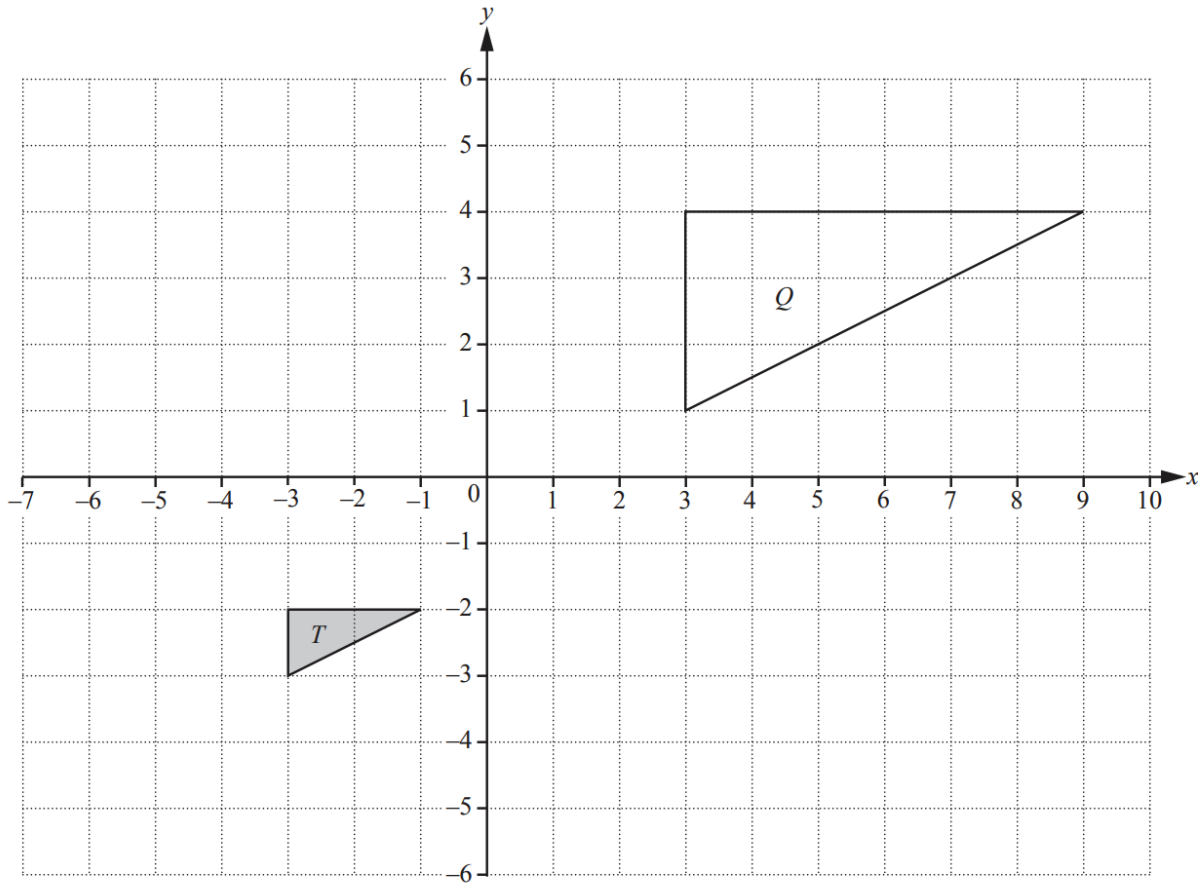
$\overrightarrow{MG}$ = ... [2]

(ii) H is a point on TQ such that $TH : HQ = 3 : 1$.

Use vectors to show that H lies on MG.

[2]

2 (a)



(i) Draw the image of triangle T after a translation by the vector $\begin{pmatrix} 5 \\ -2 \end{pmatrix}$. [2]

(ii) Draw the image of triangle T after a reflection in the line $y = 1$. [2]

(iii) Describe fully the **single** transformation that maps triangle T onto triangle Q.

.....

..... [3]

(b) $\mathbf{M} = \begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$ $\mathbf{N} = \begin{pmatrix} 4 & 3 \\ 1 & k \end{pmatrix}$ $\mathbf{P} = \begin{pmatrix} 1 & 3 \\ 0 & 6 \end{pmatrix}$

(i) Work out $\mathbf{M} + \mathbf{P}$.

$\begin{pmatrix} \quad & \quad \\ \quad & \quad \end{pmatrix}$ [1]

(ii) Work out $\mathbf{PM}$.

$\begin{pmatrix} \quad & \quad \\ \quad & \quad \end{pmatrix}$ [2]

(iii) $|\mathbf{M}| = |\mathbf{N}|$

Find the value of k.

$k =$ ..... [3]

(c) **(i)** Describe fully the **single** transformation represented by the matrix $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}$.

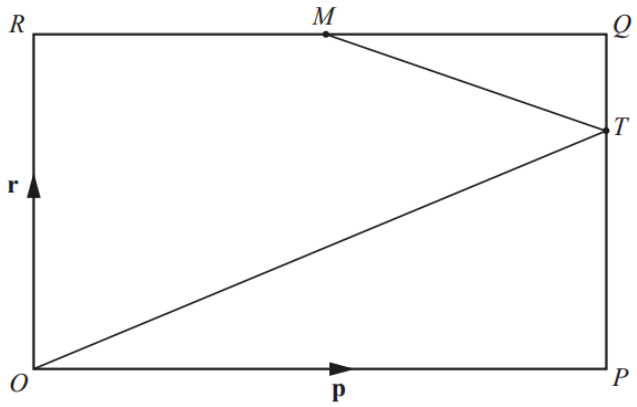
.....

..... [3]

(ii) Find the matrix which represents a reflection in the line $y = x$.

$\begin{pmatrix} \quad & \quad \\ \quad & \quad \end{pmatrix}$ [2]

7



NOT TO SCALE

$OPQR$ is a rectangle and O is the origin.
M is the midpoint of RQ and $PT : TQ = 2 : 1$.
$\overrightarrow{OP} = \mathbf{p}$ and $\overrightarrow{OR} = \mathbf{r}$.

(a) Find, in terms of **p** and/or **r**, in its simplest form

(i) $\overrightarrow{MQ}$,

$\overrightarrow{MQ} =$ ..... [1]

(ii) $\overrightarrow{MT}$,

$\overrightarrow{MT} =$ ..... [1]

(iii) $\overrightarrow{OT}$.

$\overrightarrow{OT} =$ ..... [1]

(b) RQ and OT are extended to meet at U.

Find the position vector of U in terms of **p** and **r**.
Give your answer in its simplest form.

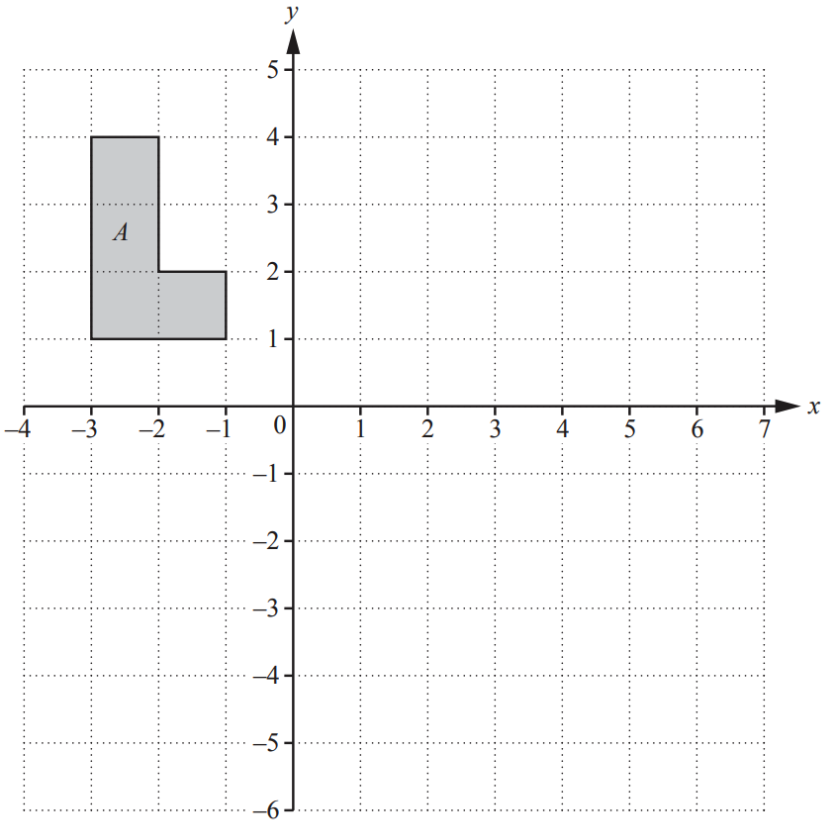
..... [2]

(c) $\overrightarrow{MT} = \begin{pmatrix} 2k \\ -k \end{pmatrix}$ and $|\overrightarrow{MT}| = \sqrt{180}$.

Find the positive value of k.

$k =$ ..... [3]

3 **(a)**



On the grid, draw the image of

(i) shape A after a reflection in the line $x = 1$, [2]

(ii) shape A after an enlargement with scale factor -2, centre $(0, 1)$, [2]

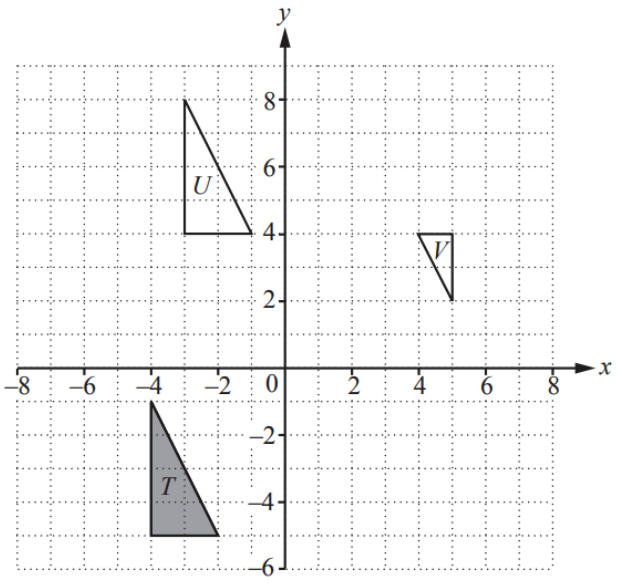
(iii) shape A after the transformation represented by the matrix $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}$. [3]

(b) Describe fully the **single** transformation represented by the matrix $\begin{pmatrix} 3 & 0 \\ 0 & 3 \end{pmatrix}$.

.....

..... [3]

6



(a) (i) Draw the image of triangle T after a reflection in the line $x = 0$. [2]

(ii) Draw the image of triangle T after a rotation through 90° clockwise about (–2, –1). [2]

(iii) Describe fully the **single** transformation that maps triangle T onto triangle U.

.....

..... [2]

(iv) Describe fully the **single** transformation that maps triangle T onto triangle V.

.....

..... [3]

(b) (i) Find the matrix that represents the transformation in **part (a)(i)**.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

(ii) Describe fully the **single** transformation represented by the inverse of the matrix in **part (b)(i)**.

.....

..... [2]

8 $\mathbf{A} = \begin{pmatrix} 2 & 0 \\ -1 & 5 \\ 3 & -4 \end{pmatrix}$ $\mathbf{B} = \begin{pmatrix} 1 & 3 \\ -1 & 5 \end{pmatrix}$ $\mathbf{C} = \begin{pmatrix} 7 \\ -4 \end{pmatrix}$ $\mathbf{D} = \begin{pmatrix} 2 & 5 \end{pmatrix}$

(a) Work out each of the following if the answer is possible.
If a calculation is not possible, write "not possible" in the answer space.

(i) **BA**

[1]

(ii) **2A**

[1]

(iii) **CD**

[2]

(iv) **DC**

[2]

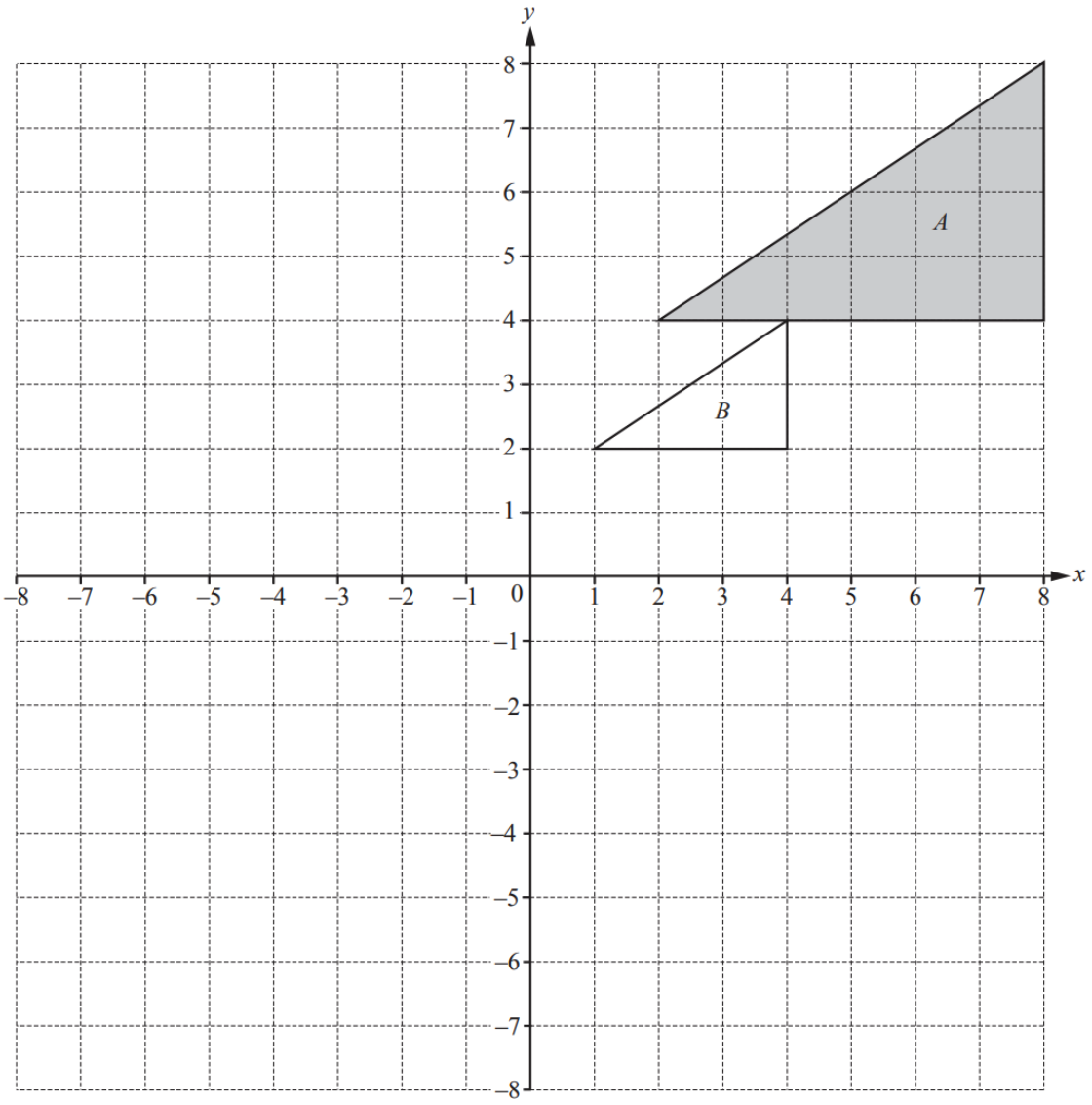
(v) $\mathbf{B}^2$

[2]

(b) Find $\mathbf{B}^{-1}$, the inverse of **B**.

( ) [2]

5



(a) $\mathbf{v} = \begin{pmatrix} -4 \\ -8 \end{pmatrix}$

(i) Draw the image of triangle A after the translation by vector $\mathbf{v}$. [2]

(ii) Calculate $|\mathbf{v}|$.

..... [2]

(b) **(i)** Describe fully the **single** transformation that maps triangle A onto triangle B.

.....

..... [3]

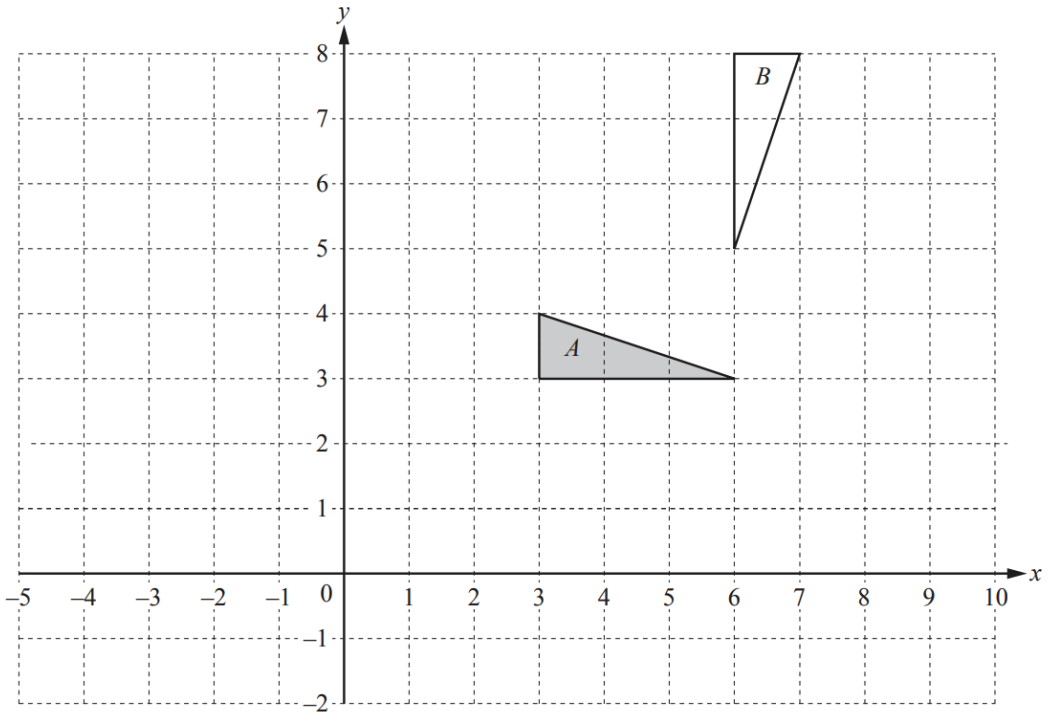
(ii) Find the matrix that represents the transformation that maps triangle A onto triangle B.

$\begin{pmatrix} & \\ & \end{pmatrix}$ [2]

(iii) Calculate the determinant of the matrix in **part (b)(ii)**.

..... [1]

4



(a) Draw the image when triangle A is reflected in the line $x = 1$. [2]

(b) Draw the image when triangle A is translated by the vector $\begin{pmatrix} -2 \\ 3 \end{pmatrix}$. [2]

(c) Draw the image when triangle A is enlarged by scale factor 2 with centre (4, 5). [2]

(d) Describe fully the **single** transformation that maps triangle A onto triangle B.

.....

..... [3]

9 **(a)** $\mathbf{m} = \begin{pmatrix} 3 \\ 2 \end{pmatrix}$ $\mathbf{n} = \begin{pmatrix} -2 \\ 3 \end{pmatrix}$

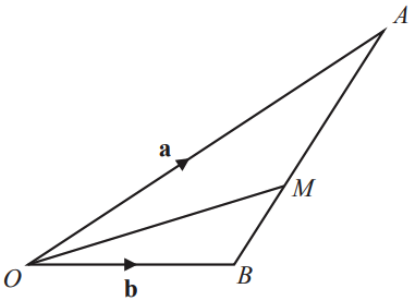
(i) Work out $2\mathbf{m} - 3\mathbf{n}$.

$\begin{pmatrix} \quad \\ \quad \end{pmatrix}$ [2]

(ii) Calculate $|2\mathbf{m} - 3\mathbf{n}|$.

..... [2]

(b) **(i)**



NOT TO SCALE

In the diagram, O is the origin, $\overrightarrow{OA} = \mathbf{a}$ and $\overrightarrow{OB} = \mathbf{b}$.
The point M lies on AB such that $AM : MB = 3 : 2$.

Find, in terms of **a** and **b**, in its simplest form

(a) $\overrightarrow{AB}$,

$\overrightarrow{AB}$ = ... [1]

(b) $\overrightarrow{AM}$,

$\overrightarrow{AM}$ = ... [1]

(c) the position vector of M.

.....[2]

(ii) OM is extended to the point C.
The position vector of C is $\mathbf{a} + k\mathbf{b}$.

Find the value of k.

k = ...[1]

4(a)	Triangle at (–4, –4) (–1, –3) (–4, –3)	**2**	**B1** for correct points not joined or for reflection in any $y = k$ or for reflection in $x = -1$
4(b)	Triangle at (1, 1) (1, 4) (2, 4)	**2**	**B1** for correct points not joined or rotation 90 clockwise around any point or rotation 90 anticlockwise around (0, 0)
4(c)	Translation $\begin{pmatrix} 5 \\ -6 \end{pmatrix}$	**2**	**B1** for translation or correct vector oe

2(d)	$\frac{1}{2}\mathbf{c} + \frac{1}{3}\mathbf{d}$	**3**	**B2** for correct unsimplified answer or **M1** for $\overrightarrow{CT} = -\mathbf{c} + \frac{2}{3}\mathbf{d}$ oe or $\overrightarrow{TC} = \mathbf{c} - \frac{2}{3}\mathbf{d}$ oe or for correct route

2(a)(i)	triangle with vertices at (–2, –1) (–8, –1) (–2, –5)	**2**	**B1** for correct reflection in $y = x$
2(a)(ii)	triangle with vertices at (–1, –1) (–1, –7) (3, –7)	**2**	**B1** for translation by $\begin{pmatrix} k \\ -9 \end{pmatrix}$ or $\begin{pmatrix} -2 \\ k \end{pmatrix}$
2(b)(i)	Enlargement [centre] (–7, 8) [sf] ½	**3**	**B1** for each
2(b)(ii)	Rotation [centre] (0, 0) 90° clockwise oe	**3**	**B1** for each

1(a)	Image at (4, –1) (4, –4) (5, –4)	**2**	**B1** for translation by $\begin{pmatrix} 8 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ -6 \end{pmatrix}$ or for correct vertices not joined
1(b)	Image at (–4, –4) (–4, –7) (–3, –4)	**2**	**B1** for reflection in $x = -1$ or $y = k$ or for correct vertices not joined
1(c)	Enlargement 3 (–5, 5)	**3**	**B1** for each
1(d)	Rotation 90° clockwise oe (1, 1)	**3**	**B1** for each

2(a)	Translation $\begin{pmatrix}1\\-6\end{pmatrix}$	**2**	**B1** for each
2(b)(i)	Image at (0, 1), (–3, 1), (–3, 2)	**2**	**B1** for reflection in $x = k$ or $y = 1$
2(b)(ii)	Image at (5, –4), (5, –1), (4, –1)	**2**	**B1** for rotation 90° anticlockwise with other centre or for rotation 90° clockwise about (6, 0)
2(b)(iii)	Image at (–1, –2), (–7, –2), (–7, –4)	**2**	**B1** for enlargement, factor –2 with other centre

2(a)(i)	Triangle at (–3, 2) (–3, 3) (–5, 2)	**2**	**B1** for correct rotation about incorrect point or for rotation 90 clockwise around (0, 0)
2(a)(ii)	Triangle at (5, –2) (6, –2) (5, 0)	**2**	**B1** for translation by $\begin{pmatrix}3\\k\end{pmatrix}$ or $\begin{pmatrix}k\\-5\end{pmatrix}$
2(b)	Enlargement [SF] 3 [Centre] (1, 4)	**3**	**B1** for each

8(a)(i)	$\begin{pmatrix}4\\4\end{pmatrix}$	**2**	**B1** for $\begin{pmatrix}4\\k\end{pmatrix}$ or $\begin{pmatrix}k\\4\end{pmatrix}$
8(a)(ii)	$\begin{pmatrix}-4\\8\end{pmatrix}$	**2**	**B1** for $\begin{pmatrix}-4\\k\end{pmatrix}$ or $\begin{pmatrix}k\\8\end{pmatrix}$
8(a)(iii)	5.39 or 5.385..	**2**	**M1** for $(-2)^2 + 5^2$ oe
8(b)(i)	$\mathbf{a} + \mathbf{b}$	**1**	
8(b)(ii)	$\frac{3}{2}\mathbf{a} + \mathbf{b}$	**2**	**M1** for a correct route, e.g. $\overrightarrow{OA} + \overrightarrow{AE}$
8(b)(iii)	$2\mathbf{a} + \frac{4}{3}\mathbf{b}$	**3**	**M2** for unsimplified $\overrightarrow{OD}$ or for $\frac{4}{3}\mathbf{b}$ or **M1** for $\overrightarrow{OD}$ attempted in terms of **a** and **b** or for $\overrightarrow{CD} = \frac{1}{3}\mathbf{b}$ or $\overrightarrow{DB} = \frac{2}{3}\mathbf{b}$ seen

2(a)(i)	Reflection $x = 1.5$	**2**	**B1** for each
2(a)(ii)	Rotation (0, −1) 90° [anticlockwise] oe	**3**	**B1** for each
2(b)(i)	Image at (5, −1) (6, −1) (6, −3)	**2**	**B1** for correct size and orientation but wrong position If 0 scored, **SC1** for enlargement SF $\frac{1}{2}$ with centre (3, 0)
2(b)(ii)	Image at (−6, 3) (−4, 3) (−6, 7)	**2**	**B1** for translation $\begin{pmatrix} -3 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ 1 \end{pmatrix}$
2(b)(iii)	Image at (2, −1) (2, −3) (6, −3)	**3**	**M2** for 3 correct coordinates soi or **M1** for $\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} -1 & -3 & -3 \\ 2 & 2 & 6 \end{pmatrix}$ or **B1** for stating reflection in $y = x$

1(a)(i)	Image at (1, 7), (4, 7), (4, 9), (3, 9)	**2**	**B1** for translation by $\begin{pmatrix} -1 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ 6 \end{pmatrix}$
1(a)(ii)	Image at (5, 3), (6, 3), (8, 5), (5, 5)	**2**	**B1** for 180° rotation with wrong centre
1(a)(iii)	Rotation 180° (4.5, 6) OR Enlargement, [factor] – 1 (4.5, 6)	**3**	**B1** for rotation **B1** for 180° **B1FT** for centre from *their* (a)(i) **B1** for enlargement **B1** for – 1 **B1FT** for centre from *their* **(a)(i)**
1(b)(i)	Image at (1, 2), (1, 5), (3, 5), (3, 4)	**2**	**B1** for $y = x$ drawn or for 3 correct points
1(b)(ii)	$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$	**2**	**B1** for one correct row or one column within a 2 by 2 matrix

3(a)(i)	Image at (–5, 4), (–2, 4), (–4, 6)	**2**	**B1** for translation by $\begin{pmatrix}-3\\k\end{pmatrix}$ or $\begin{pmatrix}k\\2\end{pmatrix}$
3(a)(ii)	Image at (2, 1), (4, –1), (2, –2)	**2**	**B1** for reflection in $y = -x$ or $y = x$ drawn
3(b)	Rotation 90°[anticlockwise] oe (1, –1)	**3**	**B1** for each
3(c)(i)	$\begin{pmatrix}-2 & 0\\0 & -2\end{pmatrix}$	**2**	**B1** for 2 by 2 matrix with one correct row or column
3(c)(ii)	Strict **FT** *their* **(c)(i)**	**1**	Answer not equal to zero **FT** *their* **(c)(i)** only if 2 by 2

3(a)(i)	(3, 5.5)	**2**	**B1** for either value correct
3(a)(ii)	$\frac{5}{4}x + \frac{7}{4}$ final answer	**3**	**B2** for answer $\frac{5}{4}x + c$ oe or for correct equation in different form or **M1** for $\frac{8-3}{5-1}$ oe **and M1** for correct substitution shown of (1, 3) or (5, 8) or *their* (a)(i) into $y =$ (*their m*)$x + c$ oe
3(b)(i)	(6, 1) (10, 6)	**2**	**B1** for 2 or 3 values correct
3(b)(ii)	(–3, 1) (–8, 5)	**2**	**B1** for 2 or 3 values correct If 0 scored, **SC1** for (3, –1) and (8, –5)
3(b)(iii)	(3, 3) (–1, 8)	**2**	**B1** for 2 or 3 values correct but not for (1, 3) and (5, 8)

3(b)(iv)	(5, –3) (11, –8)	**2**	**B1** for either or **M1** for $\begin{pmatrix}-1 & 2\\0 & -1\end{pmatrix}\begin{pmatrix}1\\3\end{pmatrix}$ or $\begin{pmatrix}-1 & 2\\0 & -1\end{pmatrix}\begin{pmatrix}5\\8\end{pmatrix}$

3(c)	Enlargement –2 Origin oe	**3**	**B1** for each

8(b)(i)	$\begin{pmatrix}0\\5\end{pmatrix}$	**1**	
8(b)(ii)	$\begin{pmatrix}-3\\-1\end{pmatrix}$	**1**	

8(b)(iii)	3.22 or 3.216... to 3.220...	**6**	**B3** for [angle AOB =] 36.8 or 36.9 or 36.84 to 36.87 or **M2** for tan[AOB] = $\frac{3}{4}$ oe or for [AOB =]2 × $\sin^{-1}$ $\left(\frac{\sqrt{(5-4)^2+(0--3)^2}}{10}\right)$ oe or for cos [AOB =] $\frac{5^2+5^2-\left(\sqrt{(5-4)^2+(0--3)^2}\right)^2}{2\times5\times5}$ oe or **M1** for recognition of right-angle with perpendicular from B to OA or x-axis or for [AB^2 =] $(5-4)^2+(0--3)^2$ or better oe or (*their* AB)^2 = $5^2+5^2-2\times5\times5\times\cos OAB$ oe **M2** for $\frac{\textit{their}\text{ angle }AOB}{360}\times2\times\pi\times5$ oe or **M1** for radius = 5 soi

7(a)	Reflection $y = -1$	**2**	**B1** for each
7(b)(i)	Image at (–6, 5) (–6, 7) (–5, 7) (–4, 5)	**2**	**B1** for translation by $\begin{pmatrix}-3\\k\end{pmatrix}$ or $\begin{pmatrix}k\\4\end{pmatrix}$
7(b)(ii)	Image at (1, –1) (3, –1) (3, –3) (2, –3)	**2**	**B1** for shape correct size and orientation but wrong position
7(b)(iii)	Image at (1, 2) (1, 6) (3, 6) (5, 2)	**2**	**B1** for shape correct size and orientation, wrong position

11(a)(i)	8**b** – 4**a** oe	**1**	
11(a)(ii)	6**b**	**1**	
11(a)(iii)	6**b** – 2**a** or 2(3**b** – **a**)	**1**	**FT** –2**a** + *their* (a)(ii)
11(b)	2 : 1 oe final answer	**3**	Dep on correct $\overrightarrow{BC}$ or correct $\overrightarrow{AC}$ seen **B2** for $\overrightarrow{BC}$ = 4**b**–2**a** or **M1** for a correct route for $\overrightarrow{BC}$ in terms of **a** and **b** or for a correct route for $\overrightarrow{AC}$ in terms of **a** and **b** If no/incorrect working seen then **SC1** for final answer of 2 : 1 (oe)

9(a)	7.07 or 7.071...	**2**	**M1** for $(-1)^2 + 7^2$ oe
9(b)	–6	**2**	**M1** for $6 \times m - 5 \times 2m$ [= 24]
9(c)(i)	(10) final answer	**2**	**B1** for answer 10 without brackets
9(c)(ii)	$\begin{pmatrix} 2 \\ 6 \end{pmatrix}$ final answer	**2**	**M1** for $\begin{pmatrix} 2 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ 6 \end{pmatrix}$
9(c)(iii)	$\begin{pmatrix} 19 & 55 \\ 33 & 96 \end{pmatrix}$ final answer	**2**	**M1** for 2 or 3 correct elements
9(c)(iv)	$\frac{1}{3}\begin{pmatrix} 9 & -5 \\ -3 & 2 \end{pmatrix}$ oe isw	**2**	**B1** for $k\begin{pmatrix} 9 & -5 \\ -3 & 2 \end{pmatrix}$ soi or det = 3 soi

4(a)(i)	Translation $\begin{pmatrix} -8 \\ 2 \end{pmatrix}$ oe	**2**	**B1** for each
4(a)(ii)	Enlargement [sf =] $\frac{1}{2}$ oe $(-4, 0)$	**3**	**B1** for each
4(a)(iii)	Rotation 90° clockwise oe $(1, -1)$	**3**	**B1** for each
4(b)	Triangle with (1, –1), (5, –1), (1,7)	**2**	**B1** for correct size and orientation in wrong position or for 3 correct points not joined

11(a)(i)	12.6 or 12.64 to 12.65	**3**	**M2** for $12^2+(-4)^2$ OR **B1** for $\begin{pmatrix}12\\-4\end{pmatrix}$ **M1** for $(their12)^2+(their-4)^2$
11(a)(ii)	$\begin{pmatrix}-11\\13\end{pmatrix}$	**2**	**B1** for $\begin{pmatrix}-11\\k\end{pmatrix}$ or $\begin{pmatrix}k\\13\end{pmatrix}$ or for $[\overrightarrow{BA}=]\begin{pmatrix}-8\\7\end{pmatrix}$
11(b)	$\frac{1}{2}$**(b – a)** oe	**2**	**M1** for correct route or correct unsimplified answer or **B1** for $\overrightarrow{QS}$ = **b** – **a** oe
11(c)(i)	$\begin{pmatrix}9&50\\10&69\end{pmatrix}$	**2**	**B1** for 2 correct elements
11(c)(ii)	$\frac{1}{11}\begin{pmatrix}8&-5\\-1&2\end{pmatrix}$ oe isw	**2**	**B1** for $k\begin{pmatrix}8&-5\\-1&2\end{pmatrix}$ or $\frac{1}{11}\begin{pmatrix}a&b\\c&d\end{pmatrix}$ or det = 11 soi

3(a)(i)	Image at (3, – 3), (7, – 3), (7, – 5)	**2**	**B1** for reflection in any $x=k$ or if 3 correct points not joined
3(a)(ii)	Image at (– 5, 1), (– 1, 1), (– 5, – 1)	**2**	**B1** for translation by $\begin{pmatrix}-2\\k\end{pmatrix}$ or $\begin{pmatrix}k\\4\end{pmatrix}$ or if 3 correct points not joined

3(a)(iii)	Image at (6, 3), (6, 4), (4, 3)	**3**	**B2** for correct size and orientation but wrong position or if 3 correct points not joined **B1** for enlargement SF ½ with centre (3, 1)
3(b)	Rotation 90° [anticlockwise]oe (– 6, – 2)	**3**	**B1** for each
3(c)	Reflection $y=-x$ oe	**2**	**B1** for each

8(a)(i)	× ✓ ✓ × × ✓	**4**	**B3** for 5 correct **B2** for 4 correct **B1** for 3 correct
8(a)(ii)	$\begin{pmatrix}5\\3\end{pmatrix}$	**1**	Fraction line and/or missing brackets scores 0
8(a)(iii)	$\begin{pmatrix}4 & 8\\1 & 2\end{pmatrix}$	**2**	**B1** for 2 or 3 correct elements (dep on 2 × 2 matrix)
8(a)(iv)	$\frac{1}{2}\begin{pmatrix}3 & -1\\-4 & 2\end{pmatrix}$ oe isw	**2**	**B1** for $k\begin{pmatrix}3 & -1\\-4 & 2\end{pmatrix}$ or determinant = 2 soi
8(b)	Rotation Origin oe 90 [anticlockwise] oe	**3**	**B1** for each

2(a)(i)	Translation $\begin{pmatrix}5\\8\end{pmatrix}$	**2**	**B1** for each Accept 5 right and 8 up
2(a)(ii)	Enlargement [sf] 0.5 oe [centre] (0, –7)	**3**	**B1** for each
2(a)(iii)	Rotation 90 [anticlockwise] oe Origin oe	**3**	**B1** for each
2(b)	Image at (–8, 1) (–8, 5) (–8, 7) (–4, 1)	**2**	**B1** for reflection of flag A in the line $x = -1$ or $y = k$ or for vertices of triangle in correct place but not joined

3(a)	Rotation 90[o] clockwise oe Origin oe	**3**	**B1** for each
3(b)(i)	Image at (–4, –1) (–4, –4) (–2, –4)	**1**	
3(b)(ii)	Image at (3, –1) (5, –1) (3, –4)	**2**	**B1** for translation by $\begin{pmatrix}7\\k\end{pmatrix}$ or $\begin{pmatrix}k\\-5\end{pmatrix}$ or for 3 correct points not joined
3(b)(iii)	Image at (–2, ½) (–2, 2) (–1, 2)	**3**	**B2** for 3 correct co-ordinates soi in working or correct size and orientation in wrong position or **M1** for $\begin{pmatrix}0.5 & 0\\0 & 0.5\end{pmatrix}\begin{pmatrix}-4 & -4 & -2\\1 & 4 & 4\end{pmatrix}$ shown or for statement: enlargement, sf 0.5, (0, 0)

11(a)(i)	$\begin{pmatrix}-19\\-2\end{pmatrix}$	**2**	**B1** for answer $\begin{pmatrix}-19\\k\end{pmatrix}$ or $\begin{pmatrix}k\\-2\end{pmatrix}$ or for $\begin{pmatrix}-9\\6\end{pmatrix}$ or $\pm\begin{pmatrix}10\\8\end{pmatrix}$ seen
11(a)(ii)	3.61 or 3.605 to 3.606	**2**	**M1** for $\sqrt{([-]3)^2+2^2}$ oe
11(a)(iii)	$-3m+5n=14$ and $2m+4n=9$	**B1**	Accept equivalents
	$[m=]-\frac{1}{2}$ or -0.5 and $[n=]\,2\frac{1}{2}$ or 2.5 or $\frac{5}{2}$ with evidence of a correct algebraic method	**4**	**M1** for correctly equating one set of coefficients of *their* equations or rearranges one of *their* equations to make m or n the subject e.g. $[m=]\,\frac{1}{2}(9-4n)$ oe **M1** for correct method to eliminate one variable for *their* equations or correctly substitutes *their m* or *their n* into the other equation e.g. $-\frac{3(9-4n)}{2}+5n=14$ oe **B1** for one correct answer
11(b)(i)(a)	$-\mathbf{a}+2\mathbf{c}$	**1**	
11(b)(i)(b)	$\frac{3}{8}(-\mathbf{a}+2\mathbf{c})$ or $-\frac{3}{8}\mathbf{a}+\frac{3}{4}\mathbf{c}$ oe	**1**	**FT** $\frac{3}{8}$ (*their* **(b)(i)(a)**) in simplest form
11(b)(i)(c)	$\frac{1}{2}(5\mathbf{a}-2\mathbf{c})$ or $\frac{5}{2}\mathbf{a}-\mathbf{c}$ oe	**1**	
11(b)(i)(d)	$\frac{1}{8}(5\mathbf{a}-2\mathbf{c})$ or $\frac{5}{8}\mathbf{a}-\frac{1}{4}\mathbf{c}$ oe	**2**	**M1** for a correct unsimplified route
11(b)(ii)	4	**1**	

1(a)(i)	Reflection $y = -1$	**2**	**B1** for each
1(a)(ii)	Triangle at (0, –3), (4, –1), (4, –3)	**2**	**B1** for translation $\begin{pmatrix} -2 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ -5 \end{pmatrix}$ or for three correct vertices
1(a)(iii)	Triangle at (–2, 2), (–2, 6), (–4, 6)	**2**	**B1** for rotation about (0, 0) 90° clockwise or 90° anticlockwise with wrong centre or for three correct vertices
1(a)(iv)	Triangle at (–3, –1), (–3, –2), (–1, –1)	**2**	**B1** for scale factor $-\frac{1}{2}$ with wrong centre or scale factor $\frac{1}{2}$ with centre (0, 0) or for three correct vertices
1(b)(i)	$\begin{pmatrix} 2 \\ 4 \end{pmatrix}$ cao	**1**	
1(b)(ii)	4.47 or 4.472…	**2**	**M1** for $(their\ 2)^2 + (their\ 4)^2$
1(b)(iii)	(7, 10)	**2**	**B1** for each
1(b)(iv)	$y = 2x - 4$ oe	**3**	**M1** for gradient = $\frac{6-2}{5-3}$ oe or answer $y = mx - 4$ **M1** for substituting (3, 2) or (5, 6) into $y = their\ mx + c$ or into $y - k = their\ m(x - h)$ or into $their\ y = mx - 4$
1(b)(v)	(0, –4)	**1**	**FT** *their* **(b)(iv)**

2 (a) (i)	Rotation	**1**	
	90° [anticlockwise] oe	**1**	
	(9, 5)	**1**	
(ii)	Translation	**1**	
	$\begin{pmatrix} -8 \\ -14 \end{pmatrix}$ oe	**1**	
(iii)	Enlargement	**1**	
	[sf] $\frac{1}{3}$	**1**	
	(– 8, – 2)	**1**	
(b) (i)	Image at (1, – 3) (2, – 3) (2, – 5)	**2**	**M1** for triangle correct size and orientation, wrong position or **SC1** for correct reflection in $y = -x$
(ii)	$\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$	**2**	**B1** for 1 correct column or row

3(a)(i)	Image at (5, 1), (7, 1), (7, 4)	**2**	**B1** reflection in $y = 4$ or $x = k$
3(a)(ii)	Image at (–1, 1), (–4, 1), (–1, 3)	**2**	**B1** correct size and correct orientation wrong position or for rotation 90° clockwise around (0, 0)
3(a)(iii)	Image at (2, – 4), (4, – 4), (2, – 1)	**2**	**B1** for translation by $\begin{pmatrix}1\\k\end{pmatrix}$ or $\begin{pmatrix}k\\-5\end{pmatrix}$
3(b)	Enlargement	**1**	
	[sf] – 0.5 oe	**1**	
	(5, 5)	**1**	
3(c)	$\begin{pmatrix}0 & -1\\1 & 0\end{pmatrix}$	**2**	**B1** for one correct column or row
3(d)(i)	(4, 2)	**2**	**M1** for $\begin{pmatrix}1 & 0\\0 & 2\end{pmatrix}\begin{pmatrix}4\\1\end{pmatrix}$ oe
3(d)(ii)	(– 4, 2)	**3**	**M2** for $\begin{pmatrix}-1 & 0\\0 & 2\end{pmatrix}$ or $\begin{pmatrix}1 & 0\\0 & 2\end{pmatrix}\begin{pmatrix}-4\\1\end{pmatrix}$ or **M1** for $\begin{pmatrix}1 & 0\\0 & 2\end{pmatrix}\begin{pmatrix}-1 & 0\\0 & 1\end{pmatrix}\left[\begin{pmatrix}4\\1\end{pmatrix}\right]$ or $\begin{pmatrix}-4\\1\end{pmatrix}$
3(d)(iii)	$\frac{1}{2}\begin{pmatrix}2 & 0\\0 & 1\end{pmatrix}$ oe isw	**3**	**M2** for det = 2 soi or $k\begin{pmatrix}2 & 0\\0 & 1\end{pmatrix}$ soi or **M1** for recognition that **Q** is inverse matrix of **G** or **GQ = I** or **QG = I**

2(a)(i)	Image at (8, 1), (10, 5), (8, 5)	**2**	**B1** for translation $\begin{pmatrix}6\\k\end{pmatrix}$ or $\begin{pmatrix}k\\-5\end{pmatrix}$ or 3 correct points not joined
2(a)(ii)	Image at (4, 10), (4, 8), (8, 8)	**2**	**B1** for rotation 90° anticlockwise but different centre or for rotation 90° clockwise about (4, 10) or 3 correct points not joined
2(a)(iii)	Image at (6, 3), (6, 5), (7, 5)	**2**	**B1** for enlargement factor $\frac{1}{2}$ but incorrect centre or 3 correct points not joined
2(b)	Reflection	**1**	
	$y = -x$ oe	**1**	If zero scored, **M1** for correct use of matrix product

2(c)(i)(a)	$\begin{pmatrix}13\\16\end{pmatrix}$	**2**	**B1** for each in a 2 by 1 matrix or **SC1** for (13 [,] 16)
2(c)(i)(b)	$\begin{pmatrix}2 & 10\\3 & 15\end{pmatrix}$	**2**	**B1** for answer any 2 by 2 matrix
2(c)(i)(c)	$\frac{1}{2}\begin{pmatrix}4 & -3\\-2 & 2\end{pmatrix}$ oe isw	**2**	**B1** for $k\begin{pmatrix}4 & -3\\-2 & 2\end{pmatrix}$ oe soi $(k \neq 0)$ or for determinant = 2 oe soi
2(c)(ii)	**NM** or **MP** or $\mathbf{N}^2$ oe or $\mathbf{P}^2$ oe	**1**	

6(a)(i)	Translation	**1**	
	$\begin{pmatrix}3\\-13\end{pmatrix}$ oe	**1**	
6(a)(ii)	Enlargement	**1**	
	[sf] $-\frac{1}{2}$ oe	**1**	
	(0, –4)	**1**	
6(b)	Image at (0, 0) (0, 6) (–4, 6) (–4, 2)	**2**	**B1** for rotation of 90° anticlockwise about the wrong centre or 90° clockwise about (3, –1) or 4 points correct but not joined.
6(c)	Image at (4, 0) (10, 0) (10, –4) (6, –4)	**2**	**B1** for reflection in $y = k$ or in $x = 1$ or 4 points correct but not joined
6(d)	Enlargement	**1**	
	[sf] 3	**1**	
	Origin oe	**1**	

11(a)(i)	$\begin{pmatrix}1 & -18\\6 & 13\end{pmatrix}$	**2**	**M1** for two or three correct elements
11(a)(ii)	$\frac{1}{11}\begin{pmatrix}4 & 3\\-1 & 2\end{pmatrix}$ or better isw	**2**	**M1** for det = 11 or [k]$\begin{pmatrix}4 & 3\\-1 & 2\end{pmatrix}$ isw
11(b)	Reflection	**1**	
	y-axis oe	**1**	
11(c)	$\begin{pmatrix}0 & 1\\-1 & 0\end{pmatrix}$	**2**	**B1** for one correct column or row

11(d)(i)	$\frac{1}{7}(4\mathbf{a}+3\mathbf{b})$ or $\frac{4}{7}\mathbf{a}+\frac{3}{7}\mathbf{b}$	**3**	**M2** for correct unsimplified answer seen or $\overrightarrow{AP}=\frac{3}{7}(\mathbf{b}-\mathbf{a})$ oe or $\overrightarrow{BP}=\frac{4}{7}(\mathbf{a}-\mathbf{b})$ oe or **M1** for $\overrightarrow{AB}=\mathbf{b}-\mathbf{a}$ or $\overrightarrow{BA}=\mathbf{a}-\mathbf{b}$ or correct route for $\overrightarrow{OP}$
11(d)(ii)	$[m=]\ \frac{7}{3}$ $[k=]\ \frac{4}{3}$	**2**	**B1** for each value or **M1** for $\frac{m}{7}(4\mathbf{a}+3\mathbf{b})=\mathbf{b}+k\mathbf{a}$ oe

4(a)(i)	Correct translation	**2**	**B1** for translation $\begin{pmatrix}6\\k\end{pmatrix}$ or $\begin{pmatrix}k\\-2\end{pmatrix}$
4(a)(ii)	Correct rotation	**2**	**B1** for rotation 180° but other centre
4(a)(iii)	Correct reflection	**2**	**B1** for reflection in $y=-x$
4(b)(i)	Enlargement [factor] $\frac{1}{2}$ or 0.5 [centre] (0, 0) oe	**3**	**B1** for each
4(b)(ii)	$\begin{pmatrix}\frac{1}{2}&0\\0&\frac{1}{2}\end{pmatrix}$ oe	**2**	**B1** for matrix of form $\begin{pmatrix}k&0\\0&k\end{pmatrix}$ oe, $k\neq 0$ or 1
4(c)	± 2.5	**3**	**B2** for $25u^2=156.25$ or $5u=[\pm]12.5$ or **M1** for $(4u)^2+(3u)^2$

5(a)(i)	Image at (0, 1), (0, 2), (–3, 1)	**2**	**B1** for reflection in $y = 0$ or $x = k$
5(a)(ii)	Image at (0, 0), (0, –2), (6, –2)	**2**	**B1** for correct size and correct orientation wrong position or for 2 correct vertices plotted
5(a)(iii)	Image at (–5, 4), (–5, 5), (–2, 4)	**2**	**B1** for translation by $\begin{pmatrix} -5 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ 3 \end{pmatrix}$
5(b)	Rotation 90° clockwise oe (4, –1)	**3**	**B1** for each
5(c)(i)	(4, 1)	**2**	**M1** for $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} 1 \\ -4 \end{pmatrix}$
5(c)(ii)	(8, –1)	**2**	**M1** for $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} 3 & 1 \\ 0 & 2 \end{pmatrix}\begin{pmatrix} 1 \\ -4 \end{pmatrix}$ or $\begin{pmatrix} 0 & -2 \\ 3 & 1 \end{pmatrix}\begin{pmatrix} 1 \\ -4 \end{pmatrix}$ or $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} -1 \\ -8 \end{pmatrix}$
5(c)(iii)	Rotation 90° anti-clockwise oe Origin oe	**3**	**B1** for each

6 (a) (i)	Rotation	**1**	
	90° [anticlockwise] oe	**1**	
	(4 , 4)	**1**	
(ii)	Enlargement	**1**	
	[centre] (5 , 1)	**1**	
	[scale factor] 2	**1**	
(b) (i)	Image at (–2, 5) (–2, 7) (–1, 7)	**2**	**B1** for translation by $\begin{pmatrix} -5 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ 3 \end{pmatrix}$
(ii)	Image at (–2, 1) (–2, –1) (–1, –1)	**2FT**	**FT** *their* triangle P reflected in line $y = 3$ **B1** for reflection of **triangle *P*** in the line $x = 3$ or $y = k$
(c)	Image at (–2, 3) (–4, 3) (–4, 4)	**3**	**B2** for 2 vertices correct in triangle or 3 correct co-ordinates soi in working or **B1** for 1 vertex in triangle correct soi or **M1** for $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} 3 & 3 & 4 \\ 2 & 4 & 4 \end{pmatrix}$ shown or statement rotation 90° [anticlockwise] about (0, 0)

9	**(a) (i)**	$\mathbf{y}$	**1**	
	(ii)	$\mathbf{x} + \mathbf{y}$	**1**	
	(iii)	$\mathbf{x} + 2\mathbf{y}$	**2**	**M1** for a correct unsimplified route or identifying $\overrightarrow{OS}$
	(b)	$-(\frac{1}{2}\mathbf{x} + \mathbf{y})$ oe	**2**	**M1** for a correct unsimplified route or $\overrightarrow{GR} = -\frac{1}{2}\mathbf{x}$ or $\overrightarrow{RG} = \frac{1}{2}\mathbf{x}$
	(c) (i)	$\overrightarrow{MG} = 2\mathbf{x} + 2\mathbf{y}$	**2**	**M1** for a correct unsimplified route e.g. $2\overrightarrow{PQ}$
	(ii)	$\overrightarrow{MH} = \mathbf{x} + \mathbf{y}$ or $\overrightarrow{HG} = \mathbf{x} + \mathbf{y}$	**M1**	Accept $\overrightarrow{HM} = -\mathbf{x} - \mathbf{y}$ or $\overrightarrow{GH} = -\mathbf{x} - \mathbf{y}$
		$\overrightarrow{MG} = 2\overrightarrow{MH}$ oe	**A1**	Dep on **(c)(i)** correct, arrows essential

2	**(a) (i)**	Triangle drawn, vertices (2, – 4), (2, – 5), (4, – 4)	**2**	**SC1** for translation $\begin{pmatrix}5\\k\end{pmatrix}$ or $\begin{pmatrix}k\\-2\end{pmatrix}$ or correct points not joined
	(ii)	Triangle drawn, vertices (– 3, 4), (– 3, 5), (– 1, 4)	**2**	**SC1** for reflection in line $y = k$ or line $x = 1$ or correct points not joined
	(iii)	Enlargement	**1**	
		[factor] 3	**1**	
		[centre] (– 6, – 5)	**1**	
	(b) (i)	$\begin{pmatrix}2 & 5\\3 & 10\end{pmatrix}$	**1**	
	(ii)	$\begin{pmatrix}10 & 14\\18 & 24\end{pmatrix}$ final answer	**2**	**SC1** for one row or one column correct
	(iii)	$\frac{1}{4}$ oe	**3**	**M2** for $1\times4-2\times3=4\times k-3\times1$ or better or **B1** for $1\times4-2\times3$ or $4\times k-3\times1$ seen
	(c) (i)	Rotation	**1**	
		90° [anti-clockwise] oe	**1**	
		(0, 0) oe	**1**	
	(ii)	$\begin{pmatrix}0 & 1\\1 & 0\end{pmatrix}$	**2**	**SC1** for one correct row or column

7	(a) (i)	$\frac{1}{2}\mathbf{p}$	1	
	(ii)	$\frac{1}{2}\mathbf{p} - \frac{1}{3}\mathbf{r}$	1	
	(iii)	$\mathbf{p} + \frac{2}{3}\mathbf{r}$	1	
	(b)	$\mathbf{r} + \frac{3}{2}\mathbf{p}$	2	**M1** for correct unsimplified answer or for correct route or for recognising $\overrightarrow{OU}$ as position vector
	(c)	6 nfww	3	**B2** for $(2k)^2 + ([-]k)^2 = 180$ oe or **M1** for $(2k)^2 + ([-]k)^2$ oe

3	(a) (i)	Image at (3, 1), (5, 1), (5, 4), (4, 4), (4, 2), (3, 2)	2	**SC1** reflection in $y = 1$ or $x = k$ or 6 correct points not joined
	(ii)	Image at (2, 1), (6, 1), (6, – 5), (4, – 5), (4, – 1), (2, – 1)	2	**SC1** for other enlargement of scale factor –2, correct size and correct orientation **or** 6 correct points but not joined
	(iii)	Image at (– 1, – 1), (– 2, – 1), (– 2, – 2), (– 4, – 2), (– 4, – 3), (– 1, – 3)	3	**M2** for 6 correct points shown in working or plotted correctly but not joined or **M1** for $\begin{pmatrix}0 & -1\\1 & 0\end{pmatrix}\begin{pmatrix}-1 & -1 & -2 & -2 & -3 & -3\\1 & 2 & 2 & 4 & 4 & 1\end{pmatrix}$ or for rotation 90° [anticlockwise] centre (0, 0) stated
	(b)	Enlargement [sf] 3 origin oe	3	**B1** for each

6	(a) (i)	Correct image (2, –5) (4, –5) (4, –1)	2	**SC1** for reflection in $y = 0$ or 3 correct points not joined
	(ii)	Correct image (–2, 1) (–6, 1) (–6, –1)	2	**SC1** for rotation 90 clockwise any centre or 3 correct points not joined
	(iii)	Translation by $\begin{pmatrix}1\\9\end{pmatrix}$	2	**B1** for each
	(iv)	Enlargement [SF] – ½ oe [Centre] (2, 1)	1 1 1	
	(b) (i)	$\begin{pmatrix}-1 & 0\\0 & 1\end{pmatrix}$	2	**B1** for one correct row or column but not the identity matrix
	(ii)	Reflection $x = 0$ oe	1 1	

8 (a) (i)	Not possible	**1**	
(ii)	$\begin{pmatrix} 4 & 0 \\ -2 & 10 \\ 6 & -8 \end{pmatrix}$ final answer	**1**	
(iii)	$\begin{pmatrix} 14 & 35 \\ -8 & -20 \end{pmatrix}$ final answer	**2**	**M1** for one correct column or row
(iv)	(–6) final answer	**2**	**M1** for 14 – 20
(v)	$\begin{pmatrix} -2 & 18 \\ -6 & 22 \end{pmatrix}$ final answer	**2**	**M1** for one correct column or row

5 (a) (i)	Image at (–2, – 4), (4, – 4), (4, 0)	**2**	**SC1** for translation $\begin{pmatrix} -4 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ -8 \end{pmatrix}$
(ii)	8.94 or 8.944…	**2**	**M1** for $\sqrt{(-4)^2 + (-8)^2}$ or $\sqrt{4^2 + 8^2}$
(b) (i)	Enlargement [factor] 0.5 oe [centre] (0, 0) oe	**1** **1** **1**	
(ii)	$\begin{pmatrix} 0.5 & 0 \\ 0 & 0.5 \end{pmatrix}$ oe	**2FT**	**FT** their scale factor from **(b)(i)** dep on enlargement and centre (0, 0) **B1FT** for one row or column
(iii)	0.25 or $\frac{1}{4}$	**1FT**	**Strict FT** *their* matrix but not for identity matrix

4	**(a)**	Triangle drawn at (–4, 3), (–1, 3), (–1, 4)	**2**	**SC1** for correct reflection in $x = k$ or $y = 1$
	(b)	Triangle drawn at (1, 7), (1, 6), (4, 6)	**2**	**SC1** for translation by $\begin{pmatrix} -2 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ 3 \end{pmatrix}$
	(c)	Triangle drawn at (2, 3), (2, 1), (8, 1)	**2**	**M1** for two correct vertices or **SC1** for correct enlargement about the wrong centre
	(d)	Rotation 90° clockwise oe (7, 4)	**1** **1** **1**	Accept –90°

9	**(a) (i)**	$\begin{pmatrix} 12 \\ -5 \end{pmatrix}$	**2**	**M1** for $\begin{pmatrix} 12 \\ k \end{pmatrix}$ or $\begin{pmatrix} k \\ -5 \end{pmatrix}$
	(ii)	13 nfww	**2FT**	**M1FT** for $\sqrt{their12^2 + their(-5)^2}$ **FT** dep on *their* **(a)** being $\begin{pmatrix} a \\ b \end{pmatrix}$ where a, b are both non-zero
	(b)(i)(a)	$\mathbf{b} - \mathbf{a}$	**1**	
	(i)(b)	$\frac{3}{5}(\mathbf{b} - \mathbf{a})$ or $\frac{3}{5}\mathbf{b} - \frac{3}{5}\mathbf{a}$ final answer	**1FT**	**FT** $\frac{3}{5}$ *their* vector, in terms of **a** and **b**, in **(b)(i)(a)**
	(i)(c)	$\frac{1}{5}(2\mathbf{a} + 3\mathbf{b})$ or $\frac{2}{5}\mathbf{a} + \frac{3}{5}\mathbf{b}$ final answer	**2**	**M1** for **a** + *their* vector in **(b)(i)(b)** or any correct route
	(ii)	$\frac{3}{2}$ oe	**1**	