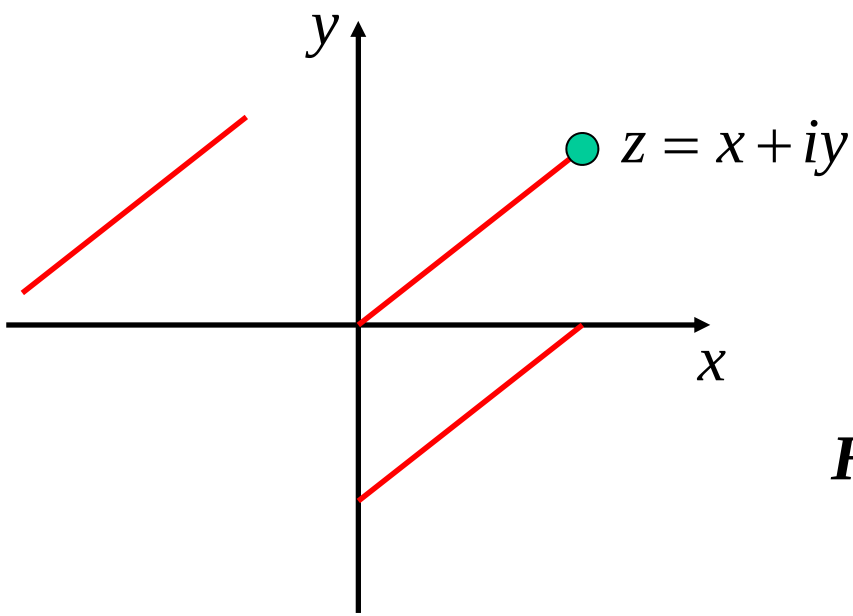
Geometrical Representation of Complex Numbers

Complex numbers can be represented on the Argand Diagram as vectors.

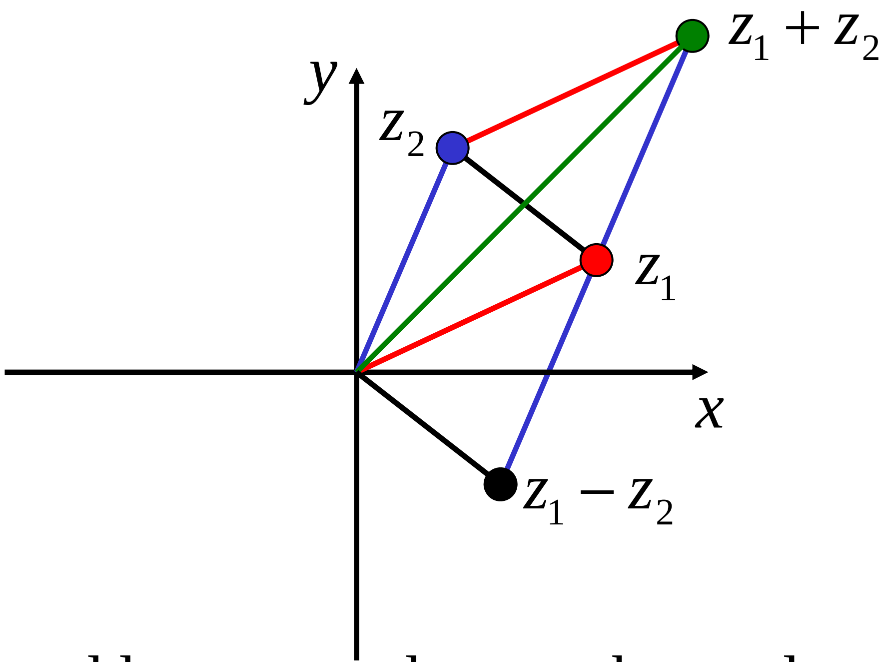


A vector always represents HEAD minus TAIL

The advantage of using vectors is that they can be moved around the Argand Diagram

No matter where the vector is placed its length (modulus) and the angle made with the *x* axis (argument) is constant

Addition / Subtraction



NOTE :

the parallelogram formed by adding vectors has two diagonals;

$z_1 + z_2$ and $z_1 - z_2$

To add two complex numbers, place the vectors ***"head to tail"***

To subtract two complex numbers, place the vectors ***"head to head"*** (or add the negative vector)

Trianglar Inequality

In any triangle a side will be shorter than the sum of the other two sides

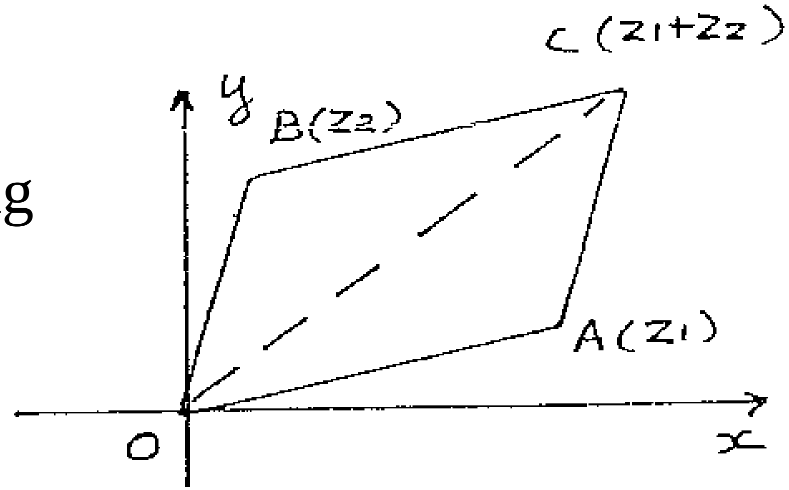
In ΔABC; $AC \leq AB + BC$

(equality occurs when AC is a straight line)

$$|z_1 + z_2| \leq |z_1| + |z_2|$$

Addition

If a point A represents z_1 and point B represents z_2 then point C representing $z_1 + z_2$ is such that the points $OACB$ form a parallelogram.

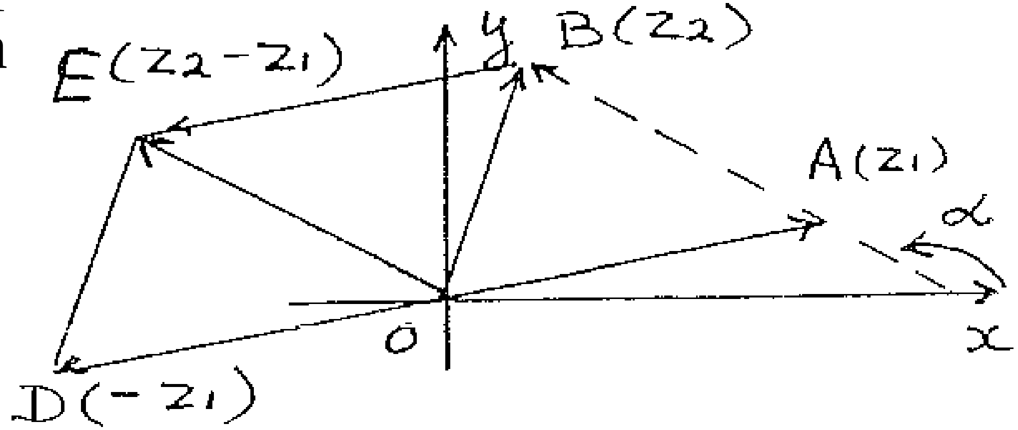


Subtraction

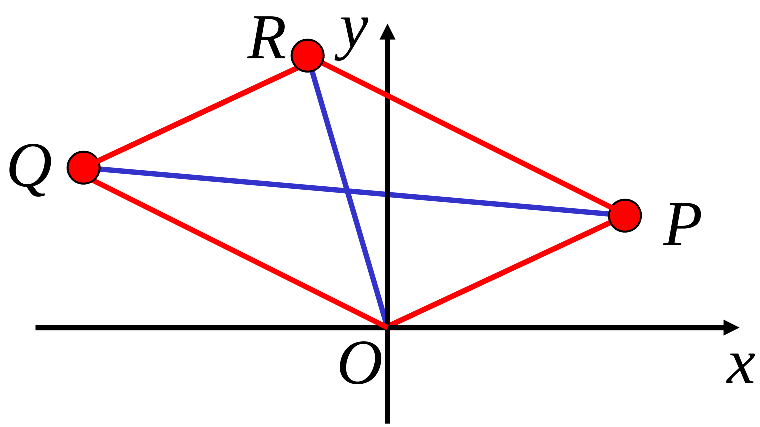
If a point D represents $-z_1$ and point E represents $z_2 - z_1$ then the points $ODEB$ form a parallelogram.

Note: $AB = |z_2 - z_1|$

$$\arg(z_2 - z_1) = \alpha$$



$e.g.(1995)$



The diagram shows a complex plane with origin *O*.
The points *P* and *Q* represent the complex numbers *z* and *w* respectively.
Thus the length of *PQ* is $|z-w|$

(i) Show that $|z-w| \leq |z|+|w|$

The length of OP is $|z|$

The length of OQ is $|w|$

The length of PQ is $|z-w|$

Using the triangular inequality on ΔOPQ

$$|z-w| \leq |z|+|w|$$

(*ii*) Construct the point *R* representing *z* + *w*, What can be said about the quadrilateral *OPRQ*?

$OPRQ$ is a parallelogram

(iii) If $|z-w|=|z+w|$, what can be said about $\frac{w}{z}$?

$$|z-w|=|z+w| \quad \text{i.e. diagonals in } OPRQ \text{ are } =$$

$\therefore OPRQ$ is a rectangle

$$\arg w - \arg z = \frac{\pi}{2}$$

$$\arg\frac{w}{z}=\frac{\pi}{2} \qquad \therefore \frac{w}{z} \text{ is purely imaginary}$$

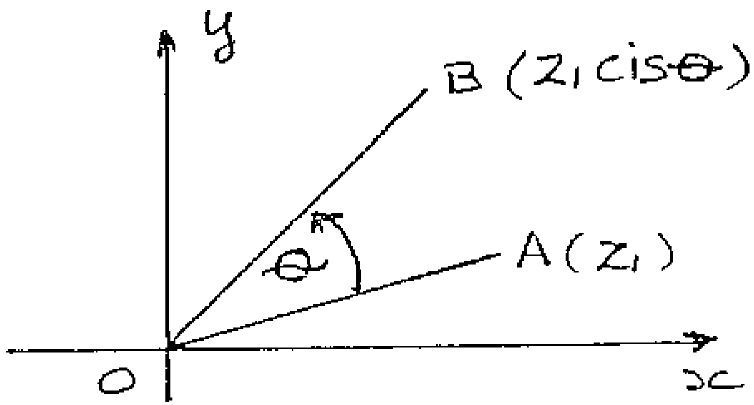
Multiplication

$$|z_1 z_2| = |z_1||z_2| \qquad \arg z_1 z_2 = \arg z_1 + \arg z_2$$

$$r_1 cis\theta_1 \times r_2 cis\theta_2 = r_1 r_2 cis(\theta_1+\theta_2)$$

i.e. if we multiply z_1 by z_2, the vector z_1 is rotated anticlockwise by θ_2 and its length is multiplied by r_2

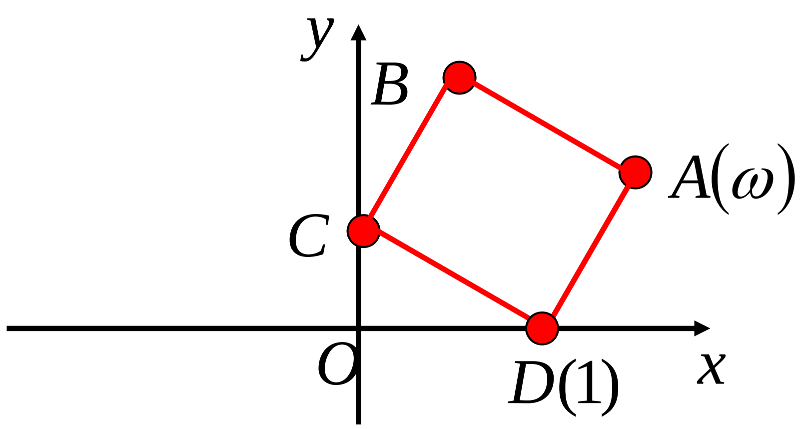
If we multiply z_1 by $cis\theta$ the vector OA will rotate by an angle of θ in an anti-clockwise direction. If we multiply by $rcis\theta$ it will also multiply the length of OA by a factor of r



Note: $\cos\frac{\pi}{2} + i\sin\frac{\pi}{2} = i \quad \therefore iz_1$ will rotate OA anticlockwise 90 degrees.

Multiplication by i is a rotation anticlockwise by $\frac{\pi}{2}$

REMEMBER: A vector is HEAD minus TAIL



$$\overrightarrow{DC} = \overrightarrow{DA} \times i$$
$$C - 1 = (\omega - 1)i$$
$$C = 1 + (\omega - 1)i$$
$$= (1 - i) + i\omega$$

OR

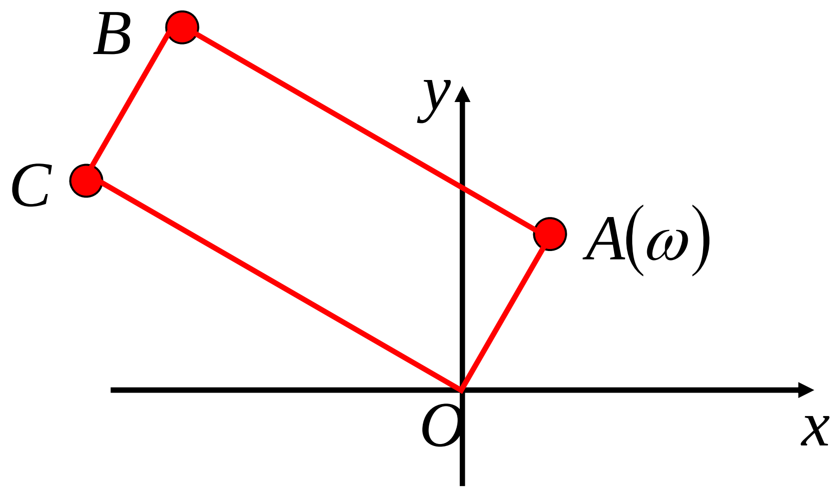
$$B = A + \overrightarrow{DC}$$
$$B = \omega + C - 1$$
$$B = \omega + (\omega - 1)i$$
$$= -i + (1 + i)\omega$$

OR

$$B = C + \overrightarrow{DA}$$
$$B = (1 - i) + i\omega + (\omega - 1)$$
$$= -i + (1 + i)\omega$$

$$\overrightarrow{DB} = \sqrt{2} cis \frac{\pi}{4} \times \overrightarrow{DA}$$
$$B - 1 = \sqrt{2}\left(\cos\frac{\pi}{4} + i\sin\frac{\pi}{4}\right)(\omega - 1)$$
$$B = (1 + i)(\omega - 1) + 1$$
$$= \omega - 1 + i\omega - i + 1$$
$$= -i + (1 + i)\omega$$

$e.g.(2000)$



In the Argand Diagram, $OABC$ is a rectangle, where $OC = 2OA$. The vertex A corresponds to the complex number ω

(i) What complex number corresponds to C?

$$\overrightarrow{OC} = \overrightarrow{OA} \times 2i$$

$$C = 2i\omega$$

(ii) What complex number corresponds to the point of intersection D of the diagonals OB and AC?

diagonals bisect in a rectangle

$\therefore D =$ midpoint of AC

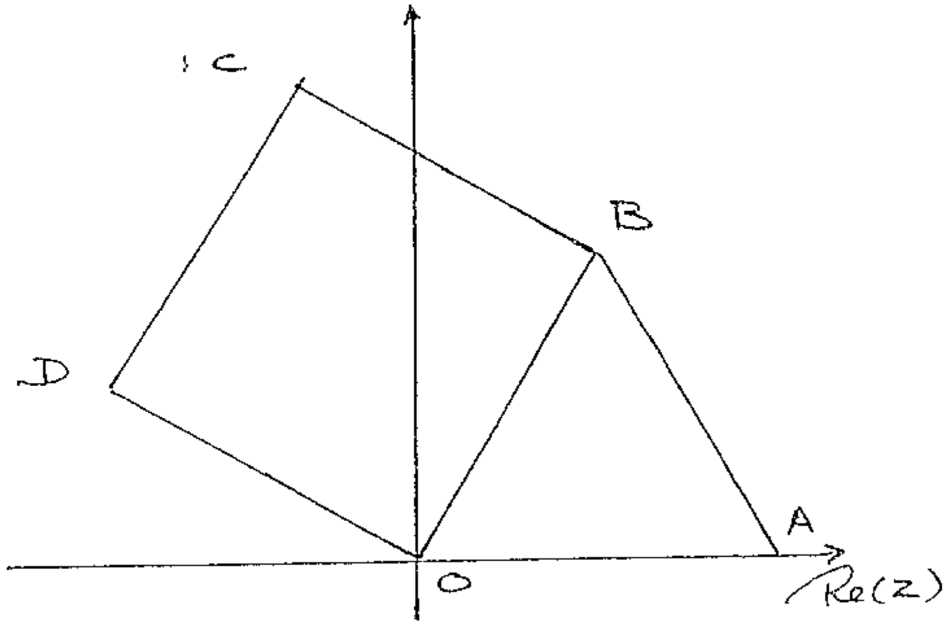
$$D = \frac{A+C}{2}$$

$$D = \frac{\omega + 2i\omega}{2}$$

$$\therefore D = \left(\frac{1}{2} + i\right)\omega$$

Examples

1. OBA is an equilateral triangle with sides of length 1 unit.
$OBCD$ is a square
Find the complex numbers represented by the points B, D and C (in exact terms in the form $x+iy$)



$$\overrightarrow{OB} = \overrightarrow{OA} \times cis\frac{\pi}{3}$$

$$B = 1cis\frac{\pi}{3}$$

$$B = \frac{1}{2} + \frac{\sqrt{3}}{2}i$$

$$\overrightarrow{OD} = \overrightarrow{OB} \times i$$

$$D = iB$$

$$D = -\frac{\sqrt{3}}{2} + \frac{1}{2}i$$

$$C = B + \overrightarrow{OD}$$

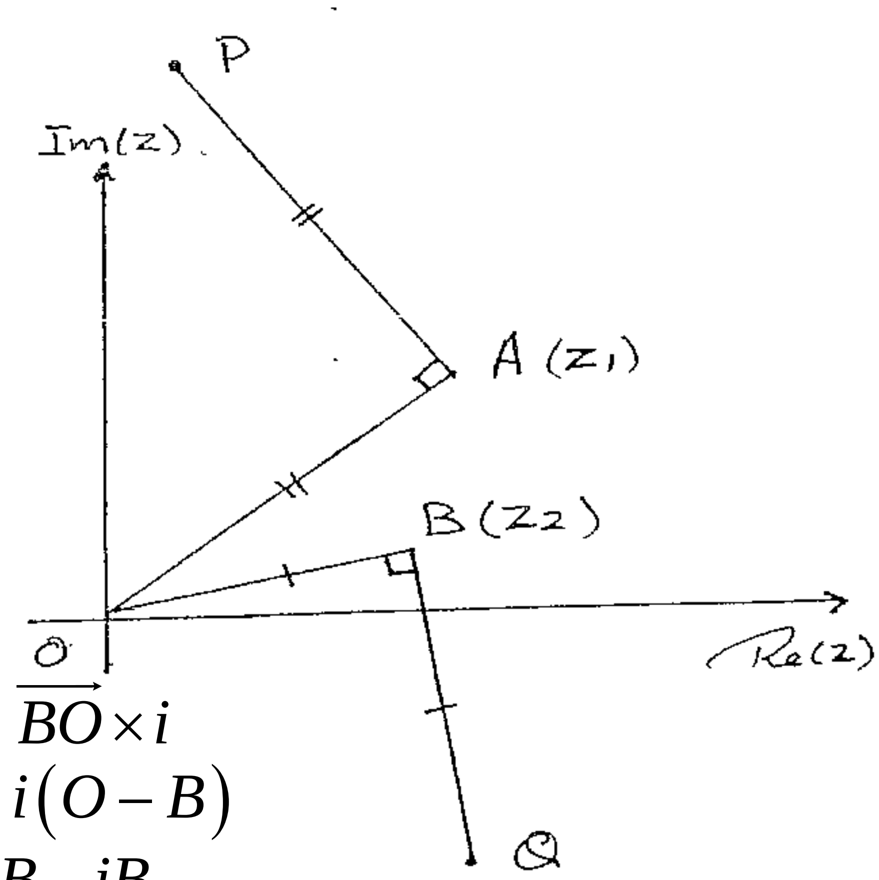
$$C = \left(\frac{1}{2} + \frac{\sqrt{3}}{2}i\right) + \left(-\frac{\sqrt{3}}{2} + \frac{1}{2}i\right)$$

$$C = \left(\frac{1-\sqrt{3}}{2}\right) + \left(\frac{1+\sqrt{3}}{2}\right)i$$

2. The points A and B in the complex plane correspond to complex numbers z_1 and z_2 respectively. Both triangles OAP and OBQ are right-isosceles triangles.

(i) Explain why P corresponds to the complex number $(1+i)z_1$.

(iii) Let M be the midpoint of PQ. What complex number corresponds to M



(i) $\overrightarrow{AP} = \overrightarrow{AO} \times -i$

$$P - A = -i(O - A)$$

$$P - z_1 = -i(0 - z_1)$$

$$P = z_1 + iz_1$$

$$P = (1+i)z_1$$

(ii) $\overrightarrow{QB} = \overrightarrow{BO} \times i$

$$Q - B = i(O - B)$$

$$Q = B - iB$$

$$Q = (1-i)z_2$$

$$M = \frac{P+Q}{2}$$

$$M = \frac{(1+i)z_1 + (1-i)z_2}{2}$$

$$M = \frac{(z_1 + z_2) + (z_1 - z_2)i}{2}$$

***Cambridge* Ex 1E; 2 to 8, 10 to 15, 18, 19, 21, 22**

***Terry Lee*: Exercise 2.6**