Chapter 5: Complex Numbers and Quadratic Equations

Exercise 5.1

Express each of the complex number given in the Exercises 1 to 10 in the form a + ib.

1. (5i) (-3/5i)

Solution:

(5i) (-3/5i) = 5 x (-3/5) x i^2
= -3 x -1 [i^2 = -1]
= 3

Hence,
(5i) (-3/5i) = 3 + i0

2. $i^9 + i^{19}$

Solution:

$i^9 + i^{19} = (i^2)^4 . i + (i^2)^9 . i$
$= (-1)^4 . i + (-1)^9 .i$
= 1 x i + -1 x i
= i – i
= 0

Hence, $i^9 + i^{19}$
= 0 + i0

3. i^{-39}

Solution:

$i^{-39} = 1/ i^{39} = 1/ i^{4 \times 9 + 3} = 1/ (1^9 \times i^3) = 1/ i^3 = 1/ (-i)$ [i^4 = 1, i^3 = -I and i^2 = -1]

Now, multiplying the numerator and denominator by i we get i^{-39} = 1 x i / (-i x i)
= i/ 1 = i

Hence,
i^{-39} = 0 + i

4. 3(7 + *i*7) + *i*(7 + *i*7)

Solution:

3(7 + *i*7) + *i*(7 + *i*7) = 21 + *i*21 + *i*7 + i^2 7
= 21 + *i*28 – 7 [i^2 = -1]
= 14 + *i*28

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Hence,
$3(7 + i7) + i(7 + i7) = 14 + i28$

5. $(1 - i) - (-1 + i6)$
Solution:

$(1 - i) - (-1 + i6) = 1 - i + 1 - i6$
$= 2 - i7$
Hence,
$(1 - i) - (-1 + i6) = 2 - i7$

6. $\left(\frac{1}{5}+i\frac{2}{5}\right)-\left(4+i\frac{5}{2}\right)$

Solution:

$$\left(\frac{1}{5}+i\frac{2}{5}\right)-\left(4+i\frac{5}{2}\right)$$
$$=\frac{1}{5}+\frac{2}{5}i-4-\frac{5}{2}i$$
$$=\left(\frac{1}{5}-4\right)+i\left(\frac{2}{5}-\frac{5}{2}\right)$$
$$=\frac{-19}{5}+i\left(\frac{-21}{10}\right)$$
$$=\frac{-19}{5}-\frac{21}{10}i$$
Hence,
$$\left(\frac{1}{5}+i\frac{2}{5}\right)-\left(4+i\frac{5}{2}\right)=\frac{-19}{5}-\frac{21}{10}i$$

7. $\left[\left(\frac{1}{3}+i\frac{7}{3}\right)+\left(4+i\frac{1}{3}\right)\right]-\left(-\frac{4}{3}+i\right)$
Solution:

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$$\left[\left(\frac{1}{3}+i\frac{7}{3}\right)+\left(4+i\frac{1}{3}\right)\right]-\left(\frac{-4}{3}+i\right)$$
$$=\frac{1}{3}+\frac{7}{3}i+4+\frac{1}{3}i+\frac{4}{3}-i$$
$$=\left(\frac{1}{3}+4+\frac{4}{3}\right)+i\left(\frac{7}{3}+\frac{1}{3}-1\right)$$
$$=\frac{17}{3}+i\frac{5}{3}$$

Hence,

$$\left[\left(\frac{1}{3}+i\frac{7}{3}\right)+\left(4+i\frac{1}{3}\right)\right]-\left(-\frac{4}{3}+i\right)=\frac{17}{3}+i\frac{5}{3}$$

8. $(1 - i)^4$

Solution:

$(1 - i)^4 = [(1 - i)^2]^2$

$= [1 + i^2 - 2i]^2$

$= [1 - 1 - 2i]^2$ $\quad [i^2 = -1]$

$= (-2i)^2$

$= 4(-1)$

$= -4$ Hence, $(1 - i)^4 = -4 + 0i$

9. $(1/3 + 3i)^3$

Solution:

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$$\left(\frac{1}{3}+3i\right)^3=\left(\frac{1}{3}\right)^3+(3i)^3+3\left(\frac{1}{3}\right)(3i)\left(\frac{1}{3}+3i\right)$$
$$=\frac{1}{27}+27i^3+3i\left(\frac{1}{3}+3i\right)$$
$$=\frac{1}{27}+27(-i)+i+9i^2 \qquad \left[i^3=-i\right]$$
$$=\frac{1}{27}-27i+i-9 \qquad \left[i^2=-1\right]$$
$$=\left(\frac{1}{27}-9\right)+i(-27+1)$$
$$=\frac{-242}{27}-26i$$

Hence, $(1/3 + 3i)^3 = -242/27 - 26i$

10. $(-2 - 1/3i)^3$
Solution:

$$\left(-2-\frac{1}{3}i\right)^3=(-1)^3\left(2+\frac{1}{3}i\right)^3$$
$$=-\left[2^3+\left(\frac{i}{3}\right)^3+3(2)\left(\frac{i}{3}\right)\left(2+\frac{i}{3}\right)\right]$$
$$=-\left[8+\frac{i^3}{27}+2i\left(2+\frac{i}{3}\right)\right]$$
$$=-\left[8-\frac{i}{27}+4i+\frac{2i^2}{3}\right] \qquad \left[i^3=-i\right]$$
$$=-\left[8-\frac{i}{27}+4i-\frac{2}{3}\right] \qquad \left[i^2=-1\right]$$
$$=-\left[\frac{22}{3}+\frac{107i}{27}\right]$$
$$=-\frac{22}{3}-\frac{107}{27}i$$

Hence,
$(-2 - 1/3i)^3 = -22/3 - 107/27i$

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Find the multiplicative inverse of each of the complex numbers given in the Exercises 11 to 13. 11. 4 – 3i
Solution:

Let's consider $z = 4 – 3i$
Then,
$\bar{z} = 4 + 3i$ and
$|z|^2 = 4^2 + (-3)^2 = 16 + 9 = 25$
Thus, the multiplicative inverse of $4 – 3i$ is given by z^{-1}

$$z^{-1} = \frac{\bar{z}}{|z|^2} = \frac{4+3i}{25} = \frac{4}{25} + \frac{3}{25}i$$

12. $\sqrt{5} + 3i$ Solution:

Let's consider $z = \sqrt{5} + 3i$

Then, $\bar{z} = \sqrt{5} - 3i$ and
$|z|^2 = (\sqrt{5})^2 + 3^2 = 5 + 9 = 14$
Thus, the multiplicative inverse of $\sqrt{5} + 3i$ is given by z^{-1}

$$z^{-1} = \frac{\bar{z}}{|z|^2} = \frac{\sqrt{5}-3i}{14} = \frac{\sqrt{5}}{14} - \frac{3i}{14}$$

13. – i
Solution:

Let's consider $z = -i$
Then, $\bar{z} = i$ and
$|z|^2 = 1^2 = 1$
Thus, the multiplicative inverse of $-i$ is given by z^{-1}

$$z^{-1} = \frac{\bar{z}}{|z|^2} = \frac{i}{1} = i$$

14. Express the following expression in the form of a + ib:

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$$\frac{\left(3+i\sqrt{5}\right)\left(3-i\sqrt{5}\right)}{\left(\sqrt{3}+\sqrt{2}i\right)-\left(\sqrt{3}-i\sqrt{2}\right)}$$

Solution:

$$\frac{\left(3+i\sqrt{5}\right)\left(3-i\sqrt{5}\right)}{\left(\sqrt{3}+\sqrt{2}i\right)-\left(\sqrt{3}-i\sqrt{2}\right)}$$

$$=\frac{(3)^2-\left(i\sqrt{5}\right)^2}{\sqrt{3}+\sqrt{2}i-\sqrt{3}+\sqrt{2}i} \qquad \left[(a+b)(a-b)=a^2-b^2\right]$$

$$=\frac{9-5i^2}{2\sqrt{2}i}$$

$$=\frac{9-5(-1)}{2\sqrt{2}i} \qquad \left[i^2=-1\right]$$

$$=\frac{9+5}{2\sqrt{2}i}\times\frac{i}{i}$$

$$=\frac{14i}{2\sqrt{2}i^2}$$

$$=\frac{14i}{2\sqrt{2}(-1)}$$

$$=\frac{-7i}{\sqrt{2}}\times\frac{\sqrt{2}}{\sqrt{2}}$$

$$=\frac{-7\sqrt{2}i}{2}$$

Hence,

$$\frac{\left(3+i\sqrt{5}\right)\left(3-i\sqrt{5}\right)}{\left(\sqrt{3}+\sqrt{2}i\right)-\left(\sqrt{3}-i\sqrt{2}\right)} = 0+\frac{-7\sqrt{2}i}{2}$$

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Exercise 5.2 Page No: 108

Find the modulus and the arguments of each of the complex numbers in Exercises 1 to 2.

1. z = – 1 – i √3 Solution:

Given,

$z = -1 - i\sqrt{3}$

Let $r\cos\theta = -1$ and $r\sin\theta = -\sqrt{3}$

On squaring and adding, we get

$(r\cos\theta)^2 + (r\sin\theta)^2 = (-1)^2 + (-\sqrt{3})^2$

$r^2(\cos^2\theta + \sin^2\theta) = 1 + 3$

$r^2 = 4 \qquad [\cos^2\theta + \sin^2\theta = 1]$

$r = \sqrt{4} = 2 \qquad [\text{Conventionally, } r > 0]$

Thus, modulus = 2

So, we have

$2\cos\theta = -1$ and $2\sin\theta = -\sqrt{3}$

$\cos\theta = \frac{-1}{2}$ and $\sin\theta = \frac{-\sqrt{3}}{2}$

As the values of both sin θ and cos θ are negative, θ lies in III Quadrant,

$\text{Argument} = -\left(\pi - \frac{\pi}{3}\right) = \frac{-2\pi}{3}$

Therefore, the modulus and argument of the complex number $-1-\sqrt{3}\,i$ are 2 and $\frac{-2\pi}{3}$ respectively.

2. z = -√3 + i Solution:

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Given,

$z = -\sqrt{3} + i$

Let $r\cos\theta = -\sqrt{3}$ and $r\sin\theta = 1$

On squaring and adding, we get

$$r^2\cos^2\theta + r^2\sin^2\theta = \left(-\sqrt{3}\right)^2 + 1^2$$

$$r^2 = 3 + 1 = 4 \qquad \left[\cos^2\theta + \sin^2\theta = 1\right]$$

$$r = \sqrt{4} = 2 \qquad \left[\text{Conventionally, } r > 0\right]$$

Thus, modulus = 2

So,

$$2\cos\theta = -\sqrt{3} \text{ and } 2\sin\theta = 1$$

$$\cos\theta = \frac{-\sqrt{3}}{2} \text{ and } \sin\theta = \frac{1}{2}$$

$$\therefore \theta = \pi - \frac{\pi}{6} = \frac{5\pi}{6} \qquad \left[\text{As } \theta \text{ lies in the II quadrant}\right]$$

Therefore, the modulus and argument of the complex number $-\sqrt{3} + i$ are 2 and $\frac{5\pi}{6}$ respectively.

Convert each of the complex numbers given in Exercises 3 to 8 in the polar form:

3. 1 – i

Solution:

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Given complex number,

$1 - i$

Let $r\cos\theta = 1$ and $r\sin\theta = -1$

On squaring and adding, we get

$$r^2\cos^2\theta + r^2\sin^2\theta = 1^2 + (-1)^2$$

$$r^2(\cos^2\theta + \sin^2\theta) = 1 + 1$$

$$r^2 = 2$$

$$r = \sqrt{2} = \text{Modulus} \quad [\text{Conventionally, } r > 0]$$

So,

$$\sqrt{2}\cos\theta = 1 \text{ and } \sqrt{2}\sin\theta = -1$$

$$\cos\theta = \frac{1}{\sqrt{2}} \text{ and } \sin\theta = -\frac{1}{\sqrt{2}}$$

$$\therefore \theta = -\frac{\pi}{4} \qquad [\text{As } \theta \text{ lies in the IV quadrant}]$$

So,

$$1 - i = r\cos\theta + i r\sin\theta = \sqrt{2}\cos\left(-\frac{\pi}{4}\right) + i\sqrt{2}\sin\left(-\frac{\pi}{4}\right)$$

$$= \sqrt{2}\left[\cos\left(-\frac{\pi}{4}\right) + i\sin\left(-\frac{\pi}{4}\right)\right]$$

Hence, this is the required polar form.

4. – 1 + i

Solution:

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Given complex number,
$-1+i$
Let $r\cos\theta = -1$ and $r\sin\theta = 1$
On squaring and adding, we get

$$r^2\cos^2\theta + r^2\sin^2\theta = (-1)^2 + 1^2$$
$$r^2(\cos^2\theta + \sin^2\theta) = 1+1$$
$$r^2 = 2$$
$$r = \sqrt{2} \qquad [\text{Conventionally, } r > 0]$$

So,

$$\sqrt{2}\cos\theta = -1 \text{ and } \sqrt{2}\sin\theta = 1$$
$$\cos\theta = -\frac{1}{\sqrt{2}} \text{ and } \sin\theta = \frac{1}{\sqrt{2}}$$
$$\therefore \theta = \pi - \frac{\pi}{4} = \frac{3\pi}{4} \qquad [\text{As } \theta \text{ lies in the II quadrant}]$$

Hence. it can be written as

$$-1+i = r\cos\theta + ir\sin\theta = \sqrt{2}\cos\frac{3\pi}{4} + i\sqrt{2}\sin\frac{3\pi}{4}$$
$$= \sqrt{2}\left(\cos\frac{3\pi}{4} + i\sin\frac{3\pi}{4}\right)$$

This is the required polar form.

5. – 1 – i
Solution:

Given complex number,
$-1-i$
Let $r\cos\theta = -1$ and $r\sin\theta = -1$
On squaring and adding, we get

$$r^2\cos^2\theta + r^2\sin^2\theta = (-1)^2 + (-1)^2$$
$$r^2(\cos^2\theta + \sin^2\theta) = 1+1$$
$$r^2 = 2$$
$$r = \sqrt{2} \qquad [\text{Conventionally, } r > 0]$$

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So,

$\sqrt{2}\cos\theta = -1$ and $\sqrt{2}\sin\theta = -1$

$\Rightarrow \cos\theta = -\frac{1}{\sqrt{2}}$ and $\sin\theta = -\frac{1}{\sqrt{2}}$

$\therefore \theta = -\left(\pi - \frac{\pi}{4}\right) = -\frac{3\pi}{4}$ [As θ lies in the III quadrant]

Hence, it can be written as

$$-1 - i = r\cos\theta + ir\sin\theta = \sqrt{2}\cos\frac{-3\pi}{4} + i\sqrt{2}\sin\frac{-3\pi}{4}$$

$$= \sqrt{2}\left(\cos\frac{-3\pi}{4} + i\sin\frac{-3\pi}{4}\right)$$

This is the required polar form.

6. – 3

Solution:

Given complex number,

–3

Let $r\cos\theta = -3$ and $r\sin\theta = 0$

On squaring and adding, we get

$$r^2\cos^2\theta + r^2\sin^2\theta = (-3)^2$$

$$r^2\left(\cos^2\theta + \sin^2\theta\right) = 9$$

$$r^2 = 9$$

$r = \sqrt{9} = 3$ [Conventionally, $r > 0$]

So,

$3\cos\theta = -3$ and $3\sin\theta = 0$

$\Rightarrow \cos\theta = -1$ and $\sin\theta = 0$

$\therefore \theta = \pi$

Hence, it can be written as

$$-3 = r\cos\theta + ir\sin\theta = 3\cos\pi + i3\sin\pi = 3(\cos\pi + i\sin\pi)$$

This is the required polar form.

7. 3 + *i*

Solution:

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Given complex number,

$\sqrt{3}+i$

Let $r\cos\theta=\sqrt{3}$ and $r\sin\theta=1$

On squaring and adding, we get

$$r^2\cos^2\theta+r^2\sin^2\theta=\left(\sqrt{3}\right)^2+1^2$$

$$r^2\left(\cos^2\theta+\sin^2\theta\right)=3+1$$

$$r^2=4$$

$$r=\sqrt{4}=2 \qquad [\text{Conventionally, } r>0]$$

So,

$$2\cos\theta=\sqrt{3} \text{ and } 2\sin\theta=1$$

$$\Rightarrow \cos\theta=\frac{\sqrt{3}}{2} \text{ and } \sin\theta=\frac{1}{2}$$

$$\therefore \theta=\frac{\pi}{6} \qquad [\text{As } \theta \text{ lies in the I quadrant}]$$

Hence, it can be written as

$$\sqrt{3}+i=r\cos\theta+ir\sin\theta=2\cos\frac{\pi}{6}+i\,2\sin\frac{\pi}{6}$$

$$=2\left(\cos\frac{\pi}{6}+i\sin\frac{\pi}{6}\right)$$

This is the required polar form.

8. ***i***

Solution:

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Given complex number, i

Let $r\cos\theta = 0$ and $r\sin\theta = 1$

On squaring and adding, we get

$$r^2\cos^2\theta + r^2\sin^2\theta = 0^2 + 1^2$$

$$r^2\left(\cos^2\theta + \sin^2\theta\right) = 1$$

$$r^2 = 1$$

$$r = \sqrt{1} = 1 \qquad [\text{Conventionally, } r > 0]$$

So,

$\cos\theta = 0$ and $\sin\theta = 1$

$$\therefore \theta = \frac{\pi}{2}$$

Hence, it can be written as

$$i = r\cos\theta + i\,r\sin\theta = \cos\frac{\pi}{2} + i\sin\frac{\pi}{2}$$

This is the required polar form.

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Exercise 5.3 Page No: 109

Solve each of the following equations:

1. $x^2 + 3 = 0$ Solution:

Given quadratic equation,
$x^2 + 3 = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = 1$, $b = 0$, and $c = 3$
So, the discriminant of the given equation will be
$D = b^2 - 4ac = 0^2 - 4 \times 1 \times 3 = -12$ Hence,
the required solutions are:

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{\pm\sqrt{-12}}{2\times 1} = \frac{\pm\sqrt{12}\,i}{2} \qquad \left[\sqrt{-1} = i\right]$$

$$\therefore\ x = \frac{\pm 2\sqrt{3}\,i}{2} = \pm\sqrt{3}\,i$$

2. $2x^2 + x + 1 = 0$
Solution:

Given quadratic equation,
$2x^2 + x + 1 = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = 2$, $b = 1$, and $c = 1$
So, the discriminant of the given equation will be
$D = b^2 - 4ac = 1^2 - 4 \times 2 \times 1 = 1 - 8 = -7$ Hence,
the required solutions are:

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-1 \pm \sqrt{-7}}{2\times 2} = \frac{-1 \pm \sqrt{7}\,i}{4} \qquad \left[\sqrt{-1} = i\right]$$

3. $x^2 + 3x + 9 = 0$
Solution:

Given quadratic equation, $x^2 + 3x + 9 = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = 1$, $b = 3$, and $c = 9$
So, the discriminant of the given equation will be
$D = b^2 - 4ac = 3^2 - 4 \times 1 \times 9 = 9 - 36 = -27$
Hence, the required solutions are:

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$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-3 \pm \sqrt{-27}}{2(1)} = \frac{-3 \pm 3\sqrt{-3}}{2} = \frac{-3 \pm 3\sqrt{3}\,i}{2} \qquad \left[\sqrt{-1} = i\right]$$

4. $-x^2 + x - 2 = 0$

Solution:

Given quadratic equation,
$-x^2 + x - 2 = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = -1$, $b = 1$, and $c = -2$
So, the discriminant of the given equation will be
$D = b^2 - 4ac = 1^2 - 4 \times (-1) \times (-2) = 1 - 8 = -7$
Hence, the required solutions are:

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-1 \pm \sqrt{-7}}{2 \times (-1)} = \frac{-1 \pm \sqrt{7}\,i}{-2} \qquad \left[\sqrt{-1} = i\right]$$

5. $x^2 + 3x + 5 = 0$

Solution:

Given quadratic equation, $x^2 + 3x + 5 = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = 1$, $b = 3$, and $c = 5$
So, the discriminant of the given equation will be
$D = b^2 - 4ac = 3^2 - 4 \times 1 \times 5 = 9 - 20 = -11$
Hence, the required solutions are:

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-3 \pm \sqrt{-11}}{2 \times 1} = \frac{-3 \pm \sqrt{11}\,i}{2} \qquad \left[\sqrt{-1} = i\right]$$

6. $x^2 - x + 2 = 0$

Solution:

Given quadratic equation, $x^2 - x + 2 = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = 1$, $b = -1$, and $c = 2$
So, the discriminant of the given equation is
$D = b^2 - 4ac = (-1)^2 - 4 \times 1 \times 2 = 1 - 8 = -7$
Hence, the required solutions are

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$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-(-1) \pm \sqrt{-7}}{2 \times 1} = \frac{1 \pm \sqrt{7}i}{2} \qquad \left[\sqrt{-1} = i\right]$$

7. $\sqrt{2}x^2 + x + \sqrt{2} = 0$
Solution:

Given quadratic equation,
$\sqrt{2}x^2 + x + \sqrt{2} = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = \sqrt{2}$, $b = 1$, and $c = \sqrt{2}$
So, the discriminant of the given equation is D $= b^2 – 4ac = (1)^2 – 4 \times \sqrt{2} \times \sqrt{2} = 1 – 8 = –7$
Hence, the required solutions are:

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-1 \pm \sqrt{-7}}{2 \times \sqrt{2}} = \frac{-1 \pm \sqrt{7}i}{2\sqrt{2}} \qquad \left[\sqrt{-1} = i\right]$$

8. $\sqrt{3}x^2 - \sqrt{2}x + 3\sqrt{3} = 0$ Solution:

Given quadratic equation,
$\sqrt{3}x^2 - \sqrt{2}x + 3\sqrt{3} = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = \sqrt{3}$, $b = -\sqrt{2}$, and $c = 3\sqrt{3}$
So, the discriminant of the given equation is D $= b^2 – 4ac = (-\sqrt{2})^2 – 4 \times \sqrt{3} \times 3\sqrt{3} = 2 – 36 = –34$
Hence, the required solutions are:

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-(-\sqrt{2}) \pm \sqrt{-34}}{2 \times \sqrt{3}} = \frac{\sqrt{2} \pm \sqrt{34}i}{2\sqrt{3}} \qquad \left[\sqrt{-1} = i\right]$$

9. $x^2 + x + 1/\sqrt{2} = 0$
Solution:

Given quadratic equation,
$x^2 + x + 1/\sqrt{2} = 0$ It can be rewritten as,
$\sqrt{2}x^2 + \sqrt{2}x + 1 = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = \sqrt{2}$, $b = \sqrt{2}$, and $c = 1$
So, the discriminant of the given equation is D $= b^2 – 4ac = (\sqrt{2})^2 – 4 \times \sqrt{2} \times 1 = 2 – 4\sqrt{2} = 2(1 – 2\sqrt{2})$ Hence, the required solutions are:

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$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-\sqrt{2} \pm \sqrt{2-4\sqrt{2}}}{2 \times \sqrt{2}} = \frac{-\sqrt{2} \pm \sqrt{2\left(1-2\sqrt{2}\right)}}{2\sqrt{2}}$$

$$= \left(\frac{-\sqrt{2} \pm \sqrt{2}\left(\sqrt{2\sqrt{2}-1}\right)i}{2\sqrt{2}}\right) \qquad \left[\sqrt{-1} = i\right]$$

$$= \frac{-1 \pm \left(\sqrt{2\sqrt{2}-1}\right)i}{2}$$

10. $\boldsymbol{x^2 + x/\sqrt{2} + 1 = 0}$

Solution:

Given quadratic equation,
$x^2 + x/\sqrt{2} + 1 = 0$ It can be rewritten as,
$\sqrt{2}x^2 + x + \sqrt{2} = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = \sqrt{2}$, $b = 1$, and $c = \sqrt{2}$
So, the discriminant of the given equation is
$D = b^2 - 4ac = (1)^2 - 4 \times \sqrt{2} \times \sqrt{2} = 1 - 8 = -7$
Hence, the required solutions are:

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-1 \pm \sqrt{-7}}{2\sqrt{2}} = \frac{-1 \pm \sqrt{7}\,i}{2\sqrt{2}} \qquad \left[\sqrt{-1} = i\right]$$

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Miscellaneous Exercise

1. Evaluate: $\left[i^{18}+\left(\frac{1}{i}\right)^{25}\right]^3$

Solution:

$$\left[i^{18}+\left(\frac{1}{i}\right)^{25}\right]^3$$

$$=\left[i^{4\times4+2}+\frac{1}{i^{4\times6+1}}\right]^3$$

$$=\left[\left(i^4\right)^4\cdot i^2+\frac{1}{\left(i^4\right)^6\cdot i}\right]^3$$

$$=\left[i^2+\frac{1}{i}\right]^3 \qquad \left[i^4=1\right]$$

$$=\left[-1+\frac{1}{i}\times\frac{i}{i}\right]^3 \qquad \left[i^2=-1\right]$$

$$=\left[-1+\frac{i}{i^2}\right]^3$$

$$=\left[-1-i\right]^3$$

$$=(-1)^3\left[1+i\right]^3$$

$$=-\left[1^3+i^3+3\cdot1\cdot i(1+i)\right]$$

$$=-\left[1+i^3+3i+3i^2\right]$$

$$=-\left[1-i+3i-3\right]$$

$$=-\left[-2+2i\right]$$

$$=2-2i$$

t

2. For any two complex numbers z_1 and z_2, prove that
Re (z_1z_2) = Re z_1 Re z_2 – Im z_1 Im z_2

Solution:

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Lets's assume $z_1 = x_1 + iy_1$ and $z_2 = x_2 + iy_2$ as two complex numbers

Product of these complex numbers, z_1z_2

$$z_1z_2 = (x_1+iy_1)(x_2+iy_2)$$
$$= x_1(x_2+iy_2)+iy_1(x_2+iy_2)$$
$$= x_1x_2 + ix_1y_2 + iy_1x_2 + i^2y_1y_2$$
$$= x_1x_2 + ix_1y_2 + iy_1x_2 - y_1y_2 \qquad [i^2=-1]$$
$$= (x_1x_2 - y_1y_2) + i(x_1y_2 + y_1x_2)$$

Now,

$$\operatorname{Re}(z_1z_2) = x_1x_2 - y_1y_2$$
$$\Rightarrow \operatorname{Re}(z_1z_2) = \operatorname{Re} z_1 \operatorname{Re} z_2 - \operatorname{Im} z_1 \operatorname{Im} z_2$$

Hence, proved.

3. Reduce $\left(\frac{1}{1-4i}-\frac{2}{1+i}\right)\left(\frac{3-4i}{5+i}\right)$ **to the standard form**

Solution:

$$\left(\frac{1}{1-4i}-\frac{2}{1+i}\right)\left(\frac{3-4i}{5+i}\right) = \left[\frac{(1+i)-2(1-4i)}{(1-4i)(1+i)}\right]\left[\frac{3-4i}{5+i}\right]$$
$$= \left[\frac{1+i-2+8i}{1+i-4i-4i^2}\right]\left[\frac{3-4i}{5+i}\right] = \left[\frac{-1+9i}{5-3i}\right]\left[\frac{3-4i}{5+i}\right]$$
$$= \left[\frac{-3+4i+27i-36i^2}{25+5i-15i-3i^2}\right] = \frac{33+31i}{28-10i} = \frac{33+31i}{2(14-5i)}$$

$$= \frac{(33+31i)}{2(14-5i)} \times \frac{(14+5i)}{(14+5i)} \qquad \left[\text{On multiplying numerator and denominator by } (14+5i)\right]$$

$$= \frac{462+165i+434i+155i^2}{2\left[(14)^2-(5i)^2\right]} = \frac{307+599i}{2(196-25i^2)}$$
$$= \frac{307+599i}{2(221)} = \frac{307+599i}{442} = \frac{307}{442} + \frac{599i}{442}$$

Hence, this is the required standard form.

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4. If $x - iy = \sqrt{\dfrac{a-ib}{c-id}}$ prove that $\left(x^2+y^2\right)^2 = \dfrac{a^2+b^2}{c^2+d^2}$.

Solution:

Chapter 5: Complex Numbers and Quadratic Equations

Given,

$$x - iy = \sqrt{\frac{a-ib}{c-id}}$$

$$= \sqrt{\frac{a-ib}{c-id} \times \frac{c+id}{c+id}} \left[\text{On multiplying numerator and denominator by } (c+id)\right]$$

$$= \sqrt{\frac{(ac+bd)+i(ad-bc)}{c^2+d^2}}$$

So,

$$(x-iy)^2 = \frac{(ac+bd)+i(ad-bc)}{c^2+d^2}$$

$$x^2 - y^2 - 2ixy = \frac{(ac+bd)+i(ad-bc)}{c^2+d^2}$$

On comparing real and imaginary parts, we get

$$x^2 - y^2 = \frac{ac+bd}{c^2+d^2}, \quad -2xy = \frac{ad-bc}{c^2+d^2} \qquad (1)$$

$$(x^2+y^2)^2 = (x^2-y^2)^2 + 4x^2y^2$$

$$= \left(\frac{ac+bd}{c^2+d^2}\right)^2 + \left(\frac{ad-bc}{c^2+d^2}\right)^2 \qquad [\text{Using } (1)]$$

$$= \frac{a^2c^2+b^2d^2+2acbd+a^2d^2+b^2c^2-2adbc}{(c^2+d^2)^2}$$

$$= \frac{a^2c^2+b^2d^2+a^2d^2+b^2c^2}{(c^2+d^2)^2}$$

$$= \frac{a^2(c^2+d^2)+b^2(c^2+d^2)}{(c^2+d^2)^2}$$

$$= \frac{(c^2+d^2)(a^2+b^2)}{(c^2+d^2)^2}$$

$$= \frac{a^2+b^2}{c^2+d^2}$$

- Hence Proved

5. Convert the following in the polar form:

Chapter 5: Complex Numbers and Quadratic Equations

(i) $\frac{1+7i}{(2-i)^2}$, **(ii)** $\frac{1+3i}{1-2i}$

Solution:

(i) Here, $z=\frac{1+7i}{(2-i)^2}$

$=\frac{1+7i}{(2-i)^2}=\frac{1+7i}{4+i^2-4i}=\frac{1+7i}{4-1-4i}$

$=\frac{1+7i}{3-4i}\times\frac{3+4i}{3+4i}=\frac{3+4i+21i+28i^2}{3^2+4^2}$ [Multiplying by its conjugate in the numerator and denominator]

$=\frac{3+4i+21i-28}{3^2+4^2}=\frac{-25+25i}{25}$

$=-1+i$

Let $r\cos\theta=-1$ and $r\sin\theta=1$

On squaring and adding, we get

$r^2(\cos^2\theta+\sin^2\theta)=1+1$

$r^2(\cos^2\theta+\sin^2\theta)=2$

$r^2=2$ $[\cos^2\theta+\sin^2\theta=1]$

$r=\sqrt{2}$ [Conventionally, $r>0$]

So,

$\sqrt{2}\cos\theta=-1$ and $\sqrt{2}\sin\theta=1$

$\Rightarrow \cos\theta=\frac{-1}{\sqrt{2}}$ and $\sin\theta=\frac{1}{\sqrt{2}}$

$\therefore \theta=\pi-\frac{\pi}{4}=\frac{3\pi}{4}$ [As θ lies in II quadrant]

Expressing as, $z=r\cos\theta+ir\sin\theta$

$=\sqrt{2}\cos\frac{3\pi}{4}+i\sqrt{2}\sin\frac{3\pi}{4}=\sqrt{2}\left(\cos\frac{3\pi}{4}+i\sin\frac{3\pi}{4}\right)$

Therefore, this is the required polar form.

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(ii) Let, $z = \frac{1+3i}{1-2i}$

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

$= \frac{1+2i+3i-6}{1+4}$

$= \frac{-5+5i}{5} = -1+i$

Now,

Let $r\cos\theta = -1$ and $r\sin\theta = 1$

On squaring and adding, we get

$r^2(\cos^2\theta + \sin^2\theta) = 1 + 1$

$r^2(\cos^2\theta + \sin^2\theta) = 2$

$r^2 = 2$ $\quad [\cos^2\theta + \sin^2\theta = 1]$

$\Rightarrow r = \sqrt{2}$ $\quad$ [Conventionally, $r > 0$]

$\therefore \sqrt{2}\cos\theta = -1$ and $\sqrt{2}\sin\theta = 1$

$\cos\theta = \frac{-1}{\sqrt{2}}$ and $\sin\theta = \frac{1}{\sqrt{2}}$

$\therefore \theta = \pi - \frac{\pi}{4} = \frac{3\pi}{4}$ $\quad$ [As θ lies in II quadrant]

Expressing as, $z = r\cos\theta + i\,r\sin\theta$

$$z = \sqrt{2}\cos\frac{3\pi}{4} + i\sqrt{2}\sin\frac{3\pi}{4} = \sqrt{2}\left(\cos\frac{3\pi}{4} + i\sin\frac{3\pi}{4}\right)$$

Therefore, this is the required polar form.

Solve each of the equation in Exercises 6 to 9.

6. $3x^2 – 4x + 20/3 = 0$ Solution:

Given quadratic equation, **$3x^2 – 4x + 20/3 = 0$**

It can be re-written as: $9x^2 – 12x + 20 = 0$ On comparing it with $ax^2 + bx + c = 0$, we get $a = 9$, $b = –12$, and $c = 20$

So, the discriminant of the given equation will be

$D = b^2 – 4ac = (–12)^2 – 4 \times 9 \times 20 = 144 – 720 = –576$

Hence, the required solutions are

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$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-(-12) \pm \sqrt{-576}}{2 \times 9} = \frac{12 \pm \sqrt{576}\, i}{18}$$
$$= \frac{12 \pm 24i}{18} = \frac{6(2 \pm 4i)}{18} = \frac{2 \pm 4i}{3} = \frac{2}{3} \pm \frac{4}{3} i$$

7. $x^2 - 2x + 3/2 = 0$ Solution:

Given quadratic equation, $x^2 - 2x + 3/2 = 0$
It can be re-written as $2x^2 - 4x + 3 = 0$ On comparing it with $ax^2 + bx + c = 0$, we get $a = 2$, $b = -4$, and $c = 3$
So, the discriminant of the given equation will be
$D = b^2 - 4ac = (-4)^2 - 4 \times 2 \times 3 = 16 - 24 = -8$
Hence, the required solutions are

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-(-4) \pm \sqrt{-8}}{2 \times 2} = \frac{4 \pm 2\sqrt{2}\, i}{4} \qquad \left[\sqrt{-1} = i\right]$$
$$= \frac{2 \pm \sqrt{2}\, i}{2} = 1 \pm \frac{\sqrt{2}}{2} i$$

8. $27x^2 - 10x + 1 = 0$
Solution:

Given quadratic equation, $27x^2 - 10x + 1 = 0$
On comparing it with $ax^2 + bx + c = 0$, we get $a = 27$, $b = -10$, and $c = 1$
So, the discriminant of the given equation will be $D = b^2 - 4ac = (-10)^2 - 4 \times 27 \times 1 = 100 - 108 = -8$
Hence, the required solutions are

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-(-10) \pm \sqrt{-8}}{2 \times 27} = \frac{10 \pm 2\sqrt{2}\, i}{54}$$
$$= \frac{5 \pm \sqrt{2}\, i}{27} = \frac{5}{27} \pm \frac{\sqrt{2}}{27} i$$

9. $21x^2 - 28x + 10 = 0$
Solution:

Given quadratic equation, $21x^2 - 28x + 10 = 0$
On comparing it with $ax^2 + bx + c = 0$, we have $a = 21$, $b = -28$, and $c = 10$

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So, the discriminant of the given equation will be D = $b^2 - 4ac = (-28)^2 - 4 \times 21 \times 10 = 784 - 840 = -56$
Hence, the required solutions are

$$x = \frac{-b \pm \sqrt{D}}{2a} = \frac{-(-28) \pm \sqrt{-56}}{2 \times 21} = \frac{28 \pm \sqrt{56}\,i}{42}$$
$$= \frac{28 \pm 2\sqrt{14}\,i}{42} = \frac{28}{42} \pm \frac{2\sqrt{14}}{42} i = \frac{2}{3} \pm \frac{\sqrt{14}}{21} i$$

10. If $z_1 = 2 - i$, $z_2 = 1 + i$, find $\left|\frac{z_1 + z_2 + 1}{z_1 - z_2 + 1}\right|$
Solution:

Given, $z_1 = 2 - i$, $z_2 = 1 + i$

So,
$$\left|\frac{z_1 + z_2 + 1}{z_1 - z_2 + 1}\right| = \left|\frac{(2-i)+(1+i)+1}{(2-i)-(1+i)+1}\right|$$
$$= \left|\frac{4}{2-2i}\right| = \left|\frac{4}{2(1-i)}\right|$$
$$= \left|\frac{2}{1-i} \times \frac{1+i}{1+i}\right| = \left|\frac{2(1+i)}{1^2 - i^2}\right|$$
$$= \left|\frac{2(1+i)}{1+1}\right| \qquad [i^2 = -1]$$
$$= \left|\frac{2(1+i)}{2}\right|$$
$$= |1+i| = \sqrt{1^2 + 1^2} = \sqrt{2}$$

Hence, the value of $\left|\frac{z_1 + z_2 + 1}{z_1 - z_2 + 1}\right|$ is $\sqrt{2}$.

11. If $a + ib = \frac{(x+i)^2}{2x^2+1}$, prove that $a^2 + b^2 = \frac{(x^2+1)^2}{(2x^2+1)^2}$.

Solution:

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Given,

$$a + ib = \frac{(x+i)^2}{2x^2+1}$$

$$= \frac{x^2 + i^2 + 2xi}{2x^2+1}$$

$$= \frac{x^2 - 1 + i2x}{2x^2+1}$$

$$= \frac{x^2-1}{2x^2+1} + i\left(\frac{2x}{2x^2+1}\right)$$

Comparing the real and imaginary parts, we have

$$a = \frac{x^2-1}{2x^2+1} \text{ and } b = \frac{2x}{2x^2+1}$$

$$\therefore a^2 + b^2 = \left(\frac{x^2-1}{2x^2+1}\right)^2 + \left(\frac{2x}{2x^2+1}\right)^2$$

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

$$= \frac{x^4 + 1 + 2x^2}{(2x^2+1)^2}$$

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

Hence proved,

$$a^2 + b^2 = \frac{(x^2+1)^2}{(2x^2+1)^2}$$

12. Let $z_1 = 2 - i$, $z_2 = -2 + i$. Find

(i) $\text{Re}\left(\frac{z_1 z_2}{\overline{z}_1}\right)$, **(ii)** $\text{Im}\left(\frac{1}{z_1 \overline{z}_1}\right)$

Solution:

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Given,

$z_1 = 2 - i,\ z_2 = -2 + i$

(i) $z_1 z_2 = (2-i)(-2+i) = -4 + 2i + 2i - i^2 = -4 + 4i - (-1) = -3 + 4i$

$\overline{z}_1 = 2 + i$

$\therefore \dfrac{z_1 z_2}{\overline{z}_1} = \dfrac{-3+4i}{2+i}$

On multiplying numerator and denominator by (2 - *i*), we get

$$\frac{z_1 z_2}{\overline{z}_1} = \frac{(-3+4i)(2-i)}{(2+i)(2-i)} = \frac{-6+3i+8i-4i^2}{2^2+1^2} = \frac{-6+11i-4(-1)}{2^2+1^2}$$

$$= \frac{-2+11i}{5} = \frac{-2}{5} + \frac{11}{5}i$$

Comparing the real parts, we have

$$\mathrm{Re}\left(\frac{z_1 z_2}{\overline{z}_1}\right) = \frac{-2}{5}$$

(ii) $\dfrac{1}{z_1 \overline{z}_1} = \dfrac{1}{(2-i)(2+i)} = \dfrac{1}{(2)^2 + (1)^2} = \dfrac{1}{5}$

On comparing the imaginary part, we get

$$\mathrm{Im}\left(\frac{1}{z_1 \overline{z}_1}\right) = 0$$

13. Find the modulus and argument of the complex $\dfrac{1+2i}{1-3i}$ **number**

Solution:

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Let $z = \frac{1+2i}{1-3i}$, then

$$z = \frac{1+2i}{1-3i} \times \frac{1+3i}{1+3i} = \frac{1+3i+2i+6i^2}{1^2+3^2} = \frac{1+5i+6(-1)}{1+9}$$

$$= \frac{-5+5i}{10} = \frac{-5}{10} + \frac{5i}{10} = \frac{-1}{2} + \frac{1}{2}i$$

Let $z = r\cos\theta + ir\sin\theta$

So,

$$r\cos\theta = \frac{-1}{2} \text{ and } r\sin\theta = \frac{1}{2}$$

On squaring and adding, we get

$$r^2\left(\cos^2\theta + \sin^2\theta\right) = \left(\frac{-1}{2}\right)^2 + \left(\frac{1}{2}\right)^2$$

$$r^2 = \frac{1}{4} + \frac{1}{4} = \frac{1}{2} \qquad [\text{Conventionally, } r > 0]$$

$$r = \frac{1}{\sqrt{2}}$$

Now,

$$\frac{1}{\sqrt{2}}\cos\theta = \frac{-1}{2} \text{ and } \frac{1}{\sqrt{2}}\sin\theta = \frac{1}{2}$$

$$\Rightarrow \cos\theta = \frac{-1}{\sqrt{2}} \text{ and } \sin\theta = \frac{1}{\sqrt{2}}$$

$$\therefore \theta = \pi - \frac{\pi}{4} = \frac{3\pi}{4} \qquad [\text{As } \theta \text{ lies in the II quadrant}]$$

14. Find the real numbers *x* and *y* if (*x* – *iy*) (3 + 5*i*) is the conjugate of – 6 – 24*i*. Solution:

Let's assume z = ($x - iy$) (3 + 5i)

$$z = 3x + 5xi - 3yi - 5yi^2 = 3x + 5xi - 3yi + 5y = (3x+5y) + i(5x-3y)$$

$$\therefore \bar{z} = (3x+5y) - i(5x-3y)$$

Also given, $\bar{z} = -6 - 24i$

And,

(3x + 5y) – i(5x – 3y) = -6 -24i

On equating real and imaginary parts, we have

3x + 5y = -6 …… (i)

5x – 3y = 24 …… (ii)

Performing (i) x 3 + (ii) x 5, we get

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(9x + 15y) + (25x – 15y) = -18 + 120
34x = 102 x =
102/34 = 3
Putting the value of *x* in equation (i), we get
3(3) + 5y = -6 5y
= -6 – 9 = -15 y
= -3
Therefore, the values of *x* and *y* are 3 and –3 respectively.

15. Find the modulus of $\frac{1+i}{1-i}-\frac{1-i}{1+i}$ **Solution:**

$$\frac{1+i}{1-i}-\frac{1-i}{1+i}=\frac{(1+i)^2-(1-i)^2}{(1-i)(1+i)}$$
$$=\frac{1+i^2+2i-1-i^2+2i}{1^2+1^2}$$
$$=\frac{4i}{2}=2i$$
$$\therefore\left|\frac{1+i}{1-i}-\frac{1-i}{1+i}\right|=|2i|=\sqrt{2^2}=2$$

16. If $(x + iy)^3 = u + iv$, then show that $\frac{u}{x}+\frac{v}{y}=4\left(x^2-y^2\right)$ **Solution:**

Given,
$$(x+iy)^3=u+iv$$
$$x^3+(iy)^3+3\cdot x\cdot iy(x+iy)=u+iv$$
$$x^3+i^3y^3+3x^2yi+3xy^2i^2=u+iv$$
$$x^3-iy^3+3x^2yi-3xy^2=u+iv$$
$$\left(x^3-3xy^2\right)+i\left(3x^2y-y^3\right)=u+iv$$

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On equating real and imaginary parts, we get

$u = x^3 - 3xy^2,\ v = 3x^2y - y^3$

$$\frac{u}{x} + \frac{v}{y} = \frac{x^3 - 3xy^2}{x} + \frac{3x^2y - y^3}{y}$$

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

$$= x^2 - 3y^2 + 3x^2 - y^2$$

$$= 4x^2 - 4y^2$$

$$= 4(x^2 - y^2)$$

$$\therefore \frac{u}{x} + \frac{v}{y} = 4(x^2 - y^2)$$

Hence proved.

17. If α and β are different complex numbers with |β| = 1, then find $\left|\frac{\beta-\alpha}{1-\bar{\alpha}\beta}\right|$ **Solution:**

Let α = *a* + *ib* and β = *x* + *iy*

Given, $|\beta| = 1$

So, $\sqrt{x^2 + y^2} = 1$

$\Rightarrow x^2 + y^2 = 1 \qquad \text{... (i)}$

$$\left|\frac{\beta-\alpha}{1-\bar{\alpha}\beta}\right| = \left|\frac{(x+iy)-(a+ib)}{1-(a-ib)(x+iy)}\right|$$

$$= \left|\frac{(x-a)+i(y-b)}{1-(ax+aiy-ibx+by)}\right|$$

$$= \left|\frac{(x-a)+i(y-b)}{(1-ax-by)+i(bx-ay)}\right|$$

$$= \frac{|(x-a)+i(y-b)|}{|(1-ax-by)+i(bx-ay)|} \qquad \left[\left|\frac{z_1}{z_2}\right| = \frac{|z_1|}{|z_2|}\right]$$

$$= \frac{\sqrt{(x-a)^2 + (y-b)^2}}{\sqrt{(1-ax-by)^2 + (bx-ay)^2}}$$

$$= \frac{\sqrt{x^2 + a^2 - 2ax + y^2 + b^2 - 2by}}{\sqrt{1 + a^2x^2 + b^2y^2 - 2ax + 2abxy - 2by + b^2x^2 + a^2y^2 - 2abxy}}$$