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Aufgabe 1:

a) i)

$$z^3 = -8i$$

Wir bringen erstmal die Zahl $-8i = 0 + -8i$ in Eulerdarstellung, der Form $z = re^{i\phi}$.

- $r = \sqrt{x^2 + y^2} = \sqrt{0^2 + (-8)^2} = \sqrt{8^2} = 8$
- $\phi = \arg(z) = \arctan\left(\frac{\operatorname{Im}(z)}{\operatorname{Re}(z)}\right)$

In unserem Fall der Winkel $\phi = -\frac{\pi}{2}$, da $x = 0$ und $y < 0$.

Also gilt:

$$\begin{aligned} -8i &= re^{i\phi} \\ -8i &= 8e^{-\frac{\pi}{2}i} \end{aligned}$$

Das heißt also:

$$\begin{aligned} z^3 &= -8i \\ \Leftrightarrow z^3 &= 8e^{-\frac{\pi}{2}i} \\ \Rightarrow r^3 &= 8 & 3\phi &= -\frac{\pi}{2} + 2k\pi, k \in \mathbb{Z} \\ r &= \sqrt[3]{8} = 2 & \phi &= -\frac{\pi}{6} + \frac{2k\pi}{3}, k \in \mathbb{Z} \end{aligned}$$

Für $k = 0, 1, 2$ bekommen wir unsere 3 verschiedenen Lösungen wie folgendes:

$$\begin{aligned} k = 0 & : y_0 = -\frac{\pi}{6} \text{ und somit } z_0 = 2e^{-\frac{\pi}{6}i} \\ k = 1 & : y_1 = -\frac{\pi}{6} + \frac{2\pi}{3} = \frac{3\pi}{6} = \frac{\pi}{2} \text{ und somit } z_1 = 2e^{\frac{\pi}{2}i} \\ k = 2 & : y_2 = -\frac{\pi}{6} + \frac{2 \times 2\pi}{3} = -\frac{\pi}{6} + \frac{4\pi}{3} = \frac{7\pi}{6} \text{ und somit } z_2 = 2e^{\frac{7\pi}{6}i} \end{aligned}$$

Allgemeine Polardarstellung:

$$z = r(\cos(\phi) + i\sin(\phi))$$

Somit sehen unsere Lösungen wie folgt aus:

$$\begin{aligned} z_0 &= 2(\cos(-\frac{\pi}{6}) + i\sin(-\frac{\pi}{6})) \\ z_1 &= 2(\cos(\frac{\pi}{6}) + i\sin(\frac{\pi}{6})) \\ z_2 &= 2(\cos(\frac{7\pi}{6}) + i\sin(\frac{7\pi}{6})) \\ \text{a)} \quad \quad \text{ii)} \end{aligned}$$

$$\begin{aligned} z^4 + 2(\sqrt{12} - 2i)z^2 + 8 - 4\sqrt{12}i &= 0 \\ z^4 + 2 \times z^2(\sqrt{12} - 2i) + (\sqrt{12} - 2i)^2 &= 0 \end{aligned}$$

Laut der binomischen Formel: $(a+b)^2 = a^2 + 2ab + b^2$ können wir die Gleichung umformen:

$$\begin{aligned} (z^2 + \sqrt{12} - 2i)^2 &= 0 \\ \Leftrightarrow z^2 + \sqrt{12} - 2i &= 0 \\ \Leftrightarrow z^2 &= -\sqrt{12} + 2i \end{aligned}$$

$-\sqrt{12} + 2i$ bringen wir zunächst in Eulerdarstellung.

$$r = \sqrt{x^2 + y^2} = \sqrt{(-12)^2 + 2^2} = \sqrt{12 + 4} = \sqrt{16} = 4$$

$$\phi = \arg(z) = \arctan\left(\frac{\operatorname{Im}(z)}{\operatorname{Re}(z)}\right) + \pi, \text{ da } x < 0.$$

$$\begin{aligned} \text{Also } \arctan\left(\frac{2}{-\sqrt{12}}\right) + \pi &= \arctan\left(\frac{2}{-2\sqrt{3}}\right) + \pi = \arctan\left(-\frac{\sqrt{3}}{3}\right) + \pi = \\ -\frac{\pi}{6} + \pi &= \frac{5\pi}{6} \end{aligned}$$

Also gilt:

$$-\sqrt{12} + 2i = 4e^{i\frac{5\pi}{6}}$$

$$z^2 \text{ in Eulerdarstellung: } z^2 = (re^{i\phi})^2 = r^2e^{i2\phi}$$

Also gilt:

$$\begin{aligned} z^2 &= -\sqrt{12} + 2i \\ \Leftrightarrow r^2e^{i2\phi} &= 4e^{i\frac{5\pi}{6}} \\ \Rightarrow r^2 = 4 \quad \text{und} \quad 2\phi &= \frac{5\pi}{6} + 2k\pi, k \in \mathbb{Z} \\ r &= 2 \quad \quad \phi = \frac{5\pi}{12} + k\pi, k \in \mathbb{Z} \end{aligned}$$

Also für $k = 0, 1$ bekommen wir unsere 2 verschiedenen Lösungen wie folgendes:

$$\begin{aligned} k = 0: \quad \phi_0 &= \frac{5\pi}{12} \text{ und somit } z_0 = 2e^{\frac{5\pi}{12}i} \\ k = 1: \quad \phi_1 &= \frac{5\pi}{12} + \pi = \frac{17\pi}{12} \text{ und somit } z_1 = 2e^{\frac{17\pi}{12}i} \end{aligned}$$

Allgemeine Polardarstellung:

$$z = r(\cos(\phi) + i\sin(\phi))$$

Somit sehen unsere Lösungen wie folgt aus:

$$\begin{aligned} z_0 &= 2(\cos(\frac{5\pi}{12}) + i\sin(\frac{5\pi}{12})) \\ z_1 &= 2(\cos(\frac{17\pi}{12}) + i\sin(\frac{17\pi}{12})) \\ \text{b)} \end{aligned}$$

$$z_1 = \sqrt{2}e^{-\frac{\pi}{4}i}$$

z_1 in allgemeine Polardarstellung:

$$z_1 = re^{i\phi}$$

Also gilt: $re^{i\phi} = \sqrt{2}e^{-\frac{\pi}{4}i}$

$$\Rightarrow r = \sqrt{2} \quad \phi = -\frac{\pi}{4}$$

Also ist z_1 in Polardarstellung:

$$\begin{aligned} z_1 &= r(\cos(\phi) + i\sin(\phi)) \\ z_1 &= \sqrt{2}(\cos(-\frac{\pi}{4}) + i\sin(-\frac{\pi}{4})) \\ z_1 &= \sqrt{2}\left(\frac{\sqrt{2}}{2} - i\frac{\sqrt{2}}{2}\right) \\ z_1 &= 1 - i \end{aligned}$$

Also $z_1 = 1 - i$ in kartesische Darstellung.

c)

Sei $z = e^{\frac{5\pi}{12}i}$ in Eulerdarstellung.

Allgemein gilt: $z = re^{i\phi}$

Also ist $re^{i\phi} = e^{\frac{5\pi}{12}i}$

$\Rightarrow r = 1$ und $\phi = \frac{5\pi}{12} = \frac{\pi}{4} + \frac{\pi}{6}$

Für die Polardarstellung gilt:

$$\begin{aligned} z &= r(\cos(\phi) + i\sin(\phi)) \\ &= 1 \times (\cos(\frac{5\pi}{12}) + i\sin(\frac{5\pi}{12})) \\ z &= (\cos(\frac{\pi}{4} + \frac{\pi}{6}) + i\sin(\frac{\pi}{4} + \frac{\pi}{6})) \end{aligned}$$

Allgemein gilt für die Additionstheoreme:

$$\cos(x+y) = \cos(x)\cos(y) - \sin(x)\sin(y)$$

$$\sin(x+y) = \sin(x)\cos(y) + \cos(x)\sin(y)$$

Mithilfe also der Additionstheorie haben wir:

$$\cos\left(\frac{\pi}{6}\right) = \frac{\sqrt{3}}{2}, \sqrt{3}\sin\left(\frac{\pi}{6}\right) = \frac{\sqrt{3}}{2} \Rightarrow \sin\left(\frac{\pi}{6}\right) = \frac{1}{2}$$

$$z = \cos\left(\frac{\pi}{4}\right) \times \cos\left(\frac{\pi}{6}\right) - \sin\left(\frac{\pi}{4}\right) \times \sin\left(\frac{\pi}{6}\right) + i \left(\sin\left(\frac{\pi}{4}\right) \times \cos\left(\frac{\pi}{6}\right) + \cos\left(\frac{\pi}{4}\right) \times \sin\left(\frac{\pi}{6}\right) \right)$$

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

$$z = \frac{\sqrt{6}}{4} - \frac{\sqrt{2}}{4} + i \left(\frac{\sqrt{6}}{4} + \frac{\sqrt{2}}{4} \right)$$

$$z = \frac{\sqrt{6} - \sqrt{2}}{4} + i \left(\frac{\sqrt{6} + \sqrt{2}}{4} \right) \text{ in kartesische Darstellung}$$