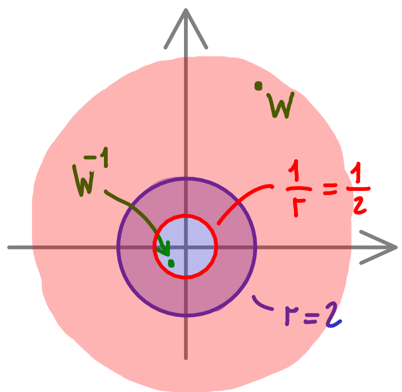
Complex Analysis – Part 15

Laurent series (generalisation of power series + holomorphic)

$\sum_{k=0}^{\infty} a_k \cdot z^k$ with radius of convergence $r \in [0,\infty]$

$$\sum_{k=0}^{\infty} a_k \cdot \left(\frac{1}{w}\right)^k \text{ is convergent } \begin{cases} \left|\frac{1}{w}\right| < r \\ \Longleftrightarrow \\ |w| > \frac{1}{r} \end{cases}$$

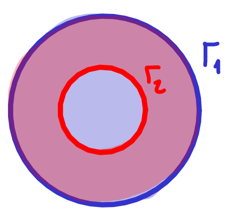


chain rule

$$\Longrightarrow \quad w \mapsto \sum_{k=0}^{\infty} a_k \cdot w^{-k} \text{ is holomorphic on } \mathbb{C} \setminus \overline{B_{\frac{1}{r}}(0)}$$

$$\left(\text{alternatively: } \text{constant} + \sum_{k=-1}^{-\infty} b_k \cdot z^k \right)$$

Combine two series:



$z \mapsto \sum_{k=0}^{\infty} a_k \cdot z^k \rightsquigarrow$ with radius of convergence r_1

$\sum_{k=1}^{\infty} b_{-k} \cdot z^k \rightsquigarrow$ with radius of convergence r

$z \mapsto \sum_{k=-1}^{-\infty} b_k \cdot z^k \rightsquigarrow$ with "radius of convergence" $r_2 = \frac{1}{r}$

Definition: A Laurent series written as $\sum_{k=-\infty}^{\infty} a_k \cdot (z-z_0)^k$ is a pair of two series:

$z \mapsto \sum_{k=0}^{\infty} a_k \cdot (z-z_0)^k$ with radius of convergence $r_1 \in [0,\infty]$

principal part

$\rightsquigarrow z \mapsto \sum_{k=-1}^{-\infty} a_k \cdot (z-z_0)^k$ with "radius of convergence" $r_2 \in [0,\infty]$

a_{-1} is called the residue of the Laurent series.

The Laurent series is a holomorphic function on $\{ z \in \mathbb{C} \mid r_2 < |z-z_0| < r_1 \}$