Complex Analysis

Math 214 Spring 2014 — Fowler 307 MWF 3:00pm - 3:55pm

 — http://faculty.oxy.edu/ron/math/312/14/

Class 22: Friday March 28

TITLE The Many, Many Implications of Cauchy's Integral Formula(s)
CURRENT READING Zill & Shanahan, §5.4-5.5
HOMEWORK Zill & Shanahan, §5.5: 7, 22, 23, 24. Chapter 5: 4,5,6,7,8,9,17. **38,40***

SUMMARY
Cauchy's Integral Formula leads to some of the most famous results in mathematics.

Applications of Cauchy's Integral Formula

Let C be a simple closed (positively oriented) contour. If f is analytic in some simply connected domain D containing C and z_0 is **any point inside** of C, then

$$\oint_C \frac{f(z)}{z-z_0}dz = 2\pi i f(z_0)$$

and

$$\oint_C \frac{f(z)}{(z-z_0)^m}dz = \frac{2\pi i}{(m-1)!}f^{(m-1)}(z_0)$$

These two results lead to a number of other results. Actually, the two formulas are just restatement of one formula, known as the *generalized Cauchy Integral Formula*. Can you see how the first expression (**CIF**) is just a special case ($m =$??) of the second one?

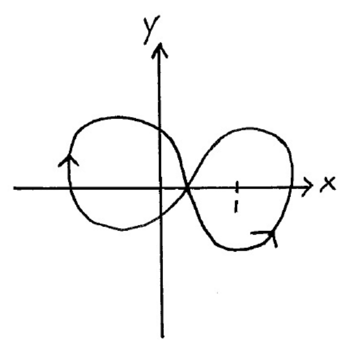
EXAMPLES

We have rewritten the integral formulas in the way above so that we can use them to actually evaluate integrals. Let's to do the following two.

$\oint_C \frac{e^{5z}}{z^3}\,dz =$

(where C is $|z| = 1$ traversed once clockwise)

$\int_C \frac{2z+1}{z(z-1)^2}\,dz =$



(where C is given in the sketch)

There are numerous theorems which directly follow from Cauchy's Integral Formula. I have listed a *few* of the more famous ones below...

Implications of Cauchy's Integral Formula

Morera's Theorem

If $f(z)$ is continuous in a simply-connected region R and if $\oint_C f(z)dz = 0$ around *every* simple closed curve C in R, then $f(z)$ is analytic in R.
(NOTE: Morera's Theorem is the converse of the Cauchy-Goursat theorem.)

Cauchy's Inequality

If $f(z)$ is analytic inside and on a circle of radius r and centered at $z = z_0$ then

$$|f^{(n)}(z_0)| \leq \frac{M \cdot n!}{r^n} \qquad\qquad n = 0, 1, 2, \ldots$$

where M is an upper bound on $|f(z)|$ on C

Liouville's Theorem

Suppose that for all z in the entire complex plane, if $f(z)$ is analytic and bounded, (i.e. $|f(z)| < M$ for some real constant M) then $f(z)$ must be a constant.

Fundamental Theorem of Algebra

Every polynomial equation $P(z) = a_0 + a_1 z + a_2 z^2 + \cdots + a_n z^n = 0$ with degree $n \geq 1$ and $a_n \neq 0$ has atleast one root.

Gauss' mean value theorem

If $f(z)$ is analytic inside and on a circle C with center z_0 and radius r then $f(z_0)$ is the mean of the values of $f(z)$ on C, namely

$$f(z_0) = \frac{1}{2\pi} \int_0^{2\pi} f(z_0 + re^{i\theta}) d\theta$$

Maximum modulus theorem

If $f(z)$ is analytic inside and on a simple closed curve C and is not identically equal to a constant, then the maximum value of $|f(z)|$ occurs on C.

Minimum modulus theorem

If $f(z)$ is analytic inside and on a simple closed curve C and $f(z) \neq 0$ inside C, then the minimum value of $|f(z)|$ occurs on C.

The Argument Theorem

Let $f(z)$ be analytic inside and on a simple closed curve C except for a finite number of poles inside C. Then

$$\frac{1}{2\pi i} \oint \frac{f'(z)}{f(z)} dz = N - P$$

where N and P are the number of zeroes and poles of $f(z)$ inside C

Rouch*é* Theorem

If $f(z)$ and $g(z)$ are analytic inside and on a simple closed curve C and if $|g(z)| < |f(z)|$ on C, then $f(z) + g(z)$ and $f(z)$ have the same number of zeros inside of C.