

Chapter 5. Elliptic modular forms and their L -functions

A modular form of weight k with respect to $SL_2(\mathbb{Z})$ is a holomorphic function on the upper half complex plane

$$\mathcal{H} = \{z \in \mathbb{C} \mid \operatorname{Im}(z) > 0\}$$

satisfying the functional equation

$$f\left(\frac{az+b}{cz+d}\right) = f(z)(cz+d)^k \quad \text{for all } \begin{pmatrix} a & b \\ c & d \end{pmatrix} \in SL_2(\mathbb{Z}).$$

Thus it is invariant under the translation $z \mapsto z+1$ and has Fourier expansion:

$$f(z) = \sum_{n=-\infty}^{\infty} a_n e(nz) \quad \text{for } e(z) = \exp(2\pi\sqrt{-1}z).$$

We always assume that $a_n = 0$ if $n < 0$. A typical example of such a modular form is given by absolutely convergent Eisenstein series

$$E'_k(z) = \sum'_{(m,n)} (mz+n)^{-k} \quad \text{for every even integer } k > 2,$$

where \sum' means that the summation is taken over all ordered pairs of integers (m,n) but $(0,0)$. The Fourier expansion of $E'_k(z)$ is well known (we will verify the expansion later):

$$E_k(z) = \left(\frac{2(2\pi\sqrt{-1})^k}{(k-1)!}\right)^{-1} E'_k(z) = 2^{-1}\zeta(1-k) + \sum_{n=1}^{\infty} \sigma_{k-1}(n)q^n,$$

where $\sigma_m(n) = \sum_{0 < d \mid n} d^m$ is the sum of m -th powers of divisors of n . In this section, we study the complex analytic theory of modular forms. To each holomorphic modular form $f = \sum_{n=0}^{\infty} a_n q^n$, we associate a Dirichlet series

$$L(s, f) = \sum_{n=1}^{\infty} a_n n^{-s},$$

and with each pair of modular forms f and $g = \sum_{n=0}^{\infty} b_n q^n$, we also associate another Dirichlet series

$$D(s, f, g) = \sum_{n=1}^{\infty} \bar{a}_n b_n n^{-s}.$$

Then, we will study algebraicity properties of these modular L -functions later in this chapter and Chapters 6 and 10.

§5.1. Classical Eisenstein series of $GL(2)_{/\mathbb{Q}}$

A subgroup of $SL_2(\mathbb{Z})$ is called a congruence subgroup if it contains all matrices $\alpha = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \pmod{N}$ in $SL_2(\mathbb{Z})$ for an integer $N > 0$. We study here Eisenstein series for congruence subgroups of $SL_2(\mathbb{Z})$. In this book, we are mainly concerned with modular forms with respect to the following type of congruence subgroups: for each positive integer N

$$\Gamma_0(N) = \left\{ \begin{pmatrix} a & b \\ c & d \end{pmatrix} \in SL_2(\mathbb{Z}) \mid c \in N\mathbb{Z} \right\}.$$

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DJ Losen



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