APPENDIX

CONJECTURES AND PROBLEMS

1. *Conjecture.* Let M be a finite, torsion-free, and reflexive h-module with the property that the ranks $L(0,y_0^{n+1}\mathrm{Ext}_h^i(M,h)) = 0$ for $i = 1,\cdots$. Then there exists an exponent l such that the submodule M^l of elements of degrees divisible by l with respect to the ring $h^l = k_0[y_0^l,\cdots,y_n^l]$ is a free h^l-module.

Maybe that without the last assumption an l exists such that

$$L(\lambda,\mathrm{Ext}_{h^l}^i(M^l,h^l)) = \begin{cases} L(\lambda,\mathrm{Ext}_h^i(M,h)) & \text{for } \lambda = -n-1 \\ 0 & \text{otherwise.} \end{cases}$$

2. *Problem.* From the Theorem of Duality follows: For a reflexive and quasifree M there exists a bilinear form $(\varepsilon,\varepsilon^*)$ for

$$\varepsilon \in \mathrm{Ext}_h^i(M,h), \qquad \varepsilon^* \in \mathrm{Ext}_h^{n-i}(M_*,h)$$

with values in k_0 such that

$$(\varepsilon,\mathrm{Ext}_h^{n-i}(M_*,h)) = 0 \Longleftrightarrow \varepsilon = 0$$

and

$$(\mathrm{Ext}^i(M,h),\varepsilon^*) = 0 \Longleftrightarrow \varepsilon^* = 0.$$

Give a natural definition for such a bilinear form.

3. *Problem.* Prove an analogue to the reduction lemma of §7 where $h = k_0[y_0,\cdots,y_n]$ is replaced by $i_0[y_0,\cdots,y_n]$ with an integral domain $i_0 \subset k_0$. The lemma will certainly not hold literally in this case, too.

Similar considerations are useful in connection with the reduction of a projective variety mod a prime divisor of its constant field.

4. *Problem.* Determine the divisors in which the ring $J(L)$ of modular forms of level L is ramified over the ring $J = J(1)$.

5. *Problem.* In the case of Hilbert modular forms there exist forms obeying the transformation law

$$f(M(z)) \prod_{\nu=1}^{n} \left(\gamma^{\nu} z^{\nu} + \delta^{\nu}\right)^{-h_{\nu}} = f(z)$$

with different exponents h_{ν}. They define in an obvious way reflexive J-ideals and therefore divisors. Use these divisors to obtain knowledge on the structure of J and the field of modular functions and determine Shimizu's rank formula §23, (33). Of course the constants V and $\gamma(w)$ cannot be found explicitly, they will be described as algebraic structure constants of J.

6. *Conjecture.* H. Klingen proved that the image of J under the operator Φ (see §21) is quasireflexive and quasiequal the full ring of modular forms in Z_1. (Zum Darstellungssatz für Siegelsche Modulformen, Math. Ztschr. **102**(1967), 30-42.) This image may be even reflexive. A proof must be based on a method of construction of all modular forms of a certain kind. Because of convergence difficulties Eisenstein and Poincaré series cannot be used for small weights. But "generalized" theta series as applied by Eichler (Zur Begründung der Theorie der automorphen Funktionen in mehreren Variablen, Aequationes Math. **3**(1969), 93-111) may serve the purpose.

Many kinds of automorphic forms are obtained by various specializations of Siegel modular forms. In all these cases the images of J may be reflexive.

7. *Conjecture.* Consider Hilbert modular forms in 2 variables with the general transformation law under problem 9. Form the

indefinite integral

$$F_1(z_1,z_2) = \int_{z_{10}}^{z_1} f(\zeta_1,z_2)\left(\zeta_1-z_1\right)^{h_1-2} d\zeta_1 .$$

It satisfies the functional equations

$$F_1(M_1(z_1),M_2(z_2))\left(\gamma_1 z_1+\delta_1\right)^{h_1-2}\left(\gamma_2 z_2+\delta_2\right)^{-h_2} = F_1(z_1,z_2) + P_M(z_1,z_2),$$

where P_M is a polynomial of degree h_1-2 with respect to the first variable, and

$$P_{MN}(z_1,z_2) = P_M(N_1(z_1),N_2(z_2))\left(\gamma_1 z_1+\delta_1\right)^{h_1-2}\left(\gamma_2 z_2+\delta_2\right)^{-h_2}+P_N(z_1,z_2).$$

Furthermore form the integral

$$P_M(z_1,z_2) = \int_{z_{20}}^{z_2} P_M(z_1,\zeta_2)\left(\zeta_2-z_2\right)^{h_2-2} d\zeta_2.$$

Then

$$P_{M,N}(z_1,z_2) = P_{MN}(z_1,z_2) - P_M(N_1(z_1),N_2(z_2))(\gamma_{N1}z_1+\delta_{N1})^{h_1-2}(\gamma_{N2}z_2+\delta_{N2})^{h_2-2}-P_N(z_1,z_2).$$

is a polynomial in both variables and satisfies the functional equations for $M,N,R \in \Gamma$:

$$P_{M,N}(R_1(z_1),R_2(z_2))\left(\gamma_{R1}z_1+\delta_{R1}\right)^{h_1-2}\left(\gamma_{R2}z_2+\delta_{R2}\right)^{h_2-2} - P_{M,NR} + P_{MN,R} - P_{N,R} = 0,$$

expressing the fact that $P_{M,N}(z)$ is a 2-cocycle in $H^2(\Gamma$, polynomials).

Show that the cohomology groups $H^i(\Gamma$, polynomials) $= 0$ for $i \neq 2$, and that the cohomology classes belonging to a modular $f \neq 0$ are $\neq 0$.

Extend the problem to other automorphic forms, also in $n > 2$ variables.

8. *Problem.* Are the rings of modular forms quasifree modules

with respect to any system of admissible coordinates?

If such a ring J is a quasifree module, is then also every reflexive J-ideal quasifree?

In §16 we made the hypothesis that these rings are even free modules for suitable admissible coordinate rings. The proof that the J are quasifree may be much easier.

9. *A numerical observation.*

For $d = 3$, we have computed the sum of class numbers in (23) for all *admissible* $q < 500$ (Proposition 4) *for which* Γ_q *is the full group of units of a maximal order of the quaternion algebra* Φ_q. These are

$$q = q_1q_2 = 5.7,\ 5.19,\ 5.31,\ 5.67,\ 5.79,\ 7.17,\ 7.29,\ 7.41,\ 7.53,\ 17.19.$$

In all these cases we found surprisingly that

$$\sum h(4(du^2-q)f^{-2}) = 5d(P_0,P_q) = \frac{5}{3}(q_1-1)(q_2-1). \tag{44}$$

It seems reasonable to conjecture this identity in general under the conditions indicated above. Comparing it with the classical class number relation

$$\sum h((u^2-4q)f^{-2}) = 2q_1(q_2+1) \qquad (q_1 > q_2)$$

it would mean that the class numbers appearing in (44) are in average $\frac{10}{\sqrt{3}}\frac{(q_1-1)(q_2-1)}{q_1(q_2+1)}$ times as large as the main average.

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