ALGEBRAIC NUMBER THEORY

LECTURE 4 SUPPLEMENTARY NOTES

Material covered: Sections 2.6 through 2.9 of textbook.

I followed the book pretty closely in this lecture, so only a few comments. Wherever Samuel states a theorem with the assumption that a field has characteristic zero or is finite, we can generalize to the field being perfect.

1. Section 2.6

To compute the determinant of the matrix

$$\begin{pmatrix} X & 0 & \ldots & a_0 \\ -1 & X & \ldots & a_1 \\ \ldots & -1 & X & a_{n-2} \\ \ldots & 0 & -1 & X + a_{n-1} \end{pmatrix}$$

first add X times the bottom row to the second last row, then X times the second last row to the third last, and so on. We get

$$\begin{pmatrix} 0 & 0 & \ldots & X^n + a_{n-1}X + \cdots + a_1 X + a_0 \\ -1 & 0 & \ldots & X^{n-1} + a_{n-1}X^{n-2} + \cdots + a_1 \\ \ldots & -1 & 0 & X^2 + a_{n-1}X + a_{n-2} \\ \ldots & 0 & -1 & X + a_{n-1} \end{pmatrix}$$

Now Laplace expand along the first column, and so on, to get that the determinant is $f(X)$, the minimal polynomial of x, which is the top right entry of the above matrix.

Example. Suppose $A \subset B \subset C$ are rings, such that B is a free module over A and C is a free module over B. Let $x \in C$. Show that

$$\text{charpoly}_{B[X]/A[X]}\text{charpoly}_{C/B}(x) = \text{charpoly}_{C/A}(x)$$

Note that this is using that $B[X]$ is a free $A[X]$ module. In particular, check that this implies that traces and norms of elements are transitive.

2. Appendix: the fundamental theorem of algebra

Let's see a slightly different proof from that in the book (it's from Grillet's Abstract Algebra).

Algebraic Number Theory

Sabine Zange

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