

Abstract Algebra

Chapter 13 - Field Theory

David S. Dummit and Richard M. Foote
Solutions Manual by postorius9902

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13 Field Theory

§13.1 Basic Theory and Field Extensions

Exercise 1. Show that $p(x) = x^3 + 3x + 8$ is irreducible in $\mathbb{Q}[x]$. Let θ be a root of $p(x)$. Find the inverse of $1 + \theta$ in $\mathbb{Q}(\theta)$.

Solution. $p(x) = x^3 + 3x + 8$ is irreducible in $\mathbb{Z}[x]$ by Eisenstein Criterion with $p = 2$. By Gauss Lemma, then it is irreducible in $\mathbb{Q}[x]$. To find $(1 + \theta)^{-1}$, we apply the Euclidean algorithm (long division) to $p(x)$ and $1 + x$. We find

$$x^3 + 3x + 8 = (1 + x)(x^2 - x + 10) - 4.$$

Evaluating at θ , we find $(1 + \theta)(\theta^2 - \theta + 10) = 4$. Therefore

$$(1 + \theta)^{-1} = \frac{\theta^2 - \theta + 10}{4}.$$

Exercise 2. Show that $x^3 - 2x - 2$ is irreducible over $\mathbb{Q}$ and let θ be a root. Compute $(1 + \theta)(1 + \theta + \theta^2)$ and $\frac{1 + \theta}{1 + \theta + \theta^2}$ in $\mathbb{Q}(\theta)$.

Solution. Let $f(x) = x^3 - 2x - 2$. f is irreducible over $\mathbb{Z}$ by Eisenstein Criterion with $p = 2$, hence over $\mathbb{Q}$ by Gauss Lemma. Now, if θ is a root of f , then $\theta^3 = 2\theta + 2$. Hence

$$(1 + \theta)(1 + \theta + \theta^2) = 1 + 2\theta + 2\theta^2 + \theta^3 = 3 + 4\theta + 2\theta^2.$$

For computing $\frac{1 + \theta}{1 + \theta + \theta^2}$, first we compute $(1 + \theta + \theta^2)^{-1}$. Applying the Euclidean algorithm, we obtain

$$x^3 - 2x - 2 = (x^2 + x + 1)(x - 1) - 2x - 3,$$

and

$$x^3 - 2x - 2 = (2x + 1)\left(\frac{x^2}{2} - \frac{x}{4} - \frac{3}{8}\right) - \frac{9}{8}.$$

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**Jeffery Alan Cole, Margaret L. Lial, John
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