

## 6 The Smith Canonical Form

### 6.1 Equivalence of Polynomial Matrices

#### DEFINITION 6.1

A matrix  $P \in M_{n \times n}(F[x])$  is called a **unit** in  $M_{n \times n}(F[x])$  if  $\exists Q \in M_{n \times n}(F[x])$  such that

$$PQ = I_n.$$

Clearly if  $P$  and  $Q$  are units, so is  $PQ$ .

#### THEOREM 6.1

A matrix  $P \in M_{n \times n}(F[x])$  is a unit in  $M_{n \times n}(F[x])$  if and only if  $\det P = c$ , where  $c \in F$  and  $c \neq 0$ .

proof

“only if”. Suppose  $P$  is a unit. Then  $PQ = I_n$  and

$$\det PQ = \det P \det Q = \det I_n = 1.$$

However  $\det P$  and  $\det Q$  belong to  $F[x]$ , so both are in fact non-zero elements of  $F$ .

“if”. Suppose  $P \in M_{n \times n}(F[x])$  satisfies  $\det P = c$ , where  $c \in F$  and  $c \neq 0$ . Then

$$P \operatorname{adj} P = (\det P)I_n = cI_n.$$

Hence  $PQ = I_n$ , where  $Q = c^{-1} \operatorname{adj} P \in M_{n \times n}(F[x])$ . Hence  $P$  is a unit in  $M_{n \times n}(F[x])$ .

#### EXAMPLE 6.1

$$P = \begin{bmatrix} 1+x & -x \\ x & 1-x \end{bmatrix} \in M_{2 \times 2}(F[x]) \text{ is a unit, as } \det P = 1.$$

#### THEOREM 6.2

Elementary row matrices in  $M_{n \times n}(F[x])$  are units:

- (i)  $E_{ij}$ : interchange rows  $i$  and  $j$  of  $I_n$ ;
- (ii)  $E_i(t)$ : multiply row  $i$  of  $I_n$  by  $t \in F$ ,  $t \neq 0$ ;
- (iii)  $E_{ij}(f)$ : add  $f$  times row  $j$  of  $I_n$  to row  $i$ ,  $f \in F[x]$ .

In fact  $\det E_{ij} = -1$ ;  $\det E_i(t) = t$ ;  $\det E_{ij}(f) = 1$ .

Similarly for elementary column matrices in  $M_{n \times n}(F[x])$ :

$$F_{ij}, F_i(t), F_{ij}(f).$$

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## **Table of Contents Smith And Boyles Intermediate Algebra For Col Lege Students**

1. Understanding the eBook Smith And Boyles Intermediate Algebra For Col Lege Students
  - The Rise of Digital Reading Smith And Boyles Intermediate Algebra For Col Lege Students
  - Advantages of eBooks Over Traditional Books
2. Identifying Smith And Boyles Intermediate Algebra For Col Lege Students
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Smith And Boyles Intermediate Algebra For Col Lege Students
  - User-Friendly Interface

4. Exploring eBook Recommendations from Smith And Boyles Intermediate Algebra For Col Lege Students
  - Personalized Recommendations
  - Smith And Boyles Intermediate Algebra For Col Lege Students User Reviews and Ratings
  - Smith And Boyles Intermediate Algebra For Col Lege Students and Bestseller Lists
5. Accessing Smith And Boyles Intermediate Algebra For Col Lege Students Free and Paid eBooks
  - Smith And Boyles Intermediate Algebra For Col Lege Students Public Domain eBooks
  - Smith And Boyles Intermediate Algebra For Col Lege Students eBook Subscription Services
  - Smith And Boyles Intermediate Algebra For Col Lege Students Budget-Friendly Options
6. Navigating Smith And Boyles Intermediate Algebra For Col Lege Students eBook Formats
  - ePub, PDF, MOBI, and More
  - Smith And Boyles Intermediate Algebra For Col Lege Students Compatibility with Devices
  - Smith And Boyles Intermediate Algebra For Col Lege Students Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Smith And Boyles Intermediate Algebra For Col Lege Students
  - Highlighting and Note-Taking Smith And Boyles Intermediate Algebra For Col Lege Students
  - Interactive Elements Smith And Boyles Intermediate Algebra For Col Lege Students
8. Staying Engaged with Smith And Boyles Intermediate Algebra For Col Lege Students
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Smith And Boyles Intermediate Algebra For Col Lege Students
9. Balancing eBooks and Physical Books Smith And Boyles Intermediate Algebra For Col Lege Students
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Smith And Boyles Intermediate Algebra For Col Lege Students
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Smith And Boyles Intermediate Algebra For Col Lege Students
  - Setting Reading Goals Smith And Boyles Intermediate Algebra For Col Lege Students
  - Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Smith And Boyles Intermediate Algebra For Col Lege Students
  - Fact-Checking eBook Content of Smith And Boyles Intermediate Algebra For Col Lege Students
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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