

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

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

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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