

## 5.3 Determinants and Cramer's Rule

### Unique Solution of a $2 \times 2$ System

The  $2 \times 2$  system

$$(1) \quad \begin{aligned} ax + by &= e, \\ cx + dy &= f, \end{aligned}$$

has a unique solution provided  $\Delta = ad - bc$  is nonzero, in which case the solution is given by

$$(2) \quad x = \frac{de - bf}{ad - bc}, \quad y = \frac{af - ce}{ad - bc}.$$

This result, called **Cramer's Rule** for  $2 \times 2$  systems, is usually learned in college algebra as part of determinant theory.

### Determinants of Order 2

College algebra introduces matrix notation and determinant notation:

$$A = \begin{pmatrix} a & b \\ c & d \end{pmatrix}, \quad \det(A) = \begin{vmatrix} a & b \\ c & d \end{vmatrix}.$$

Evaluation of a  $2 \times 2$  determinant is by **Sarrus' Rule**:

$$\begin{vmatrix} a & b \\ c & d \end{vmatrix} = ad - bc.$$

The boldface product  $ad$  is the product of the main diagonal entries and the other product  $bc$  is from the anti-diagonal.

Cramer's  $2 \times 2$  rule in determinant notation is

$$(3) \quad x = \frac{\begin{vmatrix} e & b \\ f & d \end{vmatrix}}{\begin{vmatrix} a & b \\ c & d \end{vmatrix}}, \quad y = \frac{\begin{vmatrix} a & e \\ c & f \end{vmatrix}}{\begin{vmatrix} a & b \\ c & d \end{vmatrix}}.$$

### Unique Solution of an $n \times n$ System

Cramer's rule can be generalized to an  $n \times n$  system of equations  $AX = \vec{b}$  or

$$(4) \quad \begin{aligned} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n &= b_1, \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n &= b_2, \\ \vdots &\vdots \\ a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n &= b_n. \end{aligned}$$

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