

Modern Algebra

CARTESIAN PRODUCT

Let A and B be two sets. Then

$$A \times B = \{(a, b) : a \in A, b \in B\}$$

is called Cartesian product of A and B .

If cardinality of A and B is given by

$$|A| = m, |B| = n$$

Then $|A \times B| = mn$, where A, B are non empty set.

$$(i) A \times B = \{(a, b) : a \in A, b \in B\}$$

$$\text{implies } B \times A = \{(b, a) : b \in B, a \in A\}$$

$$\text{implies } A \times B \neq B \times A$$

$$(ii) A \times B = B \times A \Leftrightarrow A = B$$

$$\text{For, if } A \times B = B \times A$$

$$\text{Let } (a, b) \in A \times B$$

$$\text{implies } (b, a) \in B \times A$$

$$\text{implies } a, b \in A \text{ and } a, b \in B$$

$$\text{implies } A = B$$

RELATIONS

A relation from set A to B is a subset of $A \times B$ and relation from set B to A is subset of $B \times A$, i.e. relation

has a direction $A \xrightarrow{R} B$ or $B \xrightarrow{R} A$

Let $A = \{a, b\}$ and $B = \{1, 2\}$, then

$$A \times B = \{(a, 1) (a, 2) (b, 1) (b, 2)\}$$

here every subset of $A \times B$ is a relation from A to B i.e.,

$$A \xrightarrow{R} B$$

Remark: ϕ is subset of $A \times B$ [or $B \times A$] implies ϕ is relation from A to B [or B to A].

Relation on a set: The relation on set A is subset of $A \times A$. If R is subset of $A \times A$ i.e. $R \subseteq A \times A$ implies, R is relation on A

i.e. if $a, b \in A$ then R_a if $(a, b) \in R$

Example 1: If cardinality $|A \cap B| = r$ then find $|(A \times B) \cap (B \times A)|$

Solution: Let $A \cap B = D$
then $D \times D \subseteq A \times B$ and $D \times D \subseteq B \times A$
implies $|D \times D| = r \times r = r^2$

Example 2: Let $A = \{a, b, c\}$ and $B = \{a, b, d\}$ then find $|(A \times B) \cap (B \times A)|$.

Solution: we have

$$A \times B = (a, a) (a, b) (a, d) (b, a) (b, b) (b, d) (c, a) (c, b) (c, d)$$

$$\text{and } B \times A = (a, a) (a, b) (a, c) (b, a) (b, b) (b, c) (d, a) (d, b) (d, c)$$

$$\text{Let } A \cap B = |D| = 2 \text{ and } |D \times D| = 2 \times 2 = 4 \text{ implies } |(A \times B) \cap (B \times A)| = 4.$$

and $B \times A = \{(1, a) (1, b) (2, a) (2, b)\}$
here every subset of $B \times A$ is a relation from B to A i.e.

$$B \xrightarrow{R} A.$$

If $|A| = m$ and $|B| = n$ where $A, B \neq \phi$

then $|A \times B| = mn$

and total number of relation from A to $B = 2^{mn} = 2^{A \times B}$

For example Let $A = \{a, b, c\}$ then

$A \times A = \{a, b, c\} \times \{a, b, c\}$
 $= \{(a, a) (a, b) (a, c) (b, a) (b, b) (b, c) (c, a) (c, b) (c, c)\}$
then every subset of $A \times A$ is relation on set A .

Modern Algebra Two

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Table of Contents Modern Algebra Two

1. Understanding the eBook Modern Algebra Two
 - The Rise of Digital Reading Modern Algebra Two
 - Advantages of eBooks Over Traditional Books
2. Identifying Modern Algebra Two
 - 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 Modern Algebra Two
 - User-Friendly Interface
4. Exploring eBook Recommendations from Modern Algebra Two
 - Personalized Recommendations
 - Modern Algebra Two User Reviews and Ratings
 - Modern Algebra Two and Bestseller Lists
5. Accessing Modern Algebra Two Free and Paid eBooks
 - Modern Algebra Two Public Domain eBooks
 - Modern Algebra Two eBook Subscription Services
 - Modern Algebra Two Budget-Friendly Options
6. Navigating Modern Algebra Two eBook Formats

- ePub, PDF, MOBI, and More
 - Modern Algebra Two Compatibility with Devices
 - Modern Algebra Two Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Modern Algebra Two
 - Highlighting and Note-Taking Modern Algebra Two
 - Interactive Elements Modern Algebra Two
 8. Staying Engaged with Modern Algebra Two
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Modern Algebra Two
 9. Balancing eBooks and Physical Books Modern Algebra Two
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Modern Algebra Two
 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
 11. Cultivating a Reading Routine Modern Algebra Two
 - Setting Reading Goals Modern Algebra Two
 - Carving Out Dedicated Reading Time
 12. Sourcing Reliable Information of Modern Algebra Two
 - Fact-Checking eBook Content of Modern Algebra Two
 - 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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