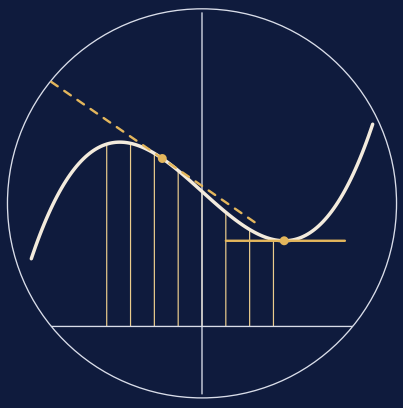
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XII

Mathematics for Class XII · CBSE

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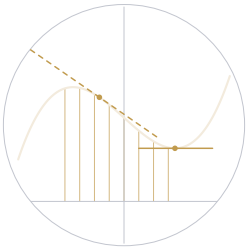
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Preface

Mathactive XII is part of the **Mathemission Book Series**, alongside *Rankers Assignment Plus*. It grew out of the notes, exercises and assignments I have written and used with my Class XII students over several years. It follows the current CBSE syllabus and the NCERT order of chapters, and, being an e-book, it is fully linked: contents, cross-references and question–solution pairs are all one click apart. It is written to be *read*, not only consulted: every chapter builds the ideas first, then lets you test them in steps of increasing difficulty.

How each chapter is organised

Chapter opener. A short introduction and a *Key Terms* checklist. Tick the boxes as the terms become familiar.

Theory. Definitions, theorems (with proofs where they help understanding) and solved examples, each set in its own box and numbered by chapter, for example *Definition 13.2*, *Theorem 13.4*, *Example 13.5*.

Quick Revision. One table of the key results of the chapter. The "See" column gives the section where each result is explained; it is a link, so one click takes you there. A *Common Mistakes* box closes the revision.

Concept Exploration Exercises (CEE). Practice sets numbered by chapter, for example *CEE 13.1*, *CEE 13.2*, each on one part of the chapter. Answers follow each exercise, and *Brief Solutions* follow the answers, so you can check your method as well as your result.

Learning Progress Assignment (LPA). A full-length test on the chapter. See below.

The Learning Progress Assignment as a test

Each LPA follows the pattern of the CBSE board paper, so that every chapter ends with a realistic rehearsal:

Section	Questions	Type (marks each)
A	1–20	Multiple choice and Assertion–Reason (1 mark)
B	21–30	Very short answer (2 marks)
C	31–40	Short answer (3 marks)
D	41–50	Long answer (5 marks)
E	3 case studies	Case-based / source-based / passage-based (4 marks)

Treat it as a test: work section by section within the suggested time, without looking at the answers. Then mark your work against the answer key at the end of each section, and study the full solutions.

Moving between questions and solutions

The worked solutions to every LPA are collected at the end of the e-book, chapter by chapter, so that they do not tempt you while you are attempting the test. The two are linked:

- under each LPA section heading, the link Solutions in back matter → takes you to its solutions;
- beside each solution heading, the link ← Back to questions brings you back to the questions.

The table of contents, the section references in the Quick Revision and the chapter headings are links too.

Topics outside the current syllabus

CBSE has removed some topics from the syllabus in recent years. Where a removed topic is still useful for understanding, or is needed by a few exercises, it is kept and marked with the tag Not in current CBSE syllabus next to its heading. You may skip these sections for the board examination; students preparing for competitive examinations will find them worth reading. Topics that no exercise needs have been left out.

A word on the answers

Every answer in this e-book has been checked, most of them by independent computation. If you still find a mistake, or a solution that could be clearer, please write to me at `mathactiveonly@gmail.com`. Corrections will go into the next update of the e-book.

How to use this e-book

Read the theory with a pencil in hand and work each example yourself before reading its solution. Use the Quick Revision the evening before a test. Do the CEEs as you finish each part of the chapter, and the LPA only when the whole chapter is done. When you get a question wrong, go back to the section it came from, not just to the solution.

Stay Mathactive!

Ashutosh Kumar (AK)
Mathemission | www.mathemission.in
November 2026

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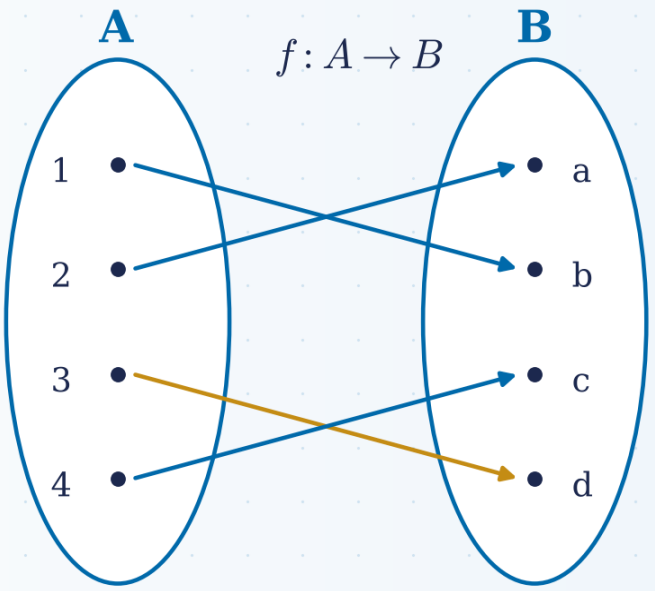
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Chapter 1
Relations and Functions

In Class 11 you met sets, relations and functions. This chapter goes deeper: the different types of relations (leading to equivalence relations and equivalence classes) and the different types of functions (one-one, onto and bijective). These ideas are the foundation for inverse trigonometric functions, calculus and much of algebra.

Key Terms

- ☐ Relation; empty, universal, identity relations
- ☐ Reflexive, symmetric, transitive
- ☐ Equivalence relation and class
- ☐ Function: domain, co-domain, range
- ☐ One-one, onto, bijective
- ☐ Composition and inverse (beyond syllabus)

1.1 Relations

Definition 1.1 Relation

A relation R from a set A to a set B is a subset of $A \times B$ in which an element of A is associated with an element of B by a definite rule:

$$R = \{(a, b) : a \in A,\ b \in B,\ a \text{ is related to } b\} \subseteq A \times B$$

We write $R : A \to B$, and $(a, b) \in R$ is also written $a\,R\,b$. A relation from A to A is called a relation *on* A.

If $n(A) = m$ and $n(B) = n$, then $n(A \times B) = mn$, so there are 2^{mn} relations from A to B.

Types of Relations on a Set

- **Empty relation:** since $\phi \subset A \times A$, ϕ is a relation on A in which no element is related to any element. E.g. on $A = \{1, 3, 5\}$, $R = \{(a, b) : a + b = 15\} = \phi$.
- **Universal relation:** $A \times A$ itself, in which every element is related to every element. E.g. on $A = \{1, 3, 4\}$, $R = \{(a, b) : a - b \text{ is an integer}\} = A \times A$.
- **Identity relation:** $I_A = \{(a, a) : a \in A\}$, each element related to itself only. E.g. on $A = \{1, 2, 3\}$, $I_A = \{(1, 1), (2, 2), (3, 3)\}$.

Definition 1.2 Reflexive, Symmetric, Transitive, Equivalence

A relation R on a set A is

- **reflexive** if $(a, a) \in R$ for every $a \in A$;
- **symmetric** if $(a, b) \in R \implies (b, a) \in R$ for all $a, b \in A$;
- **transitive** if $(a, b) \in R$ and $(b, c) \in R \implies (a, c) \in R$ for all $a, b, c \in A$;
- an **equivalence relation** if it is reflexive, symmetric *and* transitive.

***Note:* How to test a relation**

- To *disprove* a property, one counter-example is enough.
- Transitivity is only tested on pairs $(a, b), (b, c)$ that are *both* in R. If no such chain exists, R is transitive (vacuously).
- The empty relation on a non-empty set is symmetric and transitive but not reflexive.

Example 1.1

Let $A = \{a, b, c\}$ and

$$R_1 = \{(a, a), (b, b), (c, c), (a, b)\}$$
$$R_2 = \{(a, b), (b, a)\}$$
$$R_3 = \{(b, c), (c, a), (b, a)\}$$
$$R_4 = A \times A$$

Classify each relation.

Solution: R_1 is reflexive (contains every (x, x)) and transitive, but not symmetric ($(b, a) \notin R_1$).
R_2 is symmetric; not reflexive ($(a, a) \notin R_2$); not transitive ($(a, b), (b, a) \in R_2$ but $(a, a) \notin R_2$).
R_3 is transitive (the only chain is $(b, c), (c, a)$, and $(b, a) \in R_3$), but neither reflexive nor symmetric.
R_4 is the universal relation: reflexive, symmetric and transitive, hence an equivalence relation.

Example 1.2

Check whether $R = \{(a, b) : a \leq b^2\}$ on $\mathbb{R}$ is reflexive, symmetric or transitive.

Solution: *Not reflexive*: $\left(\frac{1}{2}, \frac{1}{2}\right) \notin R$ since $\frac{1}{2} > \frac{1}{4}$. *Not symmetric*: $(1, 4) \in R$ but $(4, 1) \notin R$. *Not transitive*: $(3, 2), (2, 1.5) \in R$ (as $3 \leq 4$, $2 \leq 2.25$) but $(3, 1.5) \notin R$ $(3 > 2.25)$.

1.2 Equivalence Classes

Definition 1.3 Equivalence Class

Let R be an equivalence relation on A. The equivalence class of $a \in A$ is

$$[a] = \{x \in A : x\, R\, a\}$$

the subset of A containing all the elements related to a.

Two equivalence classes are either identical or disjoint, and together they cover A (they form a *partition* of A).

Example 1.3

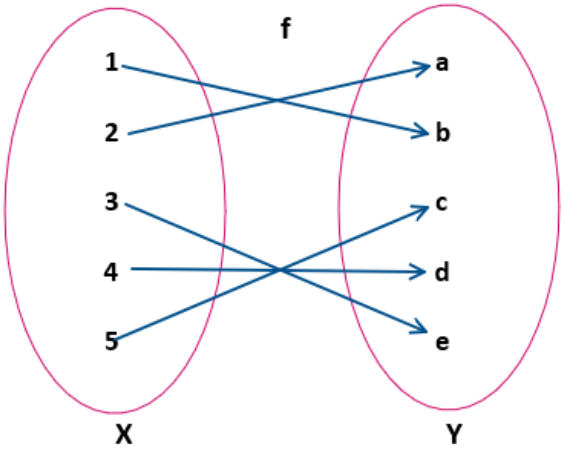
On $A = \{1, 2, 3, 4, 5\}$, $R = \{(x, y) : x - y \text{ is even}\}$. Show that R is an equivalence relation and find $[2]$ and $[3]$.

Solution: $x - x = 0$ is even (reflexive); if $x - y$ is even so is $y - x$ (symmetric); if $x - y$ and $y - z$ are even, so is their sum $x - z$ (transitive).
$[2] = \{2, 4\}$ (elements with the same parity as 2) and $[3] = \{1, 3, 5\}$.

1.3 Functions

Definition 1.4 Function

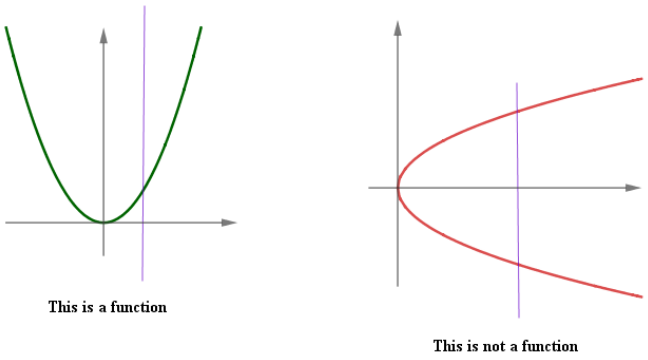
A function (mapping) $f : X \to Y$ is a rule that associates *every* element of X with a *unique* element of Y. The element $y = f(x)$ is the *image* of x.



A function $f : X \to Y$

- X is the **domain** and Y the **co-domain** of f.
- The set of images $f(X) = \{f(x) : x \in X\}$ is the **range** of f; range $\subseteq$ co-domain.
- A **real function** has domain and co-domain that are subsets of $\mathbb{R}$.
- If $n(X) = m$ and $n(Y) = n$, there are n^m functions from X to Y.

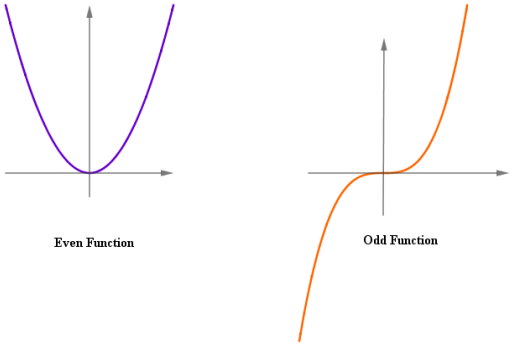
Vertical Line Test: a graph is the graph of a function if and only if no vertical line meets it more than once (a function cannot be *one-to-many*).



Vertical line test

Even and Odd Functions

f is **even** if $f(-x) = f(x)$ (graph symmetric about the y-axis, e.g. $x^2, \cos x$) and **odd** if $f(-x) = -f(x)$ (graph symmetric about the origin, e.g. $x^3, \sin x$).



Even and odd functions

1.4 Types of Functions

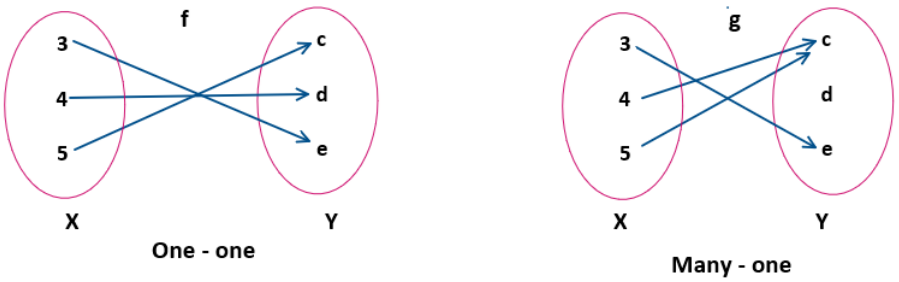
One-one (Injective) Functions

Definition 1.5 One-one Function

$f : X \to Y$ is *one-one* (injective) if distinct elements of X have distinct images:

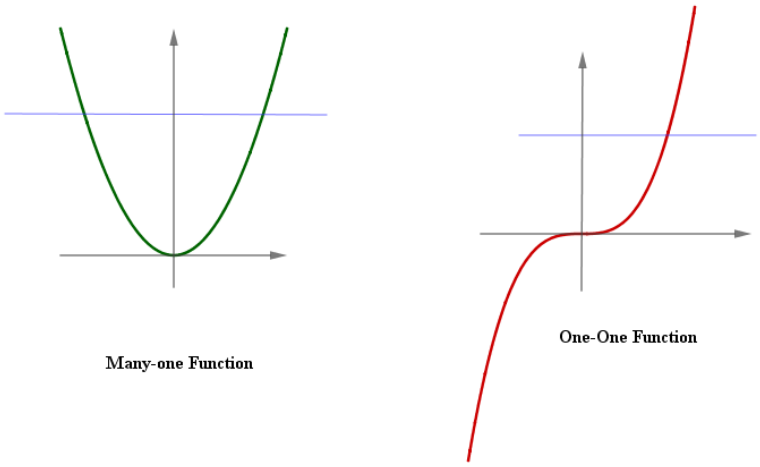
$$x_1 \neq x_2 \implies f(x_1) \neq f(x_2), \quad \text{equivalently} \quad f(x_1) = f(x_2) \implies x_1 = x_2.$$

A function that is not one-one is *many-one*: there exist $x_1 \neq x_2$ with $f(x_1) = f(x_2)$.



One-one and many-one functions

- To *prove* f is one-one, assume $f(x_1) = f(x_2)$ and deduce $x_1 = x_2$.
- To *disprove*, find two different inputs with the same image.
- **Horizontal line test:** if some horizontal line meets the graph more than once, f is many-one.
- Many-one is a type of function; one-to-many is not a function at all.



Horizontal line test

Example 1.4

Show that $f : \mathbb{N} \to \mathbb{N}$, $f(x) = x^2$, is one-one but not onto.

Solution: If $f(x_1) = f(x_2)$ then $x_1^2 = x_2^2$, and since $x_1, x_2 > 0$, $x_1 = x_2$: one-one. But $2 \in \mathbb{N}$ has no pre-image ($x^2 = 2$ has no natural solution), so f is not onto.

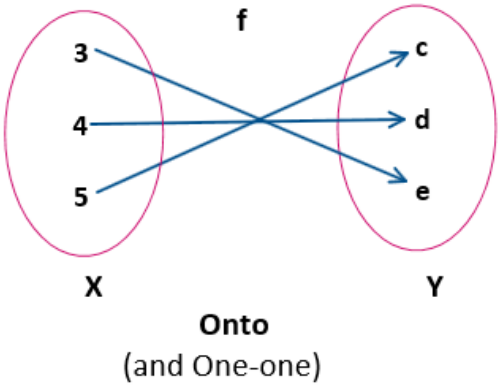
Onto (Surjective) Functions

Definition 1.6 Onto Function

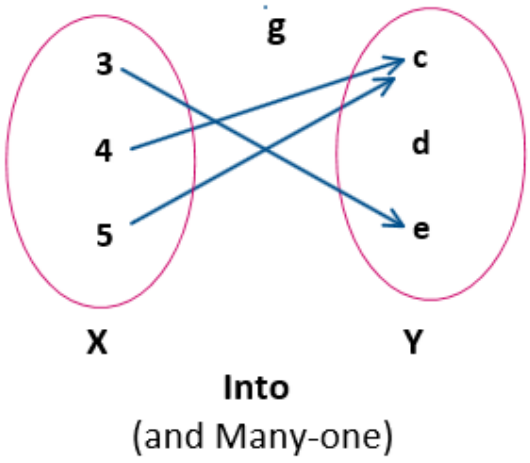
$f : X \to Y$ is *onto* (surjective) if every element of Y is the image of at least one element of X:

$$\text{for every } y \in Y \text{ there is } x \in X \text{ with } f(x) = y, \quad \text{i.e.} \quad \text{range of } f = \text{co-domain of } f.$$

A function that is not onto is called *into*.



An onto function



An into function

- To *prove* f is onto, take any y in the co-domain, solve $f(x) = y$ for x, and check that this x lies in the domain.
- Whether f is onto depends on the co-domain: the same rule can be onto for one co-domain and into for another.

Definition 1.7 Bijective Function

A function that is both one-one and onto is called *bijective* (a one-one correspondence).

Example 1.5

Show that $f : \mathbb{R} \to \mathbb{R}$, $f(x) = 2x + 3$, is bijective.

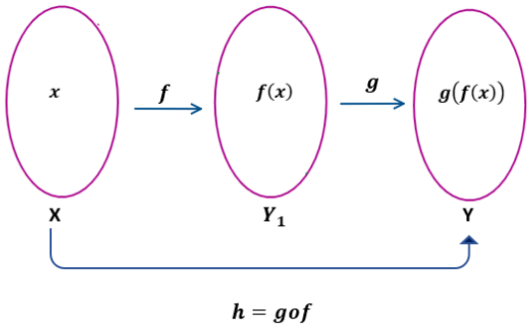
Solution: *One-one:* $f(x_1) = f(x_2) \Rightarrow 2x_1 + 3 = 2x_2 + 3 \Rightarrow x_1 = x_2$.
Onto: for any $y \in \mathbb{R}$, take $x = \frac{y-3}{2} \in \mathbb{R}$; then $f(x) = y$.
Hence f is bijective.

1.5 Composition of Functions

Not in current CBSE syllabus

Definition 1.8 Composition

If $f : X \to Y$ and $g : Y \to Z$, the composition $g \circ f : X \to Z$ is $(g \circ f)(x) = g(f(x))$.



Composition $g \circ f$

$g \circ f$ exists only if the range of f is contained in the domain of g; similarly for $f \circ g$. In general $g \circ f \neq f \circ g$.

1.6 Inverse of a Function

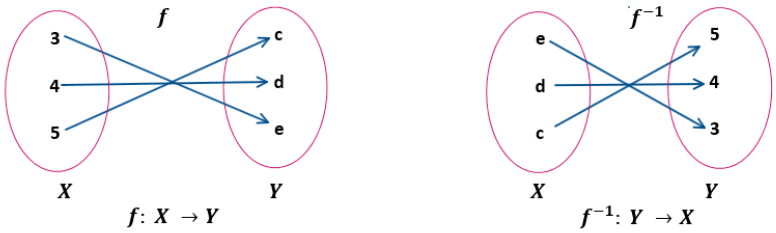
Not in current CBSE syllabus

Definition 1.9 Invertible Function

$f : X \to Y$ is *invertible* if there is a function $g : Y \to X$ with

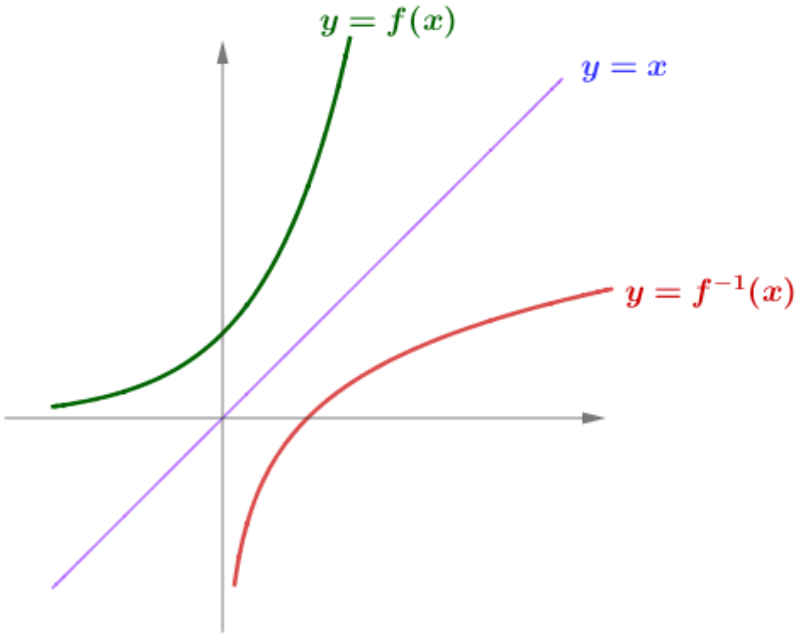
$$g(f(x)) = x \quad \text{for all } x \in X \quad \text{and} \quad f(g(y)) = y \quad \text{for all } y \in Y.$$

Then g is the inverse of f, written f^{-1}.



A function and its inverse

- f is invertible if and only if f is bijective.
- The inverse, when it exists, is unique.
- $f = f^{-1} \iff f(f(x)) = x$ for all x.
- To find f^{-1}: write $y = f(x)$, solve for x in terms of y, then $f^{-1}(y)$ is that expression.
- The graphs of $y = f(x)$ and $y = f^{-1}(x)$ are mirror images in the line $y = x$.



Graphs of f and f^{-1}

Quick Revision

Key Results & Formulas

Result ($n(A) = m$, $n(B) = n$)	**See**
Number of relations from A to B: 2^{mn}	§1.1
Equivalence = reflexive + symmetric + transitive	§1.1
Equivalence classes are disjoint and cover the whole set (a partition)	§1.2
Number of functions from A to B: n^m	§1.3
One-one functions $A \to B$ ($m \leq n$): $n(n-1)\cdots(n-m+1)$; zero if $m > n$	§1.4
Bijections $A \to B$: $n!$ if $m = n$, otherwise 0	§1.4
Onto functions from an m-set to a 2-set: $2^m - 2$	§1.4
f onto $\iff$ range = co-domain	§1.4
f invertible $\iff$ f bijective	§1.6

How to Prove It

To show	Method
Reflexive	check $(a, a) \in R$ for an *arbitrary* a
Symmetric	assume $(a, b) \in R$, deduce $(b, a) \in R$
Transitive	assume $(a, b), (b, c) \in R$, deduce $(a, c) \in R$
One-one	assume $f(x_1) = f(x_2)$, deduce $x_1 = x_2$
Onto	take any y in the co-domain, solve $f(x) = y$, check x is in the domain
Not one-one / not onto	a single counter-example

***Watch out:* Common Mistakes**

- A relation with no chain $(a, b), (b, c)$ is transitive; do not call it "not transitive".
- Reflexive needs (a, a) for *every* a in the set, not just for some.
- Onto-ness depends on the co-domain: always check that the x you solve for lies in the domain.
- $f(x) = x^2$ is not one-one on $\mathbb{R}$, but it is one-one on $[0, \infty)$; the domain matters.

Concept Exploration Exercise 1.1

[Based on Types of Relations and Equivalence Class]

1. Write all the subsets of the set $\{\phi, 2, a\}$.
2. Find the Cartesian product of the sets $A = \{3, 4\}$ and $B = \{5, 6, 1\}$. Also, find the total number of subsets of product $A \times B$.
3. Define a relation R from set $A = \{7, 8, 9, 10\}$ to set $B = \{y : y \text{ is a prime number less than } 10\}$ such that

$$R = \{(x, y) : x > y + 2; x \in A\}.$$

   (i) Write R in roster form.

   (ii) Write the sets of domain and range.

4. Consider the sets $A = \{3, 7, 2, 9\}$ and $B = \{y : y \text{ is a multiple of } 3\}$.

   (i) Write a set C in roster form such that $C = A - B$.

LPA Solutions

1. Relations and Functions

Section A

← Back to questions

MCQ & Assertion–Reason

1. $n \mid n$ (reflexive); $n \mid m, m \mid k \Rightarrow n \mid k$ (transitive); $1 \mid 2$ but $2 \nmid 1$ (not symmetric).
   $\Rightarrow$ **(D)**

2. $l \perp m \Rightarrow m \perp l$; a line is not $\perp$ to itself; $l \perp m, m \perp n \Rightarrow l \parallel n$.
   $\Rightarrow$ **(B)**

3. $2n_1 + 3 = 2n_2 + 3 \Rightarrow n_1 = n_2$; but 1 (or any even number) is not an image.
   $\Rightarrow$ **(B) injective**

4. $4 \times 3 \times 2 = 24$.
   $\Rightarrow$ **(C)**

5. $x - x + \sqrt{2} = \sqrt{2}$ is irrational: reflexive. Not symmetric: $(\sqrt{2}, 0) \in R$ but $0 - \sqrt{2} + \sqrt{2} = 0$.
   $\Rightarrow$ **(A)**

6. Equivalence relations on a set $\leftrightarrow$ partitions of the set. $\{1, 2, 3\}$ has 5 partitions.
   $\Rightarrow$ **(D)** 5

7. $\frac{1}{x_1} = \frac{1}{x_2} \Rightarrow x_1 = x_2$; 0 is never an image.
   $\Rightarrow$ **(A) one-one**

8. $x + 2$: inverse $y - 2$ stays in $\mathbb{Z}$. (x^3, $2x + 1$ miss values; $x^2 + 1$ is many-one.)
   $\Rightarrow$ **(B)**

9. All 2^n functions except the 2 constant ones.
   $\Rightarrow$ **(B)** $2^n - 2$

10. Not reflexive, not symmetric. A chain "x wife of y, y wife of z" is impossible, so transitive vacuously.
    $\Rightarrow$ **(C) only transitive**

11. All (a, a) present; $(1, 2) \in R$, $(2, 1) \notin R$; the only chain $(1, 2), (2, 3)$ gives $(1, 3) \in R$.
    $\Rightarrow$ **(A)**

12. $5 \neq 6$: no bijection.
    $\Rightarrow$ **(C)** 0

13. This is the definition of symmetry.
    $\Rightarrow$ **(A)**

14. $7x_1 - 5 = 7x_2 - 5 \Rightarrow x_1 = x_2$; $x = \frac{y+5}{7}$ for any y.
    $\Rightarrow$ **(C)**

15. Congruence is reflexive, symmetric and transitive.
    $\Rightarrow$ **(C)**

16. $f(x) = (x - 2)^2 + 1 \geq 1$, takes every value ≥ 1 on $[2, \infty)$.
    $\Rightarrow$ **(B)** $[1, \infty)$

17. No (a, a); $(2, 1) \notin R$; no chain, so transitive.
    $\Rightarrow$ **(B)**

18. Increasing on $\mathbb{R}^+$: one-one. Range $(1, \infty) \neq \mathbb{R}$: not onto.
    $\Rightarrow$ **(A)**

19. $R = \{(1, 3), (2, 6)\}$: no chain $(a, b), (b, c)$, so R is transitive. A true; R is the definition used to decide A.
    $\Rightarrow$ **(A)**

20. $f(1) = f(-1) = 2$: not one-one, so A is false. R is the correct definition.
    $\Rightarrow$ **(D)**