Chapter-1 Relations & Functions

Miscellaneous

Question 1:

Let f: $\mathbf{R} \to \mathbf{R}$ be defined as $f(x) = 10x + 7$. Find the function g: $\mathbf{R} \to \mathbf{R}$ such that $g \circ f = f \circ g = 1_{\mathbf{R}}$.

Answer :

It is given that f: $\mathbf{R} \to \mathbf{R}$ is defined as $f(x) = 10x + 7$.

One-one:

Let $f(x) = f(y)$, where $x, y \in \mathbf{R}$.

$\Rightarrow 10x + 7 = 10y + 7$

$\Rightarrow x = y$

$\therefore f$ is a one-one function.

Onto:

For $y \in \mathbf{R}$, let $y = 10x + 7$.

$$\Rightarrow x = \frac{y-7}{10} \in \mathbf{R}$$

Therefore, for any $y \in \mathbf{R}$, there exists $x = \frac{y-7}{10} \in \mathbf{R}$ such that

$$f(x) = f\left(\frac{y-7}{10}\right) = 10\left(\frac{y-7}{10}\right) + 7 = y - 7 + 7 = y.$$

$\therefore f$ is onto.

Therefore, f is one-one and onto.

Thus, f is an invertible function.

Let us define g: $\mathbf{R} \to \mathbf{R}$ as $g(y) = \frac{y-7}{10}$.

Now, we have:

$$gof(x) = g(f(x)) = g(10x+7) = \frac{(10x+7)-7}{10} = \frac{10x}{10} = 10$$

And,

$$fog(y) = f(g(y)) = f\left(\frac{y-7}{10}\right) = 10\left(\frac{y-7}{10}\right) + 7 = y - 7 + 7 = y$$

$$\therefore gof = I_{\mathbf{R}} \text{ and } fog = I_{\mathbf{R}}$$

Hence, the required function g: $\mathbf{R} \to \mathbf{R}$ is defined as $g(y) = \frac{y-7}{10}$.

Question 2:

Let f: W → W be defined as $f(n) = n - 1$, if is odd and $f(n) = n + 1$, if n is even. Show that f is invertible. Find the inverse of f. Here, W is the set of all whole numbers.

Answer :

It is given that:

f: W → W is defined as $f(n) = \begin{cases} n-1, & \text{if } n \text{ is odd} \\ n+1, & \text{if } n \text{ is even} \end{cases}$

One-one:

Let $f(n) = f(m)$.

It can be observed that if n is odd and m is even, then we will have $n - 1 = m + 1$.

$\Rightarrow n - m = 2$

However, this is impossible.

Similarly, the possibility of n being even and m being odd can also be ignored under a similar argument.

∴Both n and m must be either odd or even.

Now, if both n and m are odd, then we have:

$f(n) = f(m) \Rightarrow n - 1 = m - 1 \Rightarrow n = m$

Again, if both n and m are even, then we have:

$f(n) = f(m) \Rightarrow n + 1 = m + 1 \Rightarrow n = m$

$\therefore f$ is one-one.

It is clear that any odd number $2r + 1$ in co-domain **N** is the image of $2r$ in domain **N** and any even number $2r$ in co-domain **N** is the image of $2r + 1$ in domain **N**.

$\therefore f$ is onto.

Hence, f is an invertible function.

Let us define g: W → W as:

$$g(m) = \begin{cases} m+1, & \text{if } m \text{ is even} \\ m-1, & \text{if } m \text{ is odd} \end{cases}$$

Now, when n is odd:

$$gof(n) = g(f(n)) = g(n-1) = n-1+1 = n$$

And, when n is even:

$$gof(n) = g(f(n)) = g(n+1) = n+1-1 = n$$

Similarly, when m is odd:

$$fog(m) = f(g(m)) = f(m-1) = m-1+1 = m$$

When m is even:

$$fog(m) = f(g(m)) = f(m+1) = m+1-1 = m$$

$\therefore$ $\therefore gof = I_W$ and $fog = I_W$

Thus, f is invertible and the inverse of f is given by $f^{-1} = g$, which is the same as f.

Hence, the inverse of f is f itself.

Question 3:

If f: $\mathbf{R} \rightarrow \mathbf{R}$ is defined by $f(x) = x^2 - 3x + 2$, find $f(f(x))$.

Answer :

It is given that f: $\mathbf{R} \rightarrow \mathbf{R}$ is defined as $f(x) = x^2 - 3x + 2$.

$$\begin{aligned} f(f(x)) &= f(x^2-3x+2) \\ &= (x^2-3x+2)^2 - 3(x^2-3x+2) + 2 \\ &= x^4 + 9x^2 + 4 - 6x^3 - 12x + 4x^2 - 3x^2 + 9x - 6 + 2 \\ &= x^4 - 6x^3 + 10x^2 - 3x \end{aligned}$$

Question 4:

Show that function f: $\mathbf{R} \rightarrow \{x \in \mathbf{R}: -1 < x < 1\}$ defined by $f(x) = \frac{x}{1+|x|}$, $x \in \mathbf{R}$ is one-one and onto function.

Answer :

It is given that f: $\mathbf{R} \rightarrow \{x \in \mathbf{R}: -1 < x < 1\}$ is defined as $f(x) = \frac{x}{1+|x|}$, $x \in \mathbf{R}$.

Suppose $f(x) = f(y)$, where $x, y \in \mathbf{R}$.

$$\Rightarrow \frac{x}{1+|x|} = \frac{y}{1+|y|}$$

It can be observed that if x is positive and y is negative, then we have:

$$\frac{x}{1+x} = \frac{y}{1-y} \Rightarrow 2xy = x - y$$

Since x is positive and y is negative:

$x > y \Rightarrow x - y > 0$

But, $2xy$ is negative.

Then, $2xy \neq x - y$.

Thus, the case of x being positive and y being negative can be ruled out.

Under a similar argument, x being negative and y being positive can also be ruled out

$\therefore$ x and y have to be either positive or negative.

When x and y are both positive, we have:

$$f(x) = f(y) \Rightarrow \frac{x}{1+x} = \frac{y}{1+y} \Rightarrow x + xy = y + xy \Rightarrow x = y$$

When x and y are both negative, we have:

$$f(x) = f(y) \Rightarrow \frac{x}{1-x} = \frac{y}{1-y} \Rightarrow x - xy = y - yx \Rightarrow x = y$$

$\therefore$ f is one-one.

Now, let $y \in \mathbf{R}$ such that $-1 < y < 1$.

If x is negative, then there exists $x = \frac{y}{1+y} \in \mathbf{R}$ such that

$$f(x) = f\left(\frac{y}{1+y}\right) = \frac{\left(\frac{y}{1+y}\right)}{1 + \left|\frac{y}{1+y}\right|} = \frac{\frac{y}{1+y}}{1 + \left(\frac{-y}{1+y}\right)} = \frac{y}{1+y-y} = y.$$

If x is positive, then there exists $x = \frac{y}{1-y} \in \mathbf{R}$ such that

$$f(x) = f\left(\frac{y}{1-y}\right) = \frac{\left(\frac{y}{1-y}\right)}{1 + \left|\left(\frac{y}{1-y}\right)\right|} = \frac{\frac{y}{1-y}}{1 + \frac{y}{1-y}} = \frac{y}{1-y+y} = y.$$

$\therefore$ f is onto.

Hence, f is one-one and onto.

Question 5:

Show that the function f: **R** → **R** given by $f(x) = x^3$ is injective.

Answer :

f: **R** → **R** is given as $f(x) = x^3$.

Suppose $f(x) = f(y)$, where $x, y \in$ **R**.

$\Rightarrow x^3 = y^3$ … (1)

Now, we need to show that $x = y$.

Suppose $x \neq y$, their cubes will also not be equal.

$\Rightarrow x^3 \neq y^3$

However, this will be a contradiction to (1).

$\therefore x = y$

Hence, f is injective.

Question 6:

Give examples of two functions f: **N** → **Z** and g: **Z** → **Z** such that $g \circ f$ is injective but g is not injective.

(Hint: Consider $f(x) = x$ and $g(x) = |x|$)

Answer :

Define f: **N** → **Z** as $f(x) = x$ and g: **Z** → **Z** as $g(x) = |x|$.

We first show that g is not injective.

It can be observed that:

$g(-1) = |-1| = 1$

$g(1) = |1| = 1$

$\therefore g(-1) = g(1)$, but $-1 \neq 1$.

$\therefore g$ is not injective.

Now, gof: **N** → **Z** is defined as $gof(x) = g(f(x)) = g(x) = |x|$.

Let $x, y \in$ **N** such that $gof(x) = gof(y)$.

$\Rightarrow |x| = |y|$

Since x and $y \in$ **N,** both are positive.

$\therefore |x| = |y| \Rightarrow x = y$

Hence, gof is injective

Question 7:

Given examples of two functions f: **N** → **N** and g: **N** → **N** such that gof is onto but f is not onto.

(Hint: Consider $f(x) = x + 1$ and $g(x) = \begin{cases} x-1 & \text{if } x > 1 \\ 1 & \text{if } x = 1 \end{cases}$

Answer :

Define f: **N** → **N** by,

$f(x) = x + 1$

And, g: **N** → **N** by,

$$g(x) = \begin{cases} x-1 & \text{if } x > 1 \\ 1 & \text{if } x = 1 \end{cases}$$

We first show that g is not onto.

For this, consider element 1 in co-domain **N**. It is clear that this element is not an image of any of the elements in domain **N**.

∴ f is not onto.

Now, gof: $\mathbf{N} \rightarrow \mathbf{N}$ is defined by,

$$gof(x) = g(f(x)) = g(x+1) = (x+1)-1 \qquad [x \in \mathbf{N} \Rightarrow (x+1) > 1]$$
$$= x$$

Then, it is clear that for $y \in \mathbf{N}$, there exists $x = y \in \mathbf{N}$ such that $gof(x) = y$.

Hence, gof is onto.

Question 8:

Given a non empty set X, consider P(X) which is the set of all subsets of X.

Define the relation R in P(X) as follows:

For subsets A, B in P(X), ARB if and only if $A \subset B$. Is R an equivalence relation on P(X)? Justify you answer:

Answer :

Since every set is a subset of itself, ARA for all $A \in$ P(X).

∴R is reflexive.

Let AR$B \Rightarrow A \subset B$.

This cannot be implied to $B \subset A$.

For instance, if $A = \{1, 2\}$ and $B = \{1, 2, 3\}$, then it cannot be implied that B is related to A.

∴ R is not symmetric.

Further, if ARB and BRC, then $A \subset B$ and $B \subset C$.

$\Rightarrow A \subset C$

$\Rightarrow A$RC

∴ R is transitive.

Hence, R is not an equivalence relation since it is not symmetric.

Question 9:

Given a non-empty set X, consider the binary operation $*$: $P(X) \times P(X) \rightarrow P(X)$ given by $A * B = A \cap B$ " A, B in $P(X)$ is the power set of X. Show that X is the identity element for this operation and X is the only invertible element in $P(X)$ with respect to the operation*.

Answer :

It is given that $*: P(X) \times P(X) \rightarrow P(X)$ is defined as $A * B = A \cap B \ \forall \ A, B \in P(X)$.

We know that $A \cap X = A = X \cap A \ \forall \ A \in P(X)$.

$\Rightarrow A * X = A = X * A \ \forall \ A \in P(X)$

Thus, X is the identity element for the given binary operation *.

Now, an element $A \in P(X)$ is invertible if there exists $B \in P(X)$ such that

$A * B = X = B * A$. (As X is the identity element)

i.e.,

$A \cap B = X = B \cap A$

This case is possible only when $A = X = B$.

Thus, X is the only invertible element in $P(X)$ with respect to the given operation*.

Hence, the given result is proved.

Question 10:

Find the number of all onto functions from the set {1, 2, 3, … , n) to itself.

Answer :

Onto functions from the set {1, 2, 3, … ,n} to itself is simply a permutation on n symbols 1, 2, …, n.

Thus, the total number of onto maps from {1, 2, … , n} to itself is the same as the total number of permutations on n symbols 1, 2, …, n, which is n!.

Question 11:

Let $S = \{a, b, c\}$ and $T = \{1, 2, 3\}$. Find F^{-1} of the following functions F from S to T, if it exists.

(i) $F = \{(a, 3), (b, 2), (c, 1)\}$ (ii) $F = \{(a, 2), (b, 1), (c, 1)\}$

Answer :

$S = \{a, b, c\}$, $T = \{1, 2, 3\}$

(i) F: $S \rightarrow T$ is defined as:

$F = \{(a, 3), (b, 2), (c, 1)\}$

$\Rightarrow F(a) = 3$, $F(b) = 2$, $F(c) = 1$

Therefore, $F^{-1}: T \rightarrow S$ is given by

$F^{-1} = \{(3, a), (2, b), (1, c)\}$.

(ii) F: $S \rightarrow T$ is defined as:

$F = \{(a, 2), (b, 1), (c, 1)\}$

Since $F(b) = F(c) = 1$, F is not one-one.

Hence, F is not invertible i.e., F^{-1} does not exist.

Question 12:

Consider the binary operations*: **R** ×**R** → and o: **R** × **R** → **R** defined as $a * b = |a - b|$ and a o b = a, "a, b ∈ **R**. Show that * is commutative but not associative, o is associative but not commutative. Further, show that "a, b, c ∈ **R**, a*(b o c) = (a * b) o (a * c). [If it is so, we say that the operation * distributes over the operation o]. Does o distribute over *? Justify your answer.

Answer :

It is given that *: **R** ×**R** → and o: **R** × **R** → **R** isdefined as

$a*b=|a-b|$ and *a* o *b* = *a*, "*a*, *b* ∈ **R**.

For *a*, *b* ∈ **R**, we have:

$$a*b=|a-b|$$

$$b*a=|b-a|=|-(a-b)|=|a-b|$$

∴*a* * *b* = *b* * *a*

∴ The operation * is commutative.

It can be observed that,

$$(1*2)*3=(|1-2|)*3=1*3=|1-3|=2$$
$$1*(2*3)=1*(|2-3|)=1*1=|1-1|=0$$
$$\therefore (1*2)*3 \neq 1*(2*3) \text{ (where 1, 2, 3} \in \mathbf{R})$$

∴The operation * is not associative.

Now, consider the operation o:

It can be observed that 1 o 2 = 1 and 2 o 1 = 2.

∴1 o 2 ≠ 2 o 1 (where 1, 2 ∈ **R**)

∴The operation o is not commutative.

Let *a*, *b*, *c* ∈ **R**. Then, we have:

(*a* o *b*) o *c* = *a* o *c* = *a*

a o (*b* o *c*) = *a* o *b* = *a*

⇒ *a* o *b*) o c = *a* o (*b* o *c*)

∴ The operation o is associative.

Now, let *a*, *b*, *c* ∈ **R**, then we have:

$a * (b \text{ o } c) = a * b = |a - b|$

$(a * b) \text{ o } (a * c) = (|a-b|) \text{ o } (|a-c|) = |a-b|$

Hence, $a * (b \text{ o } c) = (a * b) \text{ o } (a * c)$.

Now,

$1 \text{ o } (2 * 3) = 1 \text{ o } (|2-3|) = 1 \text{ o } 1 = 1$

$(1 \text{ o } 2) * (1 \text{ o } 3) = 1 * 1 = |1-1| = 0$

$\therefore 1 \text{ o } (2 * 3) \neq (1 \text{ o } 2) * (1 \text{ o } 3)$ (where $1, 2, 3 \in \mathbf{R}$)

$\therefore$ The operation o does not distribute over *.

Question 13:

Given a non-empty set X, let $*: P(X) \times P(X) \to P(X)$ be defined as $A * B = (A - B) \cup (B - A)$, " A, $B \in P(X)$. Show that the empty set Φ is the identity for the operation * and all the elements A of $P(X)$ are invertible with $A^{-1} = A$. (Hint: $(A - \Phi) \cup (\Phi - A) = A$ and $(A - A) \cup (A - A) = A * A = \Phi$).

Answer :

It is given that $*: P(X) \times P(X) \to P(X)$ is defined as

$A * B = (A - B) \cup (B - A)$ " $A, B \in P(X)$.

Let $A \in P(X)$. Then, we have:

$A * \Phi = (A - \Phi) \cup (\Phi - A) = A \cup \Phi = A$

$\Phi * A = (\Phi - A) \cup (A - \Phi) = \Phi \cup A = A$

$\therefore A * \Phi = A = \Phi * A$. " $A \in P(X)$

Thus, Φ is the identity element for the given operation*.

Now, an element $A \in P(X)$ will be invertible if there exists $B \in P(X)$ such that

$A * B = \Phi = B * A$. (As Φ is the identity element)

Now, we observed that $A * A = (A - A) \cup (A - A) = \phi \cup \phi = \phi \ \forall A \in \mathrm{P}(X)$.

Hence, all the elements A of P(X) are invertible with $A^{-1} = A$.

Question 14:

Define a binary operation *on the set {0, 1, 2, 3, 4, 5} as

$$a * b = \begin{cases} a+b, & \text{if } a+b<6 \\ a+b-6 & \text{if } a+b \geq 6 \end{cases}$$

Show that zero is the identity for this operation and each element $a \neq 0$ of the set is invertible with $6 - a$ being the inverse of a.

Answer :

Let $X = \{0, 1, 2, 3, 4, 5\}$.

The operation * on X is defined as:

$$a * b = \begin{cases} a+b & \text{if } a+b<6 \\ a+b-6 & \text{if } a+b \geq 6 \end{cases}$$

An element $e \in X$ is the identity element for the operation *, if $a * e = a = e * a \ \forall a \in X$.

For $a \in X$, we observed that:

$$a * 0 = a + 0 = a \qquad [a \in X \Rightarrow a + 0 < 6]$$

$$0 * a = 0 + a = a \qquad [a \in X \Rightarrow 0 + a < 6]$$

$$\therefore a * 0 = a = 0 * a \ \forall a \in X$$

Thus, 0 is the identity element for the given operation *.

An element $a \in X$ is invertible if there exists $b \in X$ such that $a * b = 0 = b * a$.

$$\text{i.e.,} \begin{cases} a+b=0=b+a, & \text{if } a+b<6 \\ a+b-6=0=b+a-6, & \text{if } a+b \geq 6 \end{cases}$$

i.e.,

$a = -b$ or $b = 6 - a$

But, $X = \{0, 1, 2, 3, 4, 5\}$ and $a, b \in X$. Then, $a \neq -b$.

$\therefore b = 6 - a$ is the inverse of a " $a \in X$.

Hence, the inverse of an element $a \in X$, $a \neq 0$ is $6 - a$ i.e., $a^{-1} = 6 - a$.

Question 15:

Let $A = \{-1, 0, 1, 2\}$, $B = \{-4, -2, 0, 2\}$ and $f, g: A \to B$ be functions defined by $f(x) = x^2 - x, x \in$ A and $g(x) = 2\left|x - \frac{1}{2}\right| - 1,\ x \in A$. Are f and g equal?

Justify your answer. (Hint: One may note that two function $f: A \to B$ and g: $A \to$ B such that $f(a)$ = g(a) "$a \in A$, are called equal functions).

Answer :

It is given that $A = \{-1, 0, 1, 2\}$, $B = \{-4, -2, 0, 2\}$.

Also, it is given that $f, g: A \to B$ are defined by $f(x) = x^2 - x$, $x \in A$ and $g(x) = 2\left|x - \frac{1}{2}\right| - 1,\ x \in A$.

It is observed that:

$$f(-1)=(-1)^2-(-1)=1+1=2$$
$$g(-1)=2\left|(-1)-\frac{1}{2}\right|-1=2\left(\frac{3}{2}\right)-1=3-1=2$$
$$\Rightarrow f(-1)=g(-1)$$
$$f(0)=(0)^2-0=0$$
$$g(0)=2\left|0-\frac{1}{2}\right|-1=2\left(\frac{1}{2}\right)-1=1-1=0$$
$$\Rightarrow f(0)=g(0)$$
$$f(1)=(1)^2-1=1-1=0$$
$$g(1)=2\left|1-\frac{1}{2}\right|-1=2\left(\frac{1}{2}\right)-1=1-1=0$$
$$\Rightarrow f(1)=g(1)$$
$$f(2)=(2)^2-2=4-2=2$$
$$g(2)=2\left|2-\frac{1}{2}\right|-1=2\left(\frac{3}{2}\right)-1=3-1=2$$
$$\Rightarrow f(2)=g(2)$$
$$\therefore f(a)=g(a)\ \forall a\in A$$

Hence, the functions f and g are equal.

Question 16:

Let A = {1, 2, 3}. Then number of relations containing (1, 2) and (1, 3) which are reflexive and symmetric but not transitive is

(A) 1 (B) 2 (C) 3 (D) 4

Answer :

The given set is A = {1, 2, 3}.

The smallest relation containing (1, 2) and (1, 3) which is reflexive and symmetric, but not transitive is given by:

R = {(1, 1), (2, 2), (3, 3), (1, 2), (1, 3), (2, 1), (3, 1)}

This is because relation R is reflexive as (1, 1), (2, 2), (3, 3) ∈ R.

Relation R is symmetric since (1, 2), (2, 1) ∈R and (1, 3), (3, 1) ∈R.

But relation R is not transitive as (3, 1), (1, 2) ∈ R, but (3, 2) ∉ R.

Now, if we add any two pairs (3, 2) and (2, 3) (or both) to relation R, then relation R will become transitive.

Hence, the total number of desired relations is one.

The correct answer is A.

Question 17:

Let A = {1, 2, 3}. Then number of equivalence relations containing (1, 2) is

(A) 1 (B) 2 (C) 3 (D) 4

Answer :

It is given that A = {1, 2, 3}.

The smallest equivalence relation containing (1, 2) is given by,

R_1 = {(1, 1), (2, 2), (3, 3), (1, 2), (2, 1)}

Now, we are left with only four pairs i.e., (2, 3), (3, 2), (1, 3), and (3, 1).

If we odd any one pair [say (2, 3)] to R_1, then for symmetry we must add (3, 2). Also, for transitivity we are required to add (1, 3) and (3, 1).

Hence, the only equivalence relation (bigger than R_1) is the universal relation.

This shows that the total number of equivalence relations containing (1, 2) is two.

The correct answer is B.

Question 18:

Let f: **R** → **R** be the Signum Function defined as

$$f(x)=\begin{cases}1, & x>0\\ 0, & x=0\\ -1, & x<0\end{cases}$$

and g: **R** → **R** be the Greatest Integer Function given by $g(x) = [x]$, where $[x]$ is greatest integer less than or equal to x. Then does *fog* and *gof* coincide in (0, 1]?

Answer :

It is given that,

f: **R** → **R** is defined as $f(x)=\begin{cases}1, & x>0\\ 0, & x=0\\ -1, & x<0\end{cases}$

Also, g: **R** → **R** is defined as $g(x) = [x]$, where $[x]$ is the greatest integer less than or equal to x.

Now, let $x \in (0, 1]$.

Then, we have:

$[x] = 1$ if $x = 1$ and $[x] = 0$ if $0 < x < 1$.

$$\therefore\ fog(x)=f(g(x))=f([x])=\begin{cases}f(1), & \text{if } x=1\\ f(0), & \text{if } x\in(0,1)\end{cases}=\begin{cases}1, & \text{if } x=1\\ 0, & \text{if } x\in(0,1)\end{cases}$$

$$\begin{aligned}gof(x)&=g(f(x))\\ &=g(1) \qquad [x>0]\\ &=[1]=1\end{aligned}$$

Thus, when $x \in (0, 1)$, we have $fog(x) = 0$and $gof(x) = 1$.

Hence, *fog* and *gof* do not coincide in (0, 1].

Question 19:

Number of binary operations on the set $\{a, b\}$ are

(A) 10 (B) 16 (C) 20 (D) 8

Answer :

A binary operation * on $\{a, b\}$ is a function from $\{a, b\} \times \{a, b\} \rightarrow \{a, b\}$

i.e., * is a function from $\{(a, a), (a, b), (b, a), (b, b)\} \rightarrow \{a, b\}$.

Hence, the total number of binary operations on the set $\{a, b\}$ is 2^4 i.e., 16.

The correct answer is B.