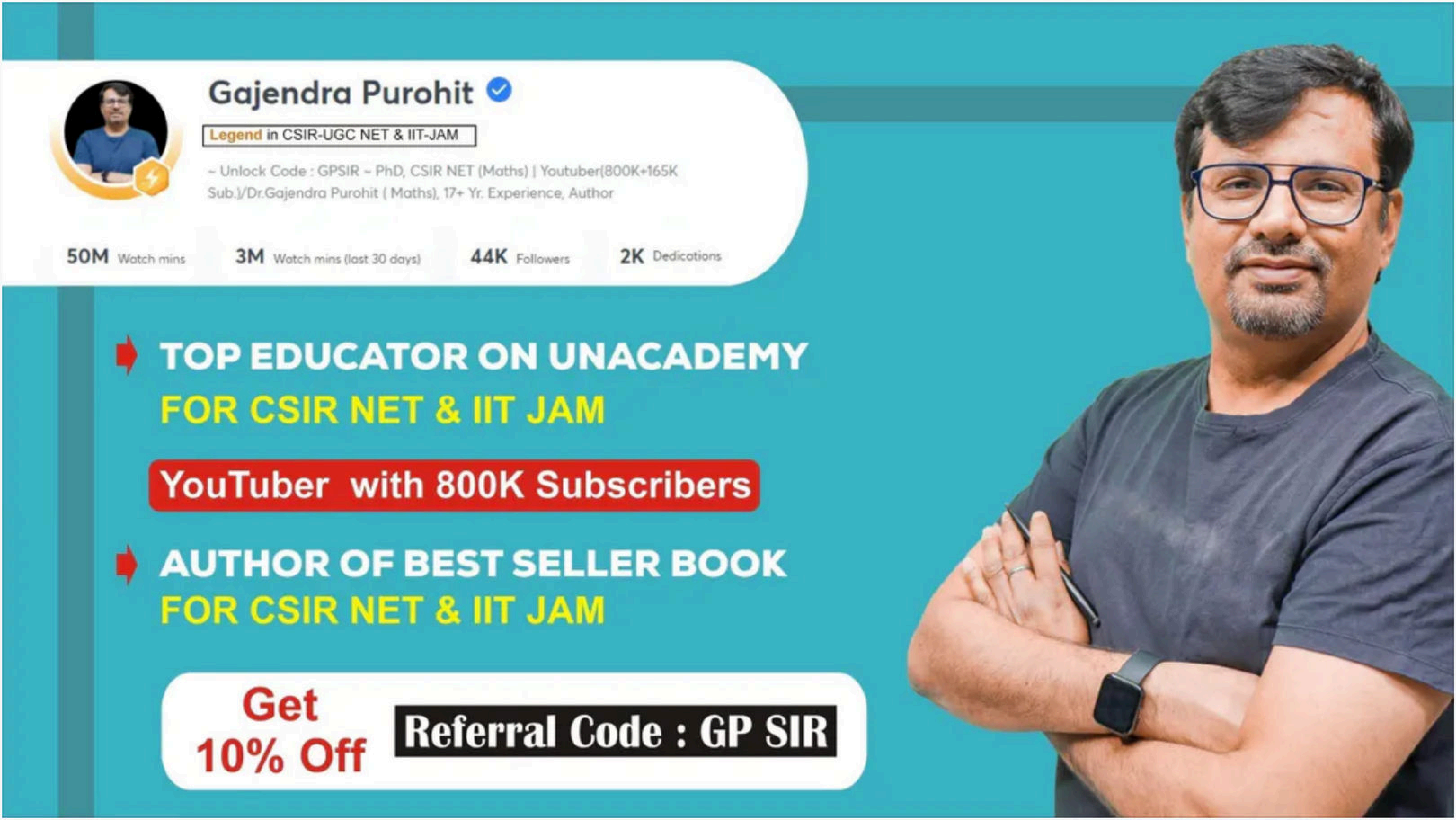
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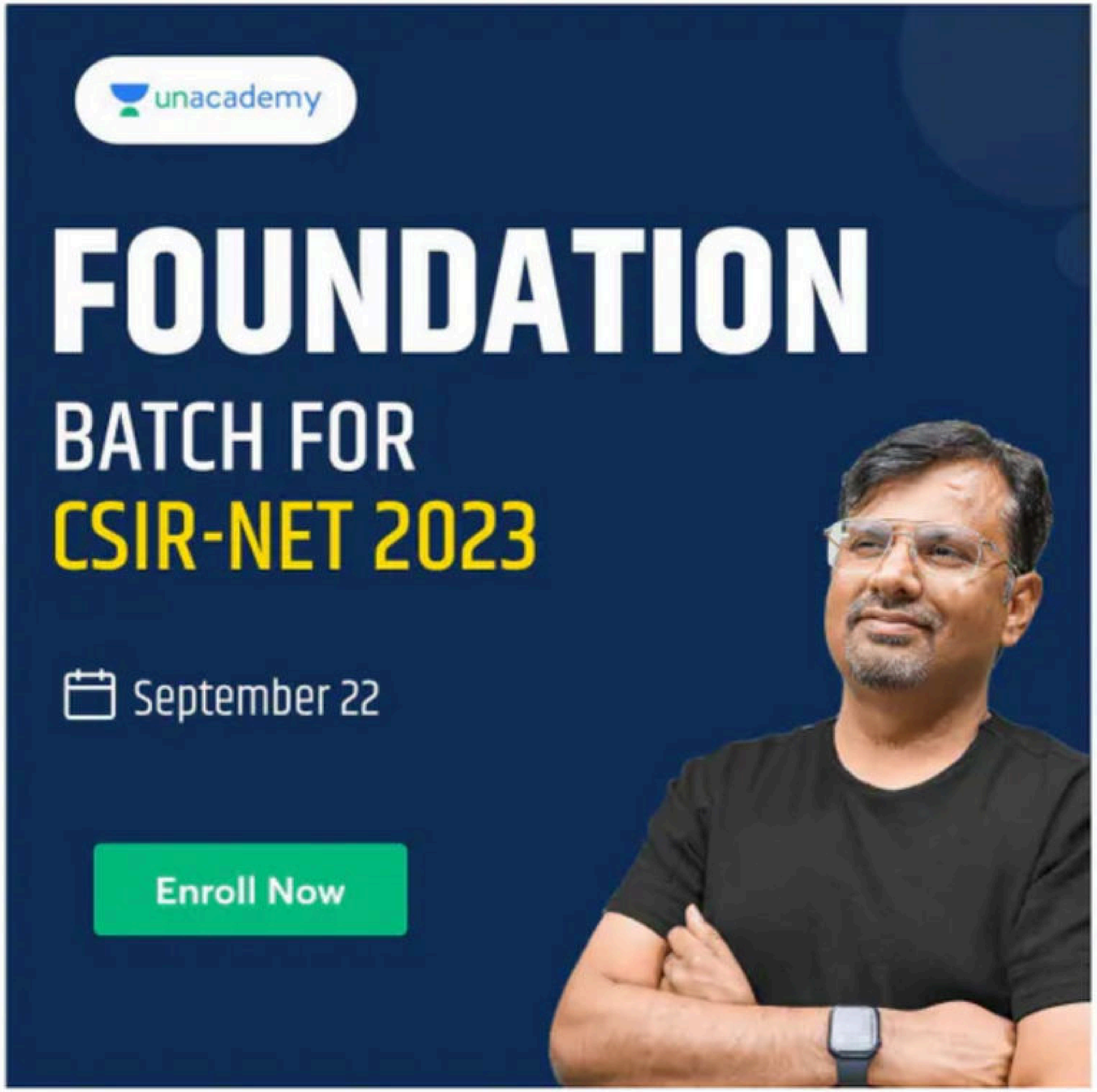

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1. **<u>Order of Group</u>** -: Number of elements in G Group is called Order of group. It is denoted by $o(G) = |G|$

OR

Let $(G,*)$ be a group. The cardinality of G (finite or Infinite) is defined as the order of the group.

Order of some special group.

i. $o(\mathbb{R}) = o(\mathbb{C}) = o(\mathbb{Z}) = o(\mathbb{Q}) = \infty$

ii. $o(\mathbb{R}^*) = o(\mathbb{Q}^*) = \infty$

iii. $o(U_n) = \emptyset(n)$, where $\emptyset$ is a euler's function.

iv. $o(D_n) = 2n$

v. $o(Q_8) = 8$

vi. $o(K_4) = 4$

vii. $o[Gl_n(\mathbb{R})] = o[Sl_n(\mathbb{R})] = \infty$

viii. $o[Gl_n(\mathbb{Z}_p)] = (p^n - p^{n-1})\,(p^n - p^{n-2})\,(p^n - p^{n-3})\ldots..$

$(p^n - 1)$

ix. $o[Sl_n(\mathbb{Z}_p)]$

$$= \frac{(p^n - p^{n-1})(p^n - p^{n-2})(p^n - p^{n-3})\ldots\ldots(p^n - 1)}{(p-1)}$$

x. $o(S_n) = n!$, (S_n will be covered in the next lecture.)

xi. $o(Z_n) = n$

2. **Order of Elements-:** Let G be a group, the order of an elements $a \in G$ is the least positive integer n such that $a^n = e$ if such n does not exist then order of element a is infinite.

The order of element $a \in G$ is denoted by $o(a)$.

Basic example of order of elements of some special Group-

(i) Possible Order of Each Element of $(\mathbb{Z}, +)$

$\mathbb{Z} = \{ \ldots., -3, -2, -1, 0, 1, 2 ,3 ,\ldots..\}$

$0 \in \mathbb{Z}$ is identity of $\mathbb{Z}$

$o(0) = 1$

$n \in \mathbb{Z}$; $|n| \geq 1$. It is not possible; order of n

can't belongs to any natural number.

Then $o(n) = \infty$, $n \in \mathbb{Z} - \{0\}$

Similarly, order of elements of $(\mathbb{Q}, +)$, $(\mathbb{R}, +)$ & $(\mathbb{C}, +)$ are 1 & ∞.

(ii) Possible Order of elements of ($\mathbb{Z}^*$, .)

Order of element of identity, $o(1) = 1$

Order of element, -1 is 2 i.e. $o(-1) = 2$

All other elements are of order ∞

(iii) Possible Order of elements of ($\mathbb{Q}^*$, .)

$1 \in \mathbb{Q}^*$ is identity of $\mathbb{Q}^*$, then $o(1) = 1$

$o(-1) = 2$; $o(a) = \infty$, $a \in \mathbb{Q}^* - \{1, -1\}$

Similarly, order of elements of ($\mathbb{R}^*$, .) are 1, 2 and ∞.

(iv) Possible Order of each element in $\mathbb{Z}_n$.

NOTE-:

a) In $\mathbb{Z}_n$, possible order of elements are $d \mid n$ [n is divisble by d].

b) If $d \mid n$ then numbers of elements of order d in $\mathbb{Z}_n$ $= \phi(d)$.

Properties of order in Product

i. If G_1 is group with identity e_1 and G_2 is group with identity e_2 then $G_1 \times G_2$ is group with identity (e_1, e_2) and with inverse (a_1^{-1} in G_1, a_2^{-1} in G_2).

ii. If $G_1, G_2, G_3, \ldots G_n$ are finite groups. Then $o(G_1 \times G_2 \times G_3 \times \ldots \times G_n) = o(G_1) \times o(G_2) \times o(G_3) \times \ldots \times o(G_n)$.

iii. $(a_1, a_2, a_3, \ldots, a_n) \in (G_1 \times G_2 \times G_3 \times \ldots \times G_n)$ then $o(a_1, a_2, a_3, \ldots, a_n) = \text{L.C.M.}\,[\,o(a_1) \text{ in } G_1, o(a_2) \text{ in } G_2, o(a_3) \text{ in } G_3, \ldots, o(a_4) \text{ in } G_n.]$

iv. No. of elements of order d in $\mathbb{Z}_n \times \mathbb{Z}_m = \Sigma\phi(d_1).\phi(d_2)$. where $d_1 | n$, $d_2 | m$ & $\text{L.C.M.}(d_1, d_2) = d$

v. $o(a) = o(xax^{-1}) = o(x^{-1}ax)$, where $a, x \in G$ and G is a group.

vi. $o(ba) = o(ab)$, where $a, b \in G$

vii. $o(a) = o(a^{-1})$, where $a \in G$

viii. $(ab)^{-1} = b^{-1}a^{-1}$, where $a, b \in G$

ix. $(a_1, a_2, \ldots, a_{n-1}\ a_n)^{-1} = (a_n^{-1}, a_{n-1}^{-1}, \ldots, a_2^{-1}, a_1^{-1})$, where $a_i \in G$

Result : Let $G = Z_k \times Z_k \ldots\ldots \times Z_k$

(p-times)

Then G has an element of order either 1 or k.

(1) G has exactly one element of order 1.

(2) Other all elements of G are of order k

i.e. number of elements of order k in G are $k^p - 1$

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Q1. Number of elements of order 7 in $Z_7 \times Z_7 \,.....\, Z_7$ (50-times)

(a) 7^{50} (b) $7^{50} - 1$

(c) $7^{50} - 2$ (d) $7^{49} - 1$

Abelian Group -: A group G is said to be abelian if $xy = yx$ such that, $x, y \in G$.

$x+y=y+x$

Properties of Abelian group-: $K_4 = \{e, a, b, ab\}$

(i) If every element of G has self-inverse then G is abelian but converse need not be true.

Example : K_4 is abelian because every elements of K_4 has self-inverse. $\mathbb{Z}_6$ is abelian but every elements of $\mathbb{Z}_6$ is not self-inverse.

$\mathbb{Z}_2 \times \mathbb{Z}_4$

(ii) Let G_1 and G_2 are two groups $G_1 \times G_2$ is abelian iff G_1 and G_2 are abelian.

$(ab)^{-1} = b^{-1}a^{-1}$
$= a^{-1}b^{-1}$

(iii) $G_1 \times G_2 \times G_3 \times \ldots\ldots G_{n-1} \times G_n$ is abelian iff each G_i, $1 \le i \le n$ is abelian

(iv) Let G be a group and $(ab)^{-1} = a^{-1}b^{-1}$ $\forall$ a, b $\in$ G iff G is abelian.

b^2a^2

(v) Let G be a group and $(ab)^2 = a^2b^2$ $\forall$ a, b $\in$ G iff G is abelian.

(vi) But G is a group and $(ab)^n = a^nb^n$ $(n \ge 3)$ $\forall$ a, b $\in$ G iff G is abelian.

Cyclic Group : A group (G, o) is called a cyclic group if every elements of G is of the form a^n, for some $a \in G$ where $n \in Z$.

Symbolically, $G = \{a^n \mid n \in Z\}$

$\Rightarrow \quad G = \{\ldots.. a^{-2}, a^{-1}, e, a, a^2, \ldots.\}$

The element a is called generator of G.

Note : If G is a cyclic group generated by a, then we write $G = \langle a \rangle$

The element of G will be of the form

$\langle a \rangle = \{\ldots. -2a, -a, 0, a, 2a, \ldots..\}$ for additive composition.

$\langle a \rangle = \{\ldots.. a^{-2}, a^{-1}, e, a, a^2 \ldots.. \}$ for multiplication composition.

Result :

(1) Let G be a group of order n and if G have an element of order n, then G must be cyclic group.

Example : Let G = {1, -1, i, -i} is a group of order 4 under multiplicative.

Now, O(1) = 1, O(-1) = 2, O(i) = 4 = O(-i)

Here, order of i & -i are equal to order of group.

So, G is cyclic and i & -i are generator of G.

Z_{10}

$\phi(10) = \phi(2)\phi(5) = 1 \times 4$

(2) Every cyclic group is abelian group.

K4

(3) Let G be a cyclic group of order n, then number of generator of group are $\phi(n)$.

Non-Cyclic group: K_4, Q_8, S_n, $(\mathbb{Q}^*, .)$, $(\mathbb{R}^*, .)$, $(\mathbb{C}^*, .)$, $(\mathbb{Q}, +)$, $(\mathbb{R}, +)$, $(\mathbb{C}, +)$, $Gl_n(\mathbb{Z}_p)$, $Sl_n(\mathbb{Z}_p)$ $(n>1)$, D_n

Some important points of cyclic group-:

(i) If G is group under addition then $G = \langle a \rangle = \{na \mid n \in \mathbb{Z}\}$.

(ii) If G is cyclic group and 'a' is generator of G then $o(G) = o(a)$. But Converse need not be true.

Example: $G = (Z, +)$

All elements other than 1 and -1 are of order infinite which is equal to order of G but they are not generator

(iii) G is a finite cyclic group and 'a' is generator of G iff $o(G) = o(a)$.

(iv) If $a^1, a^2, a^3, \ldots\ldots a^n = e$ are distinct element then G is generated by a.

(v) If G is non abelian then G is non-cyclic group

(vi) If o(G) = p(prime number) then G is cyclic group.

(vii) $\mathbb{Z}_m \times \mathbb{Z}_n$ is cyclic group iff gcd(m, n) =1 then $\mathbb{Z}_m \times \mathbb{Z}_n \approx \mathbb{Z}_{mn}$

$o(G) = 25 = 5^2$

(ix) If ‘a’ is generator of G then a^{-1} is also generator of G.

$o(G) = 49$

(x) If G be a finite cyclic group of order n then $G \approx \mathbb{Z}_n$.

(xi) If G be an infinite cyclic group then $G \approx \mathbb{Z}$.

(xii)let $G = \langle a \rangle$ be a cyclic group of order n then $G = \langle a^k \rangle$ iff g.c.d.(k, n) = 1

(xiii) If G_1 and G_2 are cyclic group then $G_1 \times G_2$ need not be cyclic group.

(xiv) If G be infinite cyclic group of order n then G has exactly two generators. Namely {1, -1}

(xv) If $O(G) = p^2$ then G is abelian group but converse need not be true

(xvi) Let G be a finite group of order pq i.e. O(G) = pq (where $p < q$ & p, q are prime)

Case – 1 : If $p \nmid q-1$, then G is cyclic.

Case – 2 : If $p \mid q-1$, then G need not be cyclic.

$O(G) = 15 = 3 \times 5$

$3 \nmid 5-1$

Cyclic

$O(G) = 21 = 3 \times 7$

Non abelian

Non cyclic

$3 \mid 7-1$

abelian

cyclic

GROUP OF ORDER 1 TO 12

$o(G) = 1$ cyclic

$\{1, -1\}, \times$

$o(G) = 2$ cyclic $(Z_2, +_2)$

$o(G) = 3$ cyclic $(Z_3, +_3)$

$o(G) = 4 = 2^2$

cyclic — abelian

$(Z_4, +_4)$

$K_4 \rightarrow Z_2 \times Z_2$

D_2

Z_4

$\phi(1) = 1$

$\phi(2) = 1$

$\phi(4) = 2$

K_4

$o(1) = 1$

$o(2) = 3$

$o(G) = 5$

$G = (\mathbb{Z}_5, +_5)$

$\phi(1) = 1$

$\phi(5) = 5^1 - 5^0 = 4$

$o(4) = 6 = 2 \times 3$

$2 \mid 3-1$

~~cyclic~~

Non abelian

$(\mathbb{Z}_6, +_6)$

$\phi(1) = 1$

$\phi(2) = 1$

$\phi(3) = 2$

$\phi(6) = 2$

S_3

$1+1+1$

$1+2$

3

$o(1) = 1$

$o(2) = \frac{3!}{1 \times 2} = 3$

$o(3) = \frac{3!}{3} = 2$

$o(G) = 7$ cyclic

$(\mathbb{Z}_7, +_7)$

$\phi(1) = 1$

$\phi(7) = 6$

$o(G) = 8 = 2^3$

cyclic: $\mathbb{Z}_8$

abelian: $\mathbb{Z}_4 \times \mathbb{Z}_2$

abelian: $\mathbb{Z}_2 \times \mathbb{Z}_2 \times \mathbb{Z}_2$

Q_8

$D_4 = \{ a,\ a^2 = e = b^4,\ ab,\ ab^2,\ ab^3,\ b,\ b^2,\ b^3 \}$

$o(1) = 1$
$o(2) = 5$
$o(4) = 2$

$Q_8 = \langle \pm 1, \pm i, \pm j, \pm k \rangle$

$o(1) = 1,\ o(-1) = 2,\ o(\pm i) = o(\pm j) = o(\pm k) = 4$

$O(G) = 9 = 3^2$

cyclic

abelian

Z_9

$Z_3 \times Z_3$

1 1

3 3

1

3

9

$\phi(1) = 1$

$\phi(3) = 2$

$\phi(9) = 6$

1

$3^2 - 1 = 8$

$O(G) = 10 = 2 \times 5$

$2 \mid 5-1$

abelian

cyclic

Z_{10}

$\phi(1) = 1$

$\phi(2) = 1$

$\phi(5) = 4$

$\phi(10) = 4$

Non abelian

$D_5 = \{ a, \; a^2 = e = b^5$

$ab, \; ab^2, \; ab^3, \; ab^4$

$b, \; b^2, \; b^3, \; b^4$

$o(1) = 1$

$o(2) = 5$

$o(5) = 4$

$o(G) = 11$

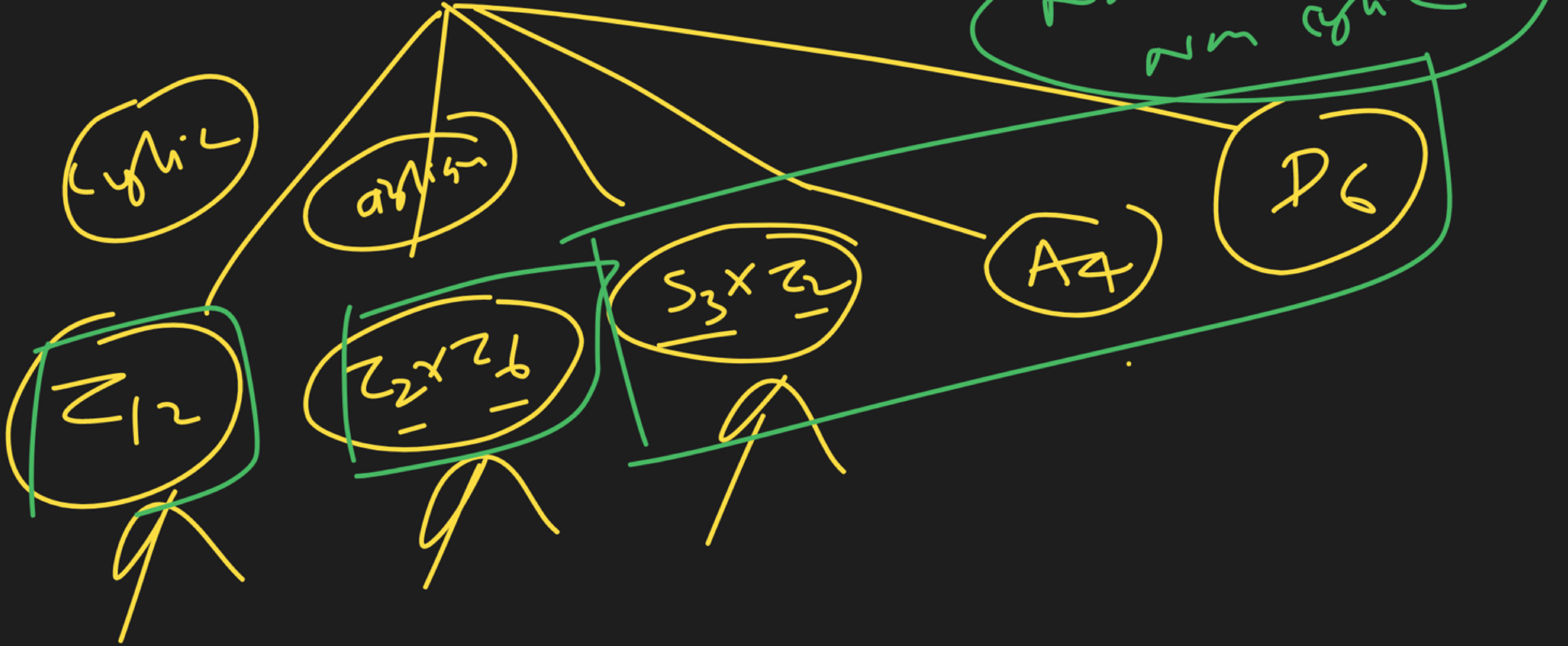
cyclic

Z_{11}

$\phi(11) = 1$

$\phi(11)\ 10$

$o(G) = 12$


cyclic
abelian
Z_{12}
$Z_2 \times Z_6$
$S_3 \times Z_2$
A_4
D_6
Non abelian
non cyclic

$O(4) = 13 = p$

Z_{13}

cyclic

$o(G) = 14 = 2 \times 7$

Non abelian

$2 \mid 7-1$

Cyclic

$\mathbb{Z}_{14}$

D_7

$o(G) = 15 = 3 \times 5$

$\mathbb{Z}_{15}$

$3 \nmid 5 = 1$

$\mathbb{Z}_2 \times \mathbb{Z}_6$

$\gcd(3,6) = 3$

$\mathbb{Z}_2 \times \mathbb{Z}_6$

$A_3 = \frac{3!}{2} = 3$

$(1,1)$

$\cancel{(1,2)}$

$(1,3)$

$\cancel{(1,1)}$

$\cancel{(3,1)}$

$\cancel{(2,2)}$

$\cancel{(2,3)}$

$\cancel{(2,6)}$

Q.1. Let G be a group of order 12 then which of the following is true

(a) G is always abelian group

(b) G has always an element of order 6

(c) G has always an elements of order 3

(d) None of these

$\mathbb{Z}_{12}$ $\quad$ $\mathbb{Z}_2 \times \mathbb{Z}_6$ $\quad$ D_6 $\quad$ A_4

$S_3 \times \mathbb{Z}_2$

$A_4 \subseteq S_4$

Q.2. Which of the following is true

(a) G is always abelian group if $O(G) < 6$

(b) G is always cyclic group if $O(G) < 6$

(c) $\exists$ a group of order 9 which is non - abelian

(d) None of these

$1 < 9$

(p^2)

Q.3. Let G be a group of order 8 then which of the following is always true

(a) G is always abelian

(b) G is always non – abelian group

(c) G has an elements of order 8

(d) None of these

Q.4. Which of the following is true

(a) G is always abelian group if $O(G) = 12$

(b) G is always cyclic group if $O(G) = 11$

(c) Every elements of order 11 in G if $O(G) = 11$

(d) None of these

A_4

Z_{11}

1

11

Result :

(1) If $O(G) = pq$ where $p < q$

(i) If $p \nmid q - 1$ then G is cyclic

(ii) If $p \mid q - 1$ then G may not be abelain group

(2) If G is non – abelian group of order pq where $p < q$ then

(i) G has an elements of order q are $q - 1$

(ii) G has an elements of order p are $q(p - 1)$

(3) If G is abelian group of order pq then G is cyclic group

Q.5. If G is abelian group then Which of the following is true

(a) G is always cyclic group if O(G) = 14

(b) G is always cyclic group if O(G) = 12

(c) G is always cyclic group if O(G) = 20

(d) G is always cyclic group if O(G) = 21

2×7

$2^2 \times 5$

Q.6. Which of the following is cyclic group

(a) O(G) = 14

(b) if O(G) = 77

(c) if O(G) = 35

(d) if O(G) = 21

(a) a, b

(b) b, c

(c) a, d

(d) a, d

7 × 11

7 ∤ 11 − 1

5 × 7

5 ∤ 7 − 1

3 × 7

3 | 7 − 1

Q.1. Consider the set of matrices $G = \left\{ \begin{bmatrix} s & b \\ 0 & 1 \end{bmatrix} : b \in \mathbf{Z}\ ,\ s \in \{-1, 1\} \right\}$. Then which of the following is true

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(a) G forms a group under addition

(b) G forms a abelian group under multiplication

(c) Every elements in G is diagonalizable over C

(d) G is finitely generated group under multiplication

Q.2. Let G be finite abelian group and $a, b \in G$ with order $(a) = m$, order $(b) = n$. which of the following are necessarily true **CSIR NET DEC. 2017**

(a) Order $(ab) = mn$

(b) Order $(ab) = \text{lcm}\{m,n\}$

(c) There is an elements of G whose order is $\text{lcm}\{a, b\}$

(d) Order$(ab) = \gcd(m, n)$

Q.3. Let G be a non – abelian group. then its order can be

(a) 25 (b) 55

(c) 125 (d) 35

Q.4. The number of generator of the additive group Z_{36} is equal to **IIT - JAM 2017**

(a) 6 (b) 12

(c) 18 (d) 36

Q.5. The value of α for which G = $\{\alpha, 1, 3, 9, 19, 27\}$ is a cyclic group under multiplication modulo 56 is

a) 5
b) 15
c) 25
d) 35

Q.6. Which of the following statements is/are TRUE?

a) If G is abelian then $(ab)^n = a^n b^n \ \forall \ n \in \mathbb{N} \ \& \ \forall \ a, b \in G$

b) If G is abelian then $\forall \ n \in \mathbb{N} \ \& \ \forall \ a, b \in G$, $(aba^{-1})^n = ab^n a^{-1}$.

c) If G is a group & $\forall \ n \in \mathbb{N} \ \& \ \forall \ a, b \in G$, $(aba^{-1})^n = ab^n a^{-1}$ then G is abelian.

d) None of these

Q.7 Let $G = Z_{15} \times Z_{10}$ be a group. then which of the following is true

(a) G has exactly one element of order 2

(b) G has exactly 5 element of order 3

(c) G has exactly 24 element of order 5

(d) G has exactly 24 element of order 10

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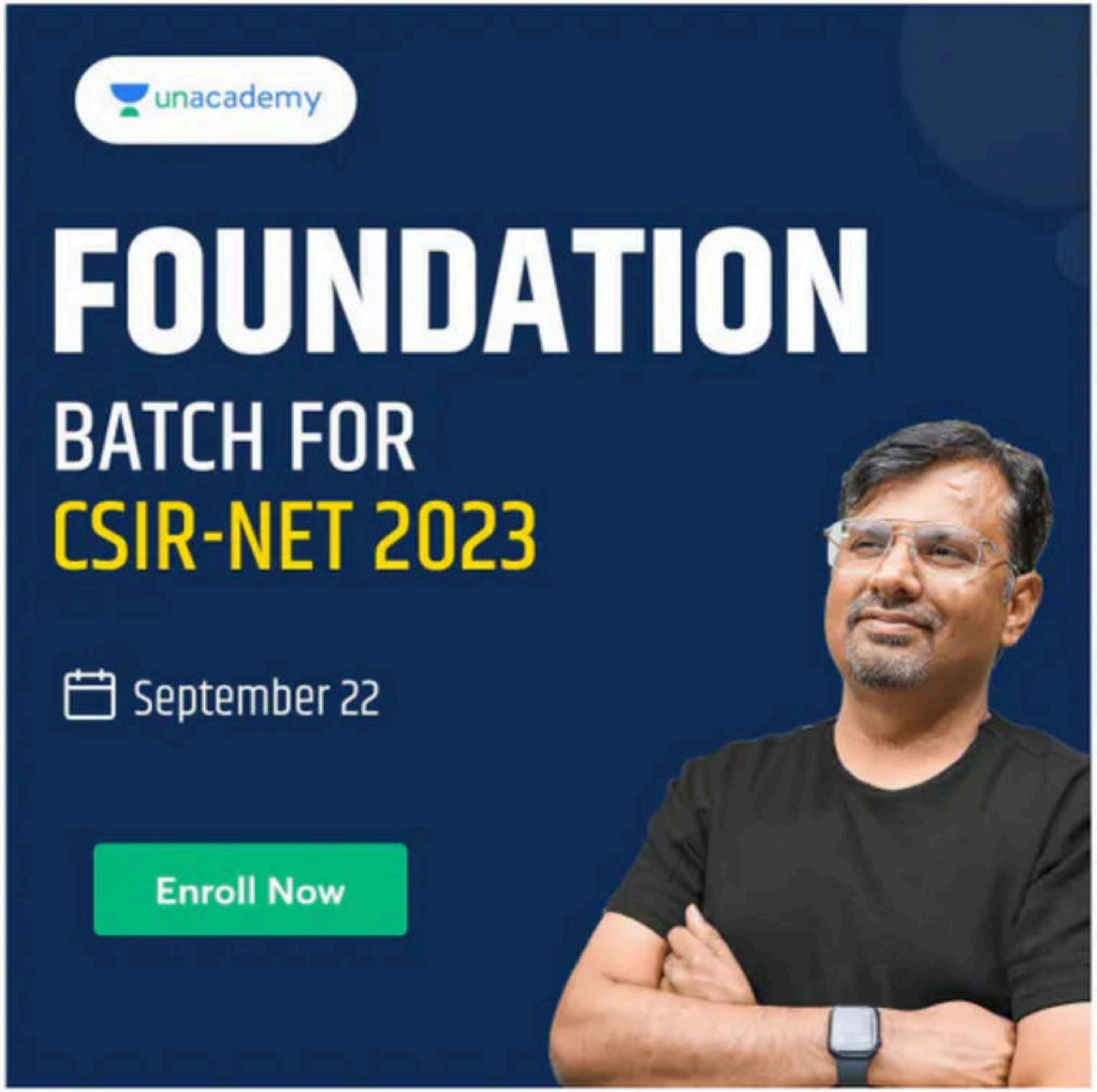
Q.8. What is the order of $GL_3(Z_4)$?

(a) $54\times72\times78\times80$

(b) $48\times60\times63$

(c) $\frac{54\times72\times78\times80}{3}$

(d) $\frac{48\times60\times63}{3}$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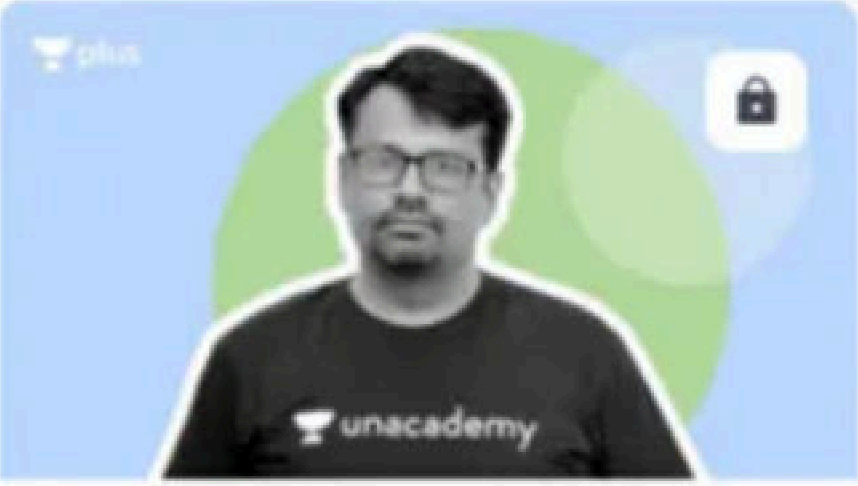

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HINDI MATHEMATICAL SCIENCES

Course on Complex Analysis & Integral Equation

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Educator highlights

- Works at **Pacific Science College**
- Studied at **M.Sc., NET, PhD(Algebra), MBA(Finance), BEd**
- PhD, NET | Plus Educator For CSIR NET | Youtuber (260K+Subs.) | Director Pacific Science College |
- Lives in **Udaipur, Rajasthan, India**
- Unacademy Educator since

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