Gajendra Purohit

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Permutation Group

Lecture Index:-i) Construction of S_n

ii) Properties of S_n

iii) Even/odd permutation

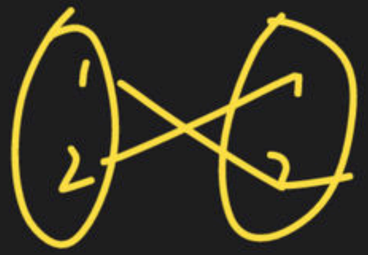
Symmetric Set/Permutation Set -:Set of all one-one onto mapping from set containing n elements to itself. It's denoted by S_n. The number of elements in S_n is n! $[o(S_n) = n!]$

$S_1 = \{e\}$

$o(S_4) = 4! = 24$

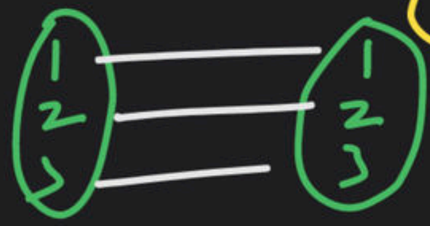
$S_2 = \langle e, (12) \rangle$

$\begin{pmatrix} 1 & 2 \\ 1 & 2 \end{pmatrix} = e$



$\begin{pmatrix} 1 & 2 \\ 2 & 1 \end{pmatrix} = (12)$

$S_3 = \langle e, (23), (13), (12), (123), (132) \rangle$



$\begin{pmatrix} 1 & 2 & 3 \\ 1 & 3 & 2 \end{pmatrix}$

$\begin{pmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \end{pmatrix}$

$\begin{pmatrix} 1 & 2 & 3 \\ 2 & 1 & 3 \end{pmatrix}$

$\begin{pmatrix} 1 & 2 & 3 \\ 2 & 3 & 1 \end{pmatrix}$

Properties of S_n

Cyclic/cycles Permutation-: Let S be a finite set. Let $a \in S$ and σ be a permutation on S.

Length of cycle-: An element $\sigma \in S_n$ is called cycle of length r if there exist r symbols such that $(i_1, i_2, i_3, \ldots i_r)$.

If length of cycle is r then it is called r - cycle

Disjoint cycle-:let $c_1 = (a_1, a_2, a_3, \ldots a_r)$ and $c_2 = (b_1, b_2, b_3, \ldots b_s)$ be two cycles, c_1, c_2 are called disjoint if there is no common symbol in these two cycles i.e., $(a_1, a_2, a_3, \ldots a_r) \cap (b_1, b_2, b_3, \ldots b_s) = \phi$

$f_1 = (123)$

$f_2 = (45)$

$f_1 = (12)$

$f_2 = (26)$

Transposition-: Every cycle of length 2 is a transposition.

(1 2 3 4 5)

4

Note-: i) every permutation $\sigma \in S_n$ can be expressed as a product of disjoint cycles.

ii) Every r-cycle can be expressed as a product of (r-1) transposition.

(1 - 2 - 2 - 2

$(1\,2\,3\,4) = (1\,4)(1\,3)(1\,2)$

even — odd transpos

$(1\,4)(1\,3)(1\,2) = \begin{pmatrix}1&2&3&4\\4&2&3&1\end{pmatrix}\begin{pmatrix}1&2&3&4\\3&2&1&4\end{pmatrix}\begin{pmatrix}1&2&3&4\\2&1&3&4\end{pmatrix}$

$= \begin{pmatrix}1&2&3&4\\2&3&4&1\end{pmatrix} = (1\,2\,3\,4)$

Product of permutation-: let $\sigma_1 \in S_n$ & $\sigma_2 \in S_n$ be two permutation of S_n, then product of permutation is $\sigma_1\sigma_2 \in S_n$.

$\sigma_1 = (123)$

$\sigma_2 = (1324) = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 3 & 4 & 2 & 1 \end{pmatrix}$

$\sigma_1\sigma_2 = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 2 & 3 & 1 & 4 \end{pmatrix} \begin{pmatrix} 1 & 2 & 3 & 4 \\ 3 & 4 & 2 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 1 & 4 & 3 & 2 \end{pmatrix} = (24)$

$\sigma_1^{-1} = (321) = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 3 & 1 & 2 & 4 \end{pmatrix}$

$\sigma_2^{-1} = (4231)$

$\sigma_2^{-1} = \begin{pmatrix} 3 & 4 & 2 & 1 \\ 1 & 2 & 3 & 4 \end{pmatrix}$

$\sigma_2^{-1} = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 4 & 3 & 1 & 2 \end{pmatrix}$

$= (1423)$

$= (4231)$

Even & Odd permutation

The number of transposition in decomposition of any permutation σ is either always odd or always even according to σ is odd or even permutation.

Odd permutation-: If $\sigma \in S_n$ be r-cycle, then σ is odd permutation if r is even or σ has odd transposition.

Even permutation-: If $\sigma \in S_n$ be r-cycle, then σ is even permutation if r is odd or σ has even transposition.

NOTE-: The permutation groups S_n exactly half are even and half are odd.

$S_3 = \{ e, (123), (13), (2) \}$ (odd)

$A_3 = \{ e, (123), (132) \}$

Alternating group,(A_n)-: The set of all even permutation of $S_n$forms w.r.t composition of mappings. It's denoted by A_n and called alternating group of even permutation.

Order of alternating group, $A_n$is $\frac{n!}{2}$.

$\sigma = (1234) = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 2 & 3 & 4 & 1 \end{pmatrix}$

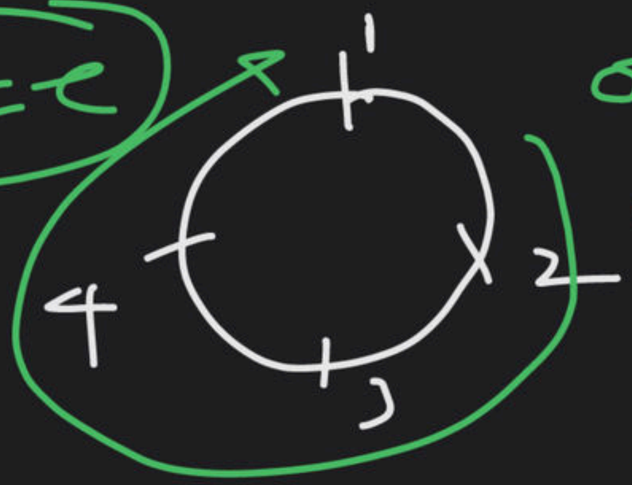
$\sigma^2 = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 2 & 3 & 4 & 1 \end{pmatrix}\begin{pmatrix} 1 & 2 & 3 & 4 \\ 2 & 3 & 4 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 3 & 4 & 1 & 2 \end{pmatrix}$

$= (13)(24)$

$\sigma^3 = \sigma^2\sigma = \begin{pmatrix} 1 & 2 & 3 & 4 \\ 3 & 4 & 1 & 2 \end{pmatrix}\begin{pmatrix} 1 & 2 & 3 & 4 \\ 2 & 3 & 4 & 1 \end{pmatrix}$

$= \begin{pmatrix} 1 & 2 & 3 & 4 \\ 4 & 1 & 2 & 3 \end{pmatrix} = (1432)$

$\sigma^4 = e$



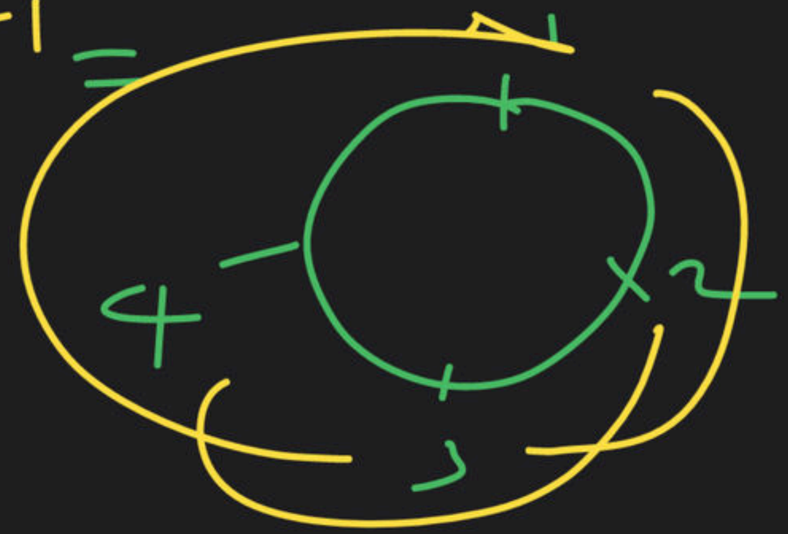
$\sigma^3 = (1432)$

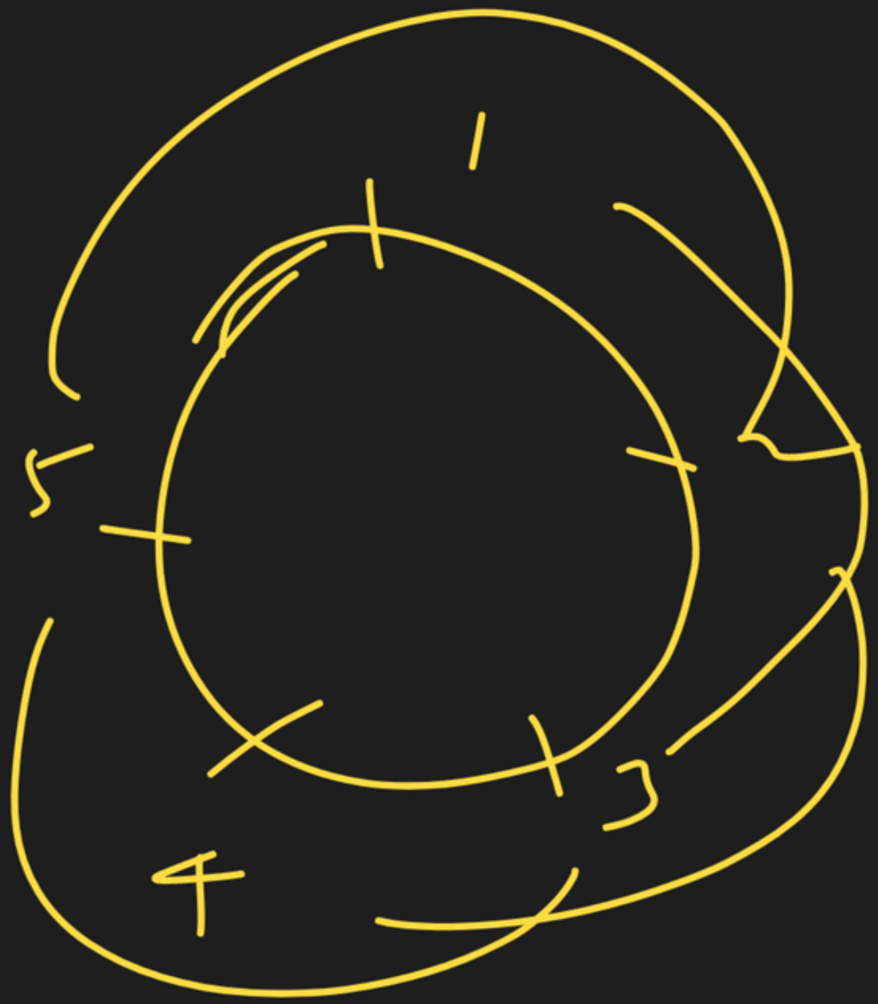
$\sigma^4 = (1)$

$\sigma^{55} = (\sigma^4)^{13}\sigma^3$

$= \sigma^3 = (1432)$

$\sigma^{-1} =$





$$\sigma = (1\ 2\ 3\ 4\ 5)$$

$$\sigma^2 = (1\ 3\ 5\ 2\ 4)$$

Q.1. : Let σ be the 100 cycle $(1\ 2\ 3\ \ldots\ 100)$ and let τ be the transposition $(49\ \ 50)$ in the permutation of $\sigma\tau$ is **IIT JAM 2019**

(a) 100 (b) 99

(c) 98 (d) 2

$\sigma = (1\,2\,3\,4\,5)$ Ans-

$T = (2\,3)$

$\sigma T = \begin{pmatrix}1&2&3&4&5\\2&3&4&5&1\end{pmatrix}\begin{pmatrix}1&2&3&4&5\\1&3&2&4&5\end{pmatrix}$

$= \begin{pmatrix}1&2&3&4&5\\2&4&3&5&1\end{pmatrix}$

$= (1\,2\,4\,5)$

Q2. Let $\alpha = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 2 & 1 & 3 & 5 & 4 & 6 \end{pmatrix}$ & $\beta = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 6 & 1 & 2 & 4 & 3 & 5 \end{pmatrix}$.

a) $\alpha^{-1} = \alpha$

b) $\beta^{-1} = \beta$

c) $\alpha\beta = \beta\alpha$

d) None of these

$\sigma^2 = e$

$\sigma = (1\ 2)(4\ 5)$

$o(\sigma) = lcm(2,2) = 2$

$\beta = (1\ 6\ 5\ 3\ 2)$

$o(\beta) = 5$

$\beta^5 = e$

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Q.3. Let $\alpha = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 2 & 3 & 4 & 5 & 1 & 7 & 8 & 6 \end{pmatrix}$ & $\beta = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 1 & 3 & 8 & 7 & 6 & 5 & 2 & 4 \end{pmatrix}$.

a) α cannot be written in product of disjoint cycles.

b) α is even permutation.

c) β is even permutation.

d) $\beta = (2\ 3\ 8\ 7\ 4)(5\ 6)$

$\sigma =$ (1 2 3 4 5) (6 7 8)

5

4 + 2

(2 3 8 4 7)(5 6)

4 | 1

Q.4. Which of the following statements is/are TRUE?

a) n be a positive integer, if n is odd then an n-cycle is odd permutation.

b) n be a positive integer, if n is odd then an n-cycle is even permutation.

c) If α is even $\Longrightarrow \alpha^{-1}$ is odd

d) If α is even $\Longrightarrow \alpha^{-1}$ is even

$\sigma = (123)$

$\sigma^{-1} = (132)$

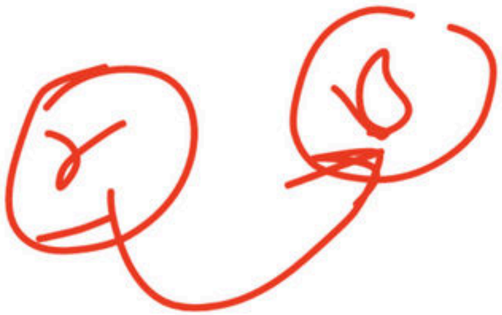
Q.5. Let α and β belong to S_n; $\alpha\beta \in A_n$, then which of the following is True?

(a) α is even and β is odd

(b) α is odd and β is even

(c) Both are even

(d) Both are odd



Q.6. Let $\sigma = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 2 & 1 & 3 & 5 & 4 & 6 \end{pmatrix}$ then which of the following is true?

(a) σ is cycle of length 4

(b) σ is product of disjoint cycle.

(c) $\sigma = (1\ 2\ 3\ 4)$

(d) None of these

$\sigma = (1\ 2)(4\ 5)$

$o(\sigma) = lcm(2,2) = 2$

Q.7. Let $\sigma = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 \\ 3 & 2 & 1 & 5 & 4 \end{pmatrix}$ then

(a) $\sigma = (1\ 2\ 3\ 4\ 5)$

(b) $\sigma = (1\ 3\ 2)(4\ 5)$

(c) $\sigma = (1\ 3)(4\ 5)$

(d) $\sigma = (1\ 4\ 5)(2\ 3)$

Q.8. Let $\sigma = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 6 & 2 & 4 & 5 & 1 & 3 \end{pmatrix}$ then number of transposition in σ

(a) 1 (b) 2 (c) 3

(d) 4

Q.9. Let $\sigma = \begin{pmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \end{pmatrix}, \tau = \begin{pmatrix} 1 & 2 & 3 \\ 2 & 1 & 3 \end{pmatrix}, J = \begin{pmatrix} 1 & 2 & 3 \\ 1 & 3 & 2 \end{pmatrix}$ then

(a) $O(\sigma\tau J) = 1$

(b) $O(\sigma\tau J) = 2$

(c) $O(\sigma) = 2$

(d) $O(\tau) = 3$

$\sigma\tau J = \begin{pmatrix} 1 & 2 & 3 \\ 2 & 1 & 3 \end{pmatrix} = (12)$

a|b

b|c

c|d

a|d

Q.10 . Let α and β are any two elements in S_n, then $\alpha^{-1}\beta^{-1}\alpha\,\beta$ is

a) Even
b) Odd
c) Depend on α and β
d) None of these

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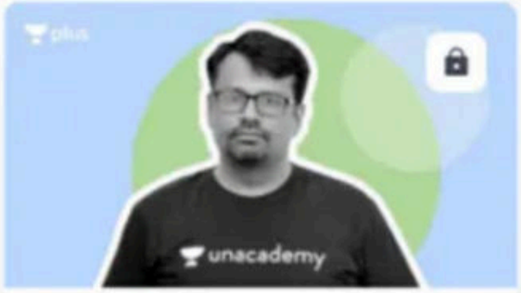

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- Studied at **M.Sc., NET, PhD(Algebra), MBA(Finance), BEd**
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- Lives in **Udaipur, Rajasthan, India**
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