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PERMUTATION & COMBINATION

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KEY CONCEPTS

DEFINITIONS :

- 1. **PERMUTATION :** Each of the arrangements in a definite order which can be made by taking some or all of a number of things is called a **PERMUTATION**.
- 2. **COMBINATION**: Each of the groups or selections which can be made by taking some or all of a number of things without reference to the order of the things in each group is called a **COMBINATION**.

FUNDAMENTAL PRINCIPLE OF COUNTING:

If an event can occur in 'm' different ways, following which another event can occur in 'n' different ways, then the total number of different ways of simultaneous occurrence of both events in a definite order is $m \times n$. This can be extended to any number of events.

RESULTS:

- (i) A Useful Notation : $n! = n (n 1) (n 2) \dots 3 \cdot 2 \cdot 1$; $n! = n (n 1)! 0! = 1! = 1; (2n)! = 2^n \cdot n! [1 \cdot 3 \cdot 5 \cdot 7 \dots (2n 1)]$ Note that factorials of negative integers are not defined.
- (ii) If ${}^{n}P_{r}$ denotes the number of permutations of n different things, taking r at a time, then ${}^{n}P_{r} = n (n-1) (n-2).... (n-r+1) = \frac{n!}{(n-r)!}$ Note that , ${}^{n}P_{n} = n!$.
- (iii) If ${}^{n}C_{r}$ denotes the number of combinations of n different things taken r at a time, then ${}^{n}C_{r} = \frac{n!}{r!(n-r)!} = \frac{{}^{n}P_{r}}{r!}$ where $r \le n$; $n \in N$ and $r \in W$.
- (iv) The number of ways in which (m + n) different things can be divided into two groups containing m & n things respectively is : $\frac{(m + n)!}{m!n!}$ If m = n, the groups are equal & in this case the number of subdivision

is $\frac{(2n)!}{n!n!2!}$; for in any one way it is possible to interchange the two groups without obtaining a new distribution. However, if 2n things are to be divided equally between two persons then the number of ways = $\frac{(2n)!}{n!n!}$.

(v) Number of ways in which (m + n + p) different things can be divided into three groups containing m, n & p things respectively is $\frac{(m + n + p)!}{m!n!p!}$, $m \neq n \neq p$. If m = n = p then the number of groups $= \frac{(3n)!}{n!n!n!3!}$.

However, if 3n things are to be divided equally among three people then the number of ways = $\frac{(3n)!}{(n!)^3}$.

- (vi) The number of permutations of *n* things taken all at a time when *p* of them are similar & of one type, q of them are similar & of another type, *r* of them are similar & of a third type & the remaining n (p + q + r) are all different is : $\frac{n!}{p!q!r!}$.
- (vii) The number of circular permutations of n different things taken all at a time is ; (n-1)!. If clockwise & anti-clockwise circular permutations are considered to be same, then it is $\frac{(n-1)!}{2}$. Note : Number of circular permutations of n things when p alike and the rest different taken all at a time distinguishing clockwise and anticlockwise arrangement is $\frac{(n-1)!}{n!}$.

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- (viii) Given n different objects, the number of ways of selecting at least one of them is, ${}^{n}C_{1} + {}^{n}C_{2} + {}^{n}C_{3} + \dots + {}^{n}C_{n} = 2^{n} - 1$. This can also be stated as the total number of combinations of n distinct things.
- (ix) Total number of ways in which it is possible to make a selection by taking some or all out of p+q+r+... things, where p are alike of one kind, q alike of a second kind, r alike of third kind & so on is given by: (p+1)(q+1)(r+1)...-1.
- (x) Number of ways in which it is possible to make a selection of m + n + p = N things, where p are alike of one kind, m alike of second kind & n alike of third kind taken r at a time is given by coefficient of x^r in the expansion of

 $(1 + x + x^2 + \dots + x^p)(1 + x + x^2 + \dots + x^m)(1 + x + x^2 + \dots + x^n).$

Note: Remember that coefficient of x^r in $(1-x)^{-n} = {}^{n+r-1}C_r$ ($n \in N$). For example the number of ways in which a selection of four letters can be made from the letters of the word **PROPORTION** is given by coefficient of x^4 in $(1 + x + x^2 + x^3) (1 + x + x^2) (1 + x + x^2) (1 + x) (1 + x) (1 + x)$.

- (xi) Number of ways in which n distinct things can be distributed to p persons if there is no restriction to the number of things received by men = p^n .
- (xii) Number of ways in which n identical things may be distributed among p persons if each person may receive none, one or more things is; ${}^{n+p-1}C_{n}$.
- (xiii)

a.

c.

$${}^{n}C_{r} = {}^{n}C_{n-r} ; {}^{n}C_{0} = {}^{n}C_{n} =$$

 ${}^{n}C_{r} + {}^{n}C_{r-1} = {}^{n+1}C_{r}$

= 1 ; **b.**
$${}^{n}C_{x} = {}^{n}C_{y} \Rightarrow x = y \text{ or } x + y = n$$

- (xiv) ${}^{n}C_{r}$ is maximum if: (a) $r = \frac{n}{2}$ if n is even. (b) $r = \frac{n-1}{2}$ or $\frac{n+1}{2}$ if n is odd.
- (xv) Let $N = p^{a.} q^{b.} r^{c.}$ where p, q, r.... are distinct primes & a, b, c.... are natural numbers then:
 - (a) The total numbers of divisors of N including 1 & N is = (a+1)(b+1)(c+1)...

(b) The sum of these divisors is
=
$$(p^0 + p^1 + p^2 + + p^a) (q^0 + q^1 + q^2 + + q^b) (r^0 + r^1 + r^2 + + r^c)....$$

(c) Number of ways in which N can be resolved as a product of two

factors is = $\frac{\frac{1}{2}(a+1)(b+1)(c+1)...}{\frac{1}{2}[(a+1)(b+1)(c+1)...+1]}$ if N is not a perfect square

- (d) Number of ways in which a composite number N can be resolved into two factors which are relatively prime (or coprime) to each other is equal to 2^{n-1} where n is the number of different prime factors in N.
- (xvi) Grid Problems and tree diagrams.

DEARRANGEMENT:

Number of ways in which n letters can be placed in n directed letters so that no letter goes into its own

envelope is = $n! \left[\frac{1}{2!} - \frac{1}{3!} + \frac{1}{4!} + \dots + (-1)^n \frac{1}{n!} \right].$

(xvii) Some times students find it difficult to decide whether a problem is on permutation or combination or both. Based on certain words / phrases occuring in the problem we can fairly decide its nature as per the following table :

PROBLEMS OF COMBINATIONS PROBLEMS OF PERMUTATIONS

- Arrangements
- Distributed group is formed
- Committee
- Geometrical problems

■ Selections, choose

- Standing in a line seated in a row
- problems on digits
- Problems on letters from a word

<u>EXERCISE–I</u>

- Q.1 The straight lines l_1 , $l_2 \& l_3$ are parallel & lie in the same plane. A total of m points are taken on the line l_1 , n points on $l_2 \&$ k points on l_3 . How many maximum number of triangles are there whose vertices are at these points?
- Q.2(a) How many five digits numbers divisible by 3 can be formed using the digits 0, 1, 2, 3, 4, 7 and 8 if each digit is to be used atmost once.
 - (b) Find the number of 4 digit positive integers if the product of their digits is divisible by 3.
- Q.3 There are 2 women participating in a chess tournament. Every participant played 2 games with the other participants. The number of games that the men played between themselves exceeded by 66 as compared to the number of games that the men played with the women. Find the number of participants & the total numbers of games played in the tournament.
- Q.4 All the 7 digit numbers containing each of the digits 1, 2, 3, 4, 5, 6, 7 exactly once, and not divisible by 5 are arranged in the increasing order. Find the (2004)th number in this list.
- Q.5 5 boys & 4 girls sit in a straight line. Find the number of ways in which they can be seated if 2 girls are together & the other 2 are also together but separate from the first 2.
- Q.6 A crew of an eight oar boat has to be chosen out of 11 men five of whom can row on stroke side only, four on the bow side only, and the remaining two on either side. How many different selections can be made?
- Q.7 An examination paper consists of 12 questions divided into parts A & B.
 Part-A contains 7 questions & Part–B contains 5 questions. A candidate is required to attempt 8 questions selecting atleast 3 from each part. In how many maximum ways can the candidate select the questions ?
- Q.8 In how many ways can a team of 6 horses be selected out of a stud of 16, so that there shall always be 3 out of A B C A' B' C', but never A A', B B' or C C' together.
- Q.9 During a draw of lottery, tickets bearing numbers 1, 2, 3,....., 40, 6 tickets are drawn out & then arranged in the descending order of their numbers. In how many ways, it is possible to have 4th ticket bearing number 25.
- Q.10 Find the number of distinct natural numbers upto a maximum of 4 digits and divisible by 5, which can be formed with the digits 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 each digit not occuring more than once in each number.
- Q.11 The Indian cricket team with eleven players, the team manager, the physiotherapist and two umpires are to travel from the hotel where they are staying to the stadium where the test match is to be played. Four of them residing in the same town own cars, each a four seater which they will drive themselves. The bus which was to pick them up failed to arrive in time after leaving the opposite team at the stadium. In how many ways can they be seated in the cars ? In how many ways can they travel by these cars so as to reach in time, if the seating arrangement in each car is immaterial and all the cars reach the stadium by the same route.
- Q.12 There are n straight lines in a plane, no 2 of which parallel, & no 3 pass through the same point. Their point of intersection are joined. Show that the number of maximum fresh lines thus introduced is $\frac{n(n-1)(n-2)(n-3)}{n}$
- Q.13 In how many ways can you divide a pack of 52 cards equally among 4 players. In how many ways the cards can be divided in 4 sets, 3 of them having 17 cards each & the 4th with 1 card.
- Q.14 A firm of Chartered Accountants in Bombay has to send 10 clerks to 5 different companies, two clerks in each. Two of the companies are in Bombay and the others are outside. Two of the clerks prefer to work in Bombay while three others prefer to work outside. In how many ways can the assignment be made if the preferences are to be satisfied.
- Q.15 A train going from Cambridge to London stops at nine intermediate stations. 6 persons enter the train during the journey with 6 different tickets of the same class. How many different sets of ticket may they have had?

- Q.16 How many arrangements each consisting of 2 vowels & 2 consonants can be made out of the letters of the word **'DEVASTATION'**?
- Q.17 Find the number of ways in which the letters of the word 'KUTKUT' can be arranged so that no two alike letters are together.
- Q.18 Find the number of words each consisting of 3 consonants & 3 vowels that can be formed from the letters of the word "**Circumference**". In how many of these c's will be together.
- Q.19 There are 5 white , 4 yellow , 3 green , 2 blue & 1 red ball. The balls are all identical except for colour. These are to be arranged in a line in 5 places. Find the number of distinct arrangements.
- Q.20 How many 4 digit numbers are there which contains not more than 2 different digits?
- Q.21 An 8 oared boat is to be manned by a crew chosen from 14 men of which 4 can only steer but can not row & the rest can row but cannot steer. Of those who can row, 2 can row on the bow side. In how many ways can the crew be arranged.
- Q.22(a) A flight of stairs has 10 steps. A person can go up the steps one at a time, two at a time, or any combination of 1's and 2's. Find the total number of ways in which the person can go up the stairs.
 - (b) You walk up 12 steps, going up either 1 or 2 steps with each stride. There is a snake on the 8th step, so you can not step there. Number of ways you can go up.
- Q.23 Each of 3 committees has 1 vacancy which is to be filled from a group of 6 people. Find the number of ways the 3 vacancies can be filled if;
 - (i) Each person can serve on atmost 1 committee.
 - (ii) There is no restriction on the number of committees on which a person can serve.
 - (iii) Each person can serve on atmost 2 committees.
- Q.24 How many ten digit whole numbers satisfy the following property they have 2 and 5 as digits, and there are no consecutive 2's in the number (i.e. any two 2's are separated by at least one 5).
- Q.25 In how many other ways can the letters of the word **MULTIPLE** be arranged;
- (i) without changing the order of the vowels
- (ii) keeping the position of each vowel fixed &
- (iii) without changing the relative order/position of vowels & consonants.
- Q.26 12 persons are to be seated at a square table, three on each side. 2 persons wish to sit on the north side and two wish to sit on the east side. One other person insists on occupying the middle seat (which may be on any side). Find the number of ways they can be seated.
- Q.27 How many integers between 1000 and 9999 have exactly one pair of equal digit such as 4049 or 9902 but not 4449 or 4040?
- Q.28 Determine the number of paths from the origin to the point (9, 9) in the cartesian plane which never pass through (5, 5) in paths consisting only of steps going 1 unit North and 1 unit East.
- Q.29 (i) Prove that : ${}^{n}P_{r} = {}^{n-1}P_{r} + r. {}^{n-1}P_{r-1}$
 - (ii) If ${}^{20}C_{r+2} = {}^{20}C_{2r-3}$ find ${}^{12}C_r$
 - (iii) Prove that ${}^{n-1}C_3 + {}^{n-1}C_4 > {}^{n}C_3$ if n > 7.
 - (iv) Find r if ${}^{15}C_{3r} = {}^{15}C_{r+3}$
- Q.30 There are 20 books on Algebra & Calculus in our library. Prove that the greatest number of selections each of which consists of 5 books on each topic is possible only when there are 10 books on each topic in the library.

EXERCISE-II

- Q.1 How many 6 digits odd numbers greater than 60,0000 can be formed from the digits 5, 6, 7, 8, 9, 0 if
 (i) repetitions are not allowed
 (ii) repetitions are allowed.
- Q.2 A man has 3 friends. In how many ways he can invite one friend everyday for dinner on 6 successive nights so that no friend is invited more than 3 times.
- Q.3 Find the number of 7 lettered words each consisting of 3 vowels and 4 consonants which can be formed using the letters of the word "DIFFERENTIATION".
- Q.4 Find the number of ways in which 3 distinct numbers can be selected from the set $\{3^1, 3^2, 3^3, \dots, 3^{100}, 3^{101}\}$ so that they form a G.P.
- Q.5 There are 2n guests at a dinner party. Supposing that the master and mistress of the house have fixed seats opposite one another, and that there are two specified guests who must not be placed next to one another. Show that the number of ways in which the company can be placed is $(2n-2)!.(4n^2-6n+4)$.
- Q.6 The members of a chess club took part in a round robin competition in which each plays every one else once. All members scored the same number of points, except four juniors whose total score were 17.5. How many members were there in the club? Assume that for each win a player scores 1 point, for draw 1/2 point and zero for losing.
- Q.7 In an election for the managing committee of a reputed club, the number of candidates contesting elections exceeds the number of members to be elected by r(r > 0). If a voter can vote in 967 different ways to elect the managing committee by voting atleast 1 of them & can vote in 55 different ways to elect (r-1) candidates by voting in the same manner. Find the number of candidates contesting the elections & the number of candidates losing the elections.

Instruction for question nos. 8 to 10:

2 Americal men; 2 British men; 2 Chinese men and one each of Dutch, Egyptial, French and German persons are to be seated for a round table conference.

- Q.8 If the number of ways in which they can be seated if exactly two pairs of persons of same nationality are together is p(6!), then find p.
- Q.9 If the number of ways in which only American pair is adjacent is equal to q(6!), then find q.
- Q.10 If the number of ways in which no two people of the same nationality are together given by r(6!), find r.
- Q.11 For each positive integer k, let S_k denote the increasing arithmetic sequence of integers whose first term is 1 and whose common difference is k. For example, S_3 is the sequence 1, 4, 7, 10..... Find the number of values of k for which S_k contain the term 361.
- Q.12 A shop sells 6 different flavours of ice-cream. In how many ways can a customer choose 4 ice-cream cones if
 - (i) they are all of different flavours (ii) they are non necessarily of different flavours
 - (iii) they contain only 3 different flavours (iv) they contain only 2 or 3 different flavours?
- Q.13 There are *n* triangles of positive area that have one vertex A(0, 0) and the other two vertices whose coordinates are drawn independently with replacement from the set $\{0, 1, 2, 3, 4\}$ e.g. (1, 2), (0, 1), (2, 2) etc. Find the value of *n*.
- Q.14(a) How many divisors are there of the number x = 21600. Find also the sum of these divisors.
 - (b) In how many ways the number 7056 can be resolved as a product of 2 factors.
 - (c) Find the number of ways in which the number 300300 can be split into 2 factors which are relatively prime.
 - (d) Find the number of positive integers that are divisors of atleast one of the numbers 10^{10} ; 15^7 ; 18^{11} .
- Q.15 How many 15 letter arrangements of 5 A's, 5 B's and 5 C's have no A's in the first 5 letters, no B's in the next 5 letters, and no C's in the last 5 letters.

- Q.16 How many different ways can 15 Candy bars be distributed between Ram, Shyam, Ghanshyam and Balram, if Ram can not have more than 5 candy bars and Shyam must have at least two. Assume all Candy bars to be alike.
- Q.17 Find the number of three digits numbers from 100 to 999 inclusive which have any one digit that is the average of the other two.
- Q.18 Find the number of distinct throws which can be thrown with 'n' six faced normal dice which are indistinguishable among themselves.
- Q.19 There are 15 rowing clubs; two of the clubs have each 3 boats on the river; five others have each 2 and the remaining eight have each 1; find the number of ways in which a list can be formed of the order of the 24 boats, observing that the second boat of a club cannot be above the first and the third above the second. How many ways are there in which a boat of the club having single boat on the river is at the third place in the list formed above?
- Q.20 Consider a 7 digit telephone number 336 7624 which has the property that the first three digit prefix, 336 equals the product of the last four digits. How many seven digit phone numbers beginning with 336 have this property, e.g. (336–7624)
- Q.21 Find the sum of all numbers greater than 10000 formed by using the digits 0, 1, 2, 4, 5 no digit being repeated in any number.
- Q.22 There are 3 cars of different make available to transport 3 girls and 5 boys on a field trip. Each car can hold up to 3 children. Find
- (a) the number of ways in which they can be accomodated.
- (b) the numbers of ways in which they can be accomodated if 2 or 3 girls are assigned to one of the cars.In both the cases internal arrangement of children inside the car is considered to be immaterial.
- Q.23 Find the number of three elements sets of positive integers $\{a, b, c\}$ such that $a \times b \times c = 2310$.
- Q.24 Find the number of integer between 1 and 10000 with at least one 8 and at least one 9 as digits.

<u>EXERCISE–III</u>

Q.1	How many different nine digit numbers can be formed from the number 223355888 by rearranging its							
	digits so that the	[JEE '2000, (Scr)]						
	(A) 16	(B) 36	(C) 60	(D) 180				
Q.2	Let T _n denote the	e number of triangles	which can be formed using	the vertices of a regular polygon of				
	'n' sides. If T_{n+1}	$_{1} - T_{n} = 21$, then 'n'	[JEE '2001, (Scr)]					
	(A) 5	(B) 7	(C) 6	(D) 4				
Q.3	The number of arrangements of the letters of the word BANANA in which the two N's do not ap							
	adjacently is			[JEE 2002 (Screening), 3]				
	(A) 40	(B) 60	(C) 80	(D) 100				
Q.4	2.4 Number of points with integral co-ordinates that lie inside a triangle whose co-							
	(0, 0), (0, 21) and	d (21,0)	[JEE 2003 (Screening), 3]					
	(A) 210	(B) 190	$(n^2(C)) 220$	(D) None				
Q.5	Using permutation	on or otherwise, prove	here n is a positive integer.					
			(11:)	[JEE 2004, 2 out of 60]				
Q.6	A rectangle with sides $2m - 1$ and $2n - 1$ is divided into squares of unit length by drawing parallel lines as shown in the diagram, then the number of rectangles possible with odd side lengths is							
	$(A)(m+n+1)^2$		(B) 4^{m+n-1}					
	$(C) m^2 n^2$		(D) mn(m+1)(n+1)	+1)				
	[JEE 2005 (Screening), 3]							

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Q.7	If r, s, t are prime numbers and p, q are the positive integers such that their LCM of p, q is is									
	the numbers of ordered pair of (p, q) is									
	(A) 252	2 (B) 254	4	(C) 225		(D) 224	[JEE 2006, 3]			
Q.8	The lett	ers of the word COCH	IN are permuted	l and all the perm	utations	are arranged in	an alphabetical			
	order as in an English dictionary. The number of words that appear before the word COCHIN is									
	(A) 360) (B) 192	2	(C) 96		(D) 48	[JEE 2007, 3]			
Q.9	Consid	er all possible permutati	ions of the letter	rs of the word EN	DEAN	DEL				
	Match the statements / Expression in Column-I with the statements / Expressions in Column-II									
		Column-I			Colun	nn-II				
	(A)	The number of permuta	tions containing	g the word ENDE	EA is	(P)	5!			
	(B)	The number of permuta	ations in which t	ons in which the letter E occurs in the			2 × 5!			
	first and the last position is									
	(C) The number of permutations in which none of the letters D L N (R) $7 \times 5!$									
	occurs in the last five positions is									
	(D)	The number of permuta	ations in which	the letters A, E, C) occurs	(S)	21 × 5!			
		only in odd positions is		, ,			[JEE 2008, 6]			
O.10	The nu	mber of seven digit inte	gers, with sum	of the digits equa	al to 10 a	and formed by	using the digits			
	1, 2 and	13 only, is	<u> </u>				6 6			
	(A) 55	(B) 66		(C) 77		(D) 88	[JEE 2009, 3]			
	. ,									
			ANSWE	ER KEY						
			EXER	CISE–I						
Q.1 m	$^{h+n+k}C_3$ -	$({}^{\mathrm{m}}\mathrm{C}_{3} + {}^{\mathrm{n}}\mathrm{C}_{3} + {}^{\mathrm{k}}\mathrm{C}_{3})$	Q.2 (a) 744;	(b) 7704	Q.3 13	, 156				
Q.4 4	316527		Q.5 43200		Q.6 14	-5 IC 15C				
Q ./ 4	20		Q.8 960		Q.9 -	$C_2 \cdot {}^{13}C_3$				
0 10	1106		0 11 $12! \cdot \frac{1}{2}$	1!.4!	0.13	52! . 52!				
Q.10	1100		Q.II 12., (3)	!)4 2!	Q.15	$(13!)^4$ ' $3!(17!)$	3			
Q.14	5400		Q.15 ${}^{45}C_6$		Q.16 1	638				
Q.17	30		Q.18 22100,	, 52	Q.19 2	111				
Q.20	5/6	210	Q.21 4.(4!)	$^{2} \cdot ^{\circ}C_{4} \cdot ^{\circ}C_{2}$	Q.22 (a) 89, (b) 63	· · · · · · · · · · · · · · · · · · ·			
Q.23	120, 216	o, 210	Q.24 143		Q.25 (1	I) 3359; (II) 5	9; (m) 359			
Q.20	2 ! 5 ! 8 (ii) 792-	(iv) $r=3$	Q.27 3888		Q.28 3	0980				
Q.29 (II) 192 , (IV) $1-3$										
012	40 155	52	02 510	_15L=11	03 53	2770				
0.4 2	500		Q.2 510 Q.6 27		Q.7 10	3				
Q.8 (50		Q.9 64		Q.10 2	244				
Q.11	24		Q.12 (i) 15, (ii	i) 126, (iii) 60, (iv	0, (iv) 105					
Q.13	256 Q.14 (a) 72; 78120; (b) 23; (c) 32; (d) 435									
Q.15	Q.16 440 Q.17 121									
0.10	n + 5 G		24!	°C 2	3!					
Q.18 ⁿ⁺³ C ₅ Q.19 $\overline{(3!)^2(2!)^5}$; ⁸ C ₁ . $\overline{(3!)^2(2!)^5}$										
Q.20	84		Q.21 311997	6	Q.22 (a) 1680; (b) 1	1140			
Q.23	40		Q.24 974							
EXERCISE-III										
Q.1 C Q.2 B Q.3 A Q.4 B Q.6 C Q.7 C Q.8 C Q.9 (A) P; (B) S; (C) Q; (D) O Q.10 C										

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