Chapter 6: Permutations and Combinations

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Exercise 6.1 — Exercise 6.1

Q1 How many 3-digit numbers can be formed from the digits 1, 2, 3, 4 and 5 assuming that (i) repetition of the digits is allowed? (ii) repetition of the digits is not allowed?

SOLUTION

(i) With repetition allowed:
Each of the 3 places can be filled by any of the 5 digits.
By the multiplication principle, the number of 3-digit numbers = 5 × 5 × 5 = 125.

(ii) Without repetition:
The hundreds place can be filled in 5 ways. After choosing one digit, the tens place can be filled in 4 ways, and the units place in 3 ways.
By the multiplication principle, the number of 3-digit numbers = 5 × 4 × 3 = 60.

Answer: (i) 125, (ii) 60

Q2 How many 3-digit even numbers can be formed from the digits 1, 2, 3, 4, 5, 6 if the digits can be repeated?

SOLUTION

For a number to be even, its units digit must be even: 2, 4, or 6 (3 choices).
The tens place can be filled by any of the 6 digits (6 choices).
The hundreds place can also be filled by any of the 6 digits (6 choices).
By the multiplication principle, the required count = 6 × 6 × 3 = 108.

Answer: 108

Q3 How many 4-letter codes can be formed using the first 10 letters of the English alphabet, if no letter can be repeated?

SOLUTION

We need to fill 4 places using the first 10 letters (A through J), with no repetition.
The 1st place: 10 choices.
The 2nd place: 9 choices (one letter used).
The 3rd place: 8 choices.
The 4th place: 7 choices.
By the multiplication principle, the number of 4-letter codes = 10 × 9 × 8 × 7 = 5040.

Answer: 5040

Q4 How many 5-digit telephone numbers can be constructed using the digits 0 to 9 if each number starts with 67 and no digit appears more than once?

SOLUTION

The first two digits are fixed as 6 and 7. We need to choose the remaining 3 digits from the digits 0–9 excluding 6 and 7, i.e., from 8 remaining digits, without repetition.
The 3rd place: 8 choices.
The 4th place: 7 choices.
The 5th place: 6 choices.
By the multiplication principle, the number of telephone numbers = 8 × 7 × 6 = 336.

Answer: 336

Q5 A coin is tossed 3 times and the outcomes are recorded. How many possible outcomes are there?

SOLUTION

Each toss has 2 possible outcomes: Head (H) or Tail (T).
For 3 tosses, by the multiplication principle:
Total outcomes = 2 × 2 × 2 = 8.

Answer: 8

Q6 Given 5 flags of different colours, how many different signals can be generated if each signal requires the use of 2 flags, one below the other?

SOLUTION

We need to choose and arrange 2 flags from 5 different flags, where order matters (one below the other gives a different signal than the reverse).

The upper position can be filled in 5 ways.

The lower position can be filled in 4 ways (any remaining flag).

By the multiplication principle, the number of signals = 5 × 4 = 20.

Answer: 20

Exercise 6.2 — Exercise 6.2

Q1 Evaluate (i) 8! (ii) 4! – 3!

SOLUTION

(i) 8! = 1 × 2 × 3 × 4 × 5 × 6 × 7 × 8 = 40320.

(ii) 4! – 3! = (1 × 2 × 3 × 4) – (1 × 2 × 3) = 24 – 6 = 18.

Answer: (i) 40320, (ii) 18

Q2 Is 3! + 4! = 7! ?

SOLUTION

Left side: 3! + 4! = 6 + 24 = 30.
Right side: 7! = 5040.
Since 30 ≠ 5040, we conclude 3! + 4! ≠ 7!.

Answer: No, 3! + 4! = 30 ≠ 5040 = 7!

Q3 Compute 8! / (6! × 2!)

SOLUTION

8! / (6! × 2!) = (8 × 7 × 6!) / (6! × 2!) = (8 × 7) / 2! = 56 / 2 = 28.

Answer: 28

Q4 If 1/6! + 1/7! = x/8!, find x.

SOLUTION

We have 1/6! + 1/7! = x/8!.
Multiply throughout by 8!:
8!/6! + 8!/7! = x
=> (8 × 7) + 8 = x
=> 56 + 8 = x
=> x = 64.

Answer: x = 64

Q5 Evaluate n! / (n – r)!, when (i) n = 6, r = 2 (ii) n = 9, r = 5.

SOLUTION

(i) n = 6, r = 2:

n! / (n – r)! = 6! / (6 – 2)! = 6! / 4! = (6 × 5 × 4!) / 4! = 6 × 5 = 30.

(ii) n = 9, r = 5:

n! / (n – r)! = 9! / (9 – 5)! = 9! / 4! = 9 × 8 × 7 × 6 × 5 = 15120.

Answer: (i) 30, (ii) 15120

Exercise 6.3 — Exercise 6.3

Q1 How many 3-digit numbers can be formed by using the digits 1 to 9 if no digit is repeated?

SOLUTION

We need to arrange 3 digits from 9 distinct digits (1–9) with no repetition.
This is the number of permutations of 9 objects taken 3 at a time:
$^{9}P_{3} = 9! / (9 – 3)! = 9! / 6! = 9 \times 8 \times 7 = 504$.

Answer: 504

Q2 How many 4-digit numbers are there with no digit repeated?

SOLUTION

Digits available: 0–9 (10 digits total). A 4-digit number cannot start with 0.
The thousands (leading) digit: 9 choices (1–9, since 0 not allowed).
The remaining 3 places are filled from the remaining 9 digits (including 0) without repetition:
$9 \times 9 \times 8 \times 7 = 4536$.

Alternatively: Total arrangements of 10 digits taken 4 at a time = $^{10}P_{4} = 5040$.
Arrangements with 0 at the thousands place = $^{9}P_{3} = 504$ (fix 0, arrange 3 from remaining 9).
Required count = 5040 – 504 = 4536.

Answer: 4536

Q3 How many 3-digit even numbers can be made using the digits 1, 2, 3, 4, 6, 7, if no digit is repeated?

SOLUTION

Available digits: 1, 2, 3, 4, 6, 7 (6 digits total). Even digits: 2, 4, 6.
For an even number, the units digit must be even: 3 choices (2, 4, or 6).
The hundreds digit: 5 choices (any digit except the one used in units place).
The tens digit: 4 choices (any digit except the two already used).
By the multiplication principle, the required count = $5 \times 4 \times 3 = 60$.

Answer: 60

Q4 Find the number of 4-digit numbers that can be formed using the digits 1, 2, 3, 4, 5 if no digit is repeated. How many of these will be even?

SOLUTION

Total 4-digit numbers using digits 1–5 without repetition:
$^5P_4 = 5! / (5 – 4)! = 5! / 1! = 120$.

For even numbers, the units digit must be 2 or 4 (2 choices).
After fixing the units digit, the remaining 3 places are filled from the remaining 4 digits:
$^4P_3 = 4 \times 3 \times 2 = 24$.
Number of even 4-digit numbers = $2 \times 24 = 48$.

Answer: Total 4-digit numbers: 120; even numbers: 48

Q5 From a committee of 8 persons, in how many ways can we choose a chairman and a vice chairman assuming one person can not hold more than one position?

SOLUTION

We need to choose 2 persons from 8 for two distinct positions (order matters).
Number of ways = $^8P_2 = 8! / (8 – 2)! = 8! / 6! = 8 \times 7 = 56$.

Answer: 56

Q6 Find n if $(n – 1)P_3 : nP_4 = 1 : 9$.

SOLUTION

Given: $(n–1)P_3 / nP_4 = 1/9$.

$(n–1)P_3 = (n–1)(n–2)(n–3)$
$nP_4 = n(n–1)(n–2)(n–3)$

So: $(n–1)(n–2)(n–3) / [n(n–1)(n–2)(n–3)] = 1/9$
$\Rightarrow 1/n = 1/9$
$\Rightarrow n = 9$.

Answer: n = 9

Q7 Find r if (i) $^5P = 2 \cdot {}^6P_{r-1}$ (ii) $^5P = {}^6P_{r-1}$

SOLUTION

(i) $^5P = 2 \cdot {}^6P_{r-1}$

$\Rightarrow 5!/(5-r)! = 2 \cdot 6!/(6-r+1)! = 2 \cdot 6!/(7-r)!$

$\Rightarrow 5!/(5-r)! = 2 \cdot 6 \cdot 5!/(7-r)(6-r)(5-r)!$

$\Rightarrow 1 = 12 / [(7-r)(6-r)]$

$\Rightarrow (7-r)(6-r) = 12$

$\Rightarrow 42 - 13r + r^2 = 12$

$\Rightarrow r^2 - 13r + 30 = 0$

$\Rightarrow (r - 3)(r - 10) = 0$

$\Rightarrow r = 3$ or $r = 10$.

Since $r \le 5$ (as $r \le n = 5$), we have $r = 3$.

(ii) $^5P = {}^6P_{r-1}$

$\Rightarrow 5!/(5-r)! = 6!/(7-r)!$

$\Rightarrow 5!/(5-r)! = 6 \cdot 5!/(7-r)(6-r)(5-r)!$

$\Rightarrow 1 = 6 / [(7-r)(6-r)]$

$\Rightarrow (7-r)(6-r) = 6$

$\Rightarrow 42 - 13r + r^2 = 6$

$\Rightarrow r^2 - 13r + 36 = 0$

$\Rightarrow (r - 4)(r - 9) = 0$

$\Rightarrow r = 4$ or $r = 9$.

Since $r \le 5$, we have $r = 4$.

Answer: (i) $r = 3$, (ii) $r = 4$

Q8 How many words, with or without meaning, can be formed using all the letters of the word EQUATION, using each letter exactly once?

SOLUTION

The word EQUATION has 8 distinct letters: E, Q, U, A, T, I, O, N.

Using all 8 letters, each exactly once, the number of arrangements = $8! = 40320$.

Answer: 40320

Q9 How many words, with or without meaning can be made from the letters of the word MONDAY, assuming that no letter is repeated, if (i) 4 letters are used at a time, (ii) all letters are used at a time, (iii) all letters are used but first letter is a vowel?

SOLUTION

The word MONDAY has 6 distinct letters: M, O, N, D, A, Y. Vowels: O, A (2 vowels). Consonants: M, N, D, Y (4 consonants).

(i) 4 letters at a time (6 distinct letters):
${}^{6}P_{4} = 6 \times 5 \times 4 \times 3 = 360$.

(ii) All 6 letters at a time:
$6! = 720$.

(iii) All 6 letters, first letter is a vowel:
Choose the first letter from the 2 vowels (O or A): 2 ways.
Arrange the remaining 5 letters in the remaining 5 positions: $5! = 120$ ways.
Total $= 2 \times 120 = 240$.

Answer: (i) 360, (ii) 720, (iii) 240

Q10 In how many of the distinct permutations of the letters in MISSISSIPPI do the four I's not come together?

SOLUTION

The word MISSISSIPPI has 11 letters: M=1, I=4, S=4, P=2.

Total distinct permutations $= 11! / (4! \times 4! \times 2!) = 39916800 / (24 \times 24 \times 2) = 34650$.

Permutations where all 4 I's come together:
Treat the four I's as a single unit. We now have 8 units: {IIII}, M, S, S, S, S, P, P.
Arrangements $= 8! / (4! \times 2!) = 40320 / (24 \times 2) = 840$.

Permutations where the four I's do NOT come together:
$= 34650 - 840 = 33810$.

Answer: 33810

Q11 In how many ways can the letters of the word PERMUTATIONS be arranged if the (i) words start with P and end with S, (ii) vowels are all together, (iii) there are always 4 letters between P and S?

SOLUTION

The word PERMUTATIONS has 12 letters: P, E, R, M, U, T, A, T, I, O, N, S.
T appears 2 times; all other letters appear once.
Total arrangements = 12! / 2! = 239500800.

(i) Words starting with P and ending with S:
Fix P at the left end and S at the right end. The remaining 10 letters are: E, R, M, U, T, A, T, I, O, N (with T appearing twice).
Arrangements of the middle 10 letters = 10! / 2! = 1814400.

(ii) Vowels all together:
Vowels in PERMUTATIONS: E, U, A, I, O (5 distinct vowels).
Consonants: P, R, M, T, T, N, S (7 letters, T appears twice).
Treat all 5 vowels as one block. The block + 7 individual consonant letters gives 8 units total, with T×2.
Arrangements of the 8 units = 8! / 2! = 20160.
The 5 vowels within the block can be arranged in 5! = 120 ways.
Total = 20160 × 120 = 2419200.

(iii) Always 4 letters between P and S:
With 12 positions, we need positions (i) and (j) for the two letters P and S such that $|i - j| = 5$ (4 letters in between).
Possible position pairs (i, i+5): (1,6), (2,7), (3,8), (4,9), (5,10), (6,11), (7,12) — 7 pairs.
For each pair, one position gets P and the other gets S: 2 arrangements.
The remaining 10 positions are filled with the remaining letters: P, E, R, M, U, T, A, T, I, O, N (10 letters, T×2).
Arrangements = 10! / 2! = 1814400.
Total = 7 × 2 × 1814400 = 25401600.

Answer: (i) 1814400, (ii) 2419200, (iii) 25401600

Exercise 6.4 — Exercise 6.4

Q1 If $nC_8 = nC_2$, find nC_2.

SOLUTION

Using the property: nC = nC_b implies a = b or a + b = n.
Since 8 ≠ 2, we have n = 8 + 2 = 10.

$nC_2 = {}^{10}C_2 = 10! / (2! \times 8!) = (10 \times 9) / 2 = 45.$

Answer: 45

Q2 Determine n if (i) ${}^{2n}C_3 : nC_3 = 12 : 1$ (ii) ${}^{2n}C_3 : nC_3 = 11 : 1$

SOLUTION

(i) ${}^{2n}C_3 / nC_3 = 12$

${}^{2n}C_3 = (2n)(2n–1)(2n–2) / 6$
$nC_3 = n(n–1)(n–2) / 6$

Ratio = [(2n)(2n–1)(2n–2)] / [n(n–1)(n–2)]
= [2n · (2n–1) · 2(n–1)] / [n(n–1)(n–2)]
= 4(2n–1) / (n–2) = 12

=> 4(2n–1) = 12(n–2)
=> 8n – 4 = 12n – 24
=> 20 = 4n
=> n = 5.

(ii) ${}^{2n}C_3 / nC_3 = 11$

From the same ratio: 4(2n–1) / (n–2) = 11
=> 4(2n–1) = 11(n–2)
=> 8n – 4 = 11n – 22
=> 18 = 3n
=> n = 6.

Answer: (i) n = 5, (ii) n = 6

Q3 How many chords can be drawn through 21 points on a circle?

SOLUTION

A chord is determined by choosing any 2 of the 21 points (order does not matter).
Number of chords = $^{21}C_2$ = 21! / (2! × 19!) = (21 × 20) / 2 = 210.

Answer: 210

Q4 In how many ways can a team of 3 boys and 3 girls be selected from 5 boys and 4 girls?

SOLUTION

Number of ways to select 3 boys from 5 = $^5C_3$ = 10.
Number of ways to select 3 girls from 4 = $^4C_3$ = 4.
By the multiplication principle, total ways = 10 × 4 = 40.

Answer: 40

Q5 Find the number of ways of selecting 9 balls from 6 red balls, 5 white balls and 5 blue balls if each selection consists of 3 balls of each colour.

SOLUTION

Select 3 red balls from 6: $^6C_3$ = 20.
Select 3 white balls from 5: $^5C_3$ = 10.
Select 3 blue balls from 5: $^5C_3$ = 10.
By the multiplication principle, total ways = 20 × 10 × 10 = 2000.

Answer: 2000

Q6 Determine the number of 5 card combinations out of a deck of 52 cards if there is exactly one ace in each combination.

SOLUTION

A standard deck has 4 aces and 48 non-ace cards.
Choose exactly 1 ace from 4: $^4C_1$ = 4 ways.
Choose the remaining 4 cards from 48 non-ace cards: $^{48}C_4$ = (48 × 47 × 46 × 45) / 24 = 194580 ways.
Total combinations = 4 × 194580 = 778320.

Answer: 778320

Q7 In how many ways can one select a cricket team of eleven from 17 players in which only 5 players can bowl if each cricket team of 11 must include exactly 4 bowlers?

SOLUTION

5 players can bowl; the remaining 12 are non-bowlers.
Choose exactly 4 bowlers from 5: ${}^{5}C_{4} = 5$ ways.
Choose the remaining 7 players from 12 non-bowlers: ${}^{12}C_{7} = 12!/(7!\times5!) = 792$ ways.
Total ways = $5 \times 792 = 3960$.

Answer: 3960

Q8 A bag contains 5 black and 6 red balls. Determine the number of ways in which 2 black and 3 red balls can be selected.

SOLUTION

Choose 2 black balls from 5: ${}^{5}C_{2} = 10$.
Choose 3 red balls from 6: ${}^{6}C_{3} = 20$.
Total ways = $10 \times 20 = 200$.

Answer: 200

Q9 In how many ways can a student choose a programme of 5 courses if 9 courses are available and 2 specific courses are compulsory for every student?

SOLUTION

The 2 compulsory courses are always included. The student must choose 3 more courses from the remaining 7 courses.
Number of ways = ${}^{7}C_{3} = 7! / (3! \times 4!) = (7 \times 6 \times 5) / 6 = 35$.

Answer: 35

Misc — Miscellaneous Exercise

Q1 How many words, with or without meaning, each of 2 vowels and 3 consonants can be formed from the letters of the word DAUGHTER?

SOLUTION

The word DAUGHTER has 8 distinct letters.
Vowels: A, U, E (3 vowels). Consonants: D, G, H, T, R (5 consonants).

Choose 2 vowels from 3: ${}^{3}C_{2} = 3$.
Choose 3 consonants from 5: ${}^{5}C_{3} = 10$.
Number of groups of 5 letters = $3 \times 10 = 30$.

Each group of 5 letters can be arranged in $5! = 120$ ways.
Total words = $30 \times 120 = 3600$.

Answer: 3600

Q2 How many words, with or without meaning, can be formed using all the letters of the word EQUATION at a time so that the vowels and consonants occur together?

SOLUTION

The word EQUATION has 8 distinct letters.
Vowels: E, U, A, I, O (5 vowels). Consonants: Q, T, N (3 consonants).

For vowels and consonants to occur together, treat the vowel group as one block and the consonant group as another block.
We have 2 blocks, which can be arranged in $2! = 2$ ways.
The 5 vowels within their block can be arranged in $5! = 120$ ways.
The 3 consonants within their block can be arranged in $3! = 6$ ways.

Total words = $2! \times 5! \times 3! = 2 \times 120 \times 6 = 1440$.

Answer: 1440

Q3 A committee of 7 has to be formed from 9 boys and 4 girls. In how many ways can this be done when the committee consists of: (i) exactly 3 girls? (ii) at least 3 girls? (iii) at most 3 girls?

SOLUTION

(i) Exactly 3 girls (and 4 boys):
Choose 3 girls from 4: $^4C_3 = 4$.
Choose 4 boys from 9: $^9C_4 = 126$.
Total = $4 \times 126 = 504$.

(ii) At least 3 girls (3 or 4 girls):
Exactly 3 girls: 504 (from part i).
Exactly 4 girls (and 3 boys): $^4C_4 \times {}^9C_3 = 1 \times 84 = 84$.
Total = $504 + 84 = 588$.

(iii) At most 3 girls (0, 1, 2, or 3 girls):
0 girls (7 boys): $^4C_0 \times {}^9C_7 = 1 \times 36 = 36$.
1 girl (6 boys): $^4C_1 \times {}^9C_6 = 4 \times 84 = 336$.
2 girls (5 boys): $^4C_2 \times {}^9C_5 = 6 \times 126 = 756$.
3 girls (4 boys): 504 (from part i).
Total = $36 + 336 + 756 + 504 = 1632$.

Answer: (i) 504, (ii) 588, (iii) 1632

Q4 If the different permutations of all the letters of the word EXAMINATION are listed as in a dictionary, how many words are there in this list before the first word starting with E?

SOLUTION

The word EXAMINATION has 11 letters: E, X, A, M, I, N, A, T, I, O, N.
A appears 2 times, I appears 2 times, N appears 2 times; remaining letters E, X, M, T, O are distinct.

Words that come before those starting with E in dictionary order are words starting with A (since A < E alphabetically).

Words starting with A: fix A in the first position. The remaining 10 letters are: E, X, A, M, I, N, T, I, O, N, with I×2 and N×2.
Arrangements = $10! / (2! \times 2!) = 3628800 / 4 = 907200$.

Therefore, 907200 words appear before the first word starting with E.

Answer: 907200

Q5 How many 6-digit numbers can be formed from the digits 0, 1, 3, 5, 7 and 9 which are divisible by 10 and no digit is repeated?

SOLUTION

A number is divisible by 10 if and only if its units digit is 0.

Fix 0 at the units place. The remaining 5 digits (1, 3, 5, 7, 9) must fill the remaining 5 places (the leading digit can be any of these 5, so no zero-leading issue).

Number of arrangements of 5 digits in 5 places = 5! = 120.

Answer: 120

Q6 The English alphabet has 5 vowels and 21 consonants. How many words with two different vowels and 2 different consonants can be formed from the alphabet?

SOLUTION

Choose 2 different vowels from 5: ${}^{5}C_{2} = 10$.

Choose 2 different consonants from 21: ${}^{21}C_{2} = 210$.

Number of groups of 4 letters = 10 × 210 = 2100.

Each group of 4 letters can be arranged in 4! = 24 ways.

Total words = 2100 × 24 = 50400.

Answer: 50400

Q7 In an examination, a question paper consists of 12 questions divided into two parts i.e., Part I and Part II, containing 5 and 7 questions, respectively. A student is required to attempt 8 questions in all, selecting at least 3 from each part. In how many ways can a student select the questions?

SOLUTION

The student must attempt 8 questions total with at least 3 from Part I (5 questions) and at least 3 from Part II (7 questions).

The possible distributions (Part I, Part II) are: (3, 5), (4, 4), (5, 3).

Case 1 — 3 from Part I, 5 from Part II: ${}^{5}C_{3} \times {}^{7}C_{5} = 10 \times 21 = 210$.

Case 2 — 4 from Part I, 4 from Part II: ${}^{5}C_{4} \times {}^{7}C_{4} = 5 \times 35 = 175$.

Case 3 — 5 from Part I, 3 from Part II: ${}^{5}C_{5} \times {}^{7}C_{3} = 1 \times 35 = 35$.

Total ways = 210 + 175 + 35 = 420.

Answer: 420

Q8 Determine the number of 5-card combinations out of a deck of 52 cards if each selection of 5 cards has exactly one king.

SOLUTION

A standard deck has 4 kings and 48 non-king cards.
Choose exactly 1 king from 4: ${}^{4}C_{1} = 4$ ways.
Choose the remaining 4 cards from 48 non-king cards: ${}^{48}C_{4} = (48 \times 47 \times 46 \times 45) / 24 = 194580$ ways.
Total combinations = $4 \times 194580 = 778320$.

Answer: 778320

Q9 It is required to seat 5 men and 4 women in a row so that the women occupy the even places. How many such arrangements are possible?

SOLUTION

There are 9 seats in total. The even-numbered seats are 2, 4, 6, 8 — exactly 4 seats.
The 4 women must occupy these 4 even seats: they can be arranged in 4! = 24 ways.
The 5 men occupy the remaining 5 odd seats (1, 3, 5, 7, 9): they can be arranged in 5! = 120 ways.
Total arrangements = $4! \times 5! = 24 \times 120 = 2880$.

Answer: 2880

Q10 From a class of 25 students, 10 are to be chosen for an excursion party. There are 3 students who decide that either all of them will join or none of them will join. In how many ways can the excursion party be chosen?

SOLUTION

Let the 3 students who decide together be a group. Two cases arise:

Case 1 — All 3 join the party: The 3 students are included, so we choose the remaining 7 from the other 22 students.

Ways = $^{22}C_7$ = 170544.

Case 2 — None of the 3 joins: All 10 students are chosen from the remaining 22 students.
Ways = $^{22}C_{10}$ = 646646.

Total ways = 170544 + 646646 = 817190.

Answer: 817190

Q11 In how many ways can the letters of the word ASSASSINATION be arranged so that all the S's are together?

SOLUTION

The word ASSASSINATION has 13 letters: A=3, S=4, I=2, N=2, T=1, O=1.

Treat all 4 S's as a single unit {SSSS}. Together with the remaining 9 letters (A, A, A, I, N, I, N, T, O), we have 10 units to arrange.
These 10 units contain: A×3, I×2, N×2, T×1, O×1, and the S-block×1.

Number of arrangements = 10! / (3! × 2! × 2!) = 3628800 / (6 × 2 × 2) = 3628800 / 24 = 151200.

Answer: 151200