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First Edition : 2017

Second Edition : 2018

Third Edition : 2019

Fourth Edition : 2020

Fifth Edition : 2021

Sixth Edition : 2022

Seventh Edition : 2023

Typeset at : IES Master Publication, New Delhi-110016

PREFACE

Union Public Services Commission (UPSC) in its quest for best engineering minds looks for the very basic pride of an engineer, which it tests through quantitative and analytical abilities of candidates. The profession itself calls for putting candidates in situations, both human and technical, where things are tied into hundred knots. As an engineer one is expected to think critically, detect systematic themes while analysing data, and achieve thoroughness with accuracy in deriving solutions under challenging circumstances.

To test these qualities in an ESE, GATE & other Engineering Exam aspirant, in the year 2017, UPSC introduced Engineering Aptitude as a part of the syllabus for the common paper of ESE in 2017. Also, Engineering Apptitude is having good weightage in GATE & other engineering exams, and thus, it is important for GATE & others exams too. With an objective to develop these abilities, IES Master has come up with the revised and updated **Seventh edition** of the book Engineering Aptitude that acquaints an ESE aspirant to thousands of problems under various sub-heads such as probability, polynomials, speed-time, work-time, clock and calendar, as well as geometry and measurements that they might come across during their professional career. Covering more than **170 topics under 25 chapters in 5 units**, this book is an effort by IES Master to offer the complete theory of ESE syllabus along with previous years questions from **UPSC (last 40 years), GATE (last 14 years), and ESE (last 7 years) to the ESE aspirants**.

As you flip through the pages of this book, it captures your imagination with subtleness, and exposes you to more than **1,820^{+} problems**, enough to give your pen the required strength to take on any competitive exams including ESE, GATE and PSUs.

Having gone through the clarity and conciseness offered in this revised edition, we hope that as your fingers follow your command, the brain will engineer solutions no matter how difficult the challenge is.

IES Master Publication

New Delhi

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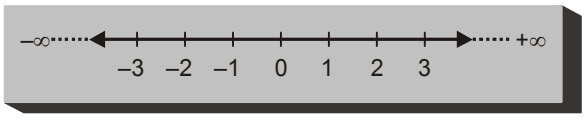
1.1 NUMBER SYSTEM

NUMBER LINE

Number line is a line on which all the positive and negative numbers can be represent in a sequence. It stretches from negative infinity to positive infinity.



DEFINITION OF VARIOUS TYPES OF NUMBERS

Natural Numbers

Counting Numbers 1, 2, 3, 4, ... are called Natural Numbers. The symbolic representation is N, i.e.,

N = {1, 2, 3, 4, 5, ...}.

Whole Numbers

All the natural numbers together with '0' are called Whole Numbers and the symbolic representation is W, i.e., W = {0, 1, 2, 3, 4, ...}

Integers

An integer is a number that can be written without a fractional component, it is represented by 'Z'.
Integers are further classified into positive integers (2, 4, 5 etc.), zero (0) and negative integers (–2, –5 etc.).

Rational Numbers

A number which can be expressed in the form of $\frac{p}{q}$ where, p and q are integers and $q \neq 0$, is called a rational number.

For example : *Any integer number is a rational number since, it can be written as the ratio of two integer numbers, one the integer number itself and another number is 1.*

Other examples of rational number are $\frac{2}{3}, -\frac{3}{7}, \ldots$ etc.

Note : *A decimal represents a rational number if and only if it has a finite number of digits. But recurring decimals are exceptions as they are also assumed as Rational Numbers, i.e., all recurring decimals are rational numbers.*

Irrational Numbers

A real number, which is not rational, is called **irrational number**. An irrational number has non-terminating and non-recurring decimal part.

Between any two numbers, there are infinite numbers of irrational numbers.

Examples of irrational numbers are : $\sqrt{3}, \sqrt{5}, \sqrt[3]{7}, \sqrt[4]{11}$

Numbers π and e are also irrational number because both have non-terminating and non-recurring decimal part.

π = 3.14159265358979… and e = 2.71828182859045… where, e is called Euler's number.

Note : *Any terminating **or** recurring decimal is a rational number. Any non-terminating **and** non-recurring decimal is an irrational number.*

Example 1

Which one of the following is not a rational number?

(a) $\frac{3}{8}$ (b) $-\frac{111}{23}$ (c) $\sqrt{2}$ (d) None of these

Sol. (c)

The number is option (a) and (b) are rational numbers, as they are the ratio of two integers. The number $\sqrt{2}$ is non-recurring, so it is not a rational number.

Real Numbers

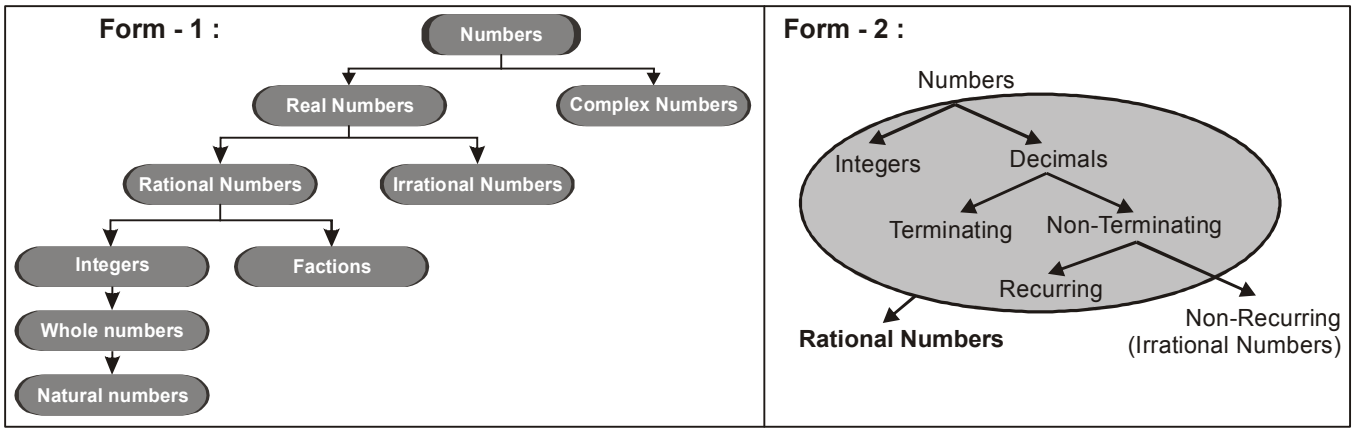
The real numbers include all the measuring numbers. The symbol for the real number is R. **All the numbers which can be represented on the number line are called real numbers.**

Complex Numbers

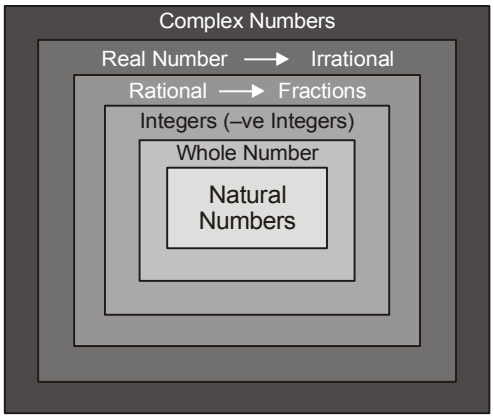
All the numbers that can be represented in a + ib form where a & b are real numbers and i = $\sqrt{-1}$ are called Complex Numbers.

$$C = \{a + ib;\ a, b \in R\ \&\ i^2 = -1\}$$

VARIOUS FORMS OF NUMBER TREE



Form - 3 :



Example 2

Consider the following statements :

I. Every natural number is a real number.
II. Every real number is a rational number.
III. Every integer is a real number.
IV. Every rational number is a real number.

Which of the above statements are correct?

(a) I, II and III (b) I, III and IV (c) II and III (d) III and IV

Sol. (b)

From the number tree, given above, all natural numbers are real numbers but its converse is not true. So, statement (I) is true.

Every real number is not a rational number, some may be irrational numbers. Hence, statement (II) is wrong.

Similarly, from number tree, we can say about statement (III) and (IV) that both the statements are true.

Recurring Decimals

A decimal in which a digit or a set of digits is repeated continuously is called a recurring decimal. For representing recurring decimal, we place bar on the repeated numbers.

For example : (i) The number *0.247632476324763* … can be represented as $0.\overline{24763}$

(ii) and similarly, the number 0.1555 … can be represented as $0.1\overline{5}$

Example 3

Express the recurring decimal $0.\overline{230}$ in the form of a fraction.

Sol.

The given decimal can be written as $0.\overline{230} = 0.230230230\ldots$ …(i)

As the bar is placed on **three digits**, so, we will multiply the above equation by 10^3

$$0.\overline{230} \times 10^3 = 230.230230\ldots \quad \ldots(ii)$$

From equation (i) and (ii), we can write

$$(10^3 - 1)\, 0.\overline{230} = 230 \quad \text{or} \quad 0.\overline{230} = \frac{230}{10^3 - 1} = \frac{230}{999}$$

Example 4

The value of $1.\overline{34} + 4.1\overline{2}$ is

(a) $\frac{133}{90}$ (b) $\frac{371}{90}$ (c) $5\frac{219}{990}$ (d) $5\frac{461}{990}$

Sol. (d)

The decimal $1.\overline{34}$ can be written as $1.\overline{34} = 1.343434\ldots$ …(i)

As the bar is placed on two digits after decimal point, so, we will multiply the above equation by 10^2

$$1.\overline{34} \times 10^2 = 134.3434\ldots \quad \ldots(ii)$$

From equation (i) and (ii)

$$(10^2 - 1)\, 1.\overline{34} = 133 \qquad \therefore \quad 1.\overline{34} = \frac{133}{99}$$

In $4.1\overline{2}$, the bar is place on one digit so it can be written as $4.1\overline{2} = 4.1222\ldots$ …(i)

by multiplying 10^2 in above equation $4.1\overline{2} \times 10^2 = 412.222\ldots$ …(ii)

by multiplying 10 the equation (i) can be written as $4.1\overline{2} \times 10 = 41.222\ldots$ ...(iii)

From equation (i) and (iii)

$$4.1\overline{2}\,(100-10) = 412-41 \qquad \therefore \quad 4.1\overline{2} = \frac{371}{90}$$

Hence, the required value is

$$1.\overline{34} + 4.1\overline{2} = \frac{133}{99} + \frac{371}{90} = \frac{1330+4081}{990} = \frac{5411}{990} = 5\frac{461}{990}$$

CONCEPT OF PRIME AND COMPOSITE NUMBERS

Prime Numbers

Prime numbers are those numbers, which do not have any factor apart from 1 (one) and itself.

Examples of prime numbers are : 2, 3, 5, 7, 11, 13, 17, 19 etc.

Composite Numbers

Composite numbers are those, which are not prime numbers.

Examples of composite numbers are : 4, 6, 8, 9, 10, 12, 14, 15, 16, 18, 20 etc.

Properties of Prime Numbers

1. The number 1 (one) is neither a prime number nor a composite number
2. The number 2 (two) is the only prime number that is even.
3. Prime and composite numbers are the properties of natural numbers only.
4. There are 25 prime numbers less than 100.
5. Prime numbers greater than 3 are of the form 6k ± 1, but the converse is not necessarily true.

Method to check whether a given number is prime or not.

Let the number be n, then take the square root of n. if it is natural number, consider it as it is and if it is not a natural number, just increase the square root of it to the next natural number.

Now divide the given number by all the prime numbers that lies below the square root obtained. If the given number is divisible by any of these prime numbers then it is not a prime number else it is a prime number.

For example, check whether 341 is prime or not?

Square root of 341 lies between 18 and 19. So, we consider it as 19.

Now prime number less than 19 are : 2, 3 5, 7, 17, 13, 17 and 19.

So, we will divide 341 by all the above prime numbers.

$\because$ 341 is divisible by 11 so it is not a prime no.

Relative Primes

Two integers are relatively **primes** or **co-primes**, if they share no common positive factors (divisors) except 1.

For example : *The numbers 3 and 4 do not have any common positive factor(s) hence, they are relative primes. But 4 and 6 are not relative primes.*

Even Numbers

All the **natural numbers**, which are divisible by the number 2 are called even numbers. Even numbers can be represented as **2k**; where, k is any natural numbers.

Odd Numbers

All the **natural numbers**, which are not even numbers i.e. which are not divisible by the number 2, are odd numbers.

Odd numbers can be represented as **(2k + 1)**; where, k is any natural number.

Note : *1. 0 is treated as an even integer. Because it comes between two odd integers 1 and –1.*

2. To find the nature of the numbers (Even or Odd) after the arithmetic operations, we should taken following under consideration :

(i) Odd number ± Odd number = Even number

(ii) Odd number ± Even number = Odd number

(iii) Even number ± Even number = Even number

(iv) Odd number × Odd number = Odd number

(v) Odd number × Even number = Even number

(vi) Even number × Even number = Even number

Perfect Numbers

If the sum of all the factors of a number, including the factor 1 and excluding the number itself, is equal to the number itself then, that number is called a **perfect number**.

For example : *28 = 1 × 2 × 2 × 7 = 4 × 7 = 2 × 14*

Hence, the different factors are (1, 2, 4, 7, 14) and the sum of these is 1 + 2 + 4 + 7 + 14 = 28. Other perfect numbers are 6, 496, 8126 etc.

Some Important Squares, Cubes, Square Roots and Cube Roots

Number (n)	Number (n^2)	Cube (n^3)	Square root ($\sqrt{n}$)	Cube root ($\sqrt[3]{n}$)
1	1	1	1.000	1.000
2	4	8	1.414	1.260
3	9	27	1.732	1.442
4	16	64	2.000	1.587
5	25	125	2.236	1.710
6	36	216	2.449	1.817
7	49	343	2.646	1.913
8	64	512	2.828	2.000
9	81	729	3.000	2.080
10	100	1000	No Need to Remember	No Need to Remember
11	121	1331		
12	144	1728		
13	169	2197		
14	196	No Need to Remember		
15	225			
16	256			
17	289			
18	324			
19	361			
20	400			
21	441			
22	484			
23	529			
24	576			
25	625			

FACTORIZATION

The process writing any number into a product of prime numbers is called factorisation.

For example, *factorisation of 2016 is as follows: 2016 = $2^5 \times 3^2 \times 7$*

Note : *(i) Factorized form of an even number = $2^{\geq 1} \times p_1^b \times p_2^c \times .....$*

(ii) Factorized form of an odd number = $2^0 \times p_1^b \times p_2^c \times ....$ where p_1, p_2, p_3... are prime factors

If the prime factorization of a number N = $P_1^a \times P_2^b \times P_3^c .... p_n^\delta$ where P_1, P_2, P_3 ....P_n are disnitict prime numbers then total number of factors of N is (a + 1) (b + 1) (c +1) ... $(\delta + 1)$

Note: *While using above formula, be careful that factorised form of expression must have prime numbers.*

Example 5

What is the total number of divisors of the number $12^{33} \times 34^{23} \times 2^{70}$?

(a) 4658 (b) 9316 (c) 2744 (d) None of these

Sol. (d)

$12^{33} \times 34^{23} \times 2^{70} = (2^2 \times 3)^{33} \times (2 \times 17)^{23} \times 2^{70} = 2^{159} \times 3^{33} \times 17^{23}$

The number of factors = (159 + 1) (33 + 1) (23 + 1) = 130560.

$\Rightarrow$ Option 'd' is correct.

Example 6

What is the maximum value of m, if the number N = 90 × 42 × 324 × 55 is divisible by 3^m?

(a) 8 (b) 7 (c) 6 (d) 5

Sol. (b)

The number N can be factorised as

N = 90 × 42 × 324 × 55 = $3^2 \times 10 \times 3 \times 14 \times 3^4 \times 4 \times 55 = 3^7 \times 10 \times 14 \times 4 \times 55$

Hence, N is divisible by 3^7, so the maximum value of m is 7.

FACTORIAL

The factorial of a non-negative integer n, denoted by n!, is defined as the product of all the positive integers less than or equal to the integer n.

From definition, $n! = \prod_{k=1}^{n} k$ or $n! = \begin{cases} 1 & ; \quad n = 0 \\ (n-1)! \times n & ; \quad n > 0 \end{cases}$

The factorial of numbers, upto 7, are given as :

n	0	1	2	3	4	5	6	7
n!	1	1	2	6	24	120	720	5040