1st class

Information Theory

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Probability Theory

- **Probability** can be defined as the chance of an event occurring. Probability is a way of assigning every "event" a value between "0" and "1"

  P **- denotes a probability.**
  A**,** ***B*****, and** ***C*** **- denote specific events.**
  P **(*A*) - denotes the probability of event A occurring.**

- **Basic Concepts**

❖ **Probability Experiment** is a chance process that leads to well-defined results called outcomes.

❖ An **outcome** is the result of a single trial of a probability experiment.

❖ **Event** Any collection of results or outcomes of a procedure.

- **Sample Space**

Sample Space is the set of all possible outcomes of a probability experiment. Sample Space Consists of all possible simple events.

EXPERIMENT	SAMPLE SPACE
Toss one coin	**H, T**
Roll a die	**1, 2, 3, 4, 5, 6**
Answer a tru question	**True, False**
Toss two coins	**HH, HT, TH, TT**

Example1: Find the sample space for rolling two dice.
Solution: Each die can land in six different ways, and two dice are rolled, the sample space can be presented by a rectangular array of pairs of numbers in the chart.

	Die 2					
Die 1	1	2	3	4	5	6
1	(1,1)	(1,2)	(1,3)	(1,4)	(1,5)	(1,6)
2	(2,1)	(2,2)	(2,3)	(2,4)	(2,5)	(2,6)
3	(3,1)	(3,2)	(3,3)	(3,4)	(3,5)	(3,6)
4	(4,1)	(4,2)	(4,3)	(4,4)	(4,5)	(4,6)
5	(5,1)	(5,2)	(5,3)	(5,4)	(5,5)	(5,6)
6	(6,1)	(6,2)	(6,3)	(6,4)	(6,5)	(6,6)

Figure 1 Sample Space for Rolling Two Dice

Example2: Find the sample space for the gender of the children if a family has three children. Use B for boy and G for girl.

Solution:

There are two genders, male and female, and each child could be either gender. Hence, there are eight possibilities, as shown here.

BBB BBG BGB GBB GGG GGB GBG BGG

- ## Event

An **event** consists of a set of outcomes of a probability experiment. An event can be one outcome or more than one outcome.

simple event : An event with one outcome

compound event: consists of two or more outcomes or simple events.

For example, if a die is rolled and a 6 shows, this result is called an *outcome,* since it is a result of a single trial. An event with one outcome is called a **simple event.** The event of getting an odd number when a die is rolled is called a **compound event,** since it consists of three outcomes or three simple events.

- ## The types of probability

There are three basic interpretations of probability:

1. Classical probability
2. Empirical or relative frequency probability
3. Subjective probability

1. Classical Probability

Classical probability uses sample spaces to determine the numerical probability that an event will happen. Classical probability assumes that all outcomes in the sample space are equally likely to occur.

For example, when a single die is rolled, each outcome has the same probability of occurring. Since there are six outcomes, each outcome has a probability of 1/6.

The probability of any event *E* is

$$\frac{\textbf{Number of outcomes in } E}{\textbf{Total number of outcomes in the sample space}}$$

This probability is denoted by

$$P(E)=\frac{n(E)}{n(S)}$$

This probability is called ***classical probability***, and it uses the sample space *S*.

Example3: If a family has three children, find the probability that two of the three children are girls.
Solution:
The sample space for the gender of the children for a family that has three children has eight outcomes, that is, BBB, BBG, BGB, GBB, GGG, GGB, GBG, and BGG.
P(two girls) = 3/8

- **Basic Rules for Computing Probability**

Rule1: The probability of any event *E* is a number (either a fraction or decimal) between and
including 0 and 1. This is denoted by $0 \le P(E) \le 1$.

Rule2: If an event *E* cannot occur (i.e., the event contains no members in the sample space), its probability is 0.

Example4: When a single die is rolled, find the probability of getting a 9.
Solution
he sample space is 1, 2, 3, 4, 5, and 6, it is impossible to get a 9. Hence, the probability is
$P(9) = 0/6 = 0$

Rule3: If an event *E* is certain, then the probability of *E* is 1.

Example5: When a single die is rolled, what is the probability of getting a number less than 7?
Solution
All outcomes—1, 2, 3, 4, 5, and 6 are less than 7, the probability is
P(number less than 7)=6/6 = 1 The event of getting a number less than 7 is certain.
Rule4: The sum of the probabilities of all the outcomes in the sample space is 1.

Example6: in the roll of a fair die, each outcome in the sample space has a probability of 1/6 . Hence, the sum of the probabilities of the outcomes is as shown.

Outcome	1		2		3		4		5		6
Probability	$\frac{1}{6}$		$\frac{1}{6}$		$\frac{1}{6}$		$\frac{1}{6}$		$\frac{1}{6}$		$\frac{1}{6}$
Sum	$\frac{1}{6}$	+	$\frac{1}{6}$	+	$\frac{1}{6}$	+	$\frac{1}{6}$	+	$\frac{1}{6}$	+	$\frac{1}{6} = \frac{6}{6} = 1$

2. Relative Frequency or empirical probability

Relative Frequency or empirical probability relies on actual experience to determine the likelihood of outcomes. The probability of an event being in a given class is

$$P(E) = \frac{\textbf{frequency for the class}}{\textbf{total frequencies in the distribution}} = \frac{f}{n}$$

Example7: In a sample of 50 people, 21 had type O blood, 22 had type A blood, 5 had type B blood, and 2 had type AB blood. Set up a frequency distribution and find the following probabilities:

a. A person has type O blood.
b. A person has type A or type B blood.
c. A person has neither type A nor type O blood.
d. A person does not have type AB blood.

Solution

Type	Frequency
A	22
B	5
AB	2
O	21
Total	50

a)P(O) = f/n = 21/50

b)P(A or B) = 22/50 +5/50 = 27/50 (Add the frequencies of the two classes)

c) *P*(neither A nor O) =5/50 + 2/50 = 7/50
(Neither A nor O means that a person has either type B or type AB blood)

d) *P* (not AB) = 1 –*P(*AB) = 1- 2/50 = 48/50 = 24/25
(The probability of not AB by subtracting the probability of type AB from 1)

Example8: Hospital records indicated that maternity patients stayed in the hospital for the number of days shown in the distribution.

Number of days stayed	Frequency
3	15
4	32
5	56
6	19
7	5
Total	127

Find these probabilities.

a. A patient stayed exactly 5 days. ***c.*** A patient stayed at most 4 days.

b. A patient stayed less than 6 days. ***d.*** A patient stayed at least 5 days.

Solution:

a) P(5) = 56/127

b) P(fewer than 6 days) 15/127+ 32/127 + 56/127 = 103/127
(Fewer than 6 days means 3, 4, or 5 days.)

c) P(at most 4 days)= 15/127 +32/127 =47/127
(At most 4 days means 3 or 4 days.)

d) P (at least 5 days)= 56/127 + 19/127 +5/127 = 80/127
(At least 5 days means 5, 6, or 7 days.)

3.Subjective Probabilities

P(E), the probability of event E is found by simply guessing or estimating its value based on knowledge of the relevant circumstances.

- **Complement of an event**

The complement of event *E* , is the set of outcomes in the sample space that are not including in the outcomes of event E, complement of event E denoted by

$$P(\overline{E}) = 1 - P(E) \quad \text{or} \quad P(E) = 1 - P(\overline{E}) \quad \text{or} \quad P(E) + P(\overline{E}) = 1$$

Example9: Birth Genders In reality, more boys are born than girls. In one typical group, there are 205 newborn babies, 105 of whom are boys. If one baby is randomly selected from the group, what is the probability that the baby is *not* a boy?

Solution: Because 105 of the 205 babies are boys, it follows that 100 of them are girls, so

***P*(not selecting a boy) = *P*(boy) = *P*(girl)** = 100/ 205 = 0.488

- **The Addition Rules for Probability**

Mutually exclusive events: Two events are **mutually exclusive events** if they cannot occur at the same time (i.e., they have no outcomes in common).

Rule1: ***When two events A and B are mutually exclusive, the probability that A or B will occur is:*** ***P*(*A* or *B*) = P(A)+P(B)**

Example10: A day of the week is selected at random. Find the probability that it is a weekend.

Solution: P(Friday or Saturday)

= P(Friday)+P(Saturday) = 1/7 + 1/7 =2/7.

Rule 2:***When two events A and B are Not mutually exclusive ,the probability that A or B occur is:*** **$P(A$ or $B) = P(A) + P(B) – P(A$ and $B)$**

where P(A and B) denotes the probability that A and B both occur at the same time

Example11: A single card is drawn at random from an ordinary deck of cards. Find the probability that it is either an ace or a black card.

Solution

Since there are 4 aces and 26 black cards (13 spades and 13 clubs), 2 of the aces are black cards, namely, the ace of spades and the ace of clubs. Hence the probabilities of the two outcomes must be subtracted since they have been counted twice.

P(ace or black card) =P(ace) +P(black card) – P(black aces)
= 4/ 52 + 26/52 - 2/52
=28/52 = 7/13

Example12: In a hospital unit there are 8 nurses and 5 physicians; 7 nurses and 3 physicians are females. If a staff person is selected, find the probability that the subject is a nurse or a male.

Solution

The sample space is shown here.

Staff	Females	Males	Total
Nurses	7	1	8
Physicians	3	2	5
Total	10	3	13

The probability is

P(nurse or male) = P(nurse)+P(male)- P(male nurse)
=8/13+3/13-1/13
=10/13

• The Multiplication Rules and Conditional Probability

The ***multiplication rules*** can be used to find the probability of two or more events that occur in sequence. Two events *A* and *B* are **independent** if the occurrence of one does not affect the probability of the occurrence of the other. (Several events are similarly independent if the occurrence of any does not affect the occurrence of the others.) If *A* and *B* are not independent, they are said to be **dependent.**

Rule1: $P(A \text{ and } B) = P(A) \cdot P(B)$

***P*(event *A* occurs in a first trial and event *B* occurs in a second trial) that's mean events A & B are independent .**

Example13: A coin is flipped and a die is rolled. Find the probability of getting a head on the coin and a 4 on the die.

Solution P (head and 4) = P(head) . P(4)
= 1/ 2 . 1/6 = 1/12

Note that the sample space for the coin is H, T; and for the die it is 1, 2, 3, 4, 5, 6.

Example14: An urn contains 3 red balls, 2 blue balls, and 5 white balls. A ball is selected and its color noted. Then it is replaced. A second ball is selected and its color noted. Find the probability of each of these.

a. Selecting 2 blue balls
b. Selecting 1 blue ball and then 1 white ball
c. Selecting 1 red ball and then 1 blue ball

Solution

a. P(blue and blue)=P(blue) . P(blue) = 2/10 .2/10 =4/100 = 1/25
b. P(blue and white)=P(blue) . P(white) = 2/10 . 5/10 = 10/100 = 1/10
c. P(red and blue) = P(red) . P(blue) = 3/10 . 2/10 = 6/100 =3/50

• Conditional probability

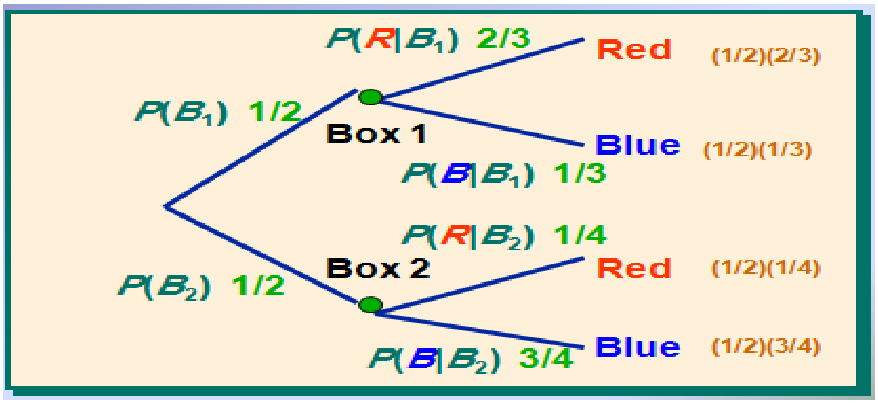
Conditional probability of an event is a probability obtained with the additional information that some other event has already occurred. P(B |A) denotes the conditional probability of event B occurring, given that A has already occurred, and it can be found by dividing the probability of events A and B both occurring by the probability of event A:

$$P(B|A) = \frac{P(A \text{ and } B)}{P(A)}$$

Rule 2: **When two events are dependent the probability of both occurring is :**

$$P(A \text{ and } B) = P(A) \bullet P(B \setminus A)$$

Example15: Box 1 contains two red balls and one blue ball. Box 2 contains three blue balls and one red ball. A coin is tossed. If it falls heads up, box 1 is selected and a ball is drawn. If it falls tails up, box 2 is selected and a ball is drawn. Find the probability of selecting a red ball.



Solution: $P(\text{red}) = (1/2)(2/3) + (1/2)(1/4)$

$= 2/6 + 1/8$

$= 8/24 + 3/24 \quad = 11/24.$

Example16: Three cards are drawn from an ordinary deck and not replaced. Find the probability of these events.

a. Getting 3 jacks

b. Getting an ace, a king, and a queen in order

Solution

a.(3 jacks) =4/52 . 3/51 .2/50 = 24/ 132,600 = 1/5525

b. *P*(ace and king and queen) = 4/52 . 4/51 . 4/50= 64/ 132,600 = 8/16,575

Example 17: A box contains black chips and white chips. A person selects two chips without replacement. If the probability of selecting a black chip *and* a white chip is 15/56 , and the probability of selecting a black chip on the first draw is 3/8 , find the probability of selecting the white chip on the second draw, *given* that the first chip selected was a black chip.

Solution

Let B selecting a black chip W selecting a white chip

Then

$$P(W|B) = \frac{P(B \text{ and } W)}{P(B)} = \frac{15/56}{3/8} = \frac{15}{56} * \frac{8}{3} = \frac{5}{7}$$

- **The Probability of "At Least One"**

To find the probability of *at least one* of something, calculate the probability of *none*, then subtract that result from 1 That is :

***P*(at least one) = 1 – *P*(none)**

Example18: Find the probability of a family having at least 1 girl among 3 children. Assume that boys and girls are equally likely and that the gender of a child is independent of the gender of any brothers or sisters.

Solution: Identify the event that is the complement of *A*.

A = not getting at least 1 girl among 3 children
= all 3 children are boys

Find the probability of the complement.

$P(A) = P(\text{boy and boy and boy})$ $= \frac{1}{2} \bullet \frac{1}{2} \bullet \frac{1}{2} = \frac{1}{8}$

Find P(A) by evaluating 1 – P(A). $P(A) = 1 - P(\overline{A}) = 1 - \frac{1}{8} = \frac{7}{8}$

Example19: A coin is tossed 5 times. Find the probability of getting at least 1 tail.

Solution: Find the probability of the complement of the event, which is "all heads," and then subtract the probability from 1 to get the probability of at least 1 tail.

$P(E) = 1 – P(\bar{E})$

*P(*at least 1 tail) = 1-*P(*all heads)

*P(*all heads) = $(1/2)^5$ = 1/32

*P(*at least 1 tail) = 1 – 1/32 = 31/32

Introduction to Information Theory

In 1948, Claude Shannon published a paper called, “A Mathematical Theory of Communication”. The publication of this paper heralded a transformation in our conception of information. In the centuries before Shannon’s paper was published, information had been viewed as a kind of poorly defined miasmic fluid. After Shannon’s paper, it became apparent that information is a well defined, and above all, measurable quantity. Shannon’s paper describes a subtle theory, which tells us something fundamental about the way the universe works. Shannon’s theory of information provides a mathematical definition of information, and describes precisely how much information can be communicated between different elements of any system. Shannon’s theory underpins our understanding of how signals and noise are related, and why there are definite limits to the rate at which information can be communicated within any system, man-made or biological. It represents one of the few examples of a single theory being responsible for creating an entirely new field of research.

Mode of the signal system

The information system is concerned with the analysis of entity called a **communication system** which has traditionally be presented by the block diagram shown in figure 1. The source of messages is the person or machine that produces the information to be communicated. The encoder associates with each message an object which is suitable for transmission over the channel. The object could be a sequence of binary digits, as in digital computer applications, or continuous waveform, as in radio communication. The channel is the medium over which the coded message is transmitted. The decoder operates on the output of the channel and attempts to extract the original message for delivery to the destination. In general, this cannot be done with complete reliability because of the effect of "noise", which is a general term for anything which tends to produce errors in transmission. The information theory is an attempt to construct a mathematical model for each block in figure 1. It is not arrive at design formulas for a communication system; nevertheless, we shall go into considerable detail concerning the theory of encoding and decoding operations.

The conventional communication system is modeled by:

1- An information source.
2- An encoding of this source.
3- A channel over or through which the information is sent.
4- A noise (error) source that is added to the signal in the channel.
5- A decoding and recovery of original information from the received signal with noise.
6- A destination for the information.

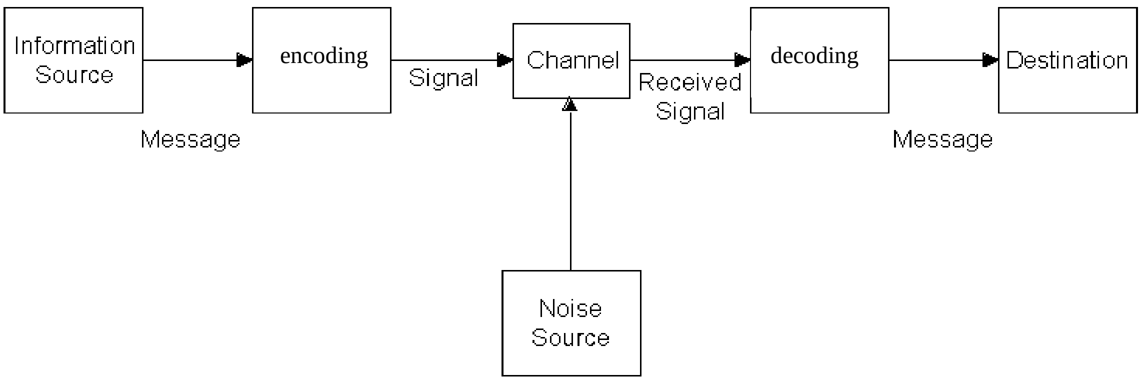


Figure 1 communication system

All communication systems involve three steps:

1. Coding a message at its source
2. Transmitting the message through a communications channel
3. Decoding the message at its destination.

- In the first step, the message has to be put into some kind of ***symbolic representation*** – words, musical notes, icons, mathematical equations, or bits.
- ***Transmission*** can be by voice, a letter, a billboard, a telephone conversation, a radio or television broadcast.
- At the destination, someone or something has to receive the symbols, and then decode them by matching them against his or her own body of information to extract the data.

Example: A source of information that produces a sequence of binary digits (0's or 1's) at the rate of one digit per second. Suppose that the digits 0 and 1 are equally likely to occur and that the digits are produced independently, so that the distribution of a given digit is unaffected by all previous digits. Suppose that the digits are to be communicated directly over a channel. The nature of the channel is unimportant at this moment, except that we specify that the probability that a particular digit is received in error is 1/4, and that the channel acts on successive inputs independently. We also assume that digits can be transmitted through the channel at a rate not to exceed 1 digit per second, show figure 2.

The performance of the communication system is measured in terms of its error probability. An errorless transmission is possible when probability of error at the receiver approaches zero.

Conditions of Events Occurrence : there are three conditions of event occurrence.

- If the event has not occurred, there is a condition of uncertainty.
- If the event has just occurred, there is a condition of surprise.
- If the event has occurred, a time back, there is a condition of having some information.

These three events occur at different times. The differences in these conditions help us gain knowledge on the probabilities of the occurrence of events.

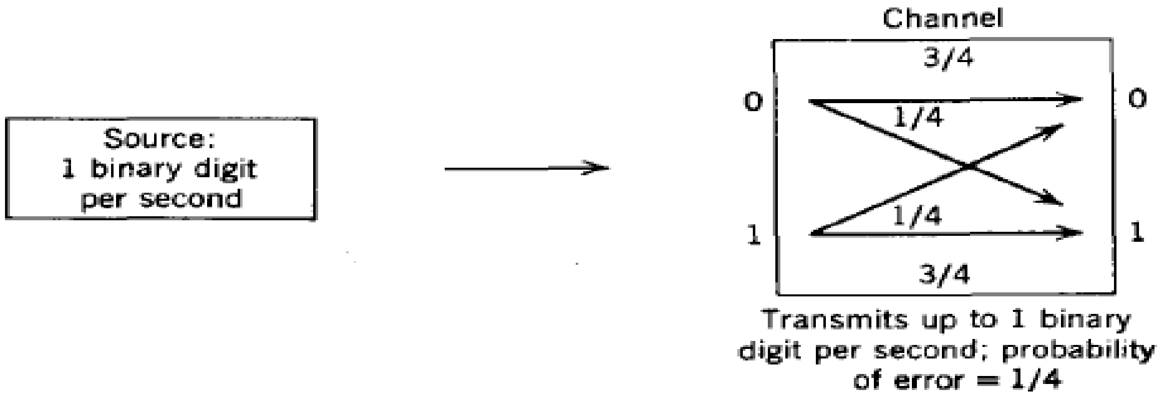


Figure 2 Transmission example

The basic laws of information can be summarized as follows. For any communication channel

1) there is a definite upper limit, the channel capacity, to the amount of information that can be communicated through that channel,

2) this limit shrinks as the amount of noise in the channel increases,

3) this limit can very nearly be reached by judicious packaging, or encoding, of data.

Information theory

Information theory is a mathematical approach to the study of coding of information along with the quantification, compression, storage, and communication of information. A basic idea in information theory is that information can be treated very much like a physical quantity, such as mass or energy. Information theory definite, unreachable limits on precisely how much information can be communicated between any two components of any system, whether this system is man-made or natural. On the other hand, **information theory** tells us that the amount of information conveyed by an event relates to its probability of occurrence. An event that is less likely to occur is said to contain more information than an event that is more likely to occur. The amount of information of an event and its probability are thus opposite.

Number system and codes

Data: is a collection of text, numbers and symbols with no meaning. which are not organized in any way and which provide no information within patterns, context, etc. Data therefore has to be processed to be with meaning

Information: is data that has meaning and that comes as a result of processing data, usually by computer. This results which enables the processed data to be used within a specific context. Information is organized or classified data in which has meaningful values for the receiver. Information is the processed data on which decisions and actions are based, and for the decision to be meaningful, the Information should be available when required, accurate and complete.

Data Representation: The CPU processes information obtained from the primary memory and returns the results to memory. There is usually a block of information called a word. A word, consisting of a number of bits, may be used to represent different objects, such as numbers, letters, species of trees, etc. The most common use of a word is for number and character representation. Each bit of an N-bit word can be a 0 or 1 independently.

bn-1	…..	b2	b1	b0

Example: 7 bits are $b_6\, b_5\, b_4\, b_3\, b_2\, b_1\, b_0$ are used to represent a number, the value of that number is $b_6 * 2^6 + b_5 * 2^5 + b_4 * 2^4 + b_3 * 2^3 + b_2 * 2^2 + b_1 * 2^1 + b_0 * 2^0$

The largest value that this can take is the binary number 1111111, representing the decimal value 127, that is

$$1 * 2^6 + 1 * 2^5 + 1 * 2^4 + 1 * 2^3 + 1 * 2^2 + 1 * 2^1 + 1 * 2^0$$

$$64 + 32 + 16 + 8 + 4 + 2 + 1$$

$$127$$

The smallest value is the binary number 0000000, representing the value 0.

Numbering Systems

The computer work with numbers, letters and symbols also the numbers transfer to specific numbers input to computer and process then output the results which transfer from machine language to language understand by humans, display on different output devices. The most numbering systems used are:

1. Decimal System
2. Binary System
3. Octal System
4. Hexadecimal System

1. **Decimal System** :The number system that we use in our day-to-day life is the decimal number system. The decimal system is said to have a **base**, or **radix**, of 10.as it uses 10 digits from 0 to 9. This means that eachdigit in the number is multiplied by 10 raised to a power corresponding to thatdigit's position:

For example, the decimal number 1234 consists of the digit 4 in the units position, 3 in the tens position, 2 in the hundreds position, and 1 in the thousands position. Its value can be written as(1 x 1000)+ (2 x 100)+ (3 x 10)+ (4 x l)

$(1 \times 10^3)+ (2 \times 10^2)+ (3 \times 10^1)+ (4 \times 10^0)$

1000 + 200 + 30 + 4 = 1234

2. **Binary system :**In the binary system, we have only two digits, 1 and 0.Thus, numbers in the binary system are represented to the base 2.Each position in a binary number represents a **0** power of the base (2). Last position in a binary number represents a **x** power of the base (2).Example :2^x where x represents the last position -1.

Step	Operation	Result	Remainder
Step 1	29 / 2	14	1
Step 2	14 / 2	7	0
Step 3	7 / 2	3	1
Step 4	3 / 2	1	1
Step 5	1 / 2	0	1

Example: for Binary Number: **11101_2** ,Calculating Decimal Equivalent

Step	Binary Number	Decimal Number
Step 1	11101_2	$((1 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0))_{10}$
Step 2	11101_2	$(16 + 8 + 4 + 0 + 1)_{10}$
Step 3	11101_2	29_{10}

3. Octal System: Octal System group binary numbers into sets of 3 bits, with each group or set of bits having a distinct value of between 000 (0) and 111 (4+2+1 = 7).Octal numbers therefore have a range of just “8” digits, (0, 1, 2, 3, 4, 5, 6, 7) making them a Base-8 numbering system. Each position in an octal number represents a 0 power of the base (8). Last position in an octal number represents a x power of the base (8). Example 8^x where x represents the last position – 1

Example: Octal Number: 25_8

Step	Octal Number	Decimal Number
Step 1	25_8	$((2 \times 8^1) + (5 \times 8^0))_{10}$
Step 2	25_8	$(16 + 5)_{10}$
Step 3	25_8	21_{10}

Octal Number : 25_8 = Decimal Number : 21_{10}

To Convert Decimal to Binary

Step	Operation	Result	Remainder
Step 1	21 / 2	10	1
Step 2	10 / 2	5	0
Step 3	5 / 2	2	1
Step 4	2 / 2	1	0
Step 5	1 / 2	0	1

Decimal Number : 21_{10} = Binary Number : 10101_2

Octal Number : 25_8 = Binary Number : 10101_2

Step	Binary Number	Octal Number
Step 1	10101_2	010 101
Step 2	10101_2	2_8 5_8
Step 3	10101_2	25_8

4. **Hexadecimal System:** Hexadecimal Numbers group binary numbers into sets of four binary digits.Being a Base-16 system, the hexadecimal numbering system uses 16 (sixteen) different digits. Uses 10 digits and 6 letters, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F. Letters represent the numbers starting from 10. A = 10. B = 11, C = 12, D = 13, E = 14, F = 15. Each position in a hexadecimal number represents a 0 power of the base (16). Last position in a hexadecimal number represents a x power of the base (16). Example 16^x where x represents the last position – 1

Example: Hexadecimal Number: $19FDE_{16}$,Calculating Decimal Equivalent

Step	Hexadecimal Number	Decimal Number
Step 1	$19FDE_{16}$	$((1 \times 16^4) + (9 \times 16^3) + (F \times 16^2) + (D \times 16^1) + (E \times 16^0))_{10}$
Step 2	$19FDE_{16}$	$((1 \times 16^4) + (9 \times 16^3) + (15 \times 16^2) + (13 \times 16^1) + (14 \times 16^0))_{10}$
Step 3	$19FDE_{16}$	$(65536+ 36864 + 3840 + 208 + 14)_{10}$
Step 4	$19FDE_{16}$	106462_{10}

Binary Number : 10101_2Calculating hexadecimal Equivalent −

Step	Binary Number	Hexadecimal Number
Step 1	10101_2	0001 0101
Step 2	10101_2	1_{16} 5_{16}
Step 3	10101_2	15_{16}

Binary Number : 10101_2 = Hexadecimal Number : 15_{16}

Step	Hexadecimal Number	Binary Number
Step 1	15_{16}	1_{16} 5_{16}
Step 2	15_{16}	0001_2 0101_2
Step 3	15_{16}	00010101_2

Hexadecimal Number : 15_{16} = Binary Number : 10101_2

Encoding

In computer memory, character are "encoded" using a character encoding schemes. Character encoding is a way of assigning a set of characters to a sequence of numbers called code points in order to facilitate data transmission For example ASCII

ASCII Code

- ASCII (American Standard Code for Information Interchange) is one of the earlier character coding schemes.
- ASCII is originally a 7-bit code. It has been extended to 8-bit to better utilize the 8-bit computer memory organization. (The 8th-bit was originally used for *parity check* in the early computers.)
- Code numbers 32D (20H) to 126D (7EH) are printable (displayable) characters as tabulated (arranged in hexadecimal and decimal) as follows:
- code numbers 65D (41H) to 90D (5AH) represents 'A' to 'Z', respectively.
- code numbers 97D (61H) to 122D (7AH) represents 'a' to 'z', respectively.
- code numbers 48D (30H) to 57D (39H) represents '0' to '9', respectively.

ASCII TABLE

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

Morse Code

Morse code is one of the familiar codes, which was once widely used. As noted earlier most systems of representing information in computers (and other machines) use two states, although the Morse code is an example of signaling system with three symbols in the underlying alphabet. The reason for the dominance of two-symbol signaling system is that two-state devices tend to be ***more reliable*** than are multistate devices. On the other hand, people clearly work better with multistate system-witness the letters of the alphabet and the decimal digits. Thus, it is necessary at time to consider codes with r symbols in their alphabets. For the Morse code, r=3. Part of the Morse code is given in the below table. The dash is supposed to be three times the length of the dot. Morse code is a ***ternary code*** (radix 3, r=3), having symbols dash and space. The Morse code is clearly a ***variable-length*** code which takes advantage of the high frequency of occurrence of some letters such as “E”, by making them short and the very infrequent letters such as “J”, relatively longer.

Symbol	Morse Code	Symbol	Morse Code
A	• —	G	— — •
B	— • • •	H	• • • •
C	— • — •	I	• •
D	— • •	J	• — — —
E	•	K	— • —
F	• • — •	L	• — • •
M	— —	T	—
N	— •	U	• • —
O	— — —	V	• • • —
P	• — — •	W	• — —
Q	— — • —	X	— • • —
R	• — •	Y	— • — —
S	• • •	Z	— — • •

Morse Code