 1

Set theory :

(i) Set: A set is a collection of objects under study, sets are ~~notat~~ usually denoted by capital letters A, B, C, X, Y, Z, etc.

For EX: students of electrical engineering in a college, rivers of India, states of India etc.

(ii) Experiment: An experiment is a physical process that is observed and whose result is noted.

... throwing a dice, etc.

observed and whose result is ...

For EX: turning a switch on or off, throwing a dice, etc.

Experiments are of two types

ⓐ deterministic ⓑ non-deterministic experiment

ⓐ Deterministic experiment:

If we are sure about the outcome of the experiment before conducting the experiment, then it is known as deterministic experiment. for EX: constructing a wall, throwing a stone upwards, etc.

(b) Non - Deterministic Experiment :

An experiment is called a non-deterministic, random probabilistic or stochastic if we are not sure that which of the possible outcomes will occur when an experiment is conducted. Here after an experiment means random experiment.

for EX: tossing a coin, throwing a dice, etc.

(iii) Trial : A single performance of an experiment is called a trial.

For Ex: tossing a coin.

(ii) Sample space or sample point:

A collection of all possible outcomes of a random exp[eriment] is called a sample space and usually denoted by S.

The elements of a sample space are called sample points.

For Ex: If a dice is thrown, then any one of 1, 2, 3, 4, 5 or 6, will appear on the face.

$S = \{1, 2, 3, 4, 5, 6\}$

Sample points of S.

(v) Discrete sample space:

A sample space is called to be discrete, if it has finitely many or a countably infinite number of elements

For Ex: tossing a coin the sample space

$$S = \{H, T\}$$

throwing a dice $S = \{1, 2, 3, 4, 5, 6\}$

etc.

(vi) Continuous Sample Space

A sample space is said to be continuous; if the elements of the sample space constitute a continuum

For Ex: All the points on a line segment.

(vii) Event: Any subset A of a sample space S ~~and each~~ is called an event.

In tossing a coin $S = \{H, T\}$

Here ϕ $\{H\}$ $\{T\}$ & $\{H, T\}$ are subsets of S and each of

Here ϕ, $\{H\}$, $\{T\}$ & $\{H, T\}$ are subset of S and each of them is an event.

3

Simple or Elementry event

If an event has only one sample point and cannot be further divided into smaller events then it is known as simple or elementry event.

For Ex: 1, 2, 3, 4, 5, 6

(b) compound event :

If an event has more than one sample point and can be obtained by combining the several elementary events is called a compound event.

for Ex :

when a coin is tossed twice then sample space

$$S = \{HH, HT, TH, TT\}$$

and each of S is a compound event.

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(viii) Favourable Event:

(ix) Equally Likely events : All six faces are equally likely to occur.

(x) compliment of an Event $\overline{A}$ or $A' = S - A$

(xi) Mutually Exclusive Events
$A \cap B = \emptyset$

(xii) Exhaustive events:
The total number of possible outcomes in any of a random experiment is called. exhaustive

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events.

(xiii) odd in favour of an event and odd against an event

Let there are be m outcomes favourable to a certain event and n outcomes are not in favour to the event in a sample space S, then odd in favour of the event $= \frac{m}{n}$

odd not in favour or against of the event $= \frac{n}{m}$.

(xiv) Permutation.

$$^{n}P_{r} = \frac{\underline{|n}}{\underline{|n-r}}$$

...bination

hardik sharma

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aryan kabra

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(xv) Combination

$$^{n}C_{r} \text{ or } \binom{n}{r} = \frac{\lfloor n}{\lfloor r \; \lfloor n-r}$$

(xvi) Union of Events :

Let A and B be two events, then A union B $(A \cup B)$ is the event that consists all the points either in A or in B or in both A and B.

(xvii) Intersection of Events :

A intersect B $(A \cap B)$

(xvii) Intersection of Events :

Let A and B be two events then A intersect B $(A \cap B)$ is the set of all those points that are contained in both A and B.

Classical

Def^n of Probability :

$$P(A) = \frac{m}{n} = \frac{\text{no. of favourable outcomes}}{\text{Total no. of outcomes}}.$$

m = ~~No~~. of favourable outcomes to A.

m = No. of favourable outcomes to A.

$\therefore n - m$ = non-favourable no. of outcomes to A

and set of non-favourable no. of outcomes is denoted by A' $\Rightarrow P(A') = \frac{n-m}{n} = 1 - \frac{m}{n} = 1 - P(A)$

$\Rightarrow P(A) + P(A') = 1$

If $P(A)$ = Prob. of success of an event $A = p$ and

$P(A')$ = ,, ,, failure ,, ,, $A = q$.

$p = P(A) = \frac{m}{n}, \quad 0 \leq p \leq 1$

$$\Rightarrow \boxed{p+q=1} \quad q = P(A') = \frac{n-m}{n} = 1-\frac{m}{n} = 1-p, \quad 0 \le q \le 1$$

Empirical or Statistical Def^n of Probability.

Let m = frequency of occurrence of event A.

n = number of independent trials of a random experiment which are repeated under the same conditions.

Then ... lim $\frac{m}{...}$,

Then $P(A) = \lim_{n \to \infty} \frac{m}{n}$,

provided limit is unique and finite.

where $\frac{m}{n}$ = relative frequency of the event A in n trials.

If $n \to \infty$ then $\frac{m}{n}$ is very close to actual probability.

This def^n of prob. is also known as relative frequency def^n of prob.

Ex. The records show that 800 of 1000 tested ceramic

Ex: If records show that 800 of 1000 tested ceramic insulators were able to withstand a certain thermal shock. Find the prob. that any one untested insulator will be able to withstand the thermal shock.

Solⁿ: Here $m = 800$, $n = 1000$. Let A be the event that any untested insulator will be able to withstand the thermal shock.

$$P(A) = \frac{800}{1000} = 0.80$$

Ex-9 : An electric engineer is studying the

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(iii) Axiomatic Def^n of Probability

If S is the sample space and A be any event of

(iii) Axiomatic Defn of Probability

If S is the sample space and A be any event of random experiment, then

(a) $0 \leq P(A) \leq 1$, for each event $A \in S$

(b) $P(S) = 1$

(c) If A_1 and A_2 are two mutually exclusive events in S, then.

$$P(A_1 \cup A_2) = P(A_1) + P(A_2).$$

(a), (b) & (c) are known as axioms of Probability.

Ex-10: Mr. X who is a broker feels that the prob that a given stock will go up in value during the day's trading is 0·6 and the prob. that it will go down in value is 0·1. What is the prob. that it will go up or down?

Sol^n: $P(A) = 0\cdot6$, $P(B) = 0\cdot1$

$$\therefore P(A \cup B) = P(A) + P(B) = 0\cdot6 + 0\cdot1 = 0\cdot7$$

Generalization of third Axioms of prob.

$\therefore\ P(A \cup B) = P(A) + P(B) = 0.6 + 0.1 = 0.7$

Generalization of third Axioms of prob.

If $A_1, A_2, \ldots, A_n$ are mutually exclusive events in a sample space S, then

$$P(A_1 \cup A_2 \cup A_3 \cdots \cup A_n) = P(A_1) + P(A_2) + \cdots + P(A_n)$$

$$P\left(\bigcup_{i=1}^{n} A_i\right) = \sum_{i=1}^{n} P(A_i)$$

...itional Law of Probability or Theorem of Total Probability. 7

Theorem 6.4.1:

Let A and B be the mutually exclusive events, then prove that $P(A \cup B) = P(A) + P(B)$

Proof: Let n be the total number of equally likely cases unit of which m_1 be the number that event A occurs and m_2 be the number that event B occurs

A occurs and m_2 be the number that event B occurs then the number of favourable cases of occuring A or B $= m_1 + m_2$

$$\therefore P(A \text{ or } B) = P(A \cup B) = \frac{m_1 + m_2}{n} = \frac{m_1}{n} + \frac{m_2}{n}.$$

but $P(A) = \frac{m_1}{n}$, $P(B) = \frac{m_2}{n}$.

$$\therefore P(A \cup B) = P(A) + P(B)$$

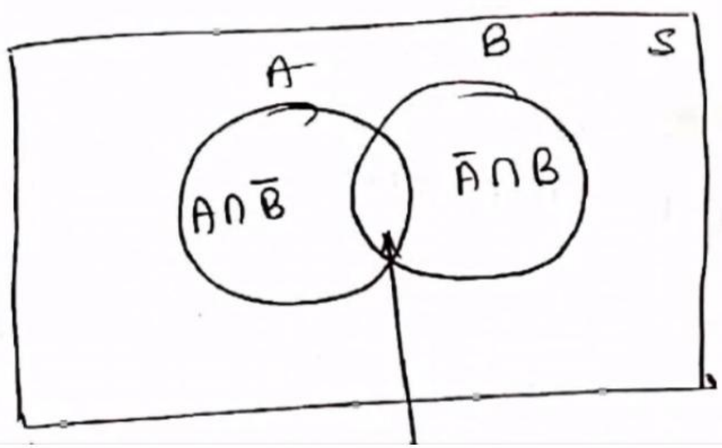
Theorem 6.4.2 :-

Let A and B be two events then show that

Theorem 6.4.2 :-

Let A and B be two events then show that

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$



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Proof:- using venn diagram

$$A \cup B = A \cup (\bar{A} \cap B)$$

where A and $\bar{A} \cap B$ are mutually exclusive events.

$$\therefore P(A \cup B) = P(A) + P(\bar{A} \cap B)$$

$$= P(A) + P(\bar{A} \cap B) + P(A \cap B) - P(A \cap B)$$

$$= P(A) + P(B) - P(A \cap B)$$

[$\because$ $(\bar{A} \cap B)$ and $(A \cap B)$ and mutually exclusive events

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$$= P(A) + P(B) - P(A \cap B)$$

$[\because (\bar{A} \cap B)$ and $(A \cap B)$ and mutually exclusive events

and $B = (A \cap B) \cup (\bar{A} \cap B)]$

$$\therefore P(B) = P(A \cap B) + P(\bar{A} \cap B).$$

$$\Rightarrow P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

Hence Proved

Remark: If A and B are mutually exclusive events, then

$$P(A \cap B) = 0$$

$P(A \cap B) = 0$

and $P(A \cup B) = P(A) + P(B)$

Theorem 6·4·3:

If A, B and C are any three events, then

$$P(A \cup B \cup C) = P(A) + P(B) + P(C) - P(A \cap B) - P(A \cap C) - P(B \cap C) + P(A \cap B \cap C)$$

Proof: $P(A \cup B \cup C) = P[A \cup (B \cup C)] = P[A] + P(B \cup C) - P(A \cap (B \cup C))$

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Proof:

$$P(A\cup B\cup C) = P[A\cup(B\cup C)] = P[A] + P(B\cup C) - P(A\cap(B\cup C))$$

using the eq. 2:

$$= P(A) + P(B) + P(C) - P(B\cap C) - [P(A\cap B)\cup P(A\cap C)]$$

$$= P(A) + P(B) + P(C) - P(B\cap C) - [P(A\cap B) + P(A\cap C) - P(A\cap B\cap C)]$$

$$= P(A) + P(B) + P(C) - P(A\cap B) - P(A\cap C) - P(B\cap C) + P(A\cap B\cap C)$$

Hence proved

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m 6.4.4 :

Prove that $P(\phi) = 0$

Proof: $S \cup \phi = S$ (S and ϕ are mutually exclusive events)

$\therefore P(S \cup \phi) = P(S)$

$\Rightarrow P(S) + P(\phi) = P(S)$

$\Rightarrow P(\phi) = 0$

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Theorem 6·4·5 Show that $P(A') = 1 - P(A)$

Proof : $A \cup A' = S$

(A and A' are ~~mutually~~ exclusive events).

$$\therefore P(A \cup A') = P(A) + P(A') = P(S) = 1 \quad (\because P(S) = 1)$$

$$\Rightarrow P(A') = 1 - P(A)$$

Hence Proved

Ex - 13 A single dice is thrown once. Find the prob. of getting a 3 or 5.

$S = \{1, 2, 3, 4, 5, 6\}$

Sol^n: $P(1) = P(2) = \text{—} \text{—} = P(6) = \frac{1}{6}$

$P(3 \text{ or } 5) = P(3) + P(5) = \frac{1}{6} + \frac{1}{6} = \frac{1}{3}$ (all are mutually exclusive events)

Ex - 15 In throwing a pair of dice, find the prob of getting 3, 5 or 11

Sol^n: $P(A) = \frac{2}{36}$, $P(B) = \frac{4}{36}$, $P(C) = \frac{2}{36}$

Ex - 13 A single dice is thrown once. Find the prob. of getting a 3 or 5.

$S = \{1, 2, 3, 4, 5, 6\}$

Sol^n: $P(1) = P(2) = \ldots = P(6) = \frac{1}{6}$

$P(3 \text{ or } 5) = P(3) + P(5) = \frac{1}{6} + \frac{1}{6} = \frac{1}{3}$ (all are mutually exclusive events)

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<u>Ex - 15</u> In throwing a pair of dice, find the prob of getting 3, 5 or 11

<u>Sol^n :</u> $P(A) = \frac{2}{36}$, $P(B) = \frac{4}{36}$, $P(C) = \frac{2}{36}$

$P(A \cup B \cup C) = P(A) + P(B) + P(C)$ (∵ A, B and C are mutually exclusive events)

$= \frac{2}{36} + \frac{4}{36} + \frac{2}{36} = \frac{2}{9}$

Conditional Probability:

Conditional Bobability:

In our daily life, it is not always possible that tw[o] or more events always happen independently but their occurrence may depend on one another, i.e, the probability of one event depends on the happening of another event.

Defn:

Let A and B be two events in S, then conditional probability of A given B is

$$= P(A/B) = \frac{P(A \cap B)}{P(B)}, \quad P(B) > 0.$$

similarly Bobability of B given A $= P(B/A) = \dfrac{P(A \cap B)}{P(A)}$, $P(A) > 0$

6.5.1 Theorem on Compound Probability of Multiplication Law of Probability

If A and B are any two events in sample space S, then

$$P(A \cap B) = P(AB) = P(A) \cdot P(B/A), \text{ if } P(A) > 0$$

$$= P(B) \cdot P(A/B), \text{ if } P(B) > 0$$

Similarly let A, B and C be three events, then

$$P(A \cap B \cap C) = P(A) \cdot P(B/A) \cdot P(C/A \cap B)$$

6.5.1 Theorem on Compound Probability of Multiplication Law of Probability

If A and B are any two events in sample space S, then

$$P(A \cap B) = P(AB) = P(A) \cdot P(B/A), \text{ if } P(A) > 0$$

$$= P(B) \cdot P(A/B), \text{ if } P(B) > 0$$

Similarly let A, B and C be three events, then

$$P(A \cap B \cap C) = P(A) \cdot P(B/A) \cdot P(C/A \cap B),$$

...pendent Events:

Two events are said to be independent if happening or non-happening of the events donot depend on each-other.

If A and B are two events, then A and B are said to be independent if

$$P(A/B) = P(A) \quad \text{and} \quad P(B/A) = P(B)$$

or

$$P(AB) = P(A \cap B) = P(A) \cdot P(B)$$

This is called special multiplication rule for independent events.

Remark: Therefore, we can say that two events A and B are independent, if and only if

(i) $P(A/B) = P(A)$, (ii) $P(B/A) = P(B)$ and (iii) $P(A \cap B) = P(A)P(B)$

and if $P(A \cap B) \neq P(A) \cdot P(B)$, then A and B are not independent events.

(iii) can be extended for more than two events.

Def^n: Let $E_1, E_2, E_3, \ldots, E_n$ be n events, then $E_1, E_2, \ldots, E_n$

Def^n: Let $E_1, E_2, E_3, \ldots, E_n$ be n events, then $E_1, E_2, \ldots, E_n$ are independent if and only if

$$P(E_1 \cap E_2 \cap \cdots \cap E_n) = P(E_1)\cdot P(E_2)\cdot P(E_3)\cdots P(E_n)$$

Theorem :

If A and B are independent events, then show that

(a) $\bar{A}$ and $\bar{B}$ are independent events.

(b) $\bar{A}$ and B are independent events.

(c) A and $\bar{B}$ are independent events.

Proof : (a) $\overline{A \cap B} = \bar{A} \cup \bar{B}$

$\Rightarrow P(\overline{A \cup B}) = P(\bar{A} \cup \bar{B}) = 1 - P(A \cup B)$ [using result $P(\bar{A}) = 1 - P(A)$]

$P(\bar{A}) = 1 - P(A)]$

$\Rightarrow P(\bar{A} \cap \bar{B}) = 1 - [P(A) + P(B) - P(A \cap B)]$

$= 1 - [P(A) + P(B) - P(A) \cdot P(B)]$

$(\because A \ \& \ B$ are independent events)

$= 1[1 - P(A)] - P(B)[1 - P(A)]$

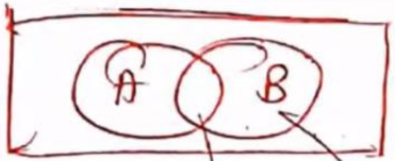
$= [1 - P(A)]\,[1 - P(B)]$

$= P(\bar{A}) \cdot P(\bar{B})$

Hence result.

(b) $B = (A \cap B) \cup (\bar{A} \cap B)$

(b) $B = (A \cap B) \cup (\bar{A} \cap B)$



$A \cap B$ and $\bar{A} \cup B$ are mutually exclusive events

$\Rightarrow B = (A \cap B) \cup (\bar{A} \cap B)$

$\therefore P(B) = P(A \cap B) + P(\bar{A} \cap B)$

$P(B) = P(A) \cdot P(B) + P(\bar{A} \cap B)$

$\Rightarrow P(\bar{A} \cap B) = P(B)\,[1 - P(A)] = P(B)\,P(\bar{A})$

$\therefore$ $\bar{A}$ and B are independent events.

Remark

Term 'Independent' is defined in terms of 'probability' of events whereas 'mutually exclusive' is defined in terms of 'events'. Moreover, mutually exclusive events never have an outcome common but independent events do have common outcome(s) provided each event is non-empty. Clearly 'independent' and 'mutually exclusive" donot have the same meaning.

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Term 'Independent' is defined in terms of 'probability' of events whereas 'mutually exclusive' is defined in terms of 'events'. Moreover, mutually exclusive events never have an outcome common but independent events do have common outcome(s) provided each event is non-empty. Clearly 'independent' and 'mutually exclusive" donot have the same meaning.

Ex-17: A dice is rolled. If the outcome is an even number what is the probability that it is prime?

Sol^n: In rolling a dice, the sample space

$$S = \{1, 2, 3, 4, 5, 6\}.$$

Let A be the event that the number is even

$$= \{2, 4, 6\}$$

and B be the event that number is prime

$$= \{2, 3, 5\}.$$

... prime

$= \{2, 3, 5\}.$

Then $A \cap B = \{2\} \Rightarrow P(A \cap B) = \frac{2}{6} = \frac{1}{3}.$

and $P(A) = \frac{3}{6} = \frac{1}{2}$

$\therefore$ P(getting a prime number / getting an event number)

$$= \frac{P(A \cap B)}{P(A)} = \frac{1/3}{1/2} = \frac{2}{3}$$

Ex-18 A family has two children. What is the probability that both are girls, given that at least one of them is a girl?

Sol^n The sample space $S = \{(b,b), (b,g), (g,b), (g,g)\}$

where b = boy, g = girl.

Let A and B be the events that both are girls and at least one is girl respectively. Then.

$$\therefore P(A/B) = \frac{P(A \cap B)}{P(B)} = \frac{1/4}{3/4} = \frac{1}{3}$$

Ex - 18 A family has two children. What is the probability that both are girls, given that at least one of them is a girl?

Sol^n The sample space $S = \{(b,b), (b,g), (g,b), (g,g)\}$

where b = boy, g = girl.

Let A and B be the events that both are girls and at least one is girl respectively. Then.

$$\therefore P(A/B) = \frac{P(A \cap B)}{P(B)} = \frac{1/4}{3/4} = \frac{1}{3}$$

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xtension of Multiplication law of Probability to n Even

Let $A_1, A_2, --, A_n$ be n events, then.

$$P(A_1 \cap A_2 \cap -- \cap A_n) = P(A_1) \cdot P(A_2/A_1) \cdot P(A_3/A_1 \cap A_2) - - P(A_n | A_1 \cap A_2 \cap - A_{n-1})$$

where $P(A_i | A_j \cap A_k \cap -- A_l)$

be the conditional probability of the event A_i given that the event $A_j, A_k, --, A_l$ have already happened.

(i) Extension of Multiplication Law of Probability for n-independent Events:—

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(1) Extension of Multiplication Law of Probability for n-independent Events –

Let $A_1, A_2, ---, A_n$ be n-independent events then

$$P(A_1 \cap A_2 \cap A_3 \cap --- \cap A_n) = P(A_1) \cdot P(A_2) \cdot --- \cdot P(A_n) \quad \text{—— (1)}$$

The above result can be proved using the concept of independence; if $A_1, A_2, ---, A_n$ are independent events then

$$P(A_2 | A_1) = P(A_2) \cdot P(A_3 | A_1 \cap A_2) = P(A_3), ---, P(A_n | A_1 \cap A_2 \cap --- \cap A_{n-1})$$
$$= P(A_n)$$

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$$= P(A_n)$$

$$\Rightarrow P(A_1 \cap A_2 \cap \dots \cap A_n) = P(A_1) \cdot P(A_2) \dots P(A_n).$$

The above result can be proved using the concept of independence, if $A_1, A_2, \dots, A_n$ are independent events then

$$P(A_2|A_1) = P(A_2), \; P(A_3|A_1 \cap A_2) = P(A_3), \dots,$$

$$P(A_n|A_1 \cap A_2 \cap \dots \cap A_{n-1}) = P(A_n)$$

$$\Rightarrow P(A_1 \cap A_2 \cap \dots \cap A_n) = P(A_1) \cdot P(A_2) \dots P(A_n)$$

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Pairwise Independent Events.

Let $A_1, A_2, \ldots, A_n$ defined on the same space

$P(A_i) > 0$; $i = 1, 2, \ldots, n$, then these events are said to be pairwise independent, if every pair of two events is independent, i.e.

$$P(A_i \cap A_j) = P(A_i) \cdot P(A_j), \quad i \neq j = 1, 2, \ldots, n$$

(iii) Mutually Independent Events :

If $A_1, A_2, \dots, A_n$ be n events in a sample space S, then they are said to be mutually independent if

$$P(A_{i1} \cap A_{i2} \cap \dots \cap A_{ik}) = P(A_{i1}) P(A_{i2}) \dots P(A_{ik})$$

Hence, the events are mutually independent if they are independent by pairs, by triplets, and by quadruples and so on.

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...s Theorem

17

...efore we discuss Baye's theorem, we shall define the rule of elimination or theorem of total probability.

Rule of Elimination or Theorem of Total Probability.

If the event A can occur along with event E. suppose that event E occur in n mutually exclusive ways $E_1, E_2, \dots E_n$, then

$$P(A) = \sum_{i=1}^{n} P(E_i) \cdot P(A/E_i), \text{ provided } P(E_i) > 0 \ \forall i = 1, 2, \dots$$

Proof.

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$P(E_i) > 0 \forall i = 1, 2, \ldots m.$

Proof:

$$A = A \cap E_1 \cup A \cap E_2 \cup \cdots \cup A \cap E_n.$$

Events $(A \cap E_1)$, $(A \cap E_2), \ldots, (A \cap E_n)$ are mutually exclusive events.

$$\therefore P(A) = P[(A \cap E_1) \cup (A \cap E_2) \cup \cdots \cup (A \cap E_n)]$$

$$= P[A \cap E_1) + P(A \cap E_2) + \cdots + P(A \cap E_n)$$

$$= \sum_{i=1}^{n} P(A \cap E_i)$$

using conditional Probability

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$$= P(A \cap E_1) + P(A \cap E_2) + \cdots + P(A \cap E_n)$$

$$= \sum_{i=1}^{n} P(A \cap E_i)$$

using conditional Probability

$$P(A \cap E_i) = P(E_i) \cdot P(A/E_i)$$

$$\therefore \; P(A) = \sum_{i=1}^{n} P(E_i) \cdot P(A/E_i)$$

Baye's Theorem

Baye's Theorem

Let $E_1, E_2, \ldots E_n$ be n mutually exclusive events of which one of them must occur. Let A be any event, then

$$P(E_i/A) = \frac{P(A \cap E_i)}{P(A)} = \frac{P(E_i)\,P(A/E_i)}{\sum_{i=1}^{n} P(E_i)\cdot P(A/E_i)}$$

Ex – 34 :

A bag contains 3 black and 4 white balls. Two balls are drawn at random one at a time without replacement. What is probability that second ball is white ?

Solⁿ : Let E_1 & E_2 be the events that first ball is black and first ball is white respectively. Let A be the event that second ball is white.

then

$$A = (A \cap E_1) \cup (A \cap E_2)$$

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$$A = (A \cap E_1) \cup (A \cap E_2)$$

$$P(A \cap E_1) = P(E_1) \cdot P(A/E_1)$$

$$= \left(\frac{3}{7}\right)\left(\frac{4}{8}\right) = \frac{2}{7}$$

Similarly $P(A \cap E_2) = P(E_2) \cdot P(A/E_2)$

$$= \left(\frac{4}{7}\right)\left(\frac{3}{8}\right) = \frac{2}{7}$$

$$\therefore P(A) = P(A \cap E_1) + P(A \cap E_2) = \frac{4}{7}$$

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