<u>INDIVIDUAL TASK-3</u>

Bayes Theorem in Real Life: choose real-world scenario (like medical testing) and apply Bayes Theorem to Calculate probabilities

1. Introduction

In real-world situations, decisions are rarely made with complete certainty. Whether it is diagnosing a disease, filtering spam emails, or predicting customer behaviour, we continuously receive **new information** that changes our understanding. Bayes' Theorem provides a systematic way to **update probabilities** when such new evidence is available.

In the healthcare sector, incorrect interpretation of test results can lead to **misdiagnosis, unnecessary treatment, mental stress, and increased medical costs**. Bayes' Theorem helps medical professionals interpret diagnostic test results more accurately by considering both **test accuracy** and **disease prevalence**.

<div align="centre">

2. Concept of Conditional Probability

Before understanding Bayes' Theorem, it is important to understand **conditional probability**.

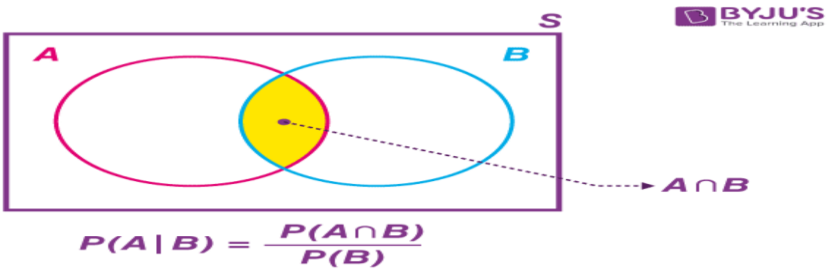
Conditional probability refers to the likelihood of an event occurring **given that another event has already occurred**. For example:

- Probability that a patient has a disease **given** the test result is positive.

This concept is extremely important in medical diagnosis, as test results alone do not provide complete certainty.

<div align="centre">

Conditional probability diagram



3. Bayes' Theorem

3.1 Definition

Bayes' Theorem is a mathematical rule used to update the probability of an event based on new evidence.

3.2 Formula

$$P(A \mid B) = \frac{P(B \mid A) \times P(A)}{P(B)}$$

Where:

- **P(A)** → Prior probability (initial belief)
- **P(B|A)** → Likelihood (evidence given event)
- **P(B)** → Total probability of evidence
- **P(A|B)** → Posterior probability (updated belief)

<div align="centre">

4. Real-World Scenario: Medical Testing

Let us consider a medical scenario involving a **rare disease**.

4.1 Given Information

• **Disease prevalence:**
$\boldsymbol{P(D) = 0.01(1\%)}$
• **Healthy population:**
$\boldsymbol{P(\bar{D}) = 0.99}$
• **Test accuracy:**
○ **True Positive Rate:**
$\boldsymbol{P(+\mid D) = 0.99}$
○ **False Positive Rate:**
$\boldsymbol{P(+\mid \bar{D}) = 0.05}$

This means the test is highly accurate, but the disease is **very rare**.

Diagnostic testing process

5. Step-by-Step Application of Bayes' Theorem

Step 1: Define Events

- **D** → Patient has the disease
- **+** → Test result is positive

Our objective is to calculate:

$$P(D \mid +)$$

Step 2: Calculate Total Probability of a Positive Test

A positive test can occur in two cases:

1. Person has disease and test is positive
2. Person does not have disease but test is falsely positive

$$P(+) = (0.99 \times 0.01) + (0.05 \times 0.99)$$
$$P(+) = 0.0099 + 0.0495 = 0.0594$$

<div align="centre">

Step 3: Calculate Posterior Probability

$$P(D \mid +) = \frac{0.99 \times 0.01}{0.0594}$$
$$P(D \mid +) \approx 0.1667(16.67\%)$$

<div align="centre">

6. Detailed Interpretation of Results

Although the test is **99% accurate**, the probability that a person actually has the disease after testing positive is **only 16.67%**.

Reason

- The disease is very rare.
- False positives occur more frequently than true positives.
- Prior probability plays a crucial role.

7. Importance of Bayes' Theorem in Healthcare

Bayes' Theorem helps in:

- Reducing incorrect diagnosis
- Avoiding unnecessary medication
- Designing better diagnostic tests
- Supporting AI-based clinical decision systems

8. Engineering and AI Perspective

In artificial intelligence and machine learning:

- Bayes' Theorem is used in **Naive Bayes classifiers**
- Helps in **pattern recognition**
- Used for **spam filtering and recommendation systems**

For BTech students, understanding Bayes' Theorem builds a strong foundation in **data science, AI, and decision theory**.

9. Conclusion

Bayes' Theorem is a powerful tool for reasoning under uncertainty. The medical testing example clearly shows that **high accuracy does not guarantee correct conclusions**. By combining prior knowledge with new evidence, Bayes' Theorem ensures better and more reliable decision-making. Its applications in healthcare, artificial intelligence, and engineering make it a vital concept for modern technology students.