**1. What is Grouping in Query Optimization?**

Grouping is an essential operation in **OLAP (Online Analytical Processing)** and **data warehousing**.

It involves **aggregating data** based on certain attributes (e.g., GROUP BY in SQL). Optimizing grouping operations improves query performance, reducing computation time and memory usage.

**2. Invariant Grouping**

**Principle**

* **Invariant Grouping** is an **optimization technique** that shifts a grouping operation **"down" in the query plan** to **reduce intermediate result size**.
* It is **useful when grouping attributes act as foreign keys** in a join operation.
* By **pushing down the grouping** before performing a join, the system can **reduce data size early**, improving efficiency.

**When Can Invariant Grouping Be Used?**

✅ **Grouping attributes are foreign keys** → The join partner does not directly contribute to the grouping result.

**3. Early Pre-Grouping**

**Principle**

* **Early Pre-Grouping** is another optimization technique that **adds an extra grouping operation before a join**, similar to a projection.
* It **reduces the amount of data before joins**, leading to **faster execution and lower memory usage**.
* Used when:  
  ✅ The **grouping condition includes join attributes**.  
  ✅ Aggregated values **do not depend on attributes of the join partner**.