

7.1 SUBGROUPS

Definition 7.1.1

Assume $\langle G, * \rangle$ is a group and $H \subset G$ and $H \neq \phi$. Then H is called a subgroup of G if H itself is a group under operation $*$ in G .

Notation: Write $H < G$ for H subgroup of G .

Subset $H = \{e\}$ and $H = G$ is always a subgroup of group G , which is named as a **trivial subgroup**. All other subgroup of G is called a **non-trivial subgroup** or **proper subgroup**.

Example 7.1.1

Set $\langle \mathbb{Z}, + \rangle$ is a group (Refer Example 7.1.1). Prove that the set E of all even numbers is a non-trivial subgroup under addition in \mathbb{Z} .

Proof

$E = \{x = 2m \mid m \in \mathbb{Z}\}$. Known that $E \subset \mathbb{Z}$ and $E \neq \phi$. Prove 4 properties of group as

Definition 7.1.1.

1. Say $y = 2n$ where $n \in \mathbb{Z}$.
Then $x + y = 2m + 2n = 2(m + n) = 2k \in E$ where $k \in \mathbb{Z}$.
Thus E is closed under addition for all $x, y, z \in E$.
2. Say $z = 2p$ where $p \in \mathbb{Z}$.
Then $(x + y) + z = (2m + 2n) + (2p) = 2(m + n + p) = 2q \in E$ where $q \in \mathbb{Z}$.
And $x + (y + z) = (2m) + (2n + 2p) = 2(m + n + p) = 2q \in E$ where $q \in \mathbb{Z}$.
Thus E is associative for all $x, y, z \in E$.
3. $e + x = x \rightarrow e + 2m = 2m \rightarrow e = 0 = 2(0) \in E$
while $x + e = x \rightarrow 2m + e = 2m \rightarrow e = 0 = 2(0) \in E$
Then an identity under addition for all $x \in E$ is $e = 0$.
4. $x + (-x) = e \rightarrow x + (-x) = 0 \rightarrow -x = -2m = 2(-m) = 2s \in E$ where $s \in \mathbb{Z}$
While $-x + x = e \rightarrow -x + x = 0 \rightarrow -x = -2m = 2(-m) = 2s \in E$
Thus there exists an inverse $x = 2(-m)$ for every $x \in E$.

$\langle E, + \rangle$ is a non-trivial subgroup of $\langle \mathbb{Z}, + \rangle$ was proven.

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