

## 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  $H \leq G$  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.

# Summer Inst On Number Theory Lect Notes

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