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# Some properties of Square element graphs over semigroups

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**Abstract**

The Square element graph over a semigroup $S$ is a simple undirected graph $\mathbb{S}q(S)$ whose vertex set consists precisely of all the non-zero elements of $S$, and two vertices $a, b$ are adjacent if and only if either $ab$ or $ba$ belongs to the set $\{t^2 : t \in S\} \setminus \{1\}$, where 1 is the identity of the semigroup (if it exists). In this paper, we study the various properties of $\mathbb{S}q(S)$. In particular, we concentrate on square element graphs over three important classes of semigroups. First, we consider the semigroup $\Omega_n$ formed by the ideals of $\mathbb{Z}_n$. Afterwards, we consider the symmetric groups $S_n$ and the dihedral groups $D_n$. For each type of semigroups mentioned, we look into the structural and other graph-theoretic properties of the corresponding square element graphs.


*Keywords:* Square element graph; Semigroup; Semigroup of ideals; Symmetric group; Dihedral group

## 1. Introduction

Graphs defined over algebraic structures reveal interesting interplay between graph-theoretic and algebraic properties. For example, zero-divisor graphs [1] have shown that the set of zero-divisors of a ring has many underlying properties which are significant from a graph-theoretic perspective.

Like the set of zero-divisors, we can consider another interesting set in an algebraic structure $R$, viz., the set of squares of $R$ (i.e., the set $T = \{x^2 \mid x \in R\}$). It is interesting to observe that exactly like the set of zero-divisors, the set of squares of a commutative ring is not closed under addition (in general) but is closed under multiplication. Using the set of squares, Sen Gupta and Sen defined the square element graph over a finite commutative ring [2], where the set of all non-zero elements of a finite commutative ring $R$ is taken as the vertex set, and two vertices are adjacent if and only if their sum is a square of some non-zero element of $R$. Later, Sen Gupta and Sen generalized the square element graphs over arbitrary rings [3]. Now once the set of squares of a ring is determined, the square element graph essentially uses only one operation of a ring. Hence, like the zero-divisor graphs, the square element graphs can also be defined over a semigroup. We define the square element graph over a semigroup in the following way:

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