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On ve-quasi and secured ve-quasi independent sets of a graph

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Abstract

In this paper, we have defined the concepts of ve-quasi independent set and secured ve-quasi independent set. In order to define these concepts we have used the concept of a vertex which m-dominates an edge. We prove a characterization of a maximal ve-quasi independent set. We also prove that the complement of a ve-quasi independent set is a ve-dominating set. We prove a necessary and sufficient condition under which a ve-quasi independent set is a secured ve-quasi independent set. Also we prove a necessary and sufficient condition under which the ve-quasi independence number and secured ve-quasi independence number decrease when a vertex is removed from the graph. Some examples have also been given.

Keywords

ve-quasi independent set, secured ve-quasi independent set, ve-quasi isolated vertex, ve-dominating set

AMS Subject Classification

05C69

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1. Introduction

The domination related results have been appeared in several articles. The concepts of vertices dominate edges and edges dominate vertices are studied by several authors. The concept of a vertex-edge dominating set (ve-dominating set) is defined by E. Sampathkumar and S. S. Kamath in [2]. A vertex $v \in V(G)$ m-dominates an edge $x \in E(G)$ if $x \in \langle N[v] \rangle$. A set $S \subseteq V(G)$ is a ve-dominating set if every edge in G is m-dominated by a vertex in S [2]. We introduce the concept of ve-quasi independent sets using the concept of ve-domination in graphs. We call a set S of vertices to be a ve-quasi independent set if whenever $u, v \in S$ are adjacent vertices, there is a vertex x in $V(G) \setminus S$ which m-dominates the edge uv in G. We also introduce the concept of secured ve-quasi independent set. A ve-quasi independent set S is a secured ve-quasi independent set if for each $v \in S$, there is a vertex u in $V(G) \setminus S$ which is adjacent to v such that $(S \setminus \{v\}) \cup \{u\}$ is a ve-quasi independent set.

We also introduce maximal ve-quasi independent set and maximum ve-quasi independent set as well as maximal secured ve-quasi independent set and maximum secured ve-quasi independent set.

2. Preliminaries and Notations

If G is a graph then $E(G)$ denotes the edge set and $V(G)$ denotes the vertex set of the graph. If v is a vertex of G then $G \setminus v$ denotes the subgraph of G obtained by removing the vertex v and all the edges incident to v. $N(v)$ denotes the set of vertices which are adjacent to v. $N[v] = N(v) \cup \{v\}$. If G is a graph then $\beta_0(G)$ denotes the independence number of a graph G. If G is a graph then the induced subgraph denoted as $\langle S \rangle$ is the graph whose vertex set is S and whose edge set consists of all the edges that have both end points in S.

3. Main Results

Definition 3.1. *Let G be a graph. A set S of vertices is said to be a ve-quasi independent set if whenever $u, v \in S$ are adjacent vertices, $N(u) \cap N(v) \cap (V(G) \setminus S) \neq \phi$.*
i.e. u and v have a common neighbor in $V(G \setminus S)$ if u and v are adjacent vertices of S.

We can also characterize a ve-quasi independent set as follows:
A subset S of $V(G)$ is a ve-quasi independent set if and only if whenever $u, v \in S$ are adjacent vertices, there is a vertex x in $V(G) \setminus S$ which m-dominates the edge uv in G.

Theorem 3.2. *Let G be a graph and $S \subset V(G)$ then S is a ve-quasi independent set if and only if $V(G \setminus S)$ is a ve-dominating set.*

Proof. First suppose that S is a ve-quasi independent set. Let $e = uv$ be any edge of G. If $u \in V(G \setminus S)$ or $v \in V(G \setminus S)$, then e is m-dominated by some vertex of $V(G \setminus S)$. Suppose $u \notin V(G \setminus S)$ and $v \notin V(G \setminus S)$. Then u and v are adjacent vertices of S. Since S is a ve-quasi independent set, there is some vertex x in $N(u) \cap N(v) \cap (V(G) \setminus S)$. Then $x \in V(G \setminus S)$ and e is m-dominated by x. Thus, we have proved that any edge of G is m-dominated by some vertex of $V(G \setminus S)$. Therefore, $V(G \setminus S)$ is a ve-dominating set.
Conversely, suppose that $V(G \setminus S)$ is a ve-dominating set. Suppose u, v are adjacent vertices of S. Now, $e = uv$ is an edge of G and $V(G \setminus S)$ is a ve-dominating set of G. Therefore, there is a vertex x in $V(G \setminus S)$ which m-dominates e. This means that u is adjacent to x or v is also adjacent to x. Therefore, $x \in N(u) \cap N(v) \cap (V(G) \setminus S)$. Therefore, $N(u) \cap N(v) \cap (V(G) \setminus S) \neq \phi$. Hence, S is a ve-quasi independent set. □

Remark 3.3. (i) *Every independent set is a ve-quasi independent set but the converse is not true in general.*

(ii) *A ve-quasi independence is a hereditary property.*

Example 3.4. *Consider the graph C_3 with vertices $\{v_1, v_2, v_3\}$*

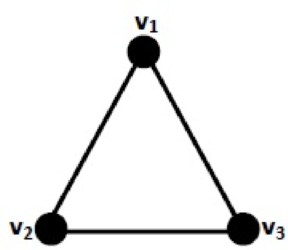

Figure 1. C_3

Let $S = \{v_2, v_3\}$. Then S is a ve-quasi independent set but it is not an independent set.

Definition 3.5. *Let G be a graph. $S \subset V(G)$ and $v \in S$. Then v is said to be a ve-quasi isolated vertex of S if whenever u is adjacent to v, $N(v) \cap N(u) \cap (V(G) \setminus S) \neq \phi$.*

Proposition 3.6. *Let G be a graph and $S \subset V(G)$. Then S is a ve-quasi independent set if and only if every vertex of S is a ve-quasi isolated vertex of S.*

Proof. First suppose that S is a ve-quasi independent set. From the definition, it is clear that each vertex of S is a ve-quasi isolated vertex of S.
Conversely, suppose each vertex of S is a ve-quasi isolated vertex of S. Let u, v be adjacent vertices of S. Now, v is a ve-quasi isolated vertex of S and u is adjacent to v. Therefore, $N(v) \cap N(u) \cap (V(G) \setminus S) \neq \phi$. This proves that S is a ve-quasi independent set. □

Definition 3.7. *Let G be a graph and $S \subset V(G)$ be a ve-quasi independent set then S is said to be a maximum ve-quasi independent set if its cardinality is maximum among all ve-quasi independent subsets of G.*
The cardinality of a maximum ve-quasi independent set is called the ve-quasi independence number of the graph G and it is denoted as $\beta_q(G)$.

Note that for any graph G, $\beta_0(G) \leq \beta_q(G)$.

Example 3.8. *Consider the figure 1*
Here, $S = \{v_2, v_3\}$ is a maximum ve-quasi independent set and $\beta_q(G) = 2$. Also $\beta_0(G) = 1$.
Thus for this graph, $\beta_0(G) < \beta_q(G)$.

Example 3.9. *Consider the graph G with vertices $\{v_1, v_2, v_3, v_4, v_5, v_6\}$*

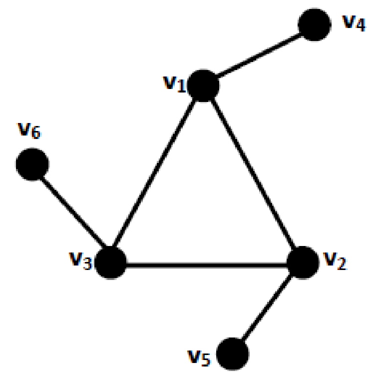

Figure 2. G

Obviously, $\beta_0(G) = 3$. Let $S = \{v_1, v_2, v_6\}$. Then S is a maximum ve-quasi independent set of G and therefore, $\beta_q(G) = 3$. Thus for this graph, $\beta_0(G) = \beta_q(G)$.

Proposition 3.10. *Let G be a graph and $v \in V(G)$. Then $\beta_q(G \setminus v) \leq \beta_q(G)$.*

Proof. Let S be a maximum ve-quasi independent subset of $G \setminus v$. Obviously, S is a ve-quasi independent subset of G.
Therefore, $\beta_q(G) \geq |S| = \beta_q(G \setminus v)$.
Therefore, $\beta_q(G \setminus v) \leq \beta_q(G)$. □

Theorem 3.11. *Let G be a graph and $v \in V$. Then $\beta_q(G \setminus v) < \beta_q(G)$ if and only if for every maximum ve-quasi independent subset S of G not containing v, there are adjacent vertices x and y of S such that $N(x) \cap N(y) \cap (V(G) \setminus S) = \{v\}$.*

Proof. First suppose that $\beta_q(G \setminus v) < \beta_q(G)$. Let S be a maximum ve-quasi independent subset of G not containing v. Since $\beta_q(G \setminus v) < \beta_q(G)$, S can not be a ve-quasi independent subset of $G \setminus v$. Therefore, there are adjacent vertices x and

y of S such that $N(x) \cap N(y) \cap (V(G \backslash v) \backslash S) = \phi$. However, $N(x) \cap N(y) \cap (V(G) \backslash S) \neq \phi$ because S is a ve-quasi independent subset of G. Therefore, $N(x) \cap N(y) \cap (V(G) \backslash S) = \{v\}$. Thus, the condition is satisfied.
Conversely, suppose the condition is satisfied.
Suppose, $\beta_q(G \backslash v) \not< \beta_q(G)$. Therefore, $\beta_q(G \backslash v) = \beta_q(G)$. Let S be a maximum ve-quasi independent subset of $G \backslash v$. Then S is also a maximum ve-quasi independent subset of G not containing v. Let x and y be adjacent vertices of S. Since S is a ve-quasi independent subset of $G \backslash v$, x and y have a common neighbor in $V(G \backslash v) \backslash S$ say u. Therefore, $u \in N(x) \cap N(y) \cap (V(G) \backslash S)$ and $u \neq v$. Therefore, $N(x) \cap N(y) \cap (V(G) \backslash S) \neq \{v\}$ for any two adjacent vertices x and y of S which contradicts the given condition.
Therefore, $\beta_q(G \backslash v) < \beta_q(G)$ □

Definition 3.12. *Let G be a graph and $S \subset V(G)$ be a ve-quasi independent set. Then S is said to be a maximal ve-quasi independent set if S is not properly contained in any ve-quasi independent subset of G.*
We may note that a ve-quasi independent set S is a maximal ve-quasi independent set if and only if for each $v \in V(G) \backslash S$, $S \cup \{v\}$ is not a ve-quasi independent set.

Theorem 3.13. *Let G be a graph and $S \subset V(G)$ be a ve-quasi independent set then S is a maximal ve-quasi independent set if and only if for each $v \in V(G) \backslash S$, one of the following two conditions is satisfied.*

(*i*) *There are adjacent vertices x and y of S such that v is the only common neighbor of x and y in $V(G) \backslash S$.*

(*ii*) *There is a vertex x in S adjacent to v such that x and v do not have a common neighbor in $V(G) \backslash S$.*

Proof. Suppose, S is a maximal ve-quasi independent set. Let $v \in V(G) \backslash S$. Now, $S \cup \{v\}$ is not a ve-quasi independent set. Therefore, there are adjacent vertices x and y of $S \cup \{v\}$ such that x and y do not have a common neighbor in $V(G) \backslash (S \cup \{v\})$.
Case (i): $x \neq v$ and $y \neq v$
Then $x, y \in S$. Now x and y do not have a common neighbor in $V(G) \backslash (S \cup \{v\})$. However x and y have a common neighbor in $V(G) \backslash S$. Therefore, v is the only common neighbor of x and y in $V(G) \backslash S$. Thus condition (i) is satisfied.
Case (ii): $x = v$ or $y = v$
We may assume that $y = v$. Then x and v are adjacent vertices and they do not have any common neighbor in $V(G) \backslash (S \cup \{v\})$. Therefore, x and v do not have a common neighbor in $V(G) \backslash S$. Thus condition (ii) is satisfied.
Conversely, suppose S is ve-quasi independent set for which condition (i) and (ii) are satisfied for each $v \in V(G) \backslash S$. Let $v \in V(G) \backslash S$. Suppose condition (i) is satisfied. Then x and y are two vertices of $S \cup \{v\}$ which are adjacent and they do not have a common neighbor in $v \in V(G) \backslash (S \cup \{v\})$. Suppose condition (ii) is satisfied. Let x be a vertex of S such that x is adjacent to v and x. And v do not have a common vertex in $v \in V(G) \backslash S$. Then x and v are adjacent vertices of $S \cup \{v\}$ such that they do not have a common neighbor in $v \in V(G) \backslash (S \cup \{v\})$.
From both the above cases it follows that S is a maximal ve-quasi independent set. □

Obviously, every maximum ve-quasi independent set is a maximal ve-quasi independent set. However, the converse is not true.

Example 3.14. *Consider the following graph G with vertices* $\{v_1, v_2, v_3, v_4, v_5\}$

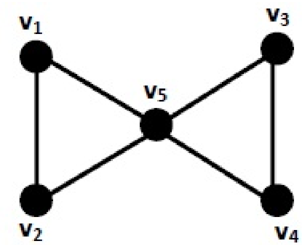

Figure 3. G

Let $T = \{v_1, v_2, v_3, v_4\}$. Then T is a maximum ve-quasi independent set of G. Let $S = \{v_1, v_3, v_5\}$. Then S is a maximal ve-quasi independent set and $|S| < |T|$. Therefore, S is a maximal ve-quasi independent set which is not a maximum ve-quasi independent set.

Definition 3.15. *Let G be a graph and $S \subset V(G)$ be a ve-quasi independent set. Then S is said to be a secured ve-quasi independent set if for each $v \in S$, there is u in $V(G) \backslash S$ which is adjacent to v such that $(S \backslash \{v\}) \cup \{u\}$ is a ve-quasi independent set.*

Example 3.16. *Consider the following graph G with vertices* $\{v_1, v_2, v_3, v_4\}$

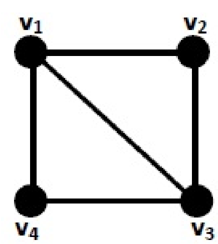

Figure 4. G

Let $S = \{v_1, v_3\}$. Then S is a secured ve-quasi independent set of G.

Example 3.17. *Consider the figure 3*
Let $S = \{v_1, v_2, v_3, v_4\}$. Then S is not a secured ve-quasi independent set of G.

Definition 3.18. *Let G be a graph and $S \subset V(G)$ be a secured ve-quasi independent set then S is said to be a maximum secured ve-quasi independent set if its cardinality is maximum among all secured ve-quasi independent subsets of G.*

The cardinality of a maximum secured ve-quasi independent set is called the secured ve-quasi independence number of the graph G and it is denoted as $\beta_{sq}(G)$.

Proposition 3.19. *Let G be a graph and suppose $\{M_1, M_2, ..., M_k\}$, $k \geq 2$ is the set of all maximum ve-quasi independent sets of G. Suppose atleast one of them is a secured ve-quasi independent set then $M_1 \cap M_2 \cap ... \cap M_k = \phi$.*

Proof. Suppose, $M_1 \cap M_2 \cap ... \cap M_k \neq \phi$. Let $v \in M_1 \cap M_2 \cap ... \cap M_k$. Suppose for some j $(j \in \{1, 2, ..., k\})$, M_j is a secured ve-quasi independent set. Then $v \in M_j$. There is a neighbor u of v such that $u \notin M_j$ and $N = (M_j \backslash \{v\}) \cup \{u\}$ is a ve-quasi independent set. Now, $|N| = |M_j|$. Therefore, M is a maximum ve-quasi independent set and therefore $N \in \{M_1, M_2, ..., M_k\}$ and therefore $v \in N$ which is a contradiction. Thus, $M_1 \cap M_2 \cap ... \cap M_k = \phi$. □

Now, we give a necessary and sufficient condition under which a ve-quasi independent set is a secured ve-quasi independent set.

Theorem 3.20. *Let G be a graph and $S \subset V(G)$ be a ve-quasi independent set. Then S is a secured ve-quasi independent set if and only if for each $v \in S$ there is a neighbor u of v in $V(G) \backslash S$, for each x, y in $(S \backslash \{v\}) \cup \{u\}$ one of the following two conditions is satisfied*

(*i*) *v is a common neighbor of x and y.*

(*ii*) *There is a common neighbor of x and y in $V(G) \backslash S$ which is different from u.*

Proof. Suppose S is a secured ve-quasi independent set. Let $v \in S$. Then there is a neighbor u of v in $V(G) \backslash S$ such that $(S \backslash \{v\}) \cup \{u\}$ is a ve-quasi independent set.
Let $x, y \in (S \backslash \{v\}) \cup \{u\}$.
Since $(S \backslash \{v\}) \cup \{u\}$ is ve-quasi independent set, x and y have a common neighbor w outside $(S \backslash \{v\}) \cup \{u\}$.
If $w = v$ then condition (i) is satisfied. If $w \neq v$ then x and y have a common neighbor outside $(S \backslash \{v\}) \cup \{u\}$ which is different from u. Thus condition (ii) is satisfied.
Conversely, suppose for each $v \in S$ there is a neighbor u of v in $V(G) \backslash S$ such that (i) or (ii) is satisfied.
Let $v \in S$ and $u \in V(G) \backslash S$ be a neighbor of v such that (i) or (ii) is satisfied. Now, we prove that $(S \backslash \{v\}) \cup \{u\}$ is a ve-quasi independent set. Let $x, y \in (S \backslash \{v\}) \cup \{u\}$. Suppose condition (i) is satisfied then v is a common neighbor of x and y outside $(S \backslash \{v\}) \cup \{u\}$. Suppose condition (ii) is satisfied. Then there is a common neighbor w of x and y outside $(S \backslash \{v\}) \cup \{u\}$ which is different from u.
This proves that $(S \backslash \{v\}) \cup \{u\}$ is a ve-quasi independent set. Thus the theorem is proved. □

Note that for any graph G, $\beta_{sq}(G) \leq \beta_q(G)$.

Corollary 3.21. *Let G be a graph. Then*

(*i*) *If $\beta_q(G) = 1$ then $\beta_{sq}(G) = \beta_q(G)$.*

(*ii*) *If $\beta_q(G) \geq 2$ and if the intersection of all maximum ve-quasi independent sets of G is non empty then $\beta_{sq}(G) < \beta_q(G)$.*

Proof. (*i*) If $\beta_q(G) = 1$ and $\beta_{sq}(G) \leq 1$ it follows that $\beta_{sq}(G) = 1 = \beta_q(G)$.

(*ii*) Suppose, $\beta_q(G) \geq 2$ and suppose the intersection of all maximum ve-quasi independent sets of G is non-empty then none of these maximum ve-quasi independent sets can be a secured ve-quasi independent set.(by the above property). Therefore, the cardinality of any maximum secured ve-quasi independent set is strictly less than $\beta_q(G)$. Thereofre, $\beta_{sq}(G) < \beta_q(G)$. □

Example 3.22. *Consider the figure 3*
In this graph, $S = \{v_1, v_2, v_3, v_4\}$ is a maximum ve-quasi independent set and therefore $\beta_q(G) = 4$. Let $T = \{v_1, v_3, v_5\}$. Then T is a maximum secured ve-quasi independent set of G and $|T| = 3$. Thus for this graph $\beta_{sq}(G) < \beta_q(G)$.

Example 3.23. *Consider the figure 1*
Here, $S_1 = \{v_1, v_2\}$, $S_2 = \{v_2, v_3\}$ and $S_3 = \{v_1, v_3\}$ are all the maximum ve-quasi independent sets of C_3 and $S_1 \cap S_2 \cap S_3 = \phi$. Also $\beta_q(C_3) = 2$ and the above sets are also maximum secured ve-quasi independent sets and therefore $\beta_{sq}(C_3) = 2$. Thus for this graph, $\beta_{sq}(C_3) \not< \beta_q(C_3)$ although $\beta_q(C_3) \geq 2$.

Example 3.24. *Consider the graph K_2 with vertices $\{v_1, v_2\}$*

Figure 5. P_2

Here, $\beta_q(K_2) = 1$ and $\beta_{sq}(K_2) = 1$.

Proposition 3.25. *Let G be a graph and $v \in V(G)$. Then $\beta_{sq}(G \backslash v) \leq \beta_{sq}(G)$.*

Proof. Let S be a maximum secured ve-quasi independent set of $G \backslash v$. Let $u \in S$. Then there is a vertex u' of $G \backslash v$ such that $u' \notin S$. u' is adjacent to u and $(S \backslash \{u\}) \cup \{u'\}$ is a ve-quasi independent set of $G \backslash v$. Note that $(S \backslash \{u\}) \cup \{u'\}$ is also a ve-quasi independent set of G and $u' \in V(G) \backslash S$. Thus we have proved that for each u in S there is a neighbor u' of u in $V(G) \backslash S$ such that $(S \backslash \{u\}) \cup \{u'\}$ is a ve-quasi independent set of G. Thus, S is a secured ve-quasi independent set of G also. Therefore, $\beta_{sq}(G) \geq |S| = \beta_{sq}(G \backslash v)$. □

Theorem 3.26. *Let G be a graph and $v \in V$. Then $\beta_{sq}(G \backslash v) < \beta_{sq}(G)$ if and only if for every maximum secured ve-quasi independent set S of G not containing v atleast one of the following two conditions holds*

(*i*) *There are adjacent vertices x and y of S such that v is the only common neighbor of x and y in $V(G) \backslash S$.*

(*ii*) *There is a vertex u in S such that for every* u' *in* $V(G\backslash v)\backslash S$, $(S\backslash\{u\})\cup\{u'\}$ *is not a ve-quasi independent set of* $G\backslash v$.

Proof. First suppose that $\beta_{sq}(G\backslash v) < \beta_{sq}(G)$.
Let S be a maximum secured ve-quasi independent set of G not containing v. Since $|S| > \beta_{sq}(G\backslash v)$, S can not be a secured ve-quasi independent set of $G\backslash v$. Then one of the following two possibilities arises.
Case (i): S is not a ve-quasi independent set of $G\backslash v$.
In this case, there are adjacent vertices x and y of S such that x and y have no common neighbor in $(V(G\backslash v)\backslash S)$. However, x and y have a common neighbor in $V(G)\backslash S$. Therefore, v is the only common neighbor of x and y in $V(G)\backslash S$.
Case (ii): S is not a secured ve-quasi independent set of $G\backslash v$. Therefore, there is a vertex u of S such that for every neighbor u' of u in $(V(G\backslash v)\backslash S)$, $S\backslash\{u\}\cup\{u'\}$ is not a ve-quasi independent set of $G\backslash v$.
Thus, condition (i) or (ii) is satisfied.
Conversely, suppose for any maximum secured ve-quasi independent set S of G not containing v, (i) or (ii) is satisfied.
Suppose, $\beta_{sq}(G\backslash v) = \beta_{sq}(G)$. Let T be a maximum secured ve-quasi independent set of $G\backslash v$. Now, T is a secured ve-quasi independent set of G also. Since $|T| = \beta_{sq}(G\backslash v) = \beta_{sq}(G)$, T is a maximum secured ve-quasi independent set of G not containing v. Note that for any two adjacent vertices x and y of S, x and y have a common neighbor in $(V(G\backslash v)\backslash S)$. Thus condition (i) is violated. Since S is a secured ve-quasi independent set of $G\backslash v$, for each $u \in S$ there is a neighbor u' of u in $(V(G\backslash v)\backslash S)$ such that $(S\backslash\{u\})\cup\{u'\}$ is a ve-quasi independent set of $G\backslash v$. Therefore, condition (ii) is also violated. Thus if we assume that $\beta_{sq}(G\backslash v) = \beta_{sq}(G)$ then both the conditions (i) and (ii) are violated for some maximum secured ve-quasi independent set S of G not containing v. This is a contradiction.
Therefore, $\beta_{sq}(G\backslash v) < \beta_{sq}(G)$ □

Example 3.27. *Consider the figure 3*

Here, $S = \{v_1, v_3, v_5\}$ *is a secured ve-quasi independent set of G. Therefore* $\beta_{sq}(G) = 3$. *Consider the subgraph* $G\backslash\{v_5\}$. *Then* $T = \{v_1, v_3\}$ *is a secured ve-quasi independent set of* $G\backslash\{v_5\}$. *Therefore* $\beta_{sq}(G\backslash v_5) = 2$. *Thus,* $\beta_{sq}(G\backslash v_5) < \beta_{sq}(G)$.

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References

[1] E. Sampathkumar and P. S. Neeralagi, The neighbourhood number of a graph, *Journal of Pure and Applied Mathematics*, (1985), 126–136.

[2] E. Sampathkumar and S. S. Kamath, Mixed Domination in Graphs, *The Indian Journal of Statistics*, (1992), 12–19.

[3] R. Laskar and K. Peters, Vertex and edge domination parameters in graphs, *Congressus Numerantium*, 48(1985), 291–305.

[4] T. W. Haynes, S. T. Hedetniemi and P. J. Slater, *Domination in Graphs Advanced Topics*, Marcel Dekker, Inc., New-York 1998.

[5] T. W. Haynes, S. T. Hedetniemi and P. J. Slater, *Fundamentals of Domination in Graphs*, Marcel Dekker, Inc., New-York 1998.

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