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EQUITABLE COLOR CLASS DOMINATION NUMBER OF SOME SPECIAL GRAPHS AND SOME DERIVED PATH GRAPHS

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Abstract: Let $\mathcal{G} = (\mathcal{V}_{p}, \mathcal{E}_{q})$ be a connected graph. Assume a group CC containing colors. Let $\tau: \mathcal{V}_{p}(\mathcal{G}) \rightarrow$ CC be an equitably colorable function. A dominating subset $\mathcal{S}_{\mathcal{P}}$ of $\mathcal{V}_{p}$ is called an equitable color class dominating set if the number of dominating nodes in each color class is equal. The least possible cardinality of an equitable color class dominating set of $\mathcal{G}$ is equitable color class domination number itself. It is indicated by γ_{ECC} $(\mathcal{G})$. In this paper we explore the equitable color class domination number of some special graphs and some derived path graphs.

Keywords: Domination, Dominating Set, Equitable Coloring, Color Class(CC), Equitable Color Class, Equitable Color Class Dominating set.

I INTRODUCTION: In graph theory, domination and coloring are the most important theories and they are still a very active field of research. The domination theory was introduced in the 1950s but it was highly researched from the mid-1970s [6] and [7]. oystein ore introduced the terms "Dominating Set" and "Domination Number" in 1962 [12]. Graph coloring is a special case of graph labeling. The first results about graph coloring deal almost exclusively with planar graphs in the form of the coloring of maps. It has been studied as an algorithmic problem since the early 1970s. In this paper, we considered all the graphs are finite, undirected with no loops. Let $\mathcal{G} = (\mathcal{V}_{p},\mathcal{E}_{q})$ be a graph. $\mathcal{V}_{p}$ is a set of nodes it is finite and non-empty and $\mathcal{E}_{q}$ is a set of edges. The degree of a node v is denoted by deg$(\mathcal{V}_{p})$. The minimum and maximum degree of a graph $\mathcal{G}$ are denoted by $\delta(\mathcal{G})$ and $\Delta(\mathcal{G})$ respectively [4].

II DEFINITIONS AND NOTATIONS:

Definition 2.1: [6] In a graph $\mathcal{G} = (\mathcal{V}_{p}, \mathcal{E}_{q})$, a subset $\mathcal{S}_{\mathcal{P}}$ of nodes is a dominating set if every node in $\mathcal{V}_{p} - \mathcal{S}_{\mathcal{P}}$ is adjacent to some node in $\mathcal{S}_{\mathcal{P}}$. The least possible cardinality of the dominating set of $\mathcal{G}$ is called its domination number and it is indicated by $\gamma(G)$.

Definition 2.2: [11] In a graph $\mathcal{G}$, adjacent nodes don't ordain the same color is known as proper coloring. The least possible number of colors used to color a graph $\mathcal{G}$ is known as its chromatic number and it is indicated by $\chi(\mathcal{G})$.

Definition 2.3: [16] A subset of nodes ordained to the same color is known as a color class.

Definition 2.4: [11] In a graph, adjacent nodes don't have the same color and the difference between the cardinality of color classes is ≤ 1 is called an equitable coloring graph. The least possible number of colors used to equitably color a graph $\mathcal{G}$ is known as its equitable chromatic number and it's indicated by $\chi_{E}(\mathcal{G})$.

Notation 2.5: Let $\mathcal{X}$ be any real number. Then $\lfloor \mathcal{X} \rfloor$ indicates the greatest integer $\leq \mathcal{X}$ and $\lceil \mathcal{X} \rceil$ indicate the smallest integer $\geq \mathcal{X}$.

Notation 2.6: If a,b be the integers and $n > 0$ then $a \equiv b$ (mod n) indicates $n|a$-b.

Definition 2.7: [9] The ordinary subdivision graph is obtained from the graph by inserting a new node of degree 2 on each edge of the graph and it is indicated by $\mathcal{S}(\mathcal{G})$.

Definition 2.8: [9] The Splitting graph of $\mathcal{G}$, $\mathcal{S}'(\mathcal{G})$ is obtained from $\mathcal{G}$ by adding for each vertex v of $\mathcal{G}$ a new vertex v' so that v' is adjacent to every vertex that is adjacent to v.

Definition 2.9: [9] The Shadow graph $\mathcal{D}_{2}(\mathcal{G})$ of a connected graph $\mathcal{G}$ is constructed by taking two copies of $\mathcal{G}$, $\mathcal{G}'$ and $\mathcal{G}''$ and joining each vertex u' in $\mathcal{G}'$ to the neighbors of the corresponding vertex u'' in $\mathcal{G}''$.

III PRIMARY RESULTS:

Definition 3.1: [5] Let $\mathcal{G} = (\mathcal{V}_p, \mathcal{E}_q)$ be a connected graph. Assume a group CC containing colors. Let τ: $\mathcal{V}_p(\mathcal{G}) \to$ CC be an equitably colorable function. A dominating subset $\mathcal{S}_\mathcal{P}$ of $\mathcal{V}_p$ is called an equitable color class dominating set if the number of dominating nodes in each color class is equal. The least possible cardinality of an equitable color class dominating set of $\mathcal{G}$ is the equitable color class domination number itself. It is indicated by γ_{ECC} $(\mathcal{G})$.

Theorem 3.2: The equitable color class domination number of a butterfly graph $(n > 1)$ $\gamma_{ECC}(\mathcal{BF}_n) = n + 2$.

Proof: Let $\mathcal{BF}_n$ be the butterfly graph with $\mathcal{V}_p(\mathcal{BF}_n) = \{u, v, w, u_i, v_i : 1 \le i \le n\}$ and $\mathcal{E}_q(\mathcal{BF}_n) = \{wu, wv, wu_i, wv_i : 1 \le i \le n\} \cup \{u_i u_{i+1}, v_i v_{i+1} : 1 \le i \le n - 1\}$. $|\mathcal{V}_p(\mathcal{BF}_n)| = 2n + 3$. χ_E of $\mathcal{BF}_n$ is $n + 2$. Let τ: $\mathcal{V}_p(\mathcal{BF}_n) \to$ CC be an equitably colorable function where CC = $\{1, 2, \ldots, n, n + 1, n + 2\}$. Ordain the color i to the nodes u_i and v_i where $1 \le i \le n$. Ordain the color $n + 1$ to the nodes u and v. Ordain the color $n + 2$ to the node w. Now we choose w, u and u_i $(1 \le i \le n)$ nodes as dominating nodes. The number of dominating nodes in each color class is same and one. Hence, γ_{ECC} $(\mathcal{BF}_n)$ is $n + 2$.

Example 3.3:

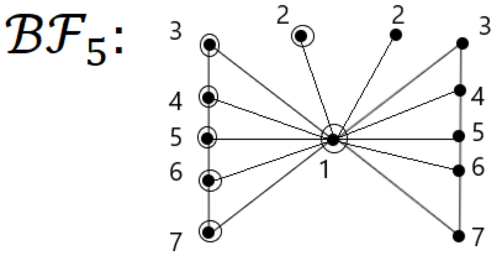

Fig.3.1

Dominating set = $\{w, u, u_1, u_2, u_3, u_4, u_5\}$.

γ_{ECC} $(\mathcal{BF}_5) = 7$.

Theorem 3.4: The equitable color class domination number of lotus inside circle graph $\gamma_{ECC}(\mathcal{LC}_n) = 4\lceil \frac{n}{6} \rceil$.

Proof: Let $\mathcal{LC}_n$ be the lotus inside circle graph with $\mathcal{V}_p(\mathcal{LC}_n) = \{u, u_i, v_i : 1 \le i \le n\}$. Let u be the center node of $\mathcal{K}_{1,n}$ and u_1, u_2, ..., u_n be the pendent vertices of $\mathcal{K}_{1,n}$. Let v_1, v_2, ..., v_n be the vertices of the cycle $\mathcal{C}_n$ such that u_1 is adjacent with v_n and v_1, u_i is adjacent with v_{i-1} and v_i $(2 \le i \le n)$. $|\mathcal{V}_p(\mathcal{LC}_n)| = 2n + 1$. χ_E of $\mathcal{LC}_n$ is $n + 2$. Let τ: $\mathcal{V}_p(\mathcal{LC}_n) \to$ CC be an equitably colorable function where CC = $\{1, 2, 3, 4\}$.

Case 1: n is odd

Ordain the color 1 to the nodes u and v_i (i is odd and $1 \le i \le n - 1$), 2 to the nodes u_n and v_i (i is even), 3 to the nodes v_n and u_i (i is odd and $1 \le i \le n - 1$) and 4 to the nodes u_i (i is even). Now we choose dominating nodes as v_{3i+1} and u_{3i+2} (i = 0, 1, 2, …, $\lceil \frac{n}{3} \rceil$-1). If $3i$+1 or $3i$+2 > n for i = $\lceil \frac{n}{3} \rceil$-1 then replacing the dominating nodes v_{3i+1} by v_{n-1} and u_{3i+2} by u_{n-2}. If $3i$+1 or $3i$+2 > n for i = $\lceil \frac{n}{3} \rceil$ and $\lceil \frac{n}{3} \rceil$-1 then replacing the dominating nodes v_{3i+1} by v_{n-2} or v_{n-1} and u_{3i+2} by u_{n-1} or u_{n-4}. These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and $\lceil \frac{n}{6} \rceil$. The total number of dominating nodes is $\lceil \frac{n}{6} \rceil + \lceil \frac{n}{6} \rceil + \lceil \frac{n}{6} \rceil + \lceil \frac{n}{6} \rceil = 4\lceil \frac{n}{6} \rceil$. Hence, when n is odd γ_{ECC} of any $\mathcal{LC}_n$ is $4\lceil \frac{n}{6} \rceil$.

Case 2: n is even

Ordain the color 1 to the nodes u and v_i (i is odd), 2 to the nodes v_i (i is even), 3 to the nodes u_i (i is odd) and 4 to the nodes u_i (i is even). Now we choose dominating nodes as v_{3i+1} and u_{3i+2} (i = 0, 1, 2, …, $\lceil \frac{n}{3} \rceil$-1). If $3i$+1 or $3i$+2 > n for i = $\lceil \frac{n}{3} \rceil$-1 then replacing the dominating nodes v_{3i+1} by v_n and u_{3i+2} by u_{n-1}. These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and $\lceil \frac{n}{6} \rceil$. The total number of dominating nodes is $\lceil \frac{n}{6} \rceil + \lceil \frac{n}{6} \rceil + \lceil \frac{n}{6} \rceil + \lceil \frac{n}{6} \rceil = 4\lceil \frac{n}{6} \rceil$. Hence, when n is even γ_{ECC} of any $\mathcal{LC}_n$ is $4\lceil \frac{n}{6} \rceil$.

Example 3.5:

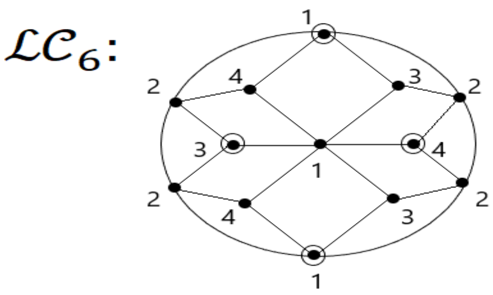

Fig.3.2

Dominating set = $\{v_1, v_4, u_2, u_5\}$.

γ_{ECC} $(\mathcal{H}_6)$ = 4.

Theorem 3.6: The equitable color class domination number of a jewel graph $\gamma_{ECC}(\mathcal{J}_n)$ = 2 + $\lfloor\frac{n}{2}\rfloor$.

Proof: Let $\mathcal{J}_n$ be the jewel graph with $\mathcal{V}_p(\mathcal{J}_n) = \{u_j, v_i : 1 \leq j \leq 4,\ 1 \leq i \leq n\}$. Let u_1, u_2, u_3, u_4 be the vertices of the cycle C_4 and v_i $(1 \leq i \leq n)$ is adjacent to u_1 and u_2. $|\mathcal{V}_p(\mathcal{J}_n)|$ = n + 4. χ_E of $\mathcal{J}_n$ is 2 + $\lfloor\frac{n}{2}\rfloor$. Let τ: $\mathcal{V}_p(\mathcal{J}_n) \rightarrow$ CC be an equitably colorable function where CC = {1, 2, …, $\lfloor\frac{n}{2}\rfloor$, $\lfloor\frac{n}{2}\rfloor$+1, $\lfloor\frac{n}{2}\rfloor$+2}.

Case 1: n is even

Ordain the color 1 to the nodes u_1 and u_3, 2 to the nodes u_2 and u_4. Now ordain the balance $\frac{n}{2}$ colors to the balance n nodes v_i so each color will ordain 2 nodes. Now we choose dominating nodes as any one node from each color class. These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and one. Hence, when n is even γ_{ECC} of any $\mathcal{J}_n$ is 2 + $\lfloor\frac{n}{2}\rfloor$.

Case 2: n is odd

Ordain the color 1 to the nodes u_1 and u_3, 2 to the nodes u_2 and u_4. Now ordain the balance $\lfloor\frac{n}{2}\rfloor$ colors to the balance n nodes so $\lfloor\frac{n}{2}\rfloor$-1 number of colors will ordain 2 nodes and the balanced one color will ordain 3 nodes. Now we choose dominating nodes as any one node from each color class. These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and one. Hence, when n is odd γ_{ECC} of any $\mathcal{J}_n$ is 2 + $\lfloor\frac{n}{2}\rfloor$.

Example 3.7:

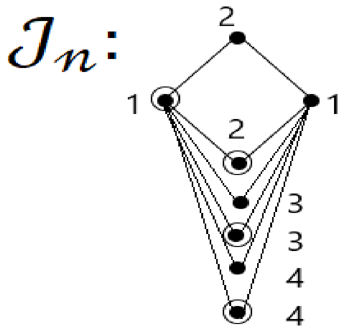

Fig.3.3

Dominating set = $\{u_1, u_4, v_2, v_4\}$

γ_{ECC} $(\mathcal{J}_4)$ = 4.

Theorem 3.8: The equitable color class domination number of a jahangir graph $\gamma_{ECC}(\mathcal{J}_{(3,n)})$ = 3 $\lceil\frac{n}{2}\rceil$.

Proof: Let $\mathcal{J}_{(3,n)}$ be the jahangir graph with $\mathcal{V}_p(\mathcal{J}_{(3,n)}) = \{v, v_i, u_i, w_i : 1 \leq i \leq n\}$. Let v and v_i $(1 \leq i \leq n)$ be the nodes of the wheel $\mathcal{W}_n$, u_i and w_i is placed the edge between the nodes v_i and v_{i+1} $(1 \leq i \leq n$-1), u_n and w_n is placed the edge between the nodes v_n and v_1. $|\mathcal{V}_p(\mathcal{J}_{(3,n)})|$ = 3n + 1. χ_E of $\mathcal{J}_{(3,n)}$ is 3. Let τ: $\mathcal{V}_p(\mathcal{J}_{(3,n)}) \rightarrow$ CC be an equitably colorable function where CC = {1, 2, 3}. Ordain the color 1 to the nodes v_i, 2 to the nodes u_i, 3 to the nodes w_i and v.

Case 1: n is even

Choose dominating nodes as v_i, u_j, w_i (i is odd, j is even, $1 \leq i, j \leq n$). These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and $\lceil\frac{n}{2}\rceil$. Hence, when n is even γ_{ECC} of any $\mathcal{J}_{(3,n)}$ is 3$\lceil\frac{n}{2}\rceil$.

Case 2: n is odd

Choose dominating nodes as v_i, u_j, w_i, u_n (i is odd, j is even, $1 \leq i, j \leq n$). These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and $\lceil\frac{n}{2}\rceil$. Hence, when n is even γ_{ECC} of any $\mathcal{J}_{(3,n)}$ is 3$\lceil\frac{n}{2}\rceil$.

Example 3.9:

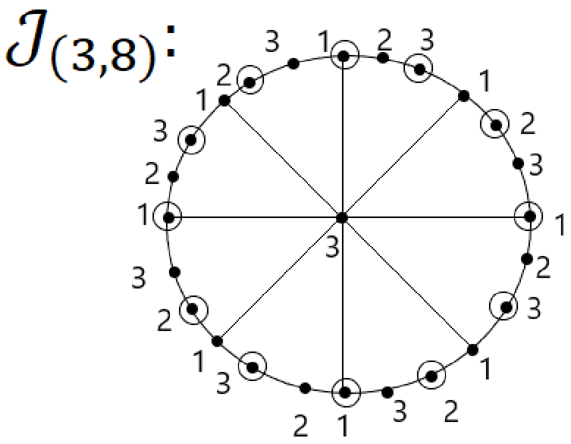

Fig.3.4

Dominating set = $\{v_1, v_3, v_5, v_7, u_2, u_4, u_6, u_8, w_1, w_3, w_5, w_7\}$.

γ_{ECC} $(\mathcal{J}_{(3,8)})$ = 12.

Theorem 3.10: The equitable color class domination number of dumbbell graph $(n > 2)$ $\gamma_{ECC}(\mathcal{D}b_n) = \begin{cases} 3\left\lceil \frac{2n}{9} \right\rceil, & n \text{ is odd} \\ 2\left\lceil \frac{n}{3} \right\rceil, & n \text{ is even} \end{cases}$

Proof: Let $\mathcal{D}b_n$ be the dumbbell graph with $\mathcal{V}_p(\mathcal{D}b_n) = \{u_i, v_i : 1 \le i \le n\}$. v_i, u_i are the nodes of two cycles $\mathcal{C}_n$ and joint the nodes v_1 and u_1. $|\mathcal{V}_p(\mathcal{D}b_n)| = 2\,n$.

Case 1: n is odd

If n is odd then χ_E of $\mathcal{D}b_n$ is 3. Let τ: $\mathcal{V}_p(\mathcal{D}b_n) \to$ CC be an equitably colorable function where CC = {1, 2, 3}. Ordain the color 1 to the nodes v_{9i+k}, $u_{9i+\ell}$ (k = {1, 6, 8}, ℓ = {3, 5, 7}and i = 0, 1, …, $\left\lceil \frac{n}{9} \right\rceil$-1), 2 to the nodes v_{9i+k}, $u_{9i+\ell}$ (k = {2, 4, 9}, ℓ = {1, 6, 8} and i = 0, 1, …, $\left\lceil \frac{n}{9} \right\rceil$-1), 3 to the nodes v_{9i+k}, $u_{9i+\ell}$ (k = {3, 5, 7}, ℓ = {2, 4, 9} and i = 0, 1, …, $\left\lceil \frac{n}{9} \right\rceil$-1).

Sub case 1: n = 18m-3, m € ℕ.

Replacing the colors between the nodes v_{n-1} and v_n, u_{n-1} and u_n.

Sub case 2: n = 18m-1, m € ℕ.

Replacing the color of the nodes v_n from 1 to 2 and u_n from 2 to 3.

Sub case 3: n = 18m+1, m € ℕ.

Replacing the color of the nodes v_n from 1 to 3 and u_n from 2 to 1.

Now choose dominating nodes as v_{9i+k}, $u_{9i+\ell}$ (k = {1, 4, 7}, ℓ = {3, 6, 9} and i = 0, 1, …, $\left\lceil \frac{n}{9} \right\rceil$-1). These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and 2$\left\lceil \frac{n}{9} \right\rceil$. Hence, when n is odd γ_{ECC} of any $\mathcal{D}b_n$ is 3$\left\lceil \frac{n}{9} \right\rceil$.

Case 2: n is even

If n is even then χ_E of $\mathcal{D}b_n$ is 2. Let τ: $\mathcal{V}_p(\mathcal{D}b_n) \to$ CC be an equitably colorable function where CC = {1, 2}. Ordain the color 1 to the nodes v_i, u_j (i is odd, j is even), 2 to the nodes v_i, u_i (i is even, j is odd). Now choose dominating nodes as by the following cases.

Sub case 1: $n \equiv 0 \pmod 6$

$v_1, v_4, v_7, \ldots, v_{n-2}$ and $u_3, u_6, u_9, \ldots, u_n$.

Sub case 2: $n \equiv 2 \pmod 6$

$v_1, v_4, v_7, \ldots, v_{n-1}$ and $u_1, u_3, u_6, \ldots, u_{n-2}$.

Sub case 3: $n \equiv -2 \pmod 6$

$v_1, v_4, v_7, \ldots, v_{n-3}, v_{n-1}$ and $u_1, u_3, u_6, \ldots, u_{n-1}$.

These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and $\left\lceil \frac{n}{3} \right\rceil$. Hence, when n is even γ_{ECC} of any $\mathcal{D}b_n$ is 2$\left\lceil \frac{n}{3} \right\rceil$.

Example 3.11:

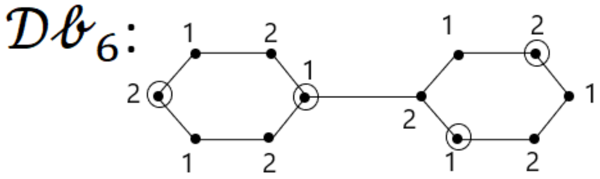

Fig.3.5

Dominating set = $\{v_1, v_4, u_3, u_6\}$

γ_{ECC} $(\mathcal{D}b_6)$ = 4.

Theorem 3.12: The equitable color class domination number of subdivision path $\mathcal{S}(\mathcal{P}_n)$ $(n > 1)$ is $2\left\lceil\frac{n}{3}\right\rceil$.

Proof:

Let $\mathcal{S}(\mathcal{P}_n)$ be the subdivision of path with $\mathcal{V}_p(\mathcal{S}(\mathcal{P}_n))$ = $\{v_i(1 \le i \le n), u_i(1 \le i \le n\text{-}1)\}$. v_i are the nodes of path $\mathcal{P}_n$ and u_i are the nodes insert between v_i and v_{i+1}. $|\mathcal{V}_p(\mathcal{S}(\mathcal{P}_n))|$ = 2 n-1.. χ_E of $\mathcal{S}(\mathcal{P}_n)$ is 2. Let τ: $\mathcal{V}_p(\mathcal{S}(\mathcal{P}_n)) \rightarrow$ CC be an equitably colorable function where CC = {1,2}. Ordain the color 1 to the v_i nodes and 2 to the u_i nodes. Now we choose dominating nodes as v_{3i+3} and u_{3i+1} (i = 0, 1, …, $\left\lceil\frac{n}{3}\right\rceil$-1). Suppose $3i + 3$ or $3i + 1 > n$ for i = $\left\lceil\frac{n}{3}\right\rceil$-1 then replace the dominating node from v_{3i+3} and u_{3i+1} to v_n and u_{n-1}. These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and $\left\lceil\frac{n}{3}\right\rceil$. Hence, γ_{ECC} of any $\mathcal{S}(\mathcal{P}_n)$ is $2\left\lceil\frac{n}{3}\right\rceil$.

Example 3.13:

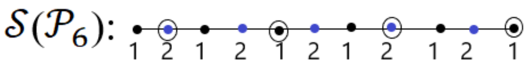

Fig 3.6

Dominating set = $\{v_3, v_6, u_1, u_4\}$.

γ_{ECC} $(\mathcal{S}(\mathcal{P}_6))$ = 4.

Theorem 3.14: The equitable color class domination number of splitting graph of path $\mathcal{S}'(\mathcal{P}_n)$ $(n > 1)$ is $2\left\lceil\frac{n}{4}\right\rceil$.

Proof:

Let $\mathcal{S}'(\mathcal{P}_n)$ be the splitting graph of path with $\mathcal{V}_p(\mathcal{S}'(\mathcal{P}_n))$ = $\{v_i, u_i : 1 \le i \le n\}$. v_i are the nodes of path $\mathcal{P}_n$ and u_i are the newly added nodes. $|\mathcal{V}_p(\mathcal{S}'(\mathcal{P}_n))|$ = 2 n.. χ_E of $\mathcal{S}'(\mathcal{P}_n)$ is 2. Let τ: $\mathcal{V}_p(\mathcal{S}'(\mathcal{P}_n)) \rightarrow$ CC be an equitably colorable function where CC = {1,2}. Ordain the color 1 to the nodes v_i, u_i (i is odd) and 2 to the nodes v_i, u_i (i is even). Now we choose dominating nodes as v_{4i+2} and v_{4i+3} (i = 0, 1, …, $\left\lceil\frac{n}{4}\right\rceil$-1). Suppose $4i + 3 > n$ for i = $\left\lceil\frac{n}{4}\right\rceil$-1 then replace the dominating node from v_{4i+3} to v_{n-1}. Suppose $4i + 2$ and $4i + 3 > n$ for i = $\left\lceil\frac{n}{4}\right\rceil$-1 then replace the dominating nodes from v_{4i+2} and v_{4i+3} to v_{n-1} and v_n.These nodes are dominates all other nodes and the number of dominating nodes in each color class are same and $\left\lceil\frac{n}{4}\right\rceil$. Hence, γ_{ECC} of any $\mathcal{S}'(\mathcal{P}_n)$ is $2\left\lceil\frac{n}{4}\right\rceil$.

Example 3.15:

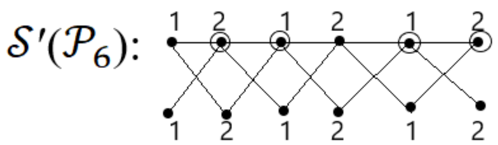

Fig 3.7

Dominating set = $\{v_2, v_3, v_5, v_6\}$.

γ_{ECC} $(\mathcal{S}'(\mathcal{P}_6))$ = 4.

Corollary 3.16: The equitable color class domination number of shadow graph of path $\mathcal{D}_2(\mathcal{P}_n)$ $(n > 1)$ is $2\left\lceil\frac{n}{3}\right\rceil$.

Proof:

Let $\mathcal{D}_2(\mathcal{P}_n)$ be the shadow graph of path with $\mathcal{V}_p(\mathcal{D}_2(\mathcal{P}_n))$ = $\{v_i(1 \le i \le n), u_i(1 \le i \le n\text{-}1)\}$. v_i are the nodes of path $\mathcal{P}_n$ and u_i are the nodes of copy of path $\mathcal{P}_n$. Joining each node v_i to the neighbours of the corresponding node u_i. $|\mathcal{V}_p(\mathcal{D}_2(\mathcal{P}_n))|$ = 2 n.. χ_E of

$\mathcal{D}_2(\mathcal{P}_n)$ is 2. Let τ: $\mathcal{V}_p(\mathcal{D}_2(\mathcal{P}_n)) \to$ CC be an equitably colorable function where CC = $\{1,2\}$. Ordain the color to the nodes and choosing dominating node is follows from the theorem 3.14.

Example 3.17:

$\mathcal{D}_2(\mathcal{P}_6)$:

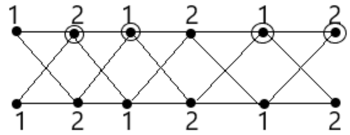

Fig 3.8

Dominating set = $\{v_2, v_3, v_5, v_6\}$.

γ_{ECC} $(\mathcal{D}_2(\mathcal{P}_6))$ = 4.

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