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Dom-Total Chromatic Number of Central Graphs

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ABSTRACT: Let G be a graph. For a given χ -total colouring of a graph G , a dominating set $S \subseteq V(G)$ is said to be a dom-total colouring set if it contains atleast one vertex of each colour class of G . The dom-total chromatic number of a graph G is the minimal cardinality taken over all its dom-total colouring sets and is denoted by $\gamma_{d-tc}(G)$. In this paper, we introduce algorithms to obtain the dom- total colouring and dom-total chromatic number central of graphs.

KEYWORDS: Dom- total chromatic number, central graph of Paths, central graph of cycles, central graph of star graphs.

I. INTRODUCTION

All graphs considered in this paper are finite, undirected graphs and we follow standard definition of graph theory as found in [1]. Let $G = (V, E)$ be a graph. The open neighborhood $N(v)$ of a vertex $v \in V(G)$ consists of the set of all vertices adjacent to v . The closed neighborhood of v is $N[v] = N(v) \cup \{v\}$. An induced subgraph $G[S]$, where S of a graph G is a graph formed from a subset S of the vertices of G and all of the edges connecting pairs of vertices in S . A graph in which every pair of vertices is joined by exactly one edge is called complete graph. A complete bi partite graph is a graph whose vertices can be partitioned into two subsets V_1 and V_2 such that no edge has both end points in the same subset, and each vertex of V_1 is connected to every vertex of V_2 and vice -verse. A star graph S_n is the complete bipartite graph $K_{1,n-1}$ (A tree with one internal node and $n-1$ leaves).

The path and cycle of order n are denoted by P_n and C_n respectively. For any two graphs G and H , we define the cartesian product, denoted by $G \times H$, to be the graph with vertex set $V(G) \times V(H)$ and edges between two vertices (u_1, v_1) and (u_2, v_2) if either $u_1 = u_2$ and $v_1 v_2 \in E(H)$ or $u_1 u_2 \in E(G)$ and $v_1 = v_2$.

A subset S of V is called a dominating set if every vertex in $V-S$ is adjacent to at least one vertex in S . The dominating set is minimal dominating set if no proper subset of S is a dominating set of G . The domination number γ is the minimum cardinality taken over all minimal dominating set of G . A γ -set is any minimal dominating set with cardinality γ .

A proper coloring of G is an assignment of colors to the vertices of G such that adjacent vertices have different colors. The minimum number of colors for which there exists a proper coloring of G is called chromatic number of G and is denoted by $\chi(G)$. A dominator coloring of G is a proper coloring of G in which every vertex of G dominates atleast one color class. The dominator chromatic number is denoted by $\chi_d(G)$ and is defined by the minimum number of colors needed in a dominator coloring of G . This concept was introduced by Raluca Michelle Gera in 2006[2].

In a proper coloring C of G , a color class of C is a set consisting of all those vertices assigned the same color. Let C^i be a minimal dominator coloring of G . We say that a color class $c_i \in C^i$ is called a non-dominated color class (n-d color class) if it is not dominated by any vertex of G . These color classes are also called repeated color classes. For a given χ -total colouring of a graph G , a dominating set $S \subseteq V(G)$ is said to be a dom- total colouring set if it contains atleast one vertex of each colour class of G . The dom-total chromatic number of a graph G is the minimal cardinality taken over all its dom-total colouring sets and is denoted by $\gamma_{d-tc}(G)$. Let G be an undirected graph with no loops and parallel edges. The graph formed by subdividing each edge exactly once and joining all the non -adjacent vertices of the graph is called the central graph. It is denoted by the symbol $C(G)$.

The central graph of a graph G is obtained by subdividing each edge of G exactly once by inserting a new vertex on every edge and joining all the non-adjacent vertices of G in the original graph G . The central graph of G is denoted by $C(G)$. Let P_n be a path graph with n vertices and the vertex set and edges set of path graph is given by $V(P_n) = \{v_1, v_2, \dots, v_n\}$ and $E(P_n) = \{v_i v_{i+1} : 1 \leq i \leq n-1\}$. The central graph of P_n is denoted by $C(P_n)$ is obtained by subdividing each edge $v_i v_{i+1}$ of P_n with a new vertex u_i and joining every pair of non-adjacent vertices of P_n . Thus,



the vertex set and edge set of $C(P_n)$ is $V(C(P_n)) = \{v_1, v_2, \dots, v_n\} \cup \{u_1, u_2, \dots, u_n\}$ and $E(C(P_n)) = \{v_i u_i : 1 \leq i \leq n-1\} \cup \{u_i v_{i+1} : 1 \leq i \leq n-1\} \cup \{v_i v_j : i \leq i \leq n-2, i+2 \leq j \leq n\}$. Let C_n be a cycle graph with n vertices and the vertex set and edge set of C_n is given by $V(C_n) = \{v_i : 1 \leq i \leq n\}$ and $E(C_n) = \{v_i v_{i+1} : 1 \leq i \leq n-1\} \cup \{v_n v_1\}$. The central graph of C_n is denoted by $C(C_n)$ is obtained by subdividing each edge of C_n with a new vertex u_i and joining every pair of non-adjacent vertices of C_n . Thus, the vertex set and edge set of $C(C_n)$ is given by $V(C(C_n)) = \{v_i : 1 \leq i \leq n\} \cup \{u_i : 1 \leq i \leq n\}$ and $E(C(C_n)) = \{v_i u_i : 1 \leq i \leq n\} \cup \{u_i v_{i+1} : 1 \leq i \leq n-1\} \cup \{u_n v_1\} \cup \{v_i v_j : 1 \leq i \leq n-2, i+2 \leq j \leq n-1\}$. A Star graph with $n+1$ vertices is denoted by $K_{1,n}$. The vertex set and edge set is given by $V(K_{1,n}) = \{v_0, v_1, v_2, \dots, v_n\}$ and $E(K_{1,n}) = \{v_0 v_i : i = 1, 2, 3, \dots, n\}$

The central graph of star graph of $K_{1,n}$ is denoted by $C(K_{1,n})$. Thus, the vertex set and edge set of $C(K_{1,n})$ is given by $V(C(K_{1,n})) = \{v_i : 1 \leq i \leq n\} \cup \{u_i : 1 \leq i \leq n\} \cup \{v_0\}$ and $E(C(K_{1,n})) = \{v_0 u_i : 1 \leq i \leq n\} \cup \{u_i v_i : 1 \leq i \leq n\} \cup \{v_i v_j : 1 \leq i \leq n, i+1 \leq j \leq n\}$

II. MAIN RESULTS

Theorem:1

The Dom-Total chromatic number of the central graph of a path P_n is given by

$$\chi_{d-tc}(C(P_n)) = \begin{cases} n - \lfloor \frac{n}{2} \rfloor, & \text{for odd } n \\ n + 1 - \lfloor \frac{n}{2} \rfloor, & \text{for even } n \end{cases}$$

Proof:

Let P_n be a path with vertex set $V(P_n) = \{v_i : 1 \leq i \leq n\}$ and edge set $E(P_n) = \{v_i v_{i+1} : 1 \leq i \leq n-1\}$

The Central graph of P_n is denoted by $C(P_n)$ and has n original vertices and $n-1$ subdivision vertices. That is $|V(C(P_n))| = 2n-1$. Thus, the vertex set and edge set of $C(P_n)$ is given by

$$V(C(P_n)) = \{v_i : 1 \leq i \leq n\} \cup \{u_i : 1 \leq i \leq n-1\}, E(C(P_n)) = \{v_i u_i : 1 \leq i \leq n-1\} \cup \{u_i v_{i+1} : 1 \leq i \leq n-1\} \cup \{v_i v_j : i \leq i \leq n-2, i+2 \leq j \leq n\}$$

Case i) When n is odd

For all $1 \leq i, j \leq n$. Let the color set be $C = \{1, 2, \dots, n\}$

Define a function $f_1: V(C(P_n)) \rightarrow C$ by

$$f_1(v_i) = \begin{cases} (2i+1) \pmod n, & \text{if } (2i+1) \not\equiv 0 \pmod n \\ n, & \text{otherwise} \end{cases}$$

$$f_1(v_n) = n \text{ and } f_1(u_{n-1}) = 1$$

$$f_1(u_i) = \begin{cases} 2(i+1) \pmod n, & \text{if } 2(i+1) \not\equiv 0 \pmod n \\ n, & \text{otherwise} \end{cases}$$

Define a function $f_2: E(C(P_n)) \rightarrow C$ by

$$f_2(v_i v_j) = \begin{cases} (i+j) \pmod n, & \text{if } (i+j) \not\equiv 0 \pmod n, j > i+1 \\ n, & \text{otherwise} \end{cases}$$

$$f_2(v_i u_j) = \begin{cases} (i+j) \pmod n, & \text{if } (i+j) \not\equiv 0 \pmod n, j > i+1 \\ n, & \text{otherwise} \end{cases}$$

The above coloring satisfies the condition for a total coloring of the central graph of path P_n for odd n . Hence, the total chromatic number of the central graph of the path P_n is n .

i.e., $\chi_T(C(P_n)) = n$, for odd n

Case ii) When n is even

For all $1 \leq i, j \leq n$. Let the color set be $C = \{1, 2, \dots, n+1\}$

Define a function $f_1: V(C(P_n)) \rightarrow C$ by

$$f_1(v_i) = \begin{cases} (2i+1) \pmod{n+1}, & \text{if } (2i+1) \not\equiv 0 \pmod{n+1} \\ n+1, & \text{otherwise} \end{cases}$$



$$f_1(u_i) = \begin{cases} 2(i+1)(\text{mod } n+1) & , \quad \text{if } 2(i+1) \not\equiv 0(\text{mod } n+1) \\ n+1 & , \quad \text{otherwise} \end{cases}$$

Define a function $f_2: E(C(P_n)) \rightarrow C$ by

$$f_2(v_i v_j) = \begin{cases} (i+j)(\text{mod } n+1) & , \quad \text{if } (i+j) \not\equiv 0(\text{mod } n+1), j > i+1 \\ n+1 & , \quad \text{otherwise} \end{cases}$$

$$f_2(v_i u_j) = \begin{cases} (i+j)(\text{mod } n+1) & , \quad \text{if } (i+j) \not\equiv 0(\text{mod } n+1), j > i+1 \\ n+1 & , \quad \text{otherwise} \end{cases}$$

The above coloring satisfies the condition for a total coloring of the central graph of path P_n for even n . Hence, the total chromatic number of the central graph of path P_n is $n+1$ for even n .

i.e., $\chi_T(C(P_n)) = n+1$, for even n

$$\chi_T(C(P_n)) = \begin{cases} n & , \quad \text{for odd } n \\ n+1 & , \quad \text{for even } n \end{cases}$$

Hence,

To determine the domination number of $C(P_n)$,

Consider the set $D = \{v_1, v_3, v_5, \dots\}$ is set consisting of every alternate original vertex of P_n

Thus, D dominates all vertices of $C(P_n)$, and no smaller set can dominate all vertices. Therefore, $\gamma(C(P_n)) = \lfloor \frac{n}{2} \rfloor$. We have,

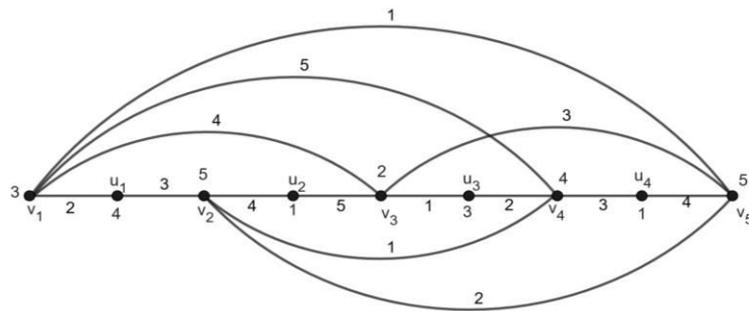
$$\gamma_{d-tc}(C(P_n)) = \chi_T(C(P_n)) - \gamma(C(P_n)) = \begin{cases} n - \lfloor \frac{n}{2} \rfloor & , \quad \text{for odd } n \\ n + 1 - \lfloor \frac{n}{2} \rfloor & , \quad \text{for even } n \end{cases}$$

Hence, the Dom-Total chromatic number of central graph of P_n is

$$\gamma_{d-tc}(C(P_n)) = \begin{cases} n - \lfloor \frac{n}{2} \rfloor & , \quad \text{for odd } n \\ n + 1 - \lfloor \frac{n}{2} \rfloor & , \quad \text{for even } n \end{cases}$$

Illustration:1

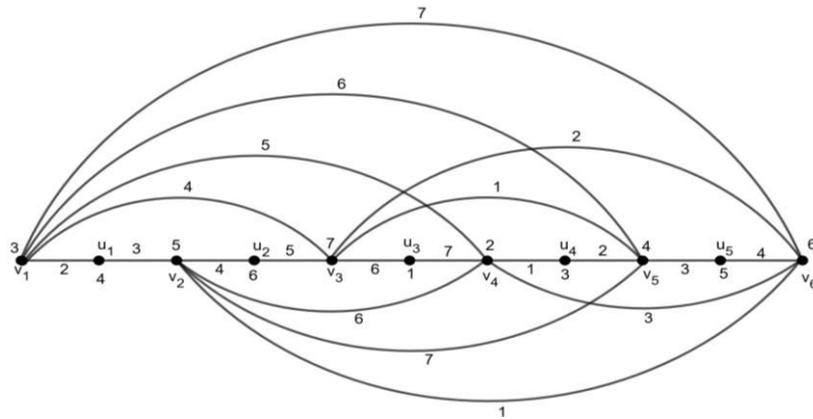
Consider the central graph of a path P_5 , here $n = 5$ which is odd. So, the total chromatic number of the central graph of the path P_5 is 5 and Dom-Total chromatic number of central graph of path P_5 is $\gamma_{d-tc}(C(P_5)) = 5 - 2 = 3$



Total coloring of central graph of path P_5 and $\gamma_{d-tc}(C(P_5)) = 3$

Illustration :2

Consider the central graph of a path P_6 , here $n = 6$ which is even. So, the total chromatic number of the central graph of the path P_6 is 7 and Dom-Total chromatic number of central graph of path P_6 is $\gamma_{d-tc}(C(P_6)) = 7 - 3 = 4$



Total coloring of central graph of path P_6 and $\gamma_{d-tc}(C(P_6)) = 4$

Theorem 2.2

The Dom-Total chromatic number of the central graph of a cycle C_n is given by

$$\gamma_{d-tc}(C(C_n)) = \begin{cases} n - \lfloor \frac{n}{2} \rfloor, & \text{for odd } n \\ n + 1 - \lfloor \frac{n}{2} \rfloor, & \text{for even } n \end{cases}$$

Proof: Let C_n be the cycle graph and has vertex set $V(C_n) = \{v_i : 1 \leq i \leq n\}$ and the edge set $E(C_n) = \{v_i v_{i+1} : 1 \leq i \leq n - 1\} \cup \{v_n v_1\}$

The central graph of cycle C_n is denoted by $C(C_n)$ and has n original vertices and n subdivision vertices. That is $|V(C(C_n))| = 2n$. Thus, the vertex set and edge set of $C(C_n)$ is given by $V(C(C_n)) = \{v_i : 1 \leq i \leq n\} \cup \{u_i : 1 \leq i \leq n\}$ and $E(C(C_n)) = \{v_i u_i : 1 \leq i \leq n\} \cup \{u_i v_{i+1} : 1 \leq i \leq n - 1\} \cup \{u_n v_1\} \cup \{v_i v_j : 1 \leq i \leq n - 2, i + 2 \leq j \leq n - 1\}$

Case i) When n is odd

For all $1 \leq i, j \leq n$. Let the color set be $C = \{1, 2, \dots, n\}$

Define a function $f_1: V(C(C_n)) \rightarrow C$ by

$$f_1(v_i) = \begin{cases} (2i + 1)(\text{mod } n) & , \quad \text{if } (2i + 1) \not\equiv 0(\text{mod } n) \\ n & , \quad \text{otherwise} \end{cases}$$

$$f_1(u_i) = \begin{cases} 2(i + 1)(\text{mod } n) & , \quad \text{if } 2(i + 1) \not\equiv 0(\text{mod } n) \\ n & , \quad \text{otherwise} \end{cases}$$

Define a function $f_2: E(C(C_n)) \rightarrow C$ by

$$f_2(v_i v_j) = \begin{cases} (i + j)(\text{mod } n) & , \quad \text{if } (i + j) \not\equiv 0(\text{mod } n), j > i + 1 \\ n & , \quad \text{otherwise} \end{cases}$$

$$f_2(v_i u_j) = \begin{cases} (i + j)(\text{mod } n + 1) & , \quad \text{if } (i + j) \not\equiv 0(\text{mod } n + 1), j > i + 1 \\ n + 1 & , \quad \text{otherwise} \end{cases}$$

The above coloring satisfies the condition for a total coloring of the central graph of cycle C_n for odd n . Hence, the total chromatic number of the central graph of the cycle C_n is n for odd n .

i.e., $\chi_T(C(C_n)) = n$, for odd n

Case ii) When n is even

For all $1 \leq i, j \leq n$. Let the color set be $C = \{1, 2, \dots, n + 1\}$

Define a function $f_1: V(C(C_n)) \rightarrow C$



$$f_1(v_i) = \begin{cases} (2i + 1)(\text{mod } n + 1) & , \quad \text{if } (2i + 1) \not\equiv 0(\text{mod } n + 1) \\ n + 1 & , \quad \text{otherwise} \end{cases}$$

$$f_1(u_i) = \begin{cases} 2(i + 1)(\text{mod } n + 1) & , \quad \text{if } 2(i + 1) \not\equiv 0(\text{mod } n + 1) \\ n + 1 & , \quad \text{otherwise} \end{cases}$$

$$f_1(u_n) = 1$$

Define a function $f_2: E(C(C_n)) \rightarrow C$

$$f_2(v_i v_j) = \begin{cases} (i + j)(\text{mod } n + 1) & , \quad \text{if } (i + j) \not\equiv 0(\text{mod } n + 1) , j > i + 1 \\ n + 1 & , \quad \text{otherwise} \end{cases}$$

$$f_2(v_i u_j) = \begin{cases} (i + j)(\text{mod } n + 1) & , \quad \text{if } (i + j) \not\equiv 0(\text{mod } n + 1) , j > i + 1 \\ n + 1 & , \quad \text{otherwise} \end{cases}$$

The above coloring satisfies the condition for a total coloring of the central graph of the cycle C_n for even n . Hence, the total chromatic number of the central graph of the cycle C_n is $n + 1$ for even n . i.e., $\chi_T(C(C_n)) = n + 1$, for even n

$$\chi_T(C(C_n)) = \begin{cases} n & , \quad \text{for odd } n \\ n + 1 & , \quad \text{for even } n \end{cases}$$

Hence,

To determine the domination number of $C(C_n)$

Consider the set $D = \{v_1, v_3, v_5, \dots\}$ is consisting of every alternate original vertex of C_n .

Thus, D dominates all vertices of $C(C_n)$ and no smaller set can dominate all vertices.

Therefore, $\gamma(C(C_n)) = \lfloor \frac{n}{2} \rfloor$

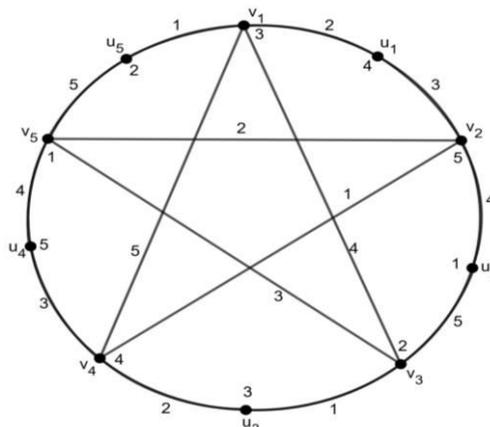
We have,

$$\gamma_{d-tc}(C(C_n)) = \chi_T(C(C_n)) - \gamma(C(C_n)) = \begin{cases} n - \lfloor \frac{n}{2} \rfloor, & \text{for odd } n \\ n + 1 - \lfloor \frac{n}{2} \rfloor, & \text{for even } n \end{cases}$$

Hence, The Dom-Total chromatic number of central graph of C_n is

$$\gamma_{d-tc}(C(C_n)) = \begin{cases} n - \lfloor \frac{n}{2} \rfloor, & \text{for odd } n \\ n + 1 - \lfloor \frac{n}{2} \rfloor, & \text{for even } n \end{cases}$$

Illustration :1 Consider the central graph of a cycle C_5 , here $n = 5$, which is odd. So, the total chromatic number of the central graph of the cycle C_5 is 5 and Dom-Total chromatic number of central graph of cycle C_5 is $\gamma_{d-tc}(C(C_5)) = 5 - 2 = 3$

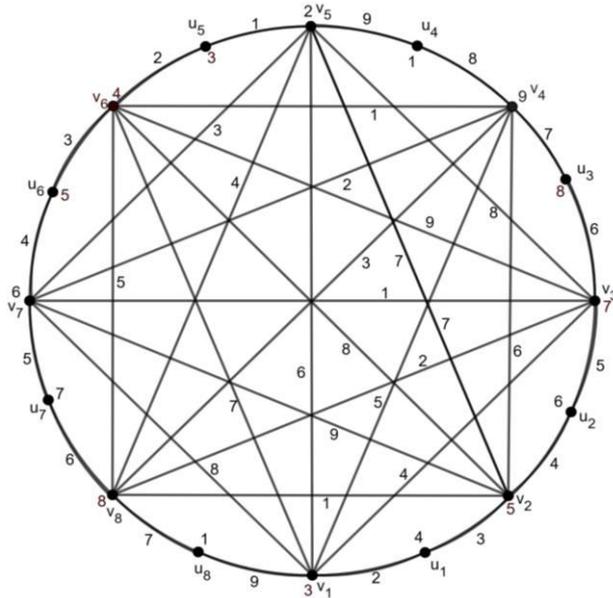


Total coloring of central graph of cycle C_5 and $\gamma_{d-tc}(C(C_5)) = 3$



Illustration :2

Consider the central graph of a cycle C_8 , here $n = 8$ which is even. So, the total chromatic number of the central graph of the cycle C_8 is 9 and Dom-Total chromatic number of central graph of cycle $\gamma_{d-tc}(C(C_8)) = 9 - 4 = 5$



Total coloring of central graph of cycle C_8 and $\gamma_{d-tc}(C(C_8)) = 5$

Theorem :3

The Dom-Total chromatic number of the central graph of a star $K_{1,n}$ is $n - 1$ for $n \geq 3$

Proof:

Let $K_{1,n}$ be a star graph and v_0 be the central vertex and $\{v_1, v_2, \dots, v_n\}$ be the pendent vertices of $K_{1,n}$

The central graph of a star $K_{1,n}$ is $C(K_{1,n})$. Let the new vertices $\{u_i : 1 \leq i \leq n\}$. Thus, the vertex and edge set of $C(K_{1,n})$ is given by $V(C(K_{1,n})) = \{v_i : 1 \leq i \leq n\} \cup \{u_i : 1 \leq i \leq n\} \cup \{v_0\}$ and $E(C(K_{1,n})) = \{v_0u_i : 1 \leq i \leq n\} \cup \{u_iv_i : 1 \leq i \leq n\} \cup \{v_iv_j : 1 \leq i \leq n-1, i+1 \leq j \leq n\}$

For $1 \leq i, j \leq n$. Let the color set be $C = \{1, 2, \dots, n+1\}$

Define a function $f_1: V(C(K_{1,n})) \rightarrow C$ by

$$f_1(v_0) = n + 1, f_1(v_i) = i, 1 \leq i \leq n, f_1(u_1) = 3, f_1(u_n) = 1, f_1(u_i) = i - 1, 2 \leq i \leq n - 1$$

Define a function $f_2: E(C(K_{1,n})) \rightarrow C$ by $f_2(v_0u_i) = i, 1 \leq i \leq n$

$$f_2(v_iv_i) = \begin{cases} 2i \pmod{n+1}, & \text{if } 2i \not\equiv 0 \pmod{n+1} \\ n+1, & \text{otherwise} \end{cases}$$

$$f_2(v_iv_j) = \begin{cases} (i+j) \pmod{n+1}, & \text{if } (i+j) \not\equiv 0 \pmod{n+1}, j \geq i \\ n+1, & \text{otherwise} \end{cases}$$

The above coloring satisfies the condition for a total coloring of the central graph of the star $K_{1,n}$. Hence the total chromatic number of the central graph of the star $K_{1,n}$ is $n + 1 \forall n \geq 3$

i.e., $\chi_T(C(K_{1,n})) = n + 1, \text{ for } n \geq 3$

To determine the domination number of $C(K_{1,n})$

Consider the set $D = \{v_0, v_1\}$ is the minimum dominating set which dominates all the vertices of $C(K_{1,n})$. Hence, $\gamma(C(K_{1,n})) = 2$

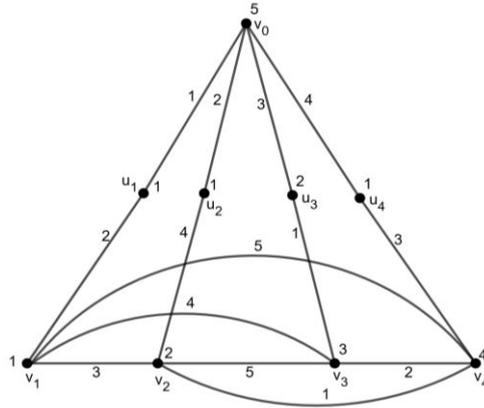


We have, $\gamma_{d-tc}(C(K_{1,n})) = \chi_T(C(K_{1,n})) - \gamma(C(K_{1,n})) = n + 1 - 2 = n - 1$

Hence, The Dom-Total chromatic number of central graph of $K_{1,n}$ is $\gamma_{d-tc}(C(K_{1,n})) = n - 1$

Illustration :1

Consider the central graph of star $K_{1,4}$, here $n = 4$. So, the total chromatic number of the central graph of star $K_{1,4}$ is 5 and the Dom-Total chromatic number of central graph of star $K_{1,4}$ is $\gamma_{d-tc}(C(K_{1,4})) = 5 - 2 = 3$



Total coloring of central graph of star $K_{1,4}$ and $\gamma_{d-tc}(C(K_{1,4})) = 3$

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