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Neighbourhood V_4-magic labeling of some subdivision graphs

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Abstract
Let $V_4 = \{0,a,b,c\}$ be the Klein-4-group with identity element 0.A graph $G = (V(G),E(G))$,with vertex set $V(G)$ and edge set $E(G)$, is said to be Neighbourhood V_4-magic if there exists a labeling $f : V(G) \to V_4 \backslash \{0\}$ such that the sum $N_f^+(v) = \sum_{u \in N(v)} f(u)$ is a constant map. If this constant is p,where p is any non zero element in V_4,then we say that f is a p-neighbourhood V_4-magic labeling of G and G is said to be a p-neighbourhood V_4-magic graph. If this constant is 0,then we say that f is a 0-neighbourhood V_4-magic labeling of G and G is said to be a 0-neighbourhood V_4-magic graph.

Keywords
Klein-4-group, a-neighbourhood V_4-magic graphs and 0-neighbourhood V_4-magic graphs.

AMS Subject Classification
05C78, 05C25.

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Contents

1. Introduction

In this paper we consider graphs that are connected, finite, simple and undirected. For graph theory notations and terminology not directly defined in this paper, we refer readers to [1]. The Klein 4-group, denoted by V_4 is an abelian group of order 4. It has elements $V_4 = \{0,a,b,c\}$,with $a+a = b+b = c+c = 0$ and $a+b = c, b+c = a, c+a = b$. A graph $G = (V(G),E(G))$, with vertex set $V(G)$ and edge set $E(G)$,is said to be Neighbourhood V_4-magic if there exists a labeling $f : V(G) \to V_4 \backslash \{0\}$ such that the sum $N_f^+(v) = \sum_{u \in N(v)} f(u)$ is a constant map. If this constant is p,where p is any non zero element in V_4,then we say that f is a p-neighbourhood V_4-magic labeling of G and G is said to be a p-neighbourhood V_4-magic graph. If this constant is 0,then we say that f is a 0-neighbourhood V_4-magic labeling of G and G is said to be a 0-neighbourhood V_4-magic graph.

The subdivision graph of a graph G is denoted by $S(G)$ and is obtained by inserting an additional vertex to each edge of G. In this paper, we investigate Neighbourhood V_4-magic labeling of subdivision graph of some graphs and we classify them into the following three categories:

(i) $\Omega_a :=$ the class of all a-neighbourhood V_4-magic graphs,

(ii) $\Omega_0 :=$ the class of all 0-neighbourhood V_4-magic graphs, and

(iii) $\Omega_{a,0} := \Omega_a \cap \Omega_0$.

2. Main Results

Theorem 2.1. [2] *$C_n \in \Omega_a$ if and only if $n \equiv 0(\bmod 4)$.*

Theorem 2.2. *For $n \geq 3$, $S(C_n) \in \Omega_a$ if and only if $n \equiv 0(\bmod 2)$.*

Proof. We have $S(C_n) \simeq C_{2n}$. Then by Theorem 2.1, $S(C_n) \in \Omega_a$ if and only if $2n \equiv 0(\bmod 4)$, ie, if and only if $n \equiv 0(\bmod 2)$. This completes the proof. □

Theorem 2.3. *$S(C_n) \in \Omega_0$ for all $n \geq 3$.*

Proof. By labeling all the vertices of $S(C_n)$ by a, we get $S(C_n) \in \Omega_0$. □

Corollary 2.4. *For $n \geq 3$, $S(C_n) \in \Omega_{a,0}$ if and only if $n \equiv 0(\bmod 2)$.*

Proof. Proof directly follows from Theorem 2.2 and Theorem 2.3. □

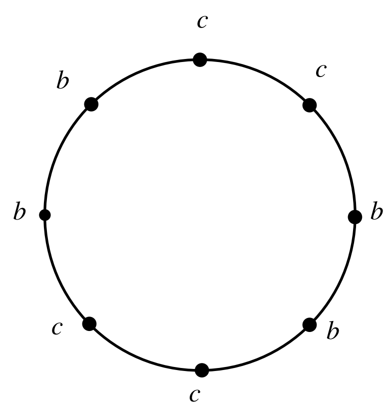

Figure 1. An a-neighbourhood V_4-magic labeling of $S(C_4)$.

Definition 2.5. [3] *The friendship graph or the Dutch windmill graph, denoted by F_m(or $D_3^{(m)}$) is the graph obtained by taking m copies of C_3 with one vertex in common.*

Theorem 2.6. *$S(F_m) \notin \Omega_a$ for any $m \geq 1$.*

Proof. Consider the Friendship graph F_m with vertex set $\{w, u_i, v_i : 1 \leq i \leq m\}$ and edge set $\{wu_i, wv_i, u_iv_i : 1 \leq i \leq m\}$. Let $u_i^{'}, v_i^{'}, w_i$ be the vertices in $S(F_m)$ corresponding to the edges wu_i, wv_i, u_iv_i of F_m. Suppose that $S(F_m) \in \Omega_a$ for some m with a labeling f. Then $N_f^+(w_1) = a$ implies that either $f(u_1) = b$ and $f(v_1) = c$ or $f(u_1) = c$ and $f(v_1) = b$. Without loss of generality, assume that $f(u_1) = b$ and $f(v_1) = c$. Now $N_f^+(u_1^{'}) = a$ implies that $f(w) = c$, consequently $N_f^+(v_1^{'}) = 0$, which is a contradiction. Hence $S(F_m) \notin \Omega_a$ for any m. □

Theorem 2.7. *$S(F_m) \in \Omega_0$ for all $m \geq 1$.*

Proof. If we label all the vertices of $S(F_m)$ by a, we get $S(F_m) \in \Omega_0$. □

Corollary 2.8. *$S(F_m) \notin \Omega_{a,0}$ for any $m \geq 1$.*

Proof. It directly follows from Theorem 2.6. □

Definition 2.9. [5] *The helm H_n is the graph obtained from the wheel graph W_n by attaching a pendant edge at each vertex of the cycle C_n.*

Definition 2.10. [6] *The flower graph Fl_n is the graph obtained from a helm H_n by joining each pendant vertex to the central vertex of the helm.*

Theorem 2.11. *$S(Fl_n) \notin \Omega_a$ for any $n \geq 3$.*

Proof. Consider the flower graph Fl_n with vertex set $\{u, u_i, v_i : 1 \leq i \leq n\}$ and edge set $\{uu_i, uv_i, u_iv_i, u_iu_{i+1} : 1 \leq i \leq n\}$,where $i+1$ is taken over modulo n. Let $u_i^{'}, v_i^{'}, w_i^{'}, u_i^{''}$ be the vertices in $S(Fl_n)$ corresponding to the edges $uu_i, uv_i, u_iv_i, u_iu_{i+1}$ for $1 \leq i \leq n$,where $i+1$ is taken over modulo n. Suppose that $S(Fl_n) \in \Omega_a$ for some n with a labeling f. Then $N_f^+(u_i^{'}) = a = N_f^+(w_i^{'})$, implies that $f(u) = f(v_i)$. Therefore, $N_f^+(v_i^{'}) = 0$, a contradiction. Hence $S(Fl_n) \notin \Omega_a$ for any n. □

Theorem 2.12. *$S(Fl_n) \in \Omega_0$ for all $n \geq 3$.*

Proof. By labeling all the vertices of $S(Fl_n)$ by a, we get $S(Fl_n) \in \Omega_0$. □

Corollary 2.13. *$S(Fl_n) \notin \Omega_{a,0}$ for any $n \geq 3$.*

Proof. Proof is obvious from Theorem 2.11. □

Definition 2.14. [7] *The Sunflower SF_n is obtained from a wheel W_n with the central vertex w_0 and cycle $C_n = w_1w_2w_3 \cdots w_nw_1$ and additional vertices $v_1, v_2, v_3, \ldots, v_n$ where v_i is joined by edges to w_i and w_{i+1}, where $i+1$ is taken over modulo n.*

Theorem 2.15. *$S(SF_n) \notin \Omega_a$ for any $n \geq 3$.*

Proof. Consider the sunflower SF_n with vertex set $V = \{w_0, w_i, v_i : 1 \leq i \leq n\}$ where w_0 is the central vertex, $w_1, w_2, w_3, \ldots, w_n$ are vertices of the cycle and v_i is the vertex joined by edges to w_i and w_{i+1} where $i+1$ is taken over modulo n. For $1 \leq i \leq n$, let $w_i^{'}, v_i^{'}, v_i^{''}, u_i^{'}$ be the vertices in $S(SF_n)$ corresponding to the edges $w_0w_i, w_iv_i, v_iw_{i+1}, w_iw_{i+1}$ of SF_n, where $i+1$ is taken over modulo n. Assume that $S(SF_n) \in \Omega_a$ for some n with a labeling f. Then $N_f^+(v_1^{'}) = a = N_f^+(v_1^{''})$, implies that $f(w_1) = f(w_2)$, consequently $N_f^+(u_1^{'}) = 0$. This is a contradiction. Hence $S(SF_n) \notin \Omega_a$ for any n. □

Theorem 2.16. *For $n \geq 3$, $S(SF_n) \in \Omega_0$ if $n \equiv 0(\bmod\ 2)$.*

Proof. Consider the sunflower SF_n with vertex set $V = \{w_0, w_i, v_i : 1 \leq i \leq n\}$ where w_0 is the central vertex, $w_1, w_2, w_3, \ldots, w_n$ are vertices of the cycle and v_i is the vertex joined by edges to w_i and w_{i+1} where $i+1$ is taken over modulo n. For $1 \leq i \leq n$, let $w_i^{'}, v_i^{'}, v_i^{''}, u_i^{'}$ be the vertices in $S(SF_n)$ corresponding to the edges $w_0w_i, w_iv_i, v_iw_{i+1}, w_iw_{i+1}$ of SF_n, where $i+1$ is taken over modulo n. Suppose that $n \equiv 0(\bmod\ 2)$. We define $f : V[S(SF_n)] \rightarrow V_4 \backslash \{0\}$ as :

$f(w_0) = f(w_i) = f(w_i^{'}) = f(v_i) = f(v_i^{'}) = f(v_i^{''}) = a$ for $1 \leq i \leq n$,

$$f(u_i^{'}) = \begin{cases} b & \text{if} \quad i \equiv 1(\bmod 2) \\ c & \text{if} \quad i \equiv 0(\bmod 2) \end{cases}$$

Clearly f is an a-neighbourhood V_4-magic labeling of $S(SF_n)$. This completes the proof of the theorem. □

Corollary 2.17. *$S(SF_n) \notin \Omega_{a,0}$ for any $n \geq 3$.*

Proof. It directly follows from Theorem 2.15. □

Definition 2.18. [8] *A complete bipartite graph of the form $K_{1,n}$ is called a star graph. A star graph $K_{1,n}$ is sometimes called an n-star.*

Definition 2.19. [9] *The Bistar $B_{m,n}$ is the graph obtained by joining the central vertex of $K_{1,m}$ and $K_{1,n}$ by an edge.*

Theorem 2.20. *$S(B_{m,n}) \in \Omega_a$ if and only if both m and n are even.*

Proof. Consider the bistar $B_{m,n}$ with vertex set $\{u, v, u_i, v_j : 1 \le i \le m$ and $1 \le j \le n\}$ where $u_i (1 \le i \le m)$ and $v_j (1 \le j \le n)$ are pendant vertices adjacent to u and v respectively. Let $w, u_i^{'}$ and $v_j^{'}$ be vertices in $S(B_{m,n})$ corresponding to the edges uv, uu_i and vv_j of $B_{m,n}$. Suppose that both m and n are even. Define $f : V[S(B_{m,n})] \to V_4 \backslash \{0\}$ as:

$f(u) = f(v_j) = c$ for $1 \le j \le n$
$f(v) = f(u_i) = b$ for $1 \le i \le m$
$f(w) = f(u_i^{'}) = f(v_j^{'}) = a$ for $1 \le i \le m$ and $1 \le j \le n$.
Then f is an a-neighbourhood V_4-magic labeling of $S(B_{m,n})$. Hence $S(B_{m,n}) \in \Omega_a$. Conversely, suppose that not both m and n are even. Then either m or n is odd. Without loss of generality take m is odd. If possible, let $S(B_{m,n}) \in \Omega_a$ with a labeling f. Then $N_f^+(u_i) = a$ implies that $f(u_i^{'}) = a$ for $1 \le i \le m$. Then $N_f^+(u) = a$ implies that $ma + f(u) = a$, consequently $f(u) = 0$. This is a contradiction. Hence $S(B_{m,n}) \notin \Omega_a$. Which completes the proof of the theorem. □

Theorem 2.21. *$S(B_{m,n}) \notin \Omega_0$ for any m and n.*

Proof. Proof is obvious, due to the presence of pendant vertices in $S(B_{m,n})$. □

Corollary 2.22. *$S(B_{m,n}) \notin \Omega_{a,0}$ for any m and n.*

Proof. Proof directly follows from Theorem 2.21. □

Definition 2.23. [9] *Jelly fish graph $J(m,n)$ is obtained from a 4-cycle $w_1w_2w_3w_4w_1$ by joining w_1 and w_3 with an edge and appending the central vertex of $K_{1,m}$ to w_2 and appending the central vertex of $K_{1,n}$ to w_4.*

Theorem 2.24. *$S(J(m,n)) \notin \Omega_a$ for any m and n.*

Proof. Consider the jelly fish $J(m,n)$ with vertex set $V = V_1 \cup V_2$ where $V_1 = \{w_1, w_2, w_3, w_4\}$, $V_2 = \{u_i, v_j : 1 \le i \le m, 1 \le j \le n\}$ and edge set $E = E_1 \cup E_2$, where $E_1 = \{w_1w_2, w_2w_3, w_3w_4, w_4w_1, w_1w_3\}$, $E_2 = \{w_2u_i, w_4v_j : 1 \le i \le m, 1 \le j \le n\}$. Let $u_i^{'}, v_i^{'}$ be the new vertices corresponding to the edges w_2u_i, w_4v_j and $w_1^{'}, w_2^{'}, w_3^{'}, w_4^{'}, w_5^{'}$ be the new vertices corresponding to the edges $w_1w_2, w_2w_3, w_3w_4, w_4w_1, w_1w_3$ respectively in $S(J(m,n))$. Suppose that $S(J(m,n)) \in \Omega_a$ for some m and n with a labeling function f. Then $N_f^+(w_3^{'}) = a = N_f^+(w_4^{'})$ implies that $f(w_1) = f(w_3)$. Therefore, $N_f^+(w_5^{'}) = 0$, which is a contradiction. Hence $S(J(m,n)) \notin \Omega_a$ for any m and n. □

Theorem 2.25. *$S(J(m,n)) \notin \Omega_0$ for any m and n.*

Proof. Proof is obvious, since $S(J(m,n))$ has pendant vertex in it. □

Corollary 2.26. *$S(J(m,n)) \notin \Omega_{a,0}$ for any m and n.*

Proof. Proof directly follows from Theorem 2.24. □

Definition 2.27. *The graph $P_2 \times P_n$ is called a Ladder. It is denoted by L_n.*

Theorem 2.28. *$S(L_n) \in \Omega_a$ for all $n > 1$.*

Proof. Consider the ladder L_n with vertex set $V = \{u_i, v_i : 1 \le i \le n\}$ and edge set $E = \{u_iu_{i+1}, v_iv_{i+1} : 1 \le i \le n-1\} \cup \{u_iv_i : 1 \le i \le n\}$. Let $u_i^{'}, v_i^{'}$ be the new vertices corresponding to the edges u_iu_{i+1}, v_iv_{i+1} for $1 \le i \le n-1$ and w_i be the vertices corresponding to the edges u_iv_i for $1 \le i \le n$ in $S(L_n)$. Now define $f : V[S(L_n)] \to V_4 \backslash \{0\}$ as :

$$f(u_i) = \begin{cases} b & \text{if} \quad i \equiv 1 (\text{mod } 2) \\ c & \text{if} \quad i \equiv 0 (\text{mod } 2) \end{cases}$$

$$f(v_i) = \begin{cases} c & \text{if} \quad i \equiv 1 (\text{mod } 2) \\ b & \text{if} \quad i \equiv 0 (\text{mod } 2) \end{cases}$$

$$f(u_i^{'}) = f(v_i^{'}) = c \;\text{ for }\; 1 \le i \le n-1$$

$f(w_i) = a$ for $1 < i < n$

$f(w_1) = f(w_n) = b$.
Then $N_f^+ \equiv a$. Hence $S(L_n) \in \Omega_a$. □

Definition 2.29. [10] *The open ladder $O(L_n)$ is the graph obtained from two paths of lengths $n-1$ with $V(G) = \{u_i, v_i : 1 \le i \le n\}$ and $E(G) = \{u_iu_{i+1}, v_iv_{i+1} : 1 \le i < n\} \cup \{u_iv_i : 1 < i < n\}$.*

Theorem 2.30. *$S(O(L_n)) \in \Omega_a$ for all $n > 2$.*

Proof. Consider the open ladder $O(L_n)$ with vertex set $V(G) = \{u_i, v_i : 1 \le i \le n\}$ and $E(G) = \{u_iu_{i+1}, v_iv_{i+1} : 1 \le i < n\} \cup \{u_iv_i : 1 < i < n\}$. Let $u_i^{'}, v_i^{'}$ be the new vertices corresponding to the edges u_iu_{i+1}, v_iv_{i+1} for $1 \le i < n$ and w_i be the vertices corresponding to u_iv_i for $1 < i < n$ in $S(O(L_n))$. Now define $f : V[S(O(L_n))] \to V_4 \backslash \{0\}$ as :

$$f(u_i) = \begin{cases} b & \text{if} \quad i \equiv 1 (\text{mod } 2) \\ c & \text{if} \quad i \equiv 0 (\text{mod } 2) \end{cases}$$

$$f(v_i) = \begin{cases} c & \text{if} \quad i \equiv 1 (\text{mod } 2) \\ b & \text{if} \quad i \equiv 0 (\text{mod } 2) \end{cases}$$

$$f(u_i^{'}) = f(v_i^{'}) = a \;\text{ for }\; 1 \le i \le n-1$$

$f(w_i) = a$ for $1 < i < n$

Then f is an a-neighbourhood V_4-magic labeling of $S(O(L_n))$. □

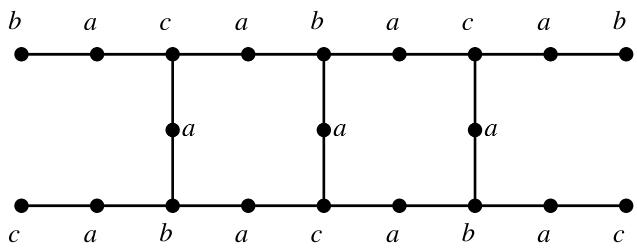

Figure 2. An a-neighbourhood V_4-magic labeling of $S(OL_5)$.

Theorem 2.31. *$S(O(L_n)) \notin \Omega_0$ for any $n > 2$.*

Proof. Proof is obvious, since $S(O(L_n))$ has pendant vertices in it. □

Corollary 2.32. *$S(O(L_n)) \notin \Omega_{a,0}$ for any $n > 2$.*

Proof. Proof directly follows from Theorem 2.31. □

Definition 2.33. *The Corona $G_1 \odot G_2$ of two graphs G_1 and G_2 is the graph obtained by taking one copy of G_1, which has p_1 vertices, and p_1 copies of G_2 and then joining the i^{th} vertex of G_1 by an edge to every vertex in the i^{th} copy of G_2.*

Definition 2.34. *The Corona $P_n \odot K_1$ is called the comb graph CB_n.*

Theorem 2.35. *$S(CB_n) \notin \Omega_a$ for any $n \geq 2$.*

Proof. Consider CB_n with vertex set $\{u_i, v_i : 1 \leq i \leq n\}$and edge set $\{u_iv_i : 1 \leq i \leq n\} \cup \{u_iu_{i+1} : 1 \leq i \leq n-1\}$. Let $v_i^{'}$ and $u_j^{'}$ be vertices in $S(CB_n)$ corresponding to the edges u_iv_i, u_ju_{j+1} for $1 \leq i \leq n$ and $1 \leq j \leq n-1$ of CB_n. Suppose that $S(CB_n) \in \Omega_a$ for some n with a labeling f. Then $N_f^+(v_i) = a$ implies that $f(v_i^{'}) = a$ for $1 \leq i \leq n$. Also, $N_f^+(u_1) = a$ implies that $f(v_1^{'}) + f(u_1^{'}) = a$, implies that $f(u_1^{'}) = 0$. This is a contradiction. Hence $S(CB_n) \notin \Omega_a$ for any n. □

Theorem 2.36. *$S(CB_n) \notin \Omega_0$ for any n.*

Proof. Proof is obvious, since $S(CB_n)$ has pendant vertices in it. □

Corollary 2.37. *$S(CB_n) \notin \Omega_{a,0}$ for any n.*

Proof. Proof directly follows from Theorem 2.36. □

Definition 2.38. [11] *A Crown graph C_n^* is obtained from C_n by attaching a pendant edge at each vertex of the cycle C_n.*

Theorem 2.39. *For $n \geq 3$, $S(C_n^*) \in \Omega_a$ if and only if $n \equiv 0(\bmod 2)$.*

Proof. Consider the crown C_n^* with vertex set $\{u_i, v_i : 1 \leq i \leq n\}$, where $u_1, u_2, u_3, \ldots, u_n$ are vertices on the cycle C_n and $v_1, v_2, v_3, \ldots, v_n$ are pendant vertices adjacent to the vertices $u_1, u_2, u_3, \ldots, u_n$ respectively. Let $v_i^{'}$ $(1 \leq i \leq n)$ be the vertices in $S(C_n^*)$ corresponding to the edges u_iv_i $(1 \leq i \leq n)$ and $u_i^{'}$ be the vertices corresponding to the edges u_iu_{i+1} $(1 \leq i \leq n)$, where $i+1$ is taken over modulo n. Suppose $S(C_n^*) \in \Omega_a$ with a labeling f. Then $N_f^+(v_1^{'}) = a$ gives either $f(u_1) = b$ or $f(u_1) = c$. Without loss of generality, take $f(u_1) = b$. Then $N_f^+(u_1^{'}) = a$ implies that $f(u_2) = c$. Also $N_f^+(u_2^{'}) = a$ implies that $f(u_3) = b$. Proceeding like this, we should have

$$f(u_i) = \begin{cases} b & \text{if} \quad i \equiv 1(\bmod 2) \\ c & \text{if} \quad i \equiv 0(\bmod 2) \end{cases}$$

Now, $N_f^+(u_n^{'}) = a$ implies that $f(u_n) = c$. Therefore, $n \equiv 0(\bmod 2)$. Conversely suppose that $n \equiv 0(\bmod 2)$. Define $f : V[S(C_n^*)] \to V_4 \backslash \{0\}$ as :

$$f(u_i) = \begin{cases} b & \text{if} \quad i \equiv 1(\bmod 2) \\ c & \text{if} \quad i \equiv 0(\bmod 2) \end{cases}$$

$$f(v_i) = \begin{cases} c & \text{if} \quad i \equiv 1(\bmod 2) \\ b & \text{if} \quad i \equiv 0(\bmod 2) \end{cases}$$

$$f(u_i^{'}) = f(v_i^{'}) = a \quad \text{for} \quad 1 \leq i \leq n.$$

Then f is an a-neighbourhood V_4-magic labeling of $S(C_n^*)$. This completes the proof of the theorem. □

Theorem 2.40. *$S(C_n^*) \notin \Omega_0$ for any $n \geq 3$.*

Proof. Proof is obvious, since $S(C_n^*)$ has pendant vertices in it. □

Corollary 2.41. *$S(C_n^*) \notin \Omega_{a,0}$ for any $n \geq 3$.*

Proof. Proof directly follows from Theorem 2.40. □

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