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Pair Difference Cordial Labeling of $m-$ copies of Path, Cycle , Star and Ladder Graphs

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ABSTRACT

In this paper we investigate the pair difference cordial labeling behaviour of $m-$ copies of Path, Star,Cycle and ladder Graphs.

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1 Introduction

In this paper we consider only finite, undirected and simple graphs. The concept of cordial labeling was introduced by Cahit[4]. Different types of cordial related labeling was studied in [1, 2, 3, 5, 16]. In the similar line the notion of pair difference cordial labeling of a graph was introduced in [8]. The pair difference cordial labeling behaviour of several graphs like path, cycle, star, wheel,triangular snake,alternate triangular snake, butterfly

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, ladder, mobius ladder, slanting ladder, union of some graphs have been investigated in [8, 9, 10, 11, 12, 13, 14, 15]. The $m-$ copies of a graph G is denoted by mG [7]. In this paper we investigate the pair difference cordial labeling behaviour of $m-$ copies of Path, Star,Cycle and Ladder graphs.

2 Preliminaries

Definition 1. [8]. *Let $G = (V, E)$ be a (p, q) graph.*
Define

$$\rho = \begin{cases} \frac{p}{2}, & \text{if } p \text{ is even} \\ \frac{p-1}{2}, & \text{if } p \text{ is odd} \end{cases}$$

and $L = \{\pm1, \pm2, \pm3, \cdots, \pm\rho\}$ called the set of labels.
Consider a mapping $f : V \longrightarrow L$ by assigning different labels in L to the different elements of V when p is even and different labels in L to $p-1$ elements of V and repeating a label for the remaining one vertex when p is odd. The labeling as defined above is said to be a pair difference cordial labeling if for each edge uv of G there exists a labeling $|f(u) - f(v)|$ such that $\left|\Delta_{f_1} - \Delta_{f_1^c}\right| \leq 1$, where Δ_{f_1} and $\Delta_{f_1^c}$ respectively denote the number of edges labeled with 1 and number of edges not labeled with 1. A graph G for which there exists a pair difference cordial labeling is called a pair difference cordial graph.

Theorem 2. [8]. *The path P_n is pair difference cordial for all values of $n \neq 3$.*

Corollary 3. [8]. *The cycle C_n is pair difference cordial if and only if $n > 3$.*

Theorem 4. [8]. *The star $K_{1,n}$ is pair difference cordial if and only if $3 \leq n \leq 6$.*

Theorem 5. [8]. *The ladder graph $L_n = P_2 \times P_n$ is pair difference cordial for all values of n.*

3 Main results

Theorem 6. *The m- copies of the path P_n, mP_n is pair difference cordial for all even values of m and for all values of n.*

Proof. Let ${P_n}^{(j)} : {a_1}^{(j)}{a_2}^{(j)}{a_3}^{(j)} \cdots {a_n}^{(j)}$ be the j^{th} copy P_n , $1 \leq j \leq m$.

Consider the first path ${P_n}^{(1)}$. Assign the labels $1, 2, 3, \cdots, n$ respectively to the vertices ${a_1}^{(1)}, {a_2}^{(1)}, {a_3}^{(1)}, \cdots, {a_n}^{(1)}$ and next consider the second path ${P_n}^{(2)}$, assign the labels $(n+1), (n+2), (n+3), \cdots, (2n)$ to the vertices ${a_1}^{(2)}, {a_2}^{(2)}, {a_3}^{(2)}, \cdots, {a_n}^{(2)}$. Next assign the labels $(2n+1), (2n+2), (2n+3), \cdots, (3n)$ respectively to the vertices ${a_1}^{(3)}, {a_2}^{(3)}, {a_3}^{(3)}, \cdots, {a_n}^{(3)}$ of the third path ${P_n}^{(3)}$. Proceeding like this until we reach the vertices ${a_1}^{(\frac{m}{2})}, {a_2}^{(\frac{m}{2})}, {a_3}^{(\frac{m}{2})}, \cdots$,

${a_n}^{(\frac{m}{2})}$ of the $\frac{m}{2}^{th}$ path ${P_n}^{(\frac{m}{2})}$.

Now assign the labels to the vertices of the remaining copies of ${P_n}^{(j)}$, $\frac{m+2}{2} \leq j \leq m$. There are two cases arises.

Case 1. $m \equiv 0 \pmod 4$.

Consider the $\frac{m+2}{2}^{th}$ copy ${P_n}^{(\frac{m+2}{2})}$. Assign the labels $-1, -3, -5 \cdots, -(2n-1)$ respectively to the vertices ${a_1}^{(\frac{m+2}{2})}, {a_2}^{(\frac{m+2}{2})}, {a_3}^{(\frac{m+2}{2})}, \cdots, {a_n}^{(\frac{m+2}{2})}$ and assign the labels $-2, -4, -6, \cdots, -2n$ to the vertices ${a_1}^{(\frac{m+4}{2})}, {a_2}^{(\frac{m+4}{2})}, {a_3}^{(\frac{m+4}{2})}, \cdots, {a_n}^{(\frac{m+4}{2})}$ of the $\frac{m+4}{2}^{th}$ copy ${P_n}^{(\frac{m+4}{2})}$. Next assign the labels $-(2n+1), -(2n+3), -(2n+5), \cdots, -(4n-1)$ respectively to the vertices ${a_1}^{(\frac{m+6}{2})}, {a_2}^{(\frac{m+6}{2})}, {a_3}^{(\frac{m+6}{2})}, \cdots, {a_n}^{(\frac{m+6}{2})}$ of the $\frac{m+6}{2}^{th}$ copy ${P_n}^{(\frac{m+6}{2})}$ and assign the labels $-(2n+2), -(2n+4), -(2n+6), \cdots, -(4n)$ to the vertices ${a_1}^{(\frac{m+8}{2})}, {a_2}^{(\frac{m+8}{2})}, {a_3}^{(\frac{m+8}{2})}, \cdots, {a_n}^{(\frac{m+8}{2})}$ of the $\frac{m+8}{2}^{th}$ copy ${P_n}^{(\frac{m+8}{2})}$. Proceeding this process until we reach the vertices ${a_1}^{(m)}, {a_2}^{(m)}, {a_3}^{(m)}, \cdots, {a_n}^{(m)}$ of the m^{th} copy ${P_n}^{(m)}$.

Case 2. $m \equiv 2 \pmod 4$.

Consider the $\frac{m+2}{2}^{th}$ copy ${P_n}^{(\frac{m+2}{2})}$. Assign the labels $-1, -3, -5 \cdots, -(2n-1)$ respectively to the vertices ${a_1}^{(\frac{m+2}{2})}, {a_2}^{(\frac{m+2}{2})}, {a_3}^{(\frac{m+2}{2})}, \cdots, {a_n}^{(\frac{m+2}{2})}$ and assign the labels $-2, -4, -6, \cdots, -2n$ to the vertices ${a_1}^{(\frac{m+4}{2})}, {a_2}^{(\frac{m+4}{2})}, {a_3}^{(\frac{m+4}{2})}, \cdots, {a_n}^{(\frac{m+4}{2})}$ of the $\frac{m+4}{2}^{th}$ copy ${P_n}^{(\frac{m+4}{2})}$. Next assign the labels $-(2n+1), -(2n+3), -(2n+5), \cdots, -(4n-1)$ respectively to the vertices ${a_1}^{(\frac{m+6}{2})}, {a_2}^{(\frac{m+6}{2})}, {a_3}^{(\frac{m+6}{2})}, \cdots, {a_n}^{(\frac{m+6}{2})}$ of the $\frac{m+6}{2}^{th}$ copy ${P_n}^{(\frac{m+6}{2})}$ and assign the labels $-(2n+2), -(2n+4), -(2n+6), \cdots, -(4n)$ to the vertices ${a_1}^{(\frac{m+8}{2})}, {a_2}^{(\frac{m+8}{2})}, {a_3}^{(\frac{m+8}{2})}, \cdots, {a_n}^{(\frac{m+8}{2})}$ of the $\frac{m+8}{2}^{th}$ copy ${P_n}^{(\frac{m+8}{2})}$. Proceeding this process until we reach the vertices ${a_1}^{(m-1)}, {a_2}^{(m-1)}, {a_3}^{(m-1)}, \cdots, {a_n}^{(m-1)}$ of the $(m-1)^{th}$ copy ${P_n}^{(m-1)}$. Finally assign the labels $-(\frac{mn}{2}-n+1), -(\frac{mn}{2}-n+3), -(\frac{mn}{2}-n+5), \cdots, -(\frac{mn}{2}+1), -(\frac{mn}{2}-n+2), -(\frac{mn}{2}-n+4), -(\frac{mn}{2}-n+6), \cdots, -(\frac{mn}{2})$ to the vertices ${a_1}^{(m)}, {a_2}^{(m)}, {a_3}^{(m)}, \cdots, {a_n}^{(m)}$ of the last copy ${P_n}^{(m)}$.

□

Theorem 7. *The m- copies of the path P_n, mP_n is pair difference cordial for all odd values of m and for all values of n.*

Proof. Let ${P_n}^{(j)} : {a_1}^{(j)}{a_2}^{(j)}{a_3}^{(j)} \cdots {a_n}^{(j)}$ be the j^{th} copy $P_n, 1 \leq j \leq m$.

Consider the first copy ${P_n}^{(1)}$. Assign the labels $1, 2, 3, \cdots, n$ respectively to the vertices ${a_1}^{(1)}, {a_2}^{(1)}, {a_3}^{(1)}, \cdots, {a_n}^{(1)}$ and next consider the second copy ${P_n}^{(2)}$, assign the labels $(n+1), (n+2), (n+3), \cdots, (2n)$ to the vertices ${a_1}^{(2)}, {a_2}^{(2)}, {a_3}^{(2)}, \cdots,$
${a_n}^{(2)}$. Next assign the labels $(2n+1), (2n+2), (2n+3), \cdots, (3n)$ respectively to the vertices ${a_1}^{(3)}, {a_2}^{(3)}, {a_3}^{(3)}, \cdots, {a_n}^{(3)}$ of the third copy ${P_n}^{(3)}$. Proceeding like this until we reach

the vertices $a_1^{(\frac{m-1}{2})}, a_2^{(\frac{m-1}{2})}, a_3^{(\frac{m-1}{2})}, \cdots, a_n^{(\frac{m-1}{2})}$ of the $\frac{m-1}{2}^{th}$ copy of the path $P_n^{(\frac{m-1}{2)}}$.

Secondly consider the m^{th} path $P_n^{(m)}$, when n is even, assign the labels $\frac{m-1}{2}n+1$,$\frac{m-1}{2}n+2$,$-(\frac{m-1}{2}n+1)$,$-(\frac{m-1}{2}n+2)$,$\frac{m-1}{2}n+3$,$\frac{m-1}{2}n+4$,$-(\frac{m-1}{2}n+3)$,$-(\frac{m-1}{2}n+4), \cdots$,$\frac{m-1}{2}n+\frac{n}{2}$,$-(\frac{m-1}{2}n+\frac{n}{2})$ respectively to the vertices $a_1^{(m)}, a_2^{(m)}, a_3^{(m)}, a_4^{(m)}$, $a_5^{(m)}, a_6^{(m)}, \cdots, a_{n-1}^{(m)}, a_n^{(m)}$. When n is odd, assign the labels $\frac{m-1}{2}n+1$,$\frac{m-1}{2}n+2$,$-(\frac{m-1}{2}n+1)$,$-(\frac{m-1}{2}n+2)$,$\frac{m-1}{2}n+3$,$\frac{m-1}{2}n+4$,$-(\frac{m-1}{2}n+3)$,$-(\frac{m-1}{2}n+4), \cdots$,$\frac{m-1}{2}n+\frac{n-1}{2}$,$-(\frac{m-1}{2}n+\frac{n-1}{2})$,$-(\frac{m-1}{2}n+\frac{n-1}{2})$ to the vertices $a_1^{(m)}, a_2^{(m)}, a_3^{(m)}, a_4^{(m)}, a_5^{(m)}, a_6^{(m)}, \cdots$, $a_{n-2}^{(m)}, a_{n-1}^{(m)}, a_n^{(m)}$ respectively .

Now assign the labels to the vertices of the remaining copies of $P_n^{(j)}$, $\frac{m+1}{2} \leq j \leq m$. There are two cases arises.

Case 1. $m \equiv 1 \pmod 4$.

Consider the $\frac{m+1}{2}^{th}$ path $P_n^{(\frac{m+1}{2})}$. Assign the labels $-1, -3, -5 \cdots, -(2n-1)$ respectively to the vertices $a_1^{(\frac{m+1}{2})}, a_2^{(\frac{m+1}{2})}, a_3^{(\frac{m+1}{2})}, \cdots, a_n^{(\frac{m+1}{2})}$ and assign the labels $-2, -4, -6, \cdots,$ $-2n$ to the vertices $a_1^{(\frac{m+3}{2})}, a_2^{(\frac{m+3}{2})}, a_3^{(\frac{m+3}{2})}, \cdots, a_n^{(\frac{m+3}{2})}$ of the $\frac{m+3}{2}^{th}$ copy $P_n^{(\frac{m+3}{2})}$. Next assign the labels $-(2n+1), -(2n+3), -(2n+5), \cdots, -(4n-1)$ respectively to the vertices $a_1^{(\frac{m+5}{2})}, a_2^{(\frac{m+5}{2})}, a_3^{(\frac{m+5}{2})}, \cdots, a_n^{(\frac{m+5}{2})}$ of the $\frac{m+5}{2}^{th}$ copy $P_n^{(\frac{m+5}{2})}$ and assign the labels $-(2n+2), -(2n+4), -(2n+6), \cdots, -(4n)$ to the vertices $a_1^{(\frac{m+7}{2})}, a_2^{(\frac{m+7}{2})}, a_3^{(\frac{m+7}{2})}, \cdots,$ $a_n^{(\frac{m+7}{2})}$ of the $\frac{m+7}{2}^{th}$ copy $P_n^{(\frac{m+7}{2})}$. Proceeding this process until we reach the vertices $a_1^{(m-1)}, a_2^{(m-1)}, a_3^{(m-1)}, \cdots, a_n^{(m-1)}$ of the $(m-1)^{th}$ copy $P_n^{(m-1)}$.

Case 2. $m \equiv 3 \pmod 4$.

Consider the $\frac{m+1}{2}^{th}$ copy $P_n^{(\frac{m+1}{2})}$. Assign the labels $-1, -3, -5 \cdots, -(2n-1)$ respectively to the vertices $a_1^{(\frac{m+1}{2})}, a_2^{(\frac{m+1}{2})}, a_3^{(\frac{m+1}{2})}, \cdots, a_n^{(\frac{m+1}{2})}$ and assign the labels $-2, -4, -6, \cdots,$ $-2n$ to the vertices $a_1^{(\frac{m+3}{2})}, a_2^{(\frac{m+3}{2})}, a_3^{(\frac{m+3}{2})}, \cdots, a_n^{(\frac{m+3}{2})}$ of the $\frac{m+3}{2}^{th}$ copy $P_n^{(\frac{m+3}{2})}$. Next assign the labels $-(2n+1), -(2n+3), -(2n+5), \cdots, -(4n-1)$ respectively to the vertices $a_1^{(\frac{m+5}{2})}, a_2^{(\frac{m+5}{2})}, a_3^{(\frac{m+5}{2})}, \cdots, a_n^{(\frac{m+5}{2})}$ of the $\frac{m+5}{2}^{th}$ copy $P_n^{(\frac{m+5}{2})}$ and assign the labels $-(2n+2), -(2n+4), -(2n+6), \cdots, -(4n)$ to the vertices $a_1^{(\frac{m+7}{2})}, a_2^{(\frac{m+7}{2})}, a_3^{(\frac{m+7}{2})}, \cdots,$ $a_n^{(\frac{m+7}{2})}$ of the $\frac{m+7}{2}^{th}$ copy $P_n^{(\frac{m+7}{2})}$. Proceeding this process until we reach the vertices $a_1^{(m-2)}, a_2^{(m-2)}, a_3^{(m-2)}, \cdots, a_n^{(m-2)}$ of the $(m-2)^{th}$ copy $P_n^{(m-2)}$. Finally assign the labels $-(\frac{m-1}{2}n-n+1)$,$-(\frac{m-1}{2}n-n+3)$,$-(\frac{m-1}{2}n-n+5), \cdots$,$-(\frac{m-1}{2}n-n+n)$,$-(\frac{m-1}{2}n-n+2)$,$-(\frac{m-1}{2}n-n+4)$,$-(\frac{m-1}{2}n-n+6)$,$\cdots$,$-(\frac{m-1}{2}n-n+n-1)$ to the vertices $a_1^{(m-1)}, a_2^{(m-1)}, a_3^{(m-1)}, \cdots, a_{\frac{n+1}{2}}^{(m-1)}, a_{\frac{n+3}{2}}^{(m-1)}, a_{\frac{n+5}{2}}^{(m-1)}, \cdots, a_n^{(m-1)}$ respectively when n is odd and assign the labels $-(\frac{m-1}{2}n-n+1)$,$-(\frac{m-1}{2}n-n+3)$,$-(\frac{m-1}{2}n-n+5), \cdots$,$-(\frac{m-1}{2}n-n-1)$,$-(\frac{m-1}{2}n-n+2)$,$-(\frac{m-1}{2}n-n+4)$,$-(\frac{m-1}{2}n-n+6), \cdots$,$-(\frac{m-1}{2}n-n+n)$ to the vertices $a_1^{(m-1)}, a_2^{(m-1)}, a_3^{(m-1)}, \cdots, a_{\frac{n}{2}}^{(m-1)}$, $a_{\frac{n+2}{2}}^{(m-1)}, a_{\frac{n+4}{2}}^{(m-1)}, \cdots, a_n^{(m-1)}$ respectively when n is even.

□

Theorem 8. *The m- copies of the cycle C_n, mC_n is pair difference cordial for all values of $n \geq 3$ and for $m = 2$.*

Proof. **Case 1.** n is even.

Assign the labels $1, 2, 3, \cdots, n$ respectively to the vertices ${v_1}^{(1)}, {v_2}^{(1)}, {v_3}^{(1)}, \cdots, {v_n}^{(1)}$ and assign the labels $-1, -3, -5, \cdots, n-1$ to the vertices ${v_1}^{(2)}, {v_2}^{(2)}, {v_3}^{(2)}, \cdots, {v_{\frac{m}{2}}}^{(2)}$. Lastly assign the labels $-n, -(n-2), -(n-4), \cdots, -2$ respectively to the vertices ${v_{\frac{m+2}{2}}}^{(2)}$, ${v_{\frac{m+4}{2}}}^{(2)}$, ${v_{\frac{m+6}{2}}}^{(2)}$, $\cdots$, ${v_n}^{(2)}$.

Case 2. n is odd.

Assign the labels $1, 2, 3, \cdots, n$ respectively to the vertices ${v_1}^{(1)}, {v_2}^{(1)}, {v_3}^{(1)}, \cdots, {v_n}^{(1)}$ and assign the labels $-1, -3, -5, \cdots, -n$ to the vertices ${v_1}^{(2)}, {v_2}^{(2)}, {v_3}^{(2)}, \cdots, {v_{\frac{m+1}{2}}}^{(2)}$. Lastly assign the labels $-(n-1), -(n-3), -(n-5), \cdots, -2$ respectively to the vertices ${v_{\frac{m+3}{2}}}^{(2)}$, ${v_{\frac{m+5}{2}}}^{(2)}$, ${v_{\frac{m+7}{2}}}^{(2)}$, $\cdots$, ${v_n}^{(2)}$.

□

Theorem 9. *The m- copies of the cycle C_n, mC_n is pair difference cordial for all values of $n \geq 3$ and for $m = 3$.*

Proof. **Case 1.** n is even.

Assign the labels $1, 2, 3, \cdots, n$ respectively to the vertices ${v_1}^{(1)}, {v_2}^{(1)}, {v_3}^{(1)}, \cdots, {v_n}^{(1)}$ and assign the labels $-1, -2, -3, \cdots, -n$ to the vertices ${v_1}^{(2)}, {v_2}^{(2)}, {v_3}^{(2)}, \cdots, {v_n}^{(2)}$. Lastly assign the labels $(n+1), -(n+2), (n+2), -(n+2), \cdots, (n+\frac{n}{2}), -(n+\frac{n}{2})$ respectively to the vertices ${v_1}^{(3)}, {v_2}^{(3)}, {v_3}^{(3)}, {v_4}^{(3)}, \cdots, {v_{n-1}}^{(3)}, {v_n}^{(3)}$.

Case 2. n is odd.

Assign the labels $1, 2, 3, \cdots, n$ respectively to the vertices ${v_1}^{(1)}, {v_2}^{(1)}, {v_3}^{(1)}, \cdots, {v_n}^{(1)}$ and assign the labels $-1, -2, -3, \cdots, -n$ to the vertices ${v_1}^{(2)}, {v_2}^{(2)}, {v_3}^{(2)}, \cdots, {v_n}^{(2)}$. Finally assign the labels $(n+1), -(n+2), (n+2), -(n+2) \cdots, (n+\frac{n-1}{2}, -(n+\frac{n-1}{2})$ respectively to the vertices ${v_1}^{(3)}, {v_2}^{(3)}, {v_3}^{(3)}, {v_4}^{(3)}, \cdots, {v_{n-2}}^{(3)}, {v_{n-1}}^{(3)}$ and assign the label $-(n+\frac{n-1}{2})$ to the vertex ${v_n}^{(3)}$.

□

Theorem 10. *The m- copies of the cycle C_n, mC_n is pair difference cordial for all values of $n \geq 3$ and for all even values $m \geq 4$.*

Proof. Let ${C_n}^{(j)} : {v_1}^{(j)}{v_2}^{(j)}{v_3}^{(j)} \cdots {v_n}^{(j)}{v_1}^{(j)}$ be the j^{th} cycle ${C_n}^{(j)}, 1 \leq j \leq m.$

Consider the first copy ${C_n}^{(1)}$. Assign the labels $1, 2, 3, \cdots, n$ respectively to the vertices ${v_1}^{(1)}, {v_2}^{(1)}, {v_3}^{(1)}, \cdots, {v_n}^{(1)}$ and next consider the second copy ${C_n}^{(2)}$, assign the labels $(n+1), (n+2), (n+3), \cdots, (2n)$ to the vertices ${v_1}^{(2)}, {v_2}^{(2)}, {v_3}^{(2)}, \cdots, {v_n}^{(2)}$. Next assign the labels $(2n+1), (2n+2), (2n+3), \cdots, (3n)$ respectively to the vertices ${v_1}^{(3)}, {v_2}^{(3)}, {v_3}^{(3)}, \cdots, {v_n}^{(3)}$ of the third copy ${C_n}^{(3)}$. Proceeding like this until we reach the vertices ${v_1}^{(\frac{m}{2})}, {v_2}^{(\frac{m}{2})}, {v_3}^{(\frac{m}{2})}, \cdots, {v_n}^{(\frac{m}{2})}$ of the $(\frac{m}{2})^{th}$ cycle ${C_n}^{(\frac{m}{2})}$.

Consider the $\frac{m+2}{2}^{th}$ copy ${C_n}^{(\frac{m+2}{2})}$. Assign the labels $-1, -3, -5 \cdots, -(2n-3)$ respectively to the vertices ${v_1}^{(\frac{m+2}{2})}, {v_2}^{(\frac{m+2}{2})}, {v_3}^{(\frac{m+2}{2})}, \cdots, {v_{n-1}}^{(\frac{m+2}{2})}$ and assign the label $(2n-2)$ to the vertex ${v_n}^{(\frac{m+2}{2})}$. Now we assign the labels $-2, -4, -6, \cdots, -(2n-4)$ to the vertices ${v_1}^{(\frac{m+4}{2})}, {v_2}^{(\frac{m+4}{2})}, {v_3}^{(\frac{m+4}{2})}, \cdots, {v_{n-2}}^{(\frac{m+4}{2})}$ of the $\frac{m+4}{2}^{th}$ cycle ${C_n}^{(\frac{m+4}{2})}$ and assign the labels $-(2n), -(2n-1)$ respectively to the vertices ${v_{n-1}}^{(\frac{m+4}{2})}, {v_n}^{(\frac{m+4}{2})}$.

Next assign the labels $-(2n+1), -(2n+3), -(2n+5), \cdots, -(4n-1)$ respectively to the vertices ${v_1}^{(\frac{m+6}{2})}, {v_2}^{(\frac{m+6}{2})}, {v_3}^{(\frac{m+6}{2})}, \cdots, {v_{n-1}}^{(\frac{m+6}{2})}$ of the $\frac{m+6}{2}^{th}$ cycle ${C_n}^{(\frac{m+6}{2})}$ and assign the label $-(4n-2)$ to the vertex ${v_n}^{(\frac{m+6}{2})}$ .We now assign the labels $-(2n+2), -(2n+4), -(2n+6), \cdots, -(4n-4)$ to the vertices ${v_1}^{(\frac{m+8}{2})}, {v_2}^{(\frac{m+8}{2})}, {v_3}^{(\frac{m+8}{2})}, \cdots, {v_{n-2}}^{(\frac{m+8}{2})}$ of the $\frac{m+8}{2}^{th}$ copy ${C_n}^{(\frac{m+8}{2})}$ and assign the labels $-(4n), -(4n-1)$ respectively to the vertices ${v_{n-1}}^{(\frac{m+8}{2})}, {v_n}^{(\frac{m+8}{2})}$. Proceeding this process until we reach the vertices ${v_1}^{(m)}, {v_2}^{(m)}, {v_3}^{(m)}, \cdots, {v_n}^{(m)}$ of the m^{th} copy ${C_n}^{(m)}$.

□

Theorem 11. *The m- copies of the cycle C_n, mC_n is pair difference cordial for all values of $n \geq 4$ and for all odd values $m \geq 5$.*

Proof. Let ${C_n}^{(j)} : {v_1}^{(j)}{v_2}^{(j)}{v_3}^{(j)} \cdots {v_n}^{(j)}{v_1}^{(j)}$ be the j^{th} copy $C_n, 1 \leq j \leq m.$

Consider the first copy ${C_n}^{(1)}$. Assign the labels $1, 2, 3, \cdots, n$ respectively to the vertices ${v_1}^{(1)}, {v_2}^{(1)}, {v_3}^{(1)}, \cdots, {v_n}^{(1)}$ and next consider the second copy ${C_n}^{(2)}$, assign the labels $(n+1), (n+2), (n+3), \cdots, (2n)$ to the vertices ${v_1}^{(2)}, {v_2}^{(2)}, {v_3}^{(2)}, \cdots, {v_n}^{(2)}$. Next assign the labels $(2n+1), (2n+2), (2n+3), \cdots, (3n)$ respectively to the vertices ${v_1}^{(3)}, {v_2}^{(3)}, {v_3}^{(3)}, \cdots, {v_n}^{(3)}$ of the third copy ${C_n}^{(3)}$. Proceeding like this until we reach the vertices ${v_1}^{(\frac{m-1}{2})}, {v_2}^{(\frac{m-1}{2})}, {v_3}^{(\frac{m-1}{2})}, \cdots, {v_n}^{(\frac{m-1}{2})}$ of the $(\frac{m-1}{2})^{th}$ copy ${C_n}^{(\frac{m-1}{2})}$.

Consider the $\frac{m+1}{2}^{th}$ copy ${C_n}^{(\frac{m+1}{2})}$. Assign the labels $-1, -3, -5 \cdots, -(2n-3)$ respectively to the vertices ${v_1}^{(\frac{m+1}{2})}, {v_2}^{(\frac{m+1}{2})}, {v_3}^{(\frac{m+1}{2})}, \cdots, {v_{n-1}}^{(\frac{m+1}{2})}$ and assign the label $(2n-2)$ to the vertex ${v_n}^{(\frac{m+1}{2})}$.

Now we assign the labels $-2, -4, -6, \cdots, -(2n-4)$ to the vertices ${v_1}^{(\frac{m+3}{2})}, {v_2}^{(\frac{m+3}{2})}, {v_3}^{(\frac{m+3}{2})}, \cdots, {v_{n-2}}^{(\frac{m+3}{2})}$ of the $\frac{m+3}{2}^{th}$ cycle ${C_n}^{(\frac{m+3}{2})}$ and assign the labels $-(2n), -(2n-1)$

respectively to the vertices ${v_{n-1}}^{(\frac{m+3}{2})}$,${v_n}^{(\frac{m+3}{2})}$.

Next assign the labels $-(2n+1), -(2n+3), -(2n+5), \cdots, -(4n-1)$ respectively to the vertices ${v_1}^{(\frac{m+5}{2})}, {v_2}^{(\frac{m+5}{2})}, {v_3}^{(\frac{m+5}{2})}, \cdots, {v_{n-1}}^{(\frac{m+5}{2})}$ of the $\frac{m+5}{2}^{th}$ copy ${C_n}^{(\frac{m+5}{2})}$ and assign the label $-(4n-2)$ to the vertex ${v_n}^{(\frac{m+5}{2})}$. We now assign the labels $-(2n+2), -(2n+4), -(2n+6), \cdots, -(4n-4)$ to the vertices ${v_1}^{(\frac{m+7}{2})}, {v_2}^{(\frac{m+7}{2})}, {v_3}^{(\frac{m+7}{2})}, \cdots, {v_{n-2}}^{(\frac{m+7}{2})}$ of the $\frac{m+7}{2}^{th}$ cycle ${C_n}^{(\frac{m+7}{2})}$ and assign the labels $-(4n), -(4n-1)$ respectively to the vertices ${v_{n-1}}^{(\frac{m+7}{2})}$,${v_n}^{(\frac{m+7}{2})}$. Proceeding this process until we reach the vertices ${v_1}^{(m-1)}, {v_2}^{(m-1)}$, ${v_3}^{(m-1)}, \cdots, {v_n}^{(m-1)}$ of the $(m-1)^{th}$ copy ${C_n}^{(m-1)}$.

Now consider the m^{th} cycle ${C_n}^{(m)}$.There are four cases arises.

Case 1. $n \equiv 0 \pmod 4$.

Assign the labels $(\frac{m-1}{2}n+1)$,$(\frac{m-1}{2}n+2)$ to the vertices ${v_1}^{(m)}$,${v_2}^{(m)}$ respectively and assign the labels $-(\frac{m-1}{2}n+1)$,$-(\frac{m-1}{2}n+2)$ respectively to the vertices ${v_3}^{(m)}$,${v_4}^{(m)}$. Next we assign the labels $(\frac{m-1}{2}n+3)$,$(\frac{m-1}{2}n+4)$ to the vertices ${v_5}^{(m)}$,${v_6}^{(m)}$respectively and assign the labels $-(\frac{m-1}{2}n+3)$,$-(\frac{m-1}{2}n+4)$ respectively to the vertices ${v_7}^{(m)}$,${v_8}^{(m)}$. Now we assign the labels $(\frac{m-1}{2}n+5)$,$(\frac{m-1}{2}n+6)$ to the vertices ${v_9}^{(m)}$,${v_{10}}^{(m)}$ respectively. Proceeding like this until we reach the vertex ${v_n}^{(m)}$. Note that in this process the vertex ${v_n}^{(m)}$ get the label $-(\frac{m-1}{2}n+\frac{n}{2})$.

Case 2. $n \equiv 1 \pmod 4$.

As in case 1, assign the labels to the vertices ${v_i}^{(m)}, 1 \le i \le n-1$. Finally assign the label $-(\frac{m-1}{2}n+\frac{n-3}{2})$ the vertex ${v_n}^{(m)}$.

Case 3. $n \equiv 2 \pmod 4$.

Assign the labels to the vertices ${v_i}^{(m)}, 1 \le i \le n-2$ as in case 1 . Lastly assign the labels $-(\frac{m-1}{2}n+\frac{n}{2})$, $\frac{m-1}{2}n+\frac{n}{2}$ the vertices ${v_{n-1}}^{(m)}, {v_n}^{(m)}$ respectively.

Case 4. $n \equiv 3 \pmod 4$.

Similar to case 1, assign the labels to the vertices ${v_i}^{(m)}, 1 \le i \le n-3$. Finally assign the label $-(\frac{m-1}{2}n+\frac{n-1}{2})$,$(\frac{m-1}{2}n+\frac{n-1}{2})$,$(\frac{m-1}{2}n+\frac{n-1}{2})$ respectively the vertices ${v_{n-2}}^{(m)}, {v_{n-1}}^{(m)}, {v_n}^{(m)}$.

□

Theorem 12. *The m- copies of the star $K_{1,1}$, $mK_{1,1}$ is pair difference cordial for all values of n.*

Proof. Follows from theorem 3.1 , $mK_{1,1} \cong mP_2$ is pair difference cordial. □

Theorem 13. *The m- copies of the star $K_{1,2}$, $mK_{1,2}$ is pair difference cordial for all values of n.*

Proof. Follows from theorem 3.1 , $mK_{1,2} \cong mP_3$ is pair difference cordial. □

Theorem 14. *The m- copies of the star $K_{1,3}$, $mK_{1,3}$ is pair difference cordial for all values of m.*

Proof. Let the vertex set and the edge set of the j^{th} star ${K_{1,3}}^(j)$, $1 \leq j \leq m$ is shown below :
$V({K_{1,3}}^{(j)}) = \{v^{(j)}, {v_1}^{(j)}, {v_2}^{(j)}, {v_3}^{(j)} : 1 \leq j \leq m\}$ and
$E({K_{1,3}}^{(j)}) = \{v^{(j)}{v_1}^{(j)}, v^{(j)}{v_2}^{(j)}, v^{(j)}{v_3}^{(j)} : 1 \leq j \leq m\}$.

There are two cases arises.

Case 1. m is even.

Consider the first star ${K_{1,3}}^{(1)}$. Assign the labes $1, 2, 3, 4$ respectively to the vertices ${v_1}^{(1)}, v^{(1)}, {v_2}^{(1)}, {v_3}^{(1)}$ and assign the labels $5, 6, 7, 8$ to the vertices ${v_1}^{(2)}, v^{(2)}$, ${v_2}^{(2)}, {v_3}^{(2)}$ respectively the second copy ${K_{1,3}}^{(2)}$. Next Consider the third star ${K_{1,3}}^{(3)}$. Assign the labes $9, 10, 11, 12$ respectively to the vertices ${v_1}^{(3)}, v^{(3)}, {v_2}^{(3)}, {v_3}^{(3)}$ and assign the labels $13, 14, 15, 16$ to the vertices ${v_1}^{(4)}, v^{(4)}, {v_2}^{(4)}, {v_3}^{(4)}$ respectively the fourth copy ${K_{1,3}}^{(4)}$. Proceeding like this process until we reach the vertices of the $\frac{m}{2}^{th}$ star ${K_{1,3}}^{(\frac{m}{2})}$.

Secondly consider the $\frac{m+2}{2}^{th}$ copy ${K_{1,3}}^{(\frac{m+2}{2})}$. Assign the labes $-1, -2, -3, -4$ respectively to the vertices ${v_1}^{(\frac{m+2}{2})}, {v_2}^{(\frac{m+2}{2})}, {v_3}^{(\frac{m+2}{2})}, v^{(\frac{m+2}{2})}$ and assign the labels $-5, -6, -7, -8$ to the vertices ${v_1}^{(\frac{m+4}{2})}, {v_2}^{(\frac{m+4}{2})}, {v_3}^{(\frac{m+4}{2})}, v^{(\frac{m+4}{2})}$ respectively the $\frac{m+4}{2}^{th}$ star ${K_{1,3}}^{(\frac{m+4}{2})}$.

Next Consider the $\frac{m+6}{2}^{th}$ star ${K_{1,3}}^{(\frac{m+6}{2})}$. Assign the labes $-9, -10, -11,$ -12 respectively to the vertices ${v_1}^{(\frac{m+6}{2})}, {v_2}^{(\frac{m+6}{2})}, {v_3}^{(\frac{m+6}{2})}, v^{(\frac{m+6}{2})}$ and assign the labels $-13, -14, -15, -16$ to the vertices ${v_1}^{(\frac{m+8}{2})}, {v_2}^{(\frac{m+8}{2})}, {v_3}^{(\frac{m+8}{2})}, v^{(\frac{m+8}{2})}$ respectively the $\frac{m+8}{2}^{th}$ copy ${K_{1,3}}^{(\frac{m+8}{2})}$. Proceeding like this process until we reach the vertices of the m^{th} copy of the star $K_{1,3}$.

Case 2. m is odd.

Consider the first star ${K_{1,3}}^{(1)}$. Assign the labes $1, 2, 3, 4$ respectively to the vertices ${v_1}^{(1)}, v^{(1)}, {v_2}^{(1)}, {v_3}^{(1)}$ and assign the labels $5, 6, 7, 8$ to the vertices ${v_1}^{(2)}, v^{(2)}$, ${v_2}^{(2)}, {v_3}^{(2)}$ respectively the second copy ${K_{1,3}}^{(2)}$. Next Consider the third star ${K_{1,3}}^{(3)}$. Assign the labes $9, 10, 11, 12$ respectively to the vertices ${v_1}^{(3)}, v^{(3)}, {v_2}^{(3)}, {v_3}^{(3)}$ and assign the labels $13, 14, 15, 16$ to the vertices ${v_1}^{(4)}, v^{(4)}, {v_2}^{(4)}, {v_3}^{(4)}$ respectively the fourth star ${K_{1,3}}^{(4)}$. Proceeding like this process until we reach the vertices of the $\frac{m-1}{2}^{th}$ copy ${K_{1,3}}^{(\frac{m-1}{2})}$.

Secondly consider the $\frac{m+1}{2}^{th}$ star $K_{1,3}{}^{(\frac{m+1}{2})}$. Assign the labes $-1,-2,-3,-4$ respectively to the vertices $v_1{}^{(\frac{m+1}{2})}, v_2{}^{(\frac{m+1}{2})}, v_3{}^{(\frac{m+1}{2})}, v^{(\frac{m+1}{2})}$ and assign the labels $-5,-6,-7,-8$ to the vertices $v_1{}^{(\frac{m+3}{2})}, v_2{}^{(\frac{m+3}{2})}, v_3{}^{(\frac{m+3}{2})}, v^{(\frac{m+3}{2})}$ respectively the $\frac{m+3}{2}^{th}$ copy $K_{1,3}{}^{(\frac{m+3}{2})}$.

Next Consider the $\frac{m+5}{2}^{th}$ copy $K_{1,3}{}^{(\frac{m+5}{2})}$. Assign the labes $-9,-10,-11,-12$ respectively to the vertices $v_1{}^{(\frac{m+5}{2})}, v_2{}^{(\frac{m+5}{2})}, v_3{}^{(\frac{m+5}{2})}, v^{(\frac{m+5}{2})}$ and assign the labels $-13,-14,-15,-16$ to the vertices $v_1{}^{(\frac{m+7}{2})}, v_2{}^{(\frac{m+7}{2})}, v_3{}^{(\frac{m+7}{2})}, v^{(\frac{m+7}{2})}$ respectively the $\frac{m+7}{2}^{th}$ star $K_{1,3}{}^{(\frac{m+7}{2})}$. Proceeding like this process until we reach the vertices of the $(m-1)^{th}$ copy $K_{1,3}{}^{(m-1)}$. Finally assign the labels $\frac{m-1}{2}n+1, \frac{m-1}{2}n+2, -(\frac{m-1}{2}n+1), -(\frac{m-1}{2}n+2)$ respectively to the vertices $v_1{}^{(m)}, v_2{}^{(m)}, v_3{}^{(m)}, v^{(m)}$ of the m^{th} star $K_{1,3}{}^{(m)}$.

□

Theorem 15. *The m- copies of the star $K_{1,4}$, $mK_{1,4}$ is pair difference cordial for all values of m.*

Proof. Let the vertex set and the edge set of the i^{th} copy $K_{1,4}{}^{(}j)$, $1 \leq i \leq m$ is shown below :
$V(K_{1,4}{}^{(j)}) = \{v^{(j)}, v_1{}^{(j)}, v_2{}^{(j)}, v_3{}^{(j)}, v_4{}^{(j)} : 1 \leq j \leq m\}$ and
$E(K_{1,4}{}^{(}j)) = \{v^{(j)}v_1{}^{(j)}, v^{(j)}v_2{}^{(j)}, v^{(j)}v_3{}^{(j)}, v^{(j)}v_4{}^{(j)} : 1 \leq j \leq m\}$.

There are two cases arises.

Case 1. m is even.

Consider the first copy $K_{1,4}{}^{(1)}$. Assign the labes $1,2,3,4,5$ respectively to the vertices $v_1{}^{(1)}, v^{(1)}, v_2{}^{(1)}, v_3{}^{(1)}, v_4{}^{(1)}$ and assign the labels $6,7,8,9,10$ to the vertices $v_1{}^{(2)}, v^{(2)}, v_2{}^{(2)}$, $v_3{}^{(2)}, v_4{}^{(2)}$ respectively the second star $K_{1,4}{}^{(2)}$. Next Consider the third copy $K_{1,4}{}^{(3)}$. Assign the labes $11,12,13,14,15$ respectively to the vertices $v_1{}^{(3)}, v^{(3)}, v_2{}^{(3)}, v_3{}^{(3)}, v_4{}^{(3)}$ and assign the labels $16,17,18,19,20$ to the vertices $v_1{}^{(4)}, v^{(4)}, v_2{}^{(4)}, v_3{}^{(4)}, v_4{}^{(4)}$ respectively the fourth star $K_{1,4}{}^{(4)}$. Proceeding like this process until we reach the vertices of the $\frac{m}{2}^{th}$ copy $K_{1,4}{}^{(\frac{m}{2})}$.

Secondly consider the $\frac{m+2}{2}^{th}$ copy $K_{1,4}{}^{(\frac{m+2}{2})}$. Assign the labes $-1,-2,-3,-4,-5$ respectively to the vertices $v_1{}^{(\frac{m+2}{2})}, v^{(\frac{m+2}{2})}, v_2{}^{(\frac{m+2}{2})}, v_3{}^{(\frac{m+2}{2})}, v_4{}^{(\frac{m+2}{2})}$ and assign the labels $-6,-7,-8,-9,-10$ to the vertices $v_1{}^{(\frac{m+4}{2})}, v^{(\frac{m+4}{2})}, v_2{}^{(\frac{m+4}{2})}, v_3{}^{(\frac{m+4}{2})}$, $v_4{}^{(\frac{m+4}{2})}$ respectively the $\frac{m+4}{2}^{th}$ star $K_{1,4}{}^{(\frac{m+4}{2})}$.

Next Consider the $\frac{m+6}{2}^{th}$ star $K_{1,4}{}^{(\frac{m+6}{2})}$. Assign the labes $-11,-12,-13,-14$, -15 respectively to the vertices $v_1{}^{(\frac{m+6}{2})}, v^{(\frac{m+6}{2})}, v_2{}^{(\frac{m+6}{2})}, v_3{}^{(\frac{m+6}{2})}, v_4{}^{(\frac{m+6}{2})}$ and assign the labels $-16,-17,-18,-19,-20$ to the vertices $v_1{}^{(\frac{m+8}{2})}, v^{(\frac{m+8}{2})}, v_2{}^{(\frac{m+8}{2})}$, $v_3{}^{(\frac{m+8}{2})}, v_4{}^{(\frac{m+8}{2})}$ respectively the $\frac{m+8}{2}^{th}$ copy $K_{1,4}{}^{(\frac{m+8}{2})}$. Proceeding like this process until we reach the vertices of the m^{th} copy $K_{1,4}{}^{(m)}$.

Case 2. m is odd.

Consider the first copy $K_{1,4}{}^{(1)}$. Assign the labes $1,2,3,4,5$ respectively to the vertices $v_1{}^{(1)}, v^{(1)}, v_2{}^{(1)}, v_3{}^{(1)}, v_4{}^{(1)}$ and assign the labels $6,7,8,9,10$ to the vertices $v_1{}^{(2)}, v^{(2)}, v_2{}^{(2)}, v_3{}^{(2)}, v_4{}^{(2)}$ respectively the second star $K_{1,4}{}^{(2)}$. Next Consider the third star $K_{1,4}{}^{(3)}$. Assign the labes $11,12,13,14,15$ respectively to the vertices $v_1{}^{(3)}, v^{(3)}, v_2{}^{(3)}, v_3{}^{(3)}, v_4{}^{(3)}$ and assign the labels $16,17,18,19,20$ to the vertices $v_1{}^{(4)}, v^{(4)}, v_2{}^{(4)}, v_3{}^{(4)}, v_4{}^{(4)}$ respectively the fourth copy $K_{1,4}{}^{(4)}$. Proceeding like this process until we reach the vertices of the $\frac{m-1}{2}^{th}$ star $K_{1,4}{}^{(\frac{m-1}{2})}$.

Secondly consider the $\frac{m+1}{2}^{th}$ star $K_{1,4}{}^{(\frac{m+1}{2})}$. Assign the labes $-1,-2,-3,-4,$ -5 respectively to the vertices $v_1{}^{(\frac{m+1}{2})}, v^{(\frac{m+1}{2})}, v_2{}^{(\frac{m+1}{2})}, v_3{}^{(\frac{m+1}{2})}, v_4{}^{(\frac{m+1}{2})}$ and assign the labels $-6,-7,-8,-9,-10$ to the vertices $v_1{}^{(\frac{m+3}{2})}, v^{(\frac{m+3}{2})}, v_2{}^{(\frac{m+3}{2})}, v_3{}^{(\frac{m+3}{2})},$ $v_4{}^{(\frac{m+3}{2})}$ respectively the $\frac{m+3}{2}^{th}$ copy $K_{1,4}{}^{(\frac{m+3}{2})}$.

Next Consider the $\frac{m+5}{2}^{th}$ copy $K_{1,4}{}^{(\frac{m+5}{2})}$. Assign the labes $-11,-12,-13,-14,$ -15 respectively to the vertices $v_1{}^{(\frac{m+5}{2})}, v^{(\frac{m+5}{2})}, v_2{}^{(\frac{m+5}{2})}, v_3{}^{(\frac{m+5}{2})}, v_4{}^{(\frac{m+5}{2})}$ and assign the labels $-16,-17,-18,-19,-20$ to the vertices $v_1{}^{(\frac{m+7}{2})}, v^{(\frac{m+7}{2})}, v_2{}^{(\frac{m+7}{2})},$ $v_3{}^{(\frac{m+7}{2})}, v_4{}^{(\frac{m+7}{2})}$ respectively the $\frac{m+7}{2}^{th}$ copy $K_{1,4}{}^{(\frac{m+7}{2})}$. Proceeding like this process until we reach the vertices of the $(m-1)^{th}$ copy $K_{1,4}{}^{(m-1)}$.

Finally assign the labels $\frac{m-1}{2}n+1, \frac{m-1}{2}n+2, \frac{m-1}{2}n+1, -(\frac{m-1}{2}n+1), -(\frac{m-1}{2}n+2)$ respectively to the vertices $v_1{}^{(m)}, v^{(m)}, v_2{}^{(m)}, v_3{}^{(m)}, v_4{}^{(m)}$ of the m^{th} copy $K_{1,4}{}^{(m)}$.

□

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