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E_{3-} CORDIAL AND PRIME CORDIAL LABELING OF SOME WHEEL RELATED GRAPHS

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Abstract- ***A prime cordial labeling of a graph G is a bijectio f : V(G) → {1,2..,|V(G)|}and the induced edge function f:V(G) → {0,1} is defined by f(e=uv) =1 if gcd(f(u),f(v)) =1 =0 if gcd(f(u),f(v)) ≥ 1 Further condition is satisfied that $|e_f(0)-e_f(1)|\leq 1$where $e_f(0)$and $e_f(1)$ are the number of edges with label 0 and 1 respectively.We show that a wheel graph $W_{n+1}$is prime cordial.A k-edge labeling of a graph G is a function f :E(G)→{0….,k - 1}. Such a labeling induces a labeling on the vertex set V (G) by defining f (v) :=∑ f (e) (mod k), where the summation is taken over all the edges incident on the vertex v.For an edge labeling f, letv_f (i) (respectively $e_f(i)$) be the number of vertices (respectively edges) receiving the label i.A graph G is said to be E_k- cordial if there is an k- edge labeling f of G such that, $|v_f(i)-v_f(j)| \leq 1$ and let $|e_f(i)- e_f(j)| \leq 1$ for all $0 \leq i, j \leq k-1$.,i≠j A wheel W_{n+1} is the join of the cycle $C_n$on nvertices and K_1 . A Gear graph $G = G_{2n+1}$ is obtained from wheel graph W_{n+1} by adding a vertex on each edge of cycle C_n. We prove that Gear graph $G = G_{2n+1}$ for n≥3,and $G^{(K)}$, that is, one point union of k copies of G are E_3-cordial.***

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I. INTRODUCTION

Throughout this work all graphs are finite, simple and undirected. Let V (G) and E (G) denote the vertex set and the edge set respectively, of a graph G. Sundaram [7] et al has introduced the notionof prime cordial labeling. A prime cordial labeling of a graph G is a bijectio f : V(G) → {1,2..,|V(G)|}such that each edge (e=uv) is assigned the label 1 if gcd(f(u),f(v)) =1 and 0 if gcd(f(u),f(v)) ≥ 1.Further condition is satisfied that $|e_f(0)-e_f(1)|\leq 1$where $e_f(0)$and $e_f(1)$ are the number of edges with label o and 1 respectively.The following graphs are proved to be prime cordial.$C_n$iff n≥6,P_n if n≠3 or 5. $K_{1,n}$ (n odd); the graph obtained by sub dividing each edge of $K_{1;n}$iff n≥3;bistars,dragons,crowns,triangular snakes iff the snakes has at least ladders 3 triangles. etc.J.BhaskarBabuji [6] has proved the full binary tree, Sn1:Sn2 for all n>2 has prime cordial labeling. G.V.Ghodsara&J.P.Jena [5] proved that Cycle Cn with one chord ,Cycle Cn with twin chords,CycleCn with triangle Cn(1,1,n-2) (n≠7) are prime cordial .

A k-edge labeling of a graph G is a function : E (G) → {0…..k-1}. Such a labeling induces a labeling on the vertex set V (G) by defining f(v):=∑f (e) (mod k), where the summation is taken over all the edges incident on the vertex v. For an edge labeling f,letv_f(i) be the number of vertices receiving the label i . Similarly, let e_f(i) be the number of edges of G receiving the label i. These are called the vertex numbers and the edgenumbers for the labeling f.

In the year 2000,Cahit and Yilmaz introduced the concept of E_{k-}Cordial labeling of a graph G. A graph G is said to be E_k– cordial if there is a k-edge labeling f of G such that,$|v_f (i) - v_f (j)|\leq 1$and $|e_f(i) - e_f(j)|\leq 1$ for all $0 \leq i , j \leq k-1$.Such a map is called an E_K–cordial labelingof the graph G. If k=3 we get E_k cordial labeling.They proved that following graps are E3 –cordial.: (1) Paths P_n,n ≥ 3, (2) the complete graph K_n, n ≥3, (3) the cycle C_n, n ≥ 3, (4) the friendship graph C^t_3. (4) the fan F_n, n ≥ 3,where F_n is obtained by taking n-3 concurrent chords in a cycle C_n.(5) They also proved that

The work is partly supported by University Of Mumbai , INDIA the star $S_n=K_2^{(n)}$, n ≥ 2, is E_k – cordial if and only if n ≡ 1(mod k),for odd k and n ≡ 1(mod 2k) for k ≠ 2,but k even.

Theorem 1 The wheel W_{n+1} is prime cordial for n≥9.
Proof: Define W_{n+1} as $V(W_{n+1}) = \{ v_0,v_1,v_2,\dots v_n\}$ and $E(W_{n+1}) =\{ v_0v_i/i=1,2,\dots n\}U\{v_iv_{i+1}/i, =1,2,\dots n\}$ here i+1 is taken modulo n.Thus W_{n+1} has n+1 vertices and 2n edges.We call the edges v_0v_i as pi and edges v_iv_{i+1} as p_i.Thus pokes P_i are n in number and c_i are the cycle edges n in number.The vertex v_0 is called as hub.

Case i: n =9.
$f(v_0)=2,f(v_1) = 10, f(v_2) = 5$,$f(v_3) =7$,$f(v_4) =1$,$f(v_5) =9$,$f(v_6) =6$,$f(v_7) =3$,$f(v_8) = 4$,$f(v_9) = 8$

The cycle edges which are 9 in number ,receive the labels as $f(c1=v_1v_2) = 0$, $f(c_2) = 1$, $f(c_3) =1$, $f(c_4) = 1$, $f(c_5) = 0$, $f(c_6) = 0$, $f(c_7) = 1$, $f(c_8) = 0$, $f(c_9) = 0$, And 9 pokes receive the label as $f(p_1) = 0$, $f(p_2) = 1$, $f(p_3) = 1$, $f(p_4) = 1$, $f(p_5) = 1$, $f(p_6) = 0$, $f(p_7) = 1$, $f(p_8) = 0$, $f(p_9) = 0$,Thus $e_f(0,1) = (9,9)$.
Case ii: n =10.i.e. to show that W_{11} is prime cordial.
$f(v_0)=2$, $f(v_1) = 7$, $f(v_2) = 3$,$f(v_3) =9$,$f(v_4) =8$,$f(v_5) =4$,$f(v_6) =8$,$f(v_7) =10$,$f(v_8) =5$,$f(v_9) =1$,$f(v_{10}) = 11$

The cycle edges which are 10 in number ,receive the labels as $f(c1=v_1v_2) = 1$, $f(c_2) = 0$, $f(c_3) =0$, $f(c_4) = 0$,

$f(c_5) = 0$, $f(c_6) = 0$, $f(c_7) = 0$, $f(c_8) = 1$, $f(c_9) = 1$, $f(c_{10}) = 1$ And 10 pokes receive the label as $f(p_1) = 1, f(p_2) = 1$, $f(p_3) = 0, f(p_4) = 0$, $f(p_5) = 0$, $f(p_6) = 0$, $f(p_7) = 1, f(p_8) = 1, f(p_9) = 1$, $f(p_{10}) = 1$

Caseiii n= 9+2x,x = 1,2,3…

We introduce 2x new vertices on the cycle C_9 of W_{9+1}whose labeling is given above.Of which x new vertices are introduced between vertex v_3 and

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vertex v_4 as $v_{11}, v_{13}, v_{15} \ldots v_{9+2x}$ and another x vertices between vertex v_8 and v_9 of cycle C_{9+2x} . as $v_{10}, v_{12}, v_{14}, \ldots . v_{8+2x}$. The labeling of all these vertices is given by $v_\alpha = \alpha$.The resultant edge numbers are $e_f(0,1) = (9+x, 9+x)$

Thus the graph W_{n+1} is prime cordial for n = 9+2x.

Caseiv n= 10 +2x,x = 1,2,3…

We introduce 2x new vertices on the cycle C_{10} of W_{10+1}whose labeling is given above.We carry the same labeling of C_{10} as above. x vertices of new 2x vertices are introduced between v_8 and v_9 as $v_{11}, v_{13,15}, \ldots$, $v_{9+2x}$and other x vertices between v_4 and v_5 as $v_{12}, v_{14}, v_{16} \ldots v_{10+2x}$ with vertex label as $f(v_\alpha) = \alpha$ .Note that $e_f(0,1) = (10+x, 10+x)$

That shows that W_{n+1} is prime cordial.

E_{3-} cordiality of gear graphs.

Definition 1.1 A gear graph G = G_{2n+1}, n≥ 3 is defined as follows: V(G)={$v_0, \ldots, v_{2n}$ },E(G)={$c_i = v_0 v_{2i-1}$ /i = 1,….,n} U {$e_i = v_i v_{i+1}$/1,2,,….2n} Here i+ 1 is taken (modulo 2n.)

The vertex v_0 is called the hub of the gear graph G_{2n+1}. The edges c_i,$1 \le i \le n$, are all the edges joining the hub to alternate vertices of the cycle $C_{2n} = (v_1, \ldots v_{2n}, v_1)$.They are called the spokes of G_{2n+1}. The edgse$_i$,$1 \le i \le 2n$, are the edges on the cycle C_{2n}.

Clearly, |V(G)|= 2n+1 and |E (G)| = 3n.

Theorem 1.2The graph G = G_{2n+1} is E_3- cordial for all natural numbers n ≥ 3.

Proof: Case 1: n = 3x / x = 1,2,3..

Define f: E (G) → {0,1,2} as follows:

The edges on the cycle C_{6x} are labeled as follows:

$f(e_i)$ = 0, for i ≡1,2 (mod 6)
= 1, for i ≡3,4 (mod 6)
= 2, for i≡5,6 (mod 6)

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The 3x spokes are labelled as follows:

$f(c_i)$ = 0, for i≡1 (mod 3)
= 2, for i≡2 (mod 3)
= 1, for i≡3 (mod 3)

This induces vertex labeling as follows :$f(v_0)=0$ and

f(vi) = 2, for i≡1,4 (mod 6)
= 0, for i≡2,3 (mod 6)

= 1, for i≡5,6 (mod 6)

One can check that $v_f(0) = 2x+1, v_f(1) = v_f(2) = 2x$ and $e_f(0) = e_f(1) = e_f(2) = 3x$.

Hence f is an E_3- cordial labeling.

Case 2: n =3x+4,x ≥ 0. In this case we give E_3 – cordial labeling as follows:

Type A : We extend the labeling f given in case 1 as follows: For 1 ≤ i ≤ 6x label the first consecutive 6x edges $e_1, \ldots, e_{6x}$ on the cycle C_{6x+8} and the corresponding 3x spokes as in Case1. The remaining 8 edges on the cycle are labelled as follows:

$f(e_{6x+1}) = 1$, $f(e_{6x+2}) = 1$, $f(e_{6x+3}) = 0$, $f(e_{6x+4}) = 0$, $f(e_{6x+5}) = 2$, $f(e_{6x+6}) = 1$, $f(e_{6x+7}) = 1$, $f(e_{6x+8}) = 2$. The remaining 4 spokes are labelled as follows: $f(c_{3x+1}) = f(c_{3x+4}) = 2$; $f(c_{3x+2}) = f(c_{3x+3}) = 0$.

One can check that the extra new vertices on the cycle C_{6x+8} receive

the labels as follows: $f(v_{6x+1})=2$, $f(v_{6x+2})=2$, $f(v_{6x+3})=1$, $f(v_{6x+4})=0$, $f(v_{6x+5})=2$, $f(v_{6x+6})=0$, $f(v_{6x+7})=1$, $f(v_{6x+8})=0$ and

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$f(v_0) = 1$,that is the hub receives the label 1.

This shows that the label numbers are $v_f(0) = v_f(1) = v_f(2) = 2x+3$ and $e_f(0) = e_f(1) = e_f(2) = 3x+4$. We note that for this Type A labeling $f(v_0) = 1$ and the labeling of type A is an E_3- cordial labeling.

Case 3 : n = 3x+5,x ≥ 0. Again we give use Type A labeling which is E_3 –cordial: We extend the same f in the case 1 as follows: For 1 ≤ i ≤ 6x label the first consecutive 6x edges $e_1, \ldots, e_{6x}$ on the cycle C_{6x+10} and the corresponding 3x spokes as in thecase 1.The remaining 10 edges on cycle are labelled as follows: $f(e_{6x+1})=0$, $f(e_{6x+2})=0$, $f(e_{6x+3})=0$, $f(e_{6x+4})=1$, $f(e_{6x+5})=1$, $f(e_{6x+6})=1$, $f(e_{6x+7})=2$, $f(e_{6x+8})=2$, $f(e_{6x+9})=0$, $f(e_{6x+10})=2$. The last 5 spokes are labelled as follows : $f(c_{3x+1})=2$, $f(c_{3x+2})=1$, $f(c_{3x+3})=0$, $f(c_{3x+4})=2$, $f(c_{3x+5})=1$.

One can check that the labels of the additional 10 cycel vertices are $f(v_{6x+1})=1$, $f(v_{6x+2})=0$, $f(v_{6x+3})=1$, $f(v_{6x+4})=1$, $f(v_{6x+5})=2$, $f(v_{6x+6})=2$, $f(v_{6x+7})=2$, $f(v_{6x+8})=1$, $f(v_{6x+9})=0$, $f(v_{6x+10})=2$. Note that $f(v_0)=0$, that is, the hub receives the label 0. This gives $v_f(0) = 2x+3$, $v_f(1) = v_f(2) = 2x+4$ and $e\ f(0) = 3x+5$, $e_f(1) = e_f(2) = 3x+5$. Hence this is an E_3 – cordial labeling.

This shows that $G_{2n+1}$is E_3 – cordial for all n ≥ 3.

Let G = G_{2n+1}. by the one point union G^k of k copies of G, we mean the graph obtained by taking k copies $H_1, \ldots, H_{k*}$ of G and identifying their hubs. The common hub is still denoted by v_0. For the graph H_α, the other vertices are denoted by $v_{\alpha,}1, \ldots, v_{\alpha,2n}$. The edges likewise are denoted by $e_{\alpha,1}, \ldots, e_{\alpha,2n}$and $c_{\alpha,1}, \ldots, c_{\alpha,n}$.

Theorem 2: G $^{(k)}$ is E_3- cordial where G = G_{6X+1}

Proof: We note that | V ($G^{(k)}$)| =1+6kx and | E($G^{(k)}$)| =9xk. We define an labeling on $G^{(k)}$ as follows:

For e =$e_{\alpha,m}$ε E($G^{(k)}$), then define $g(e_{\alpha,m}) = f(e_{\alpha,m})$,1 ≤ m ≤ k. Similary,

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for e = $c_{\alpha,m}$ε E($G^{(k)}$), then define $g(c_{\alpha,m}) = f(c_{\alpha,m})$,1 ≤ m ≤ k, where f is the labeling constructed in case 1 of Theorem 1.

It is now easy to see that $v_g(0) = 2xk + 1$, $v_g(1) = v_g(2) = 2xk$ and $e_g(i) = 3xk$, i = 0,1,2. Hence g is an E_3-cordial labeling.

Before proving the main theorem, we needto construct more labeling for G = G_{2n+1} when n = 3x +4 or 3x + 5. Some of these are not E_3-cordial labelings.

Alternate labeling for G_{2n+1},n = 3x + 4 or n =3x + 5.

Type B and Type C labelings for G_{6x+9}, that is,for n = 3x + 4.

Type B: For $1 \leq i \leq 6x$, label the first consecutive 6x edges $e_1,\ldots,e_{6x}$ on the cycle C_{6x+8} and corresponding 3x spokes as in Case 1 of Theorem 1. Corresponding 6x vertices on the cycle C_{6X+8} also receive the same labels as in Case 1 of Theorem 1. The remaining 8 edges of the cycle are labeled as:

f (e_{6x+1}) = 1, f (e_{6x+2}) = 1, f (e_{6x+3}) = 0, f (e_{6x+4}) = 0, f (e_{6x+5}) = 2, f (e_{6x+6}) = 2,

f (e_{6x+7}) = 1, f (e_{6x+8}) = 2. The remaining 4 spoke are labelledas :f(c_{3x+1}) = 1,

f (c_{3x+2}) = f (c_{3x+3}) = 0,f (c_{3x+4}) = 2. The corresponding 8 vertices on C_{6x+8} receive the labels as follows: f(v_{6x+1}) = 1,f(v_{6x+2}) = 2,f(v_{6x+3}) = 1,f(v_{6x+4}) = 0,f(v_{6x+5}) = 2,f(v_{6x+6}) = 1,f (v_{6x+7}) = 2,f(v_{6x+8}) = 0. Note that f (v_0) =0,that is the hub receives the label 0. It is easy to see that $v_f(0) = v_f(1) = v_f(2)$ =2x + 3 and $e_f(0) = e_f(1) = e_f(2)$ = 3x + 4. Hence, this is also an E_3-cordial labeling with the hub having the label 0.

Type C: For $1 \leq i \leq 6x$ label the first consecutive 6x edges $e_1 ,\ldots, e_{6x}$ on the cycle C_{6x+8} and the corresponding 3x spokes as in Type B. The remaining 8 edges on the cycle C_{6x+8} are labelled as: f (e_{6x+1}) = 0,f (e_{6x+2}) = 1,f (e_{6x+3}) = 1,f(e_{6x+4}) = 0,f(e_{6x+5}) = 2,f (e_{6x+6}) = 0,f (e_{6x+7}) = 1,f (e_{6x+8}) = 2. The last 4 spokes are labeled as follows: f (c_{3x+1}) = 0,f (c_{3x+2}) =1 ,f (c_{3x+3}) = 2,f (c_{3x+4}) =2.

The remaining 8 vertices receive the labels follows : f (v_{6x+1}) = 2,f (v_{6x+2}) = 1,f (v_{6x+3}) = 0,f (v_{6x+4}) = 1,f (v_{6x+5}) = 1,f (v_{6x+6}) = 2,f (v_{6x+7}) =0, f (v_{6x+8}) = 0. Note that f (v_0) =2, that is the hub receives the label 2. This gives $v_f(0) = v_f(1) = v_f(2)$ =2x + 3 and $e_f(0) = e_f(1) = e_f(2)$ = 3x + 4. This shows that is also an E_3- cordial labeling.

Remark: Type A, Type B and Type C labeling have the same label numbers and are all E_3-cordial. The only difference is that in Type A the hub has the label 1, in Type B the hub has the label 0 and in Type C the hub has the label 2

Type B labeling for G_{6x+11}, that is for n = 3x+5.

TYPE B**:** For $1 \leq i \leq 6x$ label the first consecutive 6x edges $e_1,\ldots,e_{6x}$ on C_{6x+10} and corresponding 3x spokes as in the case 3, Theorem 1. The labels of the vertices involved are the same as before. The remaining 10 edges on the cycle C_{6x+10} are labelled as: f (e_{6x+1}) =1,f (e_{6x+2}) =1,f (e_{6x+3}) =0,f (e_{6x+4}) =0,f (e_{6x+5}) =2,f (e_{6x+6}) =1,f (e_{6x+7}) =0,f (e_{6x+8}) =0,f (e_{6x+9}) =2,f (e_{6x+10}) =2. The last 5 spokes are labelledas :f (C_{3x+1}) =1,f (C_{3x+2}) =2,f (C_{3x+3}) =2,f (C_{3x+4}) =1,f (C_{3x+5}) =0.

The labels of the remaining 10 vertices on the cycle are f

(v_{6x+1}) =1,f (v_{6x+2}) =2,

f (v_{6x+3}) =0,f (v_{6x+4}) =0,f (v_{6x+5}) =1,f (v_{6x+6}) =0,f (v_{6x+7}) =2,f (v_{6x+8}) =0,f (v_{6x+9}) =2,f (v_{6x+10}) =1. It is easy to see that f (v_0) = 0. This gives $v_f(0)$ =2x+5, $v_f(1) = v_f(2)$ = 2x +3 and $e_f(0) = e_f(1) = e_f(2)$ = 3x + 5.

Thusthis is not an E_3-cordial labeling.

E_3-cordiality of $G_{2n+1}^{(k)}$ for n = 3x +4, 3x +5.

For a labeling f by $v_f(0,1,2)$ we mean the triple ($v_f(0)$,$v_f(1)$,$v_f(2)$). A similar notation will be used for the edge numbers.

Theorem 3 : If G = G_{6X+9} or G = G_{6x+11}, then $G^{(k)}$, k =1,2,…is E_3-cordial.

Proof: Case 1: For G = G_{6X+9} the graph $G^{(k)}$ has (6x+8)k+1 vertices and (9x+12)k edges. Let the copies of G be $H_1,\ldots,H_k$. Assign the labeling of Type A to H_{3t+1},t =1,2,…., assign the labeling of Type B to H_{3t+2}, t =1,2,… and assign the labeling of Type C to H_{3t} , t =1,2,…. Call the resulting labeling g.

k	Label of the Hub	V_g (0,1,2)	e_g (0,1,2)
1	1	(2x+3,2x+3,2x+3)	(3x+4,3x+4,3x+4)
2	1	(4x+5,4x+6,4x+6)	(6x+8,6x+8,6x+8)
3	0	(6x+9,6x+8,6x+8)	(9x +12, 9x +12, 9x +12)
3p	0	(p(6x+8)+1,p(6x+8),p(6x+8))	(p(9x+12),p(9x+12),p(9x +12))
3p+1	1	(p(6x+8),p(6x+8),p(6x+8)+ (2x+3,2x+3,2x+3)	(p(9x+12),p(9x+12),p(9x +12)) +(3x+4,3x+4,3x+4)
3p+2	1	(p(6x+8),p(6x+8),p(6x+8)+ (4x+5,4x+6,4x+6)	(p(9x+12),p(9x+12),p(9x +12)) + (6x+8,6x+8,6x+8)

This table clearly shows that $G^{(k)}$ is E_3- cordial for every natural number k.

Case 2 :G =G_{6x+11}. G $^{(k)}$ has (6x+10) k+1 vertices and (9x+15)k edges. Let the copies of G be $H_1,\ldots,H_k$. Assign the labeling of Type A to H_{3t+1}, t= 1,2,…, assign the labeling of Type B to H_{3t+2} and to H_{3t}, t=1,2,…, Call the resulting labeling g. The following table gives the label numbers of the resulting labeling.

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k	Label of the Hub	V_g (0,1,2)	e_g (0,1,2)
1	0	(2x+3,2x+4,2x+4)	(3x+5,3x+5,3x+5)
2	0	(4x+7,4x+7,4x+7)	(6x+10,6x+10,6x+10)
3	0	(6x+11,6x+11,6x+10)	(9x +15, 9x +15, 9x +15)
3p	0	(p(6x+10)+1,p(6x+10),p(6x+10))	(p(9x+15),p(9x+15),p(9x +15))
3p+1	0	(p(6x+10)+1,p(6x+10),p(6x+10)) +(2x+3,2x+4,2x+4)	(p(9x+15),p(9x+15),p(9x +15)) +(3x+5,3x+5,3x+5)
3p+2	0	(p(6x+10),p(6x+10),p(6x+10)) +(4x+7,4x+7,4x+7)	(p(9x+15),p(9x+15),p(9x +15)) + (6x+10,6x+10,6x+10)

Again this table shows that $G^{(k)}$ is E_3-cordial.

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