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An Investigation of Corona Domination Number for Some Special Graphs and Jahangir Graph

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Abstract:

In this work, the study of corona domination in graphs is carried over which was initially proposed by G. Mahadevan *et al.* Let H be a simple graph. A dominating set S of a graph is said to be a corona-dominating set if every vertex in $< S >$ is either a pendant vertex or a support vertices. The minimum cardinality among all corona-dominating sets is called the corona-domination number and is denoted by $\gamma_{CD}(H)$. (i.e)$\gamma_{CD}(H) = min\{|S| : S \; is \; a \; CD - set \; of \; H\}$. In this work, the exact value of the corona domination number for some specific types of graphs are given. Also, some results on the corona domination number for some classes of graphs are obtained and the method used in this paper is a well-known number theory concept with some modification this method can also be applied to obtain the results on other domination parameters.

Keywords: Corona dominating set, Dominating set, Jahangir graph, Pendant and Support vertex, Tadpole graph.

Introduction:

Every graph $H = (X(H), Y(H))$ considered here are connected finite, undirected, without isolated vertex and loops. A dominating set [1]S is a set of vertices of H with the condition that every $x \in X - S$, $d(x, S) = 1$. The minimum cardinality among all the dominating sets is called the domination number of H, denoted by $\gamma(H)$. The concept of corona domination was introduced by G.Mahadevan*et al.*[2]. The corona domination number (CD number) γ_{CD} is a minimum cardinality of the dominating set S, with the subgraph induced by S having either pendant or support vertices only. For example see Fig. 1. In recent years many authors have studied the different concept in graph theory and domination theory such as order sum graph[3], tadpole domination[4] etc. Let $M'(H)$ be the middle graph of H if two vertices x and y in the vertex set of $M'(H)$ are adjacent if x, y are in $Y(H)$ and x, y are adjacent in $H \; or \; x$ is in $X(H), y$ is in $y(H)$ and x is incident to y in H. The central graph $C'(H)$ of H is obtained by subdividing each edge in $Y(H)$ and joining all the non-adjacent vertices in H. A wheel graph[5]$W_{1,r}, r \geq 3$ is obtained by joining a single vertex to all the vertices of a cycle C_r. A graph obtained by attaching a pendant edge at each vertex of C_r is called helm graph H_r[5].Joining the pendant vertices of the helm graph to form a cycle will give a closed helm graph CH_r. The friendship graph F_r[5] is obtained by attaching the r-copies of C_3 at a common vertex. A graph constructed by joining a C_r to an end vertex of P_s by a bridge is called the tadpole graph $T_{r,s}$. The Cartesian product of two paths P_2 and P_r gives the ladder graph[5]$P_2 \boxtimes P_r$. A single vertex is adjacent to s vertices of C_{rs} at a distance r to one another on C_{rs} is called a Jahangir graph $J_{r,s}$. Consider a sequence of cycle C_4say $C_4^1, C_4^2, C_4^3, \ldots, C_4^r$, a diamond snake graph D_r is obtained by pasting $x_1^i to x_n^{i-1}$ where $1 \leq i \leq r$. The k^{th} power H^k of the graph H is graph with same set of vertices and two vertices $x$and y in H are adjacent whenever $d(x, y) \leq k$. The shadow graph $S^{'}(H)$ of a graph H is that a graph obtained by adding a new vertex $x^{'}$ for each vertex x of H and joining x' to the neighbors of x in H.

The CD-number for the fan and generalized fan graph $F_{r,s}$,the complement of the ladder graph $P_2 \boxtimes P_r$,the GoldnerHarary graph, the CD-number for the central graph of $K_{1,r}$, the CD-number for the Bull graph, the CD-number for the claw graph and the Konigsberg bridge graph are 2, the CD-number for m-shadow and m-splitting graph of P_r and C_r is same as the CD-number of P_r and C_r, the CD-number for the Moster spindle graph [5], the CD-number for Wagner graph is 3, the CD-number for King's tour graph is 12.

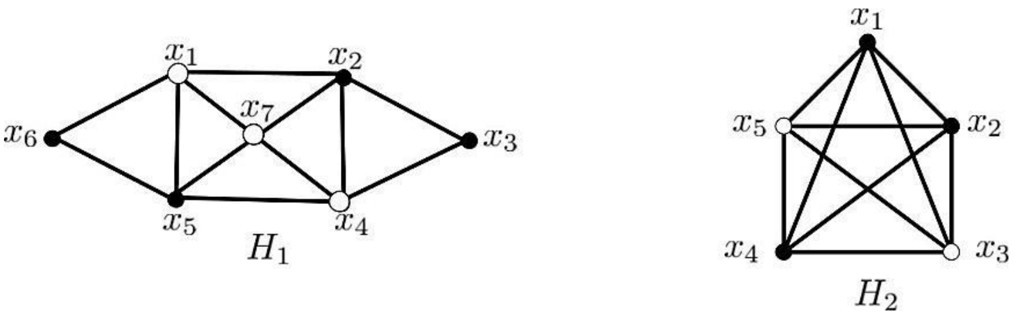

Figure 1. Example of corona domination number

Here, $\{x_1, x_4, x_7\}$ is the minimum corona dominating set of H_1, hence the $\gamma_{CD}(H_1) = 3$ and $\{x_3, x_5\}$ is the minimum corona dominating set of H_2, hence the $\gamma_{CD}(H_2) = 2$. For any complete graph K_r, $\gamma_{CD}(K_r) = 2$.

Examining the CD-number for some special graphs

Theorem 1:[6]LetD_r be a diamond snake graph. Then $\gamma(D_r) = r + 1$

Theorem 2: Let D_r be a diamond snake graph. Then $\gamma_{CD}(D_r) = r + 1$

Proof: Let $X(D_r) = \{x_1, x_2, \ldots, x_r, y_1, y_2, \ldots, y_{r-1}, z_1, z_2, \ldots, z_{r-1}\}$then $Y(D_r) = \{x_i y_i, x_i z_i, x_{i+1} y_i, x_{i+1} z_i : 1 \le i \le r - 1\}$. Let $S_1 = \{x_i : i \text{ is even}\} \cup \{y_i : i \text{ is odd}\}$. Then $S = \begin{cases} S_1 & if \;\; r \text{ is odd}, \\ S_1 \cup \{y_{r-1}\} & if \;\; r \text{ is even}. \end{cases}$ is a CD- set of D_r. Thus $\gamma_{CD}(D_r) \le |S| = r + 1$.Since $\gamma(D_r) = r + 1$,the result follows.

Theorem 3: Let H be the middle graph of a friendship graph. Then $\gamma_{CD}(H) = 2r$.

Proof: Let $X(H) = \{x_0, x_1^{(i)}, x_2^{(i)}, y_1^{(i)}, y_2^{(i)}, y_3^{(i)} : i = 1,2,3,\ldots,r\}$,then $Y(H) = \{x_0 y_2^{(i)}, x_0 y_3^{(i)}, x_1^{(i)} y_1^{(i)}, x_2^{(i)} y_1^{(i)}, x_1^{(i)} y_2^{(i)}, x_2^{(i)} y_3^{(i)}, y_2^{(i)} y_3^{(i)}, y_1^{(i)} y_2^{(i)}, y_1^{(i)} y_3^{(i)}, y_3^{(j)} y_2^{(j+1)}, y_2^{(1)} y_3^{(r)} : 1 \le i \le r \text{ and } 1 \le j \le r - 1\}$. Let $S = \{y_1^{(i)}, y_2^{(i)} i = 1,2,3,\ldots,r\}$ be a CD- set of H. Thus $\gamma_{CD}(H) \le |S| = 2r$. Suppose there exist a dominating set D of cardinality at most $d = 2r - 1$, then$< D >$ has an isolated vertex. Hence $|D| \ge d + 1 = 2r$. Therefore the proof.

Example 1:

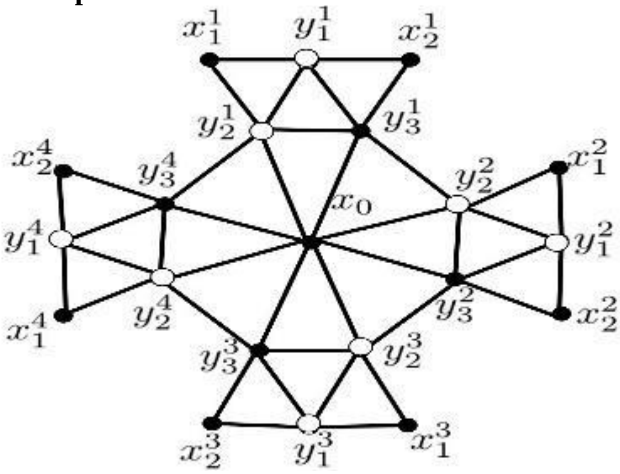

Figure 2. Middle graph of $M(F_4)$

For the Fig.2, the minimum CD-set is the vertices with white dots and hence the CD-number is 8.

Theorem 4: For any $s$and $r \equiv 0 \; or \; 1 \; or \; 3 \; (mod \; 4)$,

$$\gamma_{CD}(T_{r,s}) = \begin{cases} \lceil \frac{r}{2} \rceil + \lceil \frac{s}{2} \rceil & if \;\; s \equiv 0 \; or \; 2 \; or \; 3 (mod \; 4), \\ \lceil \frac{r}{2} \rceil + \lfloor \frac{s}{2} \rfloor & if \;\; s \equiv 1 (mod \; 4). \end{cases}$$

Proof: Let $X(T_{r,s}) = \{x_1, x_2, x_3, \ldots, x_r, y_1, y_2, y_3, \ldots, y_s\}$. Then $Y(T_{r,s}) = \{x_i x_{i+1}, x_1 x_r, y_j y_{j+1}, x_1 y_1 : 1 \le i \le r - 1, 1 \le j \le s - 1\}$. Let $S_1 = \{x_i : i \equiv 1 \; or \; 2 \; (mod \; 4)\} \cup \{y_i : i \equiv 0 \; or \; 3 \; (mod \; 4)\}$. Then

$$S = \begin{cases} S_1 & if \quad s \equiv 0 \; or \; 1 (mod\; 4), \\ S_1 \cup \{y_{s-1}\} & if \quad s \equiv 2 \; or \; 3 (mod\; 4). \end{cases}$$ is a CD-set of $T_{r,s}$. Thus

$$\gamma_{CD}(T_{r,s}) \leq |S| = \begin{cases} \lceil\frac{r}{2}\rceil + \lceil\frac{s}{2}\rceil & if \quad s \equiv 0 \; or \; 2 \; or \; 3 (mod\; 4), \\ \lceil\frac{r}{2}\rceil + \lfloor\frac{s}{2}\rfloor & if \quad s \equiv 1 (mod\; 4). \end{cases}$$

Suppose there exist a dominating set D of cardinality at most

$$d = \begin{cases} \lceil\frac{r}{2}\rceil + \lceil\frac{s}{2}\rceil - 1 & if \quad s \equiv 0 \; or \; 2 \; or \; 3 (mod\; 4), \\ \lceil\frac{r}{2}\rceil + \lfloor\frac{s}{2}\rfloor - 1 & if \quad s \equiv 1 (mod\; 4), \end{cases}$$

then$< D >$ has an isolated vertex.Hence

$$|D| \geq d + 1 = \begin{cases} \lceil\frac{r}{2}\rceil + \lceil\frac{s}{2}\rceil & if \quad s \equiv 0 \; or \; 2 \; or \; 3 (mod\; 4), \\ \lceil\frac{r}{2}\rceil + \lfloor\frac{s}{2}\rfloor & if \quad s \equiv 1 (mod\; 4). \end{cases}$$

Therefore the proof.

Theorem 5: For any $s$and $r \equiv 2 \; (mod\; 4)$,

$$\gamma_{CD}(T_{r,s}) = \begin{cases} \lceil\frac{r}{2}\rceil + \lceil\frac{s}{2}\rceil + 1 & if \quad s \equiv 0 \; or \; 2 \; or \; 3 (mod\; 4), \\ \lceil\frac{r}{2}\rceil + \lfloor\frac{s}{2}\rfloor + 1 & if \quad s \equiv 1 (mod\; 4). \end{cases}$$

Proof: Let $X(T_{r,s}) = \{x_1, x_2, x_3, \ldots, x_r, y_1, y_2, y_3, \ldots, y_s\}$. Then $Y(T_{r,s}) = \{x_i x_{i+1}, x_1 x_r, y_j y_{j+1}, x_1 y_1 : 1 \leq i \leq r-1, 1 \leq j \leq s-1\}$. Let $S_1 = \{x_i : i \equiv 1 \; or \; 2 \; (mod\; 4)\} \cup \{y_i : i \equiv 0 \; or \; 3 \; (mod\; 4)\}$. Then

$$S = \begin{cases} S_1 & if \quad s \equiv 0 \; or \; 1 (mod\; 4), \\ S_1 \cup \{y_{s-1}\} & if \quad s \equiv 2 \; or \; 3 (mod\; 4). \end{cases}$$ is a CD-set of $T_{r,s}$. Thus

$$\gamma_{CD}(T_{r,s}) \leq |S| = \begin{cases} \lceil\frac{r}{2}\rceil + \lceil\frac{s}{2}\rceil + 1 & if \quad s \equiv 0 \; or \; 2 \; or \; 3 (mod\; 4), \\ \lceil\frac{r}{2}\rceil + \lfloor\frac{s}{2}\rfloor + 1 & if \quad s \equiv 1 (mod\; 4). \end{cases}$$

Suppose there exist a dominating set D of cardinality at most

$$d = \begin{cases} \lceil\frac{r}{2}\rceil + \lceil\frac{s}{2}\rceil & if \quad s \equiv 0 \; or \; 2 \; or \; 3 (mod\; 4), \\ \lceil\frac{r}{2}\rceil + \lfloor\frac{s}{2}\rfloor & if \quad s \equiv 1 (mod\; 4). \end{cases}$$

then$< D >$ has an isolated vertex. Thus

$$|D| \geq d + 1 = \begin{cases} \lceil\frac{r}{2}\rceil + \lceil\frac{s}{2}\rceil + 1 & if \quad s \equiv 0 \; or \; 2 \; or \; 3 (mod\; 4), \\ \lceil\frac{r}{2}\rceil + \lfloor\frac{s}{2}\rfloor + 1 & if \quad s \equiv 1 (mod\; 4). \end{cases}$$

Therefore the proof.

Example 2: The CD-set of $T_{10,6}$ is given in Fig.3 with the white vertices, which is minimum. Hence $\gamma_{CD}(T_{10,6}) = 9$.

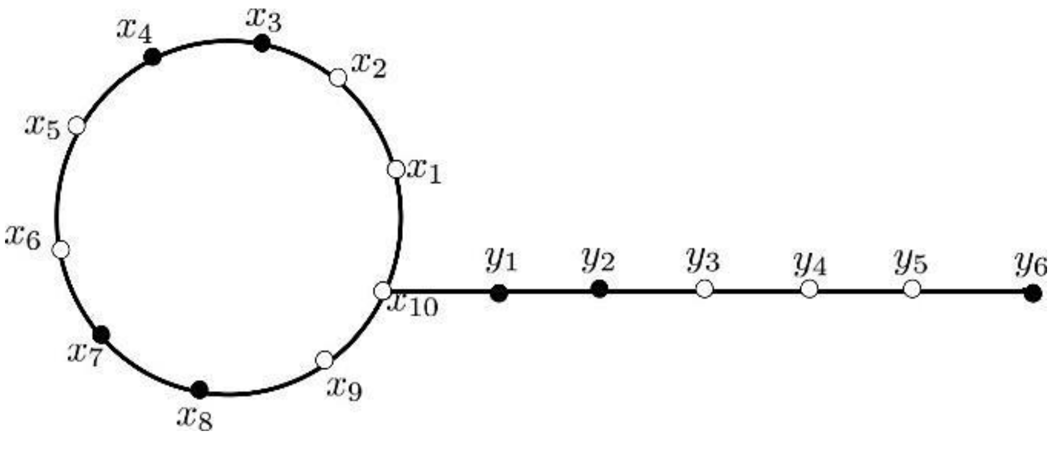

Figure 3.Tadpole$J_{10,6}$

Theorem 6: Let H be the middle graph of $W_{1,r}$. Then

$$\gamma_{CD}(H) = \begin{cases} r + 1 & if \quad r \equiv 0 (mod\; 3), \\ \lceil\frac{r}{3}\rceil + \lfloor\frac{2r}{3}\rfloor + 1 & if \quad r \equiv 1 \; or \; 2 (mod\; 3). \end{cases}$$

Proof: Let $X(H) = \{x_1, x_2, x_3, \ldots, x_r, y_1, y_2, y_3, \ldots, y_r, z_1, z_2, z_3, \ldots, z_r, x_0\}$

and $Y(H) = \{x_0 z_i, x_i z_i, z_j z_{j+1}, y_j y_{j+1}, y_i z_i, y_{k-1} z_k, x_i y_i, x_k y_{k-1}, z_1 z_r, y_1 y_r, z_1 y_r, x_1 y_r : 1 \leq i \leq r, 1 \leq j \leq r-1, 2 \leq k \leq r\}$. Let $S_1 = \{x_0, x_i, y_j, z_k : i \equiv 1 \; (mod\; 3), j \equiv 0 \; (mod\; 3), k \equiv 2 \; (mod\; 3)\}$. Then

$$S = \begin{cases} S_1 & if \quad r \equiv 0 \; or \; 2 (mod\; 3), \\ S_1 \cup \{z_{r-1}, y_{r-1}\} - \{x_r, z_r\} & if \quad r \equiv 1 (mod\; 3). \end{cases}$$

is a CD-set of H. Thus

$$\gamma_{CD}(H) \le |S| = \begin{cases} r+1 & if \;\; r \equiv 0(mod\, 3), \\ \lceil \frac{r}{3} \rceil + \lfloor \frac{2r}{3} \rfloor + 1 & if \;\; r \equiv 1 \; or \; 2(mod\, 3). \end{cases}$$

Suppose there exist a dominating set D of cardinality at most

$$d = \begin{cases} r & if \;\; r \equiv 0(mod\, 3), \\ \lceil \frac{r}{3} \rceil + \lfloor \frac{2r}{3} \rfloor & if \;\; r \equiv 1 \; or \; 2(mod\, 3), \end{cases}$$ the

n$< D >$ has an isolated vertex. Thus

$$|D| \ge d+1 = \begin{cases} r & if \;\; r \equiv 0(mod\, 3), \\ \lceil \frac{r}{3} \rceil + \lfloor \frac{2r}{3} \rfloor + 1 & if \;\; r \equiv 1 \; or \; 2(mod\, 3). \end{cases}$$

Therefore the proof.

Examining the CD-number for Jahangir graph

Theorem 7: For any $r \ge 3$, $\gamma_{CD}(J_{r,2}) = \lceil \frac{r}{2} \rceil + 1$.

Proof: Let $X(J_{r,2}) = \{x_1.x_2, x_3, \dots, x_{2r}, x\}$and $Y(J_{r,2}) = \{xx_j, x_i x_{i+1}, x_1 x_{2r} : 1 \le i \le 2r - 1, j \equiv 1\ (mod\ 2)\}$. Then $S = \{x, x_i : i \equiv 1\ (mod\ 2)\}$ is CD-set for$J_{r,2}$. Thus $\gamma_{CD}(J_{r,2}) \le |S| = \lceil \frac{r}{2} \rceil + 1$. Suppose there exist a dominating set D of cardinality at most $d = \lceil \frac{r}{2} \rceil$, then $< D >$ has an isolated vertex. Thus $|D| \ge d + 1 = \lceil \frac{r}{2} \rceil + 1$. Therefore the proof.

Theorem 8: For any $r \ge 3$, $\gamma_{CD}(J_{r,3}) = r + 1$.

Proof: Let $X(J_{r,3}) = \{x_1.x_2, x_3, \dots, x_{3r}, x\}$and $Y(J_{r,3}) = \{xx_j, x_i x_{i+1}, x_1 x_{3r} : 1 \le i \le 3r - 1, j \equiv 1\ (mod\ 3)\}$. Then $S = \{x, x_i : i \equiv 1\ (mod\ 3)\}$ is CD-set for$J_{r,2}$. Thus $\gamma_{CD}(J_{r,3}) \le |S| = r + 1$. Suppose there exist a dominating set D of cardinality at most $d = r$, then $< D >$ has an isolated vertex. Thus $|D| \ge d + 1 = r + 1$. Therefore the proof.

Theorem 9: For any $r \ge 3$, $\gamma_{CD}(J_{r,5}) = 2(r + 1)$.

Proof: Let $X(J_{r,5}) = \{x_1.x_2, x_3, \dots, x_{5r}, x\}$and $Y(J_{r,5}) = \{xx_j, x_i x_{i+1}, x_1 x_{5r} : 1 \le i \le 5r - 1, j \equiv 1\ (mod\ 5)\}$. Then $S = \{x, x_i : i \equiv 3\ or\ 4\ (mod\ 5)\} \cup \{x, x_1\}$ is a CD-set for$J_{r,5}$. Thus $\gamma_{CD}(J_{r,5}) \le |S| = 2(r + 1)$. Suppose there exist a dominating set D of cardinality at most $d = 2r + 1$, then $< D >$ has an isolated vertex. Thus $|D| \ge d + 1 = 2(r + 1)$. Therefore the proof.

Example 3: Consider the graph $J_{3,5}$ and $\{x, x_1, x_3, x_4, x_8, x_9, x_{13}, x_{14}\}$ in Fig.4 gives the minimum corona dominating set, hence $\gamma_{CD}(J_{3,5}) = 8$.

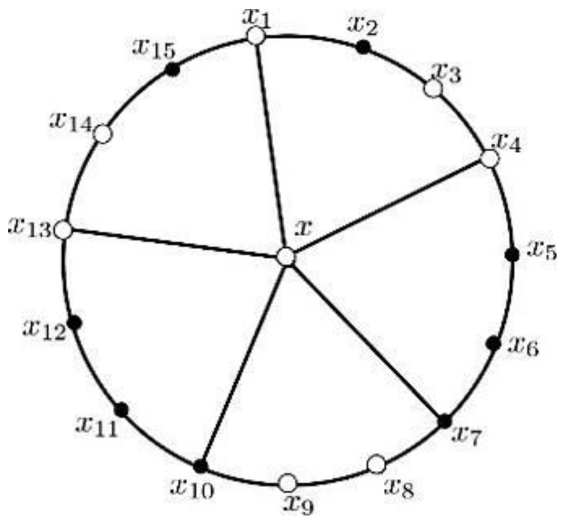

Figure 4. Jahangir $J_{3,5}$

Theorem 10: For any $r \ge 3$, $\gamma_{CD}(J_{r,7}) = 3r + 1$.

Proof: Let $X(J_{r,7}) = \{x_1.x_2, x_3, \dots, x_{7r}, x\}$and $Y(J_{r,5}) = \{xx_j, x_i x_{i+1}, x_1 x_{7r} : 1 \le i \le 7r - 1, j \equiv 1\ (mod\ 7)\}$. Then $S = \{x, x_i : i \equiv 1\ or\ 4\ or\ 5\ (mod\ 7)\}$ is a CD-set for$J_{r,7}$. Thus $\gamma_{CD}(J_{r,7}) \le |S| = 3r + 1$. Suppose there exist a dominating set D of cardinality at most $d = 3r$, then $< D >$ has an isolated vertex.
Thus $|D| \ge d + 1 = 3r + 1$. Therefore the proof.

Theorem 11: Let $s = 2k or\ 2l + 1$, where $k \ge 2\ andl \ge 4$. If $r \ge 3$, then

$$\gamma_{CD}(J_{r,s}) = \begin{cases} \frac{rs}{2} + 1 & if \;\; rs \equiv 2(mod\, 4), \\ \lceil \frac{rs}{2} \rceil & otherwise\,. \end{cases}$$

Proof: Let $X(J_{r,s}) = \{x_1, x_2, x_3, \dots, x_{rs}, x\}$and $Y(J_{r,s}) = \{xx_j, x_i x_{i+1}, x_1 x_{rs} : 1 \le i \le rs - 1, j \equiv 1\ (mods)\}$. Then $S = \{x_i : i \equiv 1\ or\ 2\ (mod\ 4)\}$ is a CD-set for $J_{r,s}$. Thus

$$\gamma_{CD}(J_{r,s}) \le |S| = \gamma_{CD}(J_{r,s}) = \begin{cases} \frac{rs}{2} + 1 & if \;\; rs \equiv 2(mod\, 4), \\ \lceil \frac{rs}{2} \rceil & otherwise\,. \end{cases}$$

Suppose there exist a dominating set D of cardinality at most

$$d = \begin{cases} \frac{rs}{2} & if \;\; rs \equiv 2(mod\, 4), \\ \lceil \frac{rs}{2} \rceil - 1 & otherwise\,, \end{cases}$$ then

$< D >$ has an isolated vertex. Thus

$$|D| \ge d + 1 = \begin{cases} \frac{rs}{2} + 1 & if \;\; rs \equiv 2(mod\, 4), \\ \lceil \frac{rs}{2} \rceil & otherwise. \end{cases}$$

Therefore the proof.

Example 4:

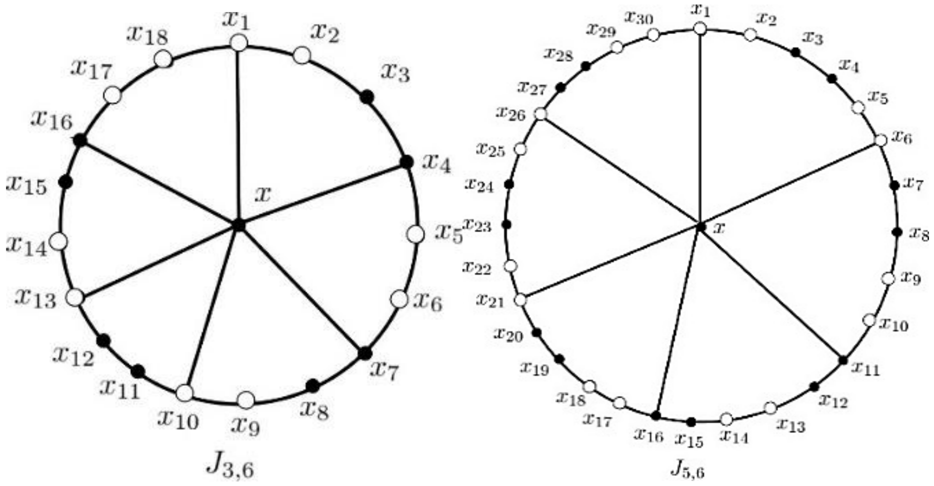

Figure 5. Jahangir $J_{3,6}$ and $J_{5,6}$

For Fig.5, the white vertices give the minimum corona dominating set and hence $\gamma_{CD}(J_{3,6}) = 10$ and $\gamma_{CD}(J_{5,6}) = 16$.

Conclusion:

In this work, the CD-number for some special graphs and the Jahangir graph are found. Moreover, these results are characterized with other domination parmaeters, which will be reported in the successive papers.

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Author's Declaration:

- Conflict of interest: None
- We hereby confirm that all the Figures in the manuscript are ours. Besides, the Figures and images, which are not ours, have been given permission for the re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in the Gandhigram Rural Institute.

Author's contribution statement:

This work was carried out in collaboration between all authors. L P designed the idea and developed the theory through discussions with G M. Moreover, G M supervised the study and verified the analytical methods. C S designed the examples to illustrate the results. All authors read and approved the final manuscript.

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تحقيق في رقم هيمنة كورونا لبعض الرسوم البيانية الخاصة ورسم جهانجير البياني

ل برافينكومار[1] جي ماهاديفان[1*] سي سيفاغنام [2]

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الخلاصة:
في هذا العمل ، نستمر في دراسة هيمنة الاكليل في الرسوم البيانية التي تم اقتراحها لأول مرة في بواسطة جي ماهاديفان وجميع الآخرين . لنكن رسم بياني بسيط .يقال أن المجموعة المسيطرة **S**من الرسم البياني هي مجموعة تهيمن على الاكليل إذا كان كل قمة في قمة قلادة أو قمة دعم .يسمى الحد الأدنى من الأصالة بين جميع مجموعات الهيمنة على الاكليل برقم الهيمنة كورونا ويشار إليه بـ = (H) γ_{CD} **(i.e)** $min \{ | S | S$ هي مجموعة أقراص مضغوطة منمن **.{H** في هذا العمل ، قدمنا القيمة الدقيقة لرقم هيمنة الاكليل لبعض أنواع معينة من الر البيانية أن .أيضًا ، حصلنا على بعض النتائج على رقم هيمنة الاكليل لبعض فئات الرسوم البيانية والطريقة المستخدمة في هذه الورقة هي مفهوم نظرية الأعداد المعروف مع بعض التعديلات يمكن أيضًا تطبيق هذه الطريقة للحصول على النتائج على معلمات الهيمنة الأخرى.

الكلمات المفتاحية: تعيين هيمنة كورونا، تعيين مهيمنة، رسم بياني جاهانغير، قلادة ورأس دعم، رسم بياني الشرغوف.