ON INTEGRAL PERFECT FACTOGRAPH AND INTEGRAL BI-FACTOGRAPH<br>E. EBIN RAJA MERLY ${ }^{1}$, E. GIFTIN VEDHA MERLY ${ }^{2}$ AND A. M. ANTO*3<br>${ }^{1}$ Assistant Professor in Mathematics, Nesamony Memorial Christian College, Marthandam - 629165, India.<br>${ }^{2}$ Assistant Professor in Mathematics, Scott Christian College, Nagercoil - 629003, India.<br>${ }^{3}$ Research scholar in Mathematics, Nesamony Memorial Christian College, Marthandam - 629165, India.

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#### Abstract

Using the theorem of unique factorization for integers, every positive integer z can be written in the canonical form $z=p_{1}^{\alpha_{1}} p_{2}^{\alpha_{2}} \ldots p_{r}^{\alpha_{r}}$, where $p_{1}, p_{2}, \ldots p_{r}$ are distinct primes, $\alpha_{1}, \alpha_{2}, \ldots \alpha_{r}$ are positive integers. We can construct a graph $G$ which is associated with this $z$. Integral divisors of $z$ being a vertex set $V$, two distinct vertices of $V$ are adjacent in $G$ if their product is in $V$ and the corresponding graph is called Integral Factograph. For given z, we have introduced two new classes of graphs namely, Integral Perfect Factograph and Integral Bi-Factograph with respect to the values $r=1$ and $r=2$, attempt to find their degree sequence and clique number.


Keywords: Factograph, Integral Factograph, Integral Perfect factograph, Integral Bi-factograph, clique number.

## 1. INTRODUCTION

Graph indicates a finite undirected, non-trivial graph without loops and multiple edges. The order and size of a graph is denoted by p and q respectively. For terms not defined here we refer to Frank Harary[5].The concept of facto graph was introduced in [2][3]. In this paper we extent the concept to Integral Factograph. For a positive integer z, an Integral Factograph is represented as $G=(V, E)$ where $V=\left\{v_{i},-v_{i} / v_{i}\right.$ and $-v_{i}$ are factors of $\left.z\right\}$ and two distinct vertices $v_{i}$ and $v_{j}$ are adjacent if and only if their product is in V. A clique of a graph $G$ is a complete subgraph of $G$. A clique of $G$ is a maximal clique if it is not properly contained in another clique of $G$. Number of vertices in the maximal clique of $G$ is called the clique number of $G$ and is denoted by $\omega(G)$. For $v \in V, d(v)$ is the number of edges incident with $v$.

## 2. INTEGRAL PERFECT FACTOGRAPH

Definition: 2.1 An Integral factograph G with $\mathrm{z}=p_{1}{ }^{\alpha_{1}}$, where $\mathrm{p}_{1}$ is a prime and $\alpha_{1}$ is a positive integer is called Integral perfect factograph.

Theorem: 2.2 An Integral perfect factograph G is of order $2\left(\alpha_{1}+1\right)$ and the degree sequence is
(i) $\mathrm{s}_{1}: 2 \alpha_{1}+1,2 \alpha_{1}+1,2 \alpha_{1}-1,2 \alpha_{1}-1, \ldots, \alpha_{1}+1, \alpha_{1}+1, \alpha_{1}, \alpha_{1}, \ldots, 4,4,2,2$, when $\alpha_{1}$ is even.
(ii) $\mathrm{s}_{2}: 2 \alpha_{1}+1,2 \alpha_{1}+1,2 \alpha_{1}-1,2 \alpha_{1}-1, \ldots, 2\left\lceil\frac{\alpha_{1}}{2}\right\rceil+1,2\left\lceil\frac{\alpha_{1}}{2}\right\rceil+1,2\left\lceil\frac{\alpha_{1}}{2}\right\rceil, 2\left\lceil\frac{\alpha_{1}}{2}\right\rceil, \ldots, 4,4,2,2$, when $\alpha_{1}$ is odd.

Proof:
Case (i): When $\alpha_{1}$ is even,

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Let $\mathrm{G}=(\mathrm{V}, \mathrm{E})$ be an Integral factograph with $\mathrm{z}=p_{1}{ }^{\alpha_{1}}$. Number of integral divisors of $p_{1}{ }^{\alpha_{1}}$ is $2\left(\alpha_{1}+1\right)$ and hence the order of G is $2\left(\alpha_{1}+1\right)$. Let $\mathrm{V}=\left\{p_{1}^{0},-p_{1}^{0}, p_{1}^{1},-p_{1}^{1}, p_{1}^{2},-p_{1}^{2}, \cdots, p_{1}{ }^{\alpha_{1}},-p_{1}{ }^{\alpha_{1}}\right\}$ be the vertex set of G . For convenience split the vertex set V into two classes such that $\mathrm{A}=\left\{p_{1}^{0}, p_{1}^{1}, p_{1}^{2}, \ldots, p_{1}{ }^{\alpha_{1}}\right\}$ and $\mathrm{B}=\left\{-p_{1}^{0},-p_{1}^{1},-p_{1}^{2}, \ldots,-p_{1}{ }^{\alpha_{1}}\right\}$. In G , We observe that for $\mathrm{i} \neq \mathrm{j}$, the vertex $p_{1}^{i}$ (or $-p_{1}^{i}$ ) is adjacent to $p_{1}^{j}$ (or $-p_{1}^{j}$ ) if and only if $\mathrm{i}+\mathrm{j} \leq \alpha_{1}$. Thus the vertex $p_{1}^{0}$ adjacent with rest of the vertices, which implies $d\left(p_{1}^{0}\right)=2 \alpha_{1}+1$ and $d\left(-p_{1}^{0}\right)=2 \alpha_{1}+1$. The vertex $p_{1}^{1}$ adjacent with $\alpha_{1}-1$ vertices from A and $\alpha_{1}$ vertices from B implies that $d\left(p_{1}^{1}\right)=2 \alpha_{1}-1$. Also, $d\left(-p_{1}^{1}\right)=2 \alpha_{1}-1$. Consider the vertex $p_{1}^{\frac{\alpha_{1}}{2}}$ in A , it is adjacent to $\frac{\alpha_{1}}{2}$ vertices of A and $\frac{\alpha_{1}}{2}+1$ vertices of B and which implies that $d\left(p_{1}^{\frac{\alpha_{1}}{2}}\right)=\alpha_{1}+1$ and $d\left(-p_{1}^{\frac{\alpha_{1}}{2}}\right)=\alpha_{1}+1$. Likewise $p_{1}^{\alpha_{1}}$ is adjacent only with $p_{1}^{0}$ and $-p_{1}^{0}$, which gives $d\left(p_{1}{ }^{\alpha_{1}}\right)=2$ and $d\left(-p_{1}{ }^{\alpha_{1}}\right)=2$. Hence the degree sequence of G is s: $2 \alpha_{1}+1$, $2 \alpha_{1}+1,2 \alpha_{1}-1,2 \alpha_{1}-1, \ldots, \alpha_{1}+1, \alpha_{1}+1, \alpha_{1}, \alpha_{1}, \ldots, 4,4,2,2$.

Similar manner we can prove for the odd case.
Theorem: 2.3 For an Integral perfect factograph $G$, the clique number is given by,

$$
\omega(\mathrm{G})=\left\{\begin{array}{l}
\left(\frac{\alpha_{1}}{2}+1\right)+\left(\frac{\alpha_{1}}{2}+1\right), \text { if } \alpha_{1} \text { is even } \\
\left(\left\lceil\frac{\alpha_{1}}{2}\right\rceil+1\right)+\left(\left\lfloor\frac{\alpha_{1}}{2}\right]+1\right), \text { if } \alpha_{1} \text { is odd }
\end{array}\right.
$$

Proof: When $\alpha_{1}$ is even,
Let $\mathrm{G}=(\mathrm{V}, \mathrm{E})$ be an Integral perfect factograph with $\mathrm{z}=p_{1}{ }^{\alpha_{1}}$. Let $\mathrm{V}=\left\{p_{1}^{0},-p_{1}^{0}, p_{1}^{1},-p_{1}^{1}, p_{1}^{2},-p_{1}^{2}, \cdots, p_{1}{ }^{\alpha_{1}},-p_{1}{ }^{\alpha_{1}}\right\}$ be the vertex set of G and we consider the set $\mathrm{S}=\left\{p_{1}^{x},-p_{1}^{x} / 0 \leq \mathrm{x} \leq \frac{\alpha_{1}}{2}\right\}$, which is a proper subset of V . We seek to prove that the subgraph of $G$ induced by $S$ is the maximal clique of $G$.

Claim: $\langle\mathrm{S}\rangle$ is a clique of G
In a perfect factograph G , we observe that for $\mathrm{i} \neq \mathrm{j}$, a vertex $p_{1}^{i}$ (or $-p_{1}^{i}$ ) is adjacent to $p_{1}^{j}$ (or $-p_{1}^{j}$ ) if and only if $\mathrm{i}+\mathrm{j} \leq \alpha_{1}$. We try to prove that every pair of distinct vertices in S is adjacent. Consider two arbitrary vertices $p_{1}^{a}$ (or $-p_{1}^{a}$ ) and $p_{1}^{b}$ (or $-p_{1}^{b}$ ) in S. Since $a+b \leq \alpha_{1}$, we have $p_{1}^{a}$ and $p_{1}^{b}$ are adjacent. Thus the subgraph induced by S is a complete subgraph of G. It remains to prove that $\langle S\rangle$ is the maximal clique of G.Take any arbitrary vertex v in V which is not in $S$. By the Integral facto graph condition, $S+\{v\}$ is not a clique of $G$ implies that $S$ is the maximal clique of $G$ and $\omega(G)=|S|=\left(\frac{\alpha_{1}}{2}+1\right)+\left(\frac{\alpha_{1}}{2}+1\right)$.

Similar manner, we can prove for the odd case.
Example: $\mathbf{2 . 4}$ consider an Integral perfect factograph G with $\mathrm{z}=p_{1}{ }^{3}$. Here order of G is 8 .


Figure: 1
We observe that, the degree sequence of $G$ is $s: 7,7,5,5,4,4,2,2$ and $\omega(G)$ is 5 .

## 3. INTEGRAL BI-FACTOGRAPH

Definition: 3.1 An Integral factograph G with $\mathrm{z}=p_{1}{ }^{\alpha_{1}} p_{2}{ }^{\alpha_{2}}$, where $p_{1}, p_{2}$ are distinct primes and $\alpha_{1}, \alpha_{2}$ are positive integers is called Integral Bi-factograph.

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Theorem: 3.2 Let $\alpha_{1}$ and $\alpha_{2}$ be two positive integers, $p_{1}$ and $p_{2}$ be two distinct primes. An Integral Bi-factograph G has order $2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)$ and the degree sequence is given by,
(i) $\mathrm{s}_{1}: 2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1,2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1,2\left(\alpha_{1}+1\right) \alpha_{2}-1,2\left(\alpha_{1}+1\right) \alpha_{2}-1, \cdots, 2\left(\alpha_{1}+1\right)\left(\frac{\alpha_{2}}{2}\right), 2\left(\alpha_{1}+1\right)\left(\frac{\alpha_{2}}{2}\right), \cdots, 2\left(\alpha_{1}+1\right)$, $2\left(\alpha_{1}+1\right), \cdots, 2\left(\frac{\alpha_{1}}{2}\right)\left(\alpha_{2}+1\right), 2\left(\frac{\alpha_{1}}{2}\right)\left(\alpha_{2}+1\right), \cdots, 2,2$, where $\alpha_{1}$ and $\alpha_{2}$ are even.
(ii) $\mathrm{s}_{2}: 2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1,2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1, \cdots, 2\left(\alpha_{1}+1\right)\left\lfloor\frac{\alpha_{2}}{2}\right\rfloor, 2\left(\alpha_{1}+1\right)\left\lfloor\frac{\alpha_{2}}{2}\right\rfloor, \cdots, 2\left\lfloor\frac{\alpha_{1}}{2}\right\rfloor\left(\alpha_{2}+1\right), 2\left\lfloor\frac{\alpha_{1}}{2}\right\rfloor\left(\alpha_{2}+1\right), \cdots, 2,2$, where $\alpha_{1}$ and $\alpha_{2}$ are odd.
(iii) $\mathrm{s}_{3}: 2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1,2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1, \cdots, 2\left(\alpha_{1}+1\right)\left(\frac{\alpha_{2}}{2}\right), 2\left(\alpha_{1}+1\right)\left(\frac{\alpha_{2}}{2}\right), \cdots, 2\left\lfloor\frac{\alpha_{1}}{2}\right\rfloor\left(\alpha_{2}+1\right), 2\left\lfloor\frac{\alpha_{1}}{2}\right\rfloor\left(\alpha_{2}+1\right), \cdots, 2,2$, where $\alpha_{1}$ is odd and $\alpha_{2}$ is even.
(iv) $\mathrm{s}_{4}: 2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1,2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1, \cdots, \quad 2\left(\alpha_{1}+1\right)\left[\frac{\alpha_{2}}{2}\right], \quad 2\left(\alpha_{1}+1\right)\left[\frac{\alpha_{2}}{2}\right\rfloor, \cdots,\left(\frac{\alpha_{1}}{2}\right)\left(\alpha_{2}+1\right),\left(\frac{\alpha_{1}}{2}\right)\left(\alpha_{2}+1\right), \cdots, 2,2$, where $\alpha_{1}$ is even and $\alpha_{2}$ is odd.

Proof: Case (i): When $\alpha_{1}$ and $\alpha_{2}$ are even,
Let $\mathrm{G}=(\mathrm{V}, \mathrm{E})$ be an Integral Bi -factograph. If $\mathrm{z}=p_{1}{ }^{\alpha_{1}} p_{2}{ }^{\alpha_{2}} \cdots p_{r}{ }^{\alpha_{r}}$, then the number integral divisors of z is $2 \prod_{i=1}^{r}\left(\alpha_{i}+1\right)$. Therefore, number of Integral divisors of $\mathrm{z}=p_{1}{ }^{\alpha}{ }^{1} p_{2}{ }^{\alpha}{ }^{\alpha}$ is $2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)$ so that the order of G is $2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)$ Let $\quad \mathrm{V}=\left\{p_{1}{ }^{0} p_{2}{ }^{0},-p_{1}{ }^{0} p_{2}{ }^{0}, p_{1}{ }^{0} p_{2}{ }^{1}, \quad-p_{1}{ }^{0} p_{2}{ }^{1}, \cdots, \quad p_{1}{ }^{0} p_{2}{ }^{\frac{\alpha_{2}}{2}+1},-p_{1}{ }^{0} p_{2} \frac{\alpha_{2}}{2}+1, \cdots, p_{1}{ }^{0} p_{2}{ }^{\alpha_{2}}\right.$, $\left.p_{1}{ }^{0} p_{2}^{\alpha_{2}} \cdots, p_{1}^{\frac{\alpha_{1}}{2}+1} p_{2}^{\alpha_{2}},-p_{1}{ }^{\frac{\alpha_{1}}{2}+1} p_{2}{ }^{\alpha_{2}}, \cdots, p_{1}^{\alpha_{1}} p_{2}^{\alpha_{2}},-p_{1}^{\alpha_{1}} p_{2}^{\alpha_{2}}\right\}$. In $G$, we observe that for $\mathrm{i} \neq \mathrm{k}, \mathrm{j} \neq \mathrm{l}$, the vertex $p_{1}{ }^{i} p_{2}{ }^{j}$ (or $-p_{1}{ }^{i} p_{2}{ }^{j}$ ) is adjacent with $p_{1}{ }^{k} p_{2}{ }^{l}$ if and only if $\mathrm{i}+\mathrm{k} \leq \alpha_{1}$ and $\mathrm{j}+\mathrm{l} \leq \alpha_{2}$. Thus the vertex $p_{1}{ }^{0} p_{2}{ }^{0}$ adjacent to rest of the vertices which implies $\mathrm{d}\left(p_{1}{ }^{0} p_{2}{ }^{0}\right)=2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1$ and $\mathrm{d}\left(-p_{1}{ }^{0} p_{2}{ }^{0}\right)=2\left(\alpha_{1}+1\right)\left(\alpha_{2}+1\right)-1$. Proceeding like that we have the degree sequence as follows $\mathrm{d}\left(p_{1}{ }^{0} p_{2}{ }^{1}\right)=2\left(\alpha_{1}+1\right) \alpha_{2}-1, \quad \mathrm{~d}\left(-p_{1}{ }^{0} p_{2}{ }^{1}\right)=2\left(\alpha_{1}+1\right) \alpha_{2}-1 \quad, \cdots$, $\mathrm{d}\left(p_{1}{ }^{0} p_{2}^{\frac{\alpha_{2}}{2}+1}\right)=2\left(\alpha_{1}+1\right)\left(\frac{\alpha_{2}}{2}\right), \mathrm{d}\left(-p_{1}{ }^{0} p_{2}{ }^{\frac{\alpha_{2}}{2}+1}\right)=2\left(\alpha_{1}+1\right)\left(\frac{\alpha_{2}}{2}\right), \cdots, \quad \mathrm{d}\left(p_{1}{ }^{0} p_{1}{ }^{\alpha_{2}}\right)=2\left(\alpha_{1}+1\right), \mathrm{d}\left(-p_{1}{ }^{0} p_{1}{ }^{\alpha_{2}}\right)=2\left(\alpha_{1}+1\right), \cdots$, $\mathrm{d}\left(p_{1}{ }^{\frac{\alpha_{1}}{2}+1} p_{2}{ }^{0}\right)=2\left(\frac{\alpha_{1}}{2}\right)\left(\alpha_{2}+1\right), \mathrm{d}\left(-p_{1}{ }^{\frac{\alpha_{1}}{2}+1} p_{2}{ }^{0}\right)=2\left(\frac{\alpha_{1}}{2}\right)\left(\alpha_{2}+1\right), \cdots, \mathrm{d}\left(p_{1}{ }^{\alpha_{1}} p_{2}{ }^{\alpha_{2}}\right)=2, \mathrm{~d}\left(-p_{1}{ }^{\alpha_{1}} p_{2}{ }^{\alpha_{2}}\right)=2$.

Similarly we can prove for the cases (ii), (iii), (iv).
Theorem: 3.3 The clique number of an Integral Bi-fact graph G is
(i) $\omega(G)=2\left(\frac{\alpha_{1}}{2}+1\right)\left(\frac{\alpha_{2}}{2}+1\right)$, when $\alpha_{1}$ and $\alpha_{2}$ are even.
(ii) $\omega(G)=2\left[\left(\left\lfloor\frac{\alpha_{1}}{2}\right\rfloor+1\right)\left(\left\lfloor\frac{\alpha_{2}}{2}\right\rfloor+1\right)\right]+2$, when $\alpha_{1}$ and $\alpha_{2}$ are odd.
(iii) $\omega(G)=2\left[\left(\left[\frac{\alpha_{1}}{2}\right]+1\right)\left(\frac{\alpha_{2}}{2}+1\right)\right]+1$, when $\alpha_{1}$ is odd and $\alpha_{2}$ is even.
(iv) $\omega(G)=2\left[\left(\frac{\alpha_{1}}{2}+1\right)\left(\left\lfloor\frac{\alpha_{2}}{2}\right\rfloor+1\right)\right]+1$, when $\alpha_{1}$ is even and $\alpha_{2}$ is odd.

Proof: Case (i): When $\alpha_{1}$ and $\alpha_{2}$ are even,
Let $\mathrm{G}=(\mathrm{V}, \mathrm{E})$ be an Integral Bi-factograph and $\mathrm{V}=\left\{p_{1}{ }^{0} p_{2}{ }^{0},-p_{1}{ }^{0} p_{2}{ }^{0}, \cdots, p_{1}{ }^{\alpha_{1}} p_{2}{ }^{\alpha_{1}}-p_{1}{ }^{\alpha_{1}} p_{2}{ }^{\alpha_{1}}\right\}$ be the vertex set of G . We consider the set $\mathrm{S}=\left\{p_{1}^{x} p_{2}^{y},-p_{1}^{x} p_{2}^{y} / 0 \leq x \leq \frac{\alpha_{1}}{2}, 0 \leq y \leq \frac{\alpha_{2}}{2}\right\}$ which is a proper subset of V.We seek to prove that the subgraph of $G$ induced by $S$ is the maximal clique of $G$. In $G$, we observe that for $\mathrm{i} \neq \mathrm{k}, \mathrm{j} \neq \mathrm{l}$, the vertex $p_{1}{ }^{i} p_{2}{ }^{j}$ (or $-p_{1}{ }^{i} p_{2}{ }^{j}$ ) is adjacent with $p_{1}{ }^{k} p_{2}{ }^{l}$ (or $-p_{1}{ }^{k} p_{2}{ }^{l}$ ) in G if and only if $\mathrm{i}+\mathrm{k} \leq \alpha_{1}$ and $\mathrm{j}+\mathrm{l} \leq \alpha_{2}$. We have to prove that every pair of distinct vertices in S are adjacent.Take two arbitray vertices $p_{1}{ }^{a} p_{2}{ }^{b}$ and $p_{1}{ }^{c} p_{2}{ }^{d}$ in S , since the maximum range of $\mathrm{a}, \mathrm{c}$ and $\mathrm{b}, \mathrm{d}$ are less than are equal to $\frac{\alpha_{1}}{2}$ and $\frac{\alpha_{1}}{2}$ respectively. Therefore, by the integral factograph condition $p_{1}{ }^{a} p_{2}{ }^{b}$ and $p_{1}{ }^{c} p_{2}{ }^{d}$ are adjacent.Thus $\langle S\rangle$ is a clique of G.It remains to show that $\langle S\rangle$ is the maximal clique of G . Take an arbitrary vertex $\mathrm{v} \in \mathrm{V} \backslash \mathrm{S}$, v cannot be adjacent to $p_{1}^{\frac{\alpha_{1}}{2}} p_{2}^{\frac{\alpha_{2}}{2}}$ in S , which implies $\langle S\rangle+\{v\}$ cannot be a clique of G . Therefore $\langle S\rangle$ is the maximal clique of $G$ and $|S|=2\left(\frac{\alpha_{1}}{2}+1\right)\left(\frac{\alpha_{2}}{2}+1\right)$, which implies that $\omega(G)=2\left(\frac{\alpha_{1}}{2}+1\right)\left(\frac{\alpha_{2}}{2}+1\right)$.

Similarly we can prove the cases (ii), (iii), (iv).

Example: 3.4 Consider an Integral Bi-factograph G with $\mathrm{z}=p_{1}{ }^{1}{p_{2}}^{1}$ which is depicted in figure.2.


Figure: 2
We observe that, the order of $G$ is 8 , the degree sequence is $s: 7,7,4,4,4,4,2,2$ and $\omega(G)$ is 6 .

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