

MULTIPLICATIVE ABC, GA, AG, AUGMENTED AND HARMONIC STATUS INDICES
OF GRAPHS

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ABSTRACT

In this study, we introduce the multiplicative atom bond connectivity status index, multiplicative geometric-arithmetic status index, multiplicative arithmetic-geometric status index, multiplicative augmented status index and multiplicative harmonic status index of a graph. We compute these multiplicative status indices for complete graphs, cycles, complete bipartite graphs, wheel graphs and friendship graphs.

Key words: Multiplicative ABC status index, multiplicative GA status index, multiplicative augmented status index, multiplicative harmonic status index, graph.

Mathematics Subjects Classification: 05C05, 05C07, 05C35, 05C90.

1. INTRODUCTION

Let $G = (V(G), E(G))$ be a simple, finite, connected graph. The degree $d_G(u)$ of a vertex u is the number of vertices adjacent to u . The distance between two vertices u and v , denoted by $d(u, v)$, is the length of the shortest $u - v$ path in a graph G . The status of a vertex u in G is defined as the sum of its distance from every other vertex in G and is denoted by $\sigma(u)$. For graph theoretic terminology, we refer [1].

A graph index is a numerical parameter mathematically derived from the graph structure. Several graph indices have their applications in various disciplines of Science and Technology, see [2, 3]. Many status indices of a graph such as harmonic status index [4], first and second status connectivity indices [5], first and second hyper status indices [6], multiplicative first and second status indices [7], multiplicative F -status index [8], multiplicative (a, b) -status index [9], first and second status coincides [10], geometric- arithmetic status index [11] studied in the literature of graph indices.

We introduce the multiplicative atom bond connectivity status index, multiplicative geometric- arithmetic status index, multiplicative arithmetic-geometric status index, multiplicative augmented status index, multiplicative harmonic status index of a graph as follows:

The multiplicative atom bond connectivity status index of a graph G is defined as

$$ABCSII(G) = \prod_{uv \in E(G)} \sqrt{\frac{\sigma(u) + \sigma(v) - 2}{\sigma(u)\sigma(v)}}.$$

The multiplicative geometric-arithmetic status index of a graph G is defined as

$$GASII(G) = \prod_{uv \in E(G)} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u) + \sigma(v)}.$$

The multiplicative arithmetic-geometric status index of a graph G is defined as

$$AGSII(G) = \prod_{uv \in E(G)} \frac{\sigma(u) + \sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}}.$$

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The multiplicative augmented status index of a graph G is defined as

$$ASIII(G) = \prod_{uv \in E(G)} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u) + \sigma(v) - 2} \right)^3.$$

The multiplicative harmonic status index of a graph G is defined as

$$HSII(G) = \prod_{uv \in E(G)} \frac{2}{\sigma(u) + \sigma(v)}.$$

Recently, some new multiplicative indices were studied, for example, in [12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32]. In this paper, some new multiplicative status indices of complete graphs, wheel graphs friendship graphs are determined.

2. RESULTS FOR COMPLETE GRAPHS

Theorem 1: Let K_n be a complete graph with n vertices and $\frac{n(n-1)}{2}$ edges. Then

$$(1) \quad ABCSII(K_n) = \left[\frac{2n-4}{(n-1)^2} \right]^{\frac{1}{4}n(n-1)}.$$

$$(2) \quad GASII(K_n) = 1.$$

$$(3) \quad AGSII(K_n) = 1.$$

$$(4) \quad ASIII(K_n) = \left[\frac{(n-1)^2}{2n-4} \right]^{\frac{3}{2}n(n-1)}.$$

$$(5) \quad HSII(K_n) = \left(\frac{1}{n-1} \right)^{\frac{1}{2}n(n-1)}.$$

Proof: For any vertex u in K_n , $\sigma(u) = n - 1$. Therefore

$$(1) \quad ABCSII(K_n) = \prod_{uv \in E(K_n)} \sqrt{\frac{\sigma(u) + \sigma(v) - 2}{\sigma(u)\sigma(v)}} = \left[\frac{n-1+n-1-2}{(n-1)(n-1)} \right]^{\frac{1}{2} \times \frac{n(n-1)}{2}} = \left[\frac{2n-4}{(n-1)^2} \right]^{\frac{1}{4}n(n-1)}.$$

$$(2) \quad GASII(K_n) = \prod_{uv \in E(K_n)} \frac{\sigma(u) + \sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}} = \left(\frac{n-1+n-1}{2\sqrt{(n-1)(n-1)}} \right)^{\frac{n(n-1)}{2}} = 1.$$

$$(3) \quad AGSII(K_n) = \prod_{uv \in E(K_n)} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u) + \sigma(v)} = \left(\frac{2\sqrt{(n-1)(n-1)}}{n-1+n-1} \right)^{\frac{n(n-1)}{2}} = 1.$$

$$(4) \quad ASIII(K_n) = \prod_{uv \in E(K_n)} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u) + \sigma(v) - 2} \right)^3 = \left(\frac{(n-1)(n-1)}{n-1+n-1-2} \right)^{\frac{3}{2}n(n-1)} = \left[\frac{(n-1)^2}{2n-4} \right]^{\frac{3}{2}n(n-1)}$$

$$(5) \quad HSII(K_n) = \prod_{uv \in E(K_n)} \frac{2}{\sigma(u) + \sigma(v)} = \left(\frac{2}{n-1+n-1} \right)^{\frac{1}{2}n(n-1)} = \left(\frac{1}{n-1} \right)^{\frac{1}{2}n(n-1)}.$$

3. RESULTS FOR COMPLETE BIPARTITE GRAPHS

Theorem 2: Let $K_{p,q}$ be a complete bipartite graph with $p+q$ vertices and pq edges. Then

$$(1) \quad ABCSII(K_{p,q}) = \left[\frac{3(p+q) - 6}{2(p^2 + q^2) - 6(p+q) + 5pq + 4} \right]^{\frac{1}{2}pq}.$$

$$(2) \quad GASII(K_{p,q}) = \left(\frac{2\sqrt{2(p^2 + q^2) - 6(p+q) + 5pq + 4}}{3(p+q) - 4} \right)^{pq}.$$

$$(3) \quad AGHII(K_{p,q}) = \left[\frac{3(p+q)-4}{2\sqrt{2(p^2+q^2)-6(p+q)+5pq+4}} \right]$$

$$(4) \quad ASIII(K_{p,q}) = \left(\frac{2(p^2+q^2)-6(p+q)+5pq+4}{3(p+q)-6} \right)^{3pq}$$

$$(5) \quad HSHI(K_{p,q}) = \left(\frac{2}{3(p+q)-4} \right)^{pq}$$

Proof: The vertex set of $K_{p,q}$ can be partitioned into two independent sets V_1 and V_2 such that $u \in V_1$ and $v \in V_2$ for every edge uv in $K_{p,q}$. Thus $d_G(u) = q$, $d_G(v) = p$. Then $\sigma(u) = q + 2(p - 1)$ and $\sigma(v) = p + 2(q - 1)$. Therefore

$$(1) \quad ABCSII(K_{p,q}) = \sqrt{\frac{\sigma(u)+\sigma(v)-2}{\sigma(u)\sigma(v)}} = \left[\frac{q+2p-2+p+2q-2-2}{(q+2p-2)(p+2q-2)} \right]^{\frac{1}{2}pq}$$

$$= \left[\frac{3(p+q)-6}{2(p^2+q^2)-6(p+q)+5pq+4} \right]^{\frac{1}{2}pq}$$

$$(2) \quad GASII(K_{p,q}) = \prod_{uv \in E(K_{p,q})} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u)+\sigma(v)}$$

$$= \left(\frac{2\sqrt{(q+2p-2)(p+2q-2)}}{q+2p-2+p+2q-2} \right)^{pq}$$

$$= \left(\frac{2\sqrt{2(p^2+q^2)-6(p+q)+5pq+4}}{3(p+q)-4} \right)^{pq}$$

$$(3) \quad AGSII(K_{p,q}) = \prod_{uv \in E(K_{p,q})} \frac{\sigma(u)+\sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}}$$

$$= \left(\frac{q+2p-2+p+2q-2}{2\sqrt{(q+2p-2)(p+2q-2)}} \right)^{pq}$$

$$= \left(\frac{3(p+q)-4}{2\sqrt{2(p^2+q^2)-6(p+q)+5pq+4}} \right)^{pq}$$

$$(4) \quad ASIII(K_{p,q}) = \prod_{uv \in E(K_{p,q})} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u)+\sigma(v)-2} \right)^3$$

$$= \left(\frac{(q+2p-2)(q+2p-2)}{q+2p-2+p+2q-2-2} \right)^{3pq}$$

$$= \left(\frac{2(p^2+q^2)-6(p+q)+5pq+4}{3(p+q)-6} \right)^{3pq}$$

$$(5) \quad HSHI(K_{p,q}) = \prod_{uv \in E(K_{p,q})} \frac{2}{\sigma(u)+\sigma(v)} = \left(\frac{2}{q+2p-2+p+2q-2} \right)^{pq}$$

$$= \left(\frac{2}{3(p+q)-4} \right)^{pq}$$

4. RESULTS FOR CYCLES

Theorem 3: Let C_n be a cycle with n vertices and n edges. Then

$$\begin{aligned}
 (1) \quad ABCSII(C_n) &= \left(\frac{8(n^2 - 4)}{n^4}\right)^{\frac{n}{2}}, && \text{if } n \text{ is even,} \\
 &= \left(\frac{8(n^2 - 5)}{(n^2 - 1)^2}\right)^{\frac{n}{2}}, && \text{if } n \text{ is odd.} \\
 (2) \quad GASII(C_n) &= 1, && \text{if } n \text{ is even,} \\
 &= 1, && \text{if } n \text{ is odd.} \\
 (3) \quad AGSII(C_n) &= 1, && \text{if } n \text{ is even,} \\
 &= 1, && \text{if } n \text{ is odd.} \\
 (4) \quad ASIII(C_n) &= \left(\frac{n^4}{8(n^2 - 4)}\right)^{3n}, && \text{if } n \text{ is even,} \\
 &= \left(\frac{(n^2 - 1)^2}{8(n^2 - 5)}\right)^{3n}, && \text{if } n \text{ is odd.} \\
 (5) \quad HSII(C_n) &= \left(\frac{4}{n^2}\right)^n, && \text{if } n \text{ is even,} \\
 &= \left(\frac{4}{n^2 - 1}\right)^n, && \text{if } n \text{ is odd.}
 \end{aligned}$$

Proof:

Case-1: Suppose n is even. Then $\sigma(u) = \frac{n^2}{4}$ for any vertex u in C_n . Thus

$$\begin{aligned}
 (1) \quad ABCSII(C_n) &= \prod_{uv \in E(C_n)} \sqrt{\frac{\sigma(u) + \sigma(v) - 2}{\sigma(u)\sigma(v)}} = \left[\frac{\frac{n^2}{4} + \frac{n^2}{4} - 2}{\frac{n^2}{4} \times \frac{n^2}{4}} \right]^{\frac{n}{2}} = \left(\frac{8(n^2 - 4)}{n^4}\right)^{\frac{n}{2}}. \\
 (2) \quad GASII(C_n) &= \prod_{uv \in E(C_n)} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u) + \sigma(v)} = \left(\frac{2\sqrt{\frac{n^2}{4} \times \frac{n^2}{4}}}{\frac{n^2}{4} + \frac{n^2}{4}}\right)^n = 1. \\
 (3) \quad AGSII(C_n) &= \prod_{uv \in E(C_n)} \frac{\sigma(u) + \sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}} = \left(\frac{\frac{n^2}{4} + \frac{n^2}{4}}{2\sqrt{\frac{n^2}{4} \times \frac{n^2}{4}}}\right)^n = 1. \\
 (4) \quad ASIII(C_n) &= \prod_{uv \in E(C_n)} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u) + \sigma(v) - 2}\right)^3 = \left[\frac{\frac{n^2}{4} \times \frac{n^2}{4}}{\frac{n^2}{4} + \frac{n^2}{4} - 2}\right]^{3n} = \left(\frac{n^4}{8(n^2 - 4)}\right)^{3n}. \\
 (5) \quad HSII(C_n) &= \prod_{uv \in E(C_n)} \frac{2}{\sigma(u) + \sigma(v)} = \left(\frac{2}{\frac{n^2}{4} + \frac{n^2}{4}}\right)^n = \left(\frac{4}{n^2}\right)^n.
 \end{aligned}$$

Case-2: Suppose n is odd. Then $\sigma(u) = \frac{n^2 - 1}{4}$ for any vertex u in C_n . Therefore

$$\begin{aligned}
 (1) \quad ABCSH(C_n) &= \prod_{uv \in E(C_n)} \sqrt{\frac{\sigma(u) + \sigma(v) - 2}{\sigma(u)\sigma(v)}} = \left[\frac{\frac{n^2 - 1}{4} + \frac{n^2 - 1}{4} - 2}{\frac{n^2 - 1}{4} \times \frac{n^2 - 1}{4}} \right]^{\frac{n}{2}} = \left(\frac{8(n^2 - 5)}{(n^2 - 1)^2} \right)^{\frac{n}{2}}. \\
 (2) \quad GASII(C_n) &= \prod_{uv \in E(C_n)} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u) + \sigma(v)} = \left(\frac{2\sqrt{\frac{n^2 - 1}{4} \times \frac{n^2 - 1}{4}}}{\frac{n^2 - 1}{4} + \frac{n^2 - 1}{4}} \right)^n = 1 \lim_{x \rightarrow \infty} \\
 (3) \quad AGSH(C_n) &= \prod_{uv \in E(C_n)} \frac{\sigma(u) + \sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}} = \left(\frac{\frac{n^2 - 1}{4} + \frac{n^2 - 1}{4}}{2\sqrt{\frac{n^2 - 1}{4} \times \frac{n^2 - 1}{4}}} \right)^n = 1 \\
 (4) \quad ASIII(C_n) &= \prod_{uv \in E(C_n)} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u) + \sigma(v) - 2} \right)^3 = \left[\frac{\frac{n^2 - 1}{4} \times \frac{n^2 - 1}{4}}{\frac{n^2 - 1}{4} + \frac{n^2 - 1}{4} - 2} \right]^{3n} = \left(\frac{(n^2 - 1)^2}{8(n^2 - 5)} \right)^{3n}. \\
 (5) \quad HSH(C_n) &= \prod_{uv \in E(C_n)} \frac{2}{\sigma(u) + \sigma(v)} = \left(\frac{2}{\frac{n^2 - 1}{4} + \frac{n^2 - 1}{4}} \right)^n = \left(\frac{4}{n^2 - 1} \right)^n.
 \end{aligned}$$

5. RESULT FOR WHEEL GRAPHS

A wheel graph W_n is the join of C_n and K_1 . A graph W_n has $n+1$ vertices and $2n$ edges. A graph W_n is presented in Figure 1.

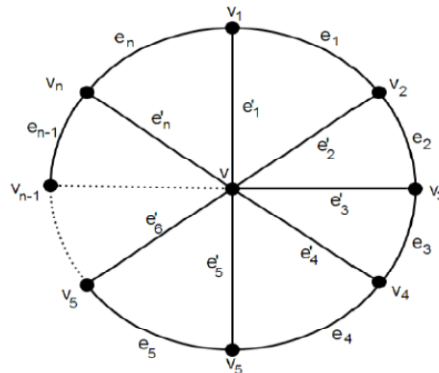


Figure-1: Wheel graph W_n

In W_n , there are two types of edges as given in Table 1.

$d_{W_n}(u), d_{W_n}(v) \setminus uv \in E(W_n)$	(3, 3)	(3, n)
Number of edges	n	n

Table-1: Edge partition of W_n

Therefore, there are two types of status edges in W_n as given in Table 2.

$\sigma(u), \sigma(v) \setminus uv \in E(W_n)$	($2n - 3, 2n - 3$)	($n, 2n - 3$)
Number of edges	n	n

Table-2: Status edge partition of W_n

Theorem 4: Let W_n be a wheel graph with $n+1$ vertices and $2n$ edges. Then

$$(1) \quad ABCSH(W_n) = \left(\frac{2\sqrt{n-2}}{2n-3}\right)^n \times \left(\frac{3n-5}{n(2n-3)}\right)^{\frac{n}{2}}.$$

$$(2) \quad GASH(W_n) = \left(\frac{2\sqrt{a^2+b^2}}{3n-3}\right)^n$$

$$(3) \quad AGSH(W_n) = \left(\frac{3n-3}{2\sqrt{n(2n-3)}}\right)^n$$

$$(4) \quad ASH(W_n) = \left(\frac{(2n-3)^2}{4(n-2)}\right)^{3n} \times \left(\frac{n(2n-3)}{3n-5}\right)^{3n}.$$

$$(5) \quad HSH(W_n) = \left(\frac{1}{2n-3}\right)^n \times \left(\frac{2}{3n-3}\right)^n.$$

Proof: By definitions and by using Table 2, we obtain

$$(1) \quad ABCSH(W_n) = \prod_{uv \in E(W_n)} \sqrt{\frac{\sigma(u) + \sigma(v) - 2}{\sigma(u)\sigma(v)}} = \left(\frac{2n-3+2n-3-2}{(2n-3)(2n-3)}\right)^{\frac{n}{2}} \times \left(\frac{n+2n-3-2}{n(2n-3)}\right)^{\frac{n}{2}}$$

$$= \left(\frac{2\sqrt{n-2}}{2n-3}\right)^n \times \left(\frac{3n-5}{n(2n-3)}\right)^{\frac{n}{2}}.$$

$$(2) \quad GASH(W_n) = \prod_{uv \in E(W_n)} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u) + \sigma(v)} = \left(\frac{2\sqrt{(2n-3)(2n-3)}}{2n-3+2n-3}\right)^n \times \left(\frac{2\sqrt{n(2n-3)}}{n+2n-3}\right)^n$$

$$= \left(\frac{2\sqrt{n(2n-3)}}{3n-3}\right)^n.$$

$$(3) \quad AGSH(W_n) = \prod_{uv \in E(W_n)} \frac{\sigma(u) + \sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}} = \left(\frac{2n-3+2n-3}{2\sqrt{(2n-3)(2n-3)}}\right)^n \times \left(\frac{n+2n-3}{2\sqrt{n(2n-3)}}\right)^n$$

$$= \left(\frac{3n-3}{2\sqrt{n(2n-3)}}\right)^n.$$

$$(4) \quad ASH(W_n) = \prod_{uv \in E(W_n)} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u) + \sigma(v) - 2}\right)^3 = \left(\frac{(2n-3)(2n-3)}{2n-3+2n-3-2}\right)^{3n} \times \left(\frac{n(2n-3)}{n+2n-3-2}\right)^{3n}$$

$$= \left(\frac{(2n-3)^2}{4(n-2)}\right)^{3n} \times \left(\frac{n(2n-3)}{3n-5}\right)^{3n}.$$

$$(5) \quad HSH(W_n) = \prod_{uv \in E(W_n)} \frac{2}{\sigma(u) + \sigma(v)} = \left(\frac{2}{2n-3+2n-3}\right)^n \times \left(\frac{2}{n+2n-3}\right)^n$$

$$= \left(\frac{1}{2n-3}\right)^n \times \left(\frac{2}{3n-3}\right)^n.$$

4. RESULTS FOR FRIENDSHIP GRAPHS

A friendship graph F_n is the graph obtained by taken $n \geq 2$ copies of C_3 with vertex in common. A graph F_4 is shown in Figure 2.

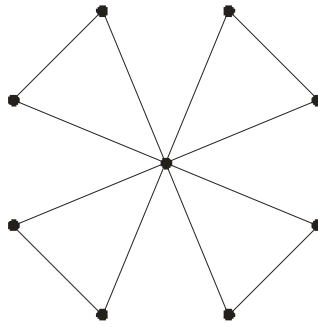


Figure-2: Friendship graph F_4

A graph F_n has $2n+1$ vertices and $3n$ edges. In F_n , there are two types of edges as follows:

$$E_1 = \{uv \in (F_n) \mid d_{F_n}(u) = d_{F_n}(v) = 2\}, \quad |E_1| = n.$$

$$E_2 = \{uv \in (F_n) \mid d_{F_n}(u) = 2, d_{F_n}(v) = 2n\}, \quad |E_2| = 2n.$$

Therefore, there are two types of status edges in F_n as given in Table 3.

$\sigma(u), \sigma(v) \setminus uv \in E(F_n)$	$(4n-2, 4n-2)$	$(2n, 4n-2)$
Number of edges	n	$2n$

Table-3: Status edge partition of F_n

Theorem 5: Let F_n be a friendship graph with $2n+1$ vertices and $3n$ edges. Then

- (1) $ABCSII(F_n) = \left(\frac{8n-6}{(4n-2)^2}\right)^{\frac{n}{2}} \times \left(\frac{3n-2}{n(4n-2)}\right)^n.$
- (2) $GASII(F_n) = \left(\frac{\sqrt{2n(4n-2)}}{3n-1}\right)^{2n}.$
- (3) $AGSII(F_n) = \left(\frac{3n-1}{\sqrt{2n(4n-2)}}\right)^{2n}.$
- (4) $ASIII(F_n) = \left(\frac{(4n-2)^2}{8n-6}\right)^{3n} \times \left(\frac{n(4n-2)}{3n-2}\right)^{6n}.$
- (5) $HSII(F_n) = \left(\frac{1}{4n-2}\right)^n \times \left(\frac{1}{3n-1}\right)^{2n}.$

Proof: by using definitions and Table 3, we deduce

- (1) $ABCSII(F_n) = \prod_{uv \in E(F_n)} \sqrt{\frac{\sigma(u) + \sigma(v) - 2}{\sigma(u)\sigma(v)}} = \left(\frac{4n-2 + 4n-2 - 2}{(4n-2)(4n-2)}\right)^{\frac{1}{2}n} \times \left(\frac{2n + 4n - 2 - 2}{2n(4n-2)}\right)^{\frac{1}{2} \times 2n}$
 $= \left(\frac{8n-6}{(4n-2)^2}\right)^{\frac{n}{2}} \times \left(\frac{3n-2}{n(4n-2)}\right)^n.$
- (2) $GASII(F_n) = \prod_{uv \in E(F_n)} \frac{2\sqrt{\sigma(u)\sigma(v)}}{\sigma(u) + \sigma(v)} = \left(\frac{2\sqrt{(4n-2)(4n-2)}}{4n-2 + 4n-2}\right)^n \times \left(\frac{2\sqrt{2n(4n-2)}}{2n + 4n - 2}\right)^{2n}$
 $= \left(\frac{\sqrt{2n(4n-2)}}{3n-1}\right)^{2n}.$
- (3) $AGSII(F_n) = \prod_{uv \in E(F_n)} \frac{\sigma(u) + \sigma(v)}{2\sqrt{\sigma(u)\sigma(v)}} = \left(\frac{4n-2 + 4n-2}{2\sqrt{(4n-2)(4n-2)}}\right)^n \times \left(\frac{2n + 4n - 2}{2\sqrt{2n(4n-2)}}\right)^{2n}$
 $= \left(\frac{3n-1}{\sqrt{2n(4n-2)}}\right)^{2n}.$

$$(4) \quad ASIII(F_n) = \prod_{uv \in E(F_n)} \left(\frac{\sigma(u)\sigma(v)}{\sigma(u) + \sigma(v) - 2} \right)^3 = \left(\frac{(4n-2)(4n-2)}{4n-2+4n-2-2} \right)^{3n} \times \left(\frac{2n(4n-2)}{2n+4n-2-2} \right)^{6n}$$

$$= \left(\frac{(4n-2)^2}{8n-6} \right)^{3n} \times \left(\frac{n(4n-2)}{3n-2} \right)^{6n}.$$

$$(5) \quad HSII(F_n) = \prod_{uv \in E(F_n)} \frac{2}{\sigma(u) + \sigma(v)} = \left(\frac{2}{4n-2+4n-2} \right)^n \times \left(\frac{2}{2n+4n-2} \right)^{2n}$$

$$= \left(\frac{1}{4n-2} \right)^n \times \left(\frac{1}{3n-1} \right)^{2n}.$$

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