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# Edge Version of Multiplicative Connectivity Indices of Some Nanotubes and Nanotorus

**Research Article**

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**Abstract:** We propose two new connectivity indices the edge version of multiplicative sum connectivity index and the edge version of multiplicative product connectivity index of a molecular graph. In this paper, we compute these indices for some families of nanotubes and nanotorus.

**MSC:** 05C05, 05C12.

**Keywords:** Molecular graph, multiplicative sum connectivity index, multiplicative product connectivity index, nanotubes, nanotorus.


## 1. Introduction

Let G be a finite, simple, connected graph with vertex set $V(G)$ and edge set $E(G)$. The degree $d_G(v)$ of a vertex v is the number of vertices adjacent to v. The degree of an edge $e = uv$ in G is defined by $d_G(E) = d_G(u) + d_G(v) - 2$. The line graph $L(G)$ of G is the graph whose vertex set corresponds to the edges of G such that two vertices of $L(G)$ are adjacent if the corresponding edges of G are adjacent. Any undefined term may be found in Kulli [1]. A molecular graph is a finite, simple graph such that its vertices correspond to the atoms and the edges to the bonds. There are several topological indices that have some applications in theoretical chemistry in QSPR/QSAR study [2, 3]. Motivated by the definition of the product connectivity index and its wide applications, Kulli [5] introduced the multiplicative sum connectivity index and multiplicative product connectivity index of a molecular graph as follows:
The multiplicative sum connectivity index of a graph $G$ is defined as

$$XII\left(G\right) = \prod_{uv \in E(G)} \frac{1}{\sqrt{d_G\left(u\right) + d_G\left(v\right)}}.$$

The multiplicative product connectivity index of a graph G is defined as

$$\chi II\left(G\right) = \prod_{uv \in E(G)} \frac{1}{\sqrt{d_G\left(u\right) d_G\left(v\right)}}.$$

We now define the edge version of multiplicative sum connectivity index of a graph $G$ as

$$XII_e\left(G\right) = \prod_{ef \in E(L(G))} \frac{1}{\sqrt{d_{L(G)}\left(e\right) + d_{L(G)}\left(f\right)}}. \tag{1}$$

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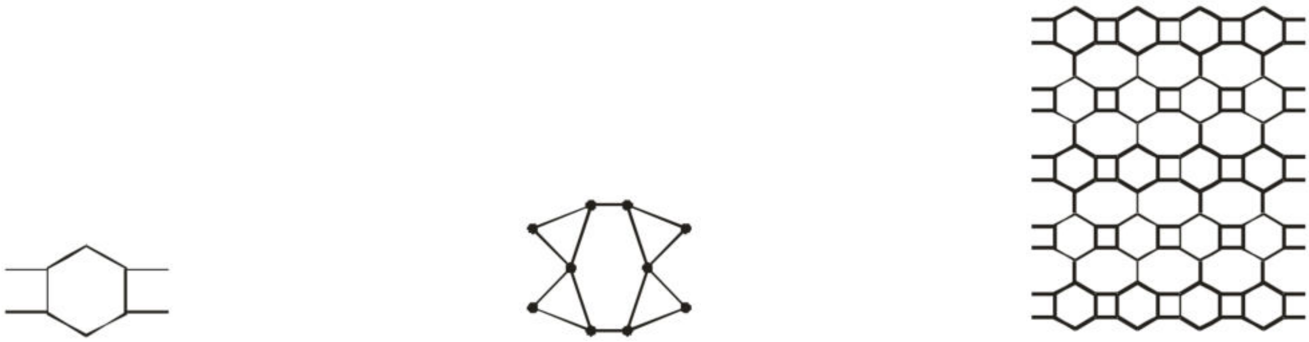
We define the edge version of multiplicative sum connectivity index of a graph G as

$$\chi II_e\left(G\right)=\prod_{ef\in E(L(G))}\frac{1}{\sqrt{d_{L(G)}\left(e\right)d_{L(G)}\left(f\right)}}. \tag{2}$$

Many other multiplicative indices were studied, for example, in [6–20]. In this paper, we determine the edge version of multiplicative sum connectivity index and the edge version of multiplicative product connectivity index for some family of nanotubes and nanotorus. For more information about nanotubes and nanotorus see [21]. The edge version of indices were studied, for example, in [22–24].

## 2. Results For $TUC_4C_6C_8$ [p, q] Nanotube

We consider the graph of 2-D lattice of $TUC_4C_6C_8\ [p,q]$ nanotube with p columns and q rows. The graph of $TUC_4C_6C_8\ [1,1]$ nanotube and $L(TUC_4C_6C_8\ [1,1])$ are shown in Figure 1 (a) and Figure 1(b) respectively. Also the graph of $TUC_4C_6C_8$ $[4,5]$ is shown in Figure 1 (c).



(a) (b) (c)

Figure 1:

In the following theorem, we compute the edge version of $XII$ index for $TUC_4C_6C_8\ [p,q]$ nanotube.

**Theorem 2.1.** *The edge version of multiplicative sum connectivity index of* $TUC_4C_6C_8\ [p,q]$ *nanotube is given by*

$$XII_e\left(TUC_4C_6C_8\left[p,q\right]\right)=\left(\frac{1}{6}\right)^{p}\times\left(\frac{1}{7}\right)^{4p}\times\left(\frac{1}{8}\right)^{9pq-7p}.$$

*Proof.* Let G be the graph of $TUC_4C_6C_8$ [p, q] nanotube. By calculation, we obtain

$$|E(L(TUC_4C_6C_8\left[p,q\right]))|=18pq-4p.$$

Also by calculation, we obtain that the edge set $E(L(G))$ can be divided into three partitions as follows:

$$E_{33}=\{ef\in E(L(G))|d_{L(G)}(e)=d_{L(G)}(f)=3\},\qquad |E_{33}|=2p.$$
$$E_{34}=\{ef\in E(L(G))|d_{L(G)}(e)=3,d_{L(G)}(f)=4\},\qquad |E_{34}|=8p.$$
$$E_{44}=\{ef\in E(L(G))|d_{L(G)}(e)=d_{L(G)}(f)=4\},\qquad |E_{44}|=18pq-14p.$$

From equation (1) and by cardinalities of the edge partitions of $L(G)$, we have

$$\begin{aligned} XII_e(G) &= \prod_{ef\in E(L(G))} \frac{1}{\sqrt{d_{L(G)}(e)+d_{L(G)}(f)}} \\ &= \left(\frac{1}{\sqrt{3+3}}\right)^{2p} \times \left(\frac{1}{\sqrt{3+4}}\right)^{8p} \times \left(\frac{1}{\sqrt{4+4}}\right)^{18pq-14p} \\ &= \left(\frac{1}{6}\right)^{p} \times \left(\frac{1}{7}\right)^{4p} \times \left(\frac{1}{8}\right)^{9pq-7p} \end{aligned}$$

In the following theorem, we compute the edge version of $\chi II$ index for $TUC_4C_6C_8$ [p, q] nanotube. □

**Theorem 2.2.** *The edge version of multiplicative product connectivity index of $TUC_4C_6C_8$ [p, q] nanotube is given by*

$$\chi II_e(TUC_4C_6C_8[p,q]) = \left(\frac{1}{9}\right)^{p} \times \left(\frac{1}{12}\right)^{4p} \times \left(\frac{1}{16}\right)^{9pq-7p}.$$

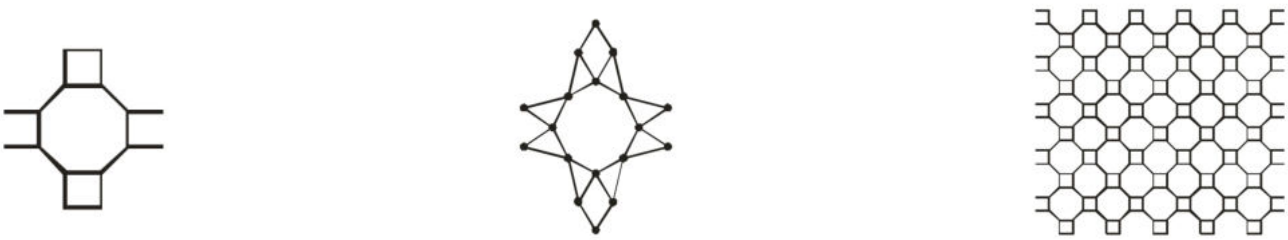
*Proof.* Let $G = TUC_4C_6C_8[p,q]$. From equation (2) and by cardinalities of the edge partitions of $L(G)$, we have

$$\begin{aligned} \chi II_e(G) &= \prod_{ef\in E(L(G))} \frac{1}{\sqrt{d_{L(G)}(e)\,d_{L(G)}(f)}} \\ &= \left(\frac{1}{\sqrt{3\times 3}}\right)^{2p} \times \left(\frac{1}{\sqrt{3\times 4}}\right)^{8p} \times \left(\frac{1}{\sqrt{4\times 4}}\right)^{18pq-14p} \\ &= \left(\frac{1}{9}\right)^{p} \times \left(\frac{1}{12}\right)^{4p} \times \left(\frac{1}{16}\right)^{9pq-7p}. \end{aligned}$$

□

## 3. Results for $TUSC_4C_8(S)$ $[p,q]$ Nanotube

We consider the graph of $TUSC_4C_8(S)$ $[p,q]$ nanotube with p columns and q rows. The graphs of $TUSC_4C_8(S)$ $[1,1]$ nanotube and $L(TUSC_4C_8(S)$ $[1,1])$ are shown in Figure 2(a) and Figure 2(b) respectively. Also the graph of $TUSC_4C_8(S)[5,4]$ nanotube is shown in Figure 2(c).



(a) (b) (c)

Figure 2:

In the following theorem, we compute the edge version of $XII$ index for $TUSC_4C_8(S)$ $[p,q]$ nanotube.

**Theorem 3.1.** *The edge version of multiplicative sum connectivity index of $TUSC_4C_8(S)$ $[p,q]$ nanotube is given by*

$$XII_e(TUSC_4C_8(S)[p,q]) = \left(\frac{1}{5}\right)^{2p} \times \left(\frac{1}{7}\right)^{4p} \times \left(\frac{1}{8}\right)^{12pq-4p}.$$

*Proof.* Let G be the graph of $TUSC_4C_8(S)\ [p,q]$ nanotube. By calculation, we obtain

$$|E(L(TUSC_4C_8(S)\ [p,q]))| = 24pq + 4p.$$

Also by calculation, we obtain that the edge set $E(L(G))$ can be divided into three partitions as follows:

$$E_{23} = \{ef \in E(L(G)) | d_{L(G)}(e) = 2, d_{L(G)}(f) = 3\}, \qquad |E_{23}| = 4p.$$
$$E_{34} = \{ef \in E(L(G)) | d_{L(G)}(e) = 3, d_{L(G)}(f) = 4\}, \qquad |E_{34}| = 8p.$$
$$E_{44} = \{ef \in E(L(G)) | d_{L(G)}(e) = d_{L(G)}(f) = 4\}, \qquad |E_{44}| = 24pq - 8p.$$

From equation (1) and by cardinalities of the edge partitions of L(G), we have

$$\begin{aligned} XII_e(G) &= \prod_{ef \in E(L(G))} \frac{1}{\sqrt{d_{L(G)}(e) + d_{L(G)}(f)}} \\ &= \left(\frac{1}{\sqrt{2+3}}\right)^{4p} \times \left(\frac{1}{\sqrt{3+4}}\right)^{8p} \times \left(\frac{1}{\sqrt{4+4}}\right)^{24pq-8p} \\ &= \left(\frac{1}{5}\right)^{2p} \times \left(\frac{1}{7}\right)^{4p} \times \left(\frac{1}{8}\right)^{12pq-4p}. \end{aligned}$$

In the following theorem, we compute the edge version of $\chi II$ index for $TUSC_4C_8(S)\ [p,q]$ nanotube. □

**Theorem 3.2.** *The edge version of multiplicative sum connectivity index of $TUSC_4C_8(S)\ [p,q]$ nanotube is given by*

$$\chi II_e(TUSC_4C_8(S)[p,q]) = \left(\frac{1}{6}\right)^{2p} \times \left(\frac{1}{12}\right)^{4p} \times \left(\frac{1}{16}\right)^{12pq-4p}.$$

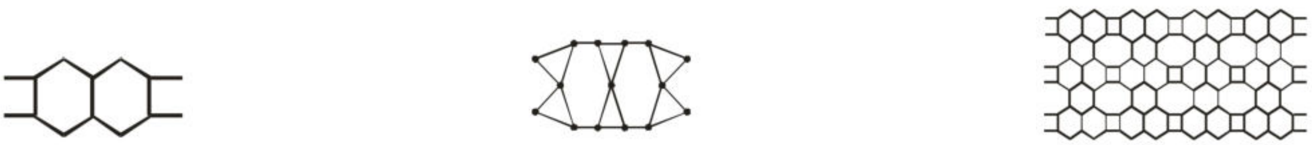
*Proof.* Let $G = TUSC_4C_8(S)\ [p,q]$. From equation (2) and by cardinalities of the edge partitions of $L(G)$, we have

$$\begin{aligned} \chi II_e(G) &= \prod_{ef \in E(L(G))} \frac{1}{\sqrt{d_{L(G)}(e)\, d_{L(G)}(f)}} \\ &= \left(\frac{1}{\sqrt{2\times 3}}\right)^{4p} \times \left(\frac{1}{\sqrt{3\times 4}}\right)^{8p} \times \left(\frac{1}{\sqrt{4\times 4}}\right)^{24pq-8p} \\ &= \left(\frac{1}{6}\right)^{2p} \times \left(\frac{1}{12}\right)^{4p} \times \left(\frac{1}{16}\right)^{12pq-4p}. \end{aligned}$$

□

## 4. Results for H-Naphtalenic NPHX [p, q] Nanotube

We now consider the graph of *H*-Naphtalenic *NPHX*[p, q] nanotube. The graphs of *NPHX* [1,1] nanotube and L(*NPHX* [1,1]) are shown in Figure 3(a) and Figure 3(b) respectively. Also the graph of *NPHX* [4,3] is shown in Figure 3(c).



(a) (b) (c)

Figure 3:

In the following theorem, we compute the edge version of *XII* index for *NPHX* [p, q] nanotube.

**Theorem 4.1.** *The edge version of multiplicative sum connectivity index of NPHX [p, q] nanotube is given by*

$$XII_e\left(NPHX\left[p,q\right]\right)=\left(\frac{1}{6}\right)^{3p}\times\left(\frac{1}{7}\right)^{6p}\times\left(\frac{1}{8}\right)^{15pq-13p}.$$

*Proof.* Let G be the graph of *NPHX* [p, q] nanotube. By calculation, we obtain

$$|E(L(NPHX[p,q]))|=30pq-8p.$$

Also by calculation, we obtain that the edge set E(L(G)) can be divided into three partitions as follows:

$$E_{33}=\{ef\in E(L(G))|d_{L(G)}(e)=d_{L(G)}(f)=3\},\qquad |E_{33}|=6p.$$
$$E_{34}=\{ef\in E(L(G))|d_{L(G)}(e)=3,d_{L(G)}(f)=4\},\qquad |E_{34}|=12p.$$
$$E_{44}=\{ef\in E(L(G))|d_{L(G)}(e)=d_{L(G)}(f)=4\},\qquad |E_{44}|=30pq-26p.$$

From equation (1) and by cardinalities of the edge partitions of $L(G)$, we have

$$\begin{aligned}XII_e\left(G\right)&=\prod_{ef\in E(L(G))}\frac{1}{\sqrt{d_{L(G)}\left(e\right)+d_{L(G)}\left(f\right)}}\\&=\left(\frac{1}{\sqrt{3+3}}\right)^{6p}\times\left(\frac{1}{\sqrt{3+4}}\right)^{12p}\times\left(\frac{1}{\sqrt{4+4}}\right)^{30pq-26p}\\&=\left(\frac{1}{6}\right)^{3p}\times\left(\frac{1}{7}\right)^{6p}\times\left(\frac{1}{8}\right)^{15pq-13p}.\end{aligned}$$

□

In the following theorem, we compute the edge version of $\chi II$ index for *NPHX* [p, q] nanotube.

**Theorem 4.2.** *The edge version of multiplicative product connectivity index of NPHX [p, q] nanotube is given by*

$$\chi II_e\left(NPHX\left[p,q\right]\right)=\left(\frac{1}{9}\right)^{3p}\times\left(\frac{1}{12}\right)^{6p}\times\left(\frac{1}{16}\right)^{15pq-13p}.$$

*Proof.* Let G be the graph of *NPHX* [p, q] nanotube. From equation (2) and by cardinalities of the edge partitions of $L(G)$, we have

$$\begin{aligned}\chi II_e\left(G\right)&=\prod_{ef\in E(L(G))}\frac{1}{\sqrt{d_{L(G)}\left(e\right)d_{L(G)}\left(f\right)}}\\&=\left(\frac{1}{\sqrt{3\times3}}\right)^{6p}\times\left(\frac{1}{\sqrt{3\times4}}\right)^{12p}\times\left(\frac{1}{\sqrt{4\times4}}\right)^{30pq-26p}\\&=\left(\frac{1}{9}\right)^{3p}\times\left(\frac{1}{12}\right)^{6p}\times\left(\frac{1}{16}\right)^{15pq-13p}.\end{aligned}$$

□

## 5. Results For $C_4C_6C_8$ [p, q] Nanotori

We consider the graph of $C_4C_6C_8$ [p, q] nanotori. The graphs of $C_4C_6C_8$ [2,1] nanotori and L($C_4C_6C_8$ [2,1]) are shown in Figure 4(a) and Figure 4(b) respectively. Also the graph of $C_4C_6C_8$ [4,4] is shown in Figure 4(c).

(a) (b) (c)

Figure 4:

In the following theorem, we compute the edge version of $XII$ index for $C_4C_6C_8$ [p, q] nanotori.

**Theorem 5.1.** *The edge version of multiplicative sum connectivity index of $C_4C_6C_8$ [p, q] nanotori is given by*

$$XII_e\left(C_4C_6C_8\left[p,q\right]\right) = \left(\frac{1}{\sqrt{6}}\right)^{3p} \times \left(\frac{1}{7}\right)^{2p} \times \left(\frac{1}{\sqrt{8}}\right)^{18pq-9p}.$$

*Proof.* Let G be the graph of $C_4C_6C_8$ [p, q] nanotori. By calculation, we obtain

$$|E(L(C_4C_6C_8[p,q]))| = 18pq - 2p.$$

Also by calculation, we obtain that the edge set $E(L(G))$ can be divided into four partitions as follows:

$$E_{24} = \{ef \in E(L(G)) | d_{L(G)}(e) = 2, d_{L(G)}(f) = 4\}, \qquad |E_{24}| = 2p.$$
$$E_{33} = \{ef \in E(L(G)) | d_{L(G)}(e) = d_{L(G)}(f) = 3\}, \qquad |E_{33}| = p.$$
$$E_{34} = \{ef \in E(L(G)) | d_{L(G)}(e) = 3, d_{L(G)}(f) = 4\}, \qquad |E_{34}| = 4p.$$
$$E_{44} = \{ef \in E(L(G)) | d_{L(G)}(e) = d_{L(G)}(f) = 4\}, \qquad |E_{44}| = 18pq - 9p.$$

From equation (1) and by cardinalities of the edge partitions of $L(G)$, we have

$$\begin{aligned} XII_e\left(G\right) &= \prod_{ef \in E(L(G))} \frac{1}{\sqrt{d_{L(G)}\left(e\right) + d_{L(G)}\left(f\right)}} \\ &= \left(\frac{1}{\sqrt{2+4}}\right)^{2p} \times \left(\frac{1}{\sqrt{3+3}}\right)^{p} \times \left(\frac{1}{\sqrt{3+4}}\right)^{4p} \times \left(\frac{1}{\sqrt{4+4}}\right)^{18pq-9p} \\ &= \left(\frac{1}{\sqrt{6}}\right)^{3p} \times \left(\frac{1}{7}\right)^{2p} \times \left(\frac{1}{\sqrt{8}}\right)^{18pq-9p}. \end{aligned}$$

□

In the following theorem, we compute the edge version of $\chi II$ index for $C_4C_6C_8$ [p, q] nanotori.

**Theorem 5.2.** *The edge version of multiplicative product connectivity index of $C_4C_6C_8$ [p, q] nanotori is given by*

$$\chi II_e\left(C_4C_6C_8\left[p,q\right]\right) = \left(\frac{1}{8}\right)^{p} \times \left(\frac{1}{3}\right)^{p} \times \left(\frac{1}{12}\right)^{2p} \times \left(\frac{1}{4}\right)^{18pq-9p}.$$

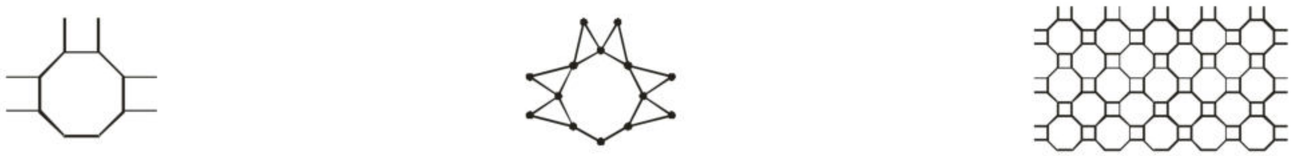
*Proof.* Let G be the graph of $C_4C_6C_8$ [p, q] nanotori. From equation (2) and by cardinalities of the edge partitions of $L(G)$, we have

$$\chi II_e(G) = \prod_{ef \in E(L(G))} \frac{1}{\sqrt{d_{L(G)}(e)\, d_{L(G)}(f)}}$$
$$= \left(\frac{1}{\sqrt{2\times 4}}\right)^{2p} \times \left(\frac{1}{\sqrt{3\times 3}}\right)^{p} \times \left(\frac{1}{\sqrt{3\times 4}}\right)^{4p} \times \left(\frac{1}{\sqrt{4\times 4}}\right)^{18pq-9p}$$
$$= \left(\frac{1}{8}\right)^{p} \times \left(\frac{1}{3}\right)^{p} \times \left(\frac{1}{12}\right)^{2p} \times \left(\frac{1}{4}\right)^{18pq-9p}.$$

□

## 6. Results For $TC_4C_8(S)$ [p, q] Nanotori

We now consider the graph of $TC_4C_8(S)$ [p, q] nanotori. The graphs of $TC_4C_8(S)$ [2,1] nanotori and $L(TC_4C_8(S)[2,1])$ are shown in Figure 5(a) and Figure 5(b) respectively. Also the graph of $TC_4C_8(S)$ [5,3] nanotori is shown in Figure 5(c).



(a) (b) (c)

Figure 5:

In the following theorem, we compute the edge version of $XII$ index for $TC_4C_8(S)$ [p, q] nanotori.

**Theorem 6.1.** *The edge version of multiplicative sum connectivity index of $TC_4C_8(S)$ [p, q] nanotori is given by*

$$XII_e(TC_4C_8(S)[p,q]) = \left(\frac{1}{5}\right)^{p} \times \left(\frac{1}{6}\right)^{2p} \times \left(\frac{1}{7}\right)^{2p} \times \left(\frac{1}{8}\right)^{12pq-7p}.$$

*Proof.* Let G be the graph of $TC_4C_8(S)$ [p, q] nanotori. By calculation, we obtain

$$|E(L(TC_4C_8(S)[p,q]))| = 24pq - 4p.$$

Also by calculation, we obtain that the edge set E(L(G)) can be divided into four partitions as follows:

$$E_{23} = \{ef \in E(L(G)) | d_{L(G)}(e) = 2, d_{L(G)}(f) = 3\}, \qquad |E_{23}| = 2p.$$
$$E_{24} = \{ef \in E(L(G)) | d_{L(G)}(e) = 2, d_{L(G)}(f) = 4\}, \qquad |E_{24}| = 4p.$$
$$E_{34} = \{ef \in E(L(G)) | d_{L(G)}(e) = 3, d_{L(G)}(f) = 4\}, \qquad |E_{34}| = 4p.$$
$$E_{44} = \{ef \in E(L(G)) | d_{L(G)}(e) = d_{L(G)}(f) = 4\}, \qquad |E_{44}| = 24pq - 14p.$$

From equation (1) and by cardinalities of the edge partitions of $L(G)$, we have

$$XII_e(G) = \prod_{ef \in E(L(G))} \frac{1}{\sqrt{d_{L(G)}(e) + d_{L(G)}(f)}}$$
$$= \left(\frac{1}{\sqrt{2+3}}\right)^{2p} \times \left(\frac{1}{\sqrt{2+4}}\right)^{4p} \times \left(\frac{1}{\sqrt{3+4}}\right)^{4p} \times \left(\frac{1}{\sqrt{4+4}}\right)^{24pq-14p}$$
$$= \left(\frac{1}{5}\right)^{p} \times \left(\frac{1}{6}\right)^{2p} \times \left(\frac{1}{7}\right)^{2p} \times \left(\frac{1}{8}\right)^{12pq-7p}.$$

□

In the next theorem, we compute the edge version of $\chi II$ index for $TC_4C_8(S)$ $[p,q]$ nanotori.

**Theorem 6.2.** *The edge version of multiplicative product connectivity index of $TC_4C_8(S)$ [p, q] nanotori is given by*

$$\chi II_e\left(C_4C_6C_8\left[p,q\right]\right)=\left(\frac{1}{6}\right)^{p}\times\left(\frac{1}{8}\right)^{2p}\times\left(\frac{1}{12}\right)^{2p}\times\left(\frac{1}{4}\right)^{24pq-14p}.$$

*Proof.* Let G be the graph of $TC_4C_8(S)$ [p, q] nanotori. From equation (2) and by cardinalities of the edge partitions of $L(G)$, we have

$$\begin{aligned}\chi II_e\left(G\right)&=\prod_{ef\in E(L(G))}\frac{1}{\sqrt{d_{L(G)}\left(e\right)d_{L(G)}\left(f\right)}}\\&=\left(\frac{1}{\sqrt{2\times 3}}\right)^{2p}\times\left(\frac{1}{\sqrt{2\times 4}}\right)^{4p}\times\left(\frac{1}{\sqrt{3\times 4}}\right)^{4p}\times\left(\frac{1}{\sqrt{4\times 4}}\right)^{24pq-14p}\\&=\left(\frac{1}{6}\right)^{p}\times\left(\frac{1}{8}\right)^{2p}\times\left(\frac{1}{12}\right)^{2p}\times\left(\frac{1}{4}\right)^{24pq-14p}.\end{aligned}$$

□

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