

# SID



ابزارهای پژوهش



سرویس ترجمه تخصصی



کارگاه‌های آموزشی



بلاگ مرکز اطلاعات علمی



سامانه ویراستاری STES



فیلم‌های آموزشی

سامانه ویراستاری (ویرایش متون فارسی، انگلیسی، عربی)

کارگاه‌ها و فیلم‌های آموزشی مرکز اطلاعات علمی



روش تحقیق کمی

روش تحقیق کمی



آموزش مهارت‌های کاربردی در تدوین و چاپ مقالات ISI

آموزش مهارت‌های کاربردی در تدوین و چاپ مقالات ISI



آموزش نرم افزار Word برای پژوهشگران

آموزش نرم افزار Word برای پژوهشگران

# Trees with the Greatest Wiener and Edge–Wiener Index

ALI GHALAVAND\*

Department of Pure Mathematics, Faculty of Mathematical Science, University of Kashan, Kashan 87317–53153, I. R. Iran

## ARTICLE INFO

### Article History:

Received: 7 April 2017

Accepted: 12 July 2017

Published online 12 July 2017

Academic Editor: Sandi Klavžar

### Keywords:

Tree

r indexWiene

Edge-Wiener index

Graph operation

## ABSTRACT

The Wiener index  $W$  and the edge-Wiener index  $W_e$  of  $G$  are defined as the sum of distances between all pairs of vertices in  $G$  and the sum of distances between all pairs of edges in  $G$ , respectively. In this paper, we identify the four trees, with the first through fourth greatest Wiener and edge–Wiener index among all trees of order  $n \geq 10$ .

© 2019 University of Kashan Press. All rights reserved

## 1. INTRODUCTION

Throughout this paper we consider undirected graphs without loops and multiple edges. Let  $G$  be such a graph with vertex and edge sets  $V(G)$  and  $E(G)$ , respectively. The distance between two vertices  $u$  and  $v$  in  $G$ , denoted by  $d(u, v|G)$ , is defined as the length of a shortest path between  $u$  and  $v$ . Let  $f = xy$  and  $g = uv$  be two edges of  $G$ . The distance between  $f$  and  $g$  is denoted by  $d_e(f, g|G)$  and defined as the distance between the vertices of  $f$  and  $g$  in the line graph of  $G$ . The degree of a vertex  $v$  in  $G$ ,  $d_G(v)$ , is the number of edges incident to  $v$  and  $N[v, G]$  denotes the set of vertices adjacent to  $v$ . A pendent vertex is a vertex with degree one. We use the notations  $\Delta = \Delta(G)$  and  $n_i = n_i(G)$  to denote the maximum degree and the number of vertices of degree  $i$  in  $G$ , respectively. Obviously,  $\sum_{i=1}^{\Delta(G)} n_i = |V(G)|$ . Let  $S \subseteq V(G)$  be any subset of vertices of  $G$ . Then the induced subgraph  $G[S]$  is the graph whose vertex set is  $S$  and whose edge set consists of all of the

\*Corresponding Author (Email address: [Ali.ghalavand.kh@gmail.com](mailto:Ali.ghalavand.kh@gmail.com))

DOI: 10.22052/ijmc.2017.81498.1279

edges in  $E(G)$  that have both endpoints in  $S$ . If  $W$  is a subset of  $V(G)$  then  $G - W$  will be the subgraph of  $G$  obtained by deleting the vertices of  $W$  and similarly, for a subset  $F$  of  $E(G)$ , the subgraph obtained by deleting all edges in  $F$  is denoted by  $G - F$ . In the case that  $W = \{v\}$  or  $F = \{xy\}$ , the subgraphs  $G - W$  and  $G - F$  will shortly be written as  $G - v$  or  $G - xy$ , respectively. For any two nonadjacent vertices  $x$  and  $y$  in  $G$ , let  $G + xy$  be the graph obtained from  $G$  by adding an edge  $xy$ .

If  $G$  is acyclic and connected graph, then  $G$  is a tree. Any tree with at least two vertices has at least two pendent vertices. The set of all  $n$ -vertex trees is denoted by  $\tau(n)$ . In chemical graph theory, a topological index is a number invariant under graph automorphisms. These numbers play a significant role in mathematical chemistry especially in the QSPR/QSAR investigations, see [7, 11].

Harold Wiener in [18], introduced **Wiener index** defined as

$$W(G) = \sum_{\{u,v\} \subseteq V(G)} d(u, v|G),$$

which is the sum of distances between all pairs of vertices of  $G$ . The **edge-Wiener** index of  $G$ , denoted by  $W_e(G)$ , is defined as

$$W_e(G) = \sum_{\{f,g\} \subseteq E(G)} d_e(f, g|G),$$

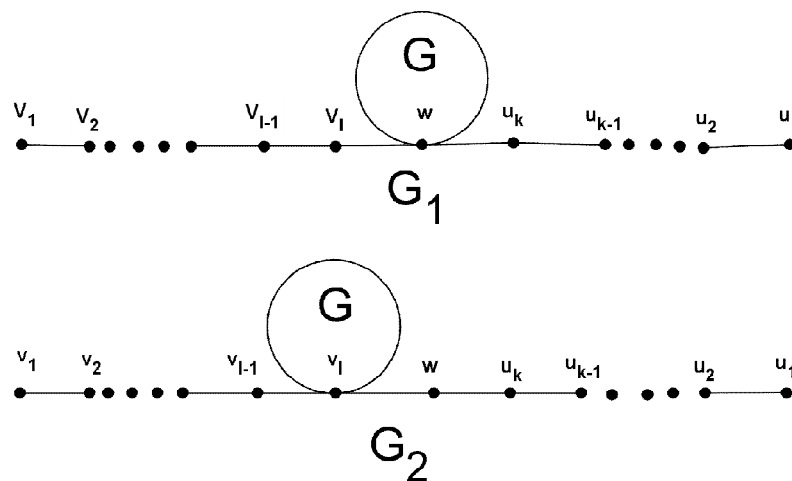
which is the sum of distances between all pairs of edges of  $G$ . This invariant was independently introduced in [10, 13]. Edge-Wiener index is one of the most interesting topological indices. Dankelmann et al. [5], recalled that,  $W_e(G) \leq \frac{2^5}{5^5} n^5 + O\left(n^{\frac{9}{2}}\right)$ , for graphs of order  $n$ . Dou et al. [6], characterized the polyphenyl chains with minimum and maximum edge-Wiener indices among all the polyphenyl chains with  $h$  hexagons. They also characterized the explicit formulas for the edge-Wiener indices of extremal polyphenyl chains. Yousefi-Azari et al. [19], proved that for every tree  $T$ ,  $Sz_e(T) = W_e(T)$ ,  $Sz_e(T)$  denotes the edge Szeged index of  $T$ . Nadjafi-Arani et al. [16], showed that for every connected graph  $G$ ,  $Sz_e(G) \geq W_e(G)$  with equality if and only if  $G$  is a tree. Alizadeh et al. [1], characterized the edge-Wiener index of suspensions, bottlenecks, and thorny graphs. Knor et al. [12], proved that  $W_e(G) \geq \frac{\delta^2-1}{4} W(G)$  where  $\delta$  denotes the minimum degree in  $G$ . Kelenc et al. [14], characterized an algorithm developed that, for a given benzenoid system  $G$  with  $m$  edges, computes the edge-Wiener index of  $G$  in  $O(m)$  time. Chen et al. [4], studied explicit relation between the Wiener index and the edge-Wiener index of the catacondensed hexagonal systems. We refer the reader to [2, 9] for more information on the edge-Wiener index. Buckley in [3] and Tratnik et al. in [17], for a tree  $T$  with  $n$  vertices proved that:

$$W_e(T) = W(T) - \frac{n(n-1)}{2}. \quad (1)$$

Deng [8], the trees with the greatest Wiener index were investigated, where the trees on  $n$  vertices ( $n \geq 9$ ) with the first to seventeenth greatest Wiener index were found. However, it turned out that the results in [8] were not correct and therefore, paper [15] was published. In that paper, the trees on  $n$  vertices ( $n \geq 28$ ) with the first to fifteenth greatest Wiener index were found. Hence by Equation (1), the trees on  $n$  vertices ( $n \geq 28$ ) with the first to fifteenth greatest Wiener index in [15] are the trees on  $n$  vertices ( $n \geq 28$ ) with the first to fifteenth greatest edge-Wiener index. In this paper, we identify the four trees, with the first through fourth greatest Wiener and edge-Wiener index among all trees of order  $n \geq 10$ .

## 2. MAIN RESULTS

In this section, some graph transformations are presented by which we can increase the edge-Wiener index of trees. By applying these graph operations, we identify the four trees, with the first through fourth greatest edge-Wiener index among all trees of order  $n \geq 10$ .



**Figure 1.** The graphs  $P, Q, G, G_1$  and  $G_2$  in Transformation A.

**Transformation A.** Suppose  $w$  is a vertex in a connected graph  $G$  with at least two vertices and  $N[w, G] = \{x_1, x_2, \dots, x_{d_G(w)}\}$ . In addition, we assume that  $P : u_k u_{k-1} \dots u_2 u_1$  and  $Q : v_l v_{l-1} \dots v_2 v_1$ , are two new paths of lengths  $k, l$  ( $k \geq l \geq 1$ ), respectively. Let  $G_1$  be the graph obtained from  $G, P$  and  $Q$  by attaching edges  $v_l w, w u_k$ , and  $G_2 = G_1 - \{w x_i : x_i \in N[w, G]\} + \{v_l x_i : x_i \in N[w, G]\}$ . Such graphs have been illustrated in Figure 1.

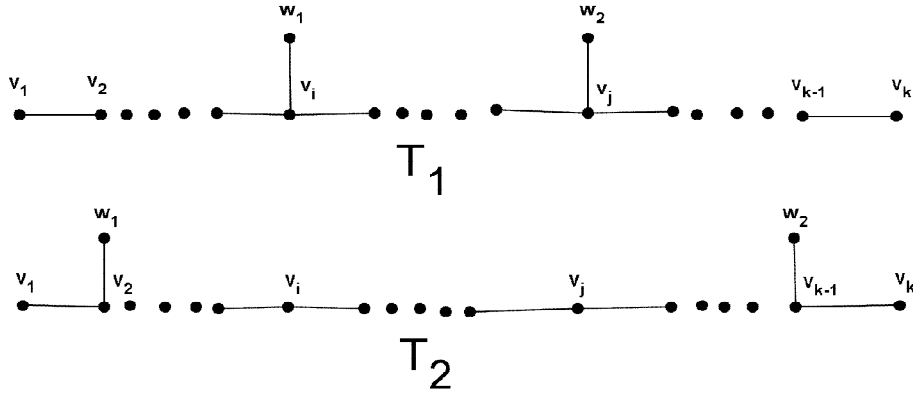
**Lemma 2. 1.** Let  $G_1$  and  $G_2$  be two graphs as shown in Figure 1. Then we have

$$W_e(G_1) < W_e(G_2).$$

**Proof.** Let  $E^*(G) = E(G) \setminus \{xw | x \in N[w, G]\}$  and  $\bar{E}(G) = E^*(G) \cup \{xv_l | x \in N[w, G]\}$ . From definition,

$$\begin{aligned}
 W_e(G_1) - W_e(G_2) &= \sum_{i=1}^{l-1} \sum_{f \in E(G)} d_e(f, v_i v_{i+1} | G_1) + \sum_{i=1}^{k-1} \sum_{f \in E(G)} d_e(f, u_i u_{i+1} | G_1) \\
 &+ \sum_{f \in E(G)} d_e(f, w u_k | G_1) \\
 &- \left[ \sum_{i=1}^{l-1} \sum_{f \in E(G)} d_e(f, v_i v_{i+1} | G_2) + \sum_{i=1}^{k-1} \sum_{f \in E(G)} d_e(f, u_i u_{i+1} | G_2) \right. \\
 &\left. + \sum_{f \in E(G)} d_e(f, w u_k | G_2) \right] \\
 &= \sum_{i=1}^{l-1} \sum_{f \in E(G)} d_e(f, v_i v_{i+1} | G_1) + \sum_{i=1}^{k-1} \sum_{f \in E(G)} d_e(f, u_i u_{i+1} | G_1) \\
 &+ \sum_{f \in E(G)} d_e(f, w u_k | G_1) \\
 &- \left[ \sum_{i=1}^{l-1} \sum_{f \in E(G)} (d_e(f, v_i v_{i+1} | G_1) - 1) \right. \\
 &+ \sum_{i=1}^{k-1} \sum_{f \in E(G)} (d_e(f, u_i u_{i+1} | G_1) + 1) \\
 &\left. + \sum_{f \in E(G)} (d_e(f, w u_k | G_1) + 1) \right] \\
 &= \sum_{i=1}^{l-1} \sum_{f \in E(G)} 1 - \sum_{i=1}^{k-1} \sum_{f \in E(G)} 1 - \sum_{f \in E(G)} 1 < 0 \text{ as } k \geq l \geq 1.
 \end{aligned}$$

which completes the proof. □



**Figure 2.** The graphs  $G_1, G_2, P, T_1$  and  $T_2$  in Transformation  $B$

**Transformation  $B$ .** Suppose  $G_1$  and  $G_2$  are two trivial graphs with vertices  $w_1$  and  $w_2$ , respectively. In addition, we assume that  $P : v_1 v_2 \dots v_{k-1} v_k$  is a path of length  $k$  ( $k \geq 5$ ). Let  $T_1$  be the graph obtained from  $G_1, G_2$  and  $P$  by attaching edges  $w_1 v_i, w_2 v_j$ , and  $T_2 = T_1 - \{w_1 v_i, w_2 v_j\} + \{w_1 v_2, w_2 v_{k-1}\}$ , such that at least one of the two  $i \neq 2, j \neq k - 1$  is true and  $1 < i < j < k$ . Such graphs have been illustrated in Figure 2.

**Lemma 2.2.** Let  $T_1$  and  $T_2$  be two graphs as shown in Figure 2. Then we have

$$W_e(T_1) < W_e(T_2).$$

**Proof.** Let  $S = \{v_1, v_2, \dots, v_i, v_{i+1}, w_1\}$  and  $R = \{v_{j-1}, v_j, \dots, v_{k-1}, v_k, w_2\}$ . Then from definition  $T_1[S] \cong T_2[S]$  and  $T_1[R] \cong T_2[R]$ . Therefore, we have,

$$\begin{aligned} W_e(T_1) - W_e(T_2) &= \sum_{h=i+1}^{k-1} d_e(w_1 v_i, v_h v_{h+1} | T_1) + \sum_{h=1}^{j-2} d_e(w_2 v_j, v_h v_{h+1} | T_1) \\ &\quad + d_e(w_1 v_i, w_2 v_j | T_1) \\ &\quad - \left[ \sum_{h=i+1}^{k-1} d_e(w_1 v_2, v_h v_{h+1} | T_2) + \sum_{h=1}^{j-2} d_e(w_2 v_{k-1}, v_h v_{h+1} | T_2) \right] \\ &\quad + d_e(w_1 v_2, w_2 v_{k-1} | T_2) \\ &= \sum_{h=i+1}^{k-1} d_e(w_1 v_i, v_h v_{h+1} | T_1) + \sum_{h=1}^{j-2} d_e(w_2 v_j, v_h v_{h+1} | T_1) \\ &\quad + d_e(w_1 v_i, w_2 v_j | T_1) \\ &\quad - \left[ \sum_{h=i+1}^{k-1} (d_e(w_1 v_i, v_h v_{h+1} | T_1) + i - 2) \right. \\ &\quad \left. + \sum_{h=1}^{j-2} (d_e(w_2 v_j, v_h v_{h+1} | T_1) + k - j - 1) \right] \end{aligned}$$

$$\begin{aligned}
 &+ (d_e(w_1 v_i, w_2 v_j | T_1) + k + i - j - 3)] \\
 &= - \left[ \sum_{h=i+1}^{k-1} (i - 2) + \sum_{h=1}^{j-2} (k - j - 1) + (k + i - j - 3) \right].
 \end{aligned}$$

Now, suppose that  $i \neq 2$ . So,

$$\begin{aligned}
 W_e(T_1) - W_e(T_2) &= - \left[ \sum_{h=i+1}^{k-1} (i - 2) + \sum_{h=1}^{j-2} (k - j - 1) + (k + i - j - 3) \right] \\
 &\leq - \left[ \sum_{h=i+1}^{k-1} (3 - 2) + \sum_{h=1}^{j-2} [(k - (k - 1) - 1) + 1] \right] < 0.
 \end{aligned}$$

If  $j \neq k - 1$ , then we have,

$$\begin{aligned}
 W_e(T_1) - W_e(T_2) &= - \left[ \sum_{h=i+1}^{k-1} (i - 2) + \sum_{h=1}^{j-2} [(k - j - 1) + (k + i - j - 3)] \right] \\
 &\leq - \left[ \sum_{h=i+1}^{k-1} (2 - 2) + \sum_{h=1}^{j-2} [(k - (k - 2) - 1) + (k + 2 - (k - 2) - 3)] \right] < 0,
 \end{aligned}$$

which completes the proof. □

Let the vertices of the path  $P_{n-1}$  be numbered consecutively by  $1, 2, \dots, n - 1$ . Construct the graph  $P_{n-1}(j)$  by attaching a pendent vertex at position  $j$  of the  $(n - 1)$ -vertex path. For positive integers  $x_1, \dots, x_m$ , and  $y_1, \dots, y_m$ , let  $T(y_1^{x_1}, \dots, y_m^{x_m})$  be the class of trees with  $x_i$  vertices of degree  $y_i$ ,  $i = 1, \dots, m$ . For some values of  $x_1, \dots, x_m$ , and  $y_1, \dots, y_m$ , the class  $T(y_1^{x_1}, \dots, y_m^{x_m})$  may be empty.

**Lemma 2.3.** Let  $P_{n-1}(2), P_{n-1}(3), P_{n-1}(4), T_1, T_2$  and  $T_3$  be six trees with  $n (\geq 10)$  vertices as shown in Figure 3. Then we have

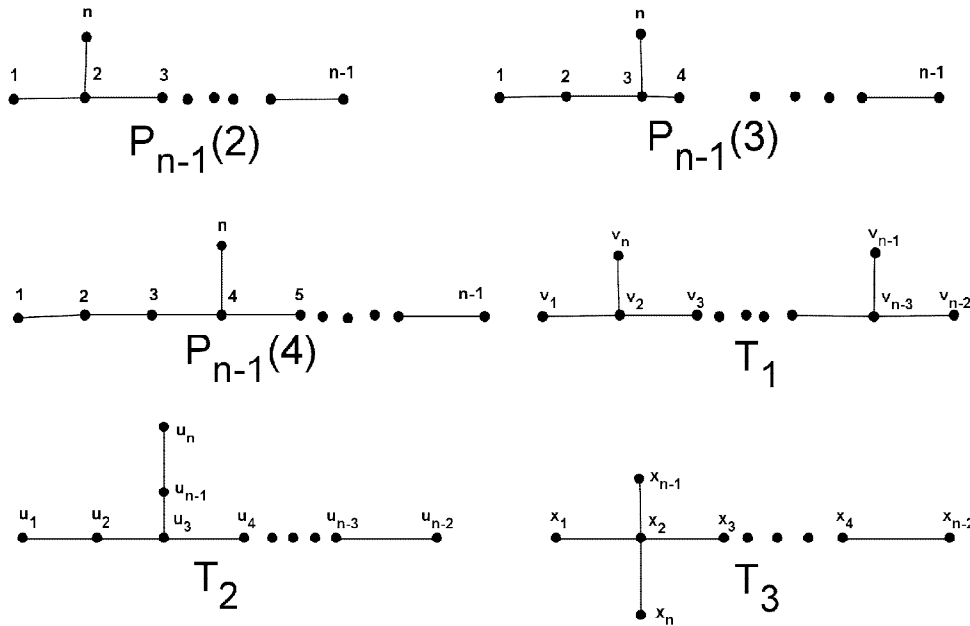
$$W_e(P_n) > W_e(P_{n-1}(2)) > W_e(P_{n-1}(3)) > W_e(T_1) > \max\{W_e(P_{n-1}(4)), W_e(T_2), W_e(T_3)\}.$$

**Proof.** By Lemma 2.1, we have  $W_e(P_n) > W_e(P_{n-1}(2)) > W_e(P_{n-1}(3))$ . Now, it is easy to see,  $P_{n-1}(3)[\{1, 2, \dots, n - 2\}] \cong P_{n-1}(4)[\{1, 2, \dots, n - 2\}] \cong T_1[\{v_1, v_2, \dots, v_{n-2}\}]$ , and  $\sum_{i=2}^{n-3} d_e((n - 1)(n - 2), (i)(i + 1) | P_{n-1}(3)) = \sum_{i=2}^{n-3} d_e((n - 1)(n - 2), (i)(i + 1) | P_{n-1}(4)) = \sum_{i=1}^{n-4} d_e(v_{n-1}v_{n-3}, v_i v_{i+1} | T_1)$ . Then for  $n \geq 10$ , we have

$$W_e(P_{n-1}(3)) - W_e(T_1) = 1 + 2 + n - 3 + \sum_{i=1}^{n-4} i - [1 + 1 + n - 4 + \sum_{i=1}^{n-4} i] > 0$$

and

$$W_e(T_1) - W_e(P_{n-1}(4)) = 1 + 1 + n - 4 + \sum_{i=1}^{n-4} i - \left[ 1 + 2 + n - 3 + \sum_{i=1}^{n-5} i \right].$$



**Figure 3.** The trees in Lemma 2.3 ( $T_1 \in T(3^2, 2^{n-6}, 1^4)$ ,  $T_2 \in T(3^1, 2^{n-4}, 1^3)$ ,  $T_3 \in T(4^1, 2^{n-5}, 1^4)$ ).

In addition,  $T_1[\{v_1, v_2, \dots, v_{n-2}\}] \cong T_2[\{u_1, u_2, \dots, u_{n-2}\}]$ ,  $\sum_{i=2}^{n-3} d_e(v_n v_2, v_i v_{i+1} | T_1) = \sum_{i=3}^{n-3} d_e(u_n u_{n-1}, u_i u_{i+1} | T_2) + d_e(u_n u_{n-1}, u_{n-1} u_3 | T_2)$  and  $\sum_{i=2}^{n-4} d_e(v_{n-1} v_{n-3}, v_i v_{i+1} | T_1) = \sum_{i=3}^{n-3} d_e(u_{n-1} u_3, u_i u_{i+1} | T_2)$ . Then we have

$$W_e(T_1) - W_e(T_2) = 1 + 1 + n - 4 + n - 4 - (2 + 3 + 1 + 2) > 0 \text{ as } n \geq 10.$$

Finally,

$$\begin{aligned} T_1[\{v_1, v_2, \dots, v_{n-2}\}] &\cong T_3[\{x_1, x_2, \dots, x_{n-2}\}], \\ \sum_{i=2}^{n-3} d_e(v_n v_2, v_i v_{i+1} | T_1) &= \sum_{i=2}^{n-3} d_e(x_{n-1} x_2, x_i x_{i+1} | T_3), \\ \sum_{i=1}^{n-4} d_e(v_{n-1} v_{n-3}, v_i v_{i+1} | T_1) &= \sum_{i=2}^{n-3} d_e(x_n x_2, x_i x_{i+1} | T_3). \end{aligned}$$

Then we have,

$$W_e(T_1) - W_e(T_3) = n - 4 - (1 + 1 + 1) > 0 \text{ as } n \geq 10.$$

which completes the proof. □

**Theorem 2.4.** Let  $P_{n-1}(2)$ ,  $P_{n-1}(3)$  and  $T_1$  be trees with  $n$  vertices as shown in Figure 3. If  $n \geq 10$  and  $T \in \tau(n) \setminus \{P_n, P_{n-1}(2), P_{n-1}(3), T_1\}$ , then

$$W_e(P_n) > W_e(P_{n-1}(2)) > W_e(P_{n-1}(3)) > W_e(T_1) > W_e(T).$$



**Proof.** From Lemma 2.3,  $W_e(P_n) > W_e(P_{n-1}(2)) > W_e(P_{n-1}(3)) > W_e(T_1)$ . Now, suppose that  $\Delta(T) = 3$  and  $n_3(T) = 1$ . In this case, if  $T \in \{P_{n-1}(i) : i = 4, 5, \dots, \lfloor \frac{n}{2} \rfloor\}$  then by Lemma 2.1 and Lemma 2.3,  $W_e(T_1) > W_e(P_{n-1}(4)) \geq W_e(T)$ . Otherwise, by Lemma 2.1 and Lemma 2.3,  $W_e(T_1) > W_e(T_2) \geq W_e(T)$ . For the case of  $\Delta(T) = 3$  and  $n_3(T) \geq 2$ , by Lemma 2.1 and Lemma 2.2,  $W_e(T_1) > W_e(T)$ . If  $\Delta(T) \geq 4$ , then by Lemma 2.1 and Lemma 2.3,  $W_e(T_1) > W_e(T_3) \geq W_e(T)$ . Otherwise,  $T \in \{P_n, P_{n-1}(2), P_{n-1}(3), T_1\}$ . This proves our theorem.  $\square$

**Corollary 2.5.** Among all trees with  $n(\geq 10)$  vertices,  $P_n$ ,  $P_{n-1}(2)$ ,  $P_{n-1}(3)$  and  $T_1$  have the maximum values of first through fourth Wiener index, respectively.

**Proof.** Equation (1) and Theorem 2.4 give us the result.  $\square$

## REFERENCES

1. Y. Alizadeh, A. Iranmanesh, T. Došlić, M. Azari, The edge Wiener index of suspensions, bottlenecks, and thorny graphs, *Glas. Mat. Ser. III* **49** (69) (2014) 1–12.
2. M. Azari, A. Iranmanesh, A. Tehranian, A method for calculating an edge version of the Wiener number of a graph operation, *Util. Math.* **87** (2012) 151–164.
3. F. Buckley, Mean distance in line graphs, *Congr. Numer.* **32** (1981) 153–162.
4. A. Chen, X. Xiong, F. Lin, Explicit relation between the Wiener index and the edge-Wiener index of the catacondensed hexagonal systems, *Appl. Math. Comput.* **273** (2016) 1100–1106.
5. P. Dankelmann, I. Gutman, S. Mukwembi, H. C. Swart, The edge–Wiener index of a graph, *Discrete Math.* **309** (2009) 3452–3457.
6. Y. Dou, H. Bian, H. Gao, H. Yu, The polyphenyl chains with extremal edge–Wiener indices, *MATCH Commun. Math. Comput. Chem.* **64** (2010) 757–766.
7. J. Devillers, A.T. Balaban, Topological Indices and Related Descriptors in QSAR and QSPR, Gordon and Breach Science Publishers, 1999.
8. H.-Y. Deng, The trees on  $n \geq 9$  vertices with the first to seventeenth greatest Wiener indices are chemical trees, *MATCH Commun. Math. Comput. Chem.* **57** (2007) 393–402.
9. A. Iranmanesh, M. Azari, Edge–Wiener descriptors in chemical graph theory: a survey, *Curr. Org. Chem.* **19** (2015) 219–239.
10. A. Iranmanesh, I. Gutman, O. Khormali, A. Mahmiani, The edge versions of Wiener index, *MATCH Commun. Math. Comput. Chem.* **61** (2009) 663–672.
11. M. Karelson, Molecular Descriptors in QSAR/QSPR, Wiley, New York, 2000.

12. M. Knor, P. Potočnik, R. Škrekovski, Relationship between the edge-Wiener index and the Gutman index of a graph, *Discrete Appl. Math.* **167** (2014) 197–201.
13. M. H. Khalifeh, H. Yousefi Azari, A. R. Ashrafi, S. G. Wagner, Some new results on distance-based graph invariants, *European J. Comb.* **30** (2009) 1149–1163.
14. A. Kelenc, S. Klavžar, N. Tratnik, The Edge–Wiener index of benzenoid systems in linear time, *MATCH Commun. Math. Comput. Chem.* **74** (2015) 521–532.
15. M. Liu, B. Liu, Q. Li, Erratum to: The trees on  $n \geq 9$  vertices with the first to seventeenth greatest Wiener indices are chemical trees, *MATCH Commun. Math. Comput. Chem.* **64** (2010) 743–756.
16. M. J. Nadjafi–Arani, H. Khodashenas, A. R. Ashrafi, Relationship between edge Szeged and edge Wiener indices of graphs, *Glas. Mat. Ser. III* **47 (67)** (2012) 21–29.
17. N. Tratnik, P. Žigert Pleteršek, Relationship between the Hosoya polynomial and the edge-Hosoya polynomial of trees, *MATCH Commun. Math. Comput. Chem.* **78** (2017) 181–187.
18. H. Wiener, Structural determination of paraffin boiling points, *J. Am. Chem. Soc.* **69** (1947) 17–20.
19. H. Yousefi–Azari, M. H. Khalifeh, A. R. Ashrafi, Calculating the edge Wiener and edge Szeged indices of graphs, *J. Comput. Appl. Math.* **235** (2011) 4866–4870.

# SID



ابزارهای پژوهش



سرویس ترجمه تخصصی



کارگاه‌های آموزشی



بلاگ مرکز اطلاعات علمی



سامانه ویراستاری STES



فیلم‌های آموزشی

سامانه ویراستاری (ویرایش متون فارسی، انگلیسی، عربی)

کارگاه‌ها و فیلم‌های آموزشی مرکز اطلاعات علمی



روش تحقیق کمی

روش تحقیق کمی



آموزش مهارت‌های کاربردی در تدوین و چاپ مقالات ISI

آموزش مهارت‌های کاربردی در تدوین و چاپ مقالات ISI



آموزش نرم افزار Word برای پژوهشگران

آموزش نرم افزار Word برای پژوهشگران