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Research Article

Mathematics

Study on Electromagnetic Feynman Graph and Its Total Edge Irregularity Strength

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KEY WORDS

Irregularity strength; Total edge irregularity strength; An electromagnetic Feynman snake graph; An electromagnetic Feynman cyclic graph.

ABSTRACT

In our paper, an electromagnetic Feynman snake graph $EmFs(n)$ and an electromagnetic Feynman cyclic graph $EmFc(n)$ have been defined. After that, the exact value of TEISs for an electromagnetic Feynman snake graph $EmFs(n)$ and an electromagnetic Feynman cyclic graph $EmFc(n)$ were deduced.

Introduction

For a simple, connected and undirected graph G, **Bača et al., (2007)** introduced the concept of an edge irregular total § -labeling, $Ж: V(G) \cup E(G) \rightarrow \{1,2,3,\dots,њ\}$ is a map in which every edges and vertices are labeled in such a way that any two edges kf and k^*f^* in G have different weights, i.e. $w_Ж(kf) \neq w_Ж(k^*f^*)$ where $w_Ж(kf) = Ж(kf) + Ж(k) + Ж(f)$ The bound of TEIS for any graph G, with maximum degree ΔG, is given in the following inequality

$$tes(G) \geq max\left\{\left\lceil\frac{\Delta G+1}{2}\right\rceil, \left\lceil\frac{|E(G)|+2}{3}\right\rceil\right\} \quad (1).$$

Conjecture (1): Ivanĉo and Jendroî (2006) For any graph G different from K_5, we have

$$tes(G) = max\left\{\left\lceil\frac{\Delta G+1}{2}\right\rceil, \left\lceil\frac{|E(G)|+2}{3}\right\rceil\right\}.$$

The conjecture has been validated for many families of graphs, for instance, a quintet snake graph, an uniform theta snake graphs, polar grid graph, heptagonal snake graph, and special families of graphs in **Salama (2019, 2020, 2021, 2022)** for zigzag graphs, helm and sun graphs, categorical product of two cycles, a categorical product of two paths, generalized Petersen graph, and certain family of graphs in **Ahmad et al. (2009, 2012, 2014, 2015, 2016)**, for hexagonal grid graphs in **Al-Mushayt et al. (2012)**, for planar graphs in **Yang et al. (2018)**, for some classes of plane graphs in **Tarawneh et al. (2021)**, for fan, wheel, triangular book, and friendship graphs in **Tilukay et al. (2015)**, for subdivision of star in **Siddiqui (2012)**, for some Cartesian product graphs in **Ramdani et al. (2013)**, for generalized web graphs and related graphs in **Indriati et al. (2015)**, for generalized prism in **Bača et al. (2014)**, for complete graph and complete bipartite graphs in **Jendroît et al. (2007)**, for disjoint union of wheel graphs in **Jeyanthi, (2015),** for more details see **Majerski and Przybylo (2014); Miškuf and Jendroî (2007); Naeem and Siddiqui (2017); Pfender (2012); Putra and Susanti, (2018); Rajasingh and Arockiamary (2015); Amar (1998)**.

In our paper, an electromagnetic Feynman snake graph $EmFs(n)$ and an electromagnetic Feynman cyclic graph $EmFc(n)$ have been defined. After that, the exact value of TEISs for an electromagnetic Feynman snake graph $EmFs(n)$ and an electromagnetic Feynman cyclic graph $EmFc(n)$ were deduced.

Main results

Definition (1): An electromagnetic Feynman snake graph is a path P_n in which we replace every edge in it by an electromagnetic Feynman graph, denoted $EmFs(n)$, see Fig. (1).

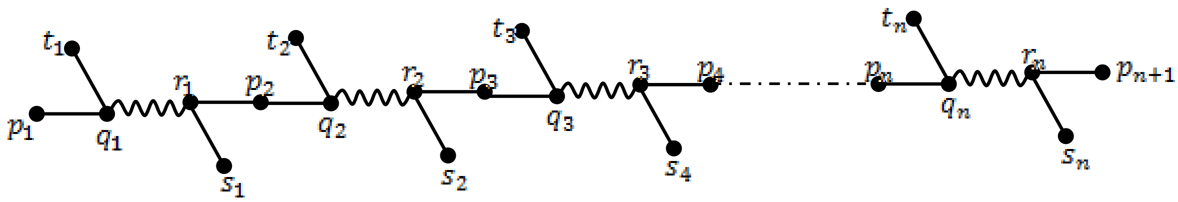

Fig. (1): An electromagnetic Feynman snake graph $EmFs(n)$

Theorem (1): For Electromagnetic Feynman snake graph $EmFs(n)$ with vertices $5n+1$ we have:

$$tes(EmFs(n)) = \left\lceil \frac{5n+2}{3} \right\rceil$$

Proof: Since the size of $EmFs(n)$ is $|\mathrm{EmFs(n)}| = 5n$ and its maximum order is $\Delta(\mathrm{EmFs(n)}) = 3$, then by substituting in (1) we find:

$$tes(EmFs(n)) \geq \left\lceil \frac{5n+2}{3} \right\rceil$$

To prove the equality, let we have §-labeling with map $Ж\colon V(EmFs(n)) \cup E(EmFs(n)) \to \{1,2,\ldots,њ\}$, where $њ = \left\lceil \frac{5n+2}{3} \right\rceil$, $Ж$ is defined as:

$$Ж(p_ɉ) = \begin{cases} 2ɉ-1 & for\, ɉ \in \left\{1,2,\ldots,\left\lceil \frac{њ+1}{2} \right\rceil - 1\right\} \\ њ & for\, ɉ \in \left\{\left\lceil \frac{њ+1}{2} \right\rceil,\ldots,n+1\right\} \end{cases}$$

$$Ж(q_ɉ) = Ж(t_ɉ) = \begin{cases} 2ɉ-1 & for\, ɉ \in \left\{1,2,\ldots,\left\lceil \frac{њ+1}{2} \right\rceil - 1\right\} \\ њ & for\, ɉ \in \left\{\left\lceil \frac{њ+1}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$Ж(r_ɉ) = Ж(s_ɉ) = \begin{cases} 2ɉ & for\, ɉ \in \left\{1,2,\ldots,\left\lceil \frac{њ+1}{2} \right\rceil - 1\right\} \\ њ & for\, ɉ \in \left\{\left\lceil \frac{њ+1}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$Ж(p_ɉ q_ɉ) = \begin{cases} ɉ & for\, ɉ \in \left\{1,2,\ldots,\left\lceil \frac{њ+1}{2} \right\rceil - 1\right\} \\ 5ɉ-2њ-2 & for\, ɉ \in \left\{\left\lceil \frac{њ+1}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$Ж(q_ɉ r_ɉ) = \begin{cases} ɉ+1 & for\, ɉ \in \left\{1,2,\ldots,\left\lceil \frac{њ+1}{2} \right\rceil - 1\right\} \\ 5ɉ-2њ & for\, ɉ \in \left\{\left\lceil \frac{њ+1}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$\text{Ж}(q_j t_j) = \begin{cases} j+1 & \text{for } j \in \left\{1,2,\ldots,\left\lceil \frac{\text{њ}+1}{2} \right\rceil - 1\right\} \\ 5j - 2\text{њ} - 1 & \text{for } j \in \left\{\left\lceil \frac{\text{њ}+1}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$\text{Ж}(r_j s_j) = \begin{cases} j+1 & \text{for } j \in \left\{1,2,\ldots,\left\lceil \frac{\text{њ}+1}{2} \right\rceil - 1\right\} \\ 5j - 2\text{њ} + 1 & \text{for } j \in \left\{\left\lceil \frac{\text{њ}+1}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$\text{Ж}(r_j p_{j+1}) = \begin{cases} j+1 & \text{for } j \in \left\{1,2,\ldots,\left\lceil \frac{\text{њ}+1}{2} \right\rceil - 2\right\} \\ 5j - 2\text{њ} + 2 & \text{for } j \in \left\{\left\lceil \frac{\text{њ}+1}{2} \right\rceil - 1\ldots,n\right\} \end{cases}$$

The above equations mean њ is maximum labeling of vertices and edges. The edge's weights of $EmFs(n)$ are given by:

$$\text{ж}(p_j q_j) = 5j - 2$$

$$\text{ж}(q_j r_j) = 5j$$

$$\text{ж}(q_j t_j) = 5j - 1$$

$$\text{ж}(r_j s_j) = 5j + 1$$

$$\text{ж}(r_j p_{j+1}) = 5j + 2$$

From the equations of the edge's weights we find they are different, so Ж is an edge irregular total њ labeling. Then:

$$tes(EmFs(n)) = \left\lceil \frac{5n+2}{3} \right\rceil$$

Definition (2): By replacing every edge in a cycle C_n by an electromagnetic Feynman graph, we have a new graph called an electromagnetic Feynman cyclic graph, denoted $EmFc(n)$, as shown in Fig. (2).

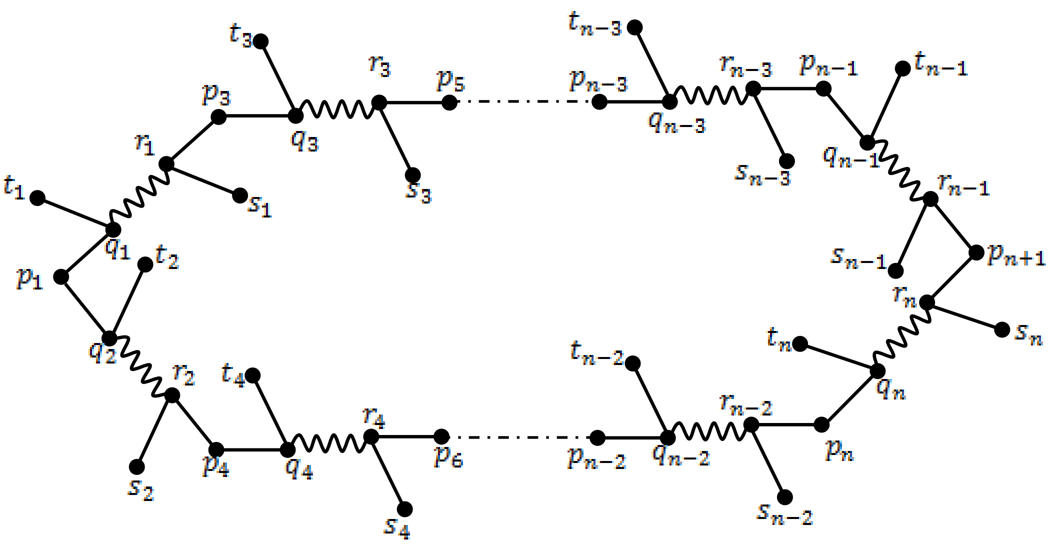

Fig. (2): An electromagnetic Feynman cyclic graph $EmFc(n)$

Lemma (1): For an electromagnetic Feynman cyclic graph $EmFc(n)$ with vertices $5n$ and $3 \leq n \leq 7$.
We find:

$$tes(EmFc(n)) = \left\lceil \frac{5n+2}{3} \right\rceil$$

Proof: For the electromagnetic Feynman cyclic graph $EmFc(n)$ with $3 \leq n \leq 7$ we find the size $|\mathrm{EmFc(n)}| = 5n$ and $\Delta(\mathrm{EmFc(n)}) = 3$ so by substetuting in (1) we have

$$tes(EmFc(n)) \geq \left\lceil \frac{5n+2}{3} \right\rceil$$

To prove the inverse inequality, we define a labeling map $Ж: V(EmFs(n)) \cup E(EmFs(n)) \to \{1,2,\dots,ҥ\}$, where $ҥ = \left\lceil \frac{5n+2}{3} \right\rceil$, given in the following:

$$Ж(p_j) = \begin{cases} 1 & j = 1 \\ 2j - 4 & for\ j \in \{3,4,\dots,n\} \\ ҥ & for\ j = n+1 \end{cases}$$

$$Ж(q_j) = Ж(t_j) = 2j - 1 \quad \forall\ j \in \{1,2,\dots,n\}$$

$$Ж(r_j) = Ж(s_j) = \begin{cases} 2j & for\ j \in \{1,2,\dots,n-1\} \\ ҥ & for\ j = n \end{cases}$$

$$Ж(p_1 q_2) = 4$$

$$Ж(p_j q_j) = \begin{cases} 1 & j = 1 \\ j+3 & for\ j \in \{3,4,\dots,n\} \end{cases}$$

$$Ж(q_j r_j) = \begin{cases} j+1 & for\ j \in \{1,2,\dots,n-1\} \\ n+1 & n \in \{3,4\} \\ n+2 & n \in \{5,6,7\} \end{cases}$$

$$Ж(q_j t_j) = j + 1 \qquad for\ j \in \{1,2,\dots,n\}$$

$$Ж(r_j s_j) = \begin{cases} j+1 & for\ j \in \{1,2,\dots,n-1\} \\ n+1 & n \in \{3,4\} \\ n+3 & n \in \{5,6,7\} \end{cases}$$

$$Ж(r_j p_{j+2}) = \begin{cases} j+2 & for\ j \in \{1,2,\dots,n-2\} \\ 3j - ҥ + 2 & for\ j = n-1 \end{cases}$$

$$Ж(r_n p_{n+1}) = 5n - 2ҥ + 2$$

The edges weights of $EmFc(n)$are given by:

$ж(p_1 q_2) = 8$

$ж(p_j q_j) = 5j - 2 \qquad for\ j \in \{1,2,\dots,n\}$

$ж(q_j r_j) = 5j \qquad for\ j \in \{1,2,\dots,n\}$

$ж(q_j t_j) = 5j - 1 \qquad for\ j \in \{1,2,\dots,n\}$

$ж(r_j s_j) = 5j + 1 \qquad for\ j \in \{1,2,\dots,n\}$

$ж(r_j p_{j+2}) = 5j + 2 \qquad for\ j \in \{1,2,\dots,n\}$

$ж(r_n p_{n+1}) = 5n + 2$

Theorem (2): If Electromagnetic Feynman cyclic graph $EmFc(n)$ with vertices $5n$ and $n \geq 8$. Then:

$$tes(EmFc(n)) = \left\lceil \frac{5n+2}{3} \right\rceil$$

Proof: Since the maximum order of $EmFc(n)$ given by $\Delta(\mathrm{EmFc(n)}) = 3$ and its size $|\mathrm{EmFc(n)}| = 5n$, substitute for these values in the inquality (1) we have:

$$tes(EmFc(n)) \geq \left\lceil \frac{5n+2}{3} \right\rceil$$

For the inverse inequality, Ж defined in the following two cases:

Case (1): $\text{њ} = 1(\mathrm{mod}2)$

$$\text{Ж}(p_{\text{ɉ}}) = \begin{cases} 1 & \text{ɉ} = 1 \\ 2\text{ɉ} - 4 & for\ \text{ɉ} \in \left\{3,4,\ldots,\left\lceil \frac{\text{њ}}{2} \right\rceil + 1\right\} \\ \text{њ} & for\ \text{ɉ} \in \left\{\left\lceil \frac{\text{њ}}{2} \right\rceil + 2,\ldots,n+1\right\} \end{cases}$$

$$\text{Ж}(q_{\text{ɉ}}) = \text{Ж}(t_{\text{ɉ}}) = \begin{cases} 2\text{ɉ} - 1 & for\ \text{ɉ} \in \left\{1,2,\ldots,\left\lceil \frac{\text{њ}}{2} \right\rceil\right\} \\ \text{њ} & for\ \text{ɉ} \in \left\{\left\lceil \frac{\text{њ}}{2} \right\rceil + 1,\ldots,n\right\} \end{cases}$$

$$\text{Ж}(r_{\text{ɉ}}) = \text{Ж}(s_{\text{ɉ}}) = \begin{cases} 2\text{ɉ} & for\ \text{ɉ} \in \left\{1,2,\ldots,\left\lceil \frac{\text{њ}}{2} \right\rceil - 1\right\} \\ \text{њ} & for\ \text{ɉ} \in \left\{\left\lceil \frac{\text{њ}}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$\text{Ж}(p_1 q_2) = 4$$

$$\text{Ж}(p_{\text{ɉ}} q_{\text{ɉ}}) = \begin{cases} 1 & \text{ɉ} = 1 \\ \text{ɉ} + 3 & for\ \text{ɉ} \in \left\{3,4,\ldots,\left\lceil \frac{\text{њ}}{2} \right\rceil\right\} \\ 3\text{ɉ} - \text{њ} + 2 & for\ \text{ɉ} = \left\lceil \frac{\text{њ}}{2} \right\rceil + 1 \\ 5\text{ɉ} - 2\text{њ} - 2 & for\ \text{ɉ} \in \left\{\left\lceil \frac{\text{њ}}{2} \right\rceil + 2,\ldots,n\right\} \end{cases}$$

$$\text{Ж}(q_{\text{ɉ}} r_{\text{ɉ}}) = \begin{cases} \text{ɉ} + 1 & for\ \text{ɉ} \in \left\{1,2,\ldots,\left\lceil \frac{\text{њ}}{2} \right\rceil - 1\right\} \\ 5\text{ɉ} - 2\text{њ} & for\ \text{ɉ} \in \left\{\left\lceil \frac{\text{њ}}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$\text{Ж}(q_{\text{ɉ}} t_{\text{ɉ}}) = \begin{cases} \text{ɉ} + 1 & for\ \text{ɉ} \in \left\{1,2,\ldots,\left\lceil \frac{\text{њ}}{2} \right\rceil - 1\right\} \\ 5\text{ɉ} - 2\text{њ} - 1 & for\ \text{ɉ} \in \left\{\left\lceil \frac{\text{њ}}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$\text{Ж}(r_{\text{ɉ}} s_{\text{ɉ}}) = \begin{cases} \text{ɉ} + 1 & for\ \text{ɉ} \in \left\{1,2,\ldots,\left\lceil \frac{\text{њ}}{2} \right\rceil - 1\right\} \\ 5\text{ɉ} - 2\text{њ} + 1 & for\ \text{ɉ} \in \left\{\left\lceil \frac{\text{њ}}{2} \right\rceil,\ldots,n\right\} \end{cases}$$

$$\text{Ж}(r_{\text{ɉ}} p_{\text{ɉ}+2}) = \begin{cases} \text{ɉ} + 1 & for\ \text{ɉ} \in \left\{1,2,\ldots,\left\lceil \frac{\text{њ}}{2} \right\rceil - 1\right\} \\ 5\text{ɉ} - 2\text{њ} + 2 & for\ \text{ɉ} \in \left\{\left\lceil \frac{\text{њ}}{2} \right\rceil\ldots,n-1\right\} \end{cases}$$

$$\text{Ж}(r_n p_{n+1}) = 5n - 2\text{њ} + 2$$

The edges weights of $EmFc(n)$ are given by:

$ж(p_1q_2)=8$

$ж(p_ȷq_ȷ)=5ȷ-2$

$ж(q_ȷr_ȷ)=5ȷ$

$ж(q_ȷt_ȷ)=5ȷ-1$

$ж(r_ȷs_ȷ)=5ȷ+1$

$ж(r_ȷp_{ȷ+2})=5ȷ+2$

$ж(r_np_{n+1})=5n+2$

Case (2): $ҥ=0(\mathrm{mod}2)$

$Ж$ Is defined for x_i, y_i, z_i, h_i and the edges x_1y_2, x_iy_i like as in case (1), but for the another edges given by:

$$Ж(q_ȷr_ȷ)=\begin{cases} ȷ+1 & for\, ȷ\in\{1,2,\dots,\lceil\frac{ҥ}{2}\rceil\} \\ 5ȷ-2ҥ & for\, ȷ\in\{\lceil\frac{ҥ}{2}\rceil+1,\dots,n\} \end{cases}$$

$$Ж(q_ȷt_ȷ)=\begin{cases} ȷ+1 & for\, ȷ\in\{1,2,\dots,\lceil\frac{ҥ}{2}\rceil\} \\ 5ȷ-2ҥ-1 & for\, ȷ\in\{\lceil\frac{ҥ}{2}\rceil+1,\dots,n\} \end{cases}$$

$$Ж(r_ȷs_ȷ)=\begin{cases} ȷ+1 & for\, ȷ\in\{1,2,\dots,\lceil\frac{ҥ}{2}\rceil\} \\ 5ȷ-2ҥ+1 & for\, ȷ\in\{\lceil\frac{ҥ}{2}\rceil+1,\dots,n\} \end{cases}$$

$$Ж(r_ȷp_{ȷ+2})=\begin{cases} ȷ+1 & for\, ȷ\in\{1,2,\dots,\lceil\frac{ҥ}{2}\rceil\} \\ 5ȷ-2ҥ+2 & for\, ȷ\in\{\lceil\frac{ҥ}{2}\rceil+1\dots,n-1\} \end{cases}$$

$$Ж(r_np_{n+1})=5n-2ҥ+2$$

The edges weights of $EmFc(n)$ are given by:

$ж(p_1q_2)=8$

$ж(p_ȷq_ȷ)=5ȷ-2$

$ж(q_ȷr_ȷ)=5ȷ$

$ж(q_ȷt_ȷ)=5ȷ-1$

$ж(r_ȷs_ȷ)=5ȷ+1$

$ж(r_ȷp_{ȷ+2})=5ȷ+2$

$ж(r_np_{n+1})=5n+2$

Conclusions

In current paper, an electromagnetic Feynman snake graph $EmFs(n)$ and an electromagnetic Feynman cyclic graph $EmFc(n)$ have been defined. After that, the exact value of TEISs for an electromagnetic Feynman snake graph $EmFs(n)$ and an electromagnetic Feynman cyclic graph $EmFc(n)$ were deduced.

The main findings and major contributions of the present work are:

1- An electromagnetic Feynman snake graph $EmFs(n)$ and an electromagnetic Feynman cyclic graph $EmFc(n)$ have been defined.

2- The exact values of TERS for an electromagnetic Feynman snake graph $EmFs(n)$ was calculated in the form

$$tes(EmFs(n)) = \left\lceil \frac{5n+2}{3} \right\rceil.$$

3- The exact values of TERS for an electromagnetic Feynman cyclic graph $EmFc(n)$ was deduced and given by

$$tes(EmFc(n)) = \left\lceil \frac{5n+2}{3} \right\rceil.$$

Data Availability

I did not use external data for our paper.

Conflict of interest

Author declares no conflict of interest in this paper.

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دراسة على الرسم البياني الكهرومغناطيسي فاينمان وقوة عدم انتظام الحواف الكلية

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