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2-Skolem Difference Mean Labeling of Some Graphs

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ABSTRACT

In this article, the concept of 2-Skolem difference mean labeling, relaxed 2-Skolem difference mean labeling, and 2-Skolem difference mean number of a graph are introduced. A graph $G = (V, E)$ with p vertices and $2q$ edges is said to have 2-Skolem difference mean labeling if it is possible to label the vertices $x \in V$ with distinct elements $f(x)$ from the set $\{1,2, \dots, p\}$ in such a way that the edge $e = uv$ is labelled with $\frac{|f(u)-f(v)|}{2}$ if $|f(u) - f(v)|$ is even, and $\frac{|f(u)-f(v)|+1}{2}$ if $|f(u) - f(v)|$ is odd, and the resulting labels of the edges are distinct and are from $\{1,1,2,2,3,3, \dots q, q\}$. A graph that admits 2-Skolem difference mean labeling is called a 2-Skolem difference mean graph. The authors studied 2-Skolem difference mean labeling of some graphs.

***Keywords*:** *2*-Skolem difference mean labeling, caterpillar, coconut tree and twig graph.

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1. INTRODUCTION

Graphs considered in this paper are finite, undirected and simple. Terms and notations not defined here are used in the sense of Harary [3]. Let $G = (V, E)$ be a graph with p vertices and q edges. $|V(G)| = p$ is called the order of G and $|E(G)| = q$ is called the size of G.

A graph labeling is an assignment of integers to the vertices or edges or both subject to certain conditions. If the domain of the mapping is the set of vertices (edges/ both), then the labeling is called vertex (edges/total) labeling.

Rosa introduced $\alpha -$ valuations in [15] which in later called graceful graphs. There are several types of graph labeling, and a detailed survey is found in [5]. The concept of Skolem difference mean labeling was introduced in [12] and further results were studied in [10,11,14,16,17]. Acharya et al proved in [1] that any connected graph can be embedded as an induced sub graph of a connected graceful graph.

Skolem difference mean labeling of some path related graphs was introduced by Dharamvirsinh Parmar and Urvisha Vaghela in [2].

Following definitions are necessary for the present study.

Definition 1.1: A path P of length n in a graph G is a sequence of distinct vertices $\{v_0, v_1, \dots, v_n\}$ where $e_i = v_i v_{i+1}$ for $i = 0,1, \dots n-1$. We also represent P by $\{e_0, e_1, \dots, e_{n-1}\}$.$v_0$and v_n are called end vertices, and $v_1, v_2, \dots, v_{n-1}$ are called internal vertices of P. A path on n points is denoted by P_n.

Definition 1.2: A cycle in a graph G is a sequence of distinct vertices $\{v_0, v_1, \dots v_{n-1}, v_n\}$ wherev_i and v_{i+1} are adjacent for all $i = 0,1, \dots n-2$ and v_{n-1} andv_0 are adjacent in G. A cycle with $n \geq 3$ vertices is denoted by C_n.C_3 is often called a triangle.

Definition 1.3: If every two vertices of a graph are adjacent, then G is called a complete graph. The complete graph with p vertices is denoted byK_p. The graph K_p is regular of degree $p-1$ and has p vertices and $\frac{p(p-1)}{2}$ edges.

Definition 1.4: The coconut tree graph $C_{m,n}$ is obtained by identifying the central vertex of $K_{1,m}$ with a pendent vertex of the path P_n.

Definition 1.5: The Bistar $B_{m,n}$ is the graph obtained from K_2 by joining m pendent edges to one end of K_2 and n pendent edges to the other end of K_2.

The edge of K_2 is called the central edge of $B_{m,n}$ and the vertices of K_2 are called the central vertices of $B_{m,n}$.

Definition 1.6: The graph $P_{n-1}(1,2, \dots, n)$ is a graph obtained from a path of vertices$v_1, v_2, \dots, v_n$ having the path length $n-1$ by joining i pendent vertices at each of its i^{th} vertex.

K. Murugan and A. Subramanian introduced the concept of Skolem difference mean graph in [12]. They studied Skolem difference mean labeling of various graphs.

The concept of edge reduced Skolem difference mean number of a graph was introduced by K. Murugan in [9]. In that paper, the author studied the edge reduced Skolem difference mean number of some graphs. In [8], the authors studied extra Skolem difference mean labeling of some graphs. In [4], the authors studied the Skolem difference mean labeling of $C_m \cup C_n (n, m \geq 3 \; and \; m \leq n)$. In [19], the authors studied Skolem difference odd mean labeling of path, cycle, and complete bipartiate graphs. In [6], the authors studied Skolem odd difference mean labeling of $T \odot \overline{K_n}$, banana tree $Bt\underbrace{(n, n, \dots, n)}_{m \; times}$, regular bamboo tree $\left(S_{n,m}\right)_k$.

Definition 1.7: Let $G = (V, E)$ be a graph with p vertices and q edges. A graph is said to be Skolem odd difference mean if there exists a function $f: V(G) \to \{0,1,2,3, \dots, p + 3q - 3\}$ satisfying f is 1-1 and the induced map $f^*: E(G) \to \{1,3,5, \dots, 2q - 1$ defined by $f^*(e) = \left\lceil \frac{f(u)-f(v)}{2} \right\rceil$ is a bijection. A graph that admits Skolem odd difference mean labeling is called Skolem odd difference mean graph. They call a Skolem odd difference mean labeling as Skolem even vertex odd difference mean labeling if all vertex labels are even. A graph that admits Skolem even vertex odd difference mean labeling is called Skolem even vertex odd difference mean graph. In that paper, they proved that the graphs $T \odot \overline{K_n}$, $St(n_1, n_2, \dots, n_m), Bt\underbrace{n, n, \dots, n}_{m \; times}$, $T\langle K_{1,n_1} : K_{1,n_2} : K_{1,n_3} : \dots : K_{1,n_m} \rangle$ and $\left(S_{n,m}\right)_k$ are Skolem odd difference mean graphs.

In [20], the authors studied Skolem difference mean labeling in duplicate graphs of path graphs, comb graph and twig graph. In [13], the authors introduced Skolem difference Lucas mean labeling of $K_{1,n}^+, K_{1,m} \oslash K_{1,n}, K_{1,m} \odot 2P_n$.

Definition 1.8: A graph G with p vertices and q edges is said to have Skolem difference Lucas mean labeling if it is possible to label the vertices $x \in v$ with distinct elements $f(x)$ from the set $\{1,2, \dots L_{p+q}\}$ in such a way that the edge $e = uv$ is labelled with $\left|\frac{f(u)-f(v)}{2}\right|$ if $|f(u) - f(v)|$ is even and $\frac{|f(u)-f(v)|+1}{2}$ if $|f(u) - f(v)|$ is odd, then the resulting edge labels are distinct and are from $\{L_1, L_2, \dots, L_q\}$. A graph that admits Skolem difference Lucas mean labeling is called a Skolem difference Lucas mean graph.

In [18], Near Skolem difference mean labeling of $C_n @ K_{1,m}, C_n \otimes K_{1,m}$ are studied.

Definition 1.9: Let G be a (p, q) graph and $f: V(G) \to \{1,2, \dots p + q - 1, p + q + 2\}$ be an injection. For each edge $e = uv$ the induced edge labeling f^* is defined as follows: $f^* = \begin{cases} \frac{|f(u)-f(v)|}{2} \; if \; |f(u) - f(v)| \; is \; even \\ \frac{|f(u)-f(v)|+1}{2} \; if \; |f(u) - f(v)| \; is \; odd \end{cases}$ Then f is called Near Skolem difference mean labeling if $f^*(e)$are all distinct and from $\{1,2,3, \dots, q\}$. A graph that admits a Near Skolem difference mean labeling is called a Near Skolem difference mean graph.

In [7], the authors introduced Skolem difference Fibonaci mean labeling and studied Skolem difference Fibonaci mean labelingof $fan \; F_n = P_n + K_1, F_m @ 2P_n$, triangular snacke graph TS_n.

Definition 1.10: A graph G with $p$vertices and q edges is said to have Skolem difference Fibonacci mean labeling if it is possible to label the vertices $x \in V$ with distinct elements $f(x)$ from the set $\{1,2,\dots,F_{p+q}\}$ in such a way that the edge $e = uv$ is labeled with $\left|\frac{f(u)-f(v)}{2}\right|$ if $|f(u)-f(v)|$ is even $\frac{|f(u)-f(v)|+1}{2}$ if $|f(u)-f(v)|$is odd, and the resulting edge labels are distinct and are from $\{F_1, F_2, \dots, F_q\}$. A graph that admits Skolem difference Fibonacci mean labeling is called a Skolem difference Fibonacci mean graph.

Motivated by the above definitions, in this paper, the authors introduce a new type of labeling called 2-Skolem difference mean labeling.

2. RESULT

In this section, the authors introduce the concept of 2-Skolem Difference Mean labeling and 2-Skolem Difference Mean number of a graph.

Definition 2.1: A graph $G = (V, E)$ with p vertices and $2q$ edges is said to have 2-Skolem difference mean labeling if it is possible to label the vertices $x \in V$ with distinct elements $f(x)$ from the set $\{1,2,\dots p\}$ in such a way that the edge $e = uv$ is labeled with $\frac{|f(u)-f(v)|}{2}$ if $|f(u)-f(v)|$ is even, and $\frac{|f(u)-f(v)|+1}{2}$ if $|f(u)-f(v)|$ is odd, and the resulting labels of the edges are distinct and are from $\{1,1,2,2,3,3,\dots q,q\}$. A graph that admits 2-Skolem difference mean labeling is called a 2-Skolem difference mean graph.

Theorem 2.2: $K_{1,2n}$ is 2-Skolem difference mean for all n.

Proof: Let G be the graph.

Let $V(G) = \{v, v_i / 1 \le i \le 2n\}$ and $E(G) = \{vv_i / 1 \le i \le 2n\}$

Let $f: V(G) \to \{1,2,\dots,2n+1\}$ as follows:

$f(v) = 2n+1$

$f(v_{2i-1}) = 2n+2-2i, 1 \le i \le n$

$f(v_{2i}) = 2n+1-2i, 1 \le i \le n$

The induced edge labels are $\{1,1,2,2,\dots,n,n\}$

Hence $K_{1,2n}$ is 2-Skolem difference mean for all n.

Example 2.3: 2-Skolem difference mean labeling of$K_{1,4}$ is illustrated in Fig. 1

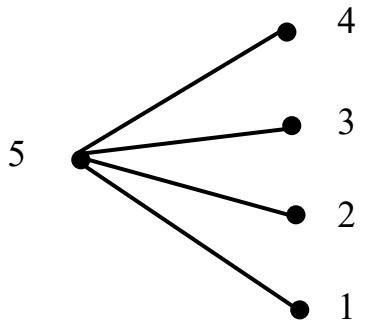


Figure 1

Theorem 2.4: P_{2n+1} is 2-Skolem difference mean for all n.

Proof: Let G be the graph P_{2n+1}

Let $V(G) = \{v_i/1 \leq i \leq 2n+1\}$ and $E(G) = \{v_i v_{i+1}/1 \leq i \leq 2n\}$

Let $f: V(G) \to \{1,2,\ldots,2n+1\}$ be defined as follows.

$f(v_{2i}) = 2n+2-i, 1 \leq i \leq n$

$f(v_{2i+1}) = 1+i, 0 \leq i \leq n$

The induced edge labels are $\{1,1,2,2,\ldots n,n\}$

Hence P_{2n+1} is 2-Skolem difference mean for all n.

Example 2.5: 2-Skolem difference means labeling of P_7 is Fig. 2

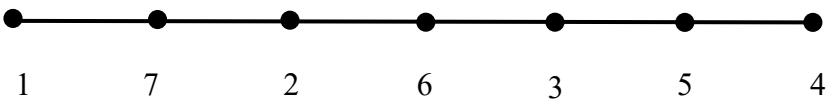


Figure 2

Theorem 2.6: $B_{m,n}$ where m and n are in opposite parity, is 2-Skolem difference mean for all $m, n \geq 1$.

Proof: Let G be the graph $B_{m,n}$

Let $V(G) = \{u, v, u_i, v_j / 1 \leq i \leq m, 1 \leq j \leq n\}$

$E(G) = \{u_i u, uv, vv_j / 1 \leq i \leq m, 1 \leq j \leq n\}$

Let $f: V(G) \to \{1,2, \ldots, 2n+1\}$ be defined as follows.

$f(u) = m + n + 2$

$f(u_i) = i, \quad 1 \leq i \leq m$

$f(v) = f(u_m) + 1$

$f(v_j) = f(u_m) + 1 + j, 1 \leq j \leq n$

Hence $B_{m,n}$ is 2-Skolem difference mean for all $m, n \geq 1$.

Example2.7: 2-Skolem difference mean labeling of $B_{2,5}$ in Fig. 3

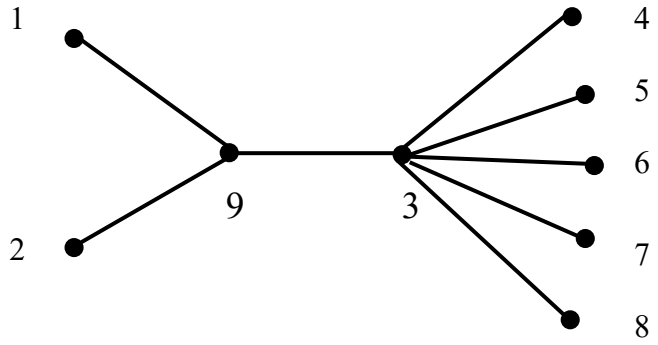


Figure 3

Theorem 2.8: The coconut tree graph $C_{m,n}$ where m and n are in opposite parity, is 2-Skolem difference mean for all $m, n \geq 1$.

Proof: Let be the coconut tree graph $C_{m,n}$

Let $V(G) = \{v_i, u_j / 1 \leq i \leq n, 1 \leq j \leq m\}$

$E(G) = \{v_i v_{i+1}, v_1 u_j / 1 \leq i \leq n-1, 1 \leq j \leq m\}$

Then $|V(G)| = n + m$ and $|E(G)| = n + m - 1$

Let $f: V(G) \to \{1,2, \ldots, m+n\}$ be defined as follows.

$f(u_j) = m + n + 1 - j, 1 \leq j \leq m$

$f(v_1) = 1$

$f(v_i) = f(u_m) + 1 - i, 2 \leq i \leq n$

The induced edge labels are $\left\{1,1,2,2,\ldots,\frac{m+n-1}{2},\frac{m+n-1}{2}\right\}$

Hence $C_{m,n}$ is 2-Skolem difference mean for all $m, n \geq 1$.

Example 2.9: 2-Skolem difference mean labeling of $C_{4,5}$ is Fig. 4

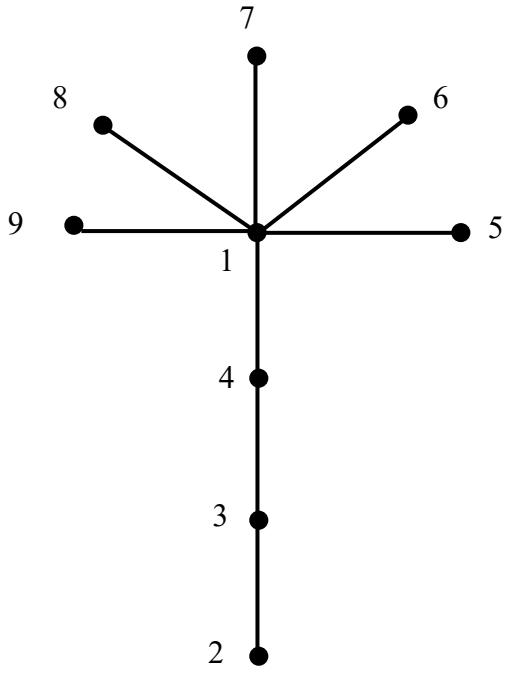


Figure 4

Theorem 2.10: The caterpillar graph $S(X_1, X_2, \ldots, X_n)$ is 2-Skolem difference mean for all n.
Proof: Let G be the caterpillar graph $S(X_1, X_2, \ldots, X_n)$.

Let $V(G) = \{u_i / 1 \leq i \leq 2n+1\} \cup \{u_{ij} / 1 \leq i \leq 2n+1, 1 \leq j \leq X_i\}$ and

$E(G) = \{u_i u_{i+1} / 1 \leq i \leq 2n\} \cup \{u_i u_{ij} / 1 \leq i \leq 2n+1, 1 \leq j \leq X_i\}$

Let $f: V(G) \to \{1,2,\ldots, X_1 + X_2 + \cdots + X_n + n\}$

Case(i)when n is odd:

Let $n = 2m + 1$

$$f(u_{2j+1}) = \sum_{i=1}^{2m+1} (X_i + 2m + 1 - X_2 - X_4 - \cdots - X_{2j} - j), 0 \le j \le m$$

$$f(u_{2j}) = X_1 + X_3 + X_5 + \cdots X_{2j-1} + j, 1 \le j \le m$$

$$f(X_{(2i+1)j}) = X_1 + X_3 + X_5 + \cdots + X_{2i-1} + i + j, 1 \le j \le X_{2i+1}, 0 \le i \le m$$

$$f(X_{2ij}) = \sum_{i=1}^{2m+1} (X_i + 2m + 1 - X_2 - X_4 - \cdots - X_{2(i-1)} - (i-1) - j, 1 \le j \le X_{2i}), 1 \le i \le m$$

Case(ii)when n is even.

Let $n = 2m$

$$f(u_{2j+1}) = \sum_{i=1}^{2m} (X_i + 2m - X_2 - X_4 - \cdots - X_{2j} - j), 0 \le j < m$$

$$f(u_{2j}) = X_1 + X_3 + \cdots + X_{2j-1} + j, 1 \le j \le m$$

$$f(X_{(2i+1)j}) = X_1 + X_3 + \cdots + X_{2i-1} + i + j, 1 \le j \le X_{2i+1}, 0 \le i < m$$

$$f(X_{2ij}) = \sum_{i=1}^{2m} (X_i + 2m - X_2 - X_4 - \cdots - X_{2(i-1)} - (i-1) - j, 1 \le j \le X_{2i}), 1 \le i \le m$$

The induced edge labels are $\left\{1,1,2,2, \ldots, \frac{X_1+X_2+\cdots+X_n+n}{2}, \frac{X_1+X_2+\cdots+X_n+n}{2}\right\}$

Hence $S(X_1, X_2, \ldots, X_n)$ is 2-Skolem difference mean for all m, n.

Example 2.11: The 2-Skolem difference mean labeling of $S(2,2,3,2)$ is Fig. 5

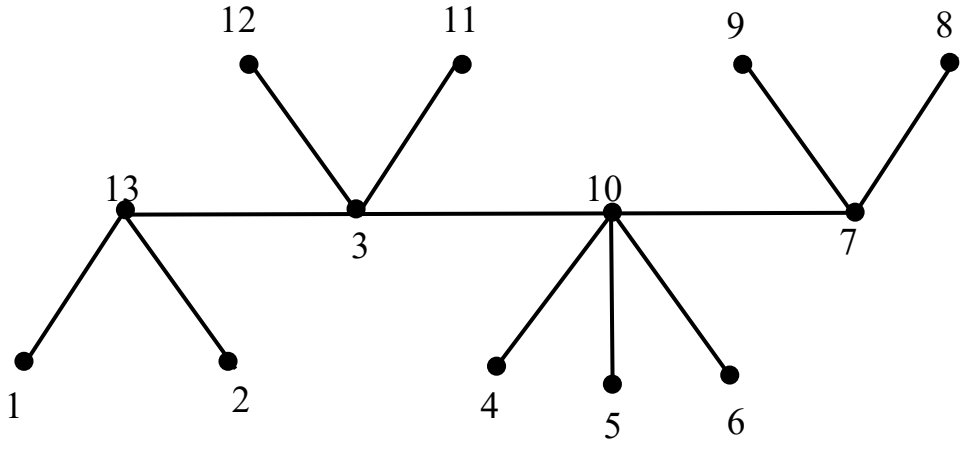


Figure 5

Corollary 2.12: When $X_i = m, 1 \leq i \leq n$, the graph $P_n \odot \overline{K_m}$ is 2-Skolem difference mean for all $n \geq 2$ and $m \geq 1$.

Example 2.13: The 2-Skolem difference mean labeling of $P_5 \odot \overline{K_2}$ is Fig. 6

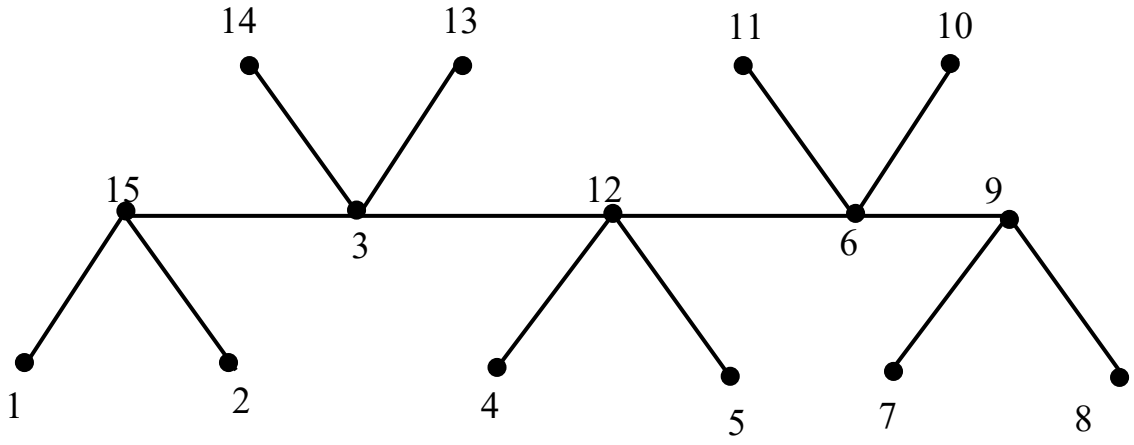


Figure 6

Corollary 2.14: The graph $P_{n-1}(1,2,\ldots,n)$ is 2-Skolem difference mean.

Example 2.15: The 2-Skolem difference mean labeling of the graph $P_3(1,2,3)$ is Fig. 7

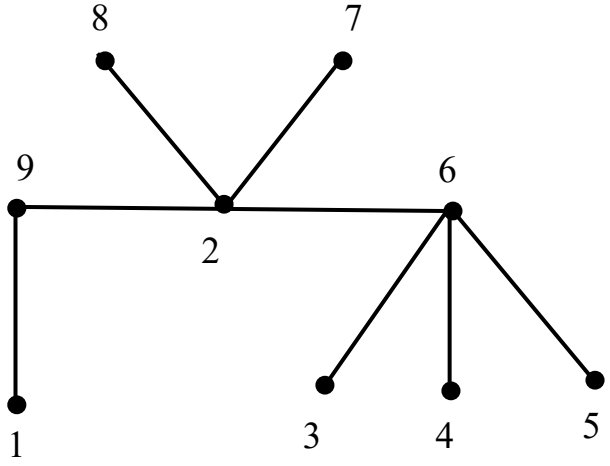


Figure 7

Theorem 2.16: The twig graph obtained from the path by attaching exactly two pendent edges to each internal vertex of the path is also 2-Skolem difference mean.

Proof: Let G be the twig graph.

Let $V(G) = \{v_i, u_j, w_j / 1 \leq i \leq n, 2 \leq j \leq n-1\}$

$E(G) = \{v_i v_{i+1}, v_j u_j, v_j w_j / 1 \leq i \leq n-1, 2 \leq j \leq n-1\}$

Let $f: V(G) \to \{1,2, \ldots, n-2\}$

$f(v_{2i+1}) = 1 + 3i, 0 \leq i \leq \frac{n-1}{2}$

$f(v_{2i}) = 3n - 7 - 3i, 1 \leq i \leq \frac{n-1}{2}$

$f(u_{2j+1}) = f(v_2) + 2 - 3j, 1 \leq j < \frac{n-1}{2}$

$f(u_{2j}) = 3j - 1, 1 \leq j \leq \frac{n-1}{2}$

$f(w_{2j+1}) = f(u_3) + 2 - 3j, 1 \leq j < \frac{n-1}{2}$

$f(w_{2j}) = 3j, 1 \leq j \leq \frac{n-1}{2}$

The induced edge labels are $\{1,1,2,2, \ldots, n, n\}$

Hence the twig graph is 2-Skolem difference mean.

Example 2.17: 2-Skolem difference mean labeling of twig graph obtained from the path P_5 by attaching exactly two pendent edges to each internal vertex of the path is Fig. 8

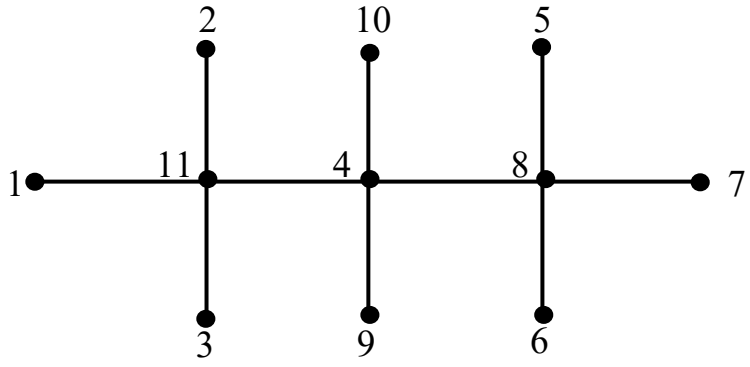


Figure 8

Theorem 2.18: Let $G = P_n \odot K_1 - e_1, n \geq 2$ where e_1 is an edge incident with the vertex v_1 in G. Then G is 2-Skolem difference mean.

Proof: Let $V(G) = \{v_i, u_j; 1 \leq i \leq n, 2 \leq j \leq n\}$

$E(G) = \{v_i v_{i+1}, v_j u_j; 1 \leq i \leq n-1, 2 \leq j \leq n\}$

Then $|V(G)| = 2n - 1$ and $|E(G)| = 2(n-1)$

Let $f: V(G) \to \{1,2, \ldots, 2n-1\}$ be defined as follows.

Case (i) when n is odd:

$$f(v_{2i-1}) = 2i - 1; 1 \leq i \leq \frac{n+1}{2}$$

$$f(v_{2i}) = 2n + 1 - 2i; 1 \leq i < \frac{n+1}{2}$$

$$f(u_{2j+1}) = 2n - 2j; 1 \leq j < \frac{n+1}{2}$$

$$f(u_{2j}) = 2j; 1 \leq j < \frac{n+1}{2}$$

Case (ii) when n is even:

$$f(v_{2i-1}) = 2i - 1; 1 \leq i \leq \frac{n}{2}$$

$$f(v_{2i}) = 2n + 1 - 2i; 1 \leq i \leq \frac{n}{2}$$

$$f(u_{2j+1}) = 2n - 2j; 1 \leq i < \frac{n}{2}$$

$$f(u_{2j}) = 2j; 1 \leq i \leq \frac{n}{2}$$

The induced edge labels are $\{1,1,2,2, \ldots, n-1, n-1\}$

Hence $G = P_n \odot K_1 - e_1$ is 2-Skolem difference mean for all $n \geq 2$.

Example 2.19: 2-Skolem mean labeling of the graphs $P_5 \odot K_1 - e_1$ and $P_4 \odot K_1 - e_1$ in Fig. 9.

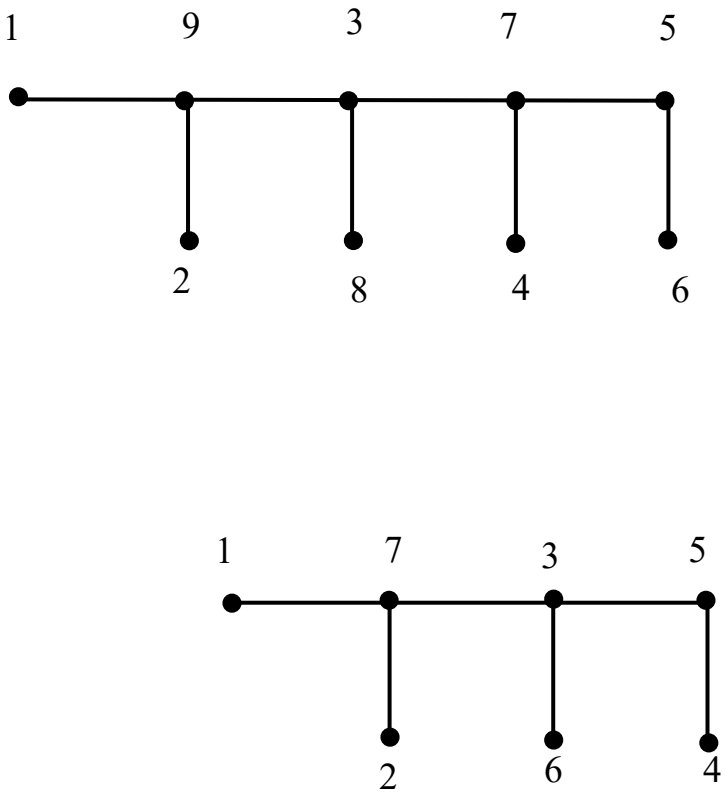
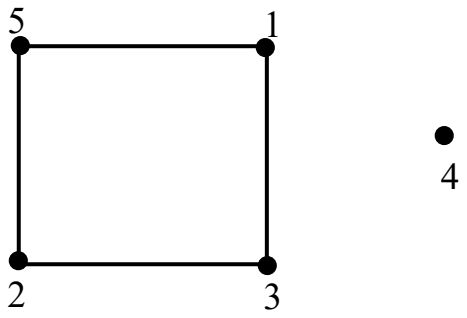


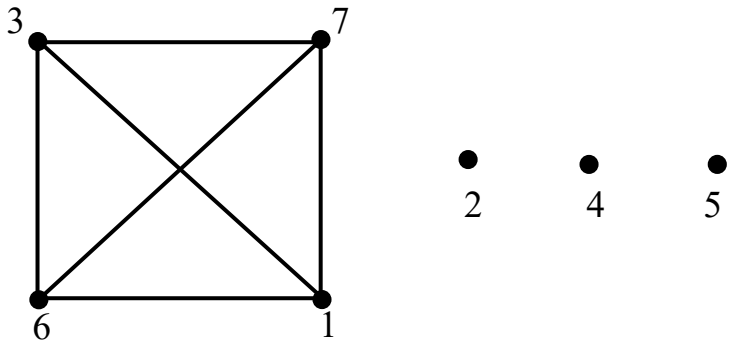
Figure 9

Definition 2.20: The 2-Skolem difference mean number σ_{2sdm} of a graph is defined as the minimum number of isolated vertices which, when added to G result in a 2-Skolem difference mean graph. If no such number exists, then $\sigma_{2sdm}(G) = \infty$.

Examples 2.21: 1.$\sigma_{2sdm}(C_4) = 1$.



2.$\sigma_{2sdm}(K_4) = 3$.



Definition 2.22: A graph $G = (V, E)$ with p vertices and $2q - 1$ edges is said to have relaxed 2-Skolem difference mean labeling if it is possible to label the vertices $x \in V$ with distinct elements $f(x)$ from the set $\{1,2, \dots p\}$ in such a way that the edge $e = uv$ is labeled with $\frac{|f(u)-f(v)|}{2}$ if $|f(u) - f(v)|$ is even and $\frac{|f(u)-f(v)|+1}{2}$ if $|f(u) - f(v)|$ is odd, and the resulting labels of the edges are distinct and are from $\{1,1,2,2,3,3, \dots q-1, q-1, q\}$. A graph that admits Relaxed 2-Skolem difference mean labeling is called a Relaxed 2-Skolem difference mean graph.

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