

King Saud University

College of Science

Department of Mathematics

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㰞 㰟 㰠 㰡 㰢 㰣 㰤 㰥 㰦 㰧 㰨 㰩 㰪 㰫 㰬 㰭 㰮 㰯 㰰 㰱 㰲 㰳 㰴 㰵 㰶 㰷 㰸 㰹 㰺 㰻 㰼 㰽 㰾 㰿 㱀 㱁 㱂 㱃 㱄 㱅 㱆 㱇 㱈 㱉 㱊 㱋 㱌 㱍 㱎 㱏 㱐 㱑 㱒 㱓 㱔 㱕 㱖 㱗 㱘 㱙 㱚 㱛 㱜 㱝 㱞 㱟 㱠 㱡 㱢 㱣 㱤 㱥 㱦 㱧 㱨 㱩 㱪 㱫 㱬 㱭 㱮 㱯 㱰 㱱 㱲 㱳 㱴 㱵 㱶 㱷 㱸 㱹 㱺 㱻 㱼 㱽 㱾 㱿 㲀 㲁 㲂 㲃 㲄 㲅 㲆 㲇 㲈 㲉 㲊 㲋 㲌 㲍 㲎 㲏 㲐 㲑 㲒 㲓 㲔 㲕 㲖 㲗 㲘 㲙 㲚 㲛 㲜 㲝 㲞 㲟 㲠 㲡 㲢 㲣 㲤 㲥 㲦 㲧 㲨 㲩 㲪 㲫 㲬 㲭 㲮 㲯 㲰 㲱 㲲 㲳 㲴 㲵 㲶 㲷 㲸 㲹 㲺 㲻 㲼 㲽 㲾 㲿 㳀 㳁 㳂 㳃 㳄 㳅 㳆 㳇 㳈 㳉 㳊 㳋 㳌 㳍 㳎 㳏 㳐 㳑 㳒 㳓 㳔 㳕 㳖 㳗 㳘 㳙 㳚 㳛 㳜 㳝 㳞 㳟 㳠 㳡 㳢 㳣 㳤 㳥 㳦 㳧 㳨 㳩 㳪 㳫 㳬 㳭 㳮 㳯 㳰 㳱 㳲 㳳 㳴 㳵 㳶 㳷 㳸 㳹 㳺 㳻 㳼 㳽 㳾 㳿 㴀 㴁 㴂 㴃 㴄 㴅 㴆 㴇 㴈 㴉 㴊 㴋 㴌 㴍 㴎 㴏 㴐 㴑 㴒 㴓 㴔 㴕 㴖 㴗 㴘 㴙 㴚 㴛 㴜 㴝 㴞 㴟 㴠 㴡 㴢 㴣 㴤 㴥 㴦 㴧 㴨 㴩 㴪 㴫 㴬 㴭 㴮 㴯 㴰 㴱 㴲 㴳 㴴 㴵 㴶 㴷 㴸 㴹 㴺 㴻 㴼 㴽 㴾 㴿 㵀 㵁 㵂 㵃 㵄 㵅 㵆 㵇 㵈 㵉 㵊 㵋 㵌 㵍 㵎 㵏 㵐 㵑 㵒 㵓 㵔 㵕 㵖 㵗 㵘 㵙 㵚 㵛 㵜 㵝 㵞 㵟 㵠 㵡 㵢 㵣 㵤 㵥 㵦 㵧 㵨 㵩 㵪 㵫 㵬 㵭 㵮 㵯 㵰 㵱 㵲 㵳 㵴 㵵 㵶 㵷 㵸 㵹 㵺 㵻 㵼 㵽 㵾 㵿 㶀 㶁 㶂 㶃 㶄 㶅 㶆 㶇 㶈 㶉 㶊 㶋 㶌 㶍 㶎 㶏 㶐 㶑 㶒 㶓 㶔 㶕 㶖 㶗 㶘 㶙 㶚 㶛 㶜 㶝 㶞 㶟 㶠 㶡 㶢 㶣 㶤 㶥 㶦 㶧 㶨 㶩 㶪 㶫 㶬 㶭 㶮 㶯 㶰 㶱 㶲 㶳 㶴 㶵 㶶 㶷 㶸 㶹 㶺 㶻 㶼 㶽 㶾 㶿 㷀 㷁 㷂 㷃 㷄 㷅 㷆 㷇 㷈 㷉 㷊 㷋 㷌 㷍 㷎 㷏 㷐 㷑 㷒 㷓 㷔 㷕 㷖 㷗 㷘 㷙 㷚 㷛 㷜 㷝 㷞 㷟 㷠 㷡 㷢 㷣 㷤 㷥 㷦 㷧 㷨 㷩 㷪 㷫 㷬 㷭 㷮 㷯 㷰 㷱 㷲 㷳 㷴 㷵 㷶 㷷 㷸 㷹 㷺 㷻 㷼 㷽 㷾 㷿 㸀 㸁 㸂 㸃 㸄 㸅 㸆 㸇 㸈 㸉 㸊 㸋 㸌 㸍 㸎 㸏 㸐 㸑 㸒 㸓 㸔 㸕 㸖 㸗 㸘 㸙 㸚 㸛 㸜 㸝 㸞 㸟 㸠 㸡 㸢 㸣 㸤 㸥 㸦 㸧 㸨 㸩 㸪 㸫 㸬 㸭 㸮 㸯 㸰 㸱 㸲 㸳 㸴 㸵 㸶 㸷 㸸 㸹 㸺 㸻 㸼 㸽 㸾 㸿 㹀 㹁 㹂 㹃 㹄 㹅 㹆 㹇 㹈 㹉 㹊 㹋 㹌 㹍 㹎 㹏 㹐 㹑 㹒 㹓 㹔 㹕 㹖 㹗 㹘 㹙 㹚 㹛 㹜 㹝 㹞 㹟 㹠 㹡 㹢 㹣 㹤 㹥 㹦 㹧 㹨 㹩 㹪 㹫 㹬 㹭 㹮 㹯 㹰 㹱 㹲 㹳 㹴 㹵 㹶 㹷 㹸 㹹 㹺 㹻 㹼 㹽 㹾 㹿 㺀 㺁 㺂 㺃 㺄 㺅 㺆 㺇 㺈 㺉 㺊 㺋 㺌 㺍 㺎 㺏 㺐 㺑 㺒 㺓 㺔 㺕 㺖 㺗 㺘 㺙 㺚 㺛 㺜 㺝 㺞 㺟 㺠 㺡 㺢 㺣 㺤 㺥 㺦 㺧 㺨 㺩 㺪 㺫 㺬 㺭 㺮 㺯 㺰 㺱 㺲 㺳 㺴 㺵 㺶 㺷 㺸 㺹 㺺 㺻 㺼 㺽 㺾 㺿 㻀 㻁 㻂 㻃 㻄 㻅 㻆 㻇 㻈 㻉 㻊 㻋 㻌 㻍 㻎 㻏 㻐 㻑 㻒 㻓 㻔 㻕 㻖 㻗 㻘 㻙 㻚 㻛 㻜 㻝 㻞 㻟 㻠 㻡 㻢 㻣 㻤 㻥 㻦 㻧 㻨 㻩 㻪 㻫 㻬 㻭 㻮 㻯 㻰 㻱 㻲 㻳 㻴 㻵 㻶 㻷 㻸 㻹 㻺 㻻 㻼 㻽 㻾 㻿 㼀 㼁 㼂 㼃 㼄 㼅 㼆 㼇 㼈 㼉 㼊 㼋 㼌 㼍 㼎 㼏 㼐 㼑 㼒 㼓 㼔 㼕 㼖 㼗 㼘 㼙 㼚 㼛 㼜 㼝 㼞 㼟 㼠 㼡 㼢 㼣 㼤 㼥 㼦 㼧 㼨 㼩 㼪 㼫 㼬 㼭 㼮 㼯 㼰 㼱 㼲 㼳 㼴 㼵 㼶 㼷 㼸 㼹 㼺 㼻 㼼 㼽 㼾 㼿 㽀 㽁 㽂 㽃 㽄 㽅 㽆 㽇 㽈 㽉 㽊 㽋 㽌 㽍 㽎 㽏 㽐 㽑 㽒 㽓 㽔 㽕 㽖 㽗 㽘 㽙 㽚 㽛 㽜 㽝 㽞 㽟 㽠 㽡 㽢 㽣 㽤 㽥 㽦 㽧 㽨 㽩 㽪 㽫 㽬 㽭 㽮 㽯 㽰 㽱 㽲 㽳 㽴 㽵 㽶 㽷 㽸 㽹 㽺 㽻 㽼 㽽 㽾 㽿 㿀 㿁 㿂 㿃 㿄 㿅 㿆 㿇 㿈 㿉 㿊 㿋 㿌 㿍 㿎 㿏 㿐 㿑 㿒 㿓 㿔 㿕 㿖 㿗 㿘 㿙 㿚 㿛 㿜 㿝 㿞 㿟 㿠 㿡 㿢 㿣 㿤 㿥 㿦 㿧 㿨 㿩 㿪 㿫 㿬 㿭 㿮 㿯 㿰 㿱 㿲 㿳 㿴 㿵 㿶 㿷 㿸 㿹 㿺 㿻 㿼 㿽 㿾 㿿 ̀ ́ ͂ ̓ ̈́ ͅ ͆ ͇ ͈ ͉ ͊ ͋ ͌ ͍ ͎ ͏ ͐ ͑ ͒ ͓ ͔ ͕ ͖ ͗ ͘ ͙ ͚ ͛ ͜ ͝ ͞ ͟ ͠ ͡ ͢ ͣ ͤ ͥ ͦ ͧ ͨ ͩ ͪ ͫ ͬ ͭ ͮ ͯ Ͱ ͱ Ͳ ͳ ʹ ͵ Ͷ ͷ ͸ ͹ ͺ ͻ ͼ ͽ Ϳ ͇͈͉͍͎̀́͂̓̈́͆͊͋͌ͅ͏͓͔͕͖͙͚͐͑͒͗͛ͣͤͥͦͧͨͩͪͫͬͭͮͯ͘͜͟͢͝͞͠͡ͰͱͲͳʹ͵Ͷͷ͸͹ͺͻͼͽͿ͇͈͉͍͎̀́͂̓̈́͆͊͋͌ͅ͏͓͔͕͖͙͚͐͑͒͗͛ͣͤͥͦͧͨͩͪͫͬͭͮͯ͘͜͟͢͝͞͠͡ͰͱͲͳʹ͵Ͷͷ͸͹ͺͻͼͽ

EX. 5.2.

#1

x_i	a	b	c	d	e	f
$\deg x_i$	2	4	1	0	2	3
	even	even	odd	even	even	odd

odd vertices

$|\text{odd vertices}| = \text{even}$

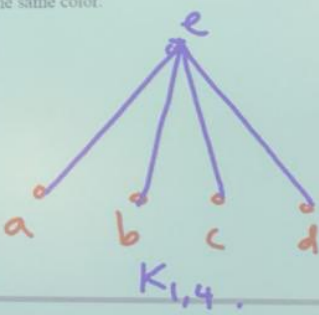
$$|V| = 6, \quad \sum_{i=1}^6 \deg x_i = 2+4+1+0+2+3 = 12 = 2|E|$$

G is a simple graph, Cause has no loops or multiple edges.

$$12 = 2|E| \Rightarrow |E| = 6$$


2. In Exercises (A) – (M) determine whether the graph is bipartite. You may find it useful to apply Theorem 4 and answer the question by determining whether it is possible to assign either red or blue to each vertex so that no two adjacent vertices are assigned the same color.

(A)



Math151 Disc Math (5.2) Graph Terminology and Special Types of Graphs By: Malek Zein AL-Abidin


(B)



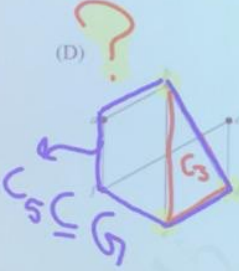
EX: 5.2
#1] X_1
deg x_1

odd (vertices)
 $|V| = 6$
 G is a
edges.

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(C)  $\because C_3 \subseteq G$ (C_3 is odd cycle)
 $\Rightarrow \therefore G$ is not bipartite.

b and f two adjacent vertices are assigned the same sign. $\therefore G$ is not a bipartite graph.

(D)  $C_3 \subseteq G$ (odd cycle) $\Rightarrow \therefore G$ is not bipartite.

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EX. 5.2.

#1

x_i	a_i
$\deg x_i$	2
	even

add (vertices)

$|V| = 6$

G is a simple graph.

3. Let G be a graph have 6 edges and the given degree sequence $1, 3, x, x$. find the value of x ?

$$\sum_{i=1}^n \deg v_i = 2|E| \Rightarrow 1 + 3 + x + x = 12$$

$$2x = 8 \Rightarrow x = 4$$

4. How many vertices does a regular graph of degree four with 10 edges have?

$$|E| = \frac{n \cdot r}{2} \Rightarrow n = \frac{2|E|}{r} = \frac{2(10)}{4} = 5$$

EX. 5.
#1] x
deg

add (ver
 $|V| = 6$

G is a
edges.

5. Can a simple graph exist with 15 vertices each of degree five? $r=5$

$\sum_{i=1}^n \deg v_i = 2|E|$ (even) | But here, we have

or $|E| = \frac{n \cdot r}{2} = \frac{75}{2} \notin \mathbb{N}$ | $\sum_{i=1}^{15} \deg v_i = \sum_{i=1}^{15} 5 = 75$ (odd)

6. How many vertices does a K_n graph with 10 edges have?

$|E(K_n)| = \frac{n(n-1)}{2}$

$10 = \frac{n(n-1)}{2} \Rightarrow n^2 - n - 20 = 0 \Rightarrow \boxed{n=5}$

7. Can a bipartite graph exist with 6 vertices and 10 edges?

$|V(K_{m,n})| = m+n = 6 \Rightarrow m = 6-n$

$|E(K_{m,n})| = m \cdot n = 10 \Rightarrow (6-n)n = 10 \Rightarrow n^2 - 6n + 10 = 0$

$\Delta = (-6)^2 - 4(10) = 36 - 40 = -4 < 0$

\therefore the eqn. has no sol. in \mathbb{N}

\Rightarrow D.N. Ex.

Ex. 5.2

#1

x_i	a_i
$\deg x_i$	2
	even

(odd vertices)

$|V| = 6$

G is a simple graph with 6 vertices and 10 edges.

8. Show that $K_{m,n}$ is regular if and only if $m = n$?

Sol. (i) $K_{m,n}$ is regular $\iff m = n$?

$K_{m,n} = (V_1 \cup V_2, E) : |V_1| = n, |V_2| = m.$

$\deg x = |V_2| = m \ \& \ \deg y = |V_1| = n.$
 $x \in V_1 \quad y \in V_2$

$\therefore K_{m,n}$ is regular $\Rightarrow \deg x = \deg y \Rightarrow m = n$

(ii) $m = n \Rightarrow K_{m,n}$ is regular?

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(5.2) Graph Terminology and Special Types of Graphs

By: Malek Zain AL-Abidin

9. If G is a simple regular graph of degree k with n vertices, show that k is even or n is even.

EX. 5.
 #1] $\frac{x}{\deg x}$
 odd (ver)
 $|V| = 6$
 G is a
 edges.

11. If $K_{3,n}$ have the same number of edges of K_n , find the value of n ?

$$\left. \begin{array}{l} |E(K_{3,n})| = 3n \\ |E(K_n)| = \frac{n(n-1)}{2} \end{array} \right\} 3n = \frac{n(n-1)}{2} \Rightarrow n-1=6 \\ \boxed{n=7}$$

12. Let G be a graph have 5 edges and the given degree sequence $2, 2, 2, 2, x$.
Decide whether G is a regular?

13. How many vertices does a regular graph of degree 3 with 10 edges have?

Ex. 5.2
#1] $\frac{x_i}{\deg x_i}$

|odd (vertices)|
 $|V| = 6$
 G is a
edges.

15. Let G be a graph have 10 edges with two vertices of 4 degrees each, and the degree of each vertex is equal to 3. Find the number of vertices

$$\sum_{i=1}^n \deg v_i = 2|E| \Rightarrow 2(4) + (n-2)(3) = 20$$

$$\boxed{n=6}$$

16. Let G be a graph have 11 edges and the given degree sequence $n, n, n, n, 2n, 2n, 3n$. find the value of n ?

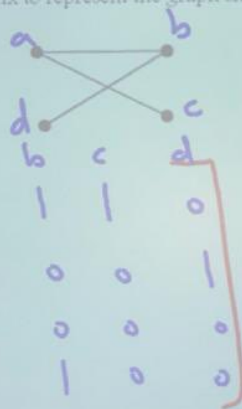
17. If $K_{m,n}$ have 42 vertices, find the number of edges?

Ex. 5.2
#1) x_i
 $\deg x_i$

add (vertices)
 $|V| = 6$

G is a $K_{m,n}$
edges.

24. Use an adjacency matrix to represent the graph shown in Figure



$$A = \begin{matrix} & \begin{matrix} a & b & c & d \end{matrix} \\ \begin{matrix} a \\ b \\ c \\ d \end{matrix} & \begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \end{matrix}$$

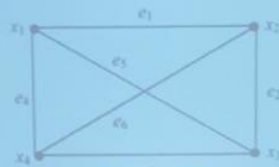
25. Draw a graph with the adjacency matrix, decide whether it is a complete graph?

$$\begin{bmatrix} 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 0 \end{bmatrix}$$

Ex 5
#1] deg

$|V| = 6$
G is a
edges.

26. Represent the graph shown in the Figure with an incidence matrix.



$$M = \begin{matrix} & \begin{matrix} e_1 & e_2 & e_3 & e_4 & e_5 & e_6 \end{matrix} \\ \begin{matrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{matrix} & \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 \end{bmatrix} \end{matrix}$$

27. Draw a graph with the incidence matrix, decide whether it is a regular graph?

EX. 5.2
#1 $\begin{matrix} x_i & a \\ \deg x_i & 2 \\ \text{even} \end{matrix}$

add (vertices)

$|V| = 6$

G is a simple graph with 6 vertices and 6 edges.

٢ ٣ ٤ ٥ ٦ ٧ ٨ ٩ ١٠ ١١ ١٢ ١٣ ١٤ ١٥

تمارين 151 رياض

نظرية الرسومات

GRAPH THEORY

~~(4-2)~~
(5, 3)

(الرسومات المتماثلة)

ISOMORPHIC GRAPHS

إعداد: مالك عبدالرحمن زين العابدين

1439 هـ

2018

SMART Board interface showing a graph theory presentation.

Graph G: A graph with 6 vertices labeled a, b, c, d, e, g . Edges connect $a-b, b-c, c-d, d-e, e-g, g-a$. There is also a diagonal edge $a-c$. A red arrow points to vertex a . A green highlight is on the edge $c-d$.

Graph H: A graph with 5 vertices labeled 1, 2, 3, 4, 5. Edges connect $1-2, 2-3, 3-4, 4-5, 5-1$. There is also a diagonal edge $1-3$. A green highlight is on the edge $2-3$.

Isomorphism: The graphs G and H are isomorphic, indicated by the symbol \cong .

Table:

x	a	b	c	d	e
$f(x)$	1	2	3	4	5

Text: نظرية الرسوم المتماثلة (مالك عبدالرحمن زين العابدين) جامعة الملك سعود - قسم الرياضيات

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Diagram (3): A graph with 3 vertices and 3 edges forming a triangle.

Handwritten notes on a chalkboard.

Ex. 5.2

#1] χ_x
deg x

add (vertices)

$|V| = 6$

G is a graph with 6 vertices and 5 edges.

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(3)

Cause G have 3 vertices of degree 2, but H have only 2 vertices of degree 2.

(4)

Cause G have two C_3 cycles, but there is only one C_3 in H .

(5)

(5)

Ex. 5.2
 #1] $\sum_{i=1}^n \deg v_i$
 add (very)
 $|V| = 6$
 G is a
 edges.

151 ريش نظرية الرسوم (الرسوم المتماثلة) مالك عبدالرحمن زين العالدين (جامعة الملك سعود - قسم الرياضيات)

س2: عين جميع الرسوم التفاضلية للجزءة الثمانية غير المتماثلة و التي عدد رؤوس كل منها 7 ؟

Q. List all nonisomorphic complete bipartite graphs with 7 total vertices ?

$$|V(K_{m,n})| = m+n = 7$$

$$1+6 = 7 \Rightarrow K_{1,6} \neq$$

$$2+5 = 7 \Rightarrow K_{2,5} \neq$$

$$3+4 = 7 \Rightarrow K_{3,4} \neq$$

من 3: إذا كان G رسماً بسيطاً عدد رؤوسه n فالتب أن $|E| + |\bar{E}| = \frac{n(n-1)}{2}$

Sol. $G \cup \bar{G} \cong K_n \Rightarrow |E| + |\bar{E}| = |E(K_n)| = \frac{n(n-1)}{2}$

من 4: عين جميع الرسوم البسيطة ذاتية التتبع التي عدد رؤوس كل منها 5.

Q. Set all simple self complementary graphs with 5 vertices

Ex. 5.2

#1 X_i

$\deg x_i$

$\{ \text{add}(\text{vertex})$

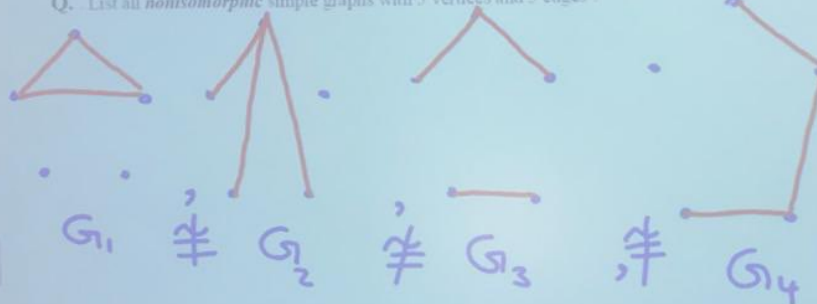
$|V| = 6$

G is a \bar{G}

edges.

س: عين جميع الرسومات البسيطة غير المتماثلة التي عند رؤوس كل منها 5 و عدد أضلاع كل منها 3.

Q. List all **nonisomorphic** simple graphs with 5 vertices and 3 edges?



من: إذا كان G رسمًا بيانيًا عدد رؤوسه n و عدد أضلاعه 56 و كان عدد أضلاع \bar{G} هو 80 فأوجد n .

Q. Let G be a simple graph with n vertices and 56 edges. If \bar{G} have 80 edges. find the value of n ?

$$|E| + |\bar{E}| = \frac{n(n-1)}{2} \Rightarrow 56 + 80 = \frac{n(n-1)}{2}$$

$$n^2 - n - 172 = 0$$

$$(n-17)(n+16) = 0$$

$$\therefore n = 17.$$

من: 7: جد مع التعليل عدد أضلاع الرسم المتمم للرسم $K_{10,14}$.

Q. Find the number of edges for the complementary graph of $K_{10,14}$. Explain the answer?

EX. 5.2
#1

x_i	a_i
$\deg x_i$	2
	Even

$|V| = 6$
 $|E| = 6$
 G is a simple graph with 6 vertices and 6 edges.

Q. Find the number of edges for the complementary graph of $K_{10,14}$. Explain the answer?

$$|E| + |\bar{E}| = \frac{|V|(|V|-1)}{2}$$

$$|E(K_{10,14})| + |E(\bar{K}_{10,14})| = \frac{(10+14)(10+14-1)}{2}$$

$$(10)(14) + |E(\bar{K}_{10,14})| = (12)(23) \Rightarrow |E(\bar{K}_{10,14})| = 276 - 140 = 136$$

س: عين جميع الرسوم البيانية البسيطة غير المتماثلة التي عدد رؤوس كل منها 4 و عدد أضلاع كل منها 3.

Q. List all *nonisomorphic* simple graphs with 4 vertices and 3 edges?

Ex. 5.2
#1 χ
deg.

add (vertices)

$$|V| = 6$$

G is a \dots
edges.

من: هل يوجد رسم G له 7 أضلاع و يحقق $G \cong \bar{G}$ ؟ وضح إجابتك.

Q. Is there exist a graph G with 7 edges satisfies $\bar{G} \cong G$? explain the answer.

Sol. $\because G \cong \bar{G}$ (self complementary) \Rightarrow

$$|E| = |\bar{E}| = 7 \Rightarrow |E| + |\bar{E}| = 7 + 7 = \frac{n(n-1)}{2}$$

$$n^2 - n - 28 = 0 \quad \Delta = (-1)^2 - 4(1)(-28) = 1 + 112 = 113$$

من: إذا كان G رسماً بسيطاً درجات رؤوسه 2, 2, 2, 3, 3, 4 فأوجد عدد أضلاع \bar{G} (الرسم المتمم).

* Q. Let G be a graph with the degree sequence 2, 2, 2, 3, 3, 4. Find the number of edges of \bar{G} ?

Sol. $|E| + |\bar{E}| = \frac{n(n-1)}{2}$

$$\frac{2+2+2+3+3+4}{2} + |\bar{E}| = \frac{6(5)}{2} = 15 \Rightarrow |\bar{E}| = 7$$

من: إذا كان G رسماً بسيطاً عدد رؤوسه 11 و عدد أضلاعه 5، فجد ضعف عدد أضلاع الرسم المتمم \bar{G} .

Q. Let G be a graph with n vertices and 5 edges. find the double edges of \bar{G} ?

DN. Ex.

Ex. #1

odd

$|V| =$

G is edges