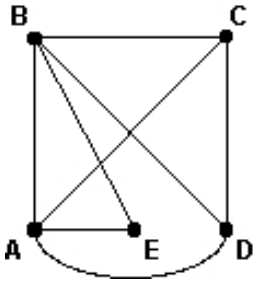
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Name:_____ Class:_____ Date:_____

Chapter 1

1. How many vertices in the graph below have odd valences?



a. 0

b. 1

c. 2

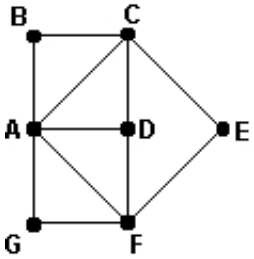
d. 4

ANSWER: c

2. On a graph that represents six cities and the roads between them, the valence of vertex A is 4. What does this mean in real-world terms?

ANSWER: If the valence of vertex A is 4, it means there are four roads that lead to town A.

3. How many vertices in the graph below have even valences?



a. 3

b. 5

c. 7

d. 11

ANSWER: b

4. A graph that represents six cities and the roads among them is connected. What does this mean in real-world terms?

ANSWER: Any pair of two cities has at least one connecting path of roads.

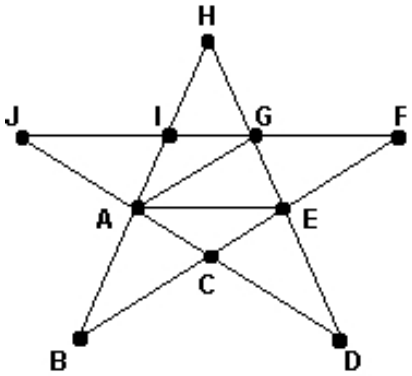
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Chapter 1

5. What is the valence of vertex *A* in the graph below?



a. 3

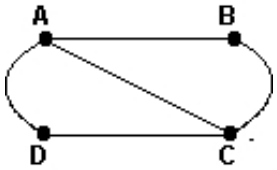
b. 4

c. 5

d. 6

ANSWER: d

6. What is the valence of vertex *A* in the graph below?



a. 3

b. 4

c. 5

d. 6

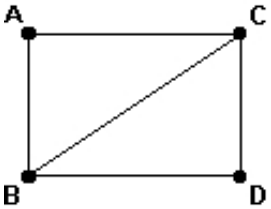
ANSWER: a

7. Describe the two conditions for a graph to have an Euler circuit.

ANSWER: The graph must be connected and have all valences even.

8. Draw a graph representing four cities, *A, B, C,* and *D,* with a road that connects each pair of cities given: *AB, AC, BC, BD, CD*.

ANSWER:



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Chapter 1

9. What is the valence of vertex *A* in the graph below?



a. 0

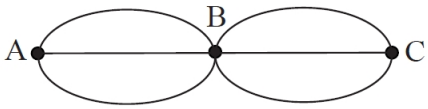
b. 1

c. 2

d. 3

ANSWER: a

10. What is the valence of vertex *B* in the graph below?



a. 3

b. 4

c. 5

d. 6

ANSWER: d

11. Which of the following defines the *valence of vertex A* of a graph?

a. The total number of vertices of the graph

b. The number of edges meeting at vertex *A*

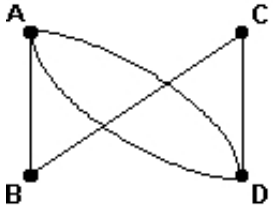
c. The total number of edges of the graph

d. None of the above

ANSWER: b

12. Draw a graph with vertices *A, B, C,* and *D* in which the valence of vertices *A* and *D* is 3 and the valence of vertices *B* and *C* is 2.

ANSWER: Answers may vary. One solution is:

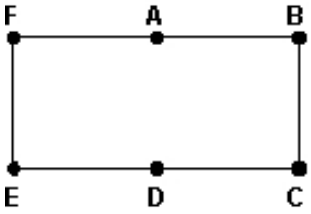


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13. What is the sum of all valences of the graph shown below?



a. 6

b. 10

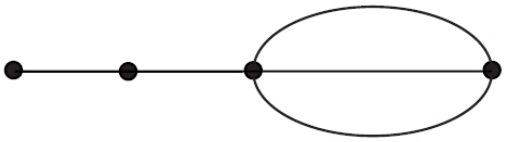
c. 12

d. 8

ANSWER: d

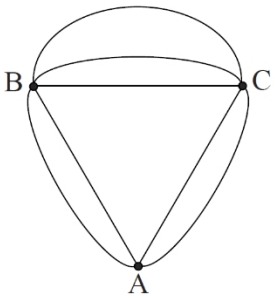
14. Draw a graph that has four vertices, with valences 1, 2, 3, and 4.

ANSWER:

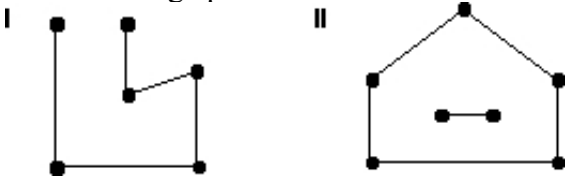


15. Draw a graph with vertices *A, B,* and *C* in which vertex *A* has valence 4 and vertices *B* and *C* have valence 5.

ANSWER:



16. Which of the graphs below are connected?



a. I only

b. II only

c. Both I and II

d. Neither I nor II

ANSWER: a

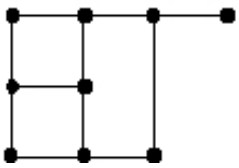
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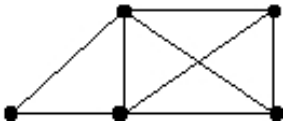
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Chapter 1

17. Which of the graphs below are connected?

I 

II 

a. I only

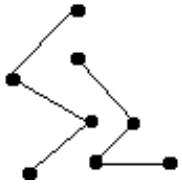
b. II only

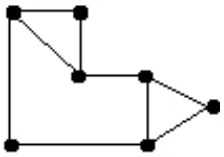
c. Both I and II

d. Neither I nor II

ANSWER: c

18. Which of the graphs below are connected?

I 

II 

a. I only

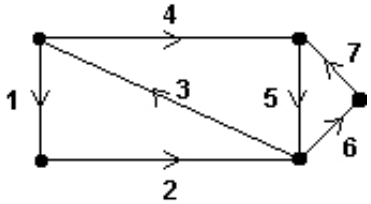
b. II only

c. Both I and II

d. Neither I nor II

ANSWER: b

19. Consider the path represented by the sequence of numbered edges on the graph below. Explain why the path is *not* an Euler circuit.



ANSWER: The path is not an Euler circuit because it does not start and stop at the same vertex.

20. Which of the following statements about a connected graph is always true?

a. Every pair of vertices is joined by a single edge.

b. A path of edges exists between any two vertices of the graph.

c. There is an even number of vertices on the graph.

d. There is an even number of edges on the graph.

ANSWER: b

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21. A graph that is not connected must have at least one vertex with valence 0.
    a. True
    b. False

    ANSWER: b

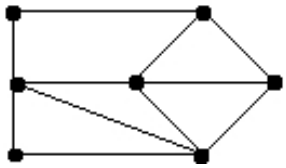
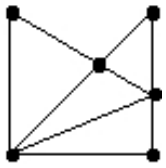
22. If a graph of four vertices has a vertex with valence 0, then the graph is not connected.
    a. True
    b. False

    ANSWER: a

23. If a graph of six vertices is connected, then there are at least five edges.
    a. True
    b. False

    ANSWER: a

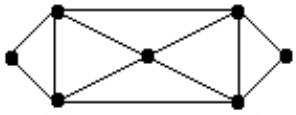
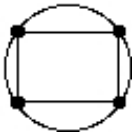
24. Which of the graphs below have Euler circuits?

I  II 

    a. I only
    b. II only
    c. Both I and II
    d. Neither I nor II

    ANSWER: b

25. Which of the graphs below have Euler circuits?

I  II 

    a. I only
    b. II only
    c. Both I and II
    d. Neither I nor II

    ANSWER: c

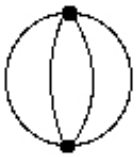
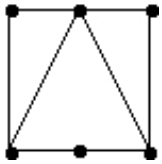
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26. Which of the graphs below have Euler circuits?

I  II 

a. I only

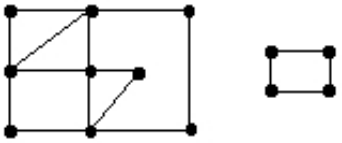
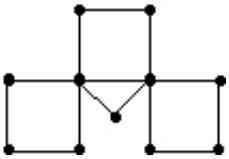
b. II only

c. Both I and II

d. Neither I nor II

ANSWER: a

27. Which of the graphs below have Euler circuits?

I  II 

a. I only

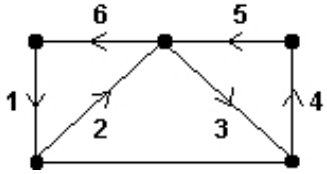
b. II only

c. Both I and II

d. Neither I nor II

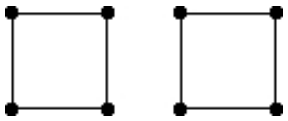
ANSWER: d

28. Consider the path represented by the sequence of numbered edges on the graph below. Explain why the path is *not* an Euler circuit.



ANSWER: The path is not an Euler circuit because it does not cover every edge of the graph.

29. Draw a graph with eight vertices, with the valence of each vertex being even, that does *not* have an Euler circuit.

ANSWER: Answers may vary. One solution is: 

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30. Which of the graphs below have Euler circuits?

I II



a. I only

b. II only

c. Both I and II

d. Neither I nor II

ANSWER: d

31. An Euler circuit of a graph passes through each vertex exactly once.

a. True

b. False

ANSWER: b

32. Every graph with an Euler circuit has an even number of edges.

a. True

b. False

ANSWER: b

33. Every graph that has an Euler circuit is connected.

a. True

b. False

ANSWER: a

34. Every connected graph has an Euler circuit.

a. True

b. False

ANSWER: b

35. Every graph with an Euler circuit has only vertices with even valences.

a. True

b. False

ANSWER: a

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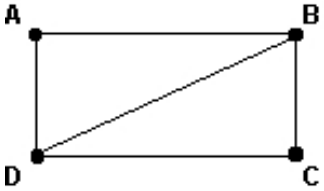
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Chapter 1

36. It is possible for a graph with all vertices of even valence to NOT have an Euler circuit.
    a. True
    b. False

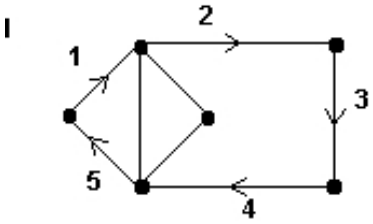
    ANSWER: a

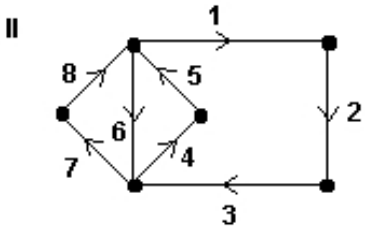
37. Explain why the graph shown below does *not* have an Euler circuit.



    ANSWER: The graph does not have an Euler circuit because the valences of vertex *B* and vertex *D* are odd.

38. Consider the paths represented by the numbered sequence of edges on the graphs below. Which path represents an Euler circuit?

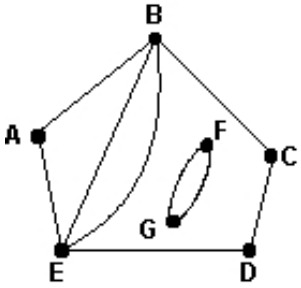




    a. I only
    b. II only
    c. Both I and II
    d. Neither I nor II

    ANSWER: b

39. Explain why the graph shown below does *not* have an Euler circuit.



    ANSWER: The graph does not have an Euler circuit because it is not connected.

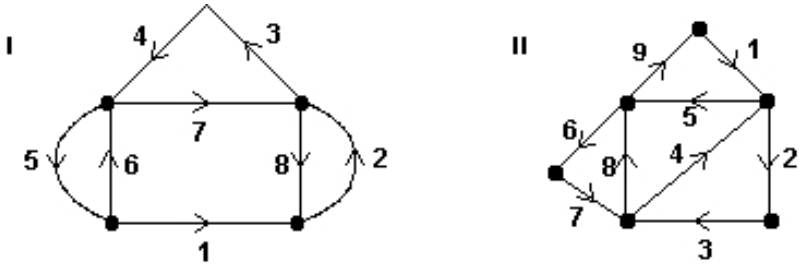
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40. Consider the paths represented by the numbered sequence of edges on the graphs below. Which path represents an Euler circuit?



a. I only

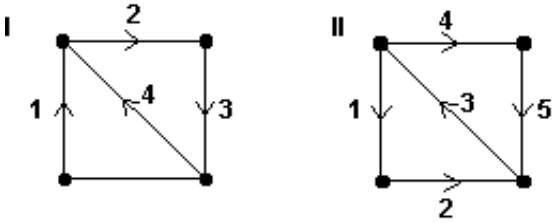
b. II only

c. Both I and II

d. Neither I nor II

ANSWER: b

41. Consider the paths represented by the numbered sequence of edges on the graphs below. Which path represents an Euler circuit?



a. I only

b. II only

c. Both I and II

d. Neither I nor II

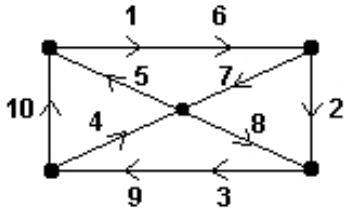
ANSWER: d

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42. Consider the path represented by the sequence of numbered edges on the graph below. Why does the path NOT represent an Euler circuit?



a. The path does not start and stop at the same vertex.

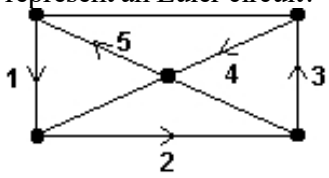
b. The path does not cover every edge of the graph.

c. The path uses some edges more than one time.

d. The path does not touch each vertex of the graph.

ANSWER: c

43. Consider the path represented by the sequence of numbered edges on the graph below. Why does the path *not* represent an Euler circuit?



a. The path does not start and stop at the same vertex.

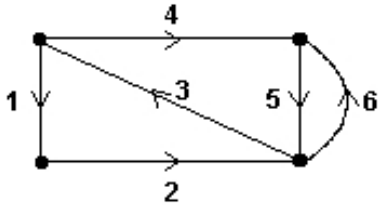
b. The path does not cover every edge of the graph.

c. The path uses some edges more than one time.

d. The path does not touch each vertex of the graph.

ANSWER: b

44. Consider the path represented by the numbered sequence of edges of the graph below. Which statement is true?



a. The path is not a circuit.

b. The path is an Euler circuit.

c. The path is a circuit but not an Euler circuit.

d. None of the above.

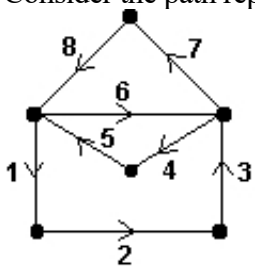
ANSWER: a

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45. Consider the path represented by the numbered sequence of edges on the graph below. Which statement is true?



a. The path is not a circuit.

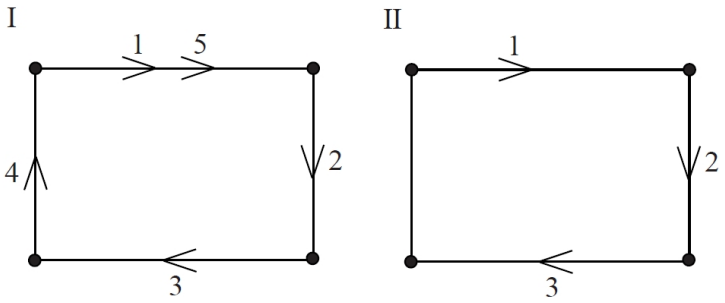
b. The path is an Euler circuit.

c. The path is a circuit but not an Euler circuit.

d. None of the above.

ANSWER: b

46. Consider the paths represented by the numbered sequence of edges on the graphs below. Which path represents an Euler circuit?



a. I only

b. II only

c. Both I and II

d. Neither I nor II

ANSWER: d

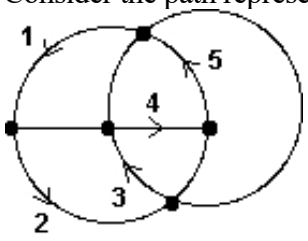
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47. Consider the path represented by the numbered sequence of edges on the graph below. Which statement is true?



a. The path is not a circuit.

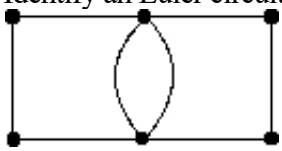
b. The path is an Euler circuit.

c. The path is a circuit but not an Euler circuit.

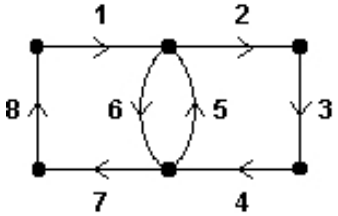
d. None of the above.

ANSWER: c

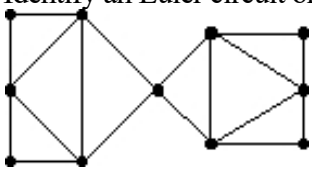
48. Identify an Euler circuit on the following graph by numbering the sequence of edges in the order traveled.



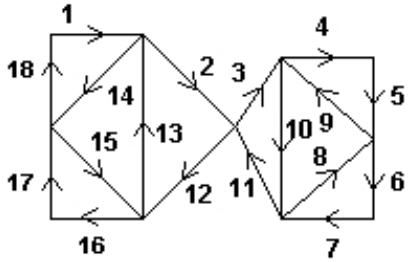
ANSWER: Answers may vary. One solution is:



49. Identify an Euler circuit on the following graph by numbering the sequence of edges in the order traveled.



ANSWER: Answers may vary. One solution is:

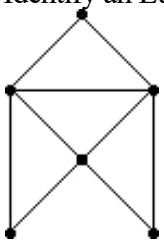


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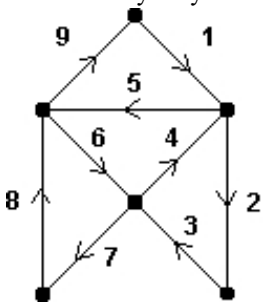
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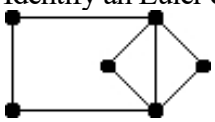
50. Identify an Euler circuit on the following graph by numbering the sequence of edges in the order traveled.



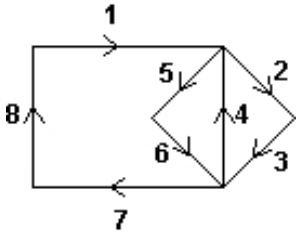
ANSWER: Answers may vary. One solution is:



51. Identify an Euler circuit on the following graph by numbering the sequence of edges in the order traveled.



ANSWER: Answers may vary. One solution is:



52. For which of the two situations below is it desirable to find an Euler circuit or an efficient eulerization of a graph?
I. A pizza delivery person takes pizzas to 10 houses in a neighborhood and then returns to pick up the next set to be delivered.
II. A postal carrier picks up mail from six collection boxes around a city.

a. I only

b. II only

c. Both I and II

d. Neither I nor II

ANSWER: d

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53. For which of the two situations below is it desirable to find an Euler circuit or an efficient eulerization of a graph?
I. After a storm, a health department worker inspects all the houses of a small village to check for damage.
II. A veteran planning a visit to all the war memorials in Washington, D.C., plots a route to follow.

a. I only

b. II only

c. Both I and II

d. Neither I nor II

ANSWER: d

54. For which of the two situations below is it desirable to find an Euler circuit or an efficient eulerization of a graph?
I. A street department employee must check the traffic signals at each intersection in a downtown area to be certain they are working.
II. An employee of a power company reads the electric meters outside each house along the streets in a residential area.

a. I only

b. II only

c. Both I and II

d. Neither I nor II

ANSWER: b

55. For which of the two situations below is it desirable to find an Euler circuit or an efficient eulerization of a graph?
I. Plowing the streets of a small village after a snow.
II. Painting the lines down the center of the roads in a town with only two-way roads.

a. I only

b. II only

c. Both I and II

d. Neither I nor II

ANSWER: c

56. After a major natural disaster, such as a flood, hurricane, or tornado, many tasks need to be completed as efficiently as possible. For which situation below would finding an Euler circuit or an efficient eulerization of a graph be the appropriate mathematical technique to apply?

a. Relief food supplies must be delivered to eight emergency shelters located at different sites in a large city.

b. The Department of Public Works must inspect traffic lights at intersections in the city to determine which are still working.

c. An insurance claims adjuster must visit 10 homes in various neighborhoods to write reports.

d. The Department of Public Works must inspect all streets in the city to remove dangerous debris.

ANSWER: d

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57. After a major natural disaster, such as a flood, hurricane, or tornado, many tasks need to be completed as efficiently as possible. For which situation below would finding an Euler circuit or an efficient eulerization of a graph be the appropriate mathematical technique to apply?

a. The electric company must check several substations for malfunctions.

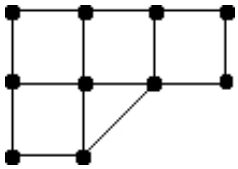
b. The gas company must check along all gas lines for possible leaks.

c. The phone company must respond to customers' needs in several parts of town.

d. The water company must spot-check the integrity of eight water towers located throughout the city.

ANSWER: b

58. In order to eulerize the graph below, give the fewest number of edges that need to be duplicated.



a. 1

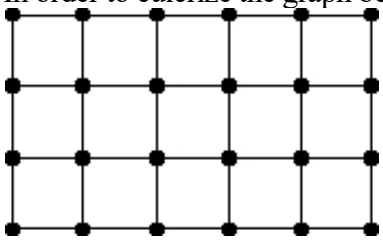
b. 2

c. 3

d. 4

ANSWER: c

59. In order to eulerize the graph below, give the fewest number of edges that need to be duplicated.



a. 4

b. 6

c. 10

d. 12

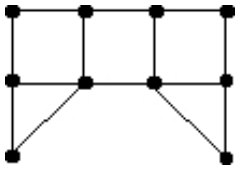
ANSWER: b

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60. In order to eulerize the graph below, give the fewest number of edges that need to be duplicated.



a. One

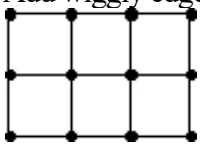
b. Two

c. Three

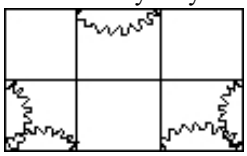
d. Four

ANSWER: d

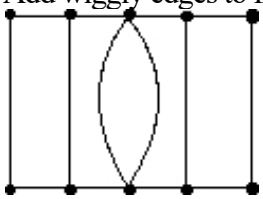
61. Add wiggly edges to find an efficient eulerization of the following graph.



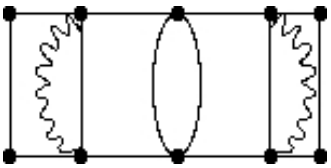
ANSWER: Answers may vary. One solution is:



62. Add wiggly edges to find an efficient eulerization of the following graph.



ANSWER: Answers may vary. One solution is:



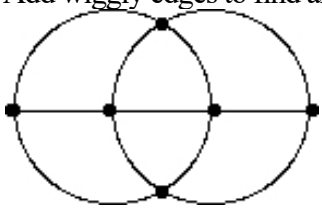
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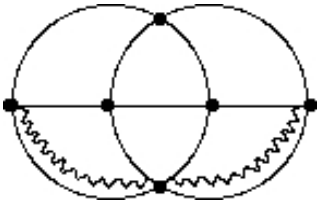
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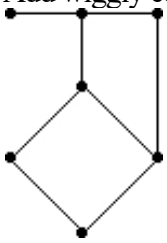
63. Add wiggly edges to find an efficient eulerization of the following graph.



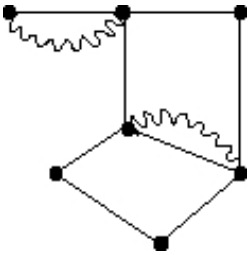
ANSWER: Answers may vary. One solution is:



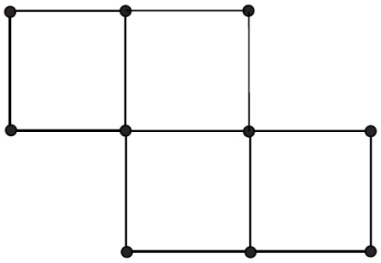
64. Add wiggly edges to find an efficient eulerization of the following graph.



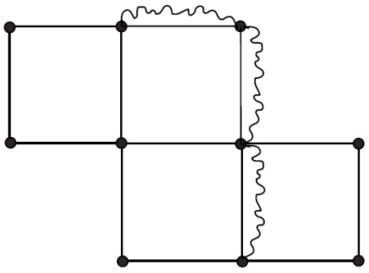
ANSWER: Answers may vary. One solution is:



65. Add wiggly edges to find an efficient eulerization of the following graph.



ANSWER: Answers may vary. One solution is:

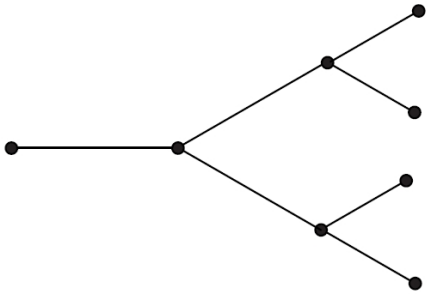


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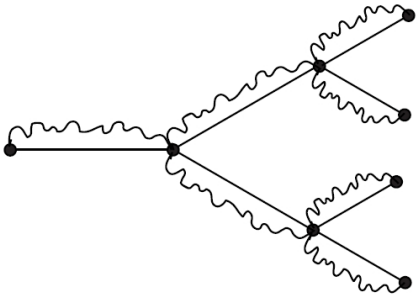
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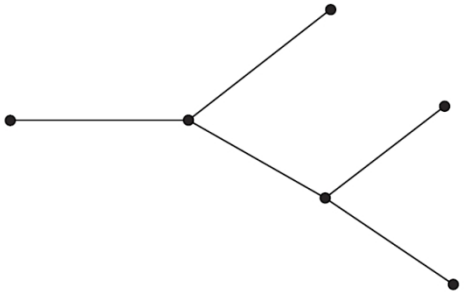
66. Add wiggly edges to find an efficient eulerization of the following graph.



ANSWER: Answers may vary. One solution is:



67. In order to eulerize the graph below, give the fewest number of edges that need to be added or duplicated.



a. Three

b. Four

c. Five

d. Six

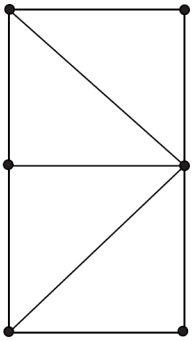
ANSWER: c

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68. In order to eulerize the graph below, give the fewest number of edges that need to be added or duplicated.



a. Two

b. Three

c. Four

d. Five

ANSWER: b

69. If a graph had eight vertices of odd valence, what is the absolute minimum number of edges that would need to be duplicated to eulerize the graph?

a. Two

b. Four

c. Six

d. Eight

ANSWER: b

70. If a graph had four vertices of odd valence, then we can duplicate two edges to eulerize the graph.

a. True

b. False

ANSWER: b

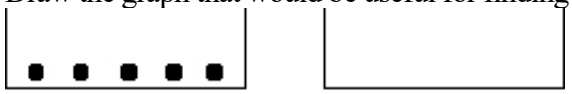
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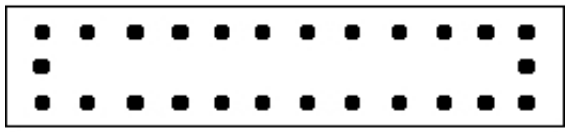
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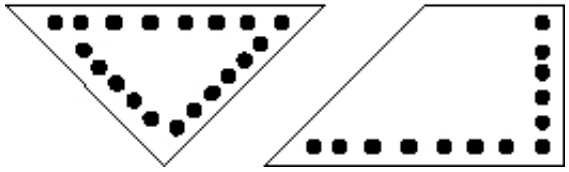
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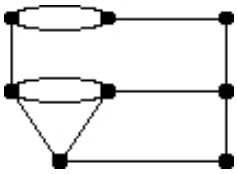
71. The map below gives the territory of a parking control officer. The dots represent meters that must be checked. Draw the graph that would be useful for finding an efficient route.



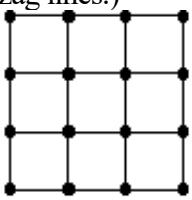




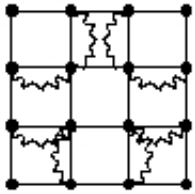
ANSWER:



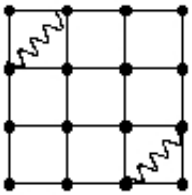
72. Which of the graphs shown below gives the best eulerization of the given graph? (In the graphs below, added edges are denoted with zigzag lines.)



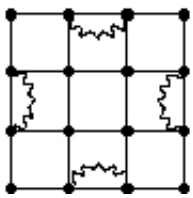
a.



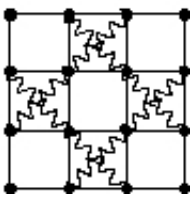
b.



c.



d.



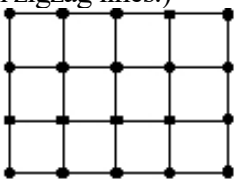
ANSWER: Graph C

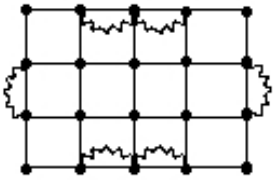
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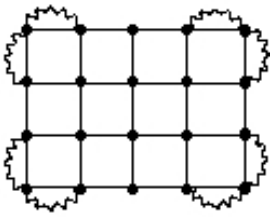
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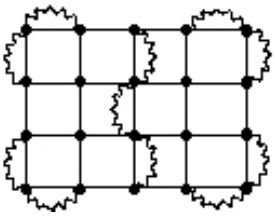
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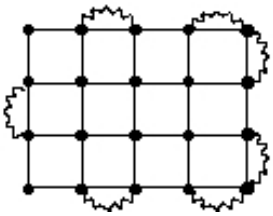
73. Which of the graphs shown below gives the best eulerization of the given graph? (In the graphs below, added edges are denoted with zigzag lines.)



a. 

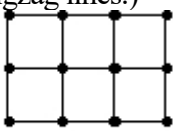
b. 

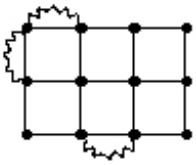
c. 

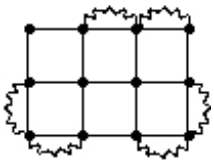
d. 

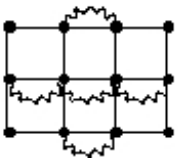
ANSWER: Graph D

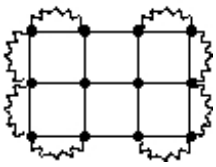
74. Which of the graphs shown below gives the best eulerization of the given graph? (In the graphs below, added edges are denoted with zigzag lines.)



a. 

b. 

c. 

d. 

ANSWER: Graph C

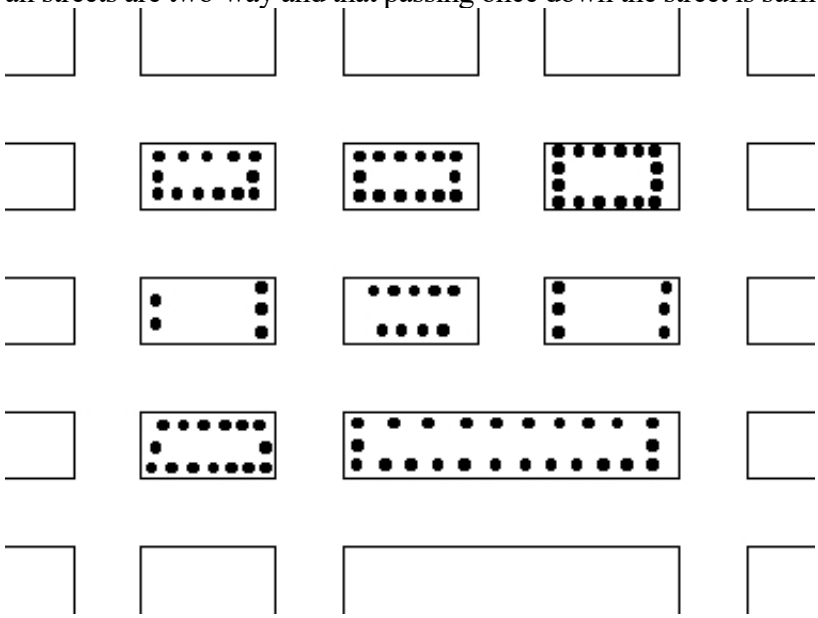
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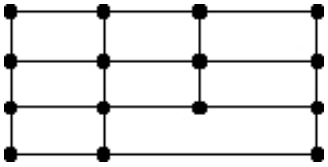
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Chapter 1

75. For the street network shown below, draw a graph that would be useful for routing a garbage truck. Assume that all streets are two-way and that passing once down the street is sufficient for collecting trash from both sides.



ANSWER:

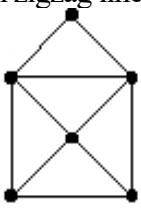


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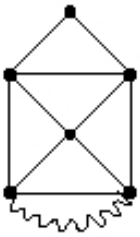
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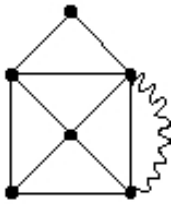
76. Which of the graphs shown below gives the best eulerization of the given graph? (In the graphs below, added edges are denoted with zigzag lines.)



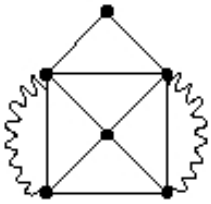
a.



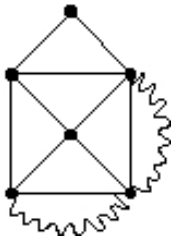
b.



c.

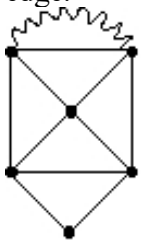


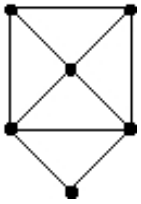
d.



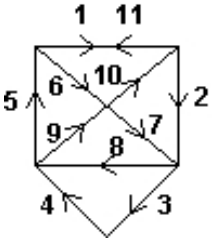
ANSWER: Graph A

77. Find an Euler circuit on the graph on the left and use it to find a circuit on the graph on the right that reuses one edge.





ANSWER: Answers may vary. One solution is:

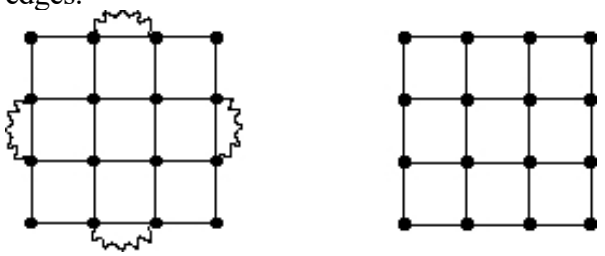


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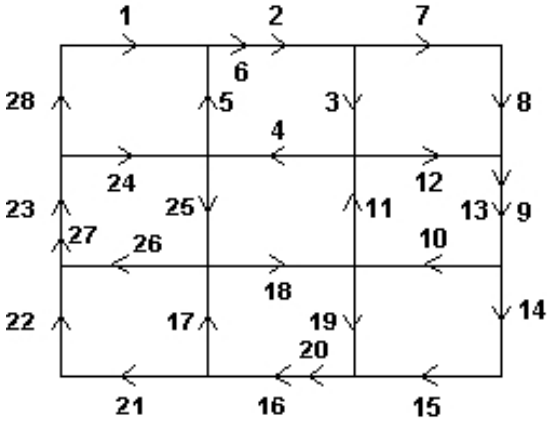
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78. Find an Euler circuit on the graph on the left and use it to find a circuit on the graph on the right that reuses four edges.



ANSWER: Answers may vary. One solution is:



79. Suppose that the edges of a graph represent streets that must be checked by a worker from the Department of Public Works. In order to eulerize the graph, we must add three edges. The real-world interpretation of this is:

a. we must travel three blocks twice in our circuit.

b. the street department will build three new streets.

c. three blocks will not be checked by the Department of Public Works.

d. it will take three workers to check all the streets in the city.

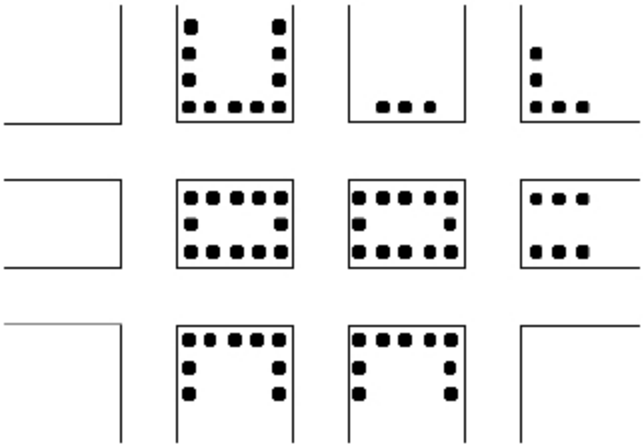
ANSWER: a

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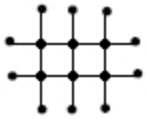
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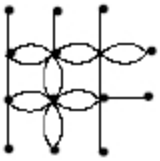
80. The map shown below illustrates part of a postal carrier's territory. The dots indicate mailboxes to which mail must be delivered. Which graph would be most useful for finding an efficient route for mail delivery?



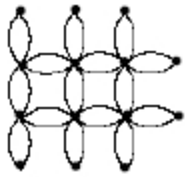
a.



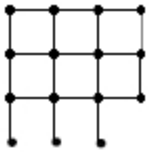
b.



c.

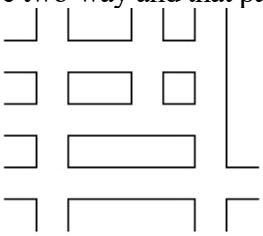


d.

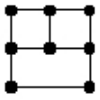


ANSWER: Graph B

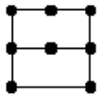
81. For the street network shown below, which graph would be most useful for routing a garbage truck? Assume that all streets are two-way and that passing down a street once would be sufficient to collect from both sides.



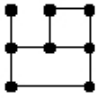
a.



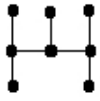
b.



c.



d.



ANSWER: Graph A

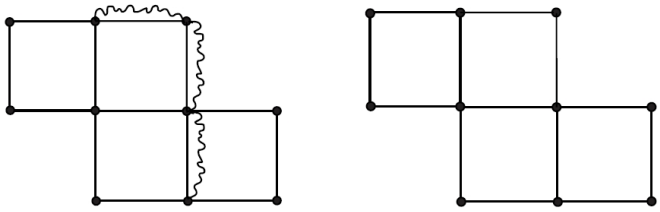
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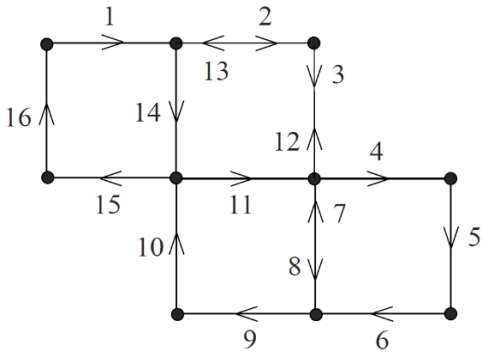
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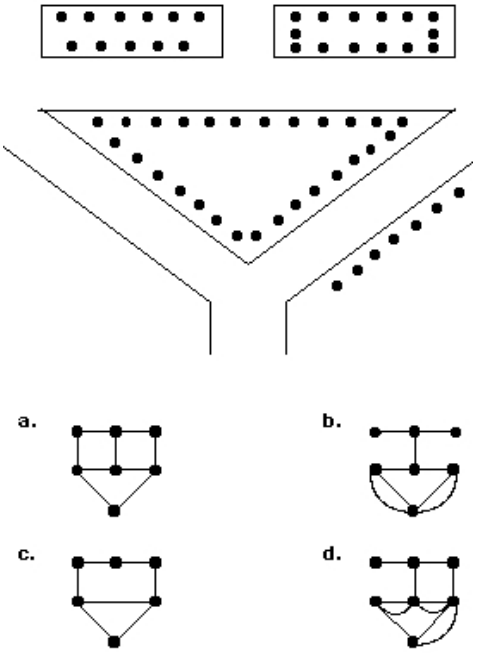
82. Find an Euler circuit on the graph on the left and use it to find a circuit on the graph on the right that reuses three edges.



ANSWER: Answers may vary. One solution is:



83. The map below shows the territory for a parking control officer. The dots represent parking meters that need to be checked. Which graph would be useful for finding an efficient route?



ANSWER: Graph D

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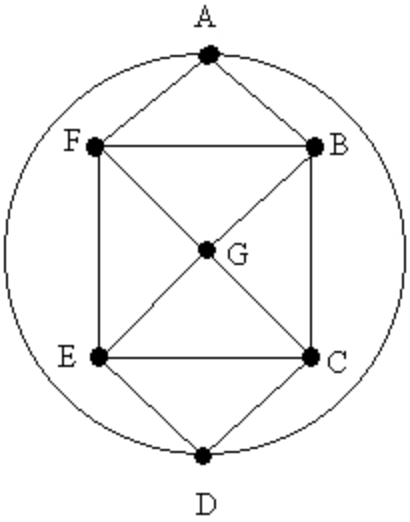
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84. Give three real-world applications in which a worker would want to find an Euler circuit on a street network.

ANSWER: Answers may vary. Some situations include:
Plowing snow
Painting lines down the center of streets
Collecting trash
Checking gutters on the corners of all streets
Checking parking meters along the edge of all streets
Delivering mail to all houses on all streets

85. In the graph below, find the largest number of paths from *A* to *G* that do not have any edges in common.



a. Two
b. Three
c. Four
d. Five

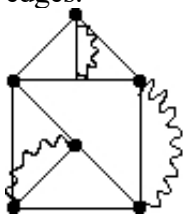
ANSWER: c

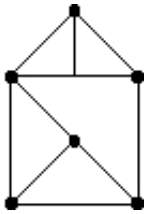
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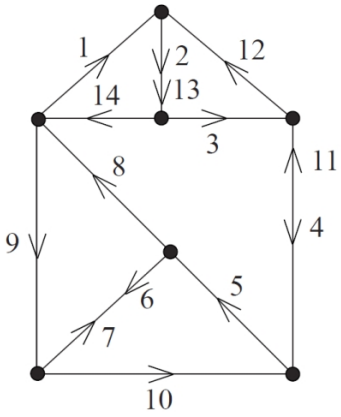
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86. Find an Euler circuit on the graph on the left and use it to find a circuit on the graph on the right that reuses three edges.





ANSWER: Answers may vary. One solution is:



87. It is possible to construct a graph such that the sum of all valences is odd.
    a. True
    b. False

    ANSWER: b

88. A graph must have even number of vertices of odd valence.
    a. True
    b. False

    ANSWER: a

89. Why would a city street department want its snowplow operator's path to follow an Euler circuit if possible?

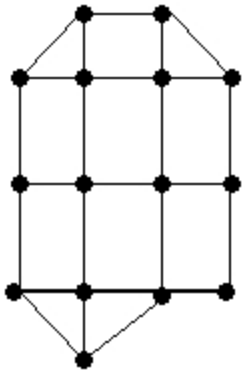
    ANSWER: If the snowplow operator followed an Euler circuit, he would end his route at the city garage where he started. Also, no time or gas would be wasted traveling down streets that were already plowed.

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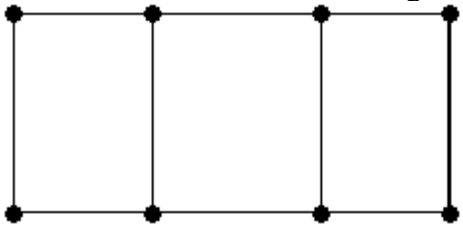
90. In order to eulerize the graph below, give the fewest number of edges that need to be added or duplicated.



a. Two
b. Three
c. Four
d. Five

ANSWER: c

91. What is the smallest number of edges that would need to be removed to disconnect the graph below?



a. One
b. Two
c. Three
d. Four

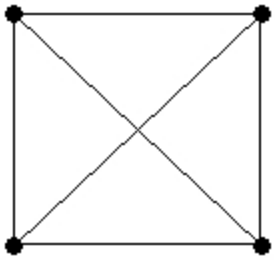
ANSWER: b

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92. What is the smallest number of edges that would need to be removed to disconnect the graph below?



a. One

b. Two

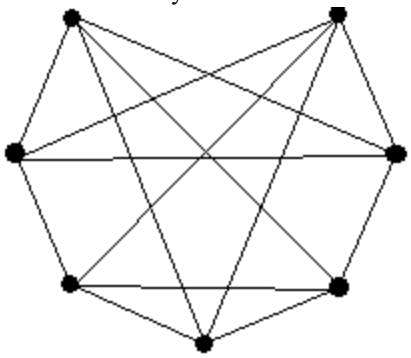
c. Three

d. Four

ANSWER: c

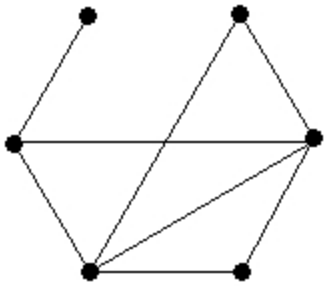
93. Draw a connected graph with seven vertices where each vertex has valence 4.

ANSWER: Answers will vary. One solution is:



94. Draw a graph with six vertices where the valences are 1, 2, 2, 3, 4, and 4.

ANSWER: Answers will vary. One solution is:



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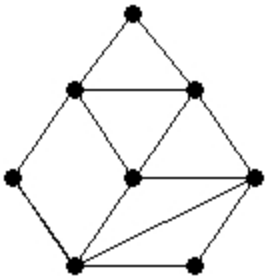
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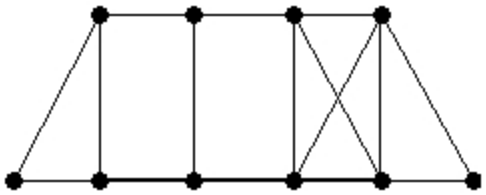
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95. Which of the graphs below have Euler circuits?

I



II



a. I only

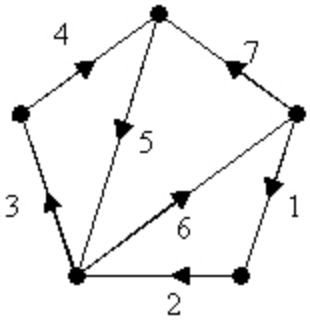
b. II only

c. Both I and II

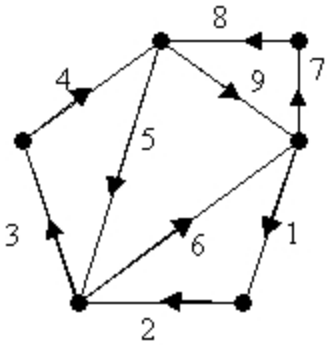
d. Neither I nor II

ANSWER: a

96. Consider the path represented by the numbered sequences of edges in the graph below. Which path represents an Euler circuit?



I



II

a. I only

b. II only

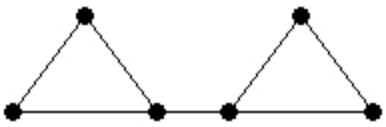
c. Both I and II

d. Neither I nor II

ANSWER: b

97. Draw a graph where every vertex has a valence of at least 2 but removing a single edge disconnects the graph.

ANSWER: Answers will vary. One solution is:

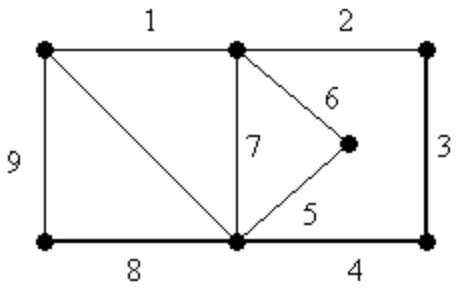


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98. Consider the path represented by the numbered sequences of edges in the graph below. Which statement is true?



a. The path is not a circuit.

b. The path is an Euler circuit.

c. The path is a circuit but not an Euler circuit.

d. None of the above.

ANSWER: c

99. If a graph had 16 vertices of odd valence, what is the absolute minimum number of edges that would need to be added (duplicated) to eulerize the graph?

a. Two

b. Four

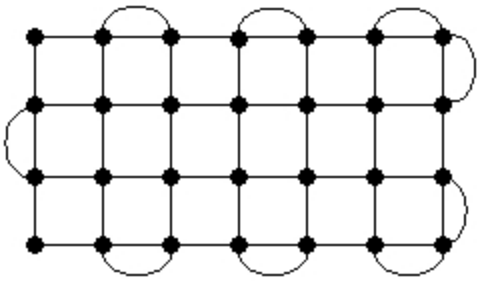
c. Six

d. Eight

ANSWER: d

100. Find an eulerization with nine added edges for a 3 × 6-block rectangular street network.

ANSWER:



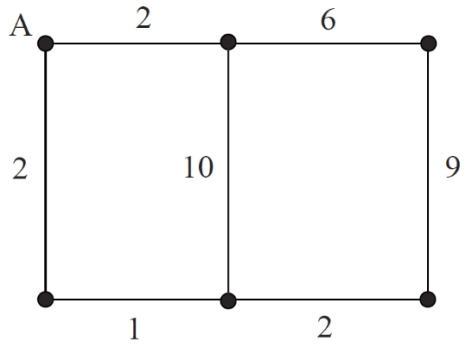
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101. The cost of a route is computed by summing the numbers along the edges used. Consider the weighted graph below.



The cheapest route starting and ending at *A* and traversing each edge at least once has what cost? (You are allowed to visit *A* between the start and end of the route.)

a. 20

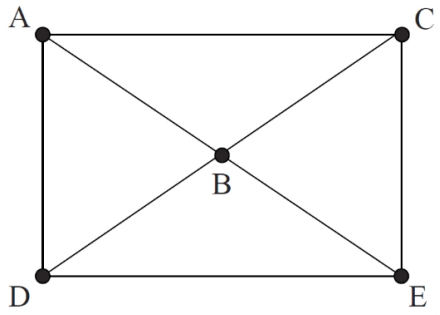
b. 28

c. 37

d. 42

ANSWER: c

102. Find the largest number of paths from *A* to *B* that do not have any edges in common.



a. One

b. Two

c. Three

d. Four

ANSWER: c

103. Is it possible to have a connected graph with seven vertices and seven edges?

a. Yes

b. No

ANSWER: a

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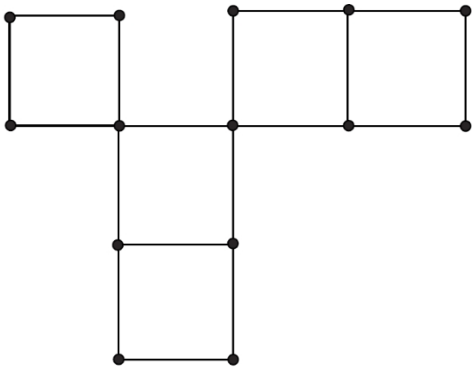
104. Can a graph with five vertices have vertices with valences 1, 2, 3, 4, and 5?
    a. Yes
    b. No

    ANSWER: b

105. A graph has four vertices, two with valence 3 and two with valence 4. How many edges does it have?
    a. Five
    b. Six
    c. Seven
    d. Eight

    ANSWER: c

106. Find the minimum number of edges that must be duplicated to create the best possible eulerization of this graph.



    a. One
    b. Two
    c. Three
    d. Four

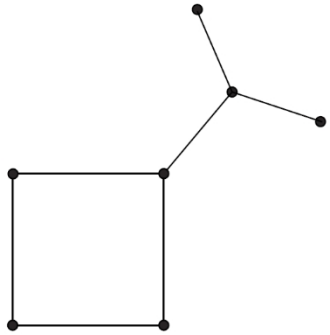
    ANSWER: b

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107. Find the minimum number of edges that must be duplicated to create the best possible eulerization of this graph.

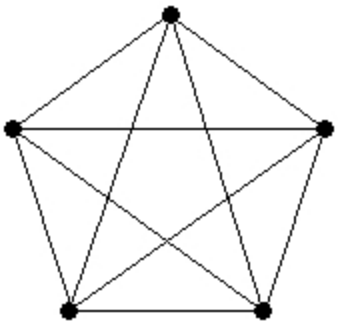


a. One
b. Two
c. Three
d. Four

ANSWER: c

108. Draw a graph with five vertices where the valence of each vertex is 4.

ANSWER: Answers will vary. One solution is:



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