Kruskal’s Algorithm for Computing MSTs

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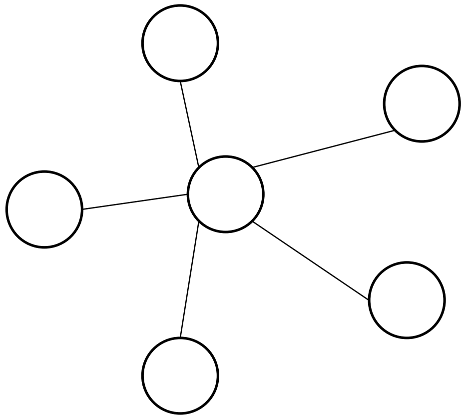
Tree

A tree is a graph with the following properties:

- The graph is connected (can go from anywhere to anywhere)

- There are no cycles(acyclic)



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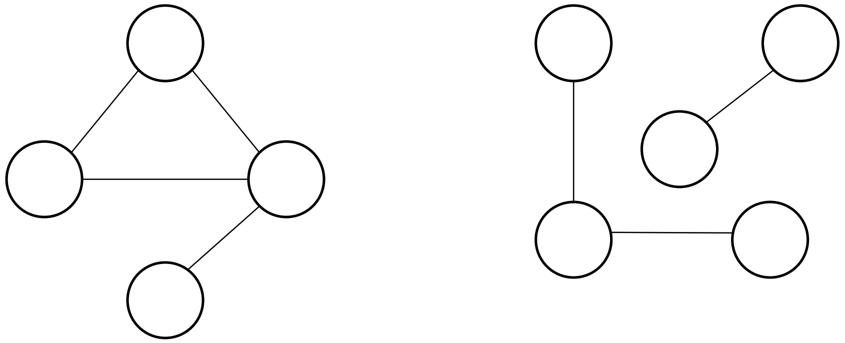


Graphs that are not trees

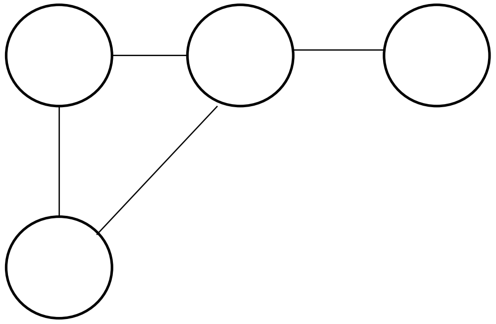
Minimum Spanning Tree (MST)

Let G=(V,E) be an undirected connected graph.

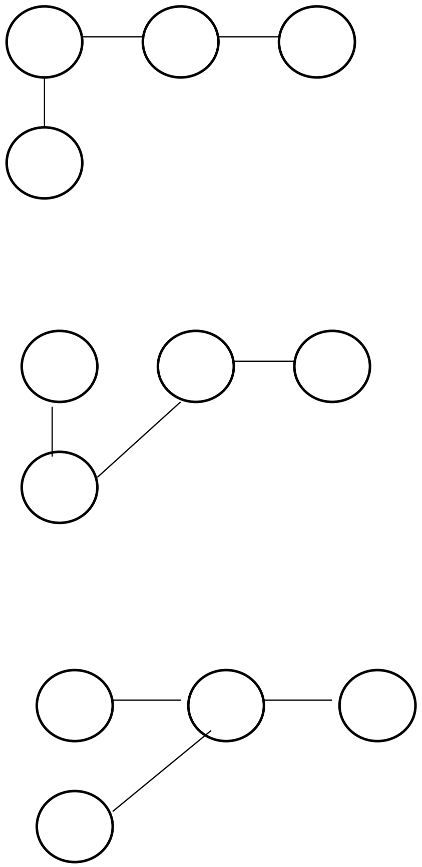
A sub graph T=(V,E’) of G is a spanning tree of G if :-

- T is a tree (i.e., it is acyclic)
- T covers all the vertices ***V***
  - contains **|*V*| - *1*** edges
- T has minimum total weight
- A single graph can have many different spanning trees.

Connected undirected graph

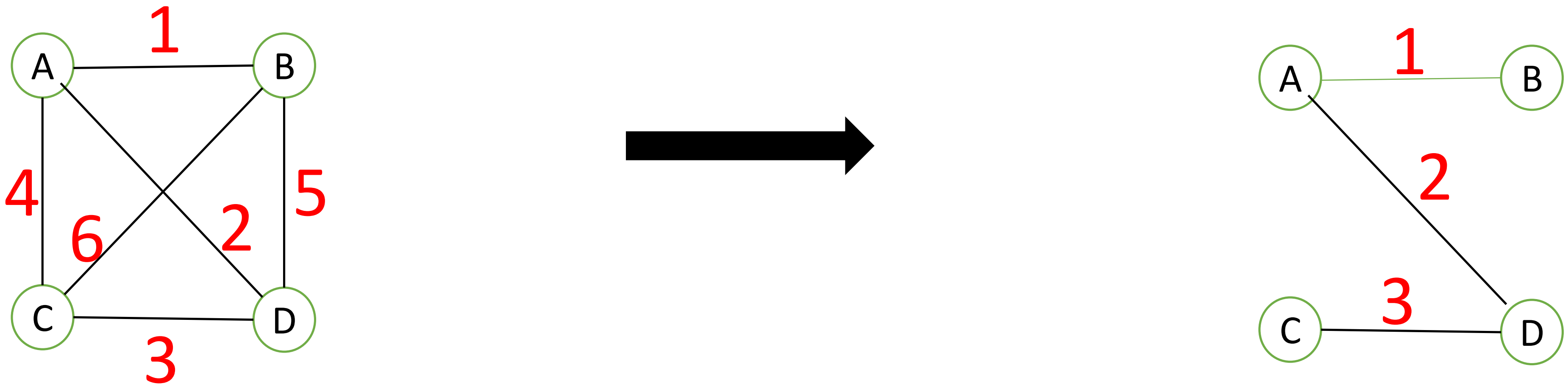


Spanning Tree



Kruskal’s Algorithm

- It is a algorithm used to find a minimum cost spanning tree for connected weighted undirected graph
- This algorithm first appeared in Proceedings of the American Mathematical Society in 1956, and was written by Joseph Kruskal



Connected Weighted

- It's a spanning tree because it connects all vertices without loops.
- Tree weight is minimum of all possibilities hence minimum cost spanning tree

Disjoint Sets

- A disjoint set is a data structure which keeps track of all elements that are separated by a number of disjoint (not connected) subsets.
- It supports three useful operations
  - MAKE-SET(x): Make a new set with a single element x
  - UNION (S1,S2): Merge the set S1 and set S2
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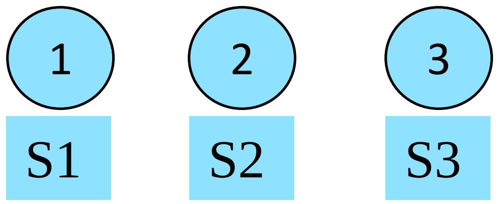

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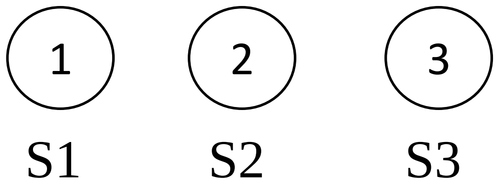

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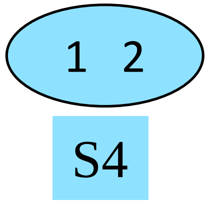

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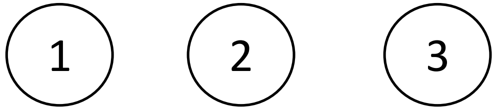

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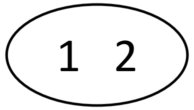

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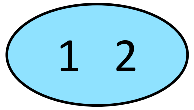

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Kruskal's Algorithm

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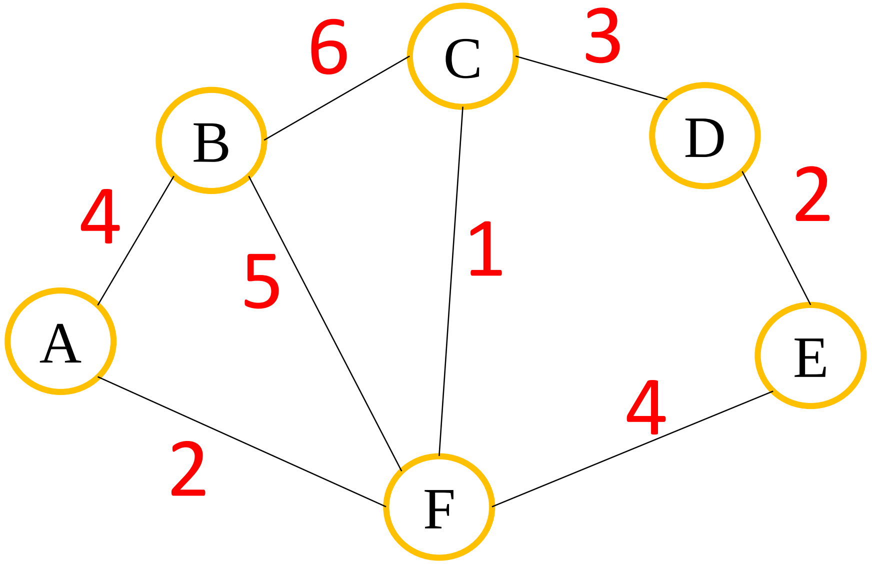

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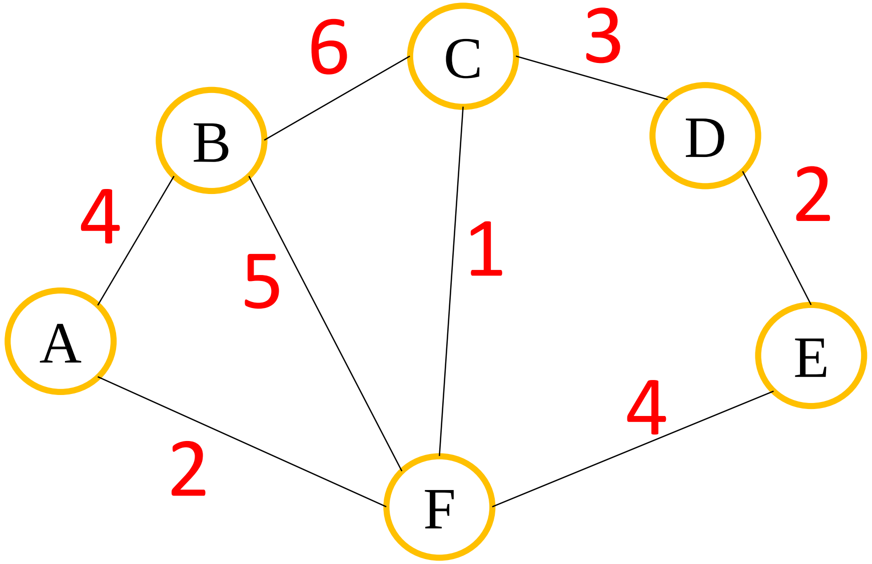

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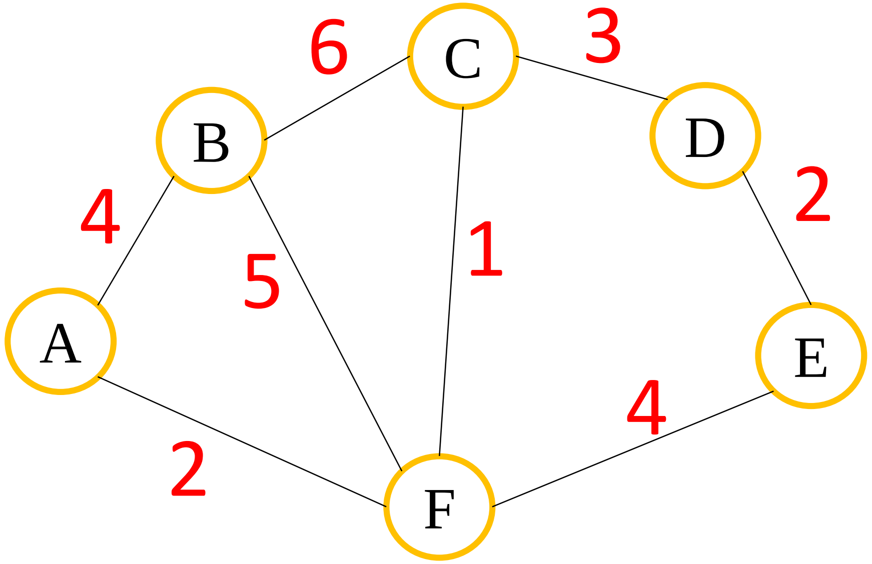

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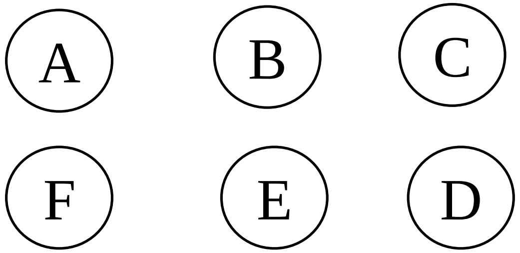

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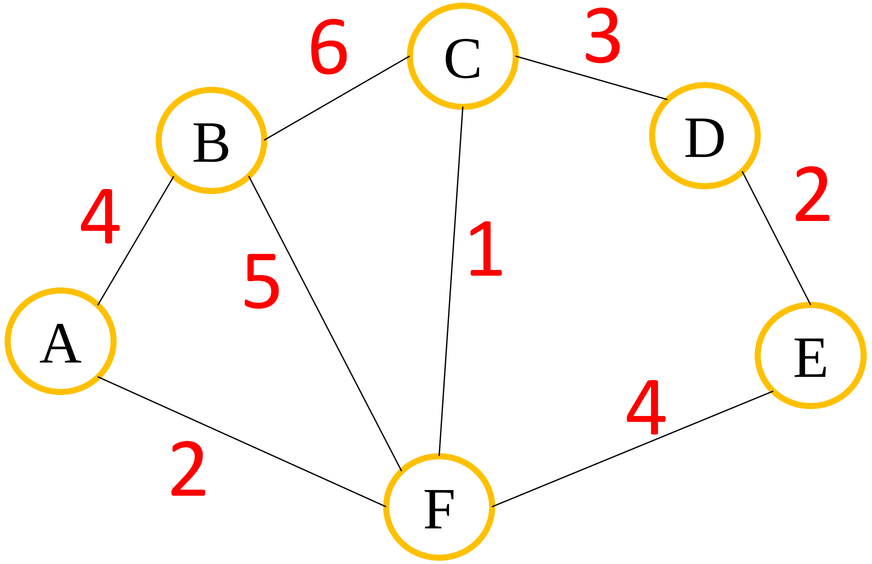

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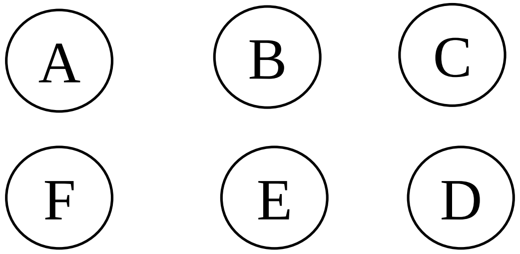

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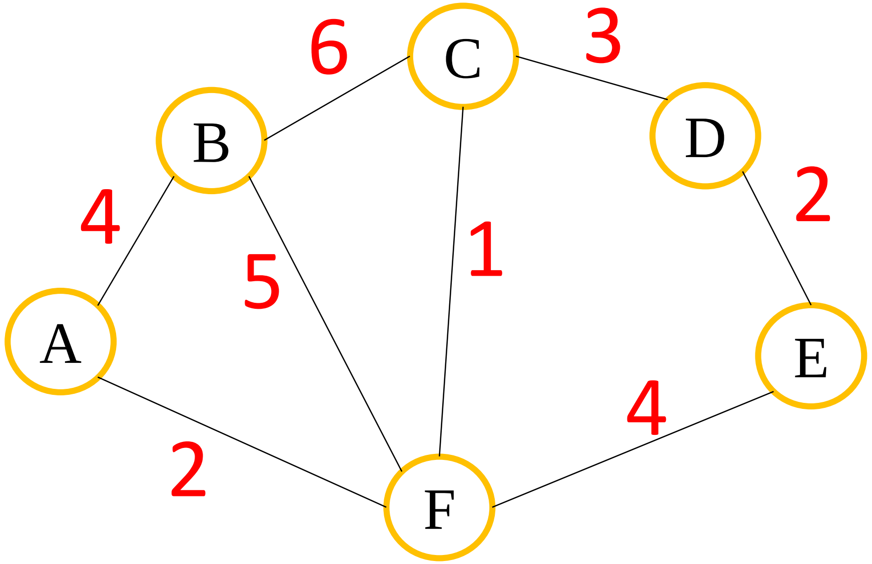

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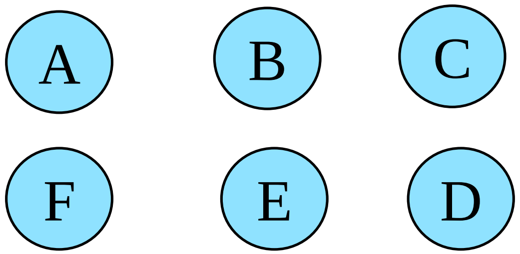

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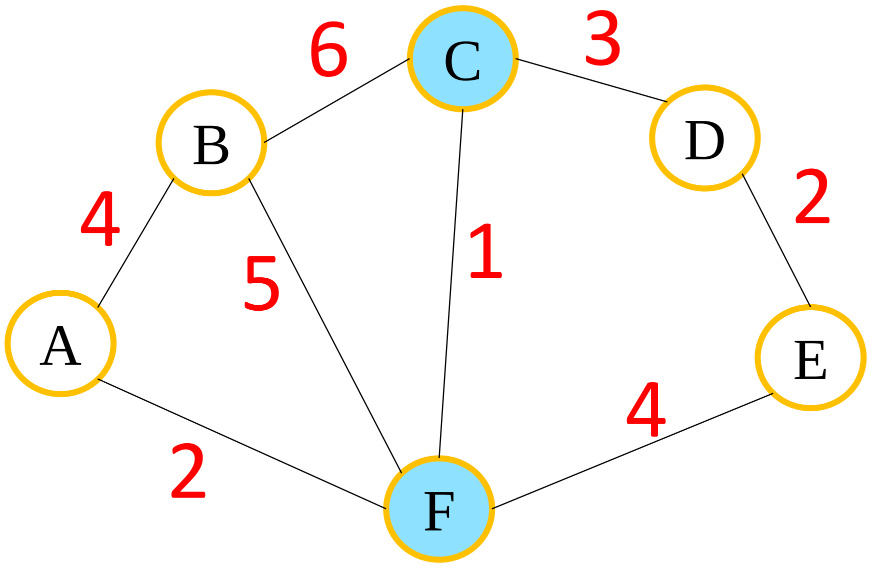

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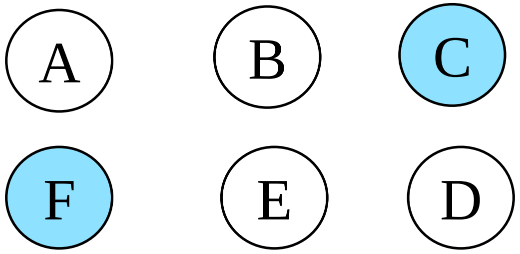

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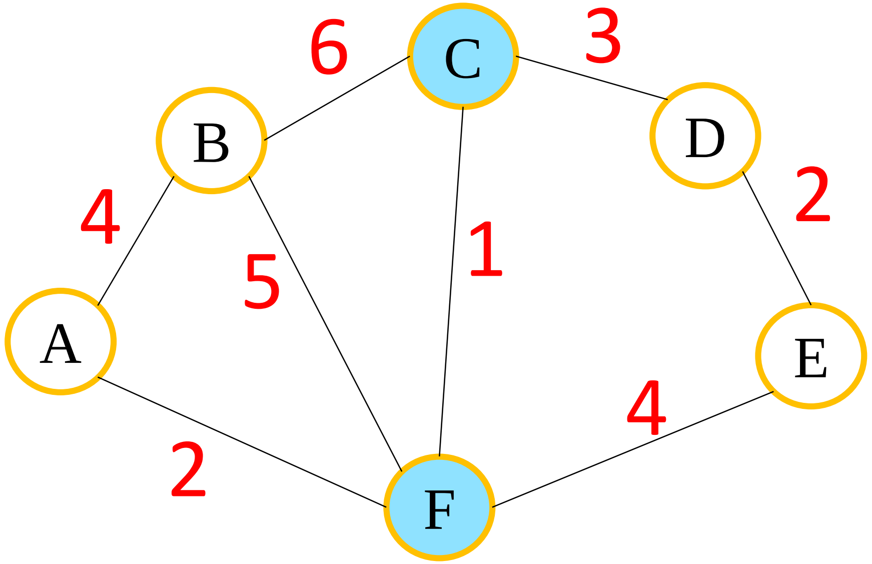

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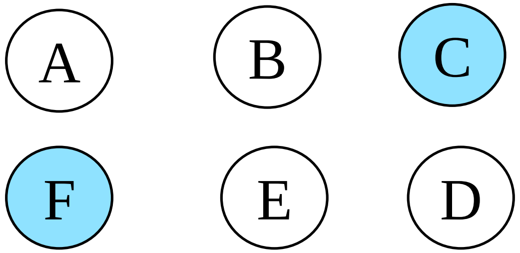

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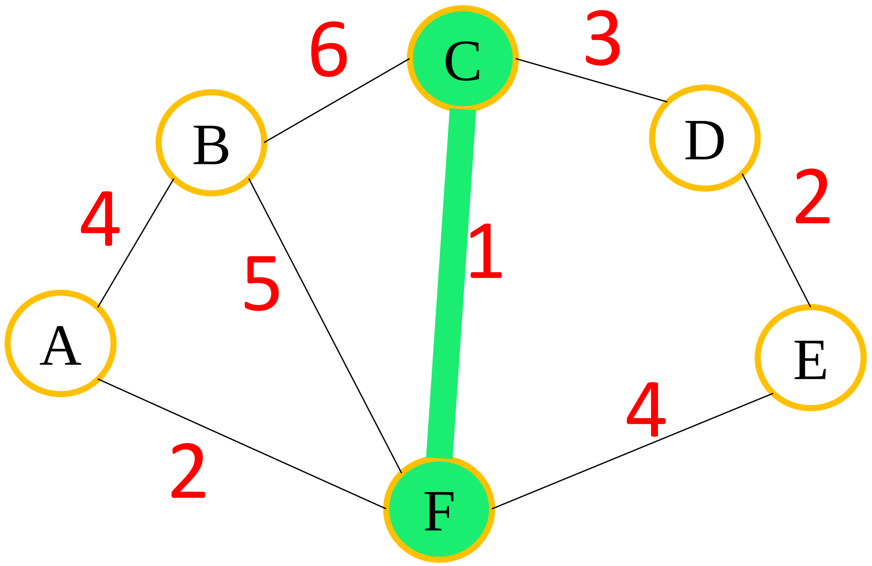

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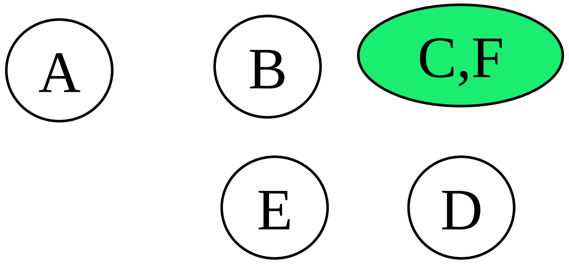

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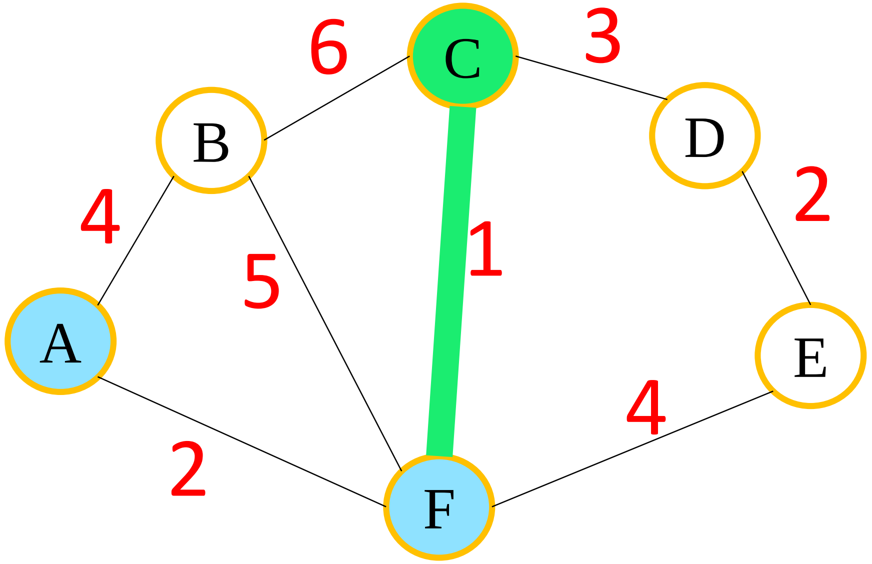

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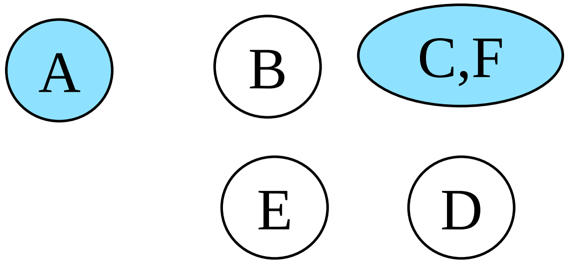

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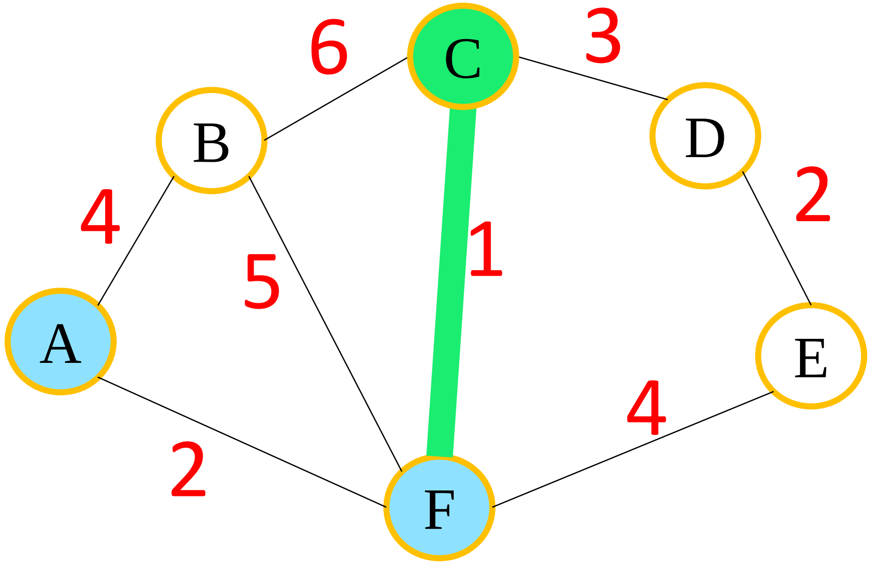

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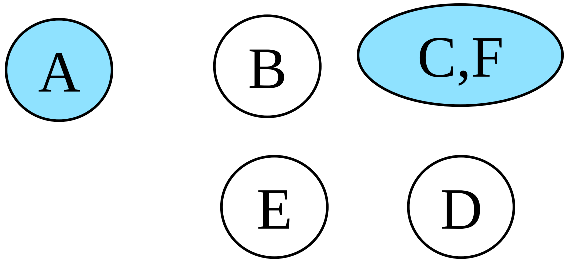

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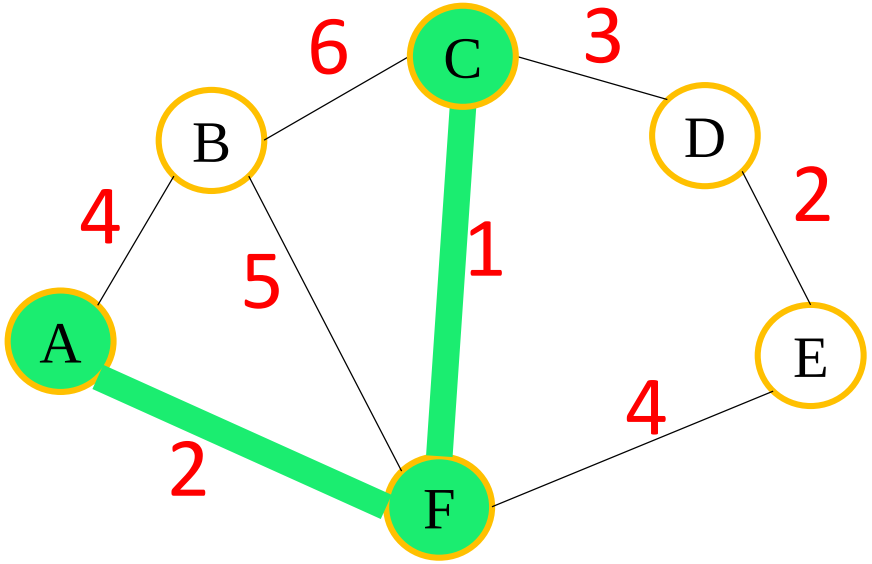

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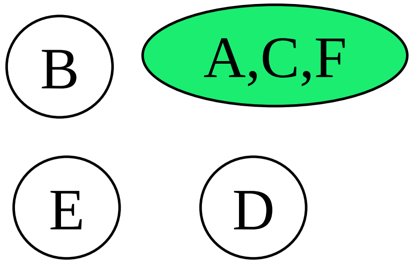

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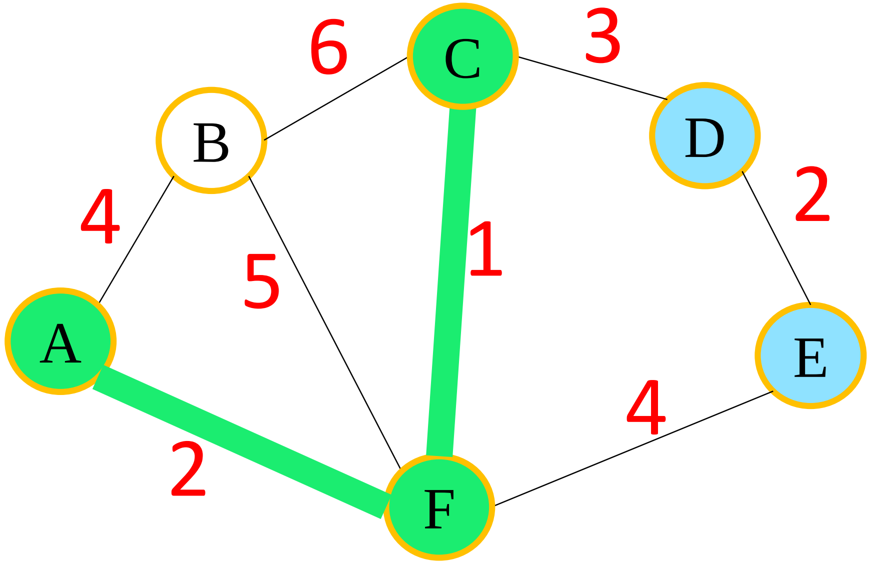

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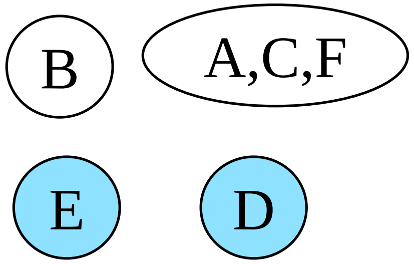

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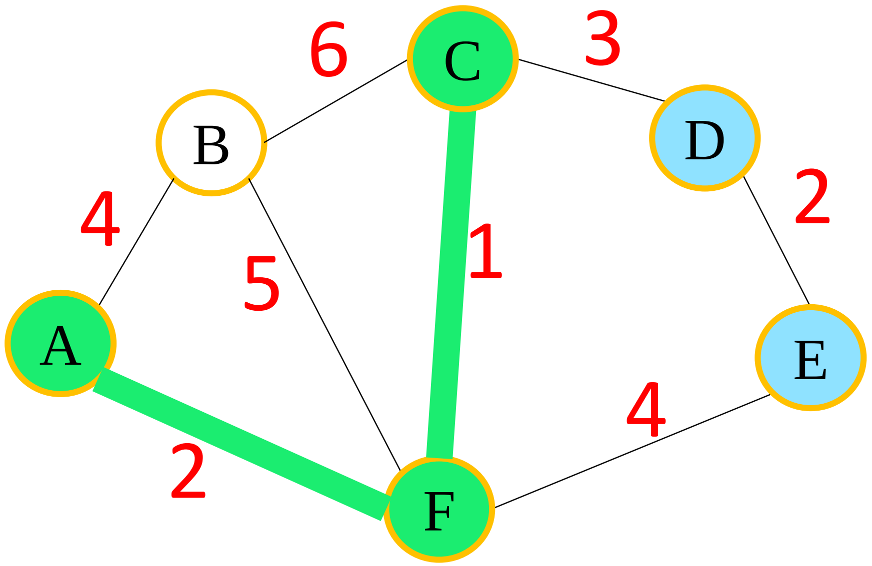

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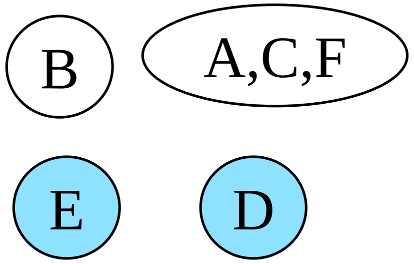

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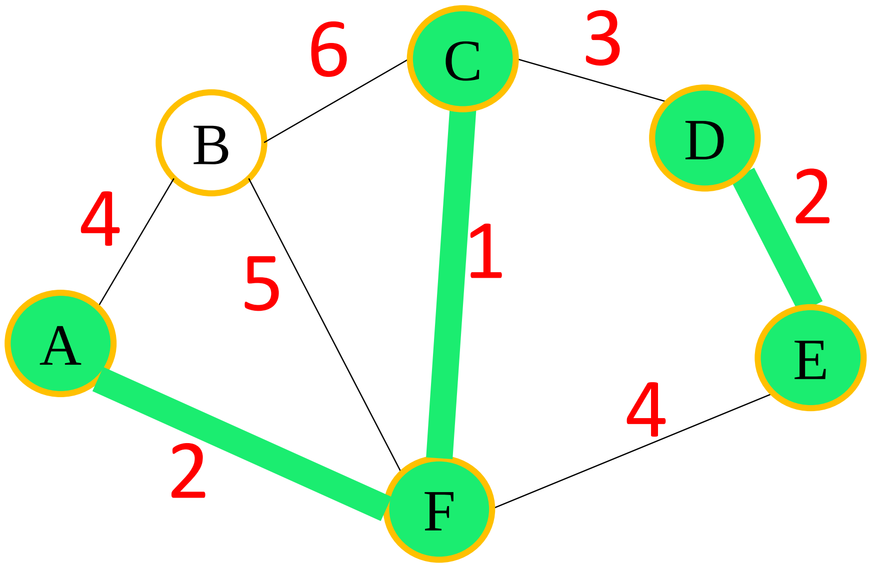

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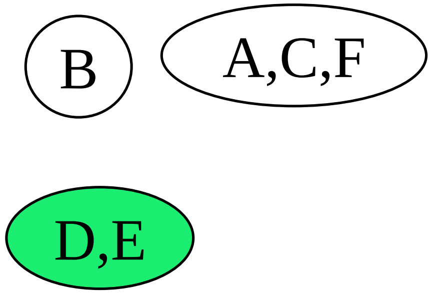

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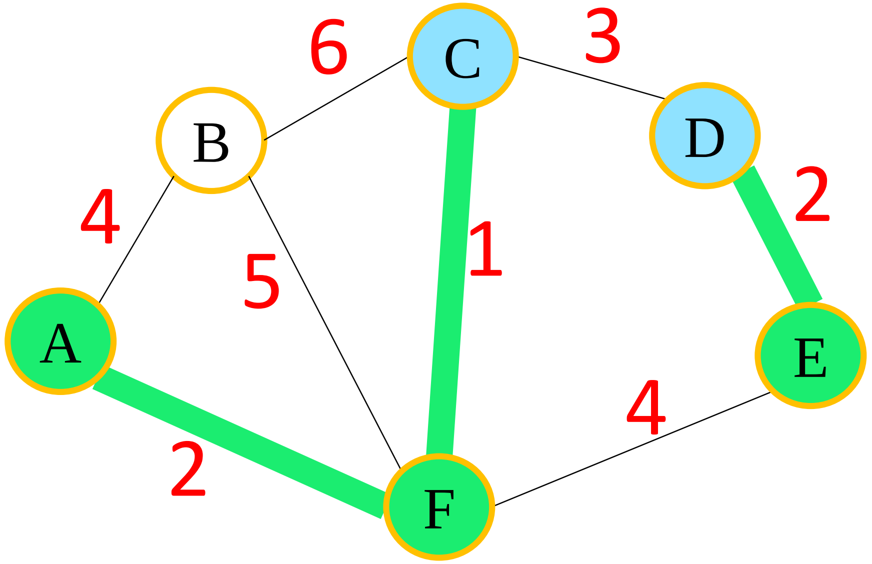

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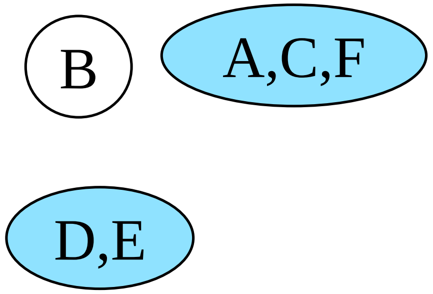

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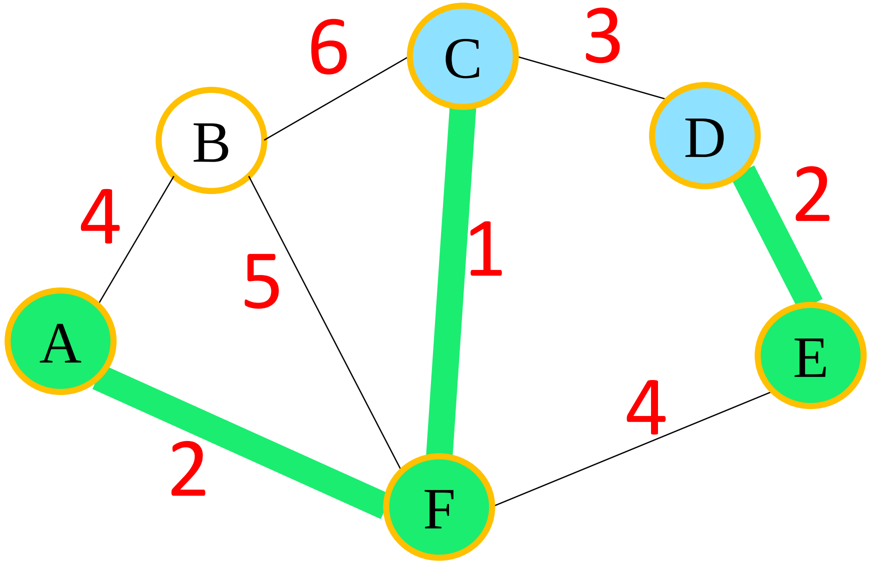
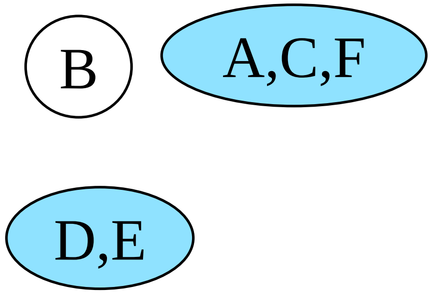


A ={(C,F),(A,F),(D,E),(C,D)}



Edges	Weight
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AF	2
DE	2
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AB	4
FE	4
BF	5
BC	6

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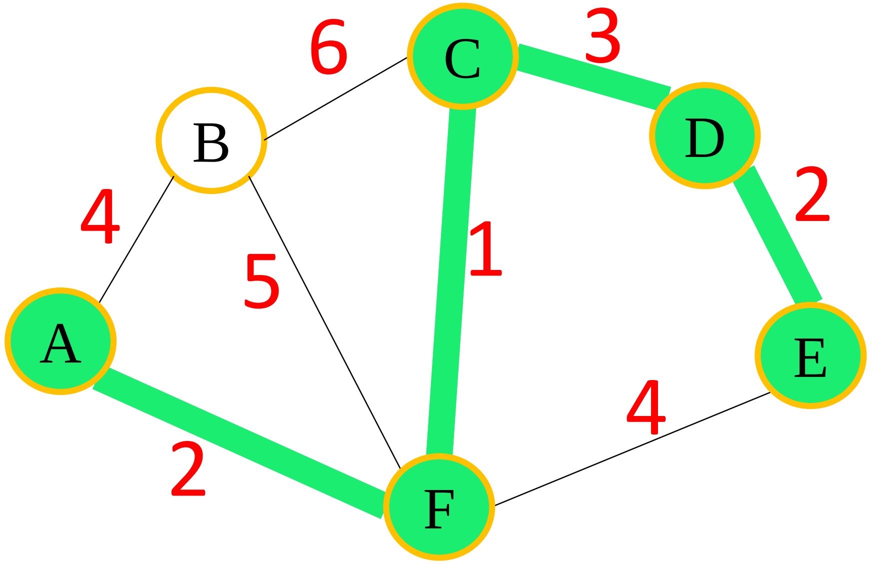
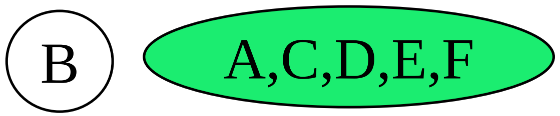


A ={(C,F),(A,F),(D,E),
(C,D)}



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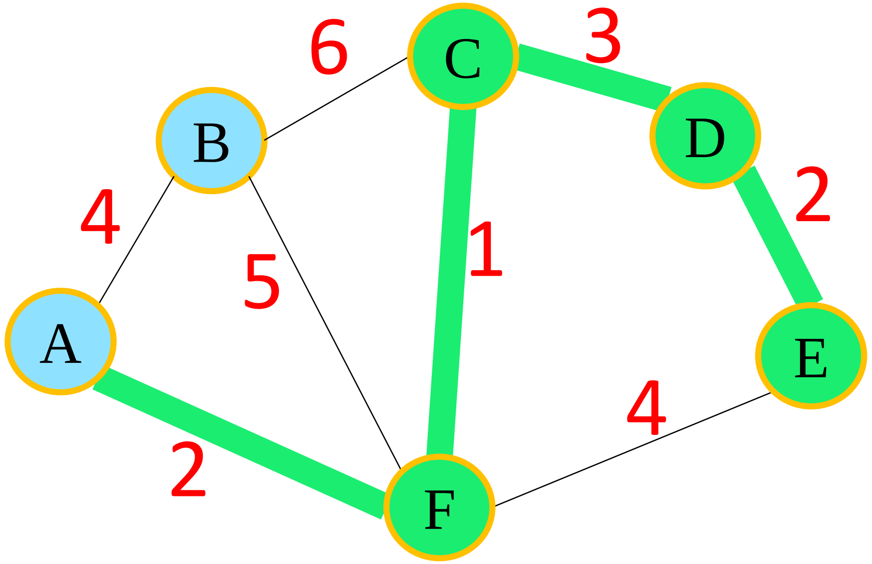

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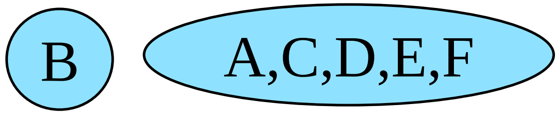

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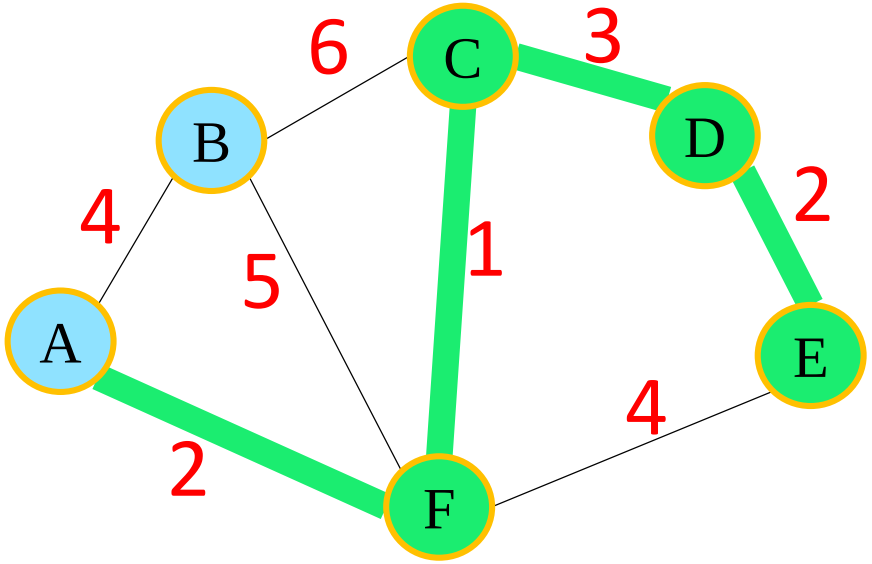
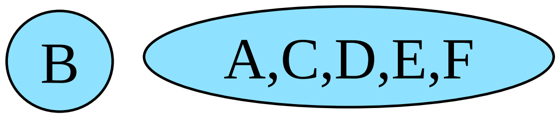


A ={(C,F),(A,F),(D,E),
(C,D),(A,B)}



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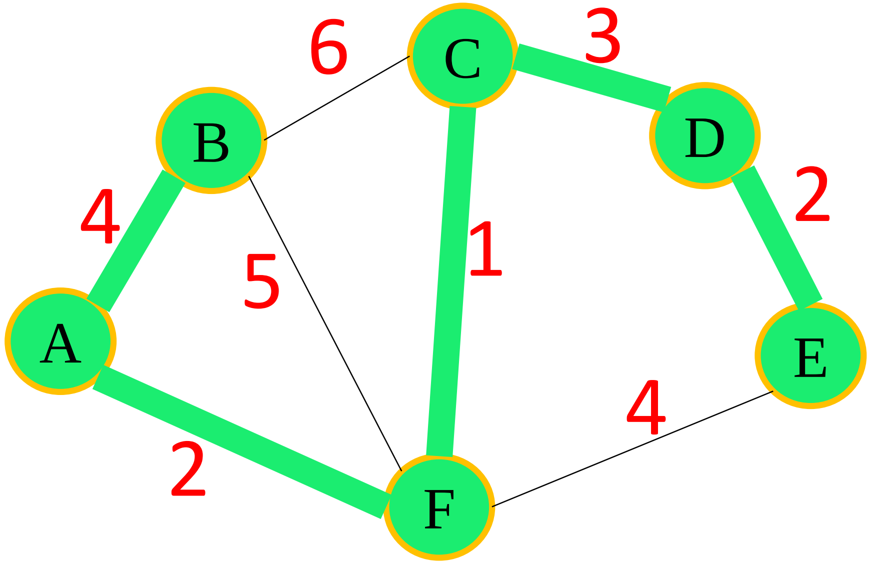

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(C,D),(A,B)}

A,B,C,D,E,F

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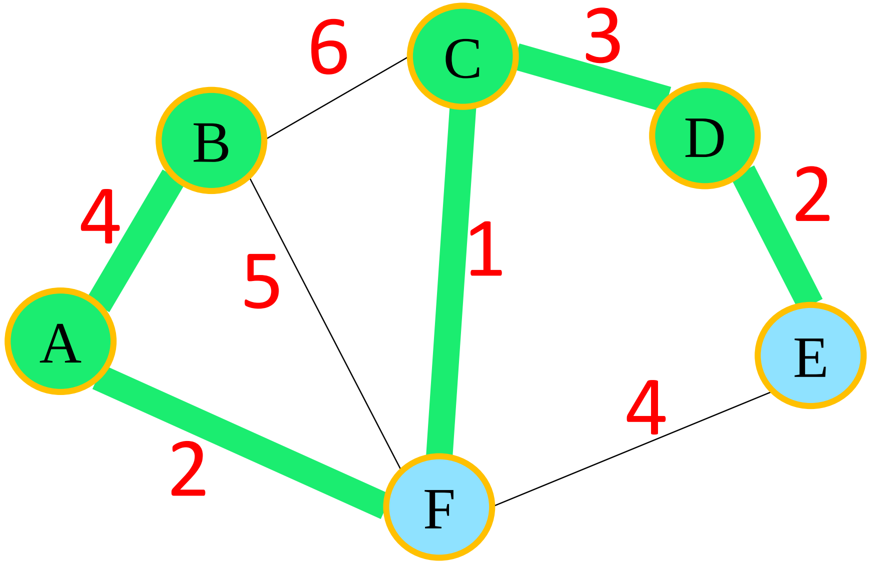
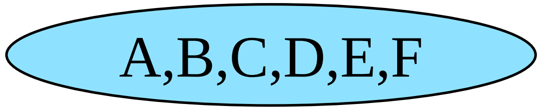


$A = \{(C,F),(A,F),(D,E),(C,D),(A,B)\}$



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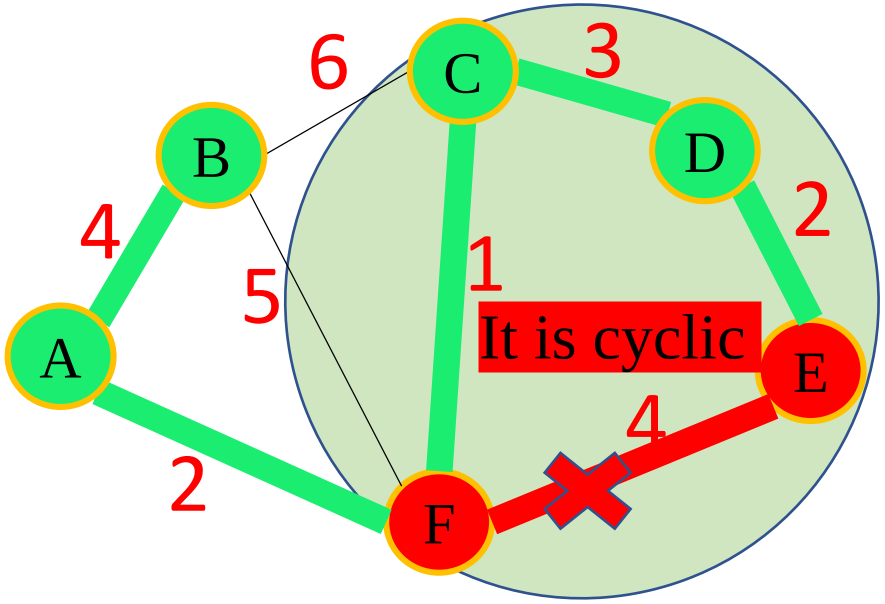

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A,B,C,D,E,F

Is in a same set.

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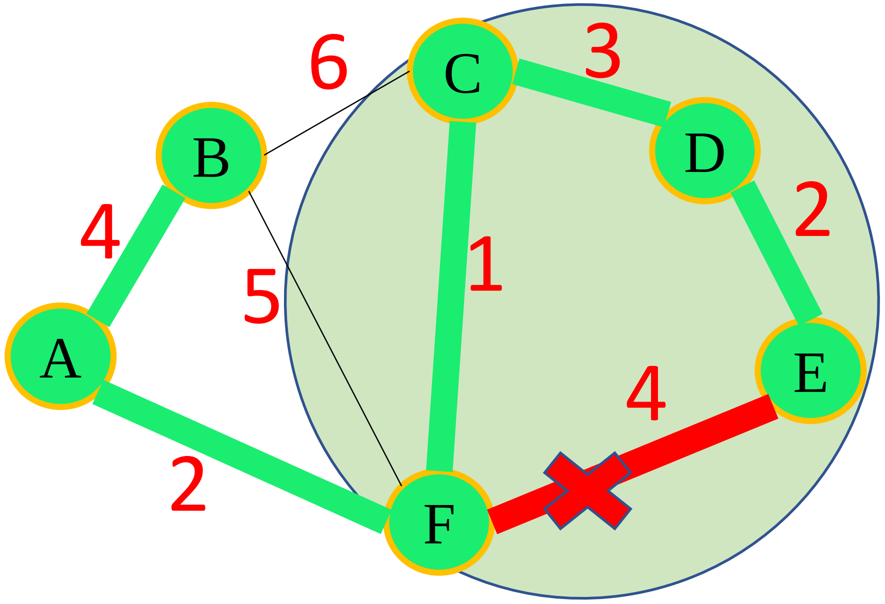

A ={(C,F),(A,F),(D,E),
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A,B,C,D,E,F

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AF	2
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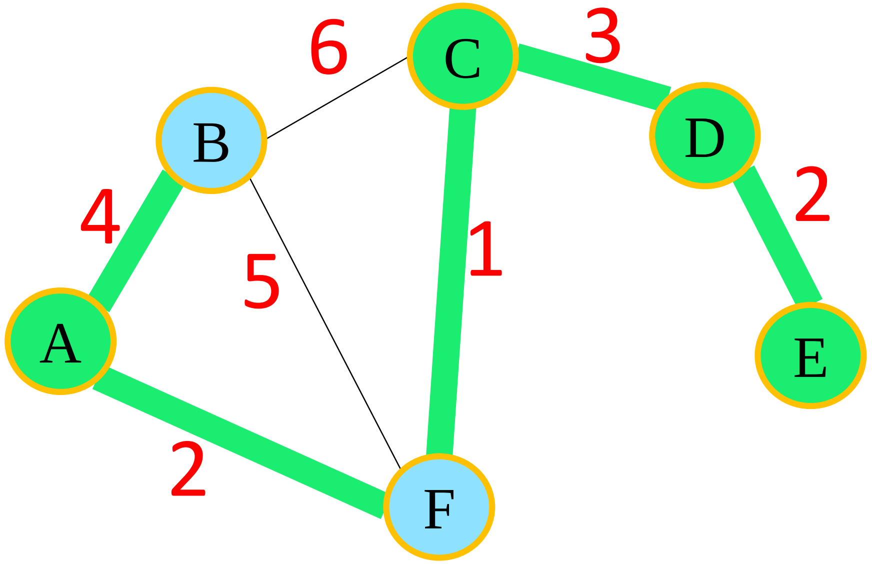

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A,B,C,D,E,F

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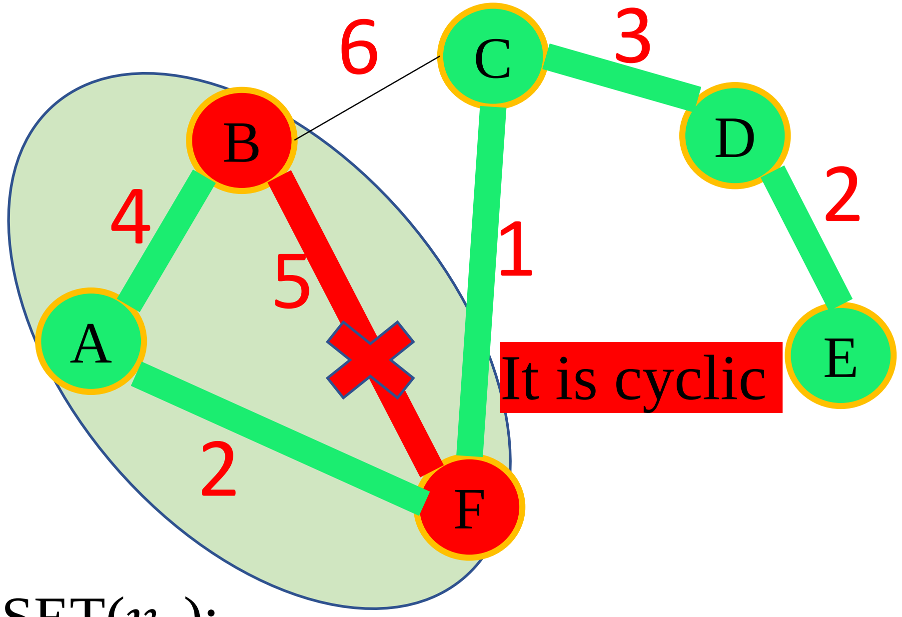

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A,B,C,D,E,F

Is in a same set.

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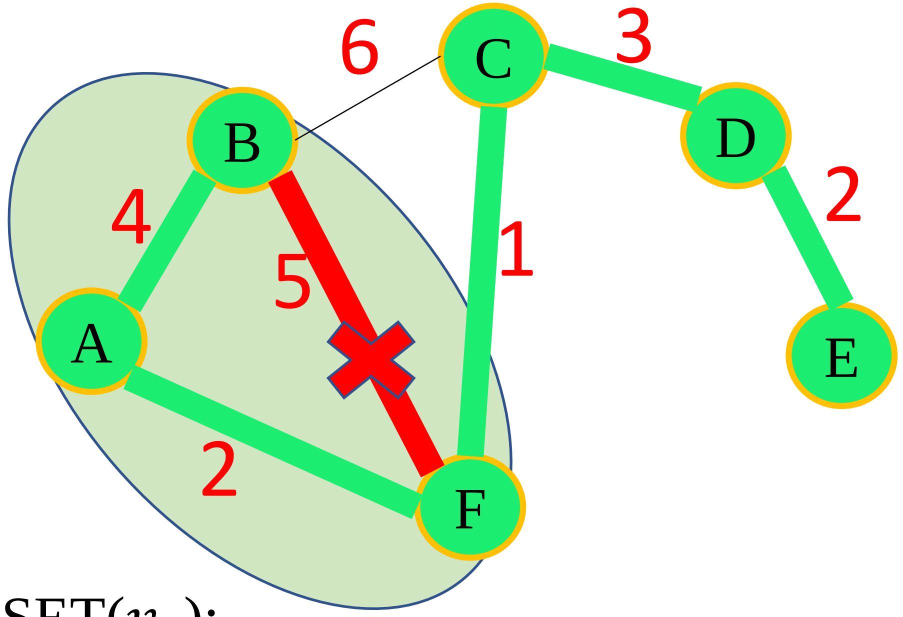

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A,B,C,D,E,F

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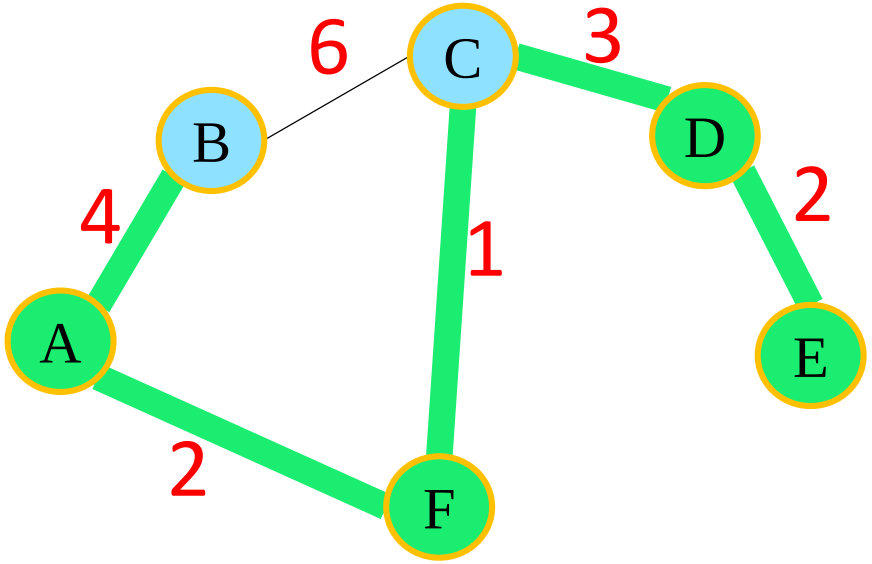

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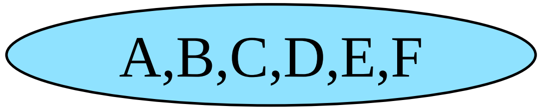

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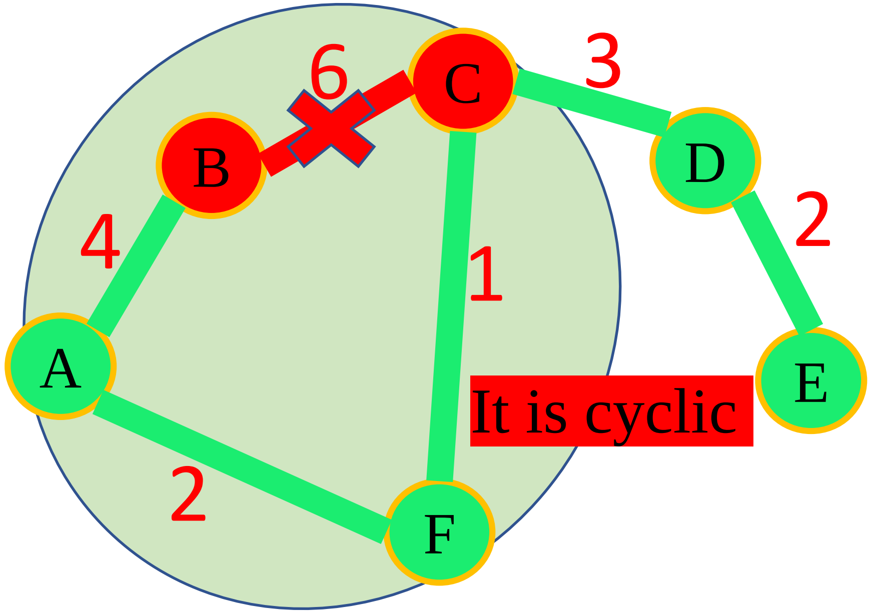

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A,B,C,D,E,F

Is in a same set.

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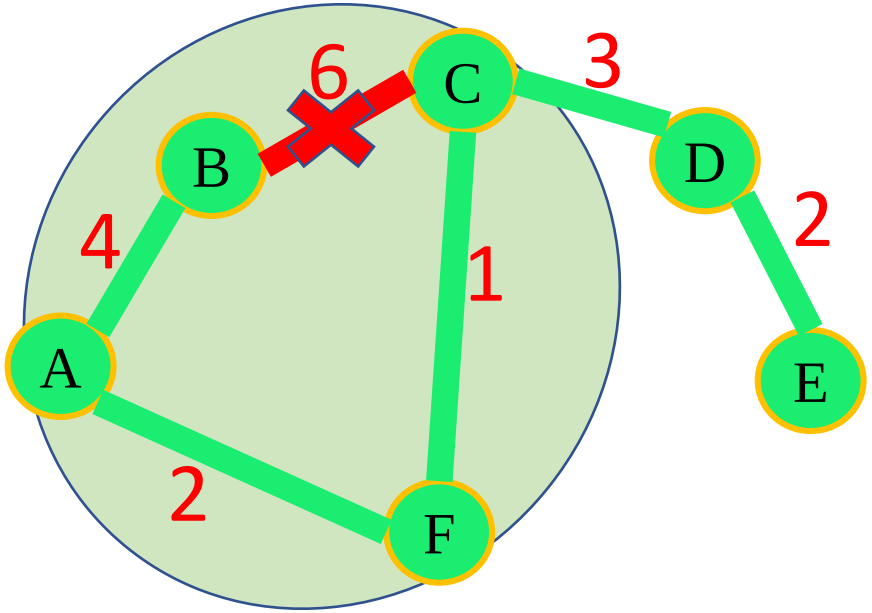

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A,B,C,D,E,F

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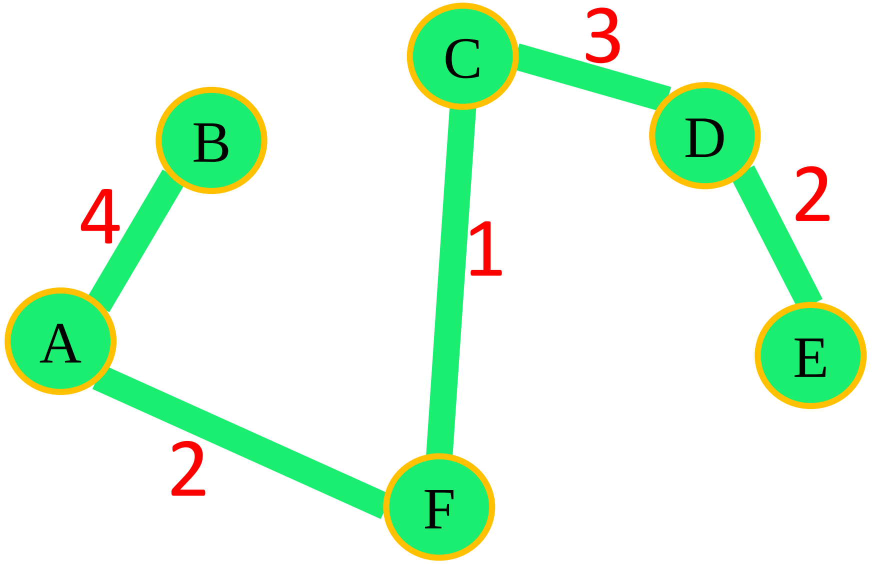

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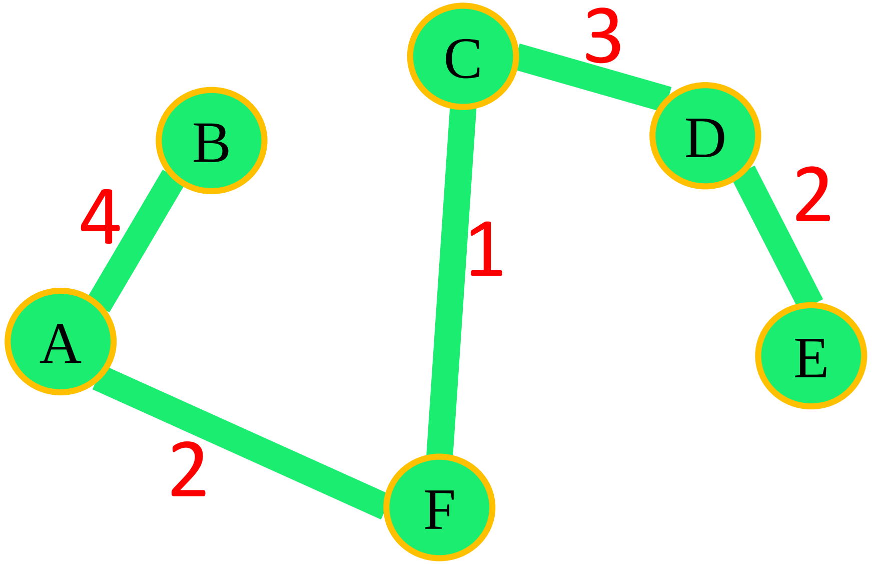

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BC	6

A ={(C,F),(A,F),(D,E),(C,D),(A,B)}

Total Weight :- 1 + 2 + 2 + 3 + 4
= 12

Time Complexity

KRUSKAL(V,E):

O(1) — $A = \emptyset$

O(V) — **foreach** $v \in$ V:
    MAKE-SET(v)

O(E log E) — Sort E by weight increasingly

O(E log V) — **foreach** $(v_1,v_2) \in$ E:
    if FIND-SET(v_1) $\neq$ FIND-SET(v_2):
        A = A $\cup$ $\{(v_1,v_2)\}$
        UNION(v_1,v_2)
    else
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return A

Time Complexity

KRUSKAL(V,E):

O(1)
A = ∅

O(V)
foreach $v \in$ V:
  MAKE-SET(v)

O(E log E)
Sort E by weight increasingly

O(E log V)
foreach $(v_1, v_2) \in$ E:
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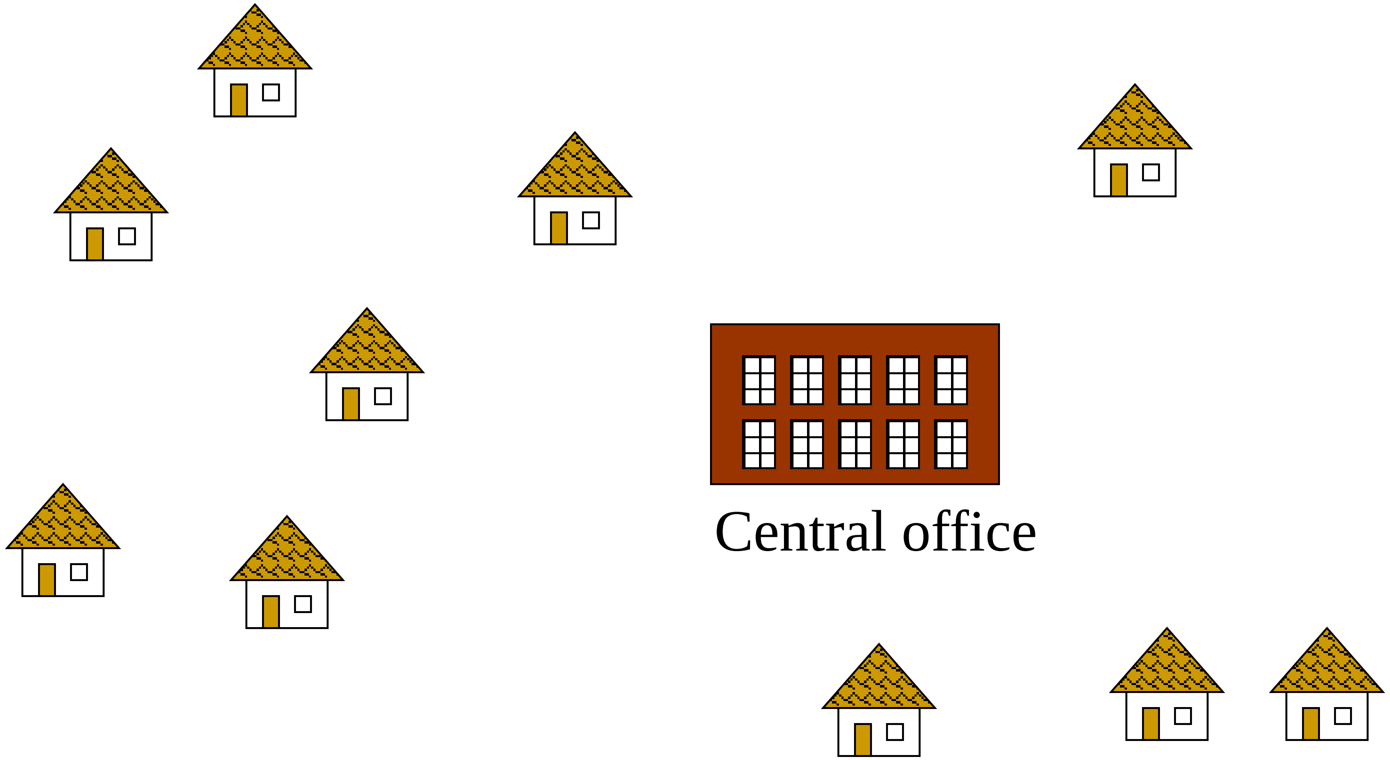
    UNION(v_1, v_2)
  else
    Remove edge (v_1, v_2)
return A

Time Complexity = O(1)+ O(V)+O(E log E)+O(E log V)
= O(E log E) + O(E log V)
Since, $|E| \leq |V|^2 \Rightarrow \log |E| = O(2 \log V) = O(\log V)$.
= O(E log V) + O(E log V)
= O(E log V)

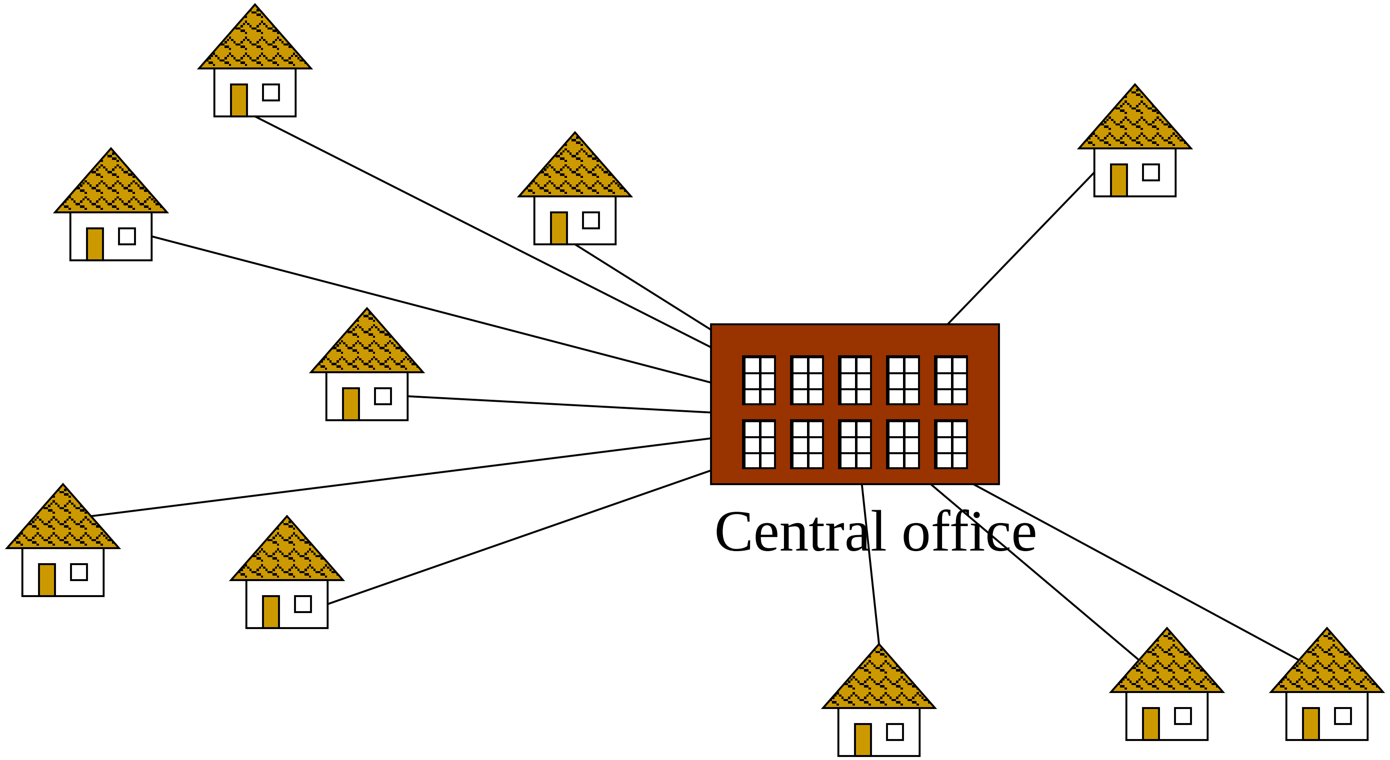
Real-life applications of Kruskal's algorithm

- Landing Cables
- TV Network
- Tour Operations
- Computer networking
- Study of Molecular bonds in Chemistry
- Routing Algorithms

Problem: Laying Telephone Wire

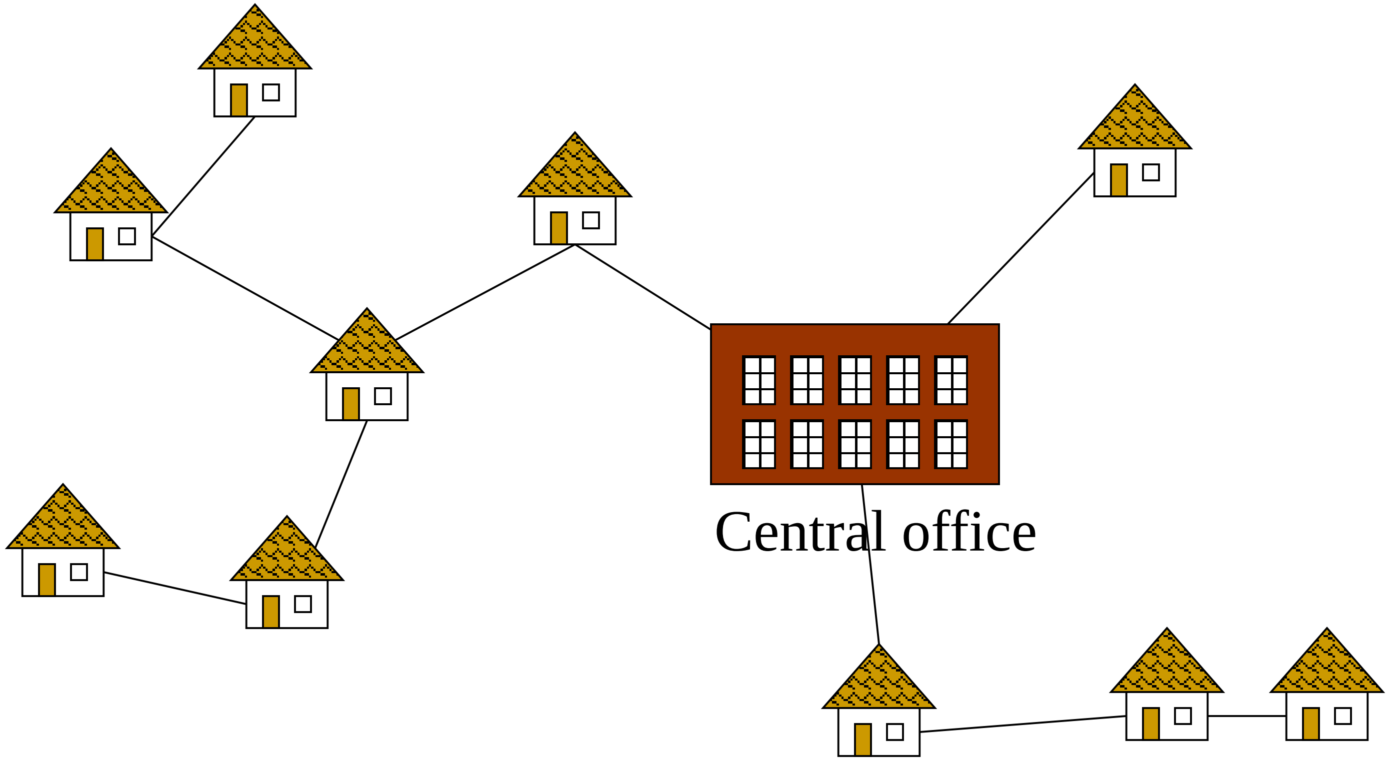


Wiring: Naïve Approach



Expensive!

Wiring: Better Approach



Minimize the total length of wire connecting the customers