Computer programme (Software Development) to calculate the conductance of different connection designs.

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CONDUCTANCE

Conductance is the characteristic of a vacuum component or system to readily allow the flow of gas and can be thought of as the inverse of resistance to flow. It must be closely considered when designing a vacuum system and selecting the pump and other components,

Well-designed piping of vacuum equipment, as well as proper component selection, increases production efficiency by minimizing the vacuum pumping time. It also minimizes energy use, making the equipment less expensive to operate.

OVERVIEW

The network/circuit of pipes are of 2 categories :

1) Can be decomposed into combination of parts that are in series/parallel
2) Cannot be decomposed into parts that are in series/parallel

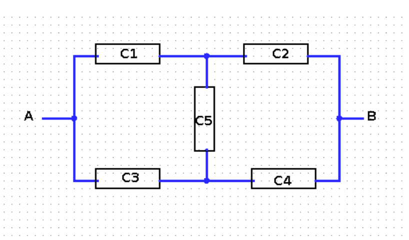
We first devise a method to find the conductance of any circuit (both type 1 and 2). For this purpose we use the **modified nodal analysis** method from Electrical Sciences. The method has been described under the next topic.

It should be noted however that the general method is quite **expensive**, requiring calculation of the **inverse of a matrix** (whose size depends upon the number of components in the network) . But a simpler way exists for circuits that can be decomposed into series parallel parts (has been discussed below). My program gives the user the choice of using either Series-Parallel mode or the General mode depending upon his/her requirements.

GENERAL NETWORKS

All the possible networks come under this category. All such networks can be expressed as graphs where edges have the value of the conductance of the pipes and the nodes correspond to the point of joining between 2 pipes. To solve the general network problem I have modified the Modified Nodal Analysis method to apply it in our cases. Essentially, Modified Nodal Analysis is used to solve electrical circuits. In this method all the Kirchoff's voltage law and Kirchoff's current law are written and are solved using Matrices (Linear Algebra). WIth modifications, I have applied it to solve for the equivalent conductance of a network of pipes.

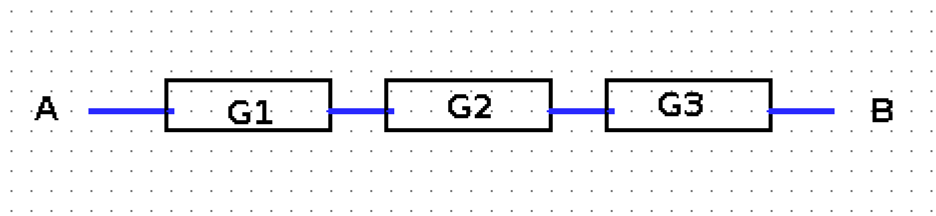
For eg. (a circuit that cannot be represented as Series-Parallel components - such for circuits equivalent conductance can be calculated only using this method)



SERIES PARALLEL NETWORKS

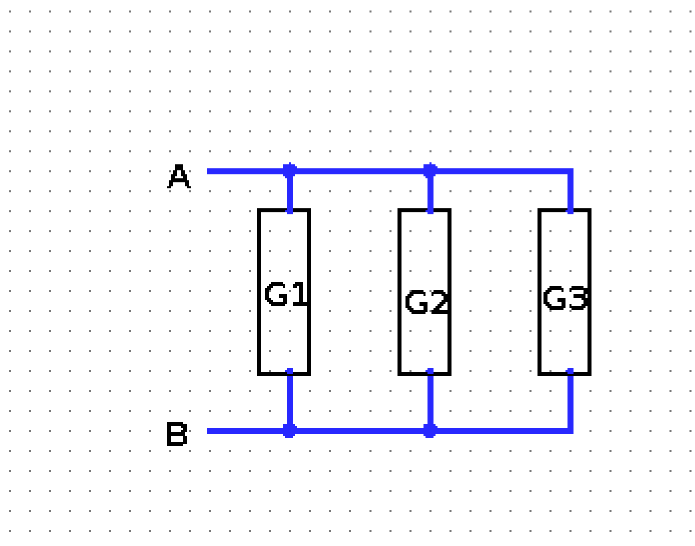
This covers a category of networks that can be decomposed into series and parallel parts. For such networks there are simple formulas that allow us to calculate their equivalent conductances.

Series Networks



$$1/G_{total} = 1/G_1 + 1/G_2 + 1/G_3$$

Parallel Networks



$$G_{total} = G_1 + G_2 + G_3$$

USAGE INSTRUCTIONS

First the user has to choose whether to use the series-parallel mode or the general mode. The following instructions are given below.

General Mode

Here the network has to be entered in a graph - based format.

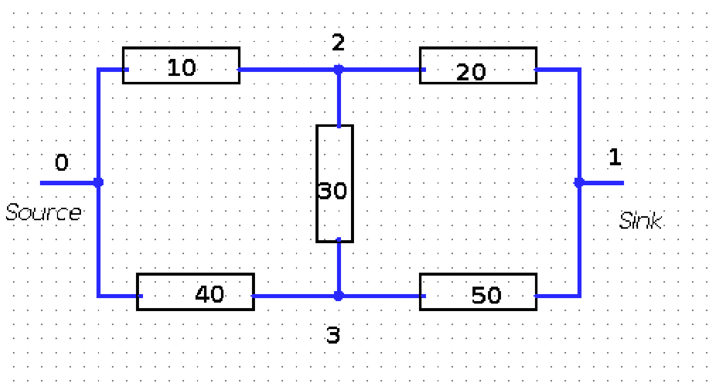
Step 1: Input the number of vertices (say n)

Step 2: Input the number of edges (say m)

Step 3: Input the edges and its conductance. Note that all n vertices must be within 0 to n-1. For eg. if between vertex 0 and vertex 2 there is a pipe of conductance 3 SI units then enter "0 2 3"

Step 4: Enter the points between which we have to calculate the conductance. For eg. in the network if the source is at vertex 1 and sink is at vertex 5 then enter "1 5"

For eg. if we want to find the conductance of the following network (**cannot be decomposed in series-parallel form**) :



Our inputs should be as follows :

```
Enter 1 if the network can be expressed in series-paralled otherwise 0
0
Enter the number of vertices : 4
Enter the number of edges : 5
Enter the network in edge - conductance format
0 2 10
2 1 20
0 3 40
3 1 50
2 3 30
Enter the 2 points between which the conductance is to be found 0 1
The equivalent conductance is : 29.047619047619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(program exited with code: 0)
Press return to continue
```
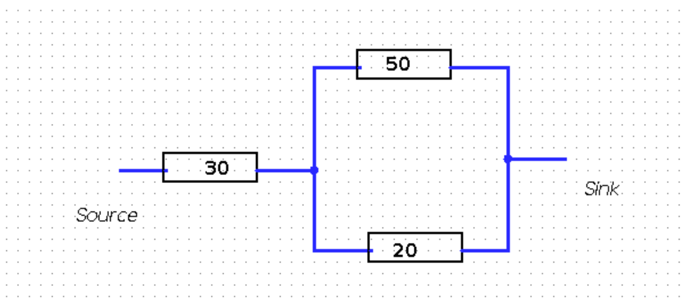

Series Parallel Mode

If components c1,c2 are in series then enter S(c1,c2) or if they are in parallel enter P(c1,c2). Using this idea even more complicated series parallel networks can be generated. Also note that there should not be any spaces between the input.

For eg . if we want to generate the following network:



We have to give the following input

```
Enter 1 if the network can be expressed in series-paralled otherwise 0
1
Enter the circuit:
S(30,P(50,20))
The equivalent conductance is 21.000000000000


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(program exited with code: 0)
Press return to continue
```
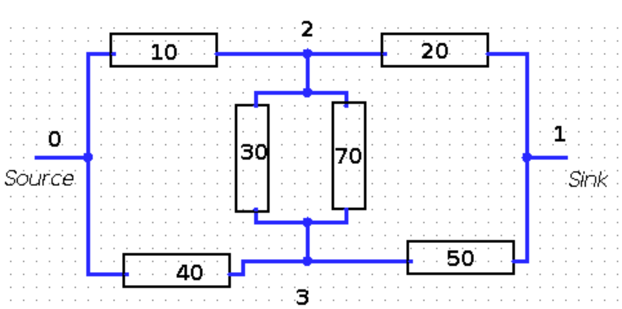

DEMONSTRATION

Here I have provided some more networks and how they can be solved using the program .

<u>Cannot be decomposed in Series parallel mode:</u>




```
Enter the network in edge - conductance format
0 2 10
2 1 20
0 3 40
3 1 50
2 3 30
2 3 70
Enter the 2 points between which the conductance is to be found 0 1
The equivalent conductance is : 29.115646258503


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(program exited with code: 0)
Press return to continue
```
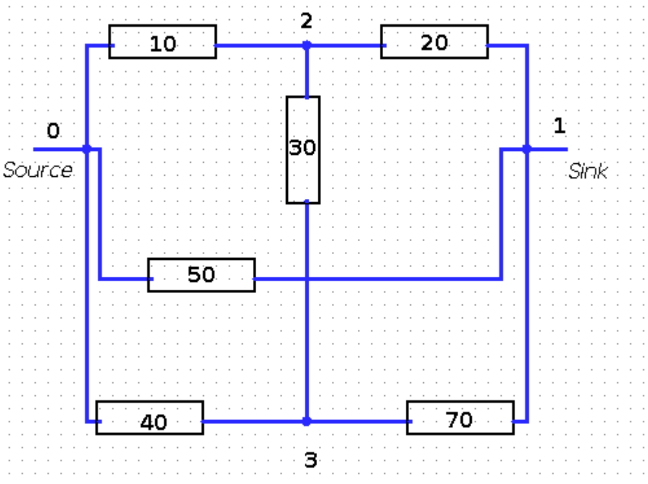

Cannot be decomposed in Series parallel mode:




```
Enter 1 if the network can be expressed in series-paralled otherwise 0
0
Enter the number of vertices : 4
Enter the number of edges : 6
Enter the network in edge - conductance format
0 2 10
0 1 50
0 3 40
3 1 70
2 1 20
2 3 30
Enter the 2 points between which the conductance is to be found 0 1
The equivalent conductance is : 82.133333333333


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(program exited with code: 0)
Press return to continue
```
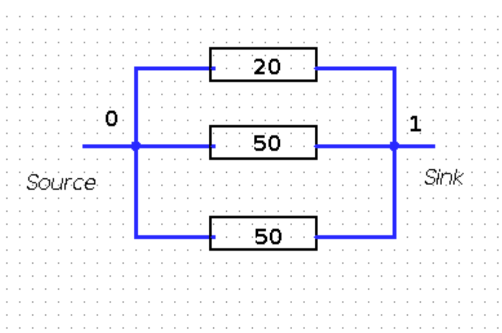

Example where it is shown that the general method also works for series-parallel network :




```
Enter 1 if the network can be expressed in series-paralled otherwise 0
0
Enter the number of vertices : 2
Enter the number of edges : 3
Enter the network in edge - conductance format
0 1 20
0 1 50
0 1 50
Enter the 2 points between which the conductance is to be found 0 1
The equivalent conductance is : 120.000000000000


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(program exited with code: 0)
Press return to continue
```
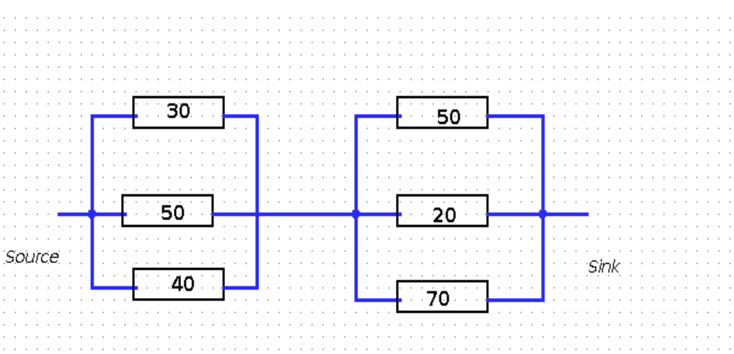

Series Parallel Network




```
Enter 1 if the network can be expressed in series-paralled otherwise 0
1
Enter the circuit:
S(P(30,50,40),P(50,20,70))
The equivalent conductance is 64.615384615385


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(program exited with code: 0)
Press return to continue
```

REFERENCE

1) https://www.codesansar.com/numerical-methods/matrix-inverse-using-gauss-jordan-cpp-output.htm (for calculating inverse of matrix)
2) https://www.swarthmore.edu/NatSci/echeeve1/Ref/mna/MNA2.html (for Modified Node Analysis)
3) https://github.com/sivasurya12032002/equivalent-resistance-calculation (for series-parallel networks)