

DR. ALVIN'S PUBLICATIONS

# NETWORK MODELING

---

BY HAND AND EXCEL  
DR. ALVIN ANG



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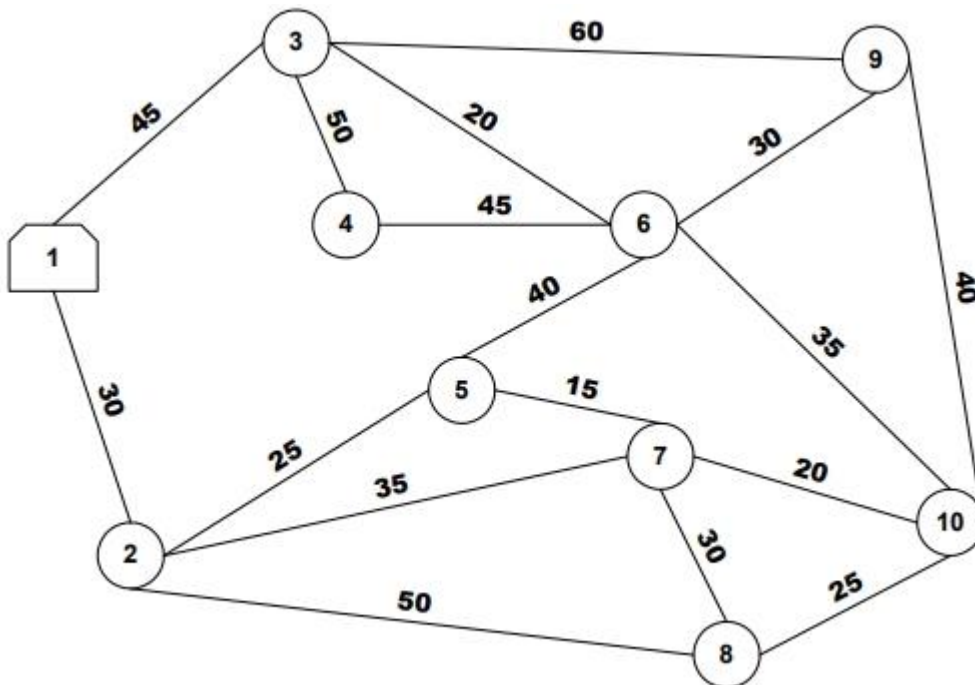
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## I. MINIMAL SPANNING TREE

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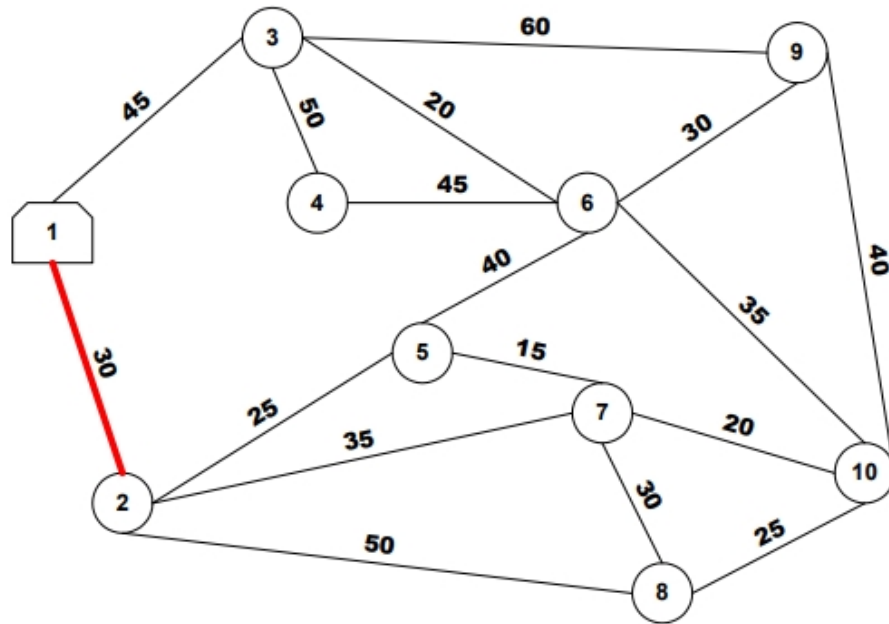
- Minimal Spanning Tree
  - Used to determine **minimum distance** to connect all nodes
  - Used in **MRT and telephone** companies
  - **Minimize length** of transit lines and phone cables

### A. EXAMPLE 1



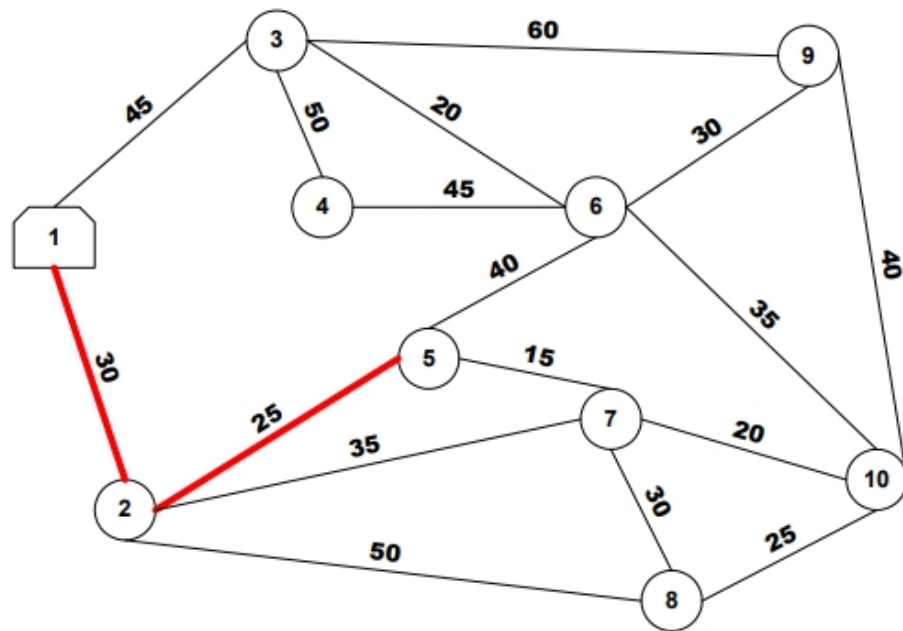
Step 1

Algorithm



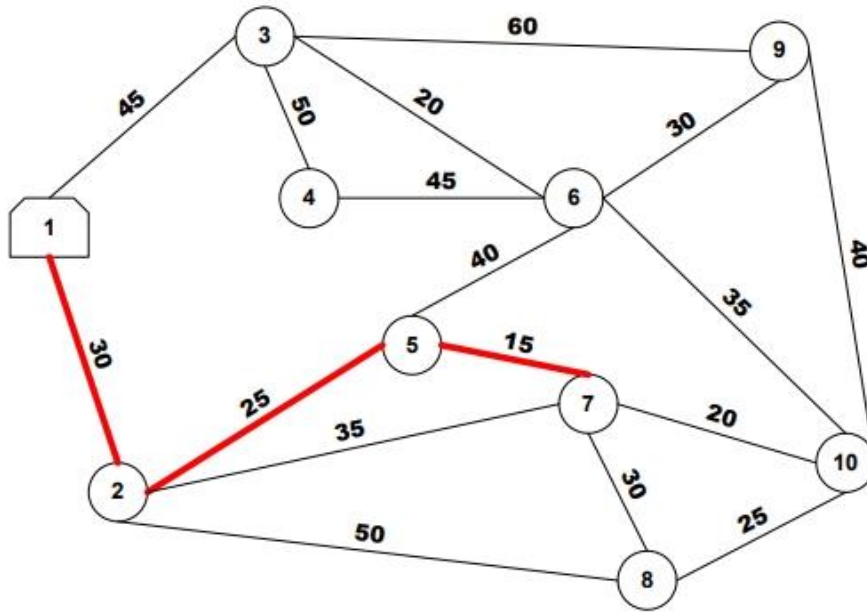
Step 2

Algorithm



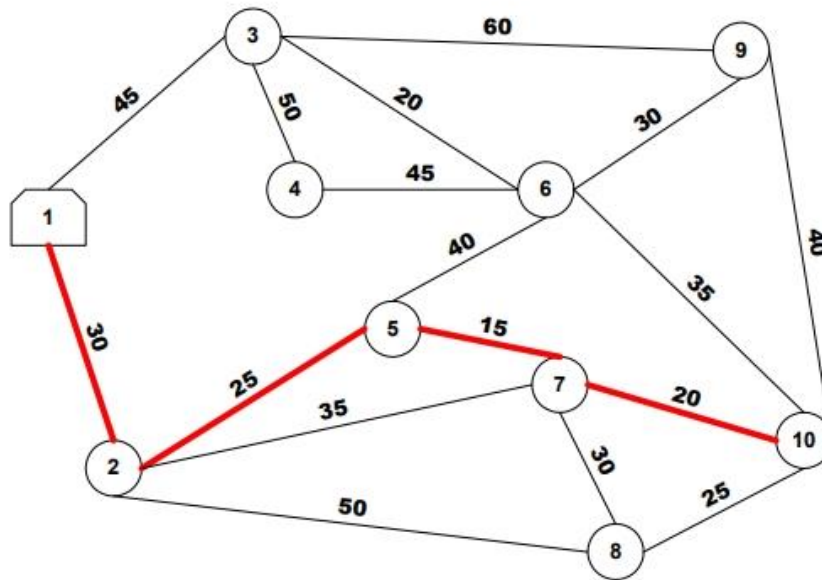
Step 3

Algorithm



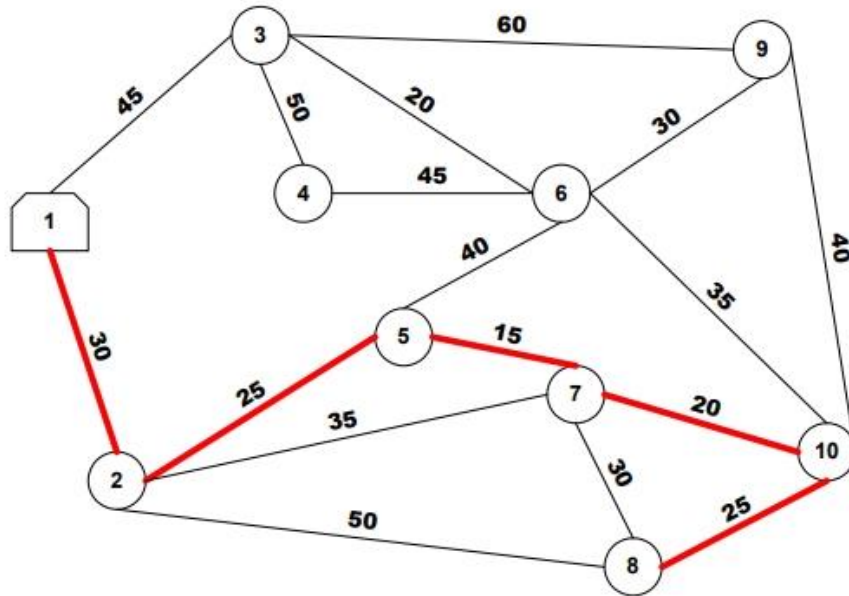
Step 4

Algorithm



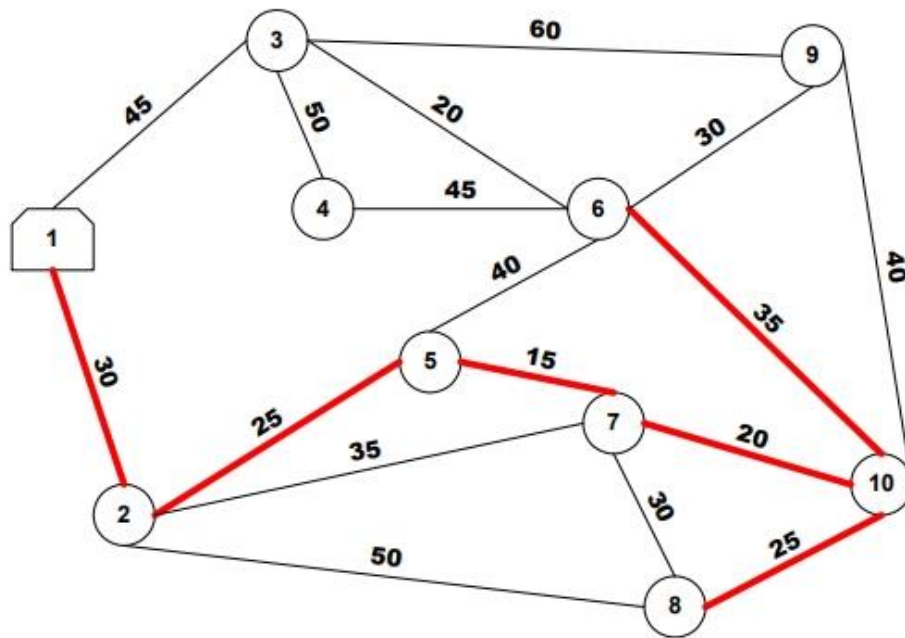
Step 5

Algorithm



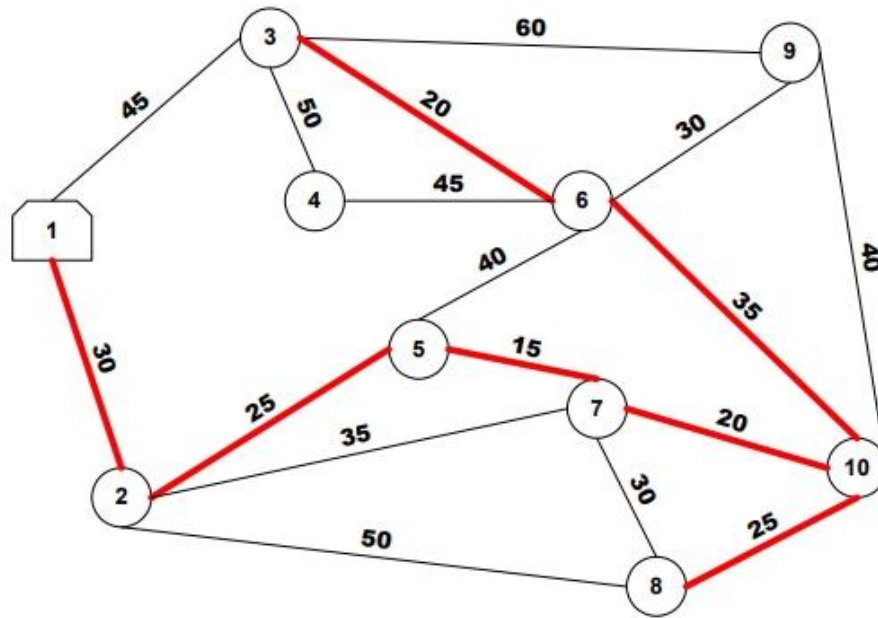
Step 6

Algorithm



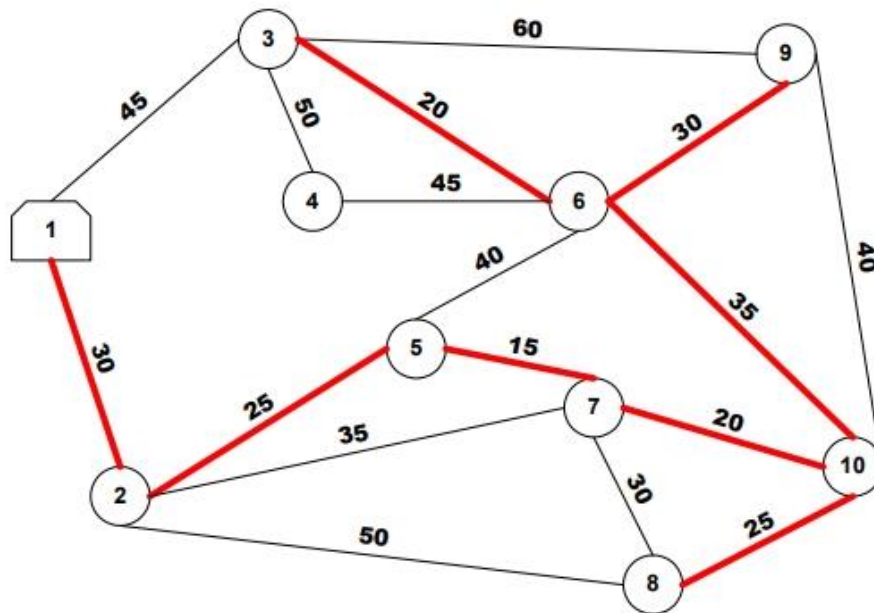
Step 7

Algorithm



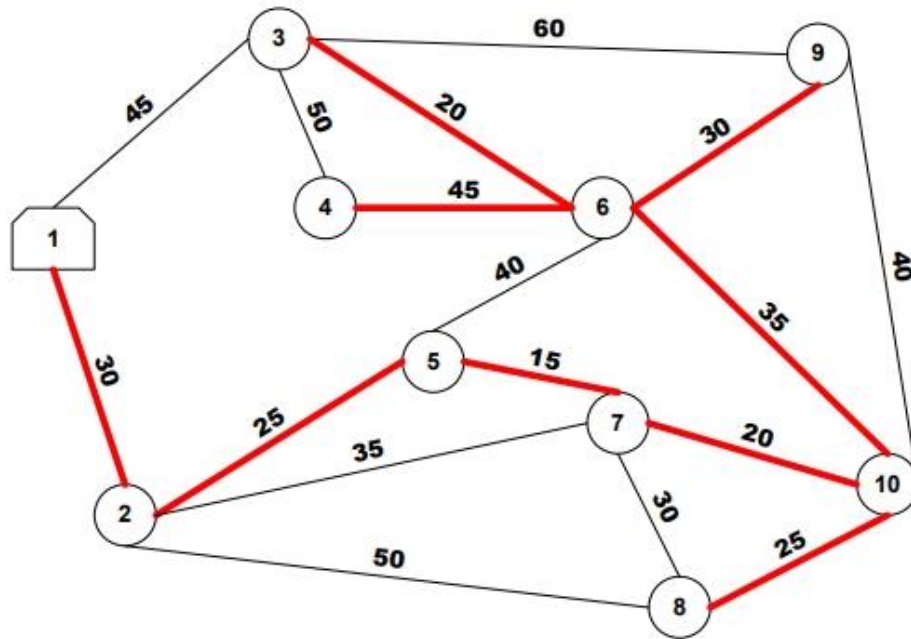
Step 8

Algorithm



Step 9

Algorithm

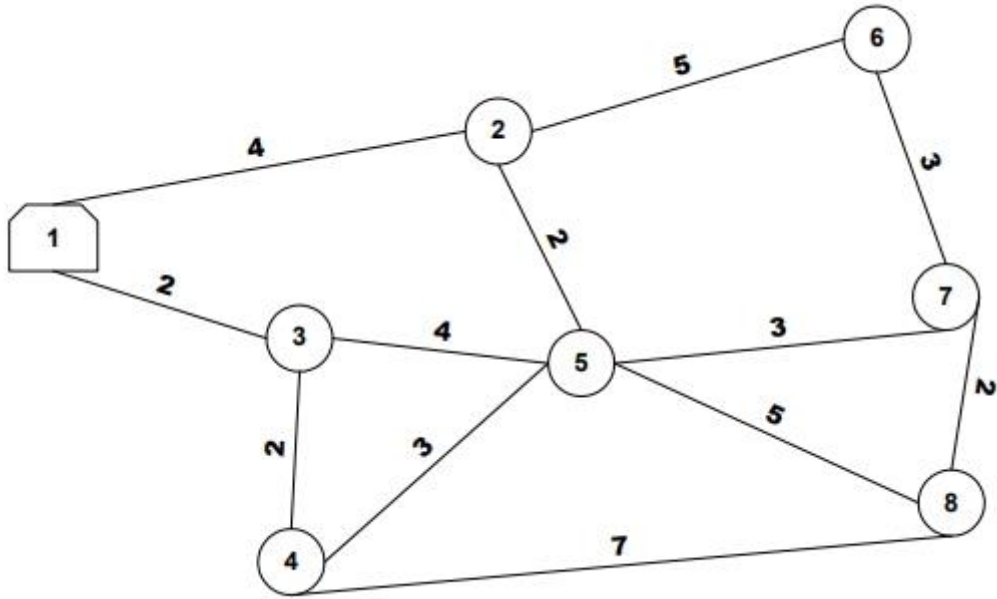


Step 10

Arcs	Values
1 -- 2	30
2 -- 5	25
5 -- 7	15
7 -- 10	20
10 -- 8	25
10 -- 6	35
6 -- 3	20
6 -- 9	30
6 -- 4	45
<b>Total</b>	<b>245</b>

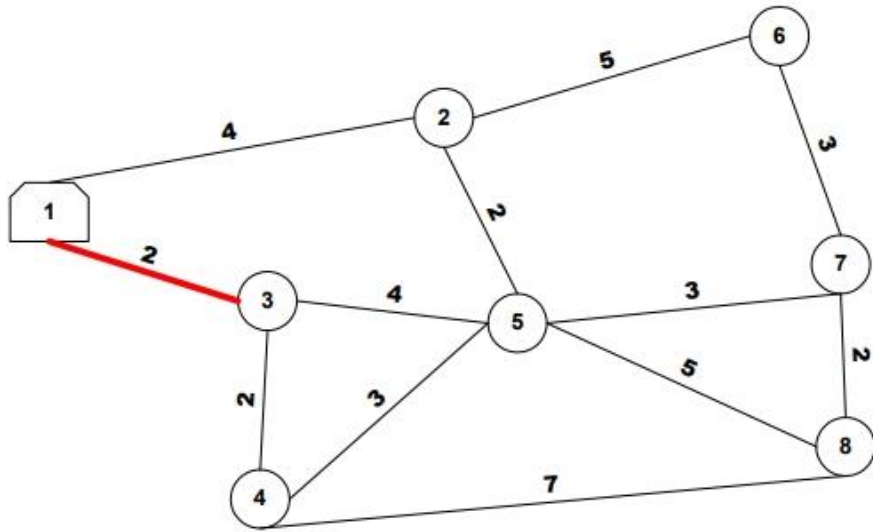


B. EXAMPLE 2



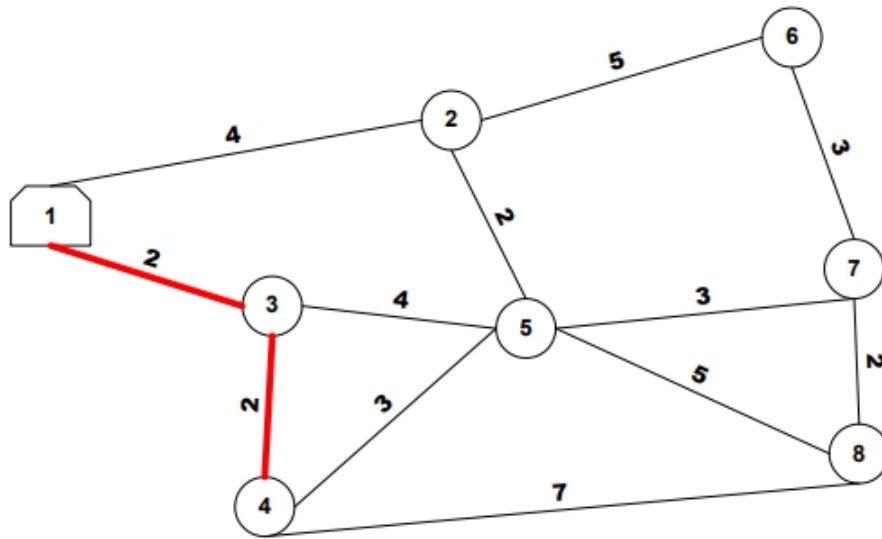
Step 1

Algorithm



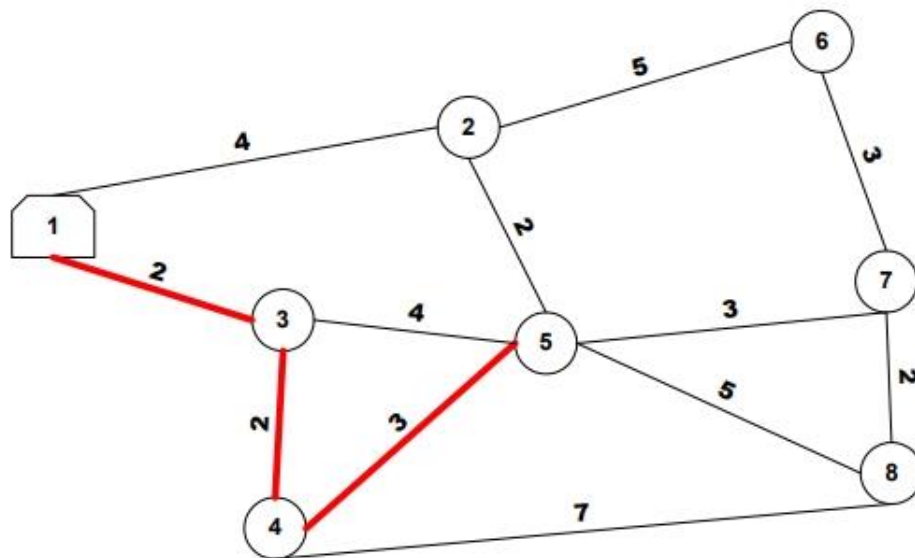
Step 2

Algorithm



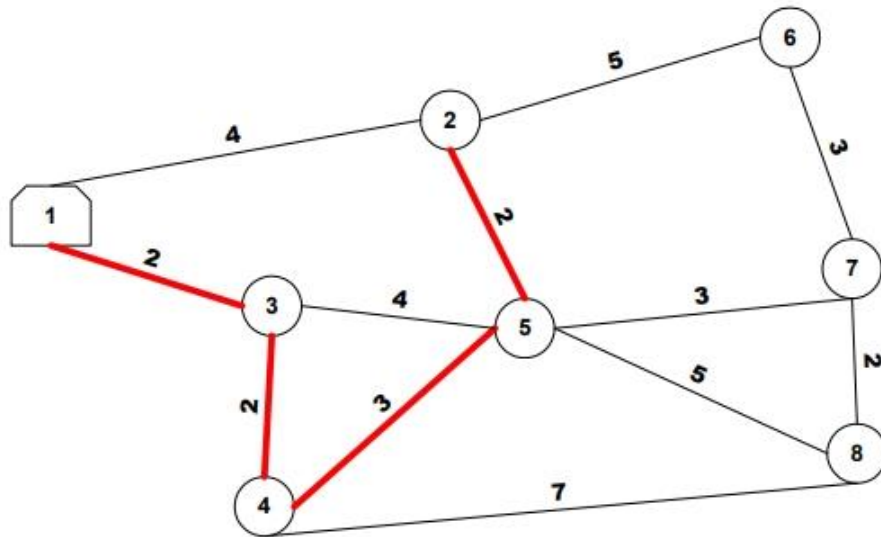
Step 3

Algorithm



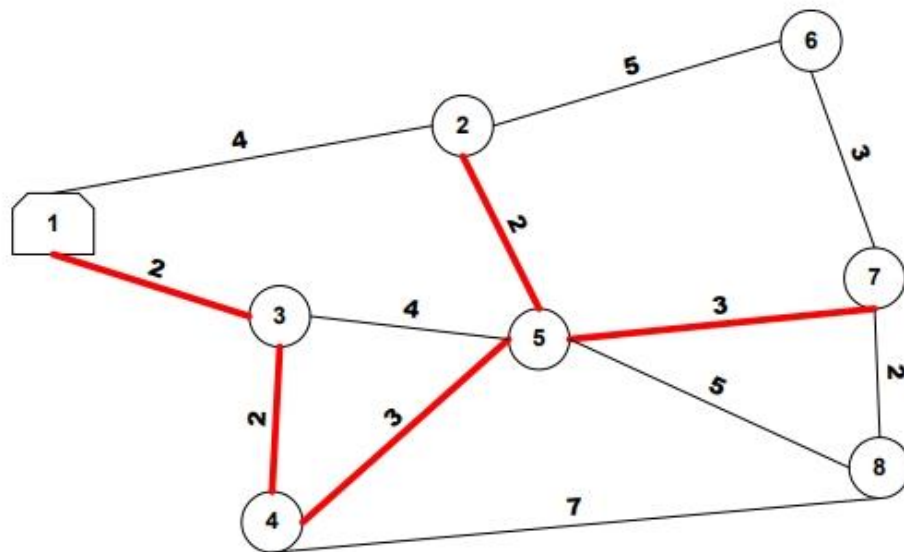
Step 4

Algorithm



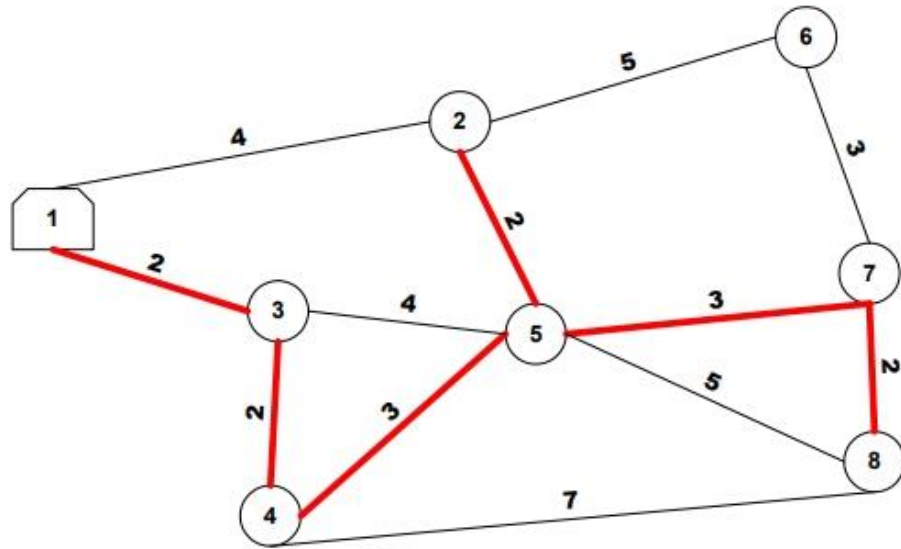
Step 5

Algorithm



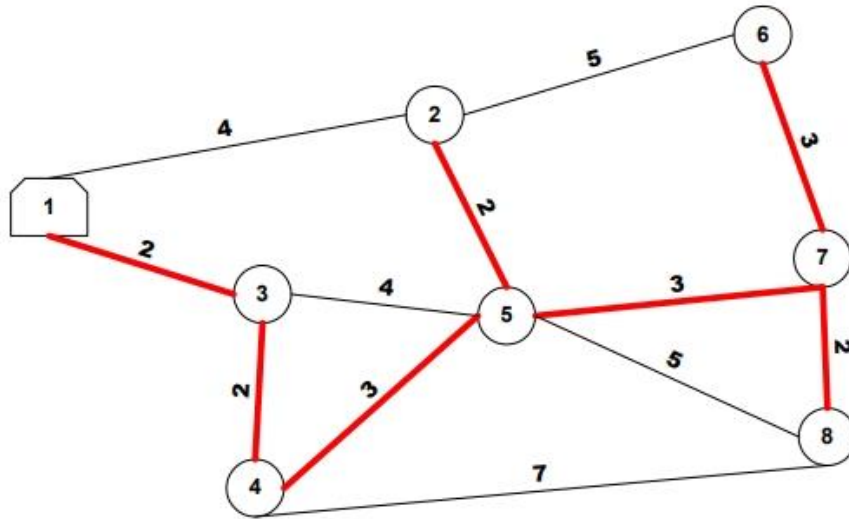
Step 6

Algorithm



Step 7

Algorithm



Step 8

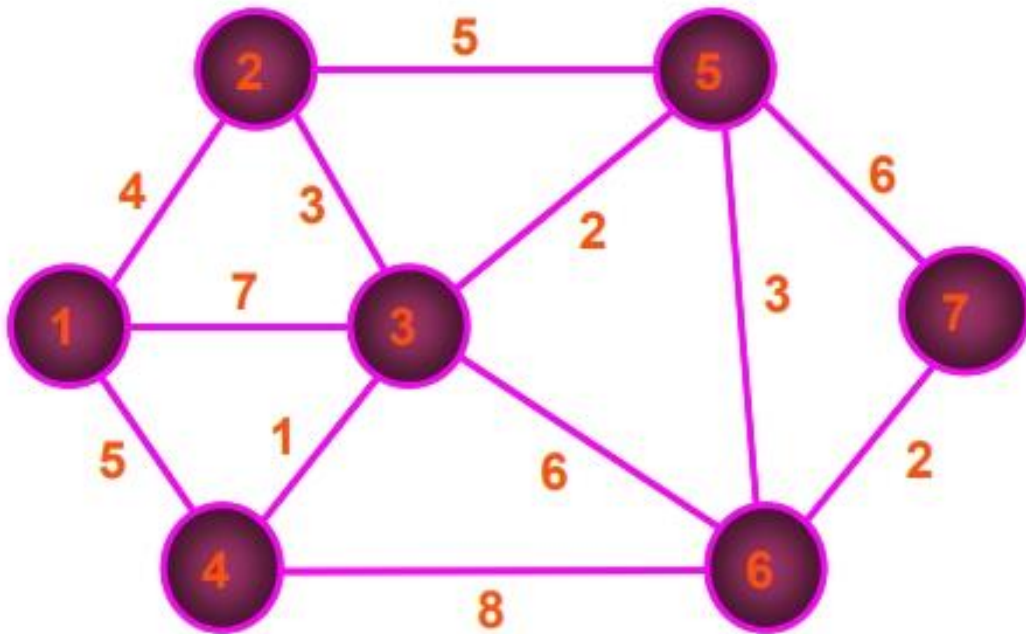
<b>1 -- 3</b>	<b>2</b>
<b>3 -- 4</b>	<b>2</b>
<b>4 --5</b>	<b>3</b>
<b>5 --2</b>	<b>2</b>
<b>5 --7</b>	<b>3</b>
<b>7 --8</b>	<b>2</b>
<b>7 --6</b>	<b>3</b>
<b>Total</b>	<b>17</b>

A. BY HAND

- **Shortest Route Algorithm**

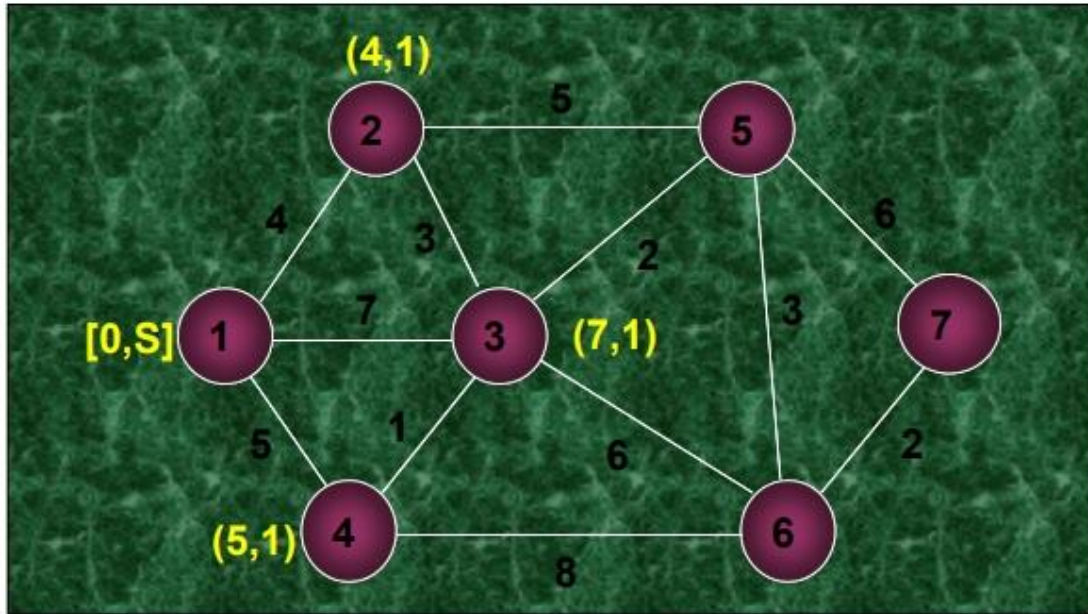
- To find **Shortest Path** from 1 node to another node
- Or **Shortest Path** from 1 node to ALL other nodes
- Practical Use:
  - GPS System / Garmin Technologies
  - You want to find shortest path from home to work?

1. EXAMPLE 1

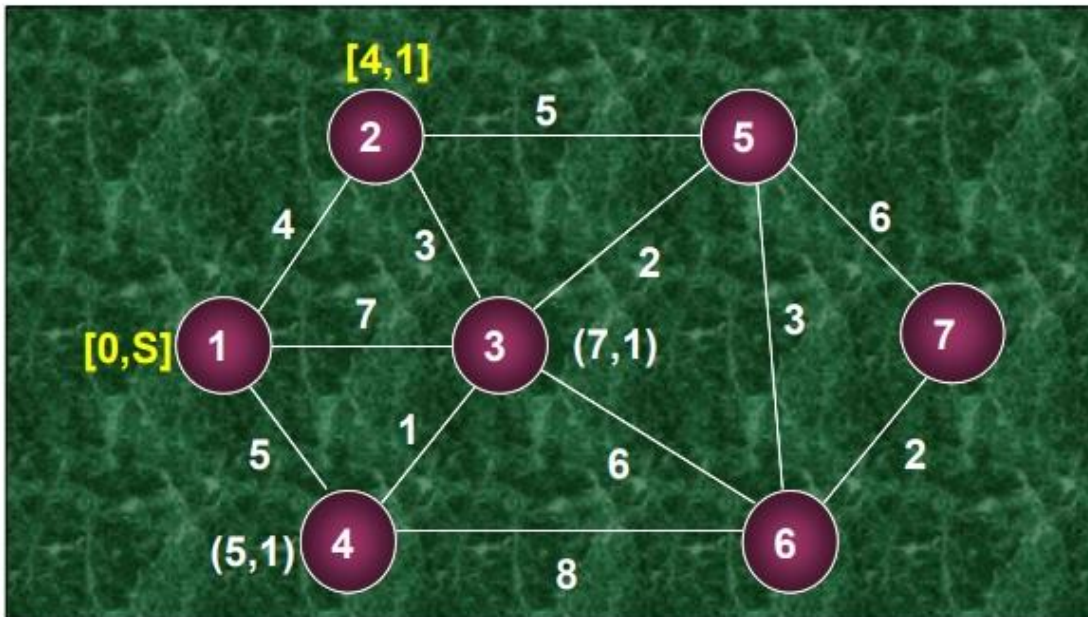




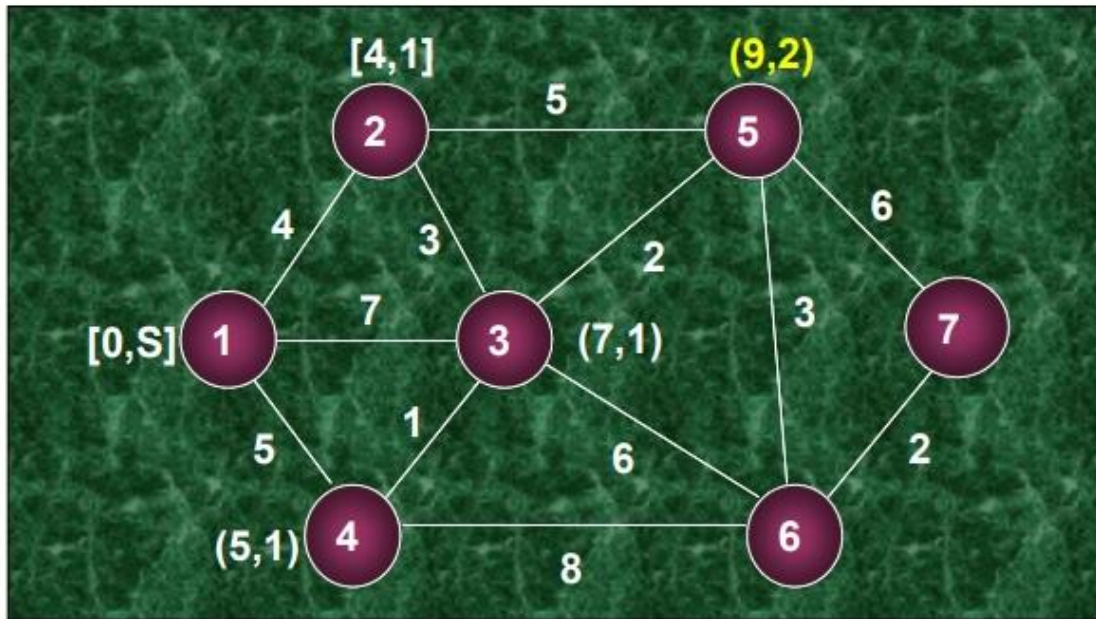
## Illustrated Problem 6.1: Step 1



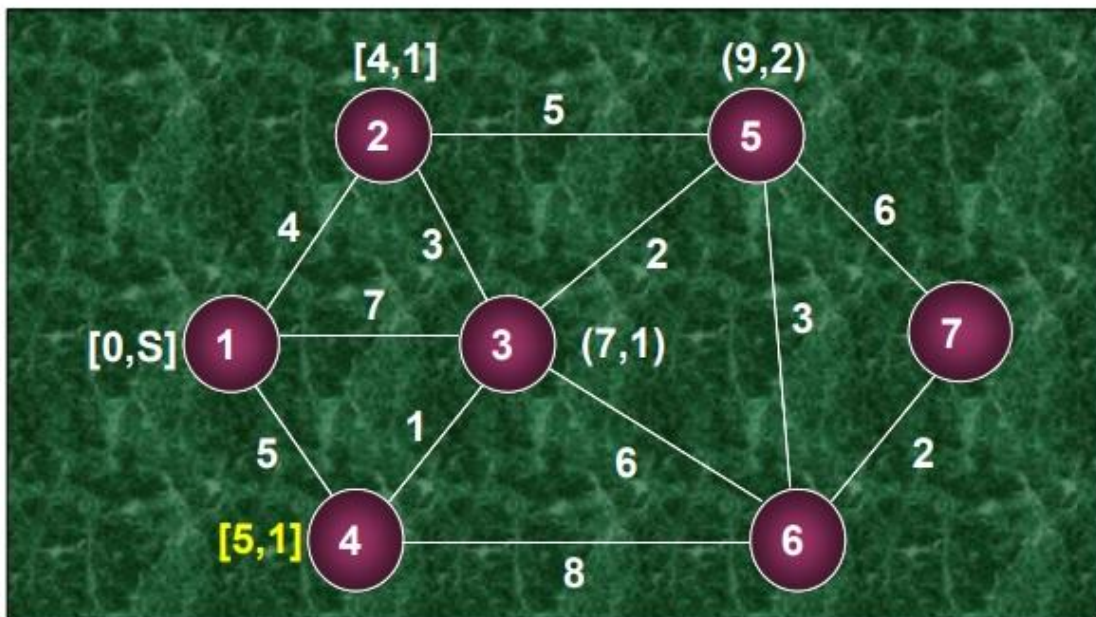
## Illustrated Problem 6.1: Step 2



### Illustrated Problem 6.1: Step 3

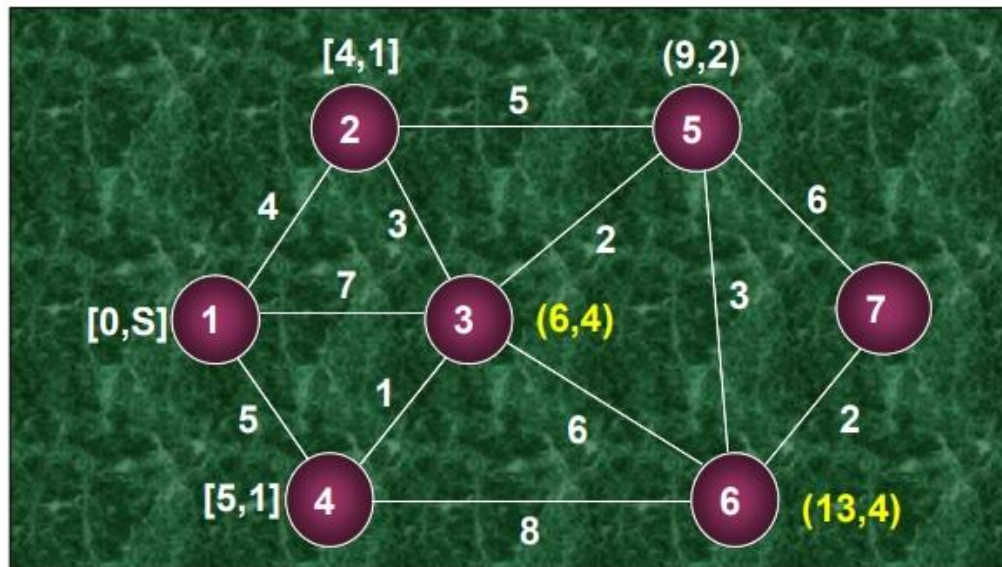


### Illustrated Problem 6.1: Step 4

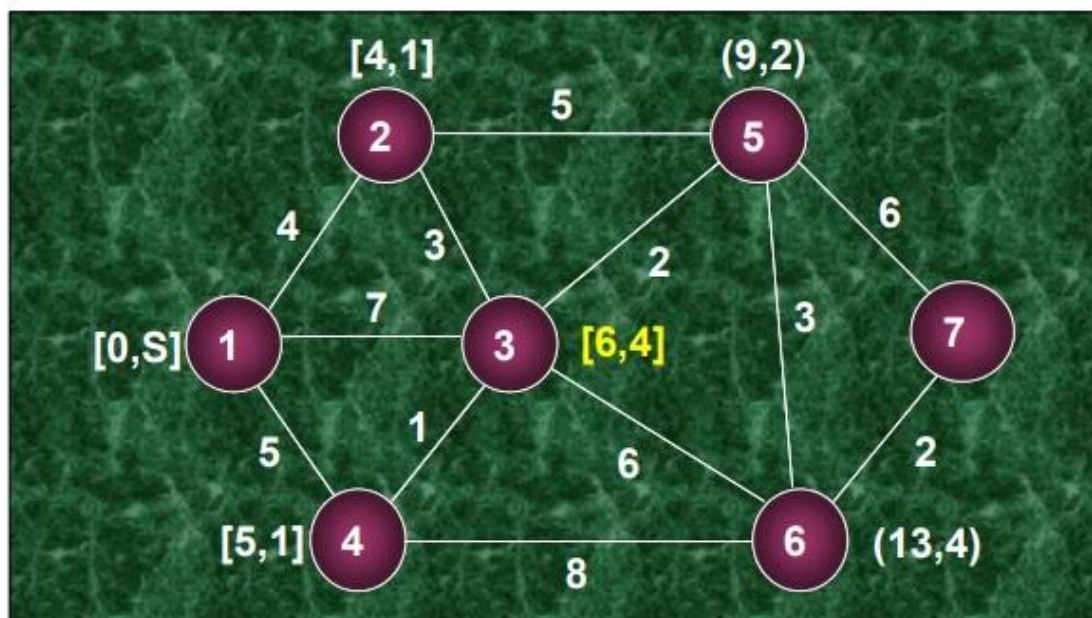




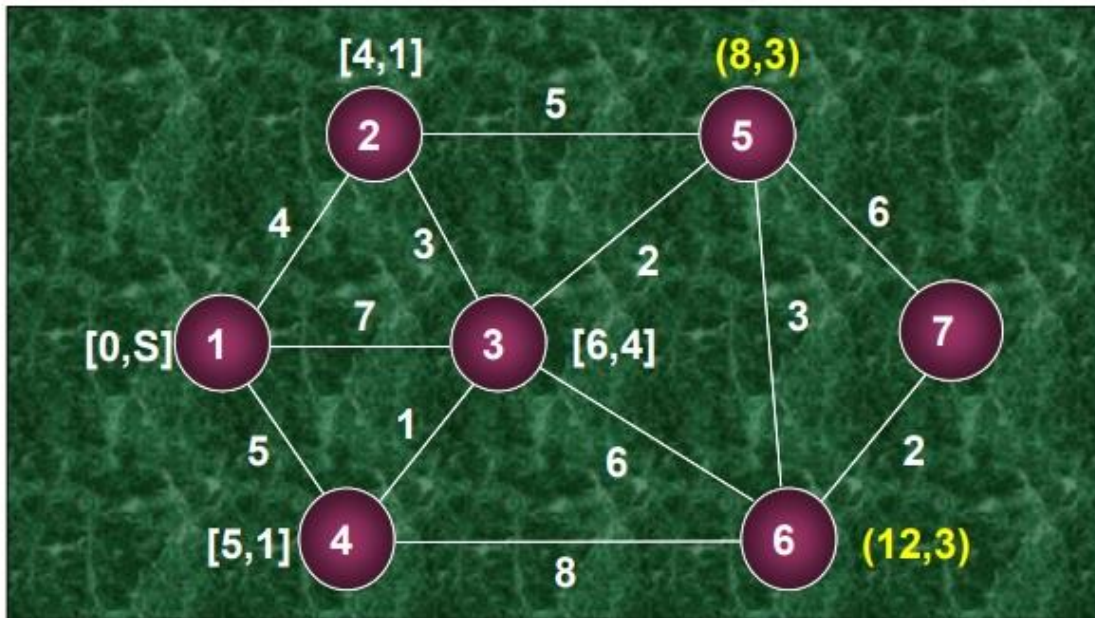
## Illustrated Problem 6.1: Step 5



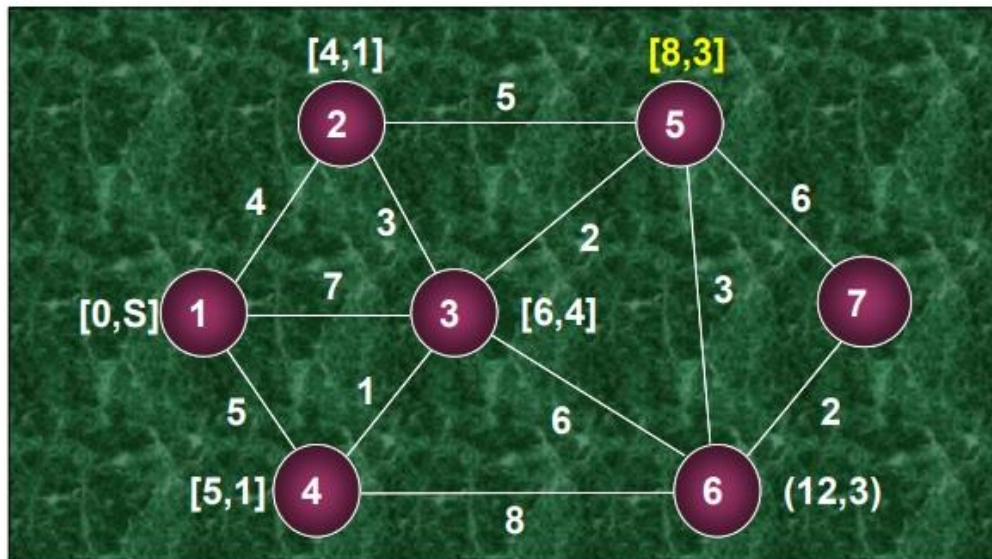
## Illustrated Problem 6.1: Step 6



## Illustrated Problem 6.1: Step 7

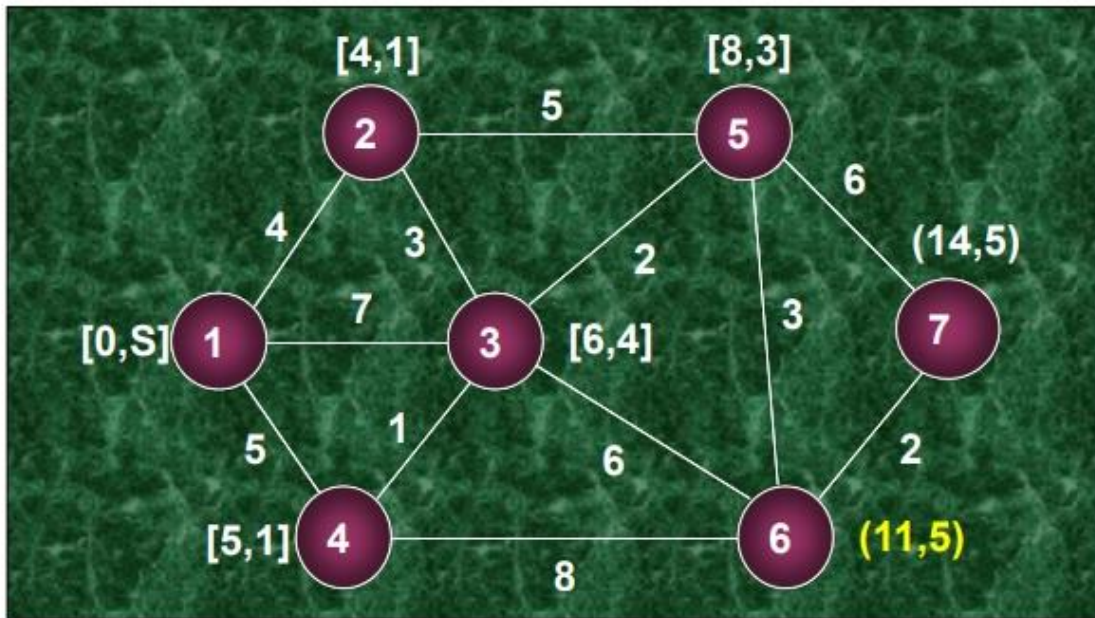


## Illustrated Problem 6.1: Step 8

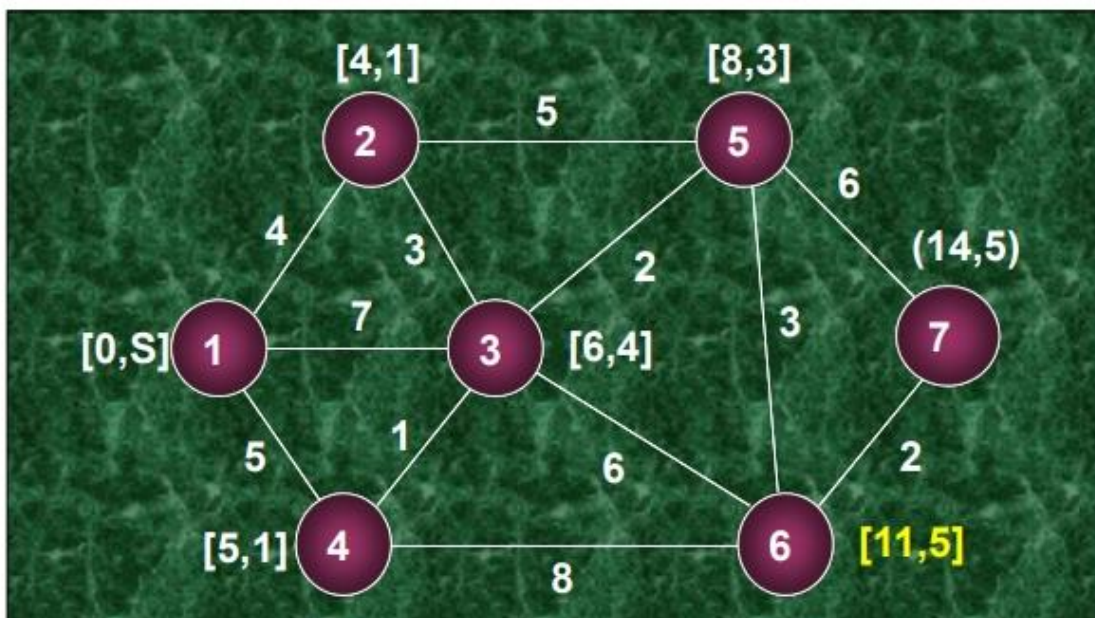




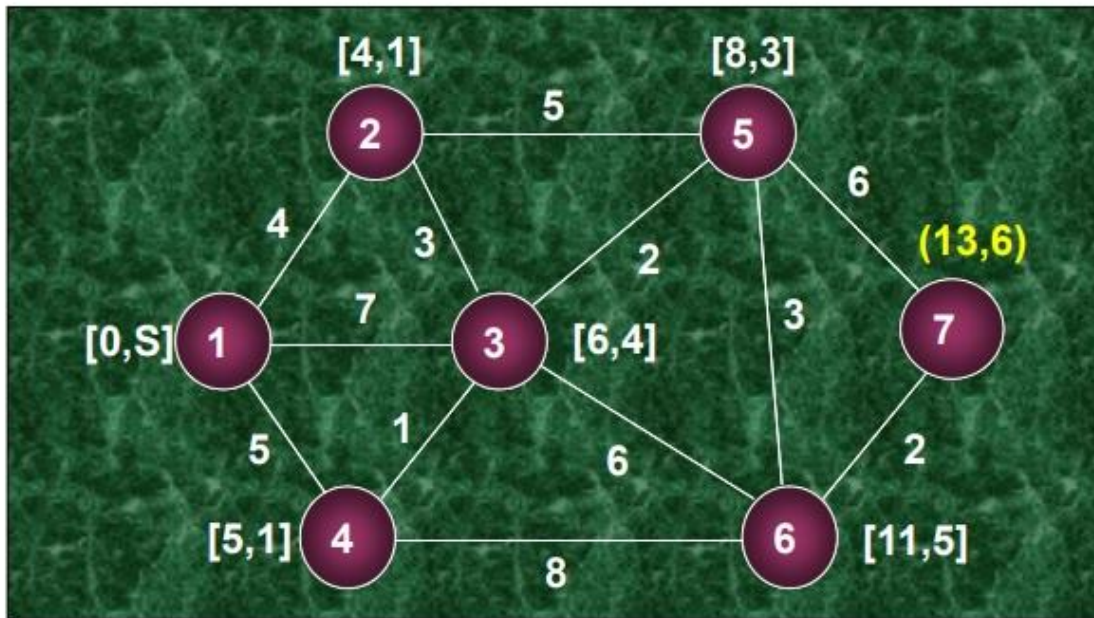
## Illustrated Problem 6.1: Step 9



## Illustrated Problem 6.1: Step 10



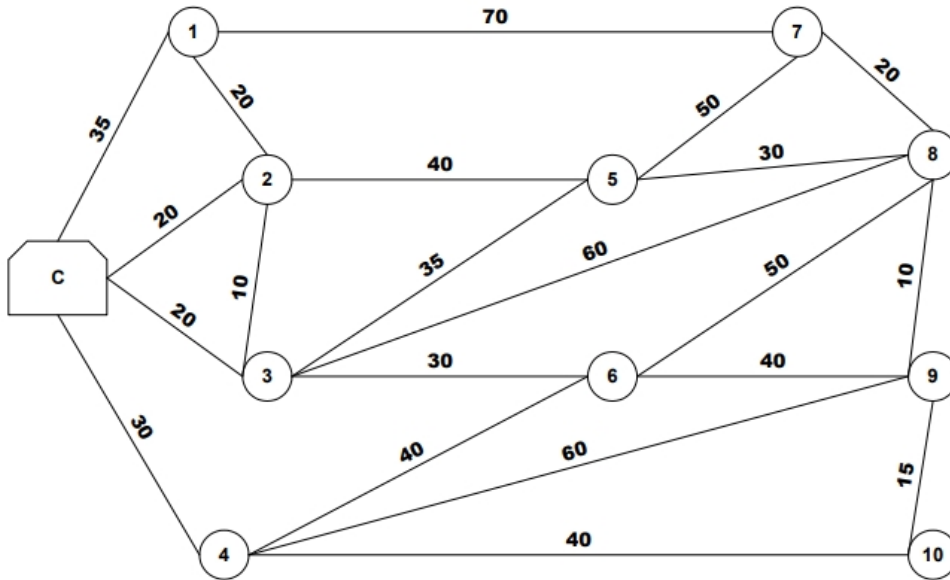
## Illustrated Problem 6.1: Step 11



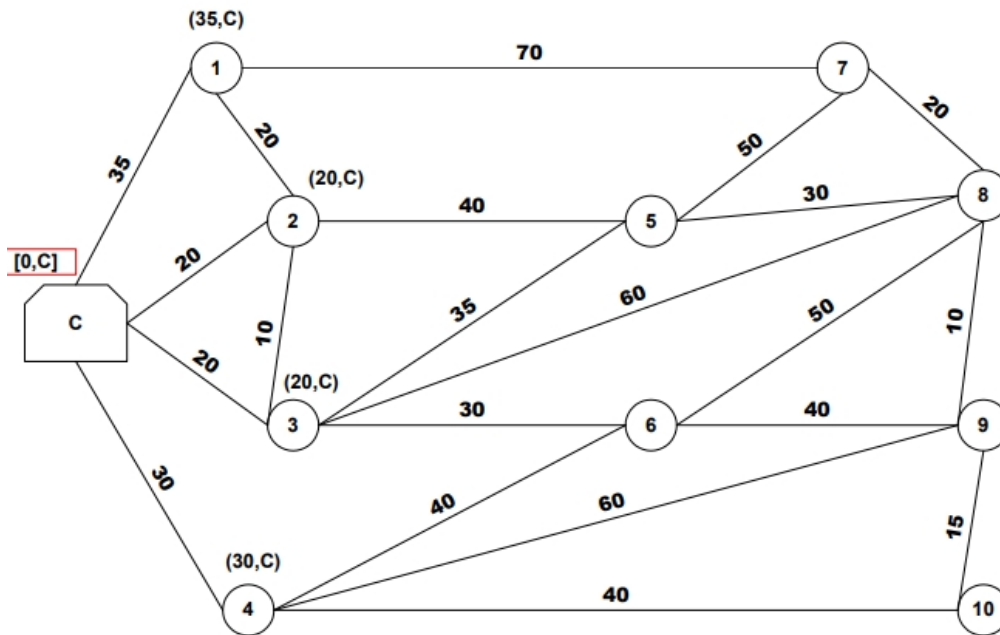
– Illustrated Problem 6.1: Step 12 (Final)

<u>Node</u>	<u>Minimum Distance</u>	<u>Shortest Route</u>
2	4	1-2
3	6	1-4-3
4	5	1-4
5	8	1-4-3-5
6	11	1-4-3-5-6
7	13	1-4-3-5-6-7

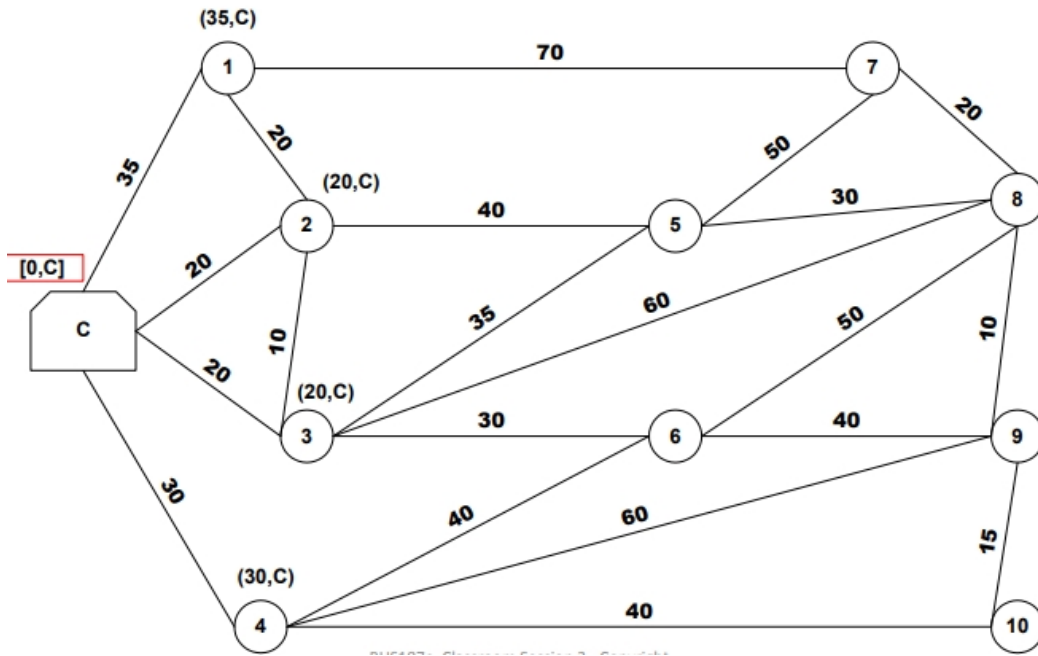
2. EXAMPLE 2



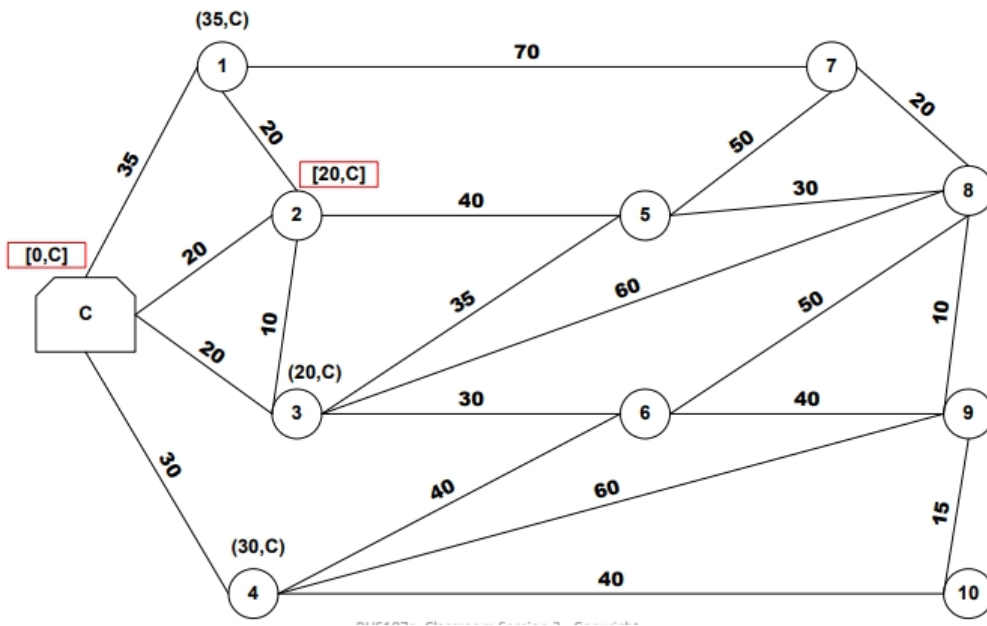
– An Old Exercise : Step **Network Modeling** Shortest Route Algorithm



– An Old Exercise : Step 2 **Network Modeling** Shortest Route Algorithm

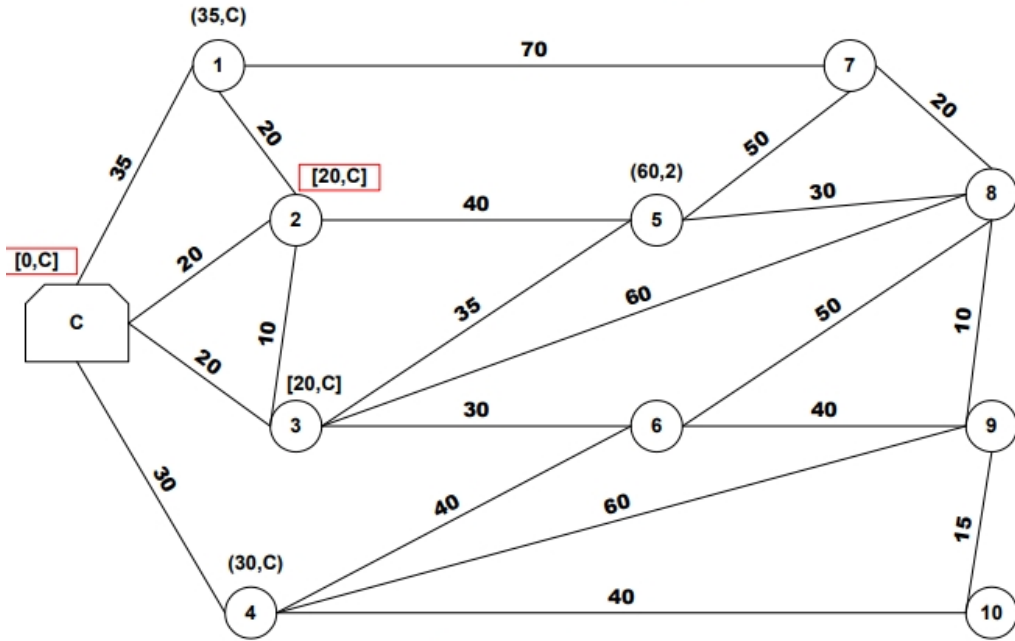


– An Old Exercise : Step 3 **Network Modeling** Shortest Route Algorithm

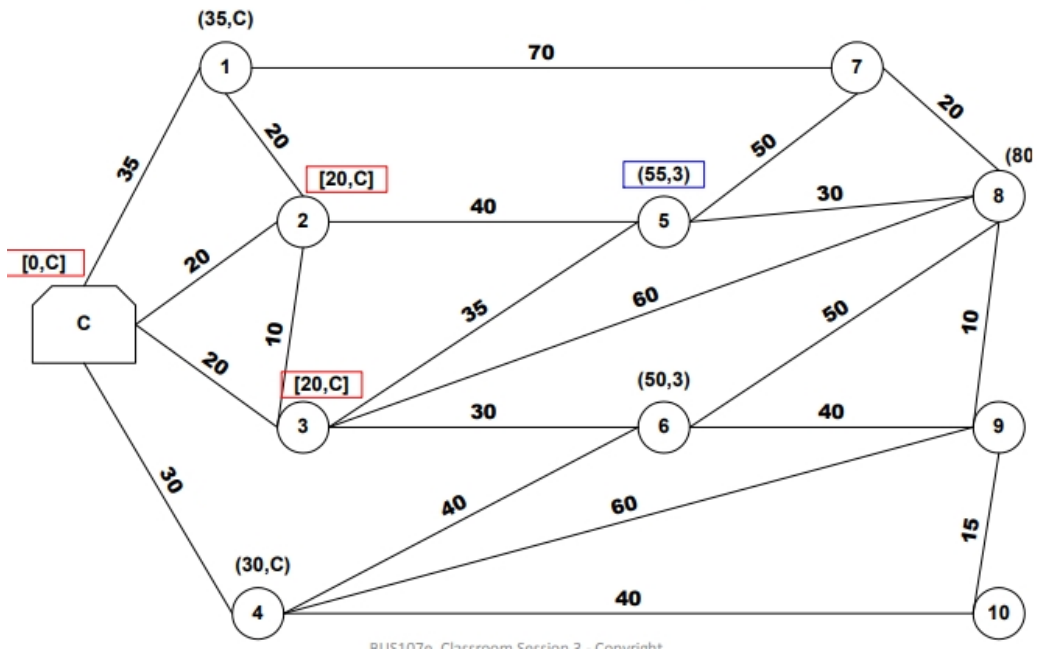




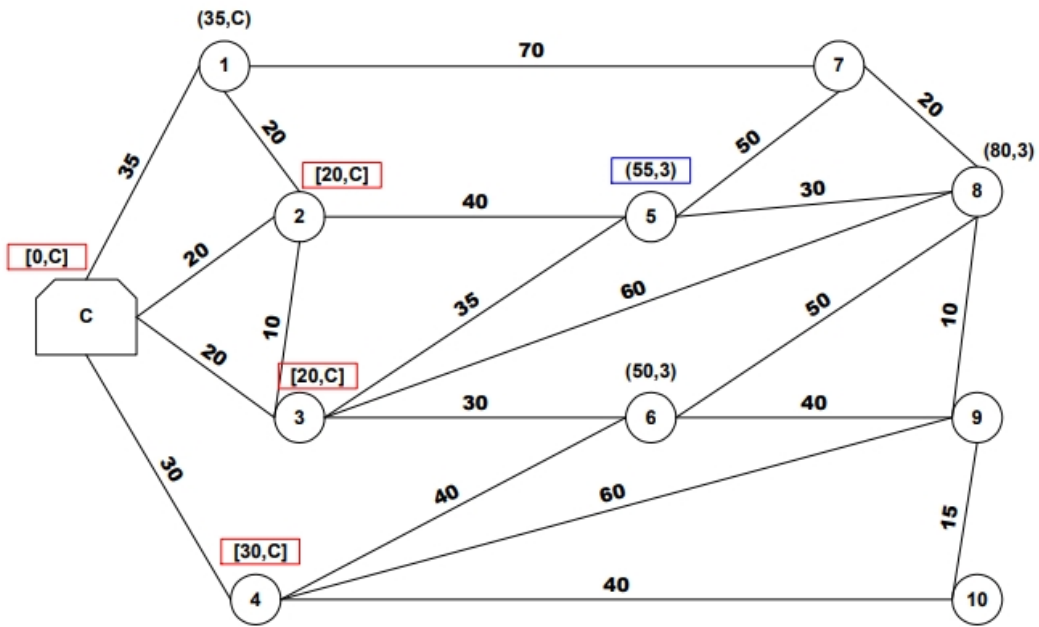
- An Old Exercise : Step 4 **Network Modeling** Shortest Route Algorithm



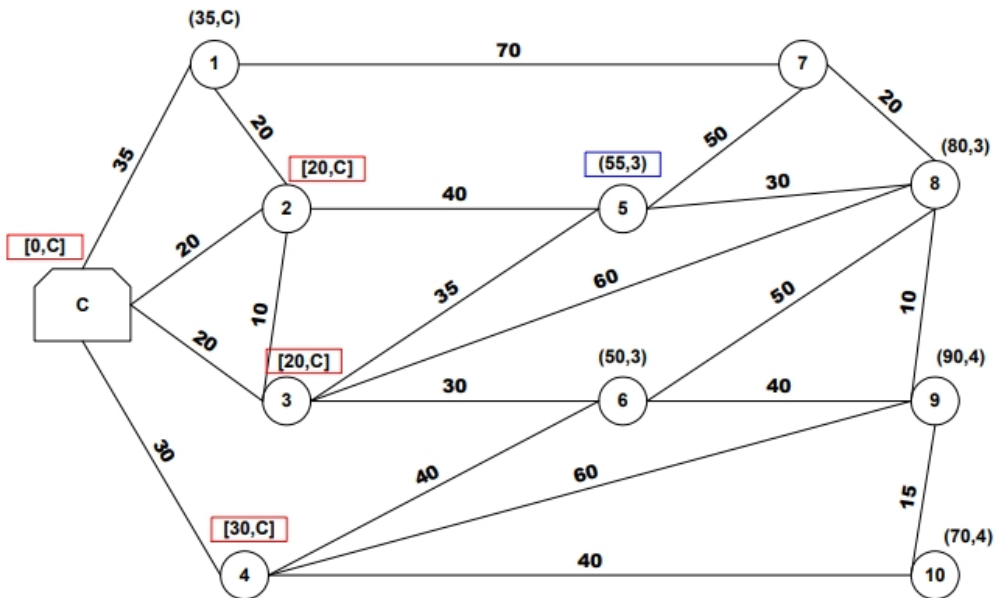
- An Old Exercise : Step 5 **Network Modeling** Shortest Route Algorithm



– An Old Exercise : Step **Network Modeling** Shortest Route Algorithm

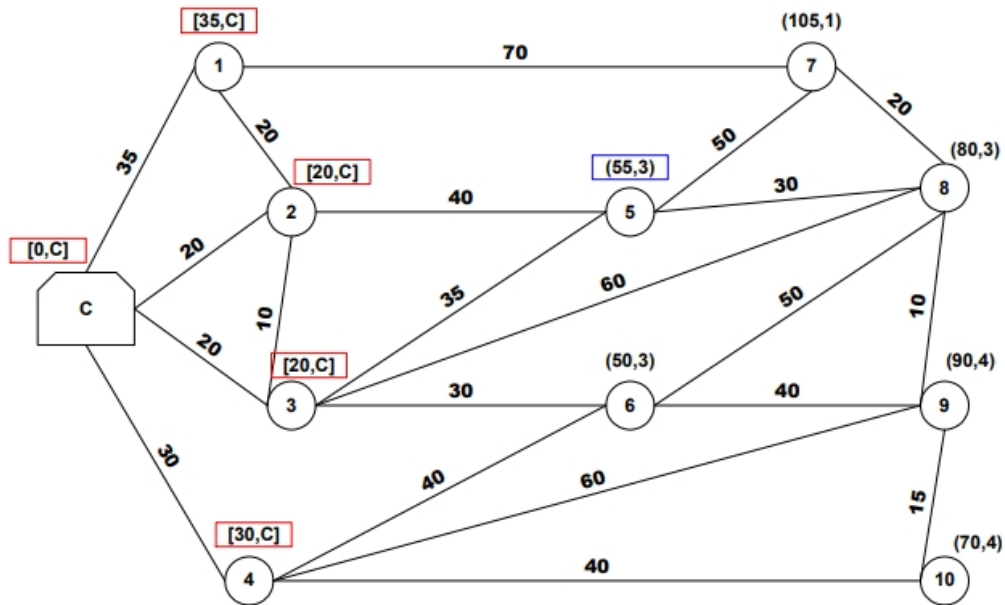


– An Old Exercise : Step **Network Modeling** Shortest Route Algorithm

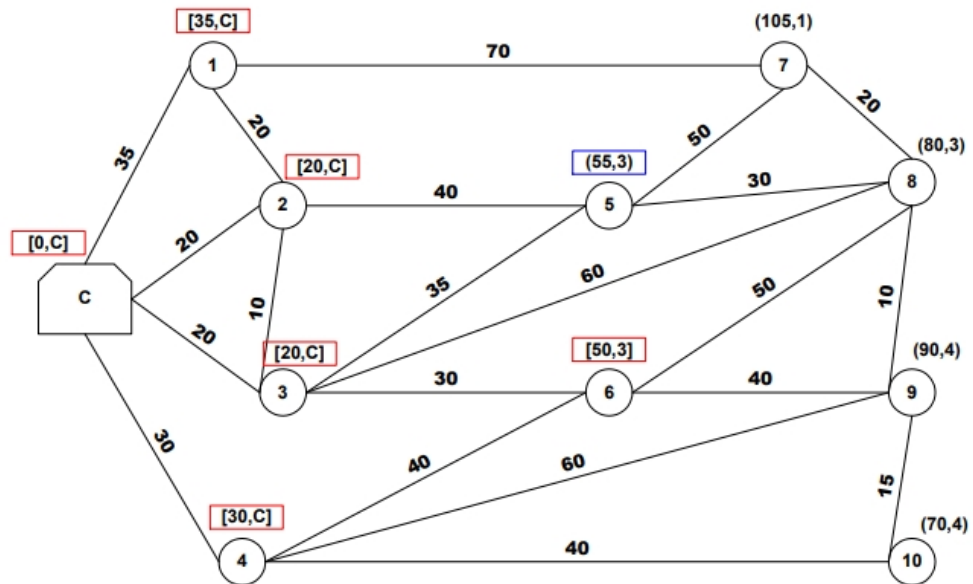




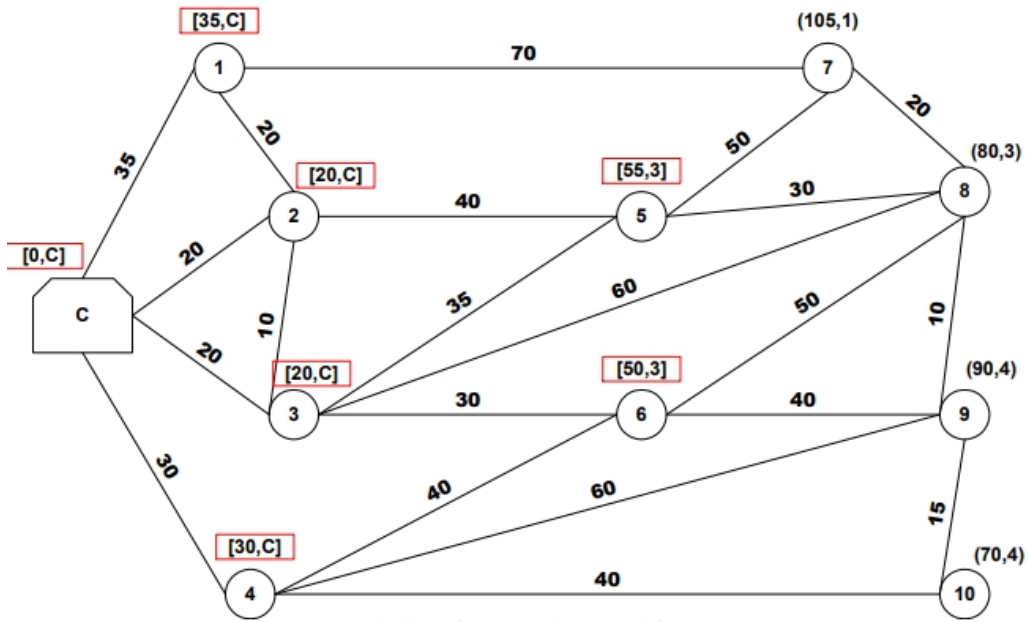
- An Old Exercise : Step 8 **Network Modeling** Shortest Route Algorithm



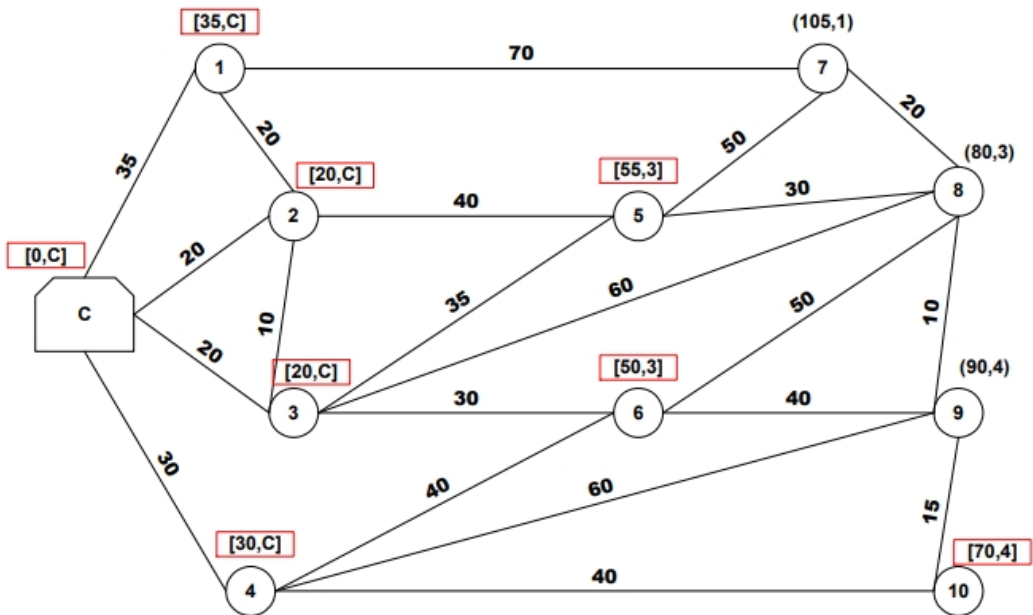
- An Old Exercise : Step 9 **Network Modeling** Shortest Route Algorithm



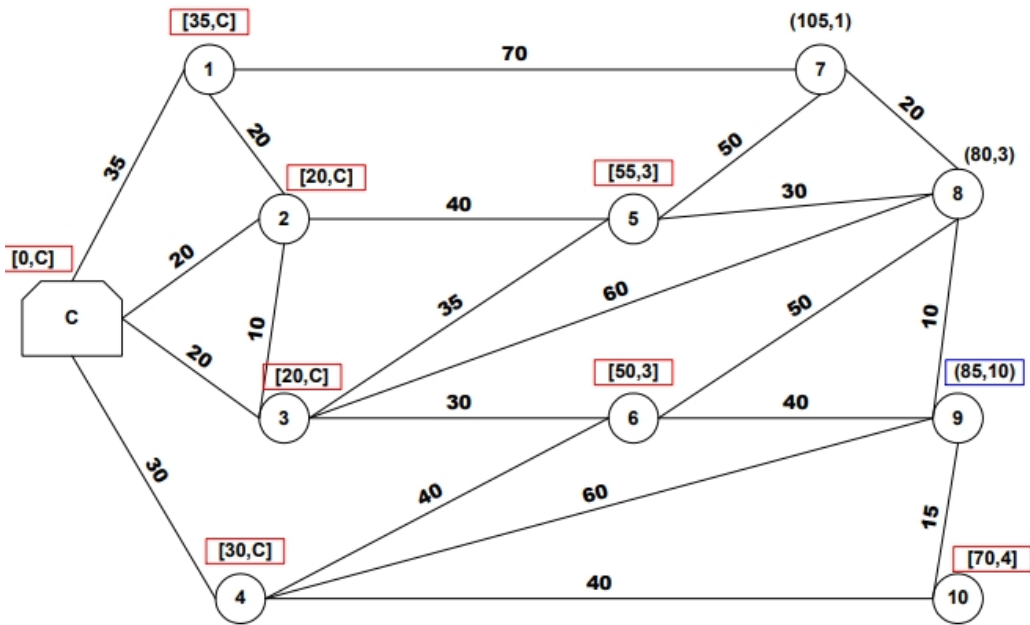
- An Old Exercise : Step 10 **Network Modeling** Shortest Route Algorithm



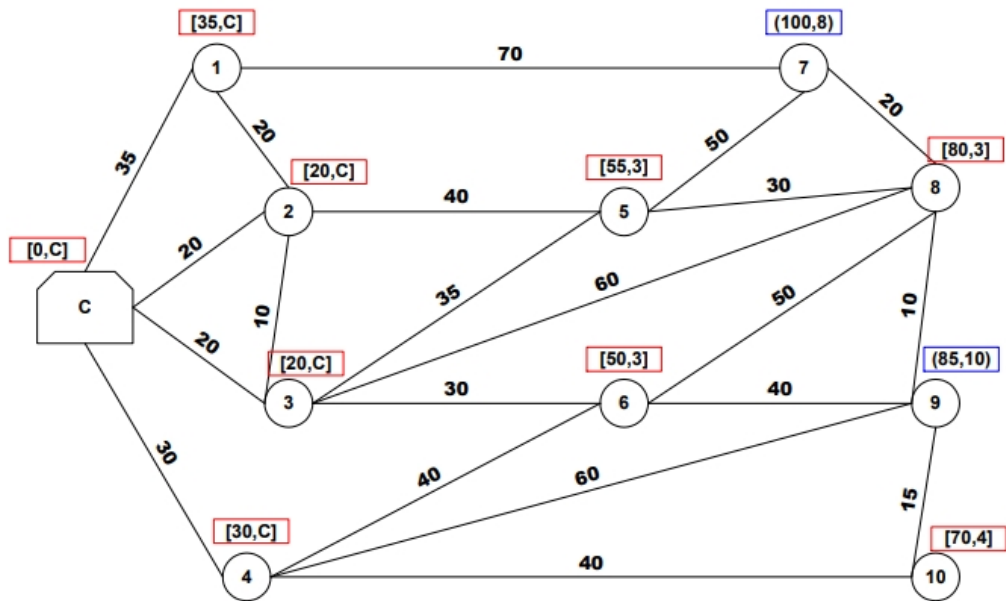
- An Old Exercise : Step 11 **Network Modeling** Shortest Route Algorithm



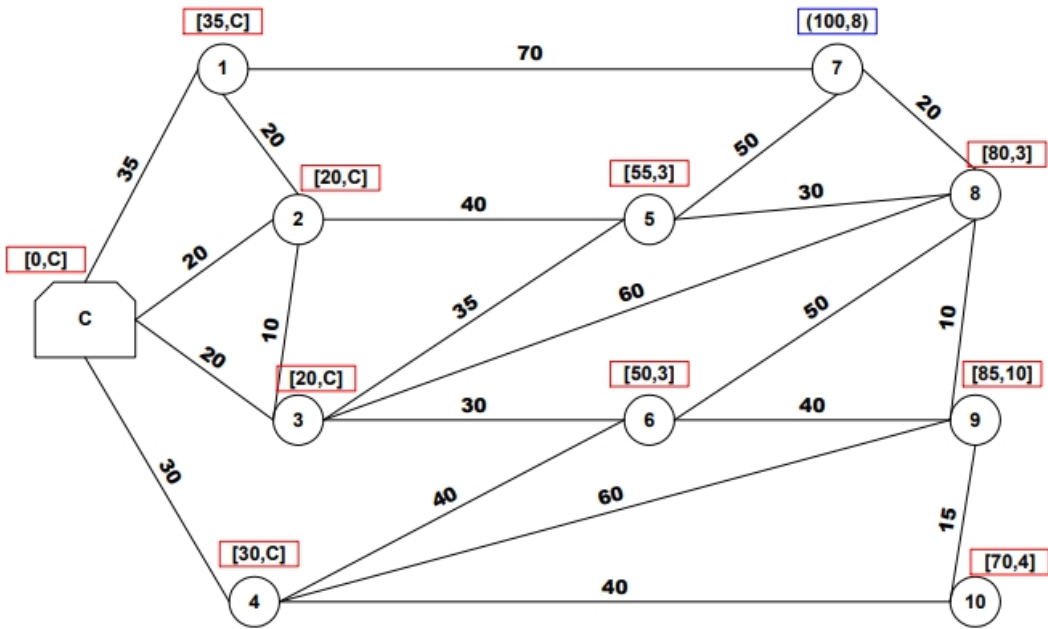
– An Old Exercise : Step 12 **Network Modeling** Shortest Route Algorithm



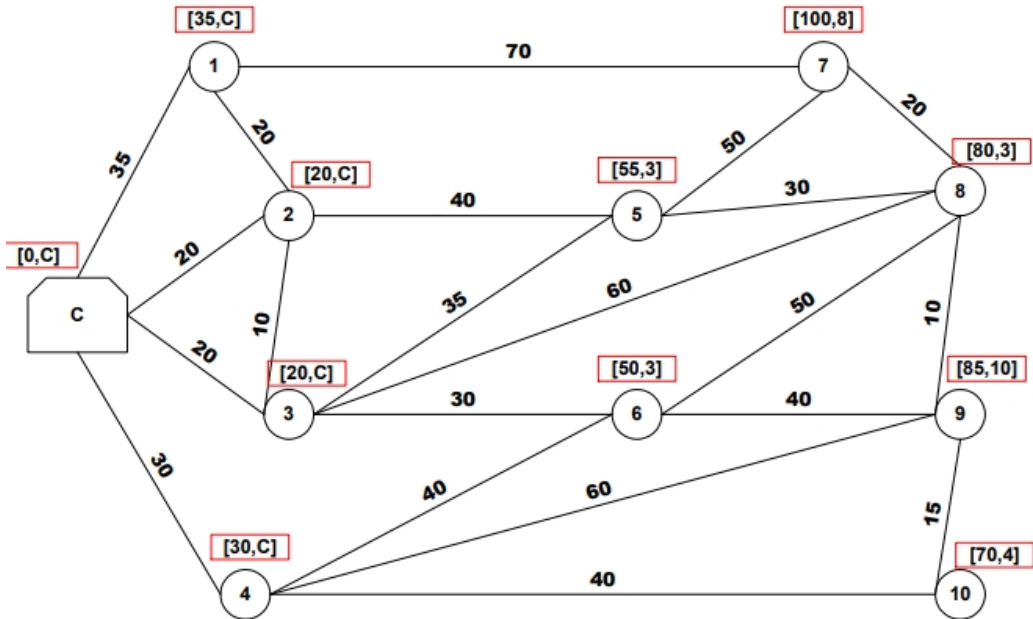
– An Old Exercise : Step 13 **Network Modeling** Shortest Route Algorithm



– An Old Exercise : Step 4 **Network Modeling** Shortest Route Algorithm



– An Old Exercise : Step 5 **Network Modeling** Shortest Route Algorithm

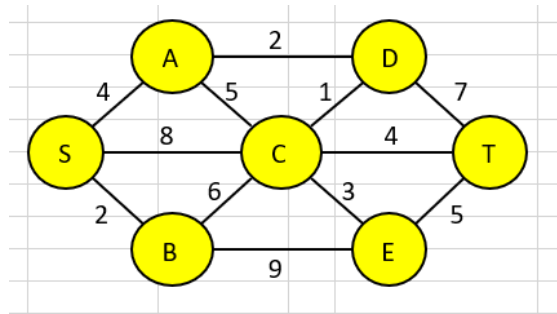


- An Old Exercise : Step 16 **Network Modeling** Shortest Route Algorithm

<b>Node</b>	<b>Shortest Route from Node C</b>	<b>Distance</b>
<b>1</b>	<b>C - 1</b>	<b>35</b>
<b>2</b>	<b>C - 2</b>	<b>20</b>
<b>3</b>	<b>C - 3</b>	<b>20</b>
<b>4</b>	<b>C - 4</b>	<b>30</b>
<b>5</b>	<b>C - 3 - 5</b>	<b>55</b>
<b>6</b>	<b>C - 3 - 6</b>	<b>50</b>
<b>7</b>	<b>C - 3 - 8 - 7</b>	<b>100</b>
<b>8</b>	<b>C - 3 - 8</b>	<b>80</b>
<b>9</b>	<b>C - 4 - 10 - 9</b>	<b>85</b>
<b>10</b>	<b>C - 4 - 10</b>	<b>70</b>

## B. USING EXCEL

File: <https://www.alvinang.sg/s/shortest-path-problem.xlsx>



- We are trying to get from S to T
- We need to find the Shortest Path and the Shortest Distance.

The optimal solution:

	A	B	C	D	E	F	G	H	I	J	K	L
1	<b>Shortest Path Problem</b>											
2												
3		From	To	Distance		Go		Nodes	Net Flow	=	Supply/Demand	
4		S	A	4		1		S	1	=	1	
5		S	B	2		0		A	0	=	0	
6		S	C	8		0		B	0	=	0	
7		A	C	5		0		C	0	=	0	
8		A	D	2		1		D	0	=	0	
9		B	C	6		0		E	0	=	0	
10		B	E	9		0		T	-1	=	-1	
11		C	A	5		0						
12		C	B	6		0						
13		C	D	1		0						
14		C	E	3		0						
15		C	T	4		1						
16		D	A	2		0						
17		D	C	1		1						
18		D	T	7		0						
19		E	B	9		0						
20		E	C	3		0						
21		E	T	5		0						
22												
23				Total Distance		11						
24												

Conclusion: SADCT is the shortest path with a total distance of 11.

- Minimal Distance is 11
- Shortest Path: SADCT.
- We will try to replicate this in Excel, Step by Step.

1. STEP 1: DEFINE FROM / TO / DISTANCE / GO

	A	B	C	D	E	F	G
1	<b>SHORTEST PATH ALGORITHM</b>						
2							
3		From	To	Distance		Go	
4		S	A	4		0	
5		S	B	2		0	
6		S	C	8		0	
7		A	C	5		0	
8		A	D	2		0	
9		B	C	6		0	
10		B	E	9		0	
11		C	A	5		0	
12		C	B	6		0	
13		C	D	1		0	
14		C	E	3		0	
15		C	T	4		0	
16		D	A	2		0	
17		D	C	1		0	
18		D	T	7		0	
19		E	B	9		0	
20		E	C	3		0	
21		E	T	5		0	

File Home Insert Page Layout **Formulas** Data Review View Add-ins Help Tell me what you want to do

fx  $\Sigma$  **Define Name**

Function Library

B4  $\times$   $\checkmark$  fx S

1 **SHORTEST PATH ALGORITHM**

From	To	Distance	Go
S	A	4	0
S	B	2	0
S	C	8	0
A	C	5	0
A	D	2	0
B	C	6	0
B	E	9	0
C	A	5	0
C	D	1	0
C	E	3	0
C	T	4	0
D	A	2	0
D	C	1	0
D	T	7	0
E	B	9	0
E	C	3	0
E	T	5	0

New Name ?

Name: **From**

Scope: Workbook

Comment:

Refers to: **=Sheet1!\$B\$4:\$B\$21**

File Home Insert Page Layout **Formulas** Data Review View Add-ins Help Tell me what you want to do

fx  $\Sigma$  **Define Name**

Function Library

C4  $\times$   $\checkmark$  fx A

1 **SHORTEST PATH ALGORITHM**

From	To	Distance	Go
S	A	4	0
S	B	2	0
S	C	8	0
A	C	5	0
A	D	2	0
B	C	6	0
B	E	9	0
C	A	5	0
C	B	6	0
C	D	1	0
C	E	3	0
C	T	4	0
D	A	2	0
D	C	1	0
D	T	7	0
E	B	9	0
E	C	3	0
E	T	5	0

New Name ?

Name: **To**

Scope: Workbook

Comment:

Refers to: **=Sheet1!\$C\$4:\$C\$21**



The screenshot shows the Excel interface with the 'Formulas' ribbon selected. The 'Name Manager' dialog box is open, displaying a list of defined names. The 'Distance' name is highlighted, with its formula set to '=Sheet1!\$D\$4:\$D\$21'. In the background spreadsheet, the 'Distance' column (D4:D21) is highlighted in blue, and the 'Go' column (E4:E21) is highlighted in yellow.

	From	To	Distance	Go
4	S	A	4	0
5	S	B	2	0
6	S	C	8	0
7	A	C	5	0
8	A	D	2	0
9	B	C	6	0
10	B	E	9	0
11	C	A	5	0
12	C	B	6	0
13	C	D	1	0
14	C	E	3	0
15	C	T	4	0
16	D	A	2	0
17	D	C	1	0
18	D	T	7	0
19	E	B	9	0
20	E	C	3	0
21	E	T	5	0

The screenshot shows the Excel interface with the 'Formulas' ribbon selected. The 'New Name' dialog box is open, showing the 'Go' name being defined with the formula '=Sheet1!\$F\$4:\$F\$21'. In the background spreadsheet, the 'Go' column (F4:F21) is highlighted in yellow.

	From	To	Distance	Go
4	S	A	4	0
5	S	B	2	0
6	S	C	8	0
7	A	C	5	0
8	A	D	2	0
9	B	C	6	0
10	B	E	9	0
11	C	A	5	0
12	C	B	6	0
13	C	D	1	0
14	C	E	3	0
15	C	T	4	0
16	D	A	2	0
17	D	C	1	0
18	D	T	7	0
19	E	B	9	0
20	E	C	3	0
21	E	T	5	0

2. STEP 2: CREATE TOTAL DISTANCE

The screenshot shows the Power BI Desktop interface with a table containing columns A through H. Column D is highlighted in blue and contains numerical values. Column F is highlighted in yellow and contains zeros. A calculated column 'TotalDistance' is being created, with its formula shown in the formula bar as '=SUMPRODUCT(Distance,Go)'. Red annotations include arrows pointing from the formula bar to the column name and the formula, and text boxes saying 'now create this...', 'type in TotalDistance as Name', and a box around the value '0' in the data table.

	A	B	C	D	E	F	G	H
7		A	C	5		0		C
8		A	D	2		0		D
9		B	C	6		0		E
10		B	E	9		0		T
11		C	A	5		0		
12		C	B	6		0		
13		C	D	1		0		
14		C	E	3		0		
15		C	T	4		0		
16		D	A	2		0		
17		D	C	1		0		
18		D	T	7		0		
19		E	B	9		0		
20		E	C	3		0		
21		E	T	5		0		
22								
23				Total Distance		0		
24								

3. STEP 3: CREATE NODES / = / SUPPLY DEMAND

Clipboard Font Alignment

H3 Nodes

	A	B	C	D	E	F	G	H	I
1	<b>SHORTEST PATH ALGORITHM</b>								
2									
3		From	To	Distance		Go		Nodes	
4		S	A	4		0		S	
5		S	B	2		0		A	
6		S	C	8		0		B	
7		A	C	5		0		C	
8		A	D	2		0		D	
9		B	C	6		0		E	
10		B	E	9		0		T	
11		C	A	5		0			
12		C	B	6		0			
13		C	D	1		0			
14		C	E	3		0			
15		C	T	4		0			
16		D	A	2		0			
17		D	C	1		0			
18		D	T	7		0			

now create this

J4 '=

	A	B	C	D	E	F	G	H	I	J
1	<b>SHORTEST PATH ALGORITHM</b>									
2										
3		From	To	Distance		Go		Nodes		
4		S	A	4		0		S		=
5		S	B	2		0		A		=
6		S	C	8		0		B		=
7		A	C	5		0		C		=
8		A	D	2		0		D		=
9		B	C	6		0		E		=
10		B	E	9		0		T		=
11		C	A	5		0				=
12		C	B	6		0				=
13		C	D	1		0				=
14		C	E	3		0				=

now create '='

SupplyDe... : now create this SupplyDemand (type into here)

	A	B	C	D	E	F	G	H	I	J	K
1	<b>SHORTEST PATH ALGORITHM</b>										
2											
3		From	To	Distance		Go		Nodes		=	Supply/Demand
4		S	A	4		0		S		=	1
5		S	B	2		0		A		=	0
6		S	C	8		0		B		=	0
7		A	C	5		0		C		=	0
8		A	D	2		0		D		=	0
9		B	C	6		0		E		=	0
10		B	E	9		0		T		=	-1
11		C	A	5		0					
12		C	B	6		0					
13		C	D	1		0					

4. STEP 4: CREATE NET FLOW

	H	I
Nodes		Net Flow
S		=SUMIF(From,H4,Go)
A		=SUMIF(From,H5,Go)-SUMIF(To,H5,Go)
B		=SUMIF(From,H6,Go)-SUMIF(To,H6,Go)
C		=SUMIF(From,H7,Go)-SUMIF(To,H7,Go)
D		=SUMIF(From,H8,Go)-SUMIF(To,H8,Go)
E		=SUMIF(From,H9,Go)-SUMIF(To,H9,Go)
T		=-SUMIF(To,H10,Go)

=SUMIF(From,H4,Go)

=SUMIF(From,H5,Go)-SUMIF(To,H5,Go)

=SUMIF(From,H6,Go)-SUMIF(To,H6,Go)

=SUMIF(From,H7,Go)-SUMIF(To,H7,Go)

=SUMIF(From,H8,Go)-SUMIF(To,H8,Go)

=SUMIF(From,H9,Go)-SUMIF(To,H9,Go)

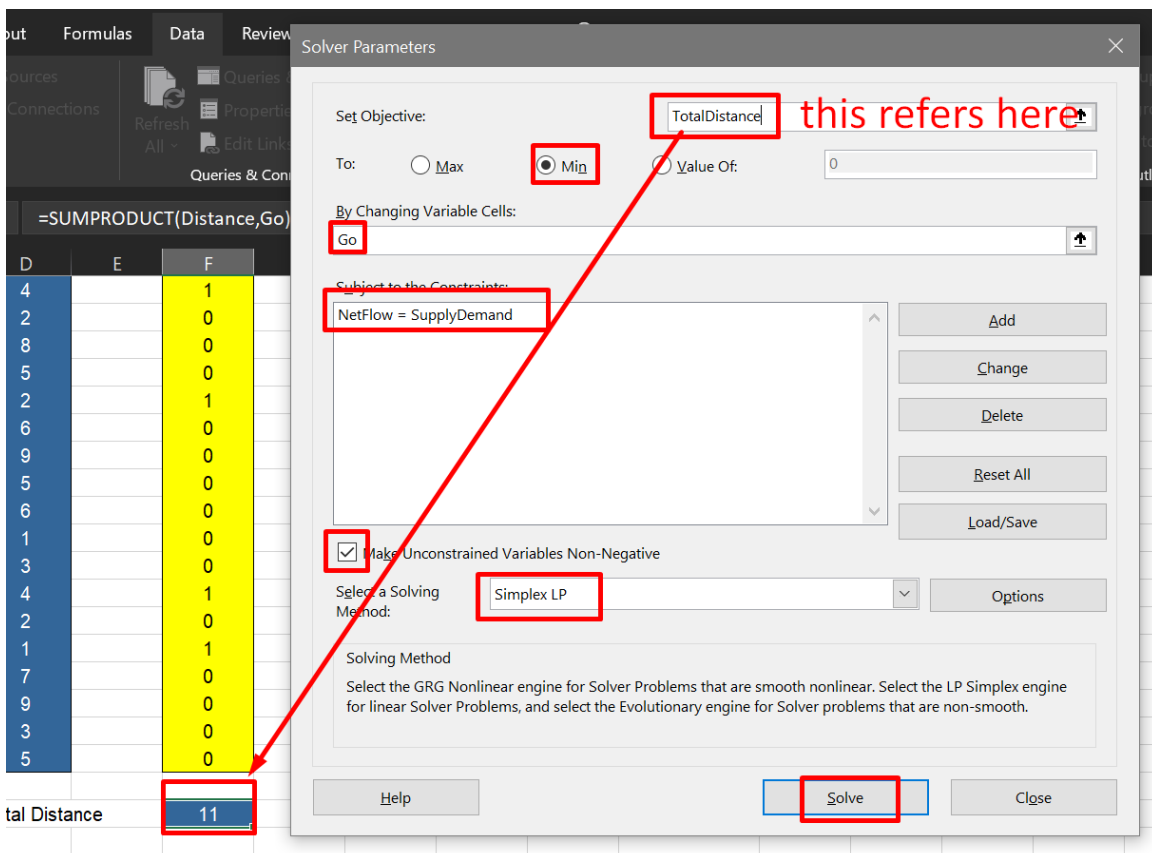
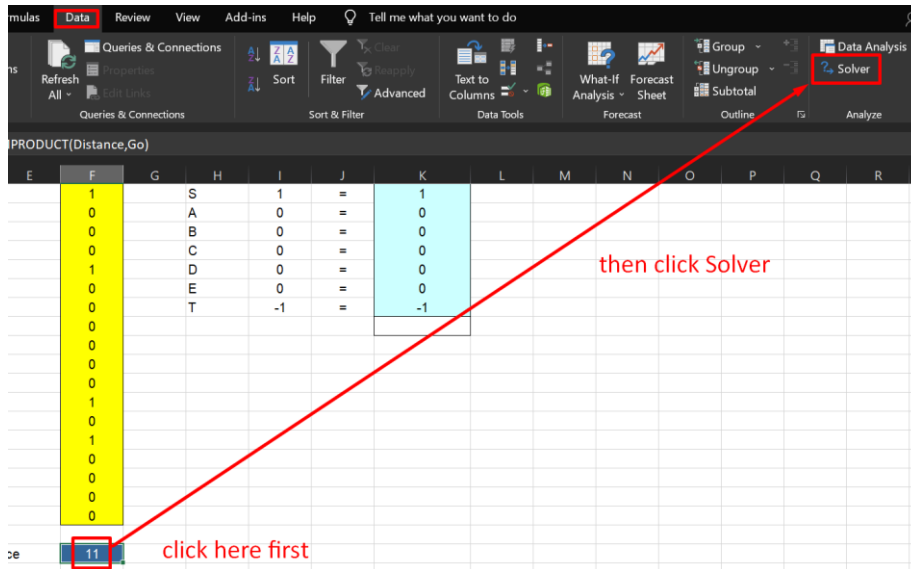
=-SUMIF(To,H10,Go)

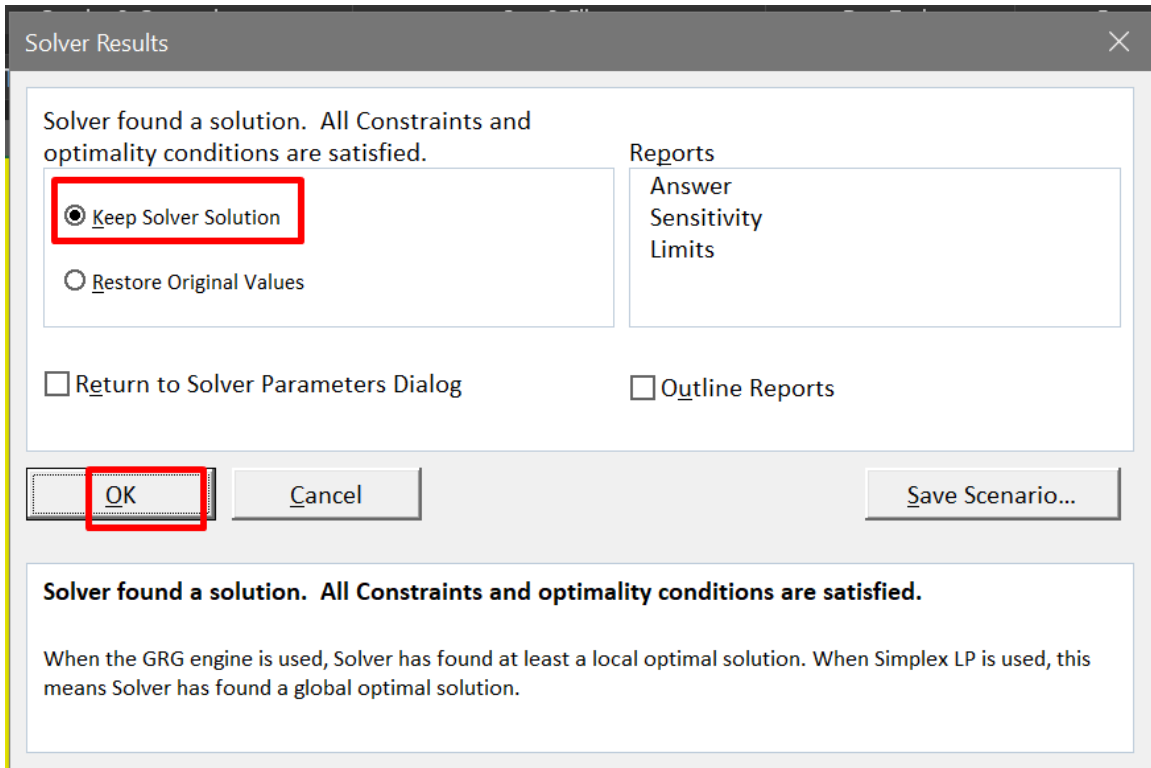
- SUMIF calculates the Net Flow of each node.
- Node S: SUMIF sums values in Go column with an "S" in the From column.
- As a result, only cell F4, F5 or F6 can be 1 (one outgoing arc).
- Node T: SUMIF sums values in Go column with a "T" in the To column.
- As a result, only cell F15, F18 or F21 can be 1 (one ingoing arc).
- For all other nodes, Excel looks in the From and To column.

select this and name it NetFlow

	A	B	C	D	E	F	G	H	I
1	<b>SHORTEST PATH ALGORITHM</b>								
2									
3		From	To	Distance		Go		Nodes	Net Flow
4		S	A	4		0		S	0
5		S	B	2		0		A	0
6		S	C	8		0		B	0
7		A	C	5		0		C	0
8		A	D	2		0		D	0
9		B	C	6		0		E	0
10		B	E	9		0		T	0
11		C	A	5		0			
12		C	B	6		0			
13		C	D	1		0			

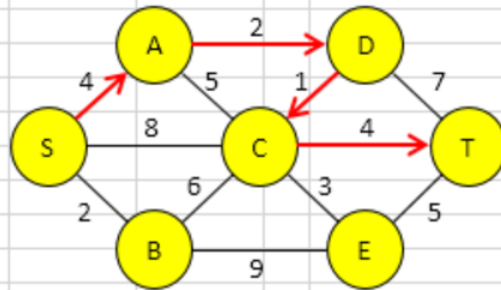
5. STEP 5: SOLVER



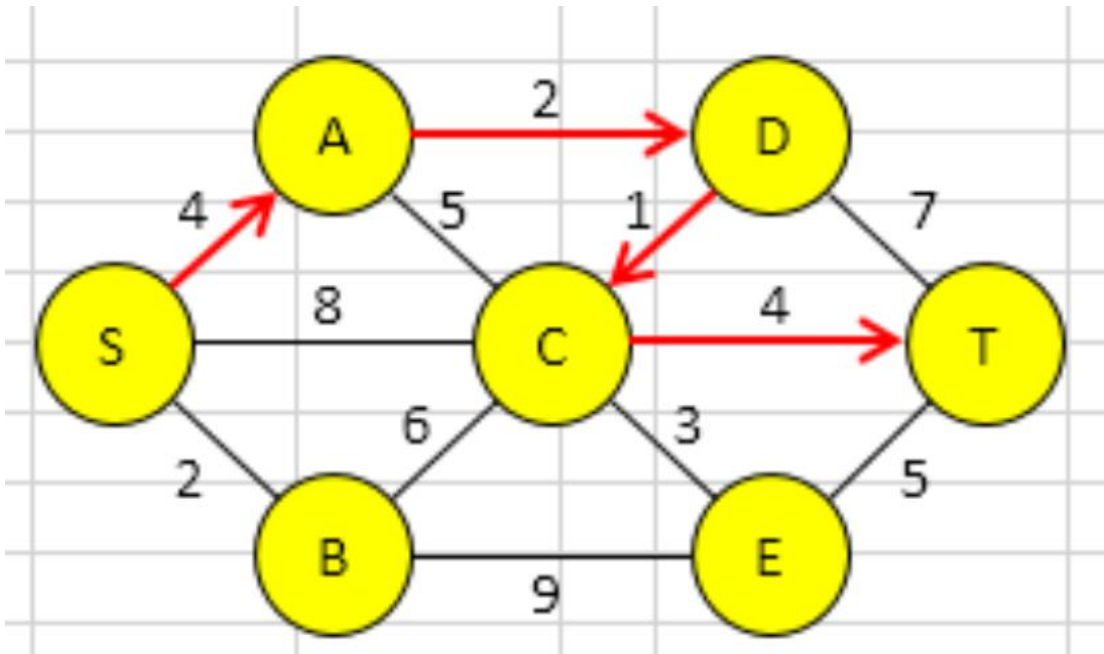


6. STEP 6: SOLUTION

From	To	Distance	Go	Nodes	Net Flow	=	Supply/Demand
S	A	4	1	S	1	=	1
S	B	2	0	A	0	=	0
S	C	8	0	B	0	=	0
A	C	5	0	C	0	=	0
A	D	2	1	D	0	=	0
B	C	6	0	E	0	=	0
B	E	9	0	T	-1	=	-1
C	A	5	0				
C	B	6	0				
C	D	1	0				
C	E	3	0				
C	T	4	1				
D	A	2	0				
D	C	1	1				
D	T	7	0				
E	B	9	0				
E	C	3	0				
E	T	5	0				
Total Distance			11				



**SOLUTION**





- Maximal Flow Problem

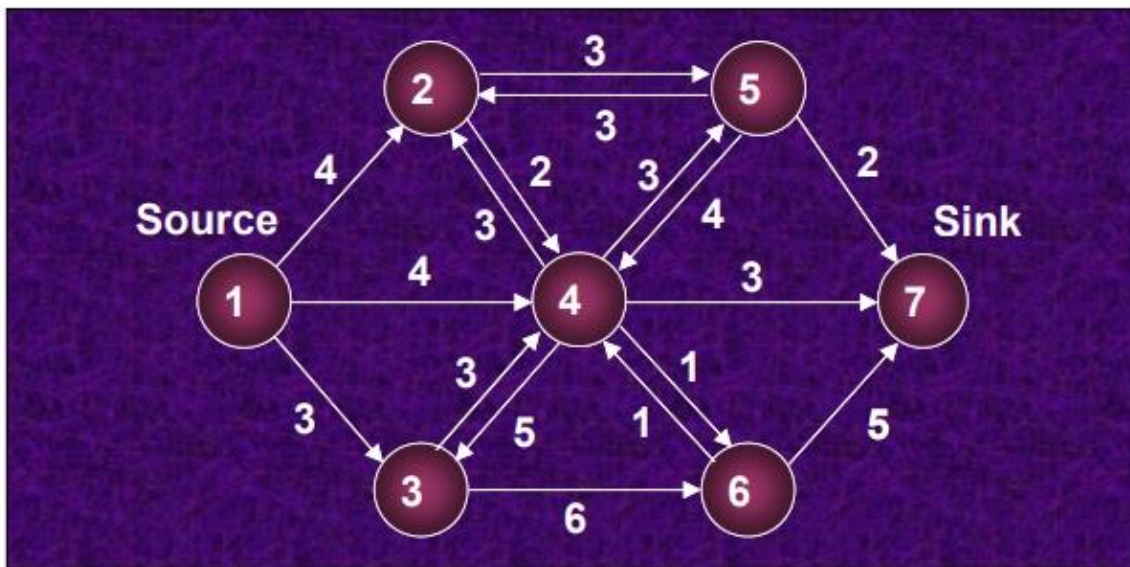
- Find **Maximum Volume of flow** from 1 node to another node
- Practical Use:
  - Find the Maximum No. of People Arriving in an Airport per day (from another country)
  - Find the Max. No. of Goods delivered to a City per day (from another State)

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A. BY HAND

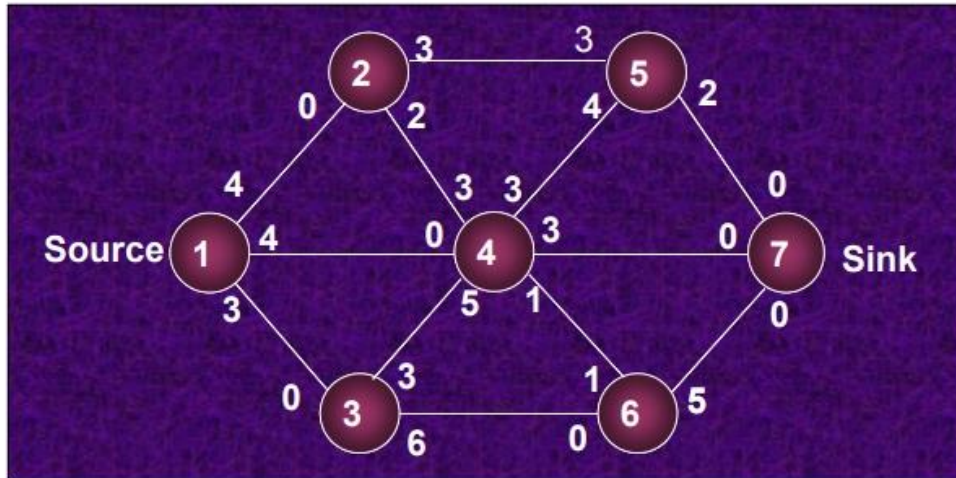
1. EXAMPLE 1



- Illustrated Problem 6.3
- Step 1

## Network Modeling

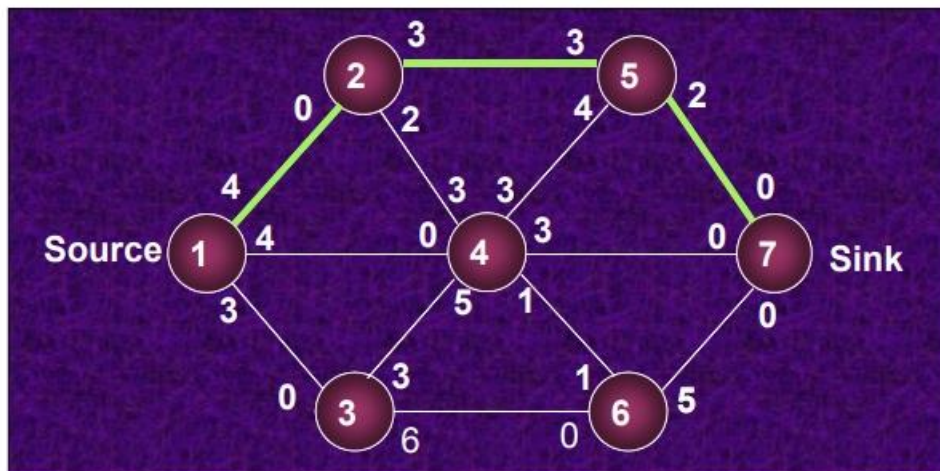
Maximal Flow Algorithm



- Illustrated Problem 6.3
- Step 2

## Network Modeling

Maximal Flow Algorithm

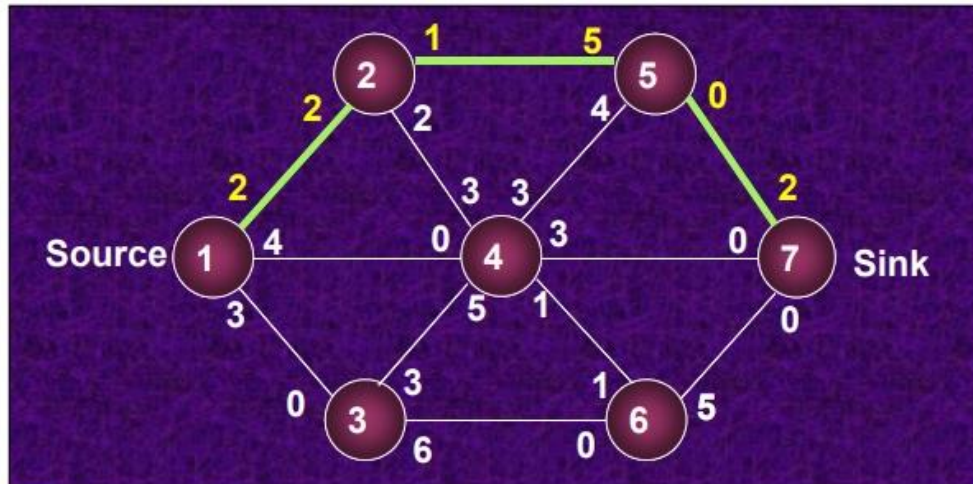


Start with route 1->2->5->7: identify the smallest out-going value (2); Subtract 2 from out-going value and add 2 to in-coming value.

- Illustrated Problem 6.3
- Step 3

## Network Modeling

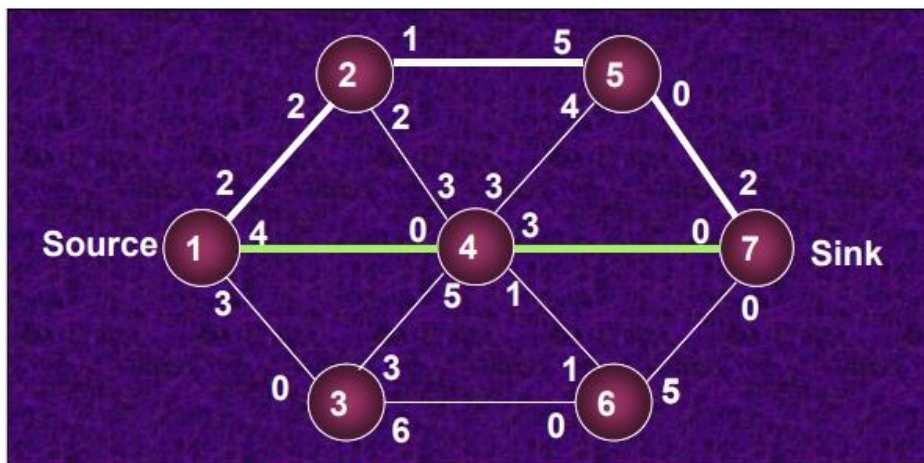
Maximal Flow Algorithm



- Illustrated Problem 6.3
- Step 4

## Network Modeling

Maximal Flow Algorithm



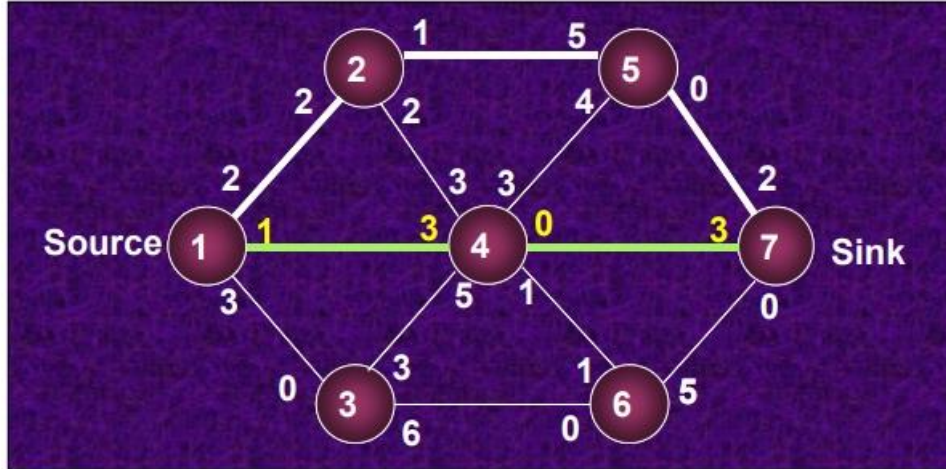
Next route: 1->4->7. Identify the smallest out-going value (3); Subtract 3 from out-going value and add 3 to in-coming value.



- Illustrated Problem 6.3
- Step 5

## Network Modeling

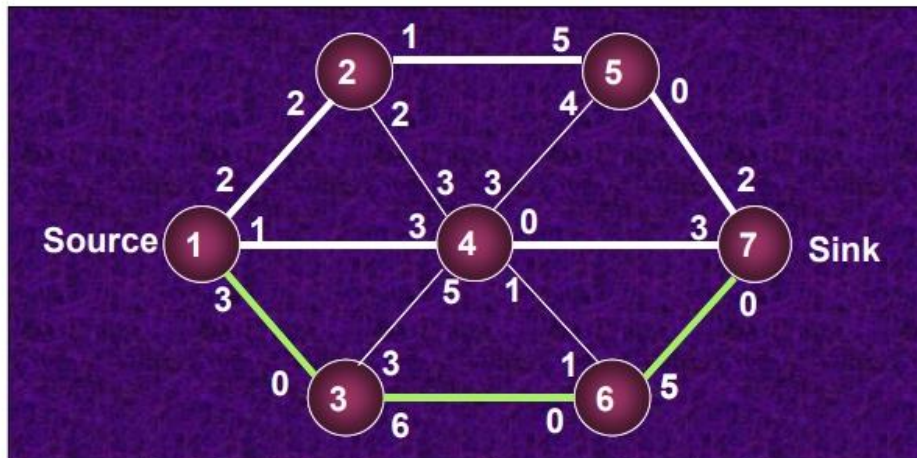
Maximal Flow Algorithm



- Illustrated Problem 6.3
- Step 6

## Network Modeling

Maximal Flow Algorithm

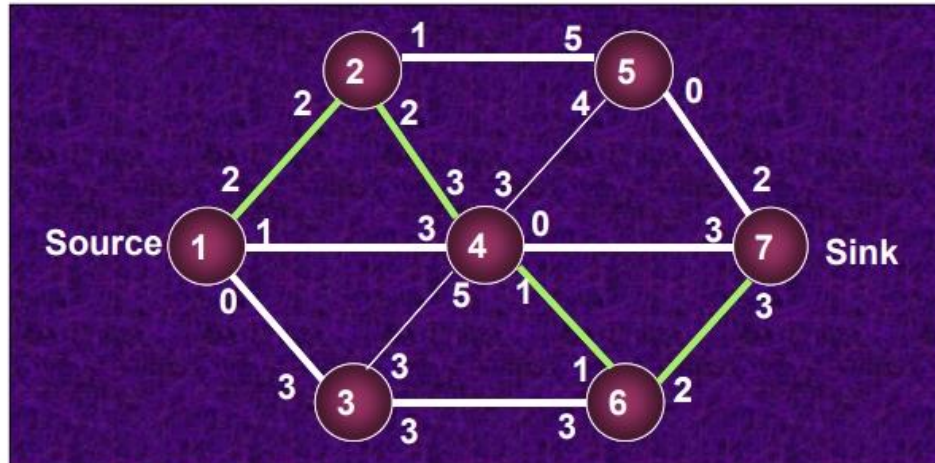


Next route: 1->3->6->7. Identify the smallest out-going value (3); Subtract 3 from out-going value and add 3 to in-coming value.

- Illustrated Problem 6.3
- Step 7

## Network Modeling

Maximal Flow Algorithm

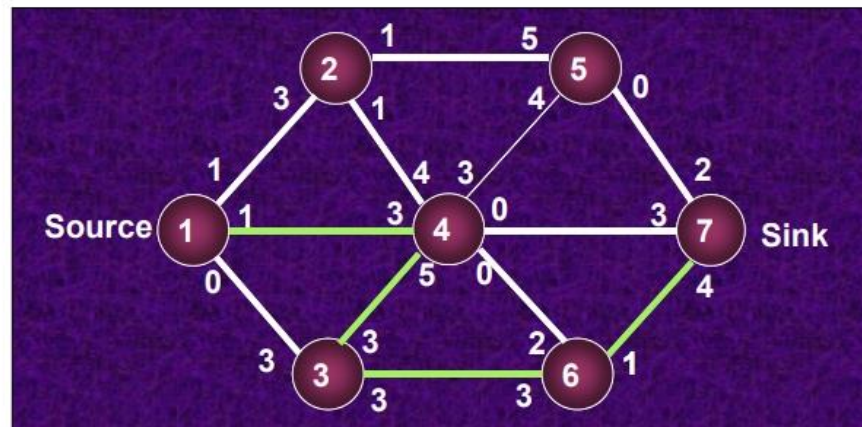


Next route: 1->2->4->6->7. Identify the smallest out-going value (1); Subtract 1 from out-going value and add 1 to in-coming value.

- Illustrated Problem 6.3
- Step 8

## Network Modeling

Maximal Flow Algorithm

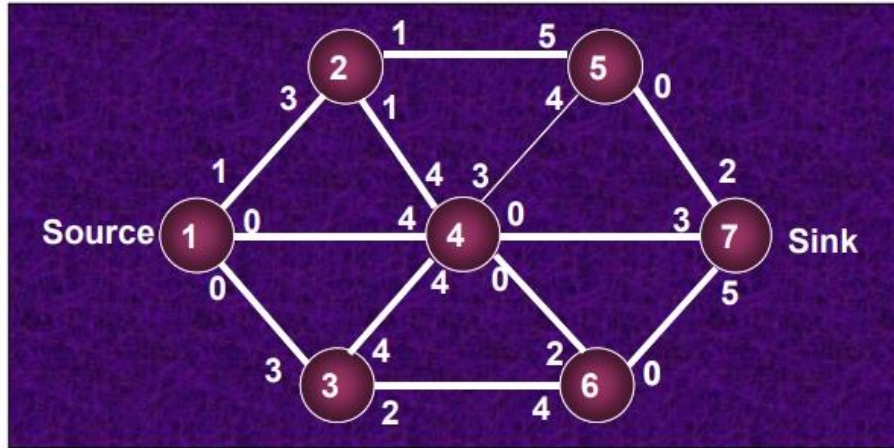


Next route: 1->4->3->6->7. Identify the smallest out-going value (1); Subtract 1 from out-going value and add 1 to in-coming value.

- Illustrated Problem 6.3
- Step 9

## Network Modeling

Maximal Flow Algorithm



- Illustrated Problem 6.3
- Step 10

## Network Modeling

Maximal Flow Algorithm

### • Conclusion

Iteration	Path	Maximum Flow
1	1->2->5->7	2
2	1->4->7	3
3	1->3->6->7	3
4	1->2->4->6->7	1
5	1->4->3->6->7	1
<b>Total</b>		<b>10</b>

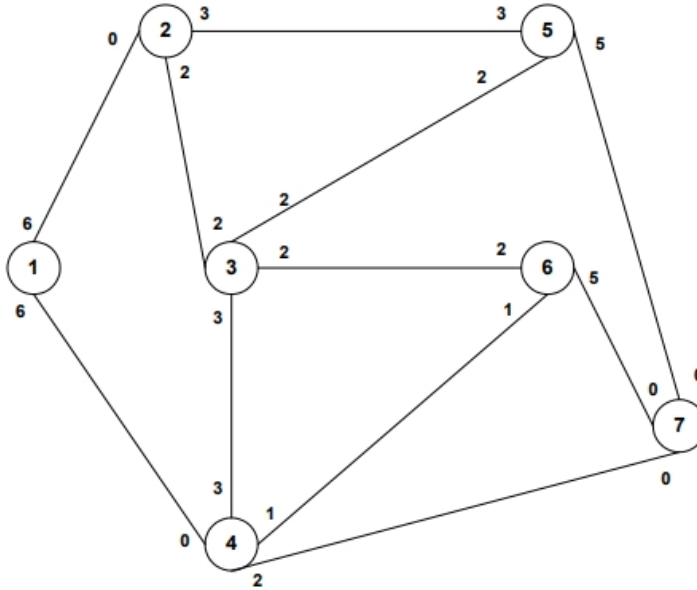


2. EXAMPLE 2

- Exercise 6.1
- Source = 1
- Sink = 7

## Network Modeling

Maximal Flow Algorithm

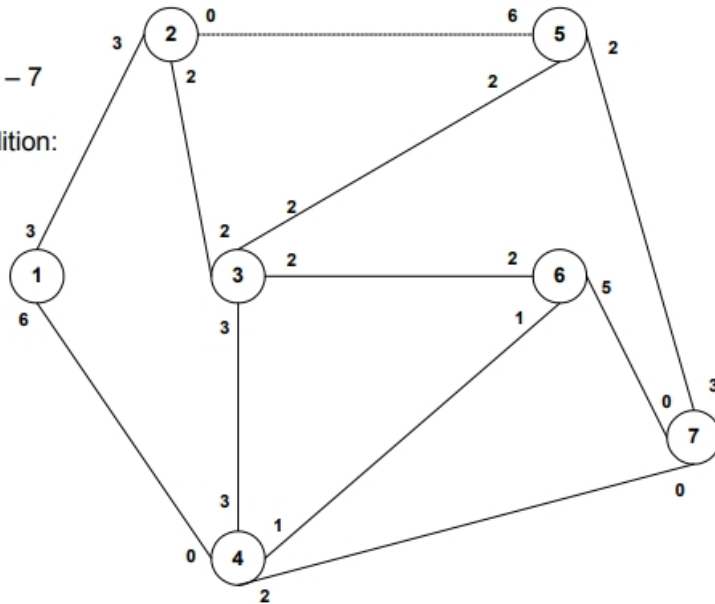


- Exercise 6.1
- Step 1

## Network Modeling

Maximal Flow Algorithm

Iteration 1:  
Chosen Path: 1 – 2 – 5 – 7  
Smallest Arc Flow: 3  
After reduction and addition:

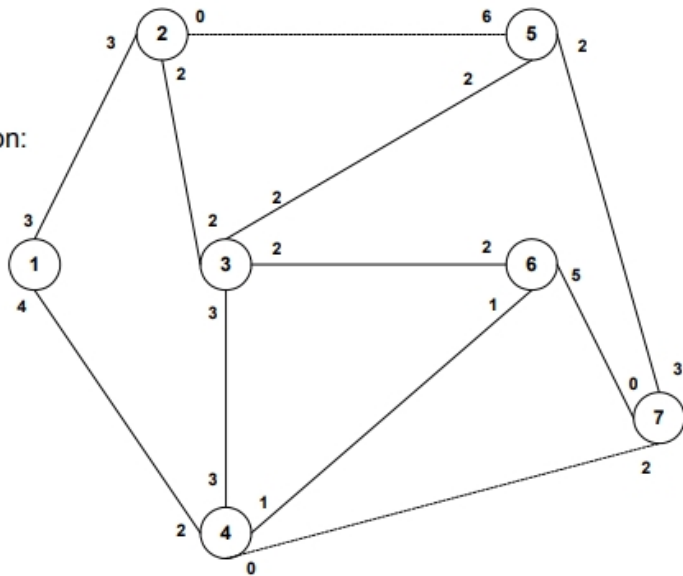


- Exercise 6.1
- Step 2

## Network Modeling

Maximal Flow Algorithm

Iteration 2:  
Chosen Path: 1 – 4 – 7  
Smallest Arc Flow: 2  
After reduction and addition:

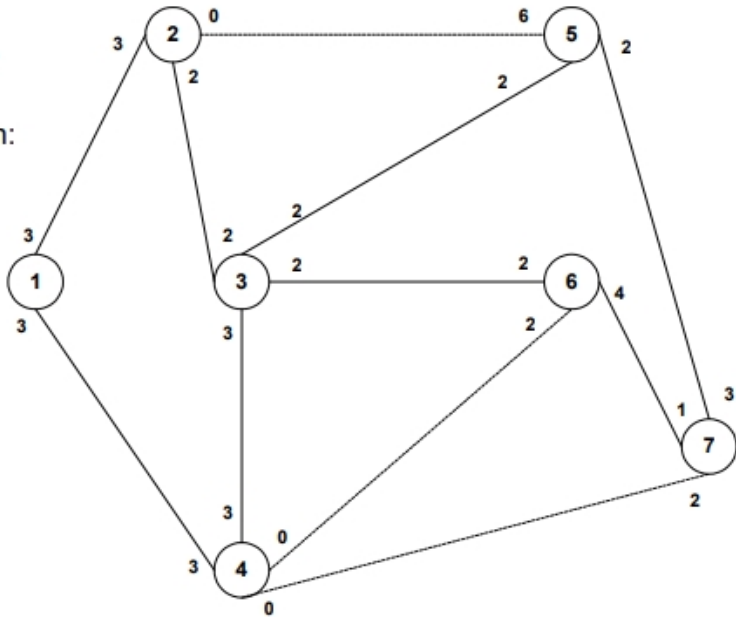


- Exercise 6.1
- Step 3

## Network Modeling

Maximal Flow Algorithm

Iteration 3:  
Chosen Path: 1 – 4 – 6 – 7  
Smallest Arc Flow: 1  
After reduction and addition:



- Exercise 6.1
- Step 4

## Network Modeling

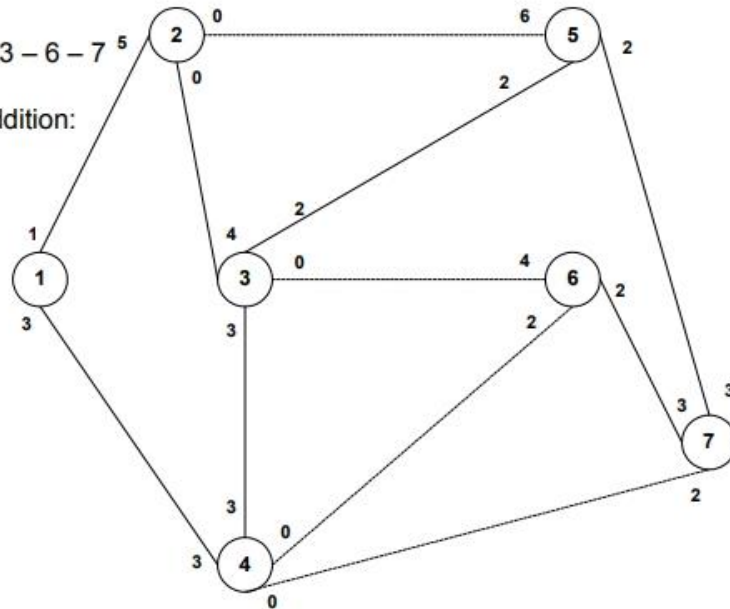
Maximal Flow Algorithm

Iteration 4:

Chosen Path: 1 - 2 - 3 - 6 - 7

Smallest Arc Flow: 2

After reduction and addition:



- Exercise 6.1
- Step 5

## Network Modeling

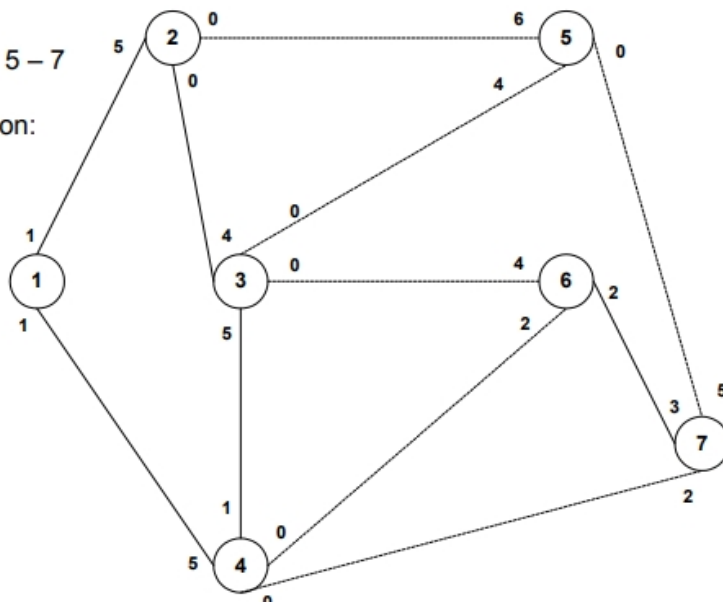
Maximal Flow Algorithm

Iteration 5:

Chosen Path: 1 - 4 - 3 - 5 - 7

Smallest Arc Flow: 2

After reduction and addition:



- Exercise 6.1
- Step 6

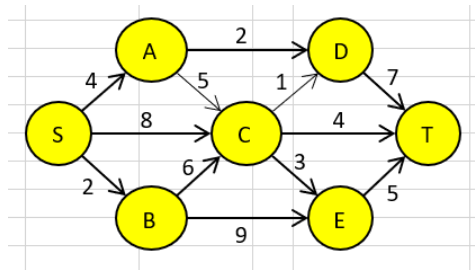
## Network Modeling

Maximal Flow  
Algorithm

Iteration	Path	Maximum Flow
1	1 - 2 - 5 - 7 - 3	3
2	1 - 4 - 7	2
3	1 - 4 - 6 - 7	1
4	1 - 2 - 3 - 6 - 7	2
5	1 - 4 - 3 - 5 - 7	2
		<b>Total: 10</b>

## B. BY EXCEL

File: <https://www.alvinang.sg/s/maximum-flow-problem.xlsx>

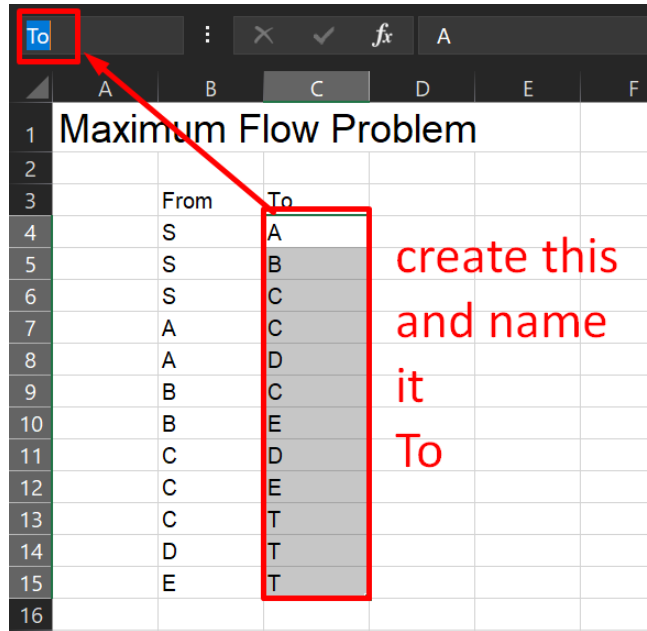
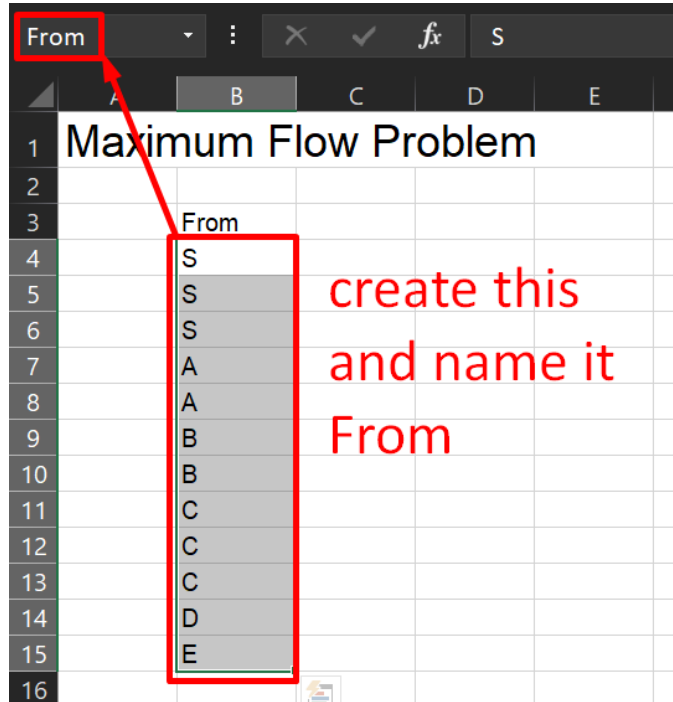


- We are trying to find out the Maximum Flow of People per day coming into Airport T from Airport S.
- The numbers represent Maximum Allowable Flow Rate (per day) coming out.

	A	B	C	D	E	F	G	H	I	J	K	L
1	<b>Maximum Flow Problem</b>											
2												
3	From	To	Flow	≤	Capacity	Nodes	Net Flow				Supply/Demand	
4	S	A	4	≤	4	S	12					
5	S	B	2	≤	2	A	0	=			0	
6	S	C	6	≤	8	B	0	=			0	
7	A	C	2	≤	5	C	0	=			0	
8	A	D	2	≤	2	D	0	=			0	
9	B	C	0	≤	6	E	0	=			0	
10	B	E	2	≤	9	T	-12					
11	C	D	1	≤	1							
12	C	E	3	≤	3							
13	C	T	4	≤	4							
14	D	T	3	≤	7							
15	E	T	5	≤	5							
16												
17	Maximum Flow		12									
18												
19												
20												
21												

- Maximum Flow Rate = 12 people per day coming into Airport T (and flowing out from Airport S).
- $S \rightarrow A = 4/4$  means max capacity is used.
- $B \rightarrow E = 2/9$  means only 2 out of 9 capacity is used.

1. STEP 1: CREATE FROM / TO / FLOW / CAPACITY





Flow

	A	B	C	D
1	Maximum Flow Problem			
2				
3		From	To	Flow
4		S	A	0
5		S	B	0
6		S	C	0
7		A	C	0
8		A	D	0
9		B	C	0
10		B	E	0
11		C	D	0
12		C	E	0
13		C	T	0
14		D	T	0
15		E	T	0
16				

E4

	A	B	C	D	E	F	G
1	Maximum Flow Problem						
2					create this		
3		From	To	Flow			
4		S	A	4	≤		
5		S	B	2	≤		
6		S	C	6	≤		
7		A	C	2	≤		
8		A	D	2	≤		
9		B	C	0	≤		
10		B	E	2	≤		
11		C	D	1	≤		
12		C	E	3	≤		
13		C	T	4	≤		
14		D	T	3	≤		
15		E	T	5	≤		
16							
17							

≤

Capacity

	A	B	C	D	E	F	G	H	I	J	
1	Maximum Flow Problem										
2											
3		From	To	Flow		Capacity					
4		S	A	4	≤	4					
5		S	B	2	≤	2					
6		S	C	6	≤	8					
7		A	C	2	≤	5					
8		A	D	2	≤	2					
9		B	C	0	≤	6					
10		B	E	2	≤	9					
11		C	D	1	≤	1					
12		C	E	3	≤	3					
13		C	T	4	≤	4					
14		D	T	3	≤	7					
15		E	T	5	≤	5					
16											

create this and call it Capacity

2. STEP 2: CREATE MAXIMUM FLOW

MaximumFlow =14

	A	B	C	D	E	F	G	H	I	J	
1	Maximum Flow Problem										
2											
3		From	To	Flow		Capacity					
4		S	A	4	≤	4					
5		S	B	2	≤	2					
6		S	C	6	≤	8					
7		A	C	2	≤	5					
8		A	D	2	≤	2					
9		B	C	0	≤	6					
10		B	E	2	≤	9					
11		C	D	1	≤	1					
12		C	E	3	≤	3					
13		C	T	4	≤	4					
14		D	T	3	≤	7					
15		E	T	5	≤	5					
16											
17		Maximum Flow		0							
18											

create this and call it MaximumFlow

3. STEP 3: CREATE NODES / SUPPLY DEMAND / =

Clipboard Font Alignment

H3 Nodes

	A	B	C	D	E	F	G	H	I	J
1	Maximum Flow Problem									
2										
3		From	To	Flow		Capacity				
4		S	A	4	≤	4				
5		S	B	2	≤	2				
6		S	C	6	≤	8				
7		A	C	2	≤	5				
8		A	D	2	≤	2				
9		B	C	0	≤	6				
10		B	E	2	≤	9				
11		C	D	1	≤	1				
12		C	E	3	≤	3				
13		C	T	4	≤	4				
14		D	T	3	≤	7				
15		E	T	5	≤	5				
16										
17		Maximum Flow		0						

Nodes  
S  
A  
B  
C  
D  
E  
T

(Ctrl)

create this

SupplyDemand 0

	A	B	C	D	E	F	G	H	I	J	K	L
1	Maximum Flow Problem											
2												
3		From	To	Flow		Capacity		Nodes			Supply/Demand	
4		S	A	4	≤	4		S			0	
5		S	B	2	≤	2		A			0	
6		S	C	6	≤	8		B			0	
7		A	C	2	≤	5		C			0	
8		A	D	2	≤	2		D			0	
9		B	C	0	≤	6		E			0	
10		B	E	2	≤	9		T			0	
11		C	D	1	≤	1						
12		C	E	3	≤	3						
13		C	T	4	≤	4						
14		D	T	3	≤	7						
15		E	T	5	≤	5						
16												
17		Maximum Flow		0								

create this and name it SupplyDemand

Maximum Flow Problem									
	From	To	Flow		Capacity	Nodes			Supply/Demand
	S	A	4	≤	4	S			
	S	B	2	≤	2	A	=		0
	S	C	6	≤	8	B	=		0
	A	C	2	≤	5	C	=		0
	A	D	2	≤	2	D	=		0
	B	C	0	≤	6	E	=		0
	B	E	2	≤	9	T			
	C	D	1	≤	1				
	C	E	3	≤	3				
	C	T	4	≤	4				
	D	T	3	≤	7				
	E	T	5	≤	5				
	Maximum Flow		0						

create =

#### 4. STEP 4: CREATE NETFLOW

Nodes	Net Flow
S	=SUMIF(From,H4,Flow)
A	=SUMIF(From,H5,Flow)-SUMIF(To,H5,Flow)
B	=SUMIF(From,H6,Flow)-SUMIF(To,H6,Flow)
C	=SUMIF(From,H7,Flow)-SUMIF(To,H7,Flow)
D	=SUMIF(From,H8,Flow)-SUMIF(To,H8,Flow)
E	=SUMIF(From,H9,Flow)-SUMIF(To,H9,Flow)
T	=-SUMIF(To,H10,Flow)

=SUMIF(From,H4,Flow)

=SUMIF(From,H5,Flow)-SUMIF(To,H5,Flow)

=SUMIF(From,H6,Flow)-SUMIF(To,H6,Flow)

=SUMIF(From,H7,Flow)-SUMIF(To,H7,Flow)

=SUMIF(From,H8,Flow)-SUMIF(To,H8,Flow)

=SUMIF(From,H9,Flow)-SUMIF(To,H9,Flow)

=-SUMIF(To,H10,Flow)

=SUMIF(From,H4,Flow)

Flow	Capacity	Nodes	Net Flow	Supply/Demand
0	4	S	0	
0	2	A	0	0
0	8	B	0	0
0	5	C	0	0
0	2	D	0	0
0	6	E	0	0
0	9	T	0	
0	1			
0	3			
0	4			
0	7			
0	5			

create this with all the formulas

5. STEP 5: SOLVER

then click on solver

From	To	Flow	Capacity	Nodes	Net Flow	Supply/Demand
S	A	0	4	S	0	0
S	B	0	2	A	0	0
S	C	0	8	B	0	0
A	C	0	5	C	0	0
A	D	0	2	D	0	0
B	C	0	6	E	0	0
B	E	0	9	T	0	0
C	D	0	1			
C	E	0	3			
C	T	0	4			
D	T	0	7			
E	T	0	5			

Maximum Flow: 0

click here first

Solver Parameters

Set Objective: MaximumFlow

To:  Max  Min  Value Of: 0

By Changing Variable Cells: Flow

Subject to the Constraints: \$I\$5:\$I\$9 = SupplyDemand  
Flow <= Capacity

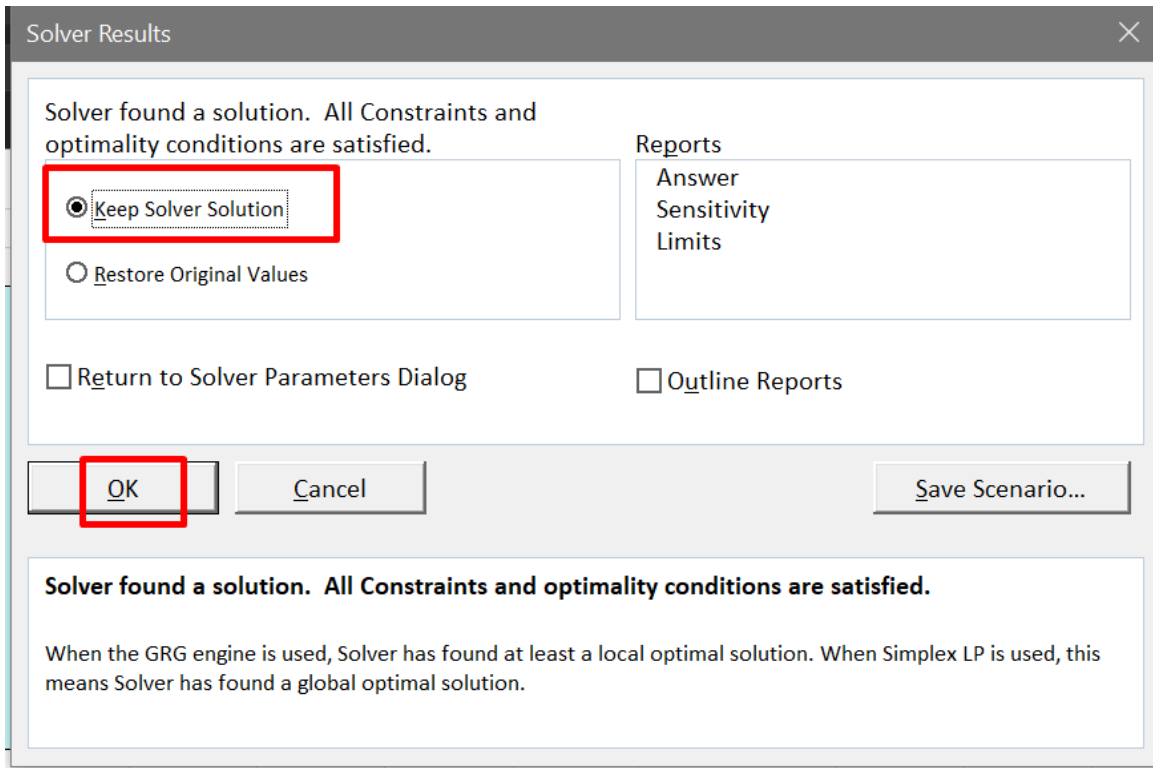
Make Unconstrained Variables Non-Negative

Select a Solving Method: Simplex LP

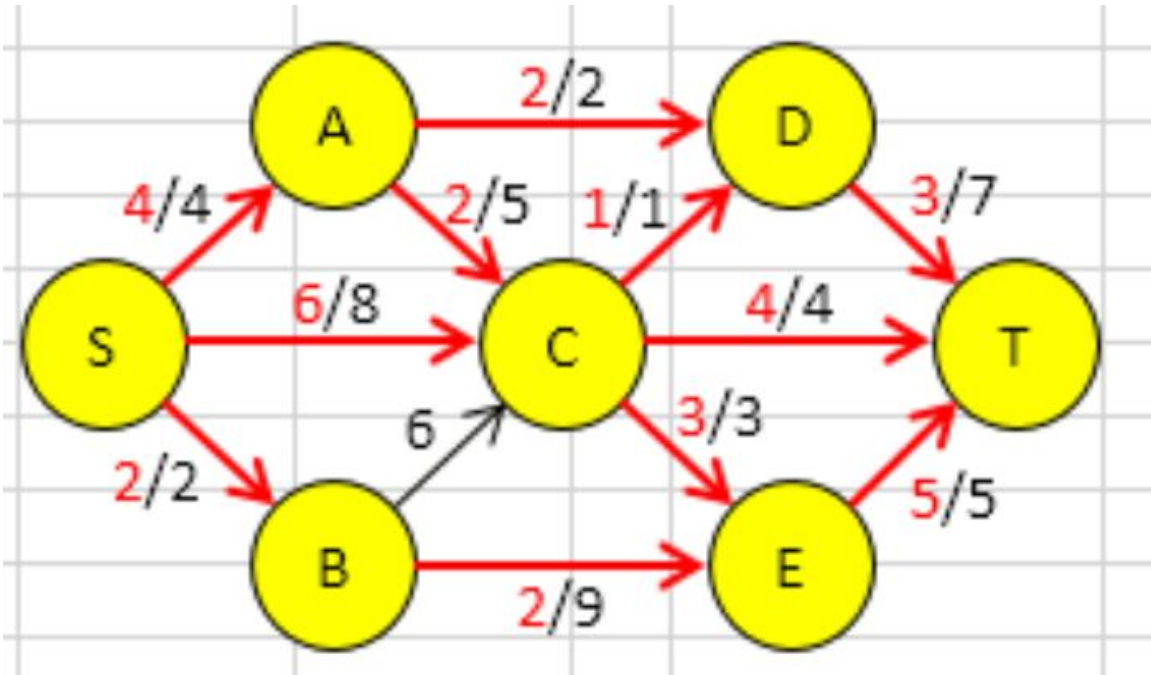
Solving Method: Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Buttons: Help, Solve, Close





6. STEP 6: SOLUTION



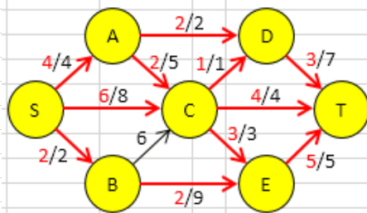
Maximum Flow Problem

From	To	Flow	Capacity
S	A	4	4
S	B	2	2
S	C	6	8
A	C	2	5
A	D	2	2
B	C	0	6
B	E	2	9
C	D	1	1
C	E	3	3
C	T	4	4
D	T	3	7
E	T	5	5

Maximum Flow 12

Nodes	Net Flow	Supply/Demand
S	12	
A	0	0
B	0	0
C	0	0
D	0	0
E	0	0
T	-12	0

Max flow out of S  
 = 4+6+2  
 = 12



Max flow in to T  
 = 3+4+5  
 = 12



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#### IV. ABOUT DR. ALVIN ANG

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Dr. Alvin Ang earned his Ph.D., Masters and Bachelor degrees from NTU, Singapore. He is a scientist, entrepreneur, as well as a personal/business advisor. More about him at [www.AlvinAng.sg](http://www.AlvinAng.sg).