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HOMEWORK 3

PROGRAM 1 RESULTS:

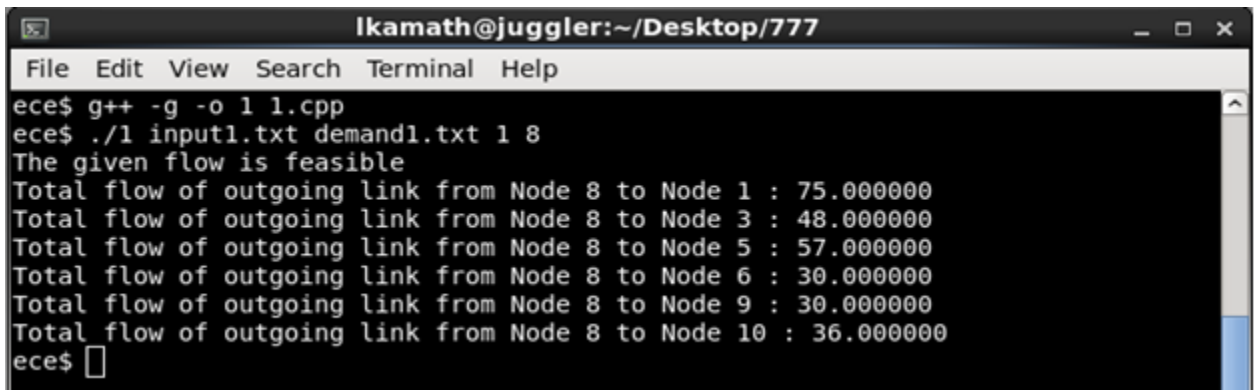
Instance 1:

Is the flow feasible?

Yes

What is the flow out of node 8 along each of its outgoing links?

Answer:

A terminal window titled 'lkamath@juggler:~/Desktop/777' with a menu bar (File, Edit, View, Search, Terminal, Help). The terminal shows the following commands and output:

```
ece$ g++ -g -o 1 1.cpp
ece$ ./1 input1.txt demand1.txt 1 8
The given flow is feasible
Total flow of outgoing link from Node 8 to Node 1 : 75.000000
Total flow of outgoing link from Node 8 to Node 3 : 48.000000
Total flow of outgoing link from Node 8 to Node 5 : 57.000000
Total flow of outgoing link from Node 8 to Node 6 : 30.000000
Total flow of outgoing link from Node 8 to Node 9 : 30.000000
Total flow of outgoing link from Node 8 to Node 10 : 36.000000
ece$
```

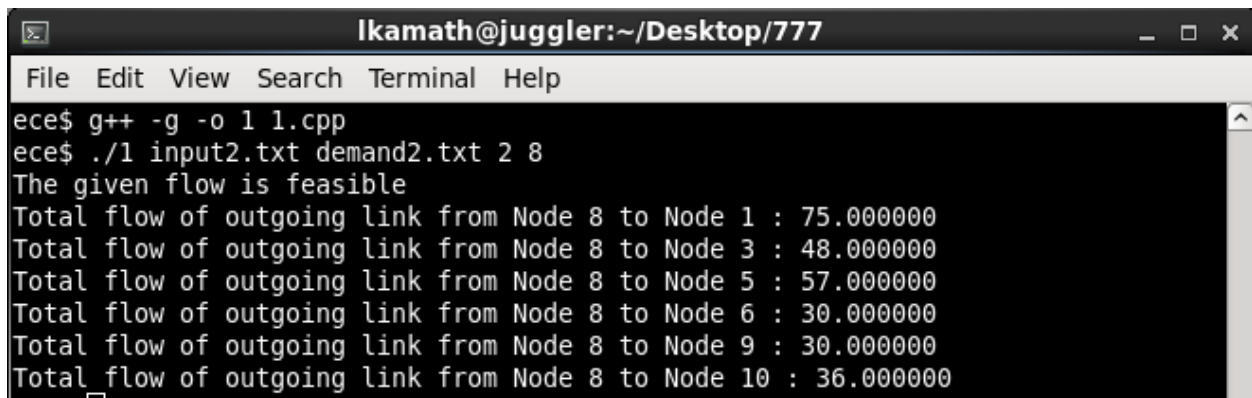
Instance 2:

Is the flow feasible?

Yes

What is the flow out of node 8 along each of its outgoing links?

Answer:

A terminal window titled 'lkamath@juggler:~/Desktop/777' with a menu bar (File, Edit, View, Search, Terminal, Help). The terminal shows the following commands and output:

```
ece$ g++ -g -o 1 1.cpp
ece$ ./1 input2.txt demand2.txt 2 8
The given flow is feasible
Total flow of outgoing link from Node 8 to Node 1 : 75.000000
Total flow of outgoing link from Node 8 to Node 3 : 48.000000
Total flow of outgoing link from Node 8 to Node 5 : 57.000000
Total flow of outgoing link from Node 8 to Node 6 : 30.000000
Total flow of outgoing link from Node 8 to Node 9 : 30.000000
Total flow of outgoing link from Node 8 to Node 10 : 36.000000
ece$
```

Instance 3:

Is the flow feasible?

Yes

What is the flow into Node 14 along each of its incoming links?

Answer:

```
Ikamath@juggler:~/Desktop/777
File Edit View Search Terminal Help
ece$ ./1 input3.txt demand3.txt 3 14
The given flow is feasible
Total flow on incoming link from Node 5 to Node 14 : 111.000000
Total flow on incoming link from Node 12 to Node 14 : 63.000000
Total flow on incoming link from Node 13 to Node 14 : 72.000000
Total flow on incoming link from Node 17 to Node 14 : 27.000000
ece$
```

Instance 4:

Is the flow feasible?

Yes

What is the flow into Node 14 along each of its incoming links?

Answer:

```
Ikamath@juggler:~/Desktop/777
File Edit View Search Terminal Help
ece$ ./1 input4.txt demand4.txt 4 14
The given flow is feasible
Total flow on incoming link from Node 5 to Node 14 : 156.000000
Total flow on incoming link from Node 12 to Node 14 : 75.000000
Total flow on incoming link from Node 13 to Node 14 : 99.000000
Total flow on incoming link from Node 17 to Node 14 : 33.000000
ece$
```

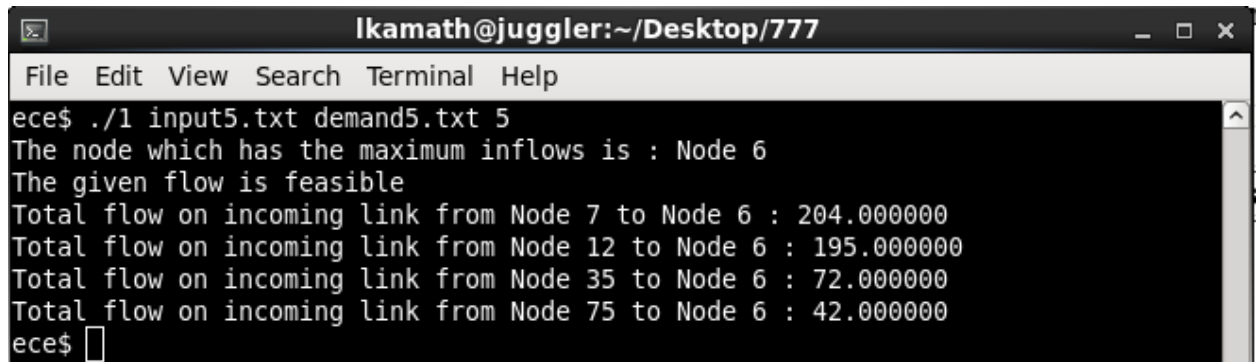
Instance 5:

Is the flow feasible?

Yes

What is the node into which the maximum amount of flow comes in, and what is the total flow into this node along each of its incoming links?

Answer:

A terminal window titled 'lkamath@juggler:~/Desktop/777' with a menu bar (File, Edit, View, Search, Terminal, Help). The terminal shows the execution of a script with the command './1 input5.txt demand5.txt 5'. The output indicates that the flow is feasible and identifies Node 6 as the node with the maximum inflows. It then lists the total flow on incoming links from four specific nodes to Node 6.

```
lkamath@juggler:~/Desktop/777
File Edit View Search Terminal Help
ece$ ./1 input5.txt demand5.txt 5
The node which has the maximum inflows is : Node 6
The given flow is feasible
Total flow on incoming link from Node 7 to Node 6 : 204.000000
Total flow on incoming link from Node 12 to Node 6 : 195.000000
Total flow on incoming link from Node 35 to Node 6 : 72.000000
Total flow on incoming link from Node 75 to Node 6 : 42.000000
ece$
```

PROGRAM 2 RESULTS:

Instance 1:

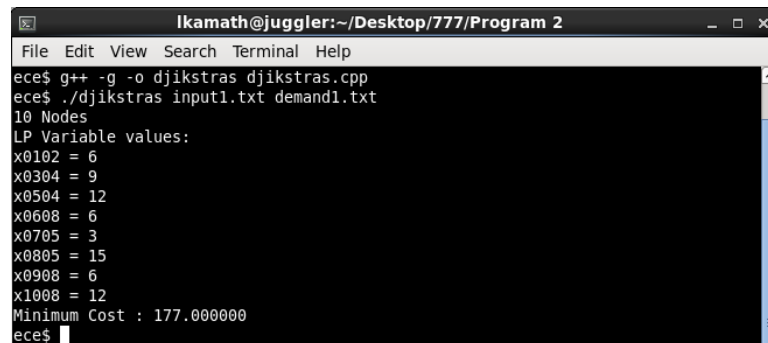
What is the flow out of node 8 along each of its outgoing links?

Answer: As we can observe from the figure below, the minimum cost is 177.0

The flow out of each of the outgoing links from node 8 is as follows:

Node 8 to Node 5 = 15.0

All other flows out of node 8 are 0



```
lkamath@juggler:~/Desktop/777/Program 2
File Edit View Search Terminal Help
ece$ g++ -g -o djikstras djikstras.cpp
ece$ ./djikstras input1.txt demand1.txt
10 Nodes
LP Variable values:
x0102 = 6
x0304 = 9
x0504 = 12
x0608 = 6
x0705 = 3
x0805 = 15
x0908 = 6
x1008 = 12
Minimum Cost : 177.000000
ece$
```

Instance 2:

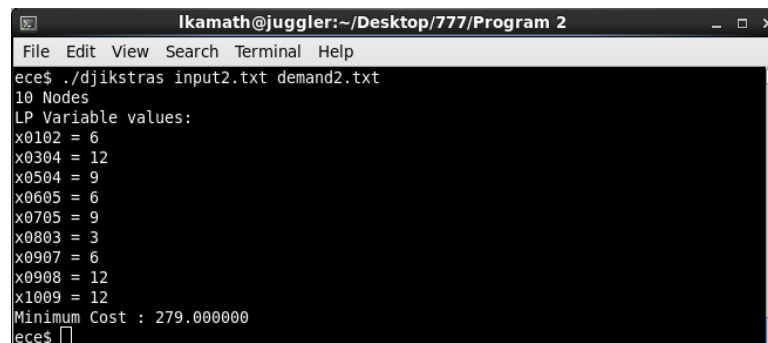
What is the flow out of node 8 along each of its outgoing links?

Answer: As we can observe from the figure below, the minimum cost is 279.0

The flow out of each of the outgoing links from node 8 is as follows:

Node 8 to Node 3 = 9.0

All other flows out of node 8 are 0



```
lkamath@juggler:~/Desktop/777/Program 2
File Edit View Search Terminal Help
ece$ ./djikstras input2.txt demand2.txt
10 Nodes
LP Variable values:
x0102 = 6
x0304 = 12
x0504 = 9
x0605 = 6
x0705 = 9
x0803 = 3
x0907 = 6
x0908 = 12
x1009 = 12
Minimum Cost : 279.000000
ece$
```

Instance 3:

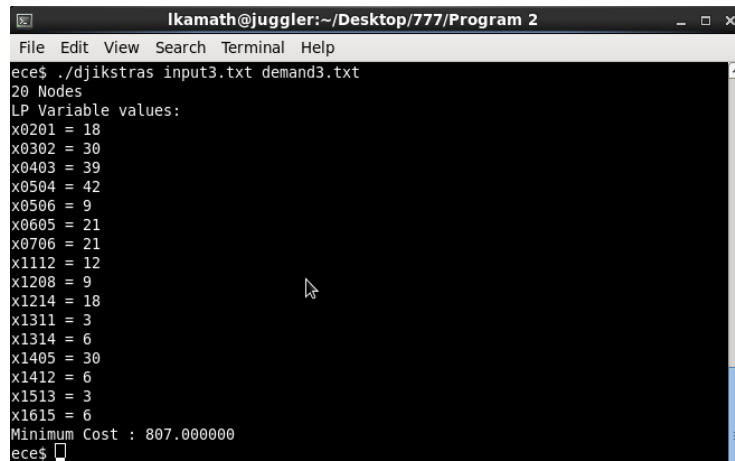
What is the flow into Node 14 along each of its incoming links?

Answer: As we can observe from the figure below, the minimum cost is 807.0
The flow into each of the incoming links of node 14 is as follows:

Node 12 to Node 14 = 18.0

Node 13 to Node 14 = 6.0

All other flows into Node 14 are 0.

A terminal window titled 'lkamath@juggler:~/Desktop/777/Program 2' showing the output of a Dijkstra's algorithm. The user has run './dijkstrastrs input3.txt demand3.txt'. The output shows '20 Nodes', 'LP Variable values:', and a list of 16 variables (x0201 to x1615) with their values. The 'Minimum Cost' is 807.000000.

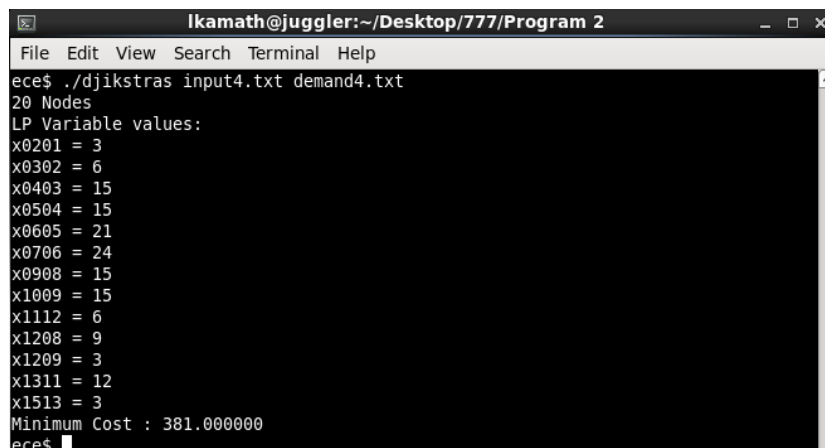
```
lkamath@juggler:~/Desktop/777/Program 2
File Edit View Search Terminal Help
ece$ ./dijkstrastrs input3.txt demand3.txt
20 Nodes
LP Variable values:
x0201 = 18
x0302 = 30
x0403 = 39
x0504 = 42
x0506 = 9
x0605 = 21
x0706 = 21
x1112 = 12
x1208 = 9
x1214 = 18
x1311 = 3
x1314 = 6
x1405 = 30
x1412 = 6
x1513 = 3
x1615 = 6
Minimum Cost : 807.000000
ece$
```

Instance 4:

What is the flow into Node 14 along each of its incoming links?

Answer: As we can observe from the figure below, the minimum cost is 381.0
The flow into each of the incoming links of node 14 is as follows:

There is no flow into node 14.

A terminal window titled 'lkamath@juggler:~/Desktop/777/Program 2' showing the output of a Dijkstra's algorithm. The user has run './dijkstrastrs input4.txt demand4.txt'. The output shows '20 Nodes', 'LP Variable values:', and a list of 15 variables (x0201 to x1513) with their values. The 'Minimum Cost' is 381.000000.

```
lkamath@juggler:~/Desktop/777/Program 2
File Edit View Search Terminal Help
ece$ ./dijkstrastrs input4.txt demand4.txt
20 Nodes
LP Variable values:
x0201 = 3
x0302 = 6
x0403 = 15
x0504 = 15
x0605 = 21
x0706 = 24
x0908 = 15
x1009 = 15
x1112 = 6
x1208 = 9
x1209 = 3
x1311 = 12
x1513 = 3
Minimum Cost : 381.000000
ece$
```

Instance 5:

What is the node into which the maximum amount of flow comes in, and what is the total flow into this node along each of its incoming links?

Answer: As we can observe from the figure below, the minimum cost is 7500.30

The node which has the maximum inflow are:

Node 18

Node 24

Node 45

Node 05

Node 67

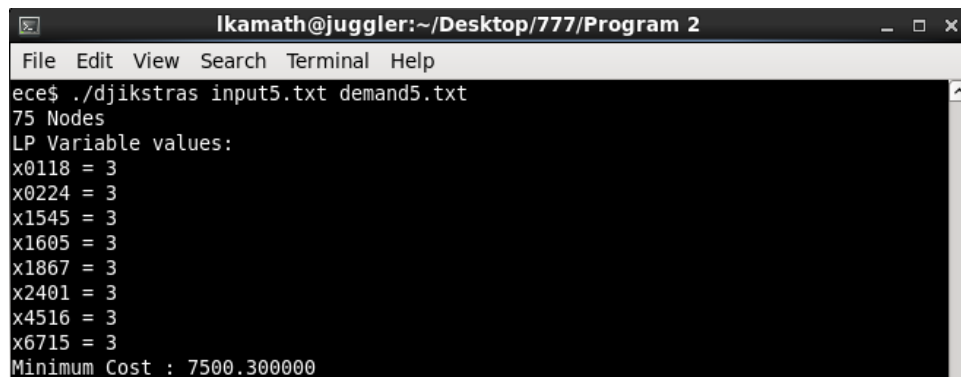
Node 01

Node 16

Node 15

Each of these nodes receive a flow of 3 units on one of it's incoming links.

All other flows on all other incoming links are 0.

A terminal window titled 'lkamath@juggler:~/Desktop/777/Program 2' with a menu bar (File, Edit, View, Search, Terminal, Help). The terminal shows the command './djikstras input5.txt demand5.txt' being executed. The output is as follows:

```
ece$ ./djikstras input5.txt demand5.txt
75 Nodes
LP Variable values:
x0118 = 3
x0224 = 3
x1545 = 3
x1605 = 3
x1867 = 3
x2401 = 3
x4516 = 3
x6715 = 3
Minimum Cost : 7500.300000
```

PROGRAM 3 RESULTS:

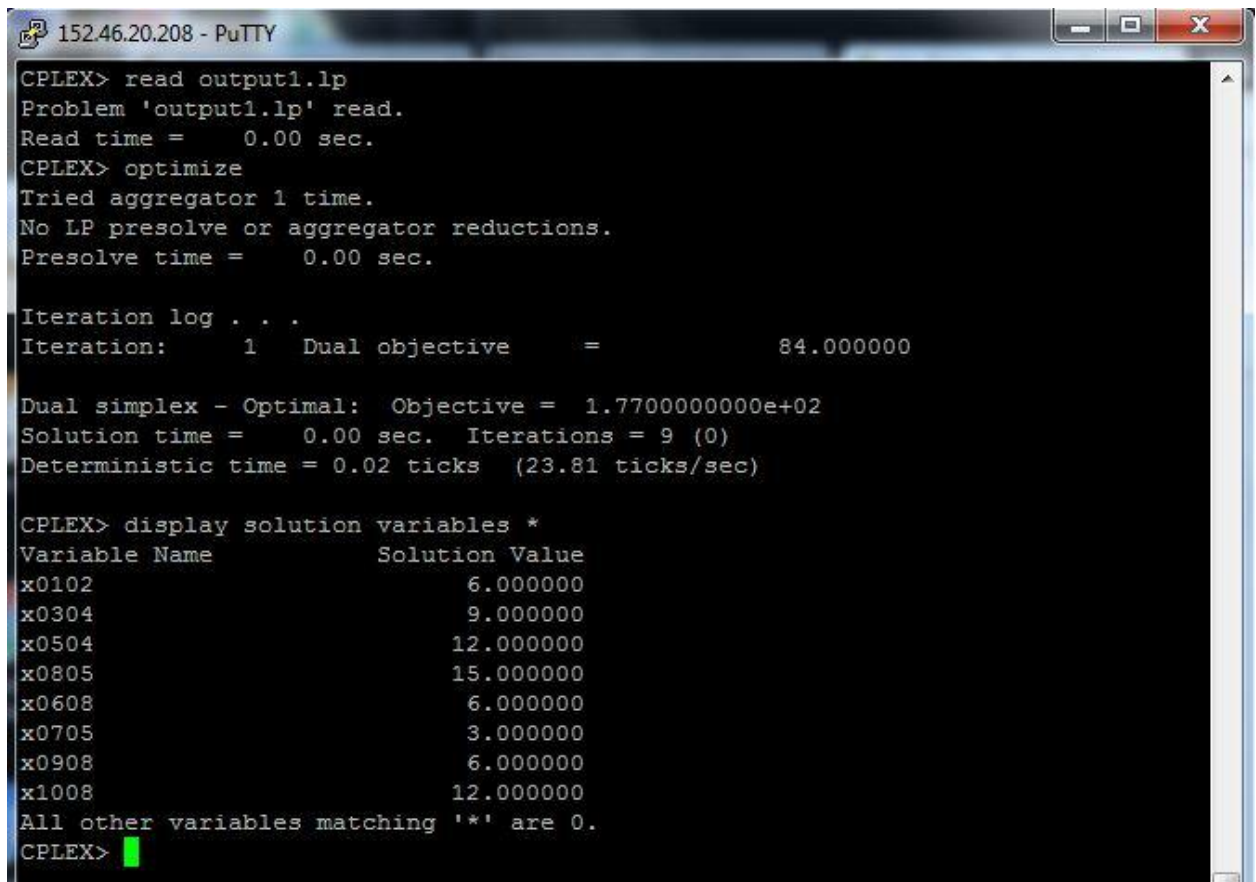
Instance 1:

What is the flow out of node 8 along each of its outgoing links?

Answer: As we can observe from the figure below, the minimum cost is 177.0
The flow out of each of the outgoing links from node 8 is as follows:

Node 8 to Node 5 = 15.0

All other flows out of node 8 are 0



```
152.46.20.208 - PuTTY
CPLEX> read output1.lp
Problem 'output1.lp' read.
Read time = 0.00 sec.
CPLEX> optimize
Tried aggregator 1 time.
No LP presolve or aggregator reductions.
Presolve time = 0.00 sec.

Iteration log . . .
Iteration: 1 Dual objective = 84.000000

Dual simplex - Optimal: Objective = 1.7700000000e+02
Solution time = 0.00 sec. Iterations = 9 (0)
Deterministic time = 0.02 ticks (23.81 ticks/sec)

CPLEX> display solution variables *
Variable Name      Solution Value
x0102              6.000000
x0304              9.000000
x0504             12.000000
x0805             15.000000
x0608              6.000000
x0705              3.000000
x0908              6.000000
x1008             12.000000
All other variables matching '*' are 0.
CPLEX>
```

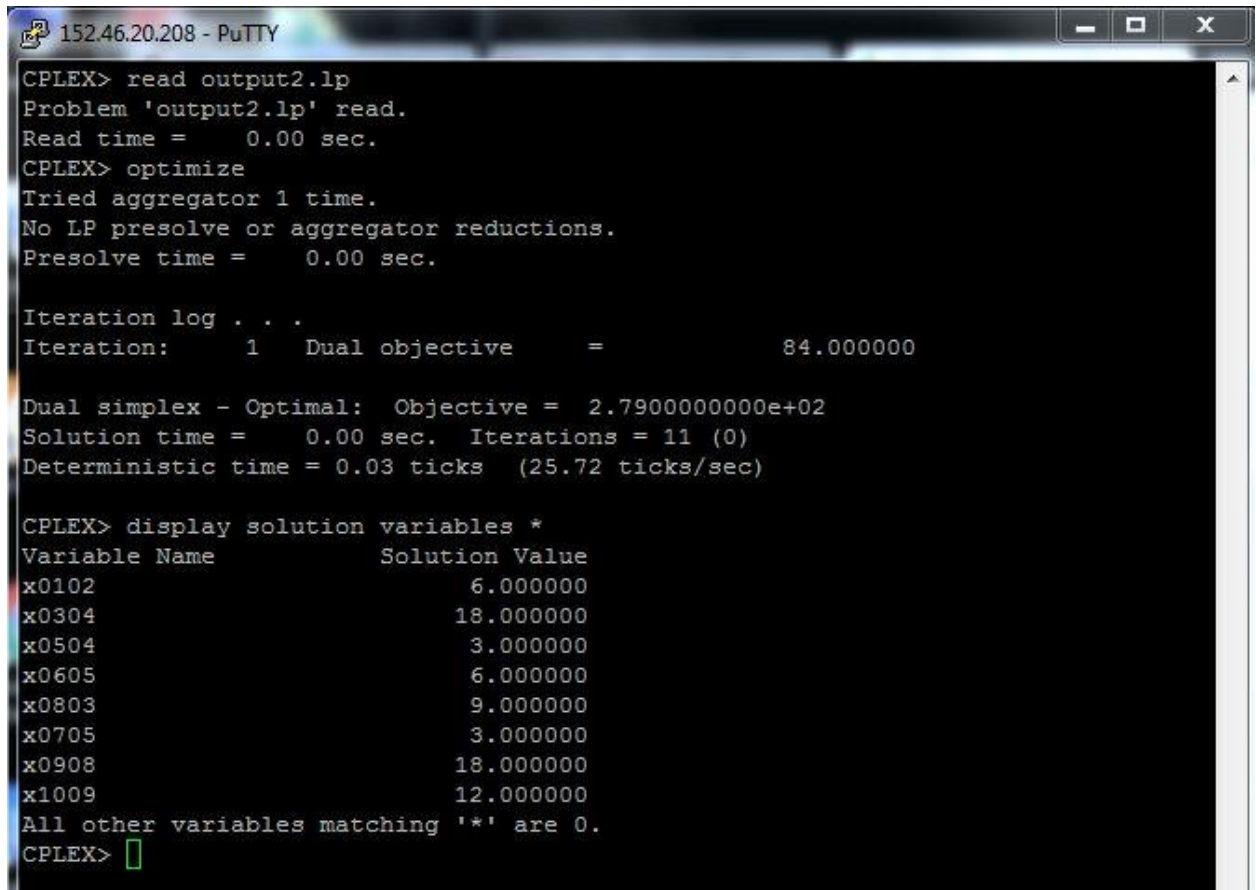
Instance 2:

What is the flow out of node 8 along each of its outgoing links?

Answer: As we can observe from the figure below, the minimum cost is 279.0
The flow out of each of the outgoing links from node 8 is as follows:

Node 8 to Node 3 = 9.0

All other flows out of node 8 are 0

A screenshot of a PuTTY terminal window titled '152.46.20.208 - PuTTY'. The window displays the output of a CPLEX solver. The text is as follows:

```
CPLEX> read output2.lp
Problem 'output2.lp' read.
Read time = 0.00 sec.
CPLEX> optimize
Tried aggregator 1 time.
No LP presolve or aggregator reductions.
Presolve time = 0.00 sec.

Iteration log . . .
Iteration: 1 Dual objective = 84.000000

Dual simplex - Optimal: Objective = 2.7900000000e+02
Solution time = 0.00 sec. Iterations = 11 (0)
Deterministic time = 0.03 ticks (25.72 ticks/sec)

CPLEX> display solution variables *
Variable Name      Solution Value
x0102              6.000000
x0304             18.000000
x0504              3.000000
x0605              6.000000
x0803              9.000000
x0705              3.000000
x0908             18.000000
x1009             12.000000
All other variables matching '*' are 0.
CPLEX> 
```


Instance 3:

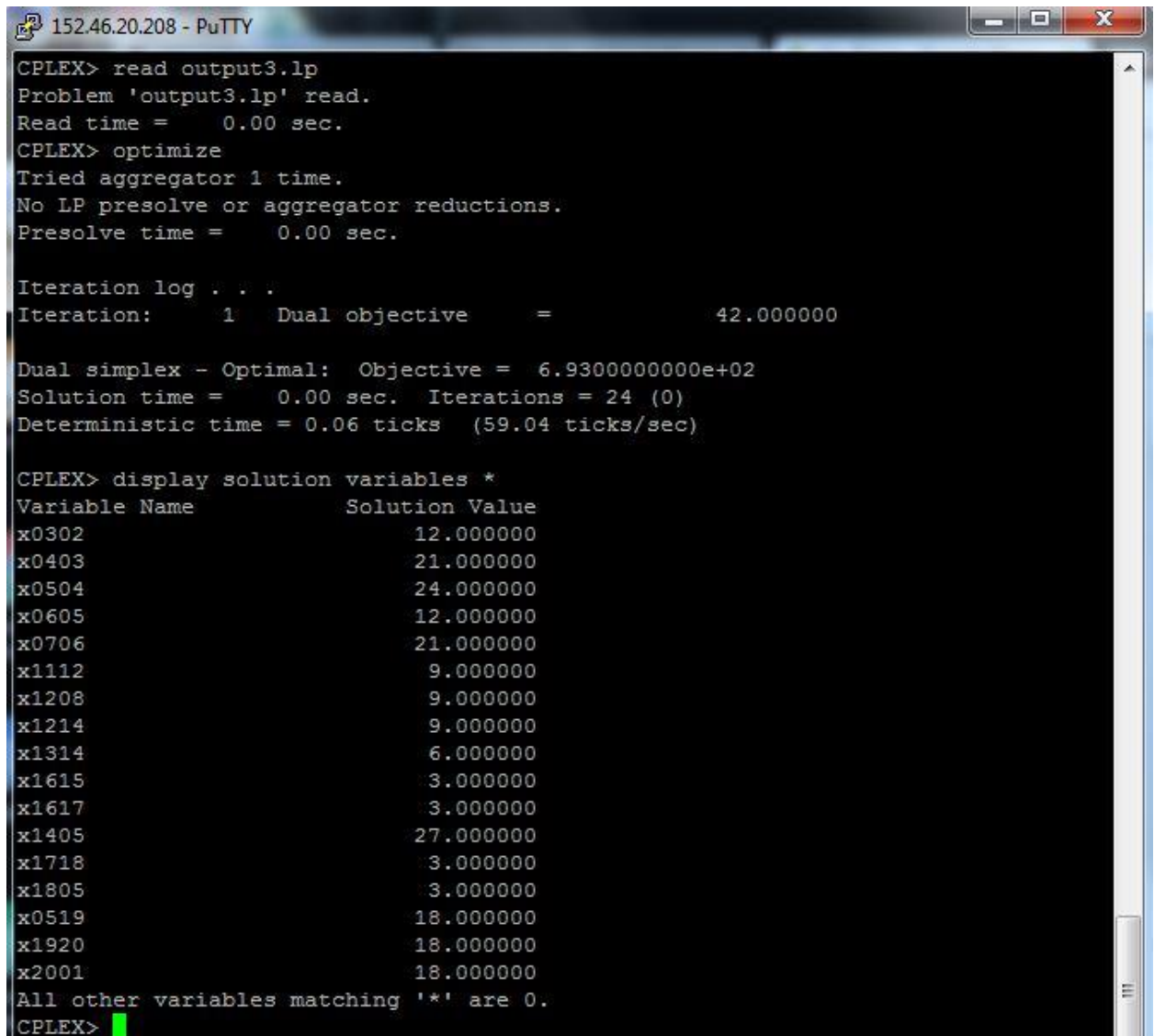
What is the flow into Node 14 along each of its incoming links?

Answer: As we can observe from the figure below, the minimum cost is 693.0
The flow into each of the incoming links of node 14 is as follows:

Node 12 to Node 14 = 9.0

Node 13 to Node 14 = 6.0

All other flows into Node 14 are 0.

A screenshot of a PuTTY terminal window titled '152.46.20.208 - PuTTY'. The window displays the output of a CPLEX solver. The text is as follows:

```
CPLEX> read output3.lp
Problem 'output3.lp' read.
Read time = 0.00 sec.
CPLEX> optimize
Tried aggregator 1 time.
No LP presolve or aggregator reductions.
Presolve time = 0.00 sec.

Iteration log . . .
Iteration: 1 Dual objective = 42.000000

Dual simplex - Optimal: Objective = 6.9300000000e+02
Solution time = 0.00 sec. Iterations = 24 (0)
Deterministic time = 0.06 ticks (59.04 ticks/sec)

CPLEX> display solution variables *
Variable Name      Solution Value
x0302              12.000000
x0403              21.000000
x0504              24.000000
x0605              12.000000
x0706              21.000000
x1112              9.000000
x1208              9.000000
x1214              9.000000
x1314              6.000000
x1615              3.000000
x1617              3.000000
x1405              27.000000
x1718              3.000000
x1805              3.000000
x0519              18.000000
x1920              18.000000
x2001              18.000000
All other variables matching '*' are 0.
CPLEX>
```

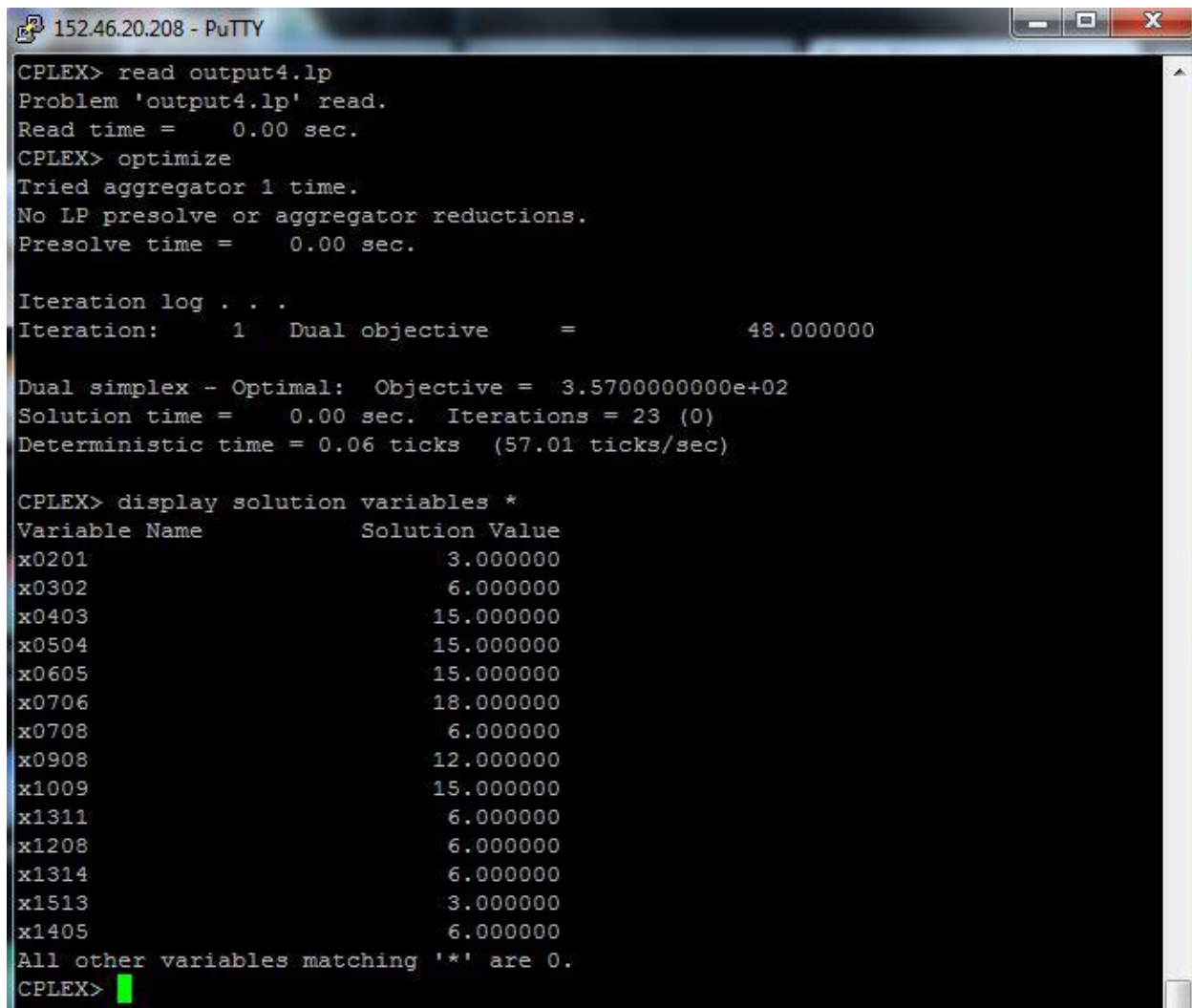
Instance 4:

What is the flow into Node 14 along each of its incoming links?

Answer: As we can observe from the figure below, the minimum cost is 357.0
The flow into each of the incoming links of node 14 is as follows:

Node 13 to Node 14 = 6.0

All other flows into Node 14 are 0.

A screenshot of a PuTTY terminal window titled '152.46.20.208 - PuTTY'. The window displays the output of a CPLEX solver. The user enters 'read output4.lp', and the solver reads the problem. Then, the user enters 'optimize', and the solver performs a dual simplex optimization. The output shows the objective value as 3.5700000000e+02, which is 357.0. The solution time is 0.00 seconds, and there are 23 iterations. The user then enters 'display solution variables *', and the solver displays the values for various variables. The variables and their values are: x0201 = 3.000000, x0302 = 6.000000, x0403 = 15.000000, x0504 = 15.000000, x0605 = 15.000000, x0706 = 18.000000, x0708 = 6.000000, x0908 = 12.000000, x1009 = 15.000000, x1311 = 6.000000, x1208 = 6.000000, x1314 = 6.000000, x1513 = 3.000000, and x1405 = 6.000000. The output also states that all other variables matching '*' are 0.

```
152.46.20.208 - PuTTY
CPLEX> read output4.lp
Problem 'output4.lp' read.
Read time = 0.00 sec.
CPLEX> optimize
Tried aggregator 1 time.
No LP presolve or aggregator reductions.
Presolve time = 0.00 sec.

Iteration log . . .
Iteration: 1 Dual objective = 48.000000

Dual simplex - Optimal: Objective = 3.5700000000e+02
Solution time = 0.00 sec. Iterations = 23 (0)
Deterministic time = 0.06 ticks (57.01 ticks/sec)

CPLEX> display solution variables *
Variable Name      Solution Value
x0201              3.000000
x0302              6.000000
x0403             15.000000
x0504             15.000000
x0605             15.000000
x0706             18.000000
x0708              6.000000
x0908             12.000000
x1009             15.000000
x1311              6.000000
x1208              6.000000
x1314              6.000000
x1513              3.000000
x1405              6.000000
All other variables matching '*' are 0.
CPLEX>
```

Instance 5:

What is the node into which the maximum amount of flow comes in, and what is the total flow into this node along each of its incoming links?

Answer: As we can observe from the figure below, the minimum cost is 7500.30

The node which has the maximum inflow are:

Node 16

Node 67

Node 01

Node 45

Node 18

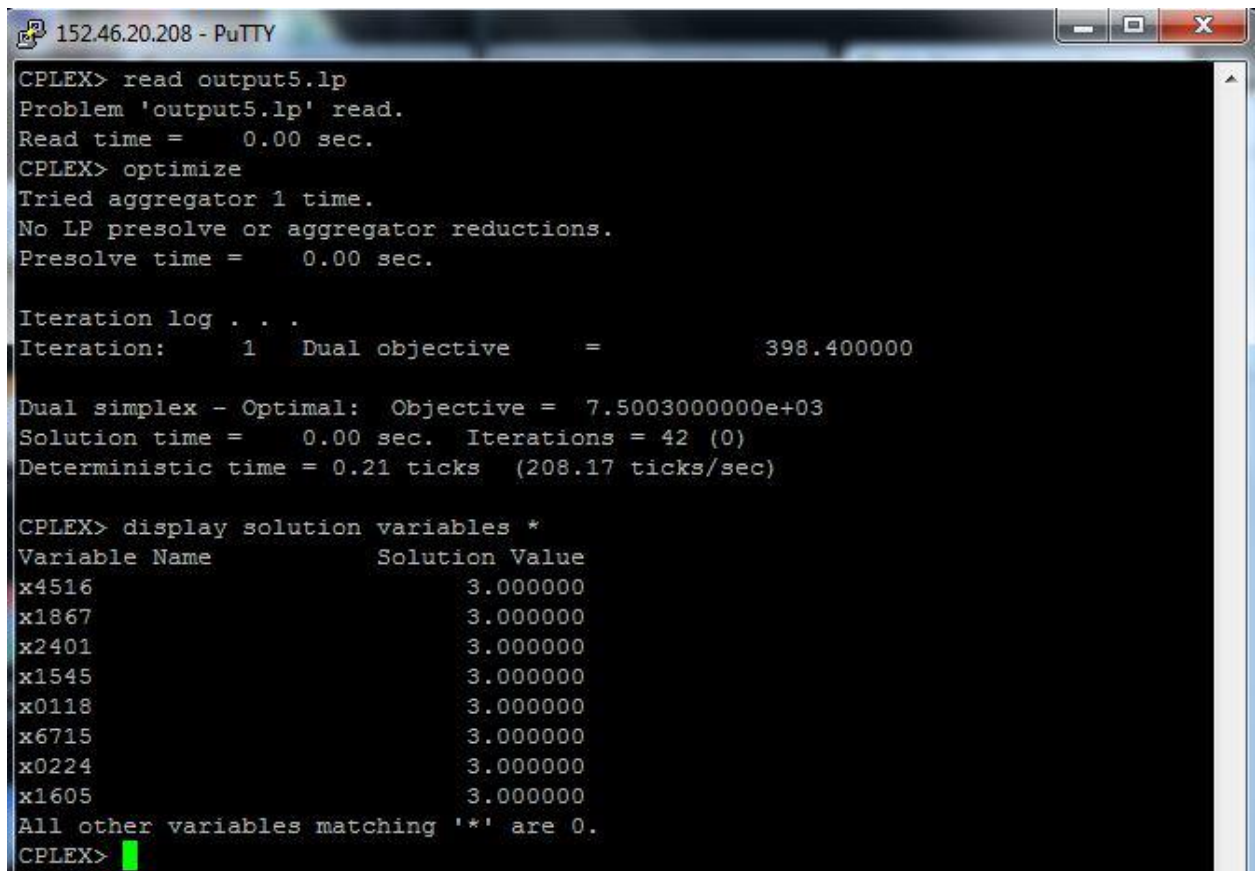
Node 15

Node 24

Node 05

Each of these nodes receive a flow of 3 units on one of it's incoming links.

All other flows on all other incoming links are 0.



```
152.46.20.208 - PuTTY
CPLEX> read output5.lp
Problem 'output5.lp' read.
Read time = 0.00 sec.
CPLEX> optimize
Tried aggregator 1 time.
No LP presolve or aggregator reductions.
Presolve time = 0.00 sec.

Iteration log . . .
Iteration: 1 Dual objective = 398.400000

Dual simplex - Optimal: Objective = 7.5003000000e+03
Solution time = 0.00 sec. Iterations = 42 (0)
Deterministic time = 0.21 ticks (208.17 ticks/sec)

CPLEX> display solution variables *
Variable Name      Solution Value
x4516              3.000000
x1867              3.000000
x2401              3.000000
x1545              3.000000
x0118              3.000000
x6715              3.000000
x0224              3.000000
x1605              3.000000
All other variables matching '*' are 0.
CPLEX>
```

NEW QUESTION:

Provide a table that lists every directed link in the topology, and specifies the total flow assigned to it by your solution. Order the links by increasing flow, breaking ties arbitrarily.

Program 1:

From	To	TotalFlow
5	18	0.000000
5	19	0.000000
17	18	0.000000
18	5	0.000000
18	17	0.000000
19	5	0.000000
19	18	0.000000
19	20	0.000000
20	19	0.000000
2	1	9.000000
1	2	12.000000
9	12	12.000000
12	9	12.000000
15	16	12.000000
16	15	18.000000
17	7	21.000000
7	8	27.000000
8	7	27.000000
14	17	27.000000
11	10	30.000000
16	17	30.000000
7	17	33.000000
17	14	33.000000
17	16	36.000000
6	7	39.000000
12	8	42.000000
7	6	51.000000
10	11	57.000000
12	11	60.000000
1	20	66.000000
20	4	66.000000
11	13	69.000000
13	11	69.000000
14	12	69.000000
4	20	72.000000
20	1	72.000000
12	14	75.000000
13	15	78.000000
10	9	81.000000
11	12	81.000000
14	13	81.000000
15	13	87.000000
2	3	93.000000
3	2	93.000000
9	8	93.000000
9	10	93.000000
8	6	96.000000
13	14	99.000000
8	9	108.000000
6	8	114.000000
3	4	153.000000
5	14	156.000000
6	5	156.000000
4	3	162.000000
5	6	165.000000
14	5	186.000000
4	5	252.000000
5	4	267.000000

Program 2:

From	To	TotalFlow
1	2	0.000000
1	20	0.000000
2	3	0.000000
3	4	0.000000
4	5	0.000000
4	20	0.000000
5	6	0.000000
5	14	0.000000
5	18	0.000000
5	19	0.000000
6	7	0.000000
6	8	0.000000
7	8	0.000000
7	17	0.000000
8	6	0.000000
8	7	0.000000
8	9	0.000000
9	10	0.000000
9	12	0.000000
10	11	0.000000
11	10	0.000000
11	13	0.000000
12	11	0.000000
12	14	0.000000
13	14	0.000000
13	15	0.000000
14	5	0.000000
14	12	0.000000
14	13	0.000000
14	17	0.000000
15	16	0.000000
16	15	0.000000
16	17	0.000000
17	7	0.000000
17	14	0.000000
17	16	0.000000
17	18	0.000000
18	5	0.000000
18	17	0.000000
19	5	0.000000
19	18	0.000000
19	20	0.000000
20	1	0.000000
20	4	0.000000
20	19	0.000000
2	1	3.000000
12	9	3.000000
15	13	3.000000
3	2	6.000000
11	12	6.000000
12	8	9.000000
13	11	12.000000
4	3	15.000000
5	4	15.000000
9	8	15.000000
10	9	15.000000
6	5	21.000000
7	6	24.000000

Program 3:

```

152.46.20.208 - PuTTY
CPLEX> read output4.lp
Problem 'output4.lp' read.
Read time = 0.00 sec.
CPLEX> optimize
Tried aggregator 1 time.
No LP presolve or aggregator reductions.
Presolve time = 0.00 sec.

Iteration log . . .
Iteration: 1 Dual objective = 48.000000

Dual simplex - Optimal: Objective = 3.5700000000e+02
Solution time = 0.00 sec. Iterations = 23 (0)
Deterministic time = 0.06 ticks (57.01 ticks/sec)

CPLEX> display solution variables *
Variable Name      Solution Value
x0201              3.000000
x0302              6.000000
x0403             15.000000
x0504             15.000000
x0605             15.000000
x0706             18.000000
x0708              6.000000
x0908             12.000000
x1009             15.000000
x1311              6.000000
x1208              6.000000
x1314              6.000000
x1513              3.000000
x1405              6.000000
All other variables matching '*' are 0.
CPLEX>

```

From	To	Total Flow
02	01	3.00
15	13	3.00
03	02	6.00
07	08	6.00
13	11	6.00
12	08	6.00
13	14	6.00
14	05	6.00
09	08	12.00
04	03	15.00
05	04	15.00
06	05	15.00
10	09	15.00
07	06	15.00