

# Operations Research

## Lab Session

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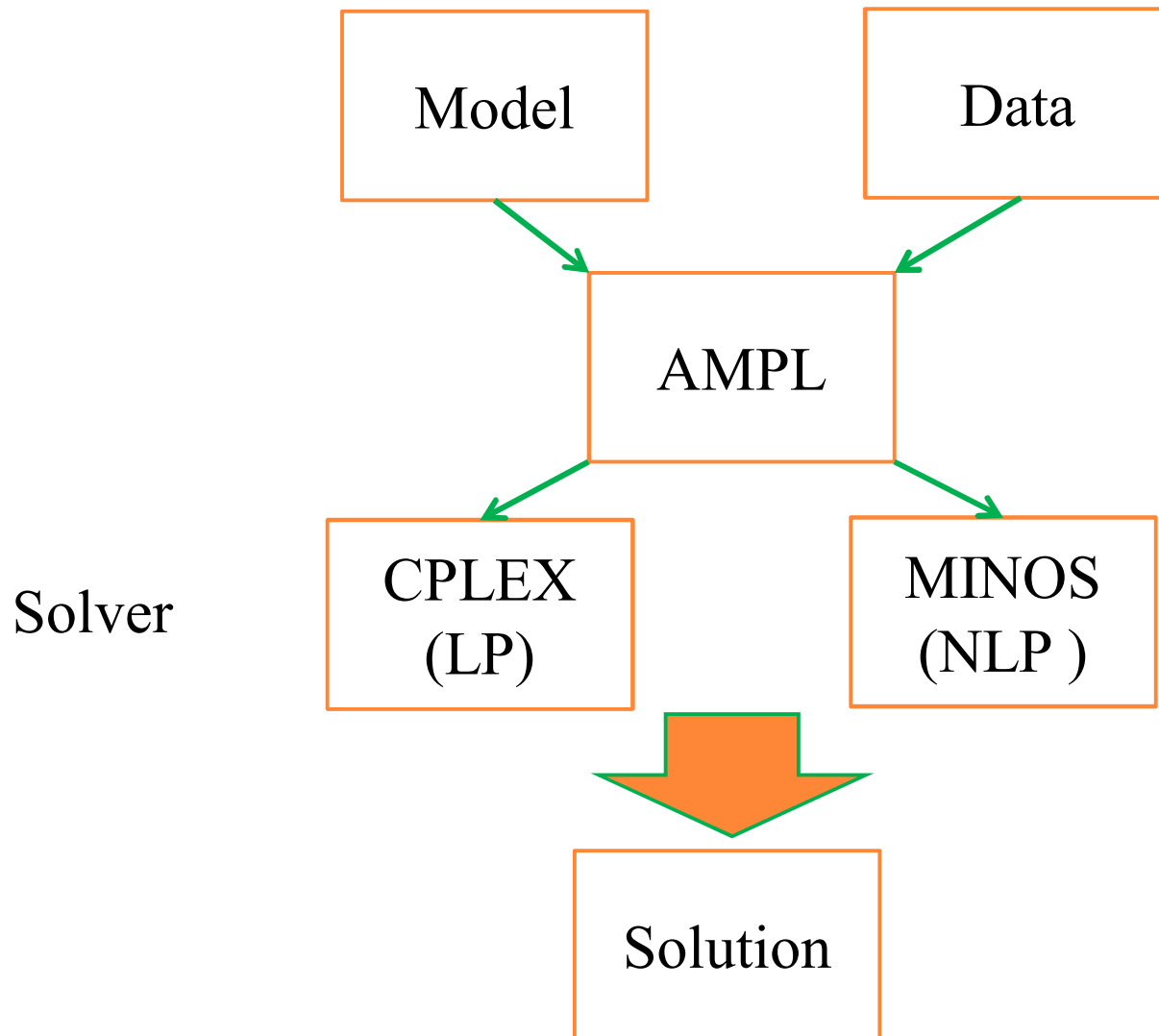
2014/03/31

# Outline

1. AMPL (A Mathematical Programming Language)

# AMPL

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# Transform method

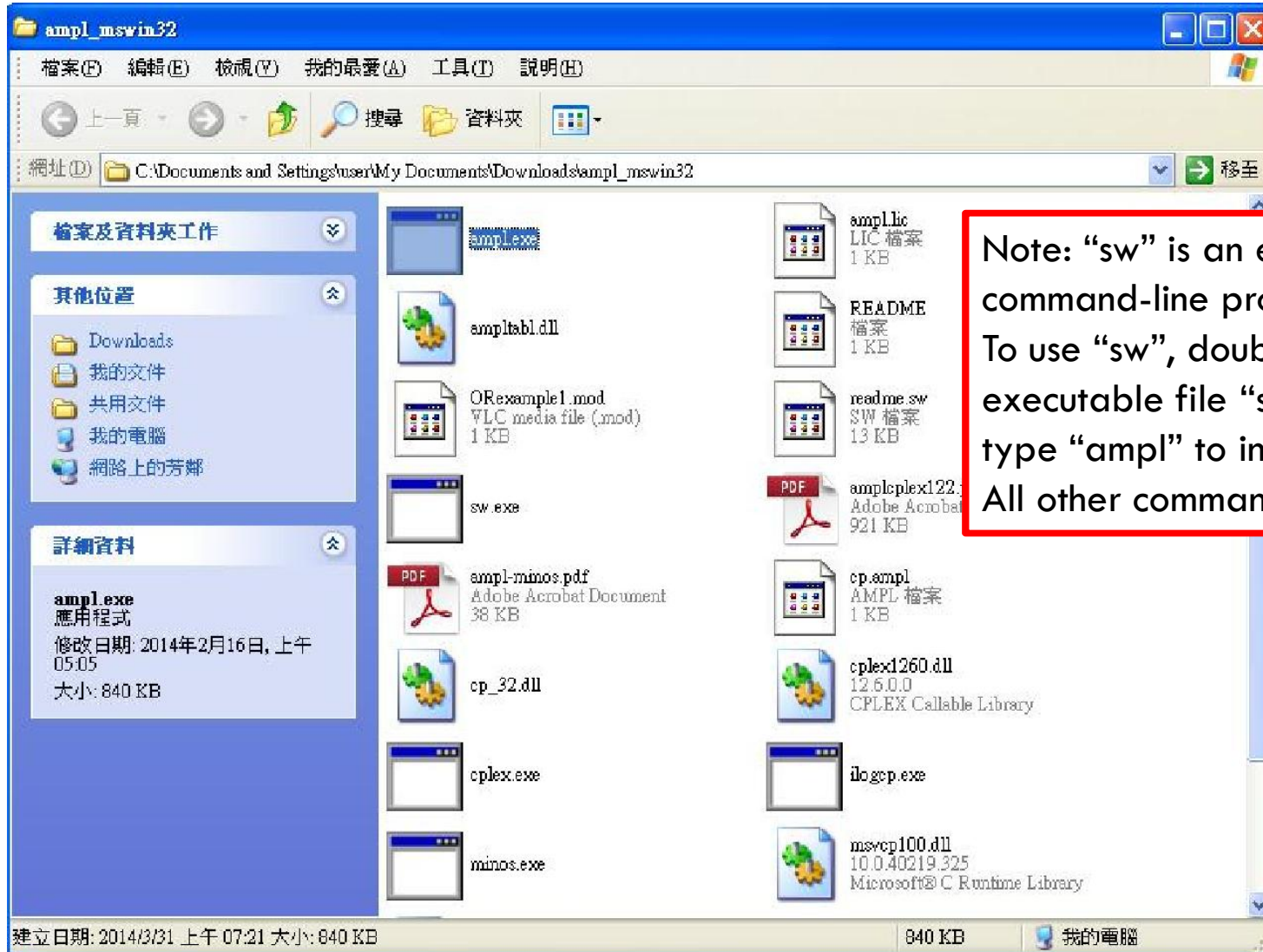
4

$$\begin{array}{ll}\text{Max} & 2x_1 + 3x_2 \\ \text{s.t.} & 5x_1 + 7x_2 \leq 48 \\ & 4x_1 + 2x_2 \leq 20 \\ & x_i \geq 0 \quad \forall i = 1, 2.\end{array}$$

```
var x1; #define variable
var x2;
```

```
maximize Z: 2*x1 + 3*x2; # objected function
subject to constraintA: 5*x1 + 7*x2 <= 48; #constraint
subject to constraintB: 4*x1 + 7*x2 <= 20;
subject to constraintC:   x1 >= 0;
subject to constraintD:   x2 >= 0;
```

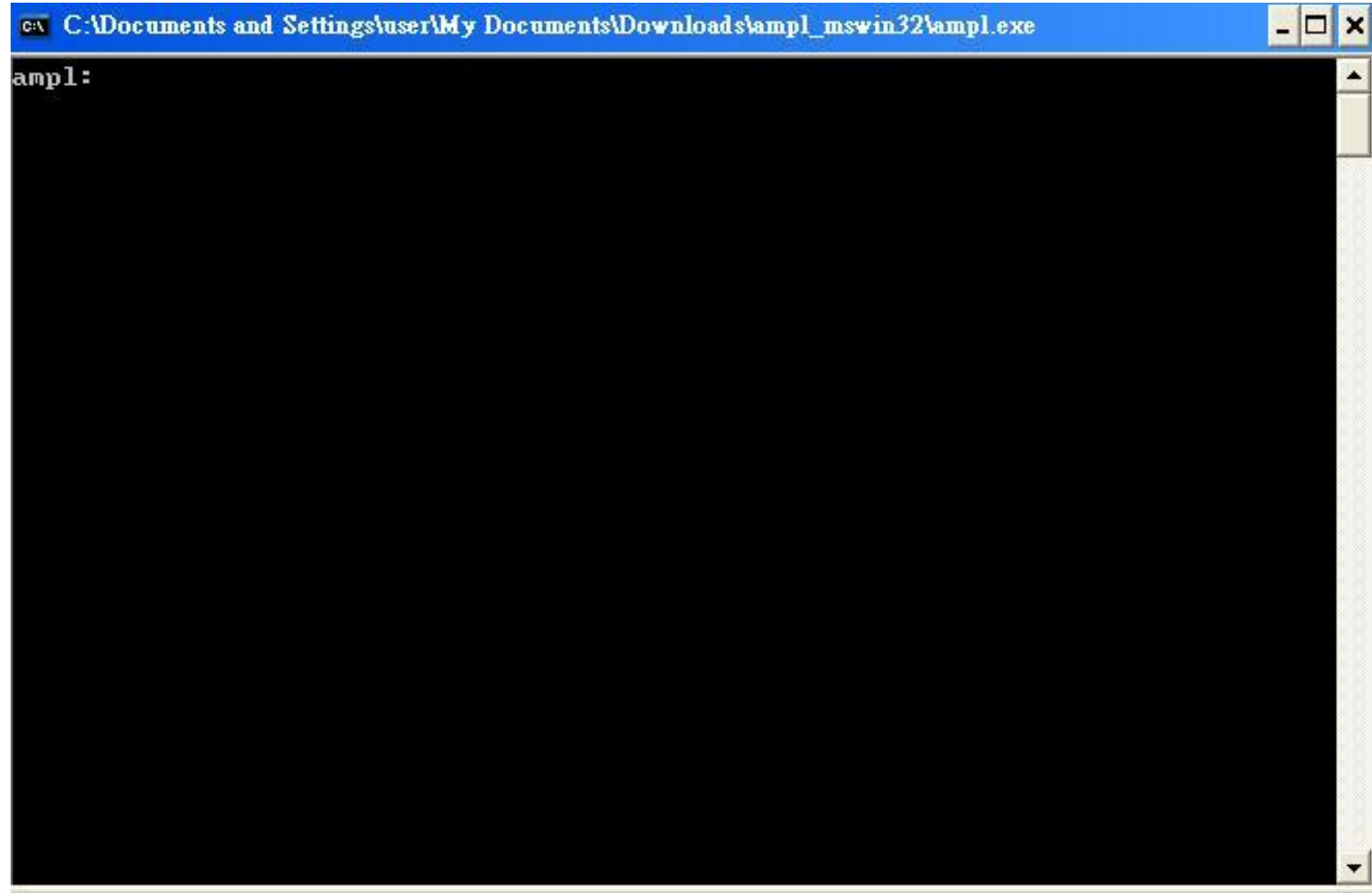
(ORexample1.mod)



Note: “sw” is an easier-to-use command-line program  
To use “sw”, double click the executable file “sw” and then type “ampl” to initiate “ampl”  
All other commands are the same

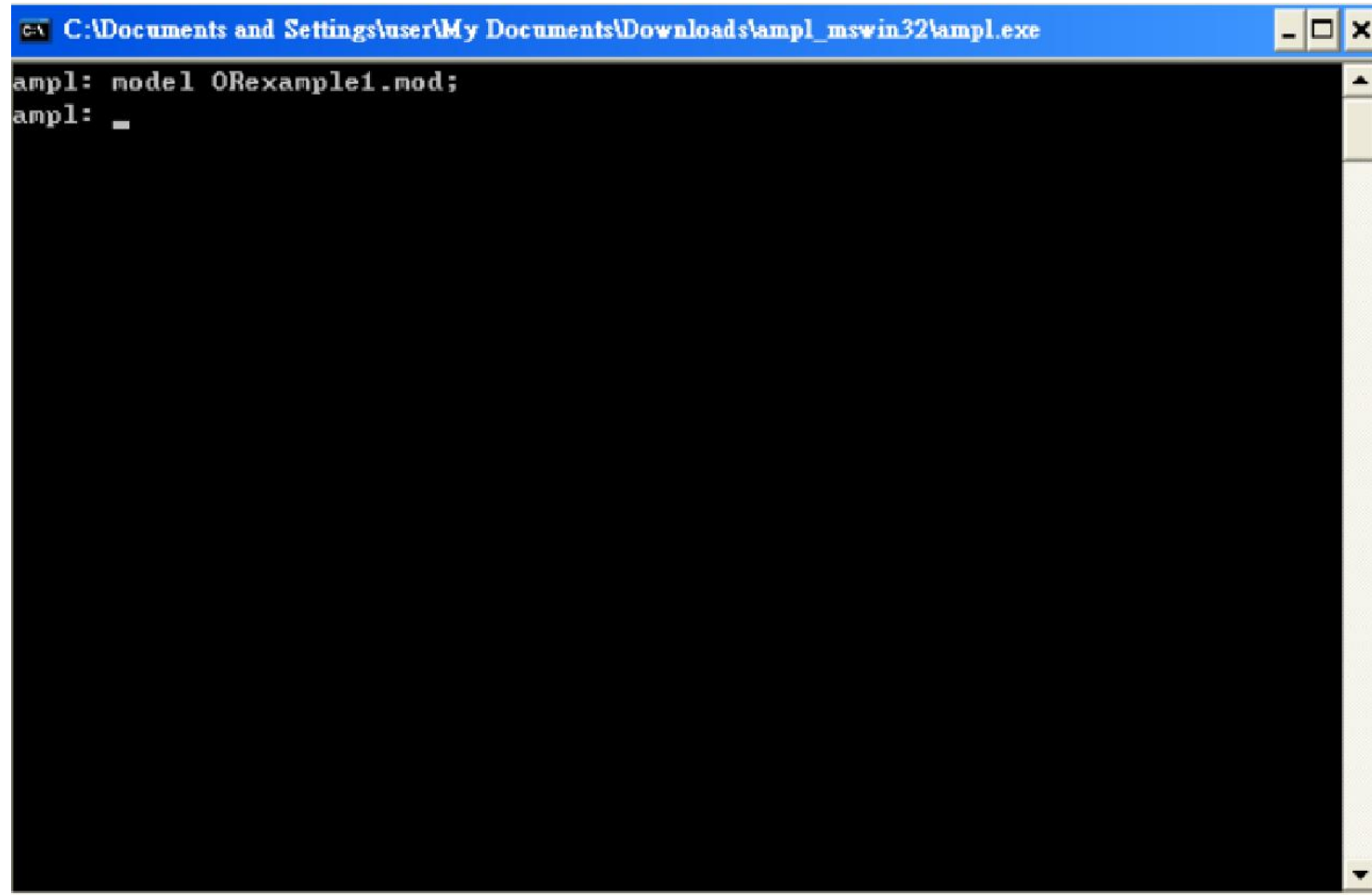
# interface

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# Input file

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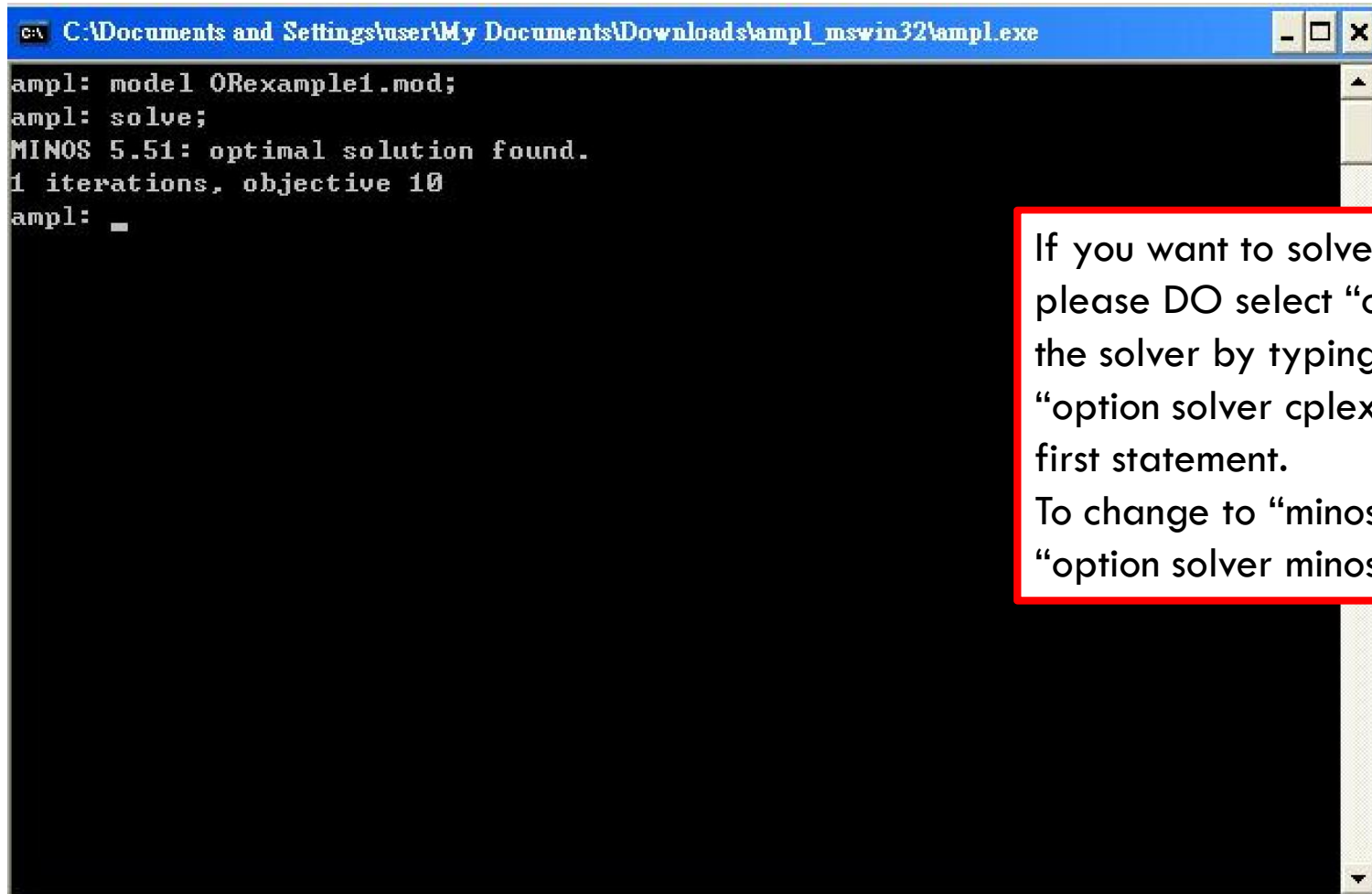


A screenshot of a Windows command prompt window. The title bar is blue and contains the text "C:\Documents and Settings\user\My Documents\Downloads\ampl\_mswin32\ampl.exe" along with standard window control buttons (minimize, maximize, close). The command prompt area is black with white text. The first line shows the command "ampl: model OExample1.mod;" and the second line shows the prompt "ampl: \_" followed by a cursor. A vertical scrollbar is visible on the right side of the command prompt area.

```
C:\Documents and Settings\user\My Documents\Downloads\ampl_mswin32\ampl.exe  
ampl: model OExample1.mod;  
ampl: _
```

# Solve operation

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```
C:\Documents and Settings\user\My Documents\Downloads\lampl_mswin32\lampl.exe  
ampl: model OReexample1.mod;  
ampl: solve;  
MINOS 5.51: optimal solution found.  
1 iterations, objective 10  
ampl: _
```

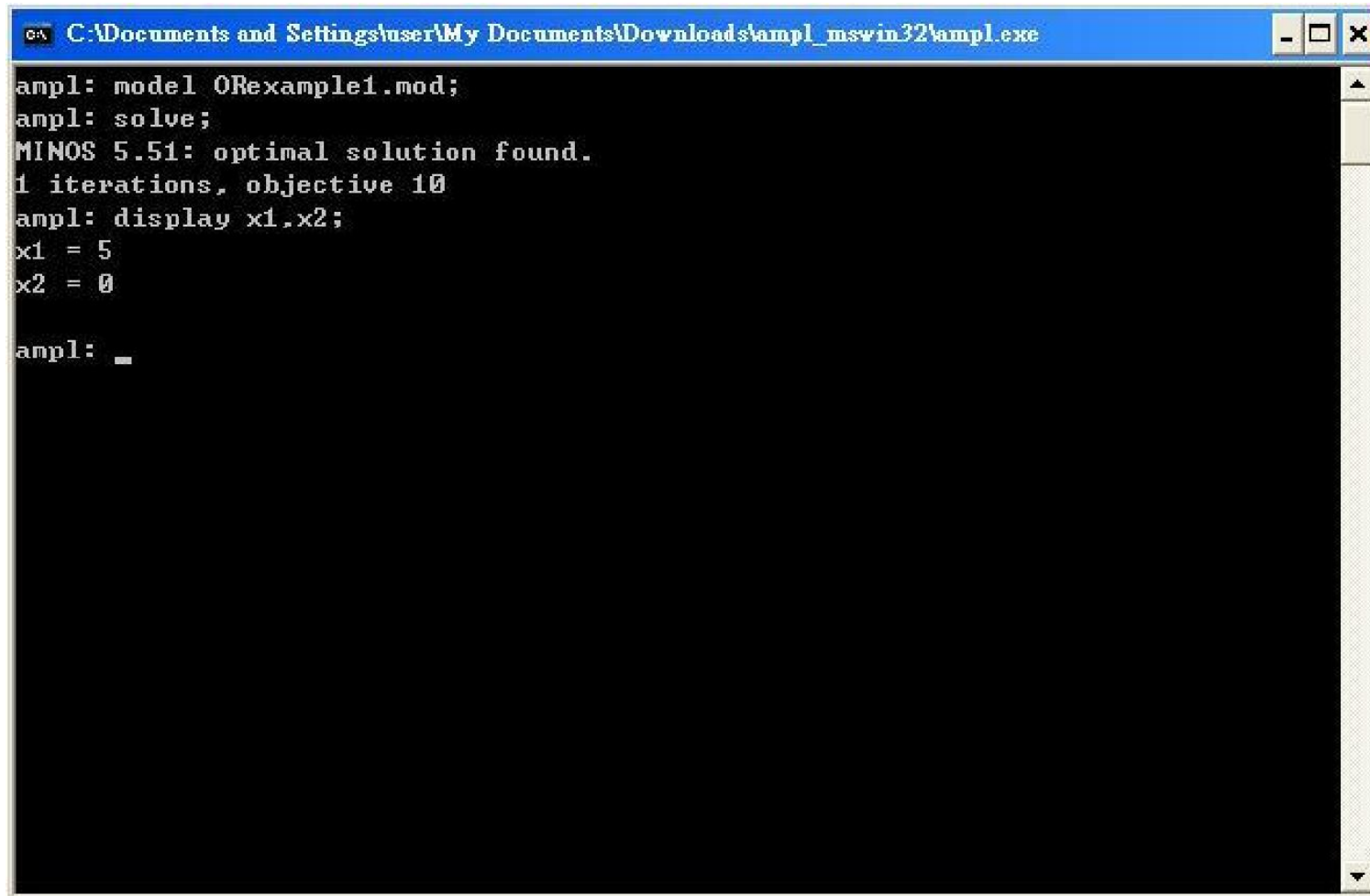
If you want to solve LPs or IPs, please DO select “cplex” as the solver by typing “option solver cplex;” as the first statement.  
To change to “minos”, type “option solver minos;”

option solver **cplex;** (assign solver)



# Display operation

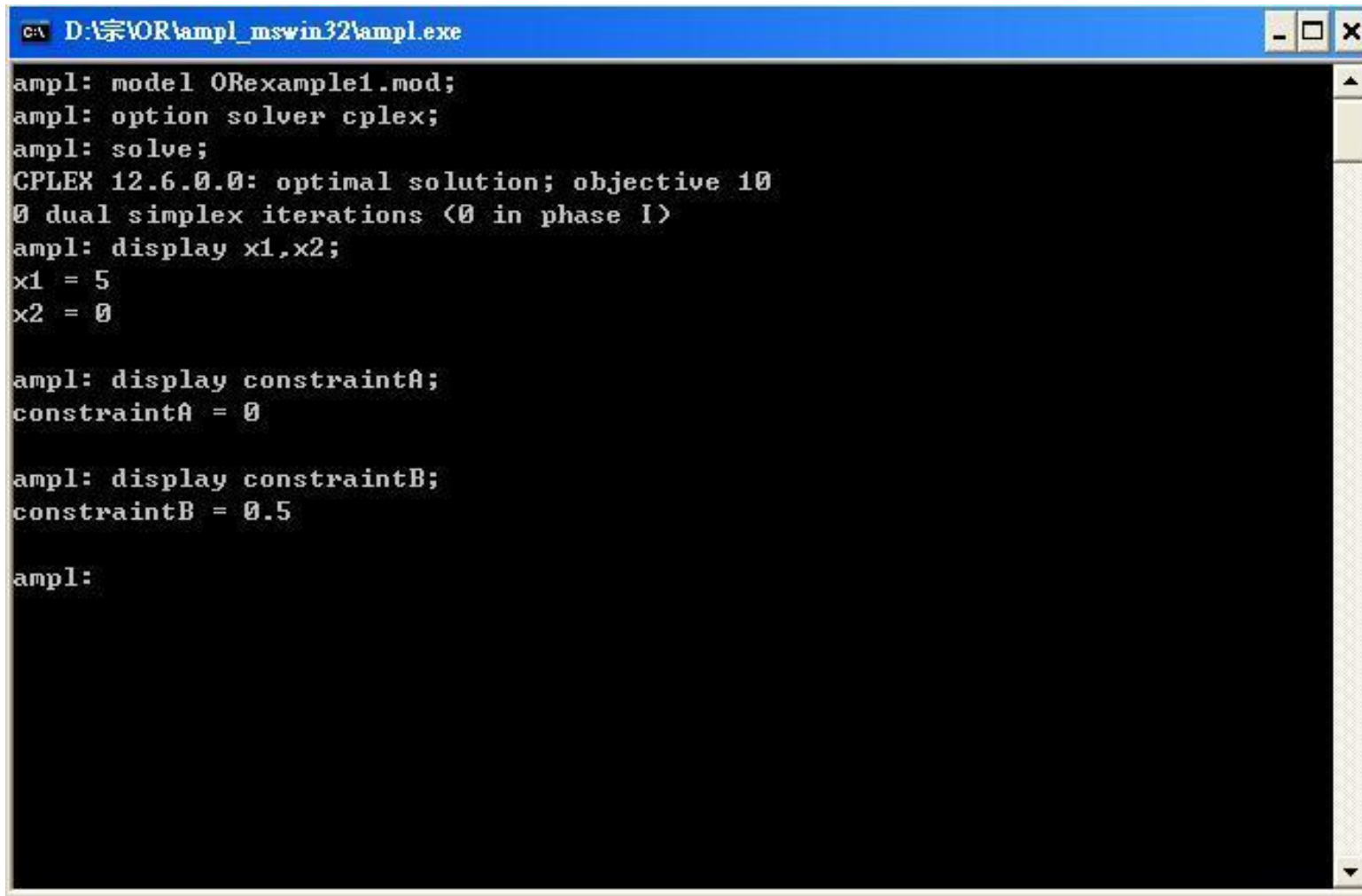
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```
C:\Documents and Settings\user\My Documents\Download\ampl_mswin32\ampl.exe  
ampl: model OExample1.mod;  
ampl: solve;  
MINOS 5.51: optimal solution found.  
1 iterations, objective 10  
ampl: display x1,x2;  
x1 = 5  
x2 = 0  
ampl: _
```

# Shadow price

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```
C:\D:\宗\OR\ampl_mswin32\ampl.exe
ampl: model OExample1.mod;
ampl: option solver cplex;
ampl: solve;
CPLEX 12.6.0.0: optimal solution; objective 10
0 dual simplex iterations (0 in phase I)
ampl: display x1,x2;
x1 = 5
x2 = 0

ampl: display constraintA;
constraintA = 0

ampl: display constraintB;
constraintB = 0.5

ampl:
```

# Reset

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- If you encounter some compilation errors, use the statement “reset;” (maybe multiple times) to clean program items loaded in memory.
  - ▣ You must do this before you reload model and data files!

# More difficult problem

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5. (10 points) John produces the drug MakeMeStrong from four chemicals. Today he must produce EXACTLY 1,000 lb of the drug. The three active ingredients in MakeMeStrong are A, B, and C. By weight, at least 5% of MakeMeStrong must consist of A, at least 4% of B, and at least 2% of C. The cost per pound of each chemical and the amount of each active ingredient in 1 lb of each chemical are given in the following table. It is necessary that at least 100 lb of chemical 2 be used. Formulate an LP whose solution would determine the cheapest way of producing today's batch of MakeMeStrong.

Chemical	Cost (\$ per lb)	A	B	C
1	8	.04	.02	.01
2	12	.06	.05	.01
3	13	.10	.03	.03
4	15	.11	.09	.04

# More difficult problem

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Let the decision variables be

$x_i$  = pounds of chemical  $i$  used,  $i = 1, \dots, 4$ .

The complete formulation of this problem is

$$\begin{array}{llllllllll} \min & 8x_1 & + & 12x_2 & + & 13x_3 & + & 15x_4 & & \\ \text{s.t.} & x_1 & + & x_2 & + & x_3 & + & x_4 & = & 1000 & \text{(Total amount produced)} \\ & 0.04x_1 & + & 0.06x_2 & + & 0.1x_3 & + & 0.11x_4 & > & 50 & \text{(Quality: ingredient A)} \\ & 0.02x_1 & + & 0.05x_2 & + & 0.03x_3 & + & 0.09x_4 & > & 40 & \text{(Quality: ingredient B)} \\ & 0.01x_1 & + & 0.01x_2 & + & 0.03x_3 & + & 0.04x_4 & > & 20 & \text{(Quality: ingredient C)} \\ & & & x_2 & & & & & > & 100 & \text{(Least amount of chemical 2)} \\ & & & & & & & x_i & > & 0 & \forall i = 1, \dots, 4. \end{array}$$

We have some parameters and sets!!!

- set  $\Rightarrow$  set
- parameter  $\Rightarrow$  param
- variable  $\Rightarrow$  var

Chemical	Cost (\$ per lb)	A	B	C
1	8	.04	.02	.01
2	12	.06	.05	.01
3	13	.10	.03	.03
4	15	.11	.09	.04

set I := 1..4; # number of chemical  
 set J := A B C; #number of ingredient

param Ingredient :

	A	B	C	:=
1	0.04	0.02	0.01	
2	0.06	0.05	0.01	
3	0.1	0.03	0.03	
4	0.11	0.09	0.4;	

Grammar:

```
var [name] {index1,index2,...} {attributes} ;
```

屬性

Example:

```
var x1;  
var x2 integer; #x2 is integer  
var x3 := 1; #x3 initial value is 1  
var x4 {i in I}; #x4 is array  
var x5 >= 0; #x5 is nonnegative  
var x6 binary; #x6 is binary
```

Grammar:

param [name] {index1,index2,...} {attributes};

Grammar:

set [set name] [set expression];

Example:

set I := 1..4;

set J := A B C;



Let the decision variables be

$x_i$  = pounds of chemical  $i$  used,  $i = 1, \dots, 4$ .

The complete formulation of this problem is

$$\begin{array}{llllllllll}
 \min & 8x_1 & + & 12x_2 & + & 13x_3 & + & 15x_4 & & \\
 \text{s.t.} & x_1 & + & x_2 & + & x_3 & + & x_4 & = & 1000 & \text{(Total amount produced)} \\
 & 0.04x_1 & + & 0.06x_2 & + & 0.1x_3 & + & 0.11x_4 & > & 50 & \text{(Quality: ingredient A)} \\
 & 0.02x_1 & + & 0.05x_2 & + & 0.03x_3 & + & 0.09x_4 & > & 40 & \text{(Quality: ingredient B)} \\
 & 0.01x_1 & + & 0.01x_2 & + & 0.03x_3 & + & 0.04x_4 & > & 20 & \text{(Quality: ingredient C)} \\
 & & & x_2 & & & & & > & 100 & \text{(Least amount of chemical 2)} \\
 & & & & & & & x_i & > & 0 & \forall i = 1, \dots, 4.
 \end{array}$$

var  $x\{i \text{ in } I\}$ ; # pound of chemical

minimize Z:  $\sum\{i \text{ in } I\} \text{ Cost}[i] * x[i]$ ;

subject to Total:  $\sum\{i \text{ in } I\} x[i] = 1000$ ; #  $x_1 + x_2 + x_3 + x_4 = 1000$ ;

subject to Quality  $\{j \text{ in } J\}$ :  $\sum\{i \text{ in } I\} \text{ Ingredient}[i,j] * x[i] \geq \text{Lower}[j]$ ;

subject to Amount1:  $x[1] \geq 0$ ;

subject to Amount2:  $x[2] \geq 100$ ;

subject to Amount3 :  $x[3] \geq 0$ ;

subject to Amount4 :  $x[4] \geq 0$ ;

Let the decision variables be

$x_i$  = pounds of chemical  $i$  used,  $i = 1, \dots, 4$ .

The complete formulation of this problem is

$$\begin{array}{llllllllll}
 \min & 8x_1 & + & 12x_2 & + & 13x_3 & + & 15x_4 & & \\
 \text{s.t.} & x_1 & + & x_2 & + & x_3 & + & x_4 & = & 1000 \quad (\text{Total amount produced}) \\
 & 0.04x_1 & + & 0.06x_2 & + & 0.1x_3 & + & 0.11x_4 & > & 50 \quad (\text{Quality: ingredient A}) \\
 & 0.02x_1 & + & 0.05x_2 & + & 0.03x_3 & + & 0.09x_4 & > & 40 \quad (\text{Quality: ingredient B}) \\
 & 0.01x_1 & + & 0.01x_2 & + & 0.03x_3 & + & 0.04x_4 & > & 20 \quad (\text{Quality: ingredient C}) \\
 & & & x_2 & & & & & > & 100 \quad (\text{Least amount of chemical 2}) \\
 & & & & & & & x_i & > & 0 \quad \forall i = 1, \dots, 4.
 \end{array}$$

subject to Amount1:  $x_1 \geq 0$ ;

subject to Amount2:  $x_2 \geq 100$ ;

subject to Amount3 :  $x_3 \geq 0$ ;

subject to Amount4 :  $x_4 \geq 0$ ;

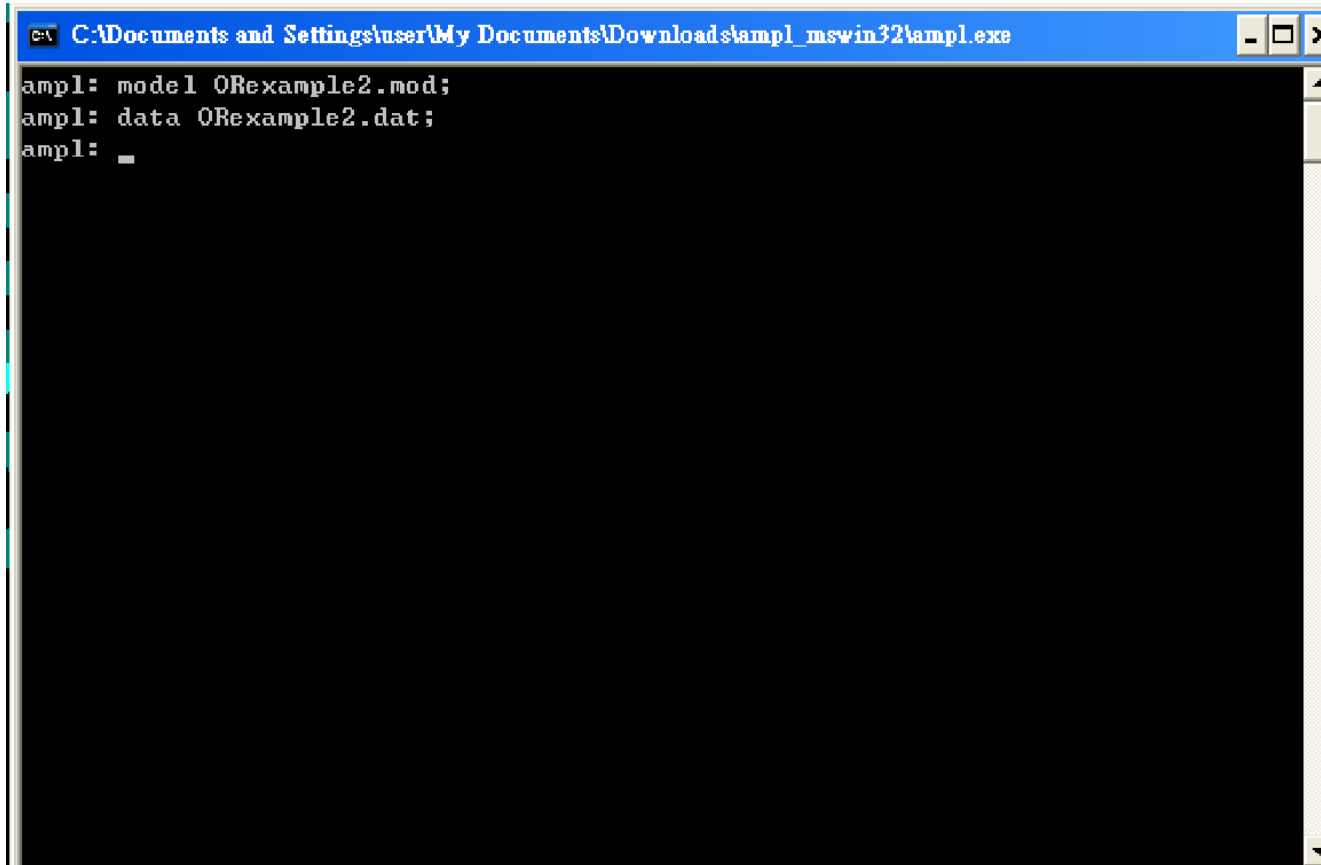
cal.dat cal.mod OExample2.mod OExample2.dat

```
1 set I;
2 set J;
3 param Ingredient{i in I, j in J};
4 param Cost{i in I};
5 param Lower{j in J};
6 var x{i in I}; # pound of chemical
7
8 minimize Z: sum{i in I} Cost[i] * x[i];
9 subject to Total: sum{i in I} x[i] = 1000; #x1+x2+x3+x4 = 1000;
10 subject to Quality{j in J}: sum{i in I} Ingredient[i,j]*x[i] >= Lower[j];
11 subject to Amount1: x[1] >= 0;
12 subject to Amount2: x[2] >= 100;
13 subject to Amount3 : x[3] >= 0;
14 subject to Amount4 : x[4] >= 0;
15
16
```

```
cal.dat cal.mod OExample2.mod OExample2.dat
1 set I := 1 2 3 4; # number of chemical
2 set J := A B C; #number of ingredient
3
4 param Ingredient:
5     ..... A      B      C      :=
6     1    0.04    0.02    0.01
7     2    0.06    0.05    0.01
8     3    0.1     0.03    0.03
9     4    0.11    0.09    0.4;
10
11 param Cost :=
12     1    8
13     2    12
14     3    13
15     4    15;
16
17 param Lower :=
18     ..... A    50
19     ..... B    40
20     ..... C    20;
```

# Input file

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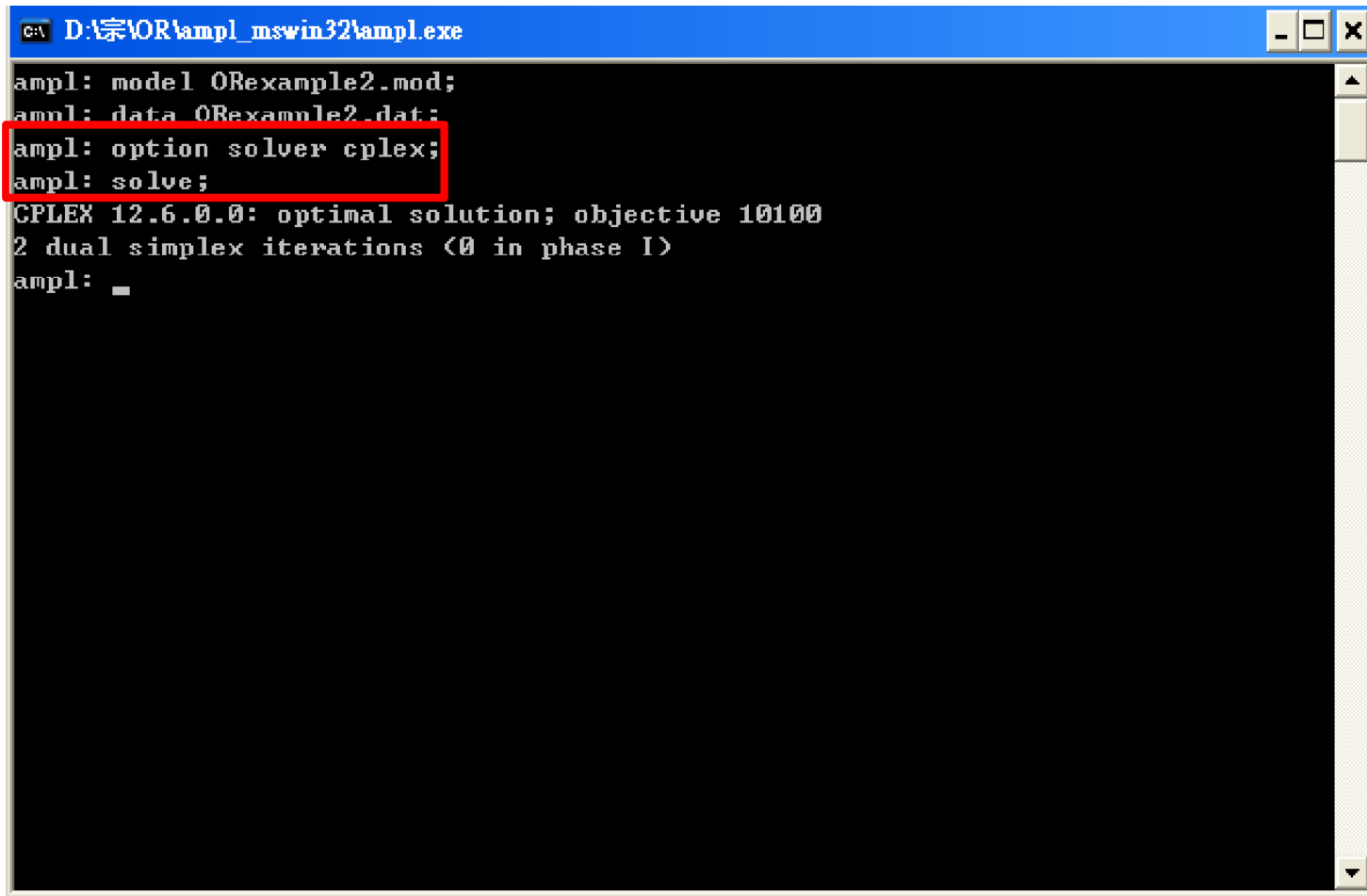


A screenshot of a Windows command window titled "C:\Documents and Settings\user\My Documents\Downloads\ampl\_mswin32\ampl.exe". The window has a blue title bar and standard Windows window controls (minimize, maximize, close). The main area is black with white text. The text shows the AMPL prompt "ampl:" followed by the commands "model OExample2.mod;" and "data OExample2.dat;". The third line shows the prompt "ampl:" followed by a single underscore character "\_".

```
C:\Documents and Settings\user\My Documents\Downloads\ampl_mswin32\ampl.exe  
ampl: model OExample2.mod;  
ampl: data OExample2.dat;  
ampl: _
```

# Result

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```
C:\D:\宗\OR\ampl_mswin32\ampl.exe
ampl: model ORexample2.mod;
ampl: data ORexample2.dat;
ampl: option solver cplex;
ampl: solve;
CPLEX 12.6.0.0: optimal solution; objective 10100
2 dual simplex iterations (0 in phase I)
ampl: _
```

Thank you 😊