leads to the formulation

$$\begin{aligned}
\text{Max} \quad & 40F + 30S \\
\text{s.t.} \quad & \\
& \tfrac{2}{5}F + \tfrac{1}{2}S \le 20 \quad \text{Material 1} \\
& \tfrac{1}{5}S \le 5 \quad \text{Material 2} \\
& \tfrac{3}{5}F + \tfrac{3}{10}S \le 21 \quad \text{Material 3} \\
& F, S \ge 0
\end{aligned}$$

Use the graphical sensitivity analysis approach to determine the range of optimality for the objective function coefficients.

2. For Problem 1 use the graphical sensitivity approach to determine what happens if an additional 3 tons of material 3 become available. What is the corresponding dual price for the constraint?

SELF test

3. Consider the following linear program:

$$\begin{aligned}
\text{Max} \quad & 2x_1 + 3x_2 \\
\text{s.t.} \quad & \\
& x_1 + x_2 \le 10 \\
& 2x_1 + x_2 \ge 4 \\
& x_1 + 3x_2 \le 24 \\
& 2x_1 + x_2 \le 16 \\
& x_1, x_2 \ge 0
\end{aligned}$$

   a. Solve this problem using the graphical solution procedure.
   b. Compute the range of optimality for the objective function coefficient of x_1.
   c. Compute the range of optimality for the objective function coefficient of x_2.
   d. Suppose the objective function coefficient of x_1 is increased from 2 to 2.5. What is the new optimal solution?
   e. Suppose the objective function coefficient of x_2 is decreased from 3 to 1. What is the new optimal solution?

SELF test

4. Refer to Problem 3. Compute the dual prices for constraints 1 and 2 and interpret them.

5. Consider the following linear program:

$$\begin{aligned}
\text{Min} \quad & x_1 + x_2 \\
\text{s.t.} \quad & \\
& x_1 + 2x_2 \ge 7 \\
& 2x_1 + x_2 \ge 5 \\
& x_1 + 6x_2 \ge 11 \\
& x_1, x_2 \ge 0
\end{aligned}$$

   a. Solve this problem using the graphical solution procedure.
   b. Compute the range of optimality for the objective function coefficient of x_1.
   c. Compute the range of optimality for the objective function coefficient of x_2.
   d. Suppose the objective function coefficient of x_1 is increased to 1.5. Find the new optimal solution.
   e. Suppose the objective function coefficient of x_2 is decreased to $\frac{1}{3}$. Find the new optimal solution.

100 labor-hours is available for assignment to the machines during the coming week. Other production requirements are that product 1 cannot account for more than 50% of the units produced and that product 3 must account for at least 20% of the units produced.

a. How many units of each product should be produced to maximize the total profit contribution? What is the projected weekly profit associated with your solution?

b. How many hours of production time will be scheduled on each machine?

c. What is the value of an additional hour of labor?

d. Assume that labor capacity can be increased to 120 hours. Would you be interested in using the additional 20 hours available for this resource? Develop the optimal product mix assuming the extra hours are made available.

26. Industrial Designs has been awarded a contract to design a label for a new wine produced by Lake View Winery. The company estimates that 150 hours will be required to complete the project. Three of the firm's graphics designers are available for assignment to this project: Lisa, a senior designer and team leader; David, a senior designer; and Sarah, a junior designer. Because Lisa has worked on several projects for Lake View Winery, management has specified that Lisa must be assigned at least 40% of the total number of hours that are assigned to the two senior designers. To provide label-designing experience, Sarah must be assigned at least 15% of the total project time. However, the number of hours assigned to Sarah must not exceed 25% of the total number of hours that are assigned to the two senior designers. Due to other project commitments, Lisa has a maximum of 50 hours available to work on this project. Hourly wage rates are $30 for Lisa, $25 for David, and $18 for Sarah.

a. Formulate a linear program that can be used to determine the number of hours each graphic designer should be assigned to the project in order to minimize total cost.

b. How many hours should each graphic designer be assigned to the project? What is the total cost?

c. Suppose Lisa could be assigned more than 50 hours. What effect would this change have on the optimal solution? Explain.

d. If Sarah were not required to work a minimum number of hours on this project, would the optimal solution change? Explain.

27. Vollmer Manufacturing makes three components for sale to refrigeration companies. The components are processed on two machines: a shaper and a grinder. The times (in minutes) required on each machine are as follows:

	Machine	
Component	**Shaper**	**Grinder**
1	6	4
2	4	5
3	4	2

The shaper is available for 120 hours, and the grinder is available for 110 hours. No more than 200 units of component 3 can be sold, but up to 1000 units of each of the other components can be sold. The company already has orders for 600 units of component 1 that must be satisfied. The profit contributions for components 1, 2, and 3 are $8, $6, and $9, respectively.

a. Formulate a linear programming model and solve for the recommended production quantities.

b. What are the ranges of optimality for the profit contributions of the three components? Interpret these ranges for company management.