**EXERCISES**

**2.11. Brown Furniture Revisited** Revisit the Brown Furniture Company (Example 2.1). As plans are being made for a new quarter, a revised set of figures on resource availabilities is compiled. The new resource limits are as follows.

|  |  |
| --- | --- |
| Fabrication hours | 2000 |
| Assembly hours | 1800 |
| Machining hours | 1600 |
| Wood supply | 9400 |

The other data, on profit contributions and resource consumptions, all remain unchanged.

1. What are the optimal production quantities of chairs, desks, and tables?
2. What is the maximum profit contribution?
3. Which constraints are binding in the optimal solution?

**2.12. Scheduling TV Production** The Kimball Video Company manufactures televisions at its main factory. The product line consists of three different flat-screen products: a plasma television, an LED television, and a 3D television. Each product requires a certain amount of time in each of three departments—Components, Assembly, and Test—shown as minutes per television in the table below. Also shown are the capacities of the three departments, in minutes available each week.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | PL | LED | 3D | *Capacity* |
| Components | 36 | 50 | 60 | 15,000 |
| Assembly | 20 | 36 | 50 | 10,500 |
| Test | 30 | 15 | 40 | 12,000 |

The unit profits for the three products are $90 for the plasma set, $120 for the LED set, and $175 for the 3D set. Based on these unit profits, what mix of the three products maximizes total weekly profits for the factory?

**2.13. Scheduling TV Production (continued)** When the management team at Kimball Video Company examines the solution to its profit-maximizing model, an agreement is reached that a practical marketing constraint had been overlooked. In particular, each item in the TV line should represent at least 15% of the total number of sets manufactured. How much does this imposition change the optimal profits?

**2.14. Diner Staffing** Alex's Diner serves food from 6am until midnight. The need for wait staff fluctuates during each day, but day-to-day differences can be ignored when plans are being made. The fluctuations are described by the table below, which displays the number of wait staff needed for each hour.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Start Time | 6am | 7am | 8am | 9am | 10am | 11am | noon | 1pm | 2pm |
| Needed | 4 | 5 | 5 | 6 | 4 | 4 | 8 | 8 | 6 |
| Start Time | 3pm | 4pm | 5pm | 6pm | 7pm | 8pm | 9pm | 10pm | 11pm |
| Needed | 5 | 3 | 5 | 7 | 6 | 5 | 3 | 2 | 2 |

Each employee on the wait staff works eight hours with a meal break of one hour. (That break must come after at least four hours but no more than five hours of work.) What is the minimum staff size needed to cover all of the hourly requirements?

**2.15. Computer Center Staffing** You are the Director of the Computer Center for Gaillard College and responsible for scheduling the staffing of the center. It is open from 8 am until midnight. You have monitored the usage of the center at various times of the day and determined that the following numbers of computer consultants are required to be on duty.

|  |  |
| --- | --- |
|  | Consultants |
| Time of day | Required |
| 8 am-noon | 4 |
| Noon-4 pm | 8 |
| 4 pm-8 pm | 10 |
| 8 pm-midnight | 6 |

Two types of computer consultants can be hired: full-time and part-time. The full-time consultants work for eight consecutive hours in any of the following shifts: morning (8 am–4 pm), afternoon (noon–8 pm), and evening (4 pm–midnight). Full-time consultants are paid $14 per hour.

Part-time consultants can be hired to work any of the four shifts listed in the table. Part-time consultants are paid $12 per hour. An additional requirement is that during every time period, at least one full-time consultant must be on duty for every part-time consultant on duty.

1. Determine a minimum-cost staffing plan for the center. In your solution, how many consultants will be paid to work full time and how many will be paid to work part time? What is the minimum cost?
2. After thinking about this problem for a while, you have decided to recognize meal breaks explicitly in the scheduling of full-time consultants. In particular, full-time consultants are entitled to a one-hour lunch break during their eight-hour shift. In addition, employment rules specify that the lunch break can start after three hours of work or after four hours of work, but those are the only alternatives. Part-time consultants do not receive a meal break. Under these conditions, find a minimum-cost staffing plan. What is the minimum cost?

**2.16. Restaurant Staffing** Tyler's Corner is a large restaurant that is open for dinner every day. The employees on the wait staff at Tyler's are scheduled to work five consecutive days each week with two consecutive days off. Their base salary is $160 per day, excluding tips. Staff who work on the weekends are paid 20% extra for the first weekend day and 25% extra for the second. The demand for staff varies throughout the week, and the manager currently faces the day-to-day staff requirements shown in the table.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *Day* | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
| *Required* | 16 | 18 | 15 | 20 | 20 | 25 | 24 |

The manager wishes to schedule the staff so that each day's requirement is covered and the total weekly salary cost is minimized.

1. What staff schedule will meet the daily requirements at minimum total cost?
2. How much overstaffing occurs in the minimum-cost schedule?

**2.17. Allocating Investments** An investor oriented to energy industries has decided to buy stock in four companies, Midwest Gas, Northeast Hydro, Southwest Solar, and Texas Wind. As shown in the table, each stock has a current price, and the investor has $500,000 dedicated to this set of purchases. In addition, research has produced estimates of the one-year return from each stock, and the investor would like to maximize the value of the portfolio after one year.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | MWG | NEH | SWS | TXW |
| *Price* | 30 | 20 | 17 | 23 |
| *Return* | 5% | 6% | 8% | 4% |

Only two conditions apply: (1) at most $250,000 can be invested in any one company, and (2) each company must account for at least 10% of the investment dollars.

1. How much money should be allocated to each of the four stocks?
2. What is the maximum dollar return? What is the corresponding percentage return?
3. If condition (2) is changed to require at least 15% in each stock, what is the optimal percentage return?

**2.18. Production Planning for Components** Rummel Electronics produces two PC cards, a modem and a network adapter. Demand for these two products exceeds the amount that the firm can make, but there are no plans to increase production capacity in the short run. Instead, the firm plans to use subcontracting.

The two main stages of production are fabrication and assembly, and either step can be subcontracted for either type of card. However, the company policy is not to subcontract both steps for either product. (That is, if modem cards are fabricated by a subcontractor, then they must be assembled in house.) Components made by subcontractors must pass through the shipping and receiving departments, just like components made internally. At present, the firm has 5200 hours available in fabrication, 3600 in assembly and 3200 in shipping/inspection. The production requirements, in hours per unit, are given in the following table:

|  |  |  |  |
| --- | --- | --- | --- |
| Product/mode | Fabrication | Assembly | Shipping |
| Modem, made entirely in-house | 0.35 | 0.16 | 0.08 |
| Network, made entirely in-house | 0.47 | 0.15 | 0.12 |
| Modem, fabricated by sub | – | 0.18 | 0.10 |
| Network, fabricated by sub | – | 0.16 | 0.15 |
| Modem, assembled by sub | 0.35 | – | 0.09 |
| Network, assembled by sub | 0.47 | – | 0.14 |

The direct material costs for the modem cards are $3.25 for manufacturing and $0.50 for assembly; for network cards, the costs are $6.10 and $0.50. Subcontracting the manufacturing operation costs $5.35 for modem cards and $8.50 for network cards. Subcontracting the assembly operation costs $1.50 for either product. Modem cards sell for $20, and network cards sell for $28. The firm’s policy, for each product, is that at most 40% of the units produced can have subcontracted fabrication, and at most 70% of the units can have subcontracted assembly.

1. Determine the production and subcontracting schedule that maximizes profits. How many units of each product should be sold, in the optimal plan? What total volume should the subcontractor handle?
2. Which department capacities limit the manufacturing volume? If 100 hours of over-time could be scheduled, which department(s) should be allocated the overtime?

**2.19. Production Planning with Environmental Constraints** You are the Operations Manager of Lovejoy Chemicals, Inc., which produces five products in a common production facility that will be subject to proposed Environmental Protection Agency (EPA) limits on particulate emissions. For each product, Lovejoy’s potential sales (demand levels that Lovejoy can capture) are expected to remain relatively flat for at least the next five years. Relevant data for each product are as follows (note: T denotes tons).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Product | Sales (T/year) | Variable costs ($/T) | Revenues ($/T) | Tons Emitted per T produced |
| A | 2000 | 700 | 1000 | 0.001 |
| B | 1600 | 600 | 800 | 0.0025 |
| C | 1000 | 1000 | 1500 | 0.03 |
| D | 1000 | 1600 | 2000 | 0.04 |
| E | 600 | 1300 | 1700 | 0.025 |

Your production facility rotates through the product line because it is capable of producing only one product at a time. The production rates differ for the products due to processing needs. It takes 0.3 hours to make one ton of A, 0.5 hours for B, and one hour each to make a ton of C, D, or E. The facility can be operated up to 4000 hours each year.

The EPA is proposing a “bubble policy” for your industry. In this form of regulation, imagine that a bubble encloses the manufacturing facility, and only total particulates that escape the bubble are regulated. This type of policy replaces historical attempts by the EPA to micromanage emissions within a firm, and it allows Lovejoy to make any changes it wishes, provided the total particulate emissions from its facility are kept below certain limits. The current proposal is to phase-in strict particulate emissions limits over the next five years. These limits on total particulate emissions are shown in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | 1 | 2 | 3 | 4 | 5 |
| Allowable emissions (T/year) | unlimited | 80 | 60 | 40 | 20 |

One strategy for satisfying these regulations is to adjust the product mix, cutting back on production of some products if necessary. Lovejoy wishes to explore this strategy before contemplating the addition of new equipment.

1. Determine the maximum profit Lovejoy can achieve from its product line in the coming year (Year 1).
2. By solving a series of models corresponding to the imposition and tightening of the emissions limit in future years, determine Lovejoy’s maximum profits in each of Years 2–5.
3. Consider the emissions limit that applies in Year 4. Determine how much Lovejoy should be willing to pay at that time to be allowed emissions of one extra ton of particulates above the limit.

**2.20. Cargo Loading** You are in charge of loading cargo ships for International Cargo Company (ICC) at a major East Coast port. You have been asked to prepare a loading plan for an ICC freight ship bound for Africa. An agricultural commodities dealer would like to transport the following products aboard this ship.

|  |  |  |  |
| --- | --- | --- | --- |
| Commodity | Tons available | Volume per ton (cu. ft) | Profit per ton ($) |
| 1 | 4000 | 40 | 70 |
| 2 | 3000 | 25 | 50 |
| 3 | 2000 | 60 | 60 |
| 4 | 1000 | 50 | 80 |

You can elect to load any and/or all of the available commodities. However, the ship has three cargo holds with the following capacity restrictions.

|  |  |  |
| --- | --- | --- |
|  | Weight | Volume |
| Cargo | capacity | capacity |
| hold | (tons) | (cu.ft.) |
| Forward | 3000 | 100,000 |
| Center | 5000 | 150,000 |
| Rear | 2000 | 120,000 |

More than one type of commodity can be placed in the same cargo hold. However, because of balance considerations, the weight in the forward cargo hold must be within 10 percent of the weight in the rear cargo hold, and the center cargo hold must be between 40 percent and 60 percent of the total weight on board.

1. What is the maximum profit and the loading plan that achieves it? What is the optimal total weight to be loaded? What is the optimal total volume to be loaded?
2. Suppose each one of the cargo holds could be expanded. Which holds and which forms of expansion (weight or volume) would allow ICC to increase its profits on this trip, and what is the marginal value of each form of expansion?

**2.21. Product Line Production Planning** The Kim Camera Company produces four different camera models, known as C1–C4. Each model can be made by two different methods. The manual method requires work in the Fabrication, Assembly, and Test departments, while the automated method combines the Assembly and Test operations in one department. The first table below describes the price and cost features of the camera models, along with marketing information on the range of possible sales in the coming month. Because model C1 is delivered to one large retailer under a long-term contract, a threshold demand quantity of 1500 units must be met. For the other models, there is flexibility in how much demand to meet, up to a ceiling that represents maximum possible sales.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | C1 | C2 | C3 | C4 |
| Price | 125 | 175 | 200 | 135 |
| Manual cost | 110 | 160 | 155 | 125 |
| Auto cost | 100 | 112 | 150 | 90 |
| Manual margin | 15 | 15 | 45 | 10 |
| Auto margin | 25 | 63 | 50 | 45 |
| Sales max. | 3000 | 2500 | 2000 | 3200 |
| Sales min. | 1500 | 0 | 0 | 0 |

The next table provides data on the various departments at the firm, consisting of the time per camera required in each department and the number of hours available in each department during the month.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | C1 | C2 | C3 | C4 | Hours |
| Manual fab. | 3 | 5 | 4 | 4 | 16,000 |
| Manual asy. | 8 | 12 | 10 | 9 | 30,000 |
| Manual test | 2 | 3 | 5 | 2 | 15,000 |
| Auto fab. | 5 | 6 | 7 | 4 | 24,000 |
| Auto asy/test | 4 | 5 | 8 | 5 | 20,000 |

1. What production plan will maximize profit for Kim Camera?
2. How would the solution in (**a**) change if there were no threshold requirement for Camera C1?

**2.22. Make/Buy Planning** The CammTex Fabric Mill is in the process of deciding on a production schedule. It wishes to know how to weave the various fabrics it will produce during the coming quarter. The sales department has confirmed orders for each of the 15 fabrics in the product line. These quarterly demands are given in the table below. Also tabulated is the variable cost for each fabric. The mill operates continuously during the quarter: 13 weeks, 7 days a week, and 24 hours a day.

CammTex uses two types of looms: general and regular. General looms can make all fabrics, and they are the only looms that can weave certain fabrics such as plaids. The production rate for each fabric on each type of loom is also given in the table. (If the production rate is zero, the fabric cannot be woven on that type of loom.) CammTex has 90 regular looms and 15 general looms.

Fabrics woven at CammTex proceed to the finishing department in the mill and are then sold. Any fabrics not woven in the mill because of limited capacity are subcontracted to an outside producer and sold at the selling price. The cost of purchasing from the subcontractor is also given in the table.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Demand | General | Regular | Mill | Sub. |
| Fabric | (yd) | (yd/hr) | (yd/hr) | ($/yd) | ($/yd) |
| 1 | 16,000 | 4.65 | 0 | 0.66 | 0.80 |
| 2 | 52,000 | 4.65 | 0 | 0.56 | 0.70 |
| 3 | 45,000 | 4.65 | 0 | 0.66 | 0.85 |
| 4 | 22,000 | 4.65 | 0 | 0.55 | 0.70 |
| 5 | 76,000 | 4.18 | 4.22 | 0.61 | 0.70 |
| 6 | 110,000 | 3.81 | 3.84 | 0.62 | 0.80 |
| 7 | 122,000 | 5.18 | 5.22 | 0.66 | 0.80 |
| 8 | 62,000 | 5.23 | 5.29 | 0.49 | 0.60 |
| 9 | 8000 | 5.23 | 5.29 | 0.50 | 0.70 |
| 10 | 69,000 | 5.23 | 5.29 | 0.44 | 0.60 |
| 11 | 70,000 | 3.73 | 3.29 | 0.61 | 0.80 |
| 12 | 82,000 | 4.18 | 4.22 | 0.57 | 0.75 |
| 13 | 10,000 | 4.40 | 4.44 | 0.54 | 0.70 |
| 14 | 360,000 | 5.23 | 5.29 | 0.31 | 0.45 |
| 15 | 62,000 | 4.18 | 4.22 | 0.50 | 0.70 |

1. What is minimum total cost of production and purchasing for CammTex?
2. Which fabrics should be made at the mill and which should be purchased? For those made at the mill, which loom types should be assigned to their production?