Show all your steps to get full credit. All problems except #1 are due on September 12. Problem #1 is due on September 19.

1. (50pt) Select an article on the application of operations research to solve a practical problem and write a summary of the article. The following are some of the journals that you can use to select your article:
   - Annals of Operations Research
   - Computers and Operations Research
   - Decision Sciences
   - European Journal of Operational Research
   - IIE Transactions
   - Informs Journal on Computing
   - Interfaces (recommended)
   - International Journal of Production Research
   - Management Science (recommended)
   - Naval Research Logistics Quarterly
   - Networks
   - Operations Research (recommended)
   - Operations Research Letters
   - Transportation Science
Make a copy of the first page of your selected article and write the full reference of the article and the journal if it is not already printed on the first page. Choose an article that is published after February 1999.

Your summary should be typed, font size between 10 and 12, and not to exceed two pages. You are welcome to include figures and tables and in that case you may use additional pages. All quotations must be explicitly indicated as such by putting them between quotation marks. All other references must be given at the end of the summary. An example of a reference in text is as follows:

... Rothkopf et al. [1998] discuss the difficulties...

An example of a reference listing at the end of your summary is as follows:

Your summary should at least include the following:
- A brief statement of what the article is about.
- A synopsis of the major results and conclusions.
- The type of operations research techniques used.
- Lessons for people involved in industrial engineering/operations research, and what you learned from the article.

You will be graded on the basis of both the quality of the contents and the clarity of your writing.
2. (10pt) A small engineering consulting firm is establishing its plan for the next year. The director and the three partners are to meet to decide which projects to pursue. Preliminary research has been done on eight projects. The expected profit for each project is given in the following table together with the number of person-days of background preparation each will require and the computer processing unit (CPU time (in hours) each will use.

<table>
<thead>
<tr>
<th>Project</th>
<th>Profit</th>
<th>Person-days</th>
<th>CPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.1</td>
<td>550</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>400</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>4</td>
<td>2.0</td>
<td>350</td>
<td>450</td>
</tr>
<tr>
<td>5</td>
<td>1.0</td>
<td>450</td>
<td>300</td>
</tr>
<tr>
<td>6</td>
<td>1.5</td>
<td>500</td>
<td>150</td>
</tr>
<tr>
<td>7</td>
<td>0.6</td>
<td>350</td>
<td>200</td>
</tr>
<tr>
<td>8</td>
<td>1.8</td>
<td>200</td>
<td>600</td>
</tr>
</tbody>
</table>

Excluding downtime, it is estimated that 1000 CPU hours will be available through the year. Presently there are 10 engineers (including the director and the partners); each works 240 days per year. At most three engineers could be let go, and management does not want to hire any new engineers for next year due to market uncertainties. A minimum of three projects need to be selected, so each partner will be in charge of at least one project for the year. The director has four favorite projects (3, 4, 5 and 8), and the company needs to select at least one of these. Because of synergies, if project 4 is selected, then project 7 must also be selected. Finally, to keep the company focused, project 1 can be selected only if project 3 is not selected. The company wants to select projects to maximize its profit. Formulate this problem as a mathematical program.

(Assign suitable symbolic names to the constants in the table and use these symbols to represent the input data rather than the actual numbers in your formulation). Is your model best classified as an LP, an NLP, an ILP or an INLP? Explain.

2. (10pt) A large copper company has 23 plants, each of which can burn 4 different kinds of fuels to produce the energy needed in smelting. Energy requirements at each plant \( p \) are known quantities \( r_p \). We also know the energy output \( e_f \) of each ton of fuel \( f \) burned and the quantity of sulfur pollution \( s_f \) released per ton of fuel \( f \) burned. In each plant \( p \), the total quantity of sulfur released should not exceed \( d_p \) due to environmental considerations. Costs vary by location, but estimates \( c_{fp} \) are available of the cost per ton for fuel \( f \) at plant \( p \). The company wants to choose mixes of fuels at plants to fulfill energy needs while minimizing cost. Formulate this problem as a mathematical problem. How many variables and constraints are in this model? Is your model best classified as an LP, an NLP, an ILP or an INLP? Explain.

3. (10pt) A metalworking shop needs to cut at least 37 large disks and 211 small ones from sheet metal rectangles of a standard size. Three cutting patterns are available. One yields 2 large disks with 34% waste, the second gives 5 small disks with 22% waste, and the last produces 1 large and 3 small disks with 27% waste. The shop seeks a minimum waste way to fulfill its requirement. Formulate a mathematical program to choose an optimum cutting plan.

4. (10pt) Mama’s Kitchen serves from 5:30am each morning until 1:30pm. Tables are set and cleared by part-time help working 4-hour shifts beginning on the hour from 5am through 10am. Most are college students who hate to get up early in the morning, so Mama’s pays $7 per hour for the 5, 6 and 7am shifts and $6 per hour for all others. The manager seeks a minimum cost staffing plan that will have 2 workers on duty for the hour beginning at 5am, and 3, 5, 5, 2, 2, 4, 6, and 3 on duty for the hours to follow. Formulate a mathematical program to select an optimal staffing plan.
5. (10pt) Assuming that the w,'s are decision variables and all other symbols are constants, determine whether each of the following mathematical programs is best described as a linear program (LP), a nonlinear program (NLP), an integer linear program (ILP), or an integer nonlinear program (INLP), and briefly explain why.