1. [20 marks] Financial quantities in North American notation are defined as:

- must begin with a leading dollar sign ($)
- an optional string of asterisks (e.g. ****) may follow the dollar sign
- there must be a non-empty string of decimal digits
- there may be an optional fractional part consisting of a decimal point and two decimal digits
- the string of digits to the left of the decimal point may contain a single zero otherwise the string of digits to the left of the decimal point may not start with a zero
- if there are more than three digits to the left of the decimal point, groups of three digits counting from the right must be separated by commas.

Examples: $****3,456.78 $0.10 $20 $1,234,567.89

Write a regular expression (or a set of regular expressions) that recognize financial quantities in this notation.

2. [20 marks] Consider the grammar

1. \[ G \rightarrow S \] $ \\
2. \[ S \rightarrow A M \] \\
3. \[ M \rightarrow S \] \\
4. \[ \rightarrow \lambda \] \\
5. \[ A \rightarrow a E \] \\
6. \[ \rightarrow b A A \] \\
7. \[ B \rightarrow b E \] \\
8. \[ \rightarrow a B B \] \\
9. \[ E \rightarrow a B \] \\
10. \[ \rightarrow b A \] \\
11. \[ \rightarrow \lambda \]

Where \[ \lambda \] is the empty string

Is the grammar LL(1)?

If it is LL(1) show the Predict Sets.

If it is not LL(1) identify a Predict Set conflict.
3. **[20 marks]** Consider the following union (i.e. variant record like) declaration:

```plaintext
union uTag : 1 .. 3 of
  case 1: x : int
          y : string(3)
          z : real
  case 2: a : array 1 .. 5 of boolean
          b : real
          c : record
e       d : string(1)
          e : real
  end record
  case 3: s : array 1 .. 9 of string(5)
          t : real
end union
```

Assume the size and alignment factors for the basic data types:

<table>
<thead>
<tr>
<th>type</th>
<th>align size</th>
<th>type</th>
<th>align size</th>
<th>type</th>
<th>align size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 .. 3</td>
<td>16 16</td>
<td>boolean</td>
<td>8 8</td>
<td>real</td>
<td>64 64</td>
</tr>
<tr>
<td>int</td>
<td>32 32</td>
<td>string(1)</td>
<td>8 8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Where a string of length K is stored in K 8-bit bytes. Show the storage allocation that would be performed for this union type using the multi-level algorithm described in lecture. Give the relative location of each field in the union and show the fill that is required.

4. **[20 marks]** Describe semantic analysis checks that a Java compiler should perform on the program fragments listed below

**Fragment A**

```plaintext
1 void method() {
  2    int I = 0;
  3    while (I < 10) {
  4      int J = 0;
  5      I ++;
  6    }
  7    System.out.println(I);
  8 }
```

**Fragment B**

```plaintext
1 for (int K = 0; K < data.length; K++) {
  2    if (data[K] == target) {
  3      index = K;
  4      break;
  5    }
  6 }
```

5. **[20 marks]** Show the symbol and type table entries that a typical compiler might produce for the union declaration in Question 3.