1) The minicomputer BASIC is modified as following:
Index register A is added and a new 13-bit register called the STACK POINTER (sp) is introduced. An incrementing and decrementing unit is connected to the sp, and sp always points to the top of the stack which occupies the beginning part of the main memory.

b) Bit positions 3 & 4 of IR (MBR) are now interpreted as follows:

<table>
<thead>
<tr>
<th>IR</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>01</td>
<td>01</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

An index adder is also available.

a) JMS 300 instruction (op-code: 100) (with no indexing and no indirect addressing) now causes the content of the PC to be incremented and pushed into the stack (i.e., placed in the location next to the present top of the stack). The next instruction to be executed is taken from memory location 300.

i) Ignoring all other instructions, write an AHPL program which describes the fetching and execution of a JMS instruction. The complete decoding of the op-code may be done in one step and the AHPL program should be structured as follows:
ii) Once the BASIC is modified as above, what new instruction would you like to incorporate? How would you assign an op-code to that instruction?

2) (Number Systems)
Let \( r \) (for radix) denote the number of distinct primitive digits used for representing numbers in a computer. Most mechanical computers used \( r=2 \), that is, binary notation.

a) Suppose that the cost of using a particular value of \( r \) is proportional to \( r \). This seems reasonable because the complexity of the storage and processing circuits needed tends to increase with \( r \). Then the cost \( c(r) \) of a radix \( r \) representation of all \( m = r^n \) possible \( n \)-digit numbers is

\[
c(r) = kmnr
\]

where \( k \) is some constant. Show that the minimum value of \( c(r) \) occurs when \( r = 3 \), assuming that \( m \) is fixed and \( r \) is an integer. This suggests that computers should use ternary \( (r=3) \) instead of binary \( (r=2) \) notation.

b) List all the arguments for NOT designing computers to use ternary \( (r=3) \) notation. Explain specifically why the argument in favor of ternary notation in part 'a' of this problem can be rejected. (A ternary computer was actually built in Poland many years ago.)

3) A floating-point processor is being designed with a number format that must meet the following requirements:

a) Numbers in the range \( \pm 1.0 \times 10^{\pm 50} \) must be represented.

b) The precision required is six decimal digits, i.e., the six most significant digits of the decimal equivalent of every number in the required range must be representable.

c) The representation of each number should be unique. Zero is to be represented by a sequence of 0's.

d) Binary arithmetic is to be used throughout with \( B=2 \), where \( B \) is the floating-point base to be used.