**Tutorial 5**

**Turing Machines**

1. Give implementation-level descriptions of Turing machines that decide the following languages over the alphabet {0,1}.

* {w|w contains an equal number of 0s and 1s}
* { w|w contains twice as many 0s and 1s}
* { w|w does not contain twice as many 0s and 1s}

1. Construct Turing machine for L = {an bm a(n+m) | n,m≥1}
2. Construct Turing machine for L = {aibjck| i\*j = k; i, j, k ≥ 1},
3. Draw a Turing machine which multiply two Binary numbers.
4. Draw a Turing machine to find 1’s complement of a binary number.
5. Draw a Turing machine which subtract two numbers in binary.
6. Let a k-PDA be a pushdown automaton that has k stacks. Thus a 0-PDA is an NFA and a 1-PDA is a conventional PDA. It is known that 1-PDAs are more powerful (recognize a larger class of languages) than 0-PDAs.
   1. Show that 2-PDAs are more powerful than 1-PDAs.
   2. Show that 3-PDAs are not more powerful than 2-PDAs.
7. Say that a write-once Turing machine is a single-tape TM that can alter each tape square at most once (including the input portion of the tape). Show that this variant Turing machine model is equivalent to the ordinary Turing machine model.
8. A Turing machine with doubly infinite tape is similar to an ordinary Turing machine, but its tape is infinite to the left as well as to the right. The tape is initially filled with blanks except for the portion that contains the input. Computation is defined as usual except that the head never encounters an end to the tape as it moves leftward. Show that this type of Turing machine recognizes the class of Turing-recognizable languages (one side infinite tape TM)
9. A Turing machine with left reset is similar to an ordinary Turing machine, but the transition function has the form:



At each point the machine can move its head right or let it stay in the same position. Show that this Turing machine variant is not equivalent to the usual version. What class of languages do these machines recognize?