Department of Computer Science and Engineering
IIT Roorkee

MTE Spring Semester 2024-25
CSN312 Principles of Programming Languages **FM: 25** **10.3.2025** **Duration: 90min**

Do not write anything on the question paper.

Answer all the questions. Answer for each question should begin on a new page.
Zero mark would be given for correct answers with no steps/unjustified steps/ incorrect justifications.
For each question, the final answer should be written explicitly as: Answer: ... .

1. For the term given below, construct an equivalent term (without any shortcut notation) with as few parentheses as possible. All the steps should be clearly justified. [5]

   (((w (λx. (λy. (λz. ((x z)(y z)))))) u) v)

2. Find the set of free variables, using the rules, for each of the following terms. [5]
   (a) (λx. x y) λz. w λw. w z y x
   (b) x λz. x λw. w z y
   State the rules for computing free variables. All the steps should be clearly justified.

3. Find the normal form of the following term using call-by-name.
   ((λf. ((λg. ((f f) g)) (λh. (k h))))(λx. (λy. y))) [5]
   All the steps should be clearly justified.

4. State the lambda term *M* corresponding to the recursive definition of *plus* function. Show the computation of *M* for *plus(2,3)*. All the steps should be clearly justified. [5]

5. Only write the answers for the following questions.

   (i) State the simplest term corresponding to *(first second id)*. [1]
   (ii) Give the normal form of (x (λw. w)). [2]
   (iii) State the primitive recursive function definition for the function *iszero*. [2]

END