1. Consider the following relational schema.
   Product(*maker*, *model*, *type*)
   PC(*model*, *speed*, *ram*, *hd*, *screen*, *price*)
   Laptop(*model*, *speed*, *ram*, *hd*, *screen*, *price*)
   Printer(*model*, *colour*, *type*, *price*)

(a) Write the following query in SQL: *Print the makers of at least two different computers (PCs or laptops) with speeds of at least 1000.* Argue the correctness of your answer.   [4]

(b) Write the above query in Tuple Relational Calculus and Domain Relational Calculus.   [6]

2. Depict all the ways in which a relation schema can violate the 3NF conditions.   [10]

3. Consider the following B+ tree of order 2. The root of the tree is node A. (In the following, $\hat{X}$ refers to a pointer to node X.)
   $A = [\hat{B}, 10, \hat{C}, 20, \hat{D}, 30, \hat{E}, 80, \hat{F}]$ $B, C,$ and D are roots of legitimate subtrees.
   $E = [\hat{G}, 35, \hat{H}, 42, \hat{I}, 50, \hat{J}, 65, \hat{K}]$ $F = [\hat{L}, 90, \hat{M}, 98, \hat{N}]$
   $G = [30, 31]$ $H = [36, 38]$ $I = [42, 43]$ $J = [51, 52, 56, 60]$ $K = [68, 69, 70, 79]$
   $L = [81, 82]$ $M = [94, 95, 96, 97]$ $N = [98, 99, 100, 105]$

(a) Name a search key, the inserting of which into the tree will cause the height of the tree to increase.   [3]
(b) Sketch the relevant portions of the tree after deleting record 81 from the given tree.   [2]

4. Sketch the result of performing the following operations on an initially empty extendible hash index. Ixx stands for "Insert xx" and Dxx stands for "delete xx".
   I01 I05 I10 I15 I51 I04 I12 I36 I64 I08 I24 I56 I16 D56 D24 D08   bucket size = 4 records. [6]

5. Consider a relation $R(a, b, c, d)$ containing 10^6 records, where each page of the relation holds 10 records. R is organized as a heap file with dense secondary indexes, and the records in R are randomly ordered. Assume that attribute a is a candidate key for R, with values lying in the range 0 to 999999.

   Consider the following three file access methods: (i) scan the whole file (ii) use a B+ tree index on $R.a$ (iii) use a hash index on $R.a$

   For each of the following queries, name the access method that is likely to require the fewest I/Os for processing the query: (a) Find all R tuples. (b) Find all R tuples such that $a < 50$. (c) Find all R tuples such that $a = 50$. Justify your answers.   [9]

6. Below are two transactions described in terms of their effect on two database elements A and B, which you may assume are integers.

   T1: READ(t,A); t=t+2; WRITE(A,t); READ(t,B); t=t*3; WRITE(B,t);
   T2: READ(s,B); s=s*2; WRITE(B,s); READ(s,A); s=s+3; WRITE(A,s);

   These transactions, in isolation, satisfy all the consistency constraints on the database. (Note that $A = B$ is not one of the constraints.)

(a) Show that the serial orders (T1,T2) and (T2,T1) are semantically equivalent.   [3]
(b) Give examples of a serializable (but not serial) schedule and a nonserializable schedule of the above 12 actions. Argue the correctness of your answers.   [4]

7. Show that the RW, WR, WW conflicts in a strict 2PL schedule are all harmless in the sense that a read or an overwrite of uncommitted data or an unrepeatable read do not occur.   [8]

RW → un repeatable read.
WR → read of un committed data
WW → overwrite of " "