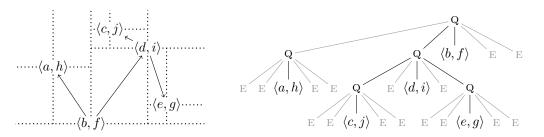
## COMPUTER SCIENCE TRIPOS Part IA – 2023 – Paper 1

## 2 Foundations of Computer Science (jdy22)

This question considers the following type qt that represents quadtrees of points:

```
type point = int * int
type qt = Empty | Quad of qt * qt * point * qt * qt
```

A value Quad(nw,ne,(x,y),sw,se) contains points in the quadrants around (x,y). x is the right bound of points in nw and sw and the left bound of points in nw and se. y is the upper bound of points in sw and se and lower bound of points in nw and ne.



(a) Write a function compare\_range to find whether a number falls below, within or above a range:

```
type range = int * int
type rel = LT | IN | GT
val compare_range : int -> range -> rel
```

For example, compare\_range 3 (2,5) should return IN, because  $2 \le 3 \le 5$ . [2 marks]

(b) Write a function has\_point to efficiently search a quadtree for a point:

```
val has_point : point -> qt -> bool
```

[8 marks]

(c) Write a function has\_point\_in to efficiently search a quadtree for a point within a rectangular region:

```
type rectangle = point * point
val has_point_in : rectangle -> qt -> bool
```

has\_point\_in (p1,p2) qt should return true if and only if qt contains a point in the rectangular region with lower-left corner p1 and upper-right corner p2.

[10 marks]