UNIVERSITY OF EDINBURGH

COLLEGE OF SCIENCE AND ENGINEERING

SCHOOL OF INFORMATICS

INFR08013 INFORMATICS 1 - FUNCTIONAL PROGRAMMING

Tuesday 20th December 2016

14:30 to 16:30

INSTRUCTIONS TO CANDIDATES

1. **Note that ALL QUESTIONS ARE COMPULSORY.**
2. **DIFFERENT QUESTIONS MAY HAVE DIFFERENT NUMBERS OF TOTAL MARKS. Take note of this in allocating time to questions.**
3. **This is an OPEN BOOK examination: notes and printed material are allowed, and USB sticks (read only), but no electronic devices.**
4. **CALCULATORS MAY NOT BE USED IN THIS EXAMINATION**

Convener: I. Simpson
External Examiner: I. Gent

THIS EXAMINATION WILL BE MARKED ANONYMOUSLY

1. (a) Write a function `f :: [Int] -> String -> Int` that computes the product of the numbers in its first argument for which the character at the corresponding position in its second argument is `'y'`. If the lengths of the two lists do not match, the extra elements in the longer list are ignored. For example:

```
f [3,5,2,4,1] "yynyn"     = 60
f [10,20,30,40,50] "abcd" = 1
f [] "baby"               = 1
f [4,3,2,1] "aye"         = 3
```

Use *basic functions*, *list comprehension*, and *library functions*, but *not recursion*. Credit may be given for indicating how you have tested your function.

[*16 marks*]

(b) Write a second function `g :: [Int] -> String -> Int` that behaves like `f`, this time using *basic functions* and *recursion*, but *not list comprehension* or *library functions*. Credit may be given for indicating how you have tested your function. [*16 marks*]

2. (a) Write a function `p :: String -> Int` that computes the sum of the even digits appearing in a string. For example:

```
p "Functional"   = 0
p "3.157/3 > 19" = 0
p "42+12=54"     = 12
p "1234567890"   = 20
```

Use *basic functions*, *list comprehension*, and *library functions*, but *not recursion*. Credit may be given for indicating how you have tested your function. [*12 marks*]

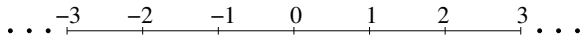
(b) Write a second function `q :: String -> Int` that behaves like `p`, this time using *basic functions* and *recursion*, but *not list comprehension* or *library functions*. Credit may be given for indicating how you have tested your function. [*12 marks*]

(c) Write a third function `r :: String -> Int` that also behaves like `p`, this time using one or more of the following higher-order library functions:

```
map     :: (a -> b) -> [a] -> [b]
filter  :: (a -> Bool) -> [a] -> [a]
foldr   :: (a -> b -> b) -> b -> [a] -> b
```

You may use basic functions but do *not* use *recursion*, *list comprehension* or *library functions* other than these three. Credit may be given for indicating how you have tested your function. [*12 marks*]

3. This question concerns simple commands for moving a robot back and forth along an infinite line like this:



The following declarations define the commands:

```
data Move =
     Go Int            -- move the given distance in the current direction
   | Turn              -- reverse direction
   | Dance             -- dance in place, without changing direction

data Command =
     Nil               -- do nothing
   | Command :#: Move  -- do a command followed by a move
```

Before and after each move, the robot is in some "state" — in a position on the line, and facing left or right:

```
type Position = Int
data Direction = L | R
type State = (Position, Direction)
```

The above declarations are provided in the template file, together with code to print values of type `Move`, `Command` and `State` and to compare them for equality, along with code that enables QuickCheck to generate arbitrary values of type `Move`, `Command` and `State`, to aid testing.

(a) Write a function `state :: Move -> State -> State` that, given a move and the current state of the robot, returns the state of the robot following the move. For example:

```
state (Go 3) (0,R) = (3,R)
state (Go 3) (0,L) = (-3,L)
state Turn (-2,L)  = (-2,R)
state Dance (4,R)  = (4,R)
```

Credit may be given for indicating how you have tested your function. [*8 marks*]

(b) When a robot moves according to the directions given in a command, it goes through a sequence of states, starting with its original state and ending with its final state. Write a function `trace :: Command -> State -> [State]` that computes this sequence of states. For example:

QUESTION CONTINUES ON NEXT PAGE

```
trace (Nil) (3,R) = [(3,R)]
trace (Nil :#: Go 3 :#: Turn :#: Go 4) (0,L)
                  = [(0,L),(-3,L),(-3,R),(1,R)]
trace (Nil :#: Go 3 :#: Turn :#: Dance :#: Turn) (0,R)
                  = [(0,R),(3,R),(3,L),(3,L),(3,R)]
trace (Nil :#: Go 3 :#: Turn :#: Go 2 :#: Go 1 :#: Turn :#: Go 4) (4,L)
                  = [(4,L),(1,L),(1,R),(3,R),(4,R),(4,L),(0,L)]
```

Credit may be given for indicating how you have tested your function. [*12 marks*]

(c) Each time the robot reaches a position that is further from its starting position than it has already visited — irrespective of the direction it is facing — it does a dance. Write a function `dancify :: Command -> Command` that takes a command and inserts `Dance` after each move (except immediately after a `Dance` move) that brings the robot to such a position. For example:

```
dancify Nil = Nil
dancify (Nil :#: Go 3 :#: Turn :#: Go 4)
            = Nil :#: Go 3 :#: Dance :#: Turn :#: Go 4
dancify (Nil :#: Go 3 :#: Turn :#: Dance :#: Turn)
            = Nil :#: Go 3 :#: Dance :#: Turn :#: Dance :#: Turn
dancify (Nil :#: Go 3 :#: Turn :#: Go 2 :#: Go 1 :#: Turn :#: Go 4)
            = Nil :#: Go 3 :#: Dance :#: Turn :#: Go 2 :#: Go 1
                                     :#: Turn :#: Go 4 :#: Dance
```

(Hint: The correct placement of the `Dance` moves doesn't depend on the robot's original state.) Credit may be given for indicating how you have tested your function. [*12 marks*]