

Name: _____

Matriculation Number: _____

Exercise	Points	Score
Types	12	
Evaluation	11	
Programming	15	
I/O and Modules	7	
Σ	45	

- You have 90 minutes time to solve the exercises.
- The exam consists of 4 exercises, for a total of 45 points (so there is 1 point per 2 minutes).
- The available points per exercise are written in the margin.
- Don't remove the staple (Heftklammer) from the exam.
- Don't write your solution in red color.

Exercise 1: Types

Consider the following Haskell code:

```
data Type a = Empty | Node a Int (Type a) deriving Eq
```

```
c = Node
```

```
d = \ x -> Node x x Empty
```

```
f x y z = if x == Empty then y else z
```

```
g x = if x > Empty then "Hello" else replicate 10 '!'
```

In each multiply choice question, exactly one statement is correct. Marking the correct statement is worth 3 points, giving no answer counts 1 point, and marking multiple or the wrong statement results in 0 points.

(a) The most general type of c is: (3)

- Type a -> a -> Int -> Type a -> Type a
- a -> Int -> Type a -> Type a
- Eq a => a -> Int -> Type a -> Type a
- Eq a => a -> Int -> Type a
- c is not type-correct.

(b) The most general type of d is: (3)

- a -> Type a
- Eq a => a -> Type a
- a -> Type (a,a)
- Int -> Type Int
- d is not type-correct.

(c) The most general type of f is (3)

- Eq a => Type a -> b -> b -> b
- Type a -> b -> b -> b
- (Eq a, Eq b) => Type a -> b -> b -> b
- Eq a => Type a -> a -> a -> a
- f is not type-correct.

(d) The most general type of g is (3)

- Type String -> String
- Ord a => Type a -> String
- Eq a => Type a -> String
- Type a -> String
- g is not type-correct.

Exercise 2: Evaluation

Consider the following Haskell code:

```
drop_last_A, drop_last_B, drop_last_C, drop_last_D, drop_last_E :: [a] -> [a]
drop_last_A xs = take (length xs - 1) xs
drop_last_B = drop 1 . reverse
drop_last_C = reverse . tail . reverse
drop_last_D xs = map fst (zip xs (tail xs))
drop_last_E xs = [ xs !! j | i <- [1 .. length xs], let j = i - 1 ]
```

- (a) Assume the input is a non-empty finite list $[x_1, \dots, x_n]$. Then most of the `drop_last_X`-functions return the list $[x_1, \dots, x_{n-1}]$. Write down all `drop_last_X`-functions that return a *different list* and also give the result of these functions. (3)

Solution:

`drop_last_B` results in $[x_{n-1}, \dots, x_1]$ and `drop_last_E` results in $[x_1, \dots, x_n]$.

- (b) Next we consider the empty list as input. Write down the result of `drop_last_X []` for $X = B, C, E$ and provide a step by step evaluation of `drop_last_D []`. (5)

As a reminder, here are the definitions of `zip` and `tail`.

```
tail (_ : xs)      = xs
tail []           = error "empty list"
zip []            = []
zip _             = []
zip _ []         = []
zip (x : xs) (y : ys) = (x,y) : zip xs ys
```

Solution:

```
drop_last_B [] = []
drop_last_C [] = error "empty list"
drop_last_D [] = map fst (zip [] (tail [])) = map fst [] = []
drop_last_E [] = []
```

- (c) Now assume the input is an infinite list. Write down all `drop_last_X`-functions which satisfy that `drop_last_X [0..]` evaluates to `[0..]`. (3)

Solution:

Only `drop_last_D` satisfies the property. All other versions do not terminate while computing the reverse or the length of the infinite list.

Exercise 3: Programming

Consider a function `find` which given a key k and a list of key-value pairs, returns v if (k, v) is the *first entry* in the list with key k , or nothing if no such pair exists.

Examples:

- `find 5 [(3, "a"), (5, "b"), (5, "c"), (2, "g")] = Just "b"`
- `find 'c' [('a',1), ('z',26)] = Nothing`

- (a) Give a suitable type-definition of `find`. In particular, the examples above should be type-correct, and one should be able to implement `find` with your type. (2)

Solution:

```
find :: Eq a => a -> [(a,b)] -> Maybe b
```

- (b) Provide a *recursive definition* of `find` that does not use any library functions on lists, except for the list constructors. (3)

Solution:

```
find k [] = Nothing
find k ((key, val) : xs)
  | k == key = Just val
  | otherwise = find k xs
```

- (c) Provide a *non-recursive definition* of `find` that is based on *list-comprehensions*. (3)

Solution:

```
find k xs = case [ val | (key, val) <- xs, key == k] of
  [] -> Nothing
  (v : _) -> Just v
```

- (d) Provide a *non-recursive definition* of `find` that is based on `foldr`. (3)

Solution:

```
find k = foldr ( \ (key,val) res -> if key == k then Just val else res) Nothing
```

- (e) Write a function `bad_item :: [(String,String)] -> Maybe String` which returns an item that is rated poorly, if such an item exists. (4)
- The input list of rated items is always given in pairs of the form (item, rating), e.g., as in `[("coffee", "medium"), ("lemonade", "poor"), ("tea", "good"), ...]`.
 - If there are many poorly rated items, return the one which is *last in alphabetical order*. You may assume that all item names are provided in lower-case letters.
 - In the definition you may use `find` from above and standard list functions like `sort`, `map`, `reverse`, ..., but neither list-comprehensions nor `filter`.

Solution:

```
bad_item = find "poor" . map ( \ (i,r) -> (r,i) ) . reverse . sort
```

Exercise 4: I/O and Modules

Consider the following Haskell module.

```
module Area where
```

```
area :: Double -> Double
area r = pi * r * r
```

Write a Haskell program (outside of the module `Area`) which asks the user for a radius and then prints the area of the circle with that radius, *precisely* as formatted in the two lines between the `prompt>...-lines`.

```
prompt> ./my_program    # start program
Enter radius: 6.72
Area of circle with radius 6.72 is 141.8692976878693.
prompt>                # program has ended
```

- The program should be compilable via `ghc --make`.
- The user made exactly one input, namely the first occurrence of the number 6.72.
- For the calculation, the method `area` has to be invoked.
- You can ignore buffering problems.

Solution:

```
import Area
```

```
main = do
  putStr "Enter radius: "
  str <- getLine
  let r = (read str :: Double)
      let res = area r
  putStrLn $ "Area of circle with radius " ++ str ++ " is " ++ show res ++ "."
```