i Read and follow these instructions carefully to increase your chance of getting good marks.

This is an open book exam. You may use any material that was written prior to the start of the exam, but you must not communicate with anybody else about the exam while it is ongoing (i.e., before 14:00).

Send any questions during the exam by email to <u>johannes.borgstrom@it.uu.se</u>. Answers that are relevant for all students will appear in <u>Piazza</u>.

This exam contains several kinds of questions. Among them are multiple-choice questions, where only a single answer is correct (unless otherwise stated). These questions are followed by a motivation question, where you must give a sufficient motivation to why your chosen answer is the correct one. The multiple-choice question and its motivation count for one point each.

You can at most obtain 48 points on this exam. The preliminary grade limits are: 24p for grade 3, 34p for grade 4, 44p for grade 5.

Read the questions carefully, and watch out for negations (not, except, et c.).

Good luck!

- 1 What is the postorder traversal of the expression tree corresponding to ((3 * 1) + (4 (11 / 5))) + 3? Välj ett alternativ:
 - 3 1 * 4 11 5 / + 3 +
 - 0 3 1 * 4 + 11 5 / 3 +
 - No other alternative is correct.
 - + + * 3 1 4 / 11 5 3
 - 0 + 3 + / 5 11 4 * 1 3

Motivate your answer to the previous question. Skriv in ditt svar här	
	Totalpoäng:
Consider the following parts of a data-structure invariant for a key:	general tree where each node has a
 If the current node has k children, then they each have Each child of the current node (except for the leftmost) of the child to its left. The key in the current node is less than or equal to any 	has a key that is greater than the ke
Which combination of these corresponds to an invariant for tree?	an implementation of a binomial
Välj ett alternativ:	
○ 1 and 3 hold at every node.	
1, 2, and 3 hold at every node.	
1 holds at every node.	
○ 1 holds at the root.	
○ 1 and 2 hold at every node.	
	Totalpoäng:
	. estanp esting.
Motivate your answer to the previous question. Skriv in ditt svar här	
	Totalpoäng:

5	How many nodes are there at least in a red-black tree of black height 3? Välj ett alternativ:	
	4	
	None of the above.	
	O 7	
	3	
	31	
		Totalpoäng: 1
6	Motivate your answer to the previous question. Skriv in ditt svar här	
		Totalpoäng: 1
7	The worst-case time complexity of insertion in a red-black tree of height h is Välj ett alternativ:	
	O(2^h)	
	O(h^2)	
	O(h)	
	O(1)	
	O(log h)	
		Totalpoäng: 1

		Totalpoäng: 1
10	Motivate your answer to the previous question. Skriv in ditt svar här	
40	Mativata value analyses to the province quanties	Totalpoäng: 1
	The implementation of foo can use overloaded definitions of the function signum.	
	The call 'foo []' must return the empty list.	
	of foo is a polymorphic function.	
	○ The implementation of foo can use overloaded definitions of the function ==.	
	The type a must belong to the typeclass Ord.	
9	Consider the following declaration, and assume that the function foo is pure. foo :: Ord a => [a] -> [a] Which statement below is false? Välj ett alternativ:	
		Totalpoäng: 1
8	Motivate your answer to the previous question. Skriv in ditt svar här	

11	Assume that a Table (as seen in Assignment 3) contains the entries	
	1 -> "PKD, 2 -> "2021".	
	What are the contents of the table if we perform the following operations?	
	exists 3, insert 1 "Easter", lookup 1, insert 2 "Break", delete 2	
	Välj ett alternativ:	
	○ 1 -> "Easter"	
	A runtime exception is thrown.	
	○ 1 -> "PKD", 1 -> "Easter", 2 -> "2021"	
	○ 1 -> "Easter", 2 -> "2021"	
	○ 1 -> "PKD", 2 -> "2021"	
		Totalpoäng: 1
12	Motivate your answer to the previous question. Skriv in ditt svar här	
		Totalpoäng: 1

11

13 Consider the following fragment of code

When running main which of the following statements are true?

Välj ett alternativ:

If you change t	he value of se	ed then it is	s possible to	get the me	essage The	numbers	are
different.							

- When main is run it always prints The numbers are the same.
- When main is run it always prints The numbers are the different.
- When main is run sometimes it prints The numbers are the same and sometims it prints The numbers are different.

Totalpoäng: 1

14

Motivate your answer to the previous question.

Skriv in ditt svar här

	 Arrays when used inside the IO Monad provide constant time access to 	elements.
	Arrays can be used either in pure code or within the IO Monad, but when they are implemented as a binary search tree.	n used in pure code
	Arrays can be used in pure code and provide constant time access to e	lements.
	 Arrays cannot be used in pure code, and are implemented as a imperation 	ve red black trees.
		Totalpoäng: ´
		rotalpoarig.
16	Motivate your answer to the previous question. Skriv in ditt svar här	
		Totalpoäng: 1
17	Consider a hash table with 20 slots that uses chaining to resolve conflicts. W the <i>maximal</i> possible chain length (worst case) of a single slot when the load Välj ett alternativ:	
	30	
	1	
	O 64	
	O None of the above the load factor can never be larger than 1	
	O 20	

15 In the standard library for Haskell there is an array data type with type <code>IOArray Int a</code>. One of

18	Motivate your answer to the previous question. Skriv in ditt svar här
	Totalpoäng: 1
19	Consider a hash table with 10 slots using the hash function h(k) = k mod 10 with linear probing, and and the following 10 integers After insert the following 10 items into the hash table 1 11 3 33 8 9 7 88 99 100 Which item will be in slot 5 Välj ett alternativ:
	O 88
	O 11
	O 1
	Nothing
	Totalpoäng: 1
	· stamp sanig.
20	Motivate your answer to the previous question. Skriv in ditt svar här
	Totalpoäng: 1

	A B B C, H C D F G G B H I	
	Nodes not listed have no outgoing edges. Which of the following options is <i>not</i> a topological sort of the graph Välj ett alternativ:	
	O E J F G A B C H I D	
	○ E J A B F G H C D I	
	○ F G A B H I C D E J	
	○ A F G B C D J E H I	
		Totalpoäng: 1
22	Motivate your answer to the previous question. Skriv in ditt svar här	
		Totalpoäng: 1

21 Given a graph with nodes A,B,C,D,E,F,G,H,I,J and directed edges

	A B C B A D C A D D B C E F E D G F G D G E F which of the following is not a breadth first search (BFS) order.	
	Välj ett alternativ:	
	ODBCEFAG	
	○ D E F B C A G	
	OABCDEFG	
	○ DBACEFG	
		Totalpoäng: 1
24	Motivate your answer to the previous question. Skriv in ditt svar här	
		Totalpoäng: 1

23 Given a graph with nodes A,B,C,D,E,F,G and (non directed) edges

				Totalpo	oär
s it always	path from the roof true that any node answer, and a pre	e to the left of th	e path is less	e on the path?	

25 Recall the definition of arithmetic expressions over integers (with plus and minus only):

data Expr = Lit Integer | Add Expr Expr | Sub Expr Expr deriving (Eq, Show)

1			
			Totalpoäng

29 Consider the following function. The function is to return the maximum element in non-empty set. If the list is empty the function returns 0.

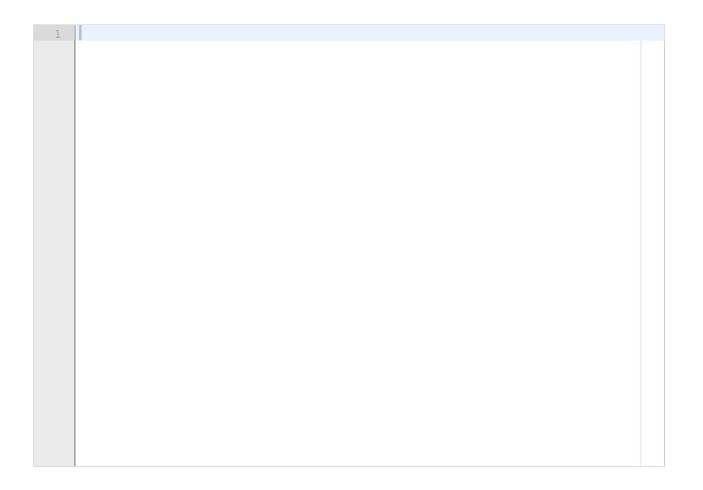
```
maxelem :: [Int] -> Int
maxelem [] = 0
maxelem [x] = x
maxelem (x:xs) =
  let smaller = maxelem [a | a <- xs, a < x]
    bigger = maxelem [a | a <- xs, a > x]
  in if smaller < bigger then bigger else smaller</pre>
```

The function is not correct. Your job is to work out why it is not correct and then:

- Write 3 test cases that show when the function is not performing correctly.
- Provide a corrected version of the above function.

You should make it clear with comments were the test cases are. If possible then you should use the HUnit syntax.

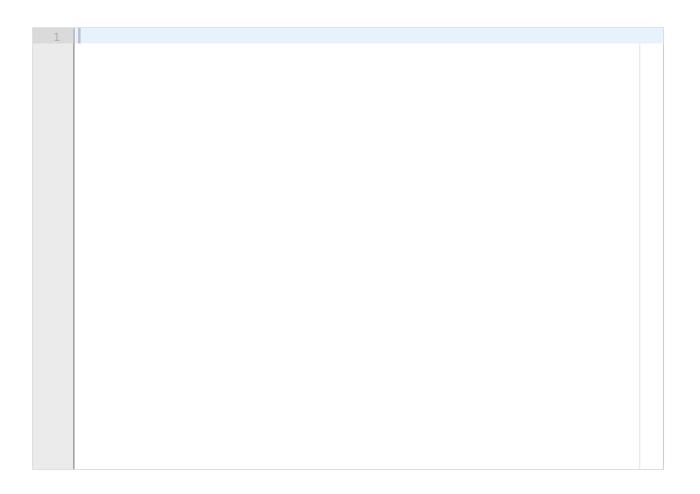
Skriv in ditt svar här



30 Consider the following pieace of code:

Write an equivlent piece of code using the do notation. You must also explain why your code is equivelent to the above fragement. You can put your explanations as comments in the code.

Skriv in ditt svar här



31	Consider the following graph on the nodes A,B,C,D,E,F with directed edges
	A B B A C C D E D F E F
	List all the strongly connected components of the graph. Skriv in ditt svar här
	Then apply (Kosaraju) algorithm to compute strongly connected components from the slides. You should explain each step in the algorithm.
	Skriv in ditt svar här
	Totalpoäng: 4