## Computer Science Qualifying Exam AM Session

Practice Exam

Computer Science Department, Reed College

You have two hours to complete this portion of the exam. There are ve problems on 9 pages. Write your answers on the blank portions of each sheet, and on extra blank pages if needed. Make sure that your name and the problem number of your answer appear clearly on each sheet.

Write your code for the height function here.

AM3. [12 points] Below is the Python de nition for a MessageBoard

Write your code for the Rentable Message Board class on this page.

- **AM4.** [12 points] Give the asymptotic worst-case running time for each of the following functions. Write this using Theta notation, fully simplified. (For example,  $(n^2)$  or  $(n \log n)$ .) For each function, the input is a list and we do not the size of the input list to be n.
  - (a) [3 points]

    def functionA(list):
     a = 0
     for b in list:
     for c in list:
     if b + c >= 0:
     a = a + 1
     else:
     a = a 1
     return a
  - (b) [3 points]
     def functionB(list):
     g = 0
     for h in list:
     g = g + h
     i = 1
     j = 1
     while i < len(list):
     j = j \* list[i]
     i = i \* 2
     return g j</pre>
  - (c) [3 points]

AM5. [12 points] Below are two Python classes that we use to de ne a doubly-linked list:

```
class Node:
    def __init__(self, value):
        self. value = value
        self.next = None
        self.prev = None
class LinkedList:
    def __i ni t__(sel f):
        self.first = None
    def prepend(self, value):
        newNode = Node(value)
        newNode.next = self.first
        if self.first is not None:
            self.first.prev = newNode
        self.first = newNode
    def output(self):
        current = self.first
        while current is not None:
            print(current. value)
            current = current.next
```

In the code's use below, we build a linked list with 712 stored both at positions 0 and 1, 8 stored at position 2, 18 stored at position 3, and 37 stored at position 4.

```
>>> II = LinkedList()
>>> II.prepend(37)
>>> II.prepend(18)
>>> II.prepend(8)
>>> II.prepend(712)
>>> II.prepend(712)
>>> II.prepend(712)
>>> II.output()
712
712
8
18
37
```

Write a method reverse that modi es the list so that the values are in the opposite order they started in. For full credit, you should not modify the value of a to self a to se

Write your code for the reverse function on this page.

### Computer Science Qualifying Exam PM Session

Practice Exam

Computer Science Department, Reed College

You have two hours to complete this portion of the exam. There are ve problems on 7 pages. Write your answers on the blank portions of each sheet, and on extra blank pages if needed. Make sure that your name and the problem number of your answer appear clearly on each sheet.

Complete each problem to the best of your ability. When the problem requests that you devise a program or a fragment of a program's code in a certain programming language you should do your best to produce working code in that language { syntactically correct and runnable { that meets the speci cation of the problem.

When you are providing code answers, if you you forget some aspect of the language, you can communicate your intended meaning for partial credit. As an example, if you forget how logical conjunction works in

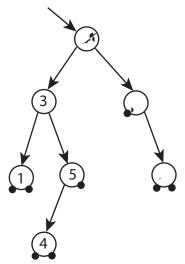
PM1. [12 points] Write a C++ function chooseBit. This is a function that takes as arguments an unsigned 8-bit integer value (of type uint8\_t) and an integer between 0 and 7 and returns the bit at the specied position in the 8-bit value. The return value should be either a 1 or a 0. For example, if the bits of the

**PM2.** [12 points] Write a Python function greater. This is a function that returns another function. It should take an integer as its argument. It should return a function that takes an integer argument and returns whether or not the argument is greater than the original.

```
>>> x = greater(12)
>>> x(20)
True
```

**PM4.** [12 points] The C++ code for binary search tree node is given below left and a picture of a binary search tree is shown to the right:

```
struct node {
   uint32_t data;
   struct node* parent;
   struct node* left_child;
   struct node* right_child;
};
```



Write a C++ fuction i nsert for inserting a value into the binary search tree. The function should take as an argument a pointer to the root node of the tree and a value to add into the tree. It should create a new node containing the value and add it into the input tree as a leaf in the appropriate location according to the binary search tree property. For this problem, we will make two assumptions. The rst is that the input tree will never be empty. The second is that the tree is not allowed to contain duplicates. Preventing duplicates means that if the value already exists in the tree, the function should not create a new node and should return false. If the value does not exist, a new node should be created and the function should return true.

PM5. [12 points] Using only the MIPS32 instructions on the guide in the bottom half of this page, write MIPS assembly code that determines whether a given value can be found in the elements pointed to by an array of pointers. Remember that pointers in MIPS are 32 bits.

Preconditions: Your code can assume that

- Elements in the array are valid 32-bit pointers that each point to a 32 bit unsigned integer.
- Register \$a0 gives the value being searched for (a 32 bit unsigned integer).
- Register \$a1 gives the (word-aligned) address of the rst element in the array.
- Register \$a2 gives the length of the array.

#### Postconditions: Upon completion

• Register \$v0 contains the index of the rst element that points to a value matching the input, or -1 otherwise.

Having completed its work, your code should jump to a label done. You can use any of the registers \$t0 through \$t9 to perform your calculations.

Please write your MIPS code on the next page, using only instructions from those listed below.

#### MIPS32 Assembly Guide

Ii \$RD, value loads an immediate value into a register Iw \$RD, (\$RS) loads a register from memory at an address speci ed in a register sw \$RS, (\$RD) stores a register into memory at an address speci ed in a register addu \$RD, \$RS1, \$RS2 add two registers, storing the sum in another subu \$RD, \$RS1, \$RS2 subtract two registers, storing the di erence in another addi u \$RD, \$RS1, value add a value to a register, storing the sum in another move \$RD, \$RS copy a register's value to another i label jump to a labeled line blt \$RS1, \$RS2, label jump to a labeled line if one register's value is less than another bltz \$RS, label jump to a labeled line if a register's value is less than zero other conditions than I t gt, le, ge, eq, ne sII \$RD, \$RS, value shifts the value in the source register value bits left sIIv \$RD, \$RS1, \$RS2 shifts the value in a source register another source register bits left Write your MIPS code here:

# Computer Science Qualifying Exam Discrete Mathematics (DM) Session

10am - 12pm, March 5, 2023 Computer Science Department, Reed College

You have two hours to complete this portion of the exam. There are four problems on 6 pages. Write your answers on the blank portions of each sheet, and on extra blank pages if needed. Make sure that your

**DM1.** [4 points each, 24 total] Below are several short questions. Write your answer clearly in the box provided. We have provided extra space if you need to do work, but there is no partial credit for these problems | if you know the answer, there's no need to write out a long explanation. When it asks for a number, please give a speci c number. (For example, don't write \5!", write \120". You have a

(e)	How many nu	imbers in f1;2	2;3;:::;1999 <i>g</i>	are integer mult	tiples of 3 or 4	but not 12?

**DM2**. [12 points] Prove that for any integers a and b we have

$$\gcd(a^5;b^5)=\gcd(a;b)^5$$

where gcd denotes the greatest common divisor. (Hint: One good solution involves prime factorization.)

**DM3**. [12 points] Let p be a prime number greater than 5. Show that  $p^2$  1 must be divisible by 24. (Hint: Consider the values of  $p^2$  mod 3 and mod 8.)

**DM4.** [12 points] Let S = f2;3;5;7;11;13;17;19g be the set of prime numbers less than 20. For a subset A S, de ne the sum of S to be  $sum(A) := {}_{k2A}k$ . Prove that there are four nonempty subsets of S with the same sum. (Hint: what is the largest possible sum(A) for A S? What is the minimum sum(A)?)