

CSc 372, Spring 1996

Mid-term Examination Solution Key

Problem 1 (6 points):

State a definition for the term "programming language".

In the slides, a programming language is said to be "a notation for the description of computation".

Name a language element or capability one would almost certainly find in a language that supports imperative programming.

Ideal answers included "a looping construct" and "the ability to change values via assignment".

Name a language element or capability one would almost certainly find in a language that supports functional programming.

Ideal answers included "recursion", "functions", and "use of functions as values".

Problem 2 (4 points):

Write ML expressions having the following types:

```
int * string list
  (1, ["x"])
int * (int * (int * int) list)
  (1, (1, [(1,1)]))
```

Define ML functions named `f` and `g` having the following types. The functions need not perform any meaningful computation. You may define additional functions to help produce the desired types.

```
f: (int -> int) * int -> bool
  fun g(1) = 1
  fun f(g, 1) = g(1) = 1
g: int -> int -> int list
  fun f 1 2 = [1, 2]
```

Problem 3 (6 points):

Consider the following ML function definitions:

```
fun h(x::xs) = x = 2
fun f(a,b,g) = h(g(a^"x")::b)
```

For each of the following identifiers, what type would ML infer, given the above definitions for `h` and `f`.

```
f?   string * int list * (string -> int) -> bool
g?   string -> int
h?   int list -> bool
a?   string
b?   int list
x?   int
```

Problem 4 (3 points):

The following ML function definition is an example of using an exception.

```
exception NotOne;
fun f(n) = if n <> 1 then (raise NotOne) else n
```

Rewrite `f` to make better use of ML's pattern matching facilities.

```
exception NotOne;
fun f(1) = 1
  | f(n) = raise NotOne
```

Problem 5 (3 points):

What is meant by the ML warning "non-exhaustive match"?

There is a type-compatible tuple that is not matched by any of the patterns defining a function.

What is one possible implication of the warning?

A match exception may be encountered when the function is executed.

Write an ML function that would produce that warning.

```
fun f(1) = 1
```

Problem 6 (4 points):

Consider this fragment of a function definition:

```
fun f(x, y, z :: zs) = ...
```

What values would be bound to `x`, `y`, `z`, and `zs` for this call, assuming that the body of the function `f` is compatible with the given values?

```
f([1] :: [], (2, [3]), [[4, 5, 6]])
```

```
x?  [[1]]
```

```
y?  (2, [3])
```

```
z?  [4, 5, 6]
```

```
zs?  []
```

Specify a function body for `f` that for the above argument tuple would produce the value 21. That is, instead of the `"..."` shown above, complete the function definition. (Hint: Don't make this too hard!)

```
fun (x, y, z :: xs) = 21
```

What is the type of `f`, given the function body you specified in the previous part of this problem?

```
'a * 'b * 'c list -> int
```

Problem 7 (5 points):

Write a function named `length` of type `int list -> int` that calculates the length of a list of integers. ...

```
fun length([]) = 0
  | length(_:int)::xs = 1 + length(xs);
```

Many persons defined a `length` function with type `'a list -> int`. Others, in trying to force the `int list` type ended up with a function that summed the elements in the list instead of counting them.

Problem 8 (8 points):

Write an ML function `avgLen` of type `'a list list -> real` that computes the average number of elements in a list of lists. For example, if a list `L` contained an empty list and a list with five elements, `avgLen(L)` would return 2.5. If the list is empty, raise the exception `EmptyList`.

```
fun avgLen(L) =
  let
    fun sum([]) = 0
      | sum(x::xs) = x + sum(xs)
    val lens = map length L
  in
    if length(L) = 0 then raise EmptyList
    else real(sum(lens)) / real(length(L))
  end
```

This problem was not intended to be difficult but in fact it had a relatively low success rate. The key observation is that the essence of the problem is calculate the average of a list of integers.

Problem 9 (8 points):

Write an ML function `F_L_eq` of type `'a list -> bool` that returns `true` if the first element in a list is equal to the last element, and returns `false` otherwise. If called with an empty list, `F_L_eq` should return `false`.

```
fun F_L_eq([]) = false
  | F_L_eq([x]) = true
  | F_L_eq(x::xs) =
    let
      fun last([x]) = x
        | last(_::xs) = last(xs)
    in
      x = last(xs)
    end
```

Problem 10 (4 points) (*)

Write an ML function `f` (`FL, VL`) that takes a list of functions (`FL`) and a list of values (`VL`) and produces a list of lists wherein the first list contains the results of applying each function in `FL` to the first element in `VL`, and so forth, such that the `N`th list contains the results of applying each function in `FL` to the `N`th element in `VL`.

```
fun f(FL, []) = []
  | f(FL, v::vs) =
    let
      fun apply_each([], x) = []
        | apply_each(f::fs, x) = f(x)::apply_each(fs, x)
    in
      apply_each(FL, v)::f(FL, vs)
    end
```

end

Problem 11 (3 points)

Lists in Icon and ML share a common syntax for literal specification of lists—the expression `[1, 2, 3]` specifies a simple list in both languages. But, ML places a constraint on lists that Icon does not—many lists that are valid in Icon are not valid in ML.

What is the constraint that ML places on lists that Icon does not?

Lists in ML must be homogeneous—all elements must be of the same type. Elements in an Icon list can be of differing types.

Give an example of a list that is valid in Icon, but not valid in ML.

```
[1, 1.0]
```

Problem 12 (2 points) (*)

Define ML functions named `f` and `g` having the following types. The functions need not perform any meaningful computation. You may define additional functions to help produce the desired types.

```
f: (string -> int) list -> int
    fun f(g::gs) = g("x") + 1;
g: string -> int -> real -> bool list
    fun g " " 1 2.0 = [true]
```

Another way:

```
fun g s i r = [s = "x", i = 1, r = 1.0];
```

Problem 13 (4 points)

Icon's `reverse(s)` built-in function produces a reversed copy of a string `s`. Write an Icon procedure `Reverse(s)` to do the same thing. Of course, `Reverse` may not use `reverse`.

```
procedure Reverse(s)
    r := ""
    every r := !s || r
    return r
end
```

Another way:

```
procedure Reverse(s)
    r := ""
```

```

        every i := 1 to *s do
            r := s[i] || r
        return r
    end

```

I had intended `Reverse` to be a trivial problem to serve as a warm-up for the Icon portion of the exam, but only a handful of persons produced a solution that would actually work.

A number of persons produced solutions that used list manipulation functions such as `push` and `pull` to manipulate strings, but in fact those functions don't work on strings. Despite that, such solutions typically received full credit.

Problem 14 (8 points)

Write an Icon procedure `Point(s)` that takes a string representation of a point in 2D cartesian space such as `"(10,20)"` and if the string is well-formed, returns the X and Y coordinates as integers in a list. If the string is not well-formed, `Point(s)` fails.

```

procedure Point(s)
    s ? {
        =" (" &
        x := tab(many(&digits)) &
        =", " &
        y := tab(many(&digits)) &
        =")" & pos(0) &
        return [integer(x), integer(y)]
    }
end

```

A number of persons tried to solve this with `split`, but if `split` was used you needed to use the three-argument form and examine each piece produced. Most of the `split`-based solutions would accept strings such as `",,2,,3,,"` or `"() () 2 () 3 ()"`, or worse.

Problem 15 (8 points)

Write an Icon program that reads standard input and produces a histogram of line lengths encountered.

```

procedure main()
    hist := table("")

    while line := read() do
        hist[*line] ||= "*"

    every pair := !sort(hist) do
        write(pair[1], "\t", pair[2])
end

```

Problem 16 (9 points):

Imagine a file with a format such as this:

```
02.sting
01.just te
10. this out
```

...

Write a program that reads such a file on standard input, assembles the lines in order based on the sequence numbers, and writes to standard output a sequence of fixed length lines. The full set of sequence numbers may be non-consecutive, as shown above, but there will be no duplicated sequence numbers.

```
procedure main(args)
  len := args[1] | 10

  lines := []

  while line := read() do
    put(lines, line)

  lines := sort(lines)
  out := ""
  every line := !lines do {
    out ||:= (line ? ( tab(upto('.')+1) & tab(0) ))
  }

  out ? {
    while write(move(len))
      write(tab(0))
  }
end
```

Problem 17 (3 points):

Write an Icon procedure `cons(x, y)` that approximates the ML operation `x :: y` as closely as possible. If the approximation is poor, explain the difficulty.

```
procedure cons(x, y)
  return [x] ||| y
end
```

It was also satisfactory to use a solution such as this:

```
procedure cons(x, y)
  return push(y, x)
end
```

if it was noted that the approximation was poor because list `y` is changed as a side-effect.

Problem 18 (3 points) (*):

Write a procedure `size(x)` that has the same result as `*x` for values of `x` that are a string, list, or table. You may not use the `*` operator in your solution.

```
procedure size(x)
  count := 0
  every !x & count += 1
  return count
end
```

Problem 19 (6 points) (*):

Write an Icon program to read standard input and print out the largest integer found in the input. ...

```
procedure main()
  while line := read() do {
    line ? while tab(upto(&digits)) do {
      val := tab(many(&digits))
      if /maxval | (val > maxval) then
        maxval := val
    }
  }

  write(\maxval|"No integers")
end
```

Several persons approached this problem with `split`, but it is necessary to split on `~&digits` rather than whitespace to achieve a correct solution.

Problem 20 (3 points) (*):

Icon has language elements to support imperative programming, but could Icon adequately support functional programming? Present an argument in support of your answer.

An argument can be made either way and therefore, answering either "yes" or "no" earned a point. A reasonable argument of any sort earned two more points.

I would argue that most of the functional solutions we studied could be implemented in Icon with a minimum of difficulty, aside from Icon lacking an equivalent to ML's pattern matching facility. (It is said that Icon supports pattern matching via string scanning, but that is a completely different facility that shares the same name.)

On the other hand, Icon has nothing like anonymous functions, composition, or currying and therefore Icon's handling of functions as values, a cornerstone of functional programming, falls short.

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Final Examination Solution Key

Problem 1 (10 points):

What is the difference between a class and an object?

An object is an instance of a class. In software, classes are used to create objects, specifying structure and behavior. In the real-world, classes are used to group objects.

What is the proper way to view the relationship between function members and data members in a C++ class?

Data members exist solely to support the operation of the function members. A class with no function members should have no data members.

Under what circumstances should a data member in a C++ class be public?

Never.

What is the difference between the class relationships of inheritance and containment?

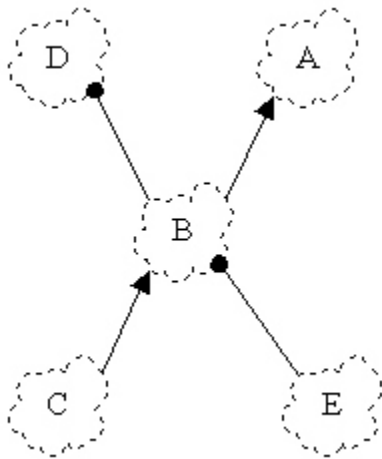
Containment is the "has-a" relationship; it should be used when instances of a class in some sense contain instances of another class. The containment might be physical or logical. Inheritance is the "is-a" relationship; it should be used when an instance of a class can be thought of as being an instance of another class.

As described by the instructor, what is the primary benefit of inheritance?

The ability to write code in terms of something general, such as a geometric shape, and then use that code with instances of derived classes that are specialized, such as circles and triangles.

Problem 2 (5 points):

Write a set of C++ class declarations that capture the relationships shown in this Booch Notation class diagram:



```
class A {};  
class E {};  
class B: public A {  
    E itsE;  
};  
class C: public B {};  
class D {  
    B itsB;  
};
```

Problem 3 (20 points):

```
#include <iostream.h>  
#include "string.h"  
  
class ReplStr {  
public:  
    ReplStr() {}  
    ReplStr(String s, int n) {  
        itsStr = s.Repl(n);  
    }  
    int Length() { return itsStr.Length(); }  
  
    String GetString() { return itsStr; }  
  
    int operator==(ReplStr rhs) {  
        return itsStr == rhs.itsStr;  
    }  
  
    int operator!=(ReplStr rhs) {  
        return !(this->GetString() == rhs.itsStr);  
    }  
  
    ReplStr operator+(ReplStr rhs)  
    {  
        String r = GetString() + rhs.GetString();  
  
        return ReplStr(r, 1);  
    }  
};
```

```

private:
    String itsStr;
};

ostream& operator<<(ostream& o, ReplStr s)
{
    o << s.GetString();
    return o;
}

```

- (5) Describe a pattern of usage for which your implementation would have poor performance characteristics and explain the difficulty. If you believe your implementation has uniformly good performance characteristics, make an argument to support that claim.

The choice to represent a `ReplStr` as a `String` makes for a simple implementation but could be very inefficient. If nothing else, construction of the `String` could be deferred until the first time `GetString` is called. (Note that length can be calculated given only the base and replication count.)

Problem 4 (5 points):

Fully implement classes `Bicycle`, `Tricycle`, and the function `CountWheels`.

```

class Cycle {
public:
    Cycle(char *owner) {
        itsOwner = new char[strlen(owner)+1];
        strcpy(itsOwner, owner);
    }

    virtual int GetNumWheels() = 0;
    char *GetOwner() { return itsOwner; }
private:
    char *itsOwner;
};

class Bicycle: public Cycle {
public:
    Bicycle(char *owner) : Cycle(owner) {}
    virtual int GetNumWheels() { return 2; }
};

class Tricycle: public Cycle {
public:
    Tricycle(char *owner) : Cycle(owner) {}
    virtual int GetNumWheels() { return 3; }
};

int CountWheels(Cycle *cycles[])

```

```

{
    int wheels = 0;

    for (Cycle **cp = cycles; *cp; cp++)
        wheels += (*cp)->GetNumWheels();

    return wheels;
}

```

Problem 5 (5 points):

Write a Prolog predicate `flip(L1, L2)` that if given a list such as `[a, b, c, d, e, f]` as `L1` it will instantiate `L2` to be the list `[b, a, d, c, f, e]`. That is, it flips the position of each element in a list on a pair-wise basis. `flip` should fail if given a list with an odd length.

```

flip([], []).

flip([X1, X2 | XS], [X2, X1 | NewXS]) :- flip(XS, NewXS).

```

Problem 6 (5 points):

State in your own words the relationship expressed by each of the rules of the `append` predicate:

```
append([], L, L).
```

The list `L` appended to the empty list is the list `L`.

```
append([X | L1], L2, [X | L3]) :- append(L1, L2, L3).
```

The list `L2` appended to the list having head `X` and tail `L1` is the list with head `X` and tail `L3` where `L3` is the result of appending `L2` to `L1`.

Problem 7 (5 points):

Write a Prolog predicate `trim(L, SL, NL)` that describes the relation that the list `NL` is the list `L` with the list `SL` removed if `SL` is a prefix or suffix of `L`. Note that if `SL` is both a prefix and a suffix, two alternatives should be generated.

```

trim(L, SL, NL) :- append(SL, NL, L).
trim(L, SL, NL) :- append(NL, SL, L).

```

Problem 8 (5 points):

Do EITHER part (8a) or part (8b), but not both. If you work on both, CLEARLY mark which solution you wish to have graded.

- (8a) Write a predicate `maxint/2` that if given a list of integers will find the largest element in the list. `maxint` should fail if given an empty list.

```
maxint([X],X).
```

```
maxint([X1,X2|XS], M) :-  
    X1 > X2, maxint([X1|XS], M).
```

```
maxint([X1,X2|XS], M) :- X1 =< X2, maxint([X2|XS], M).
```

- (8b) Write a predicate `sum_check/2` that determines if a given integer is the sum of a list of integers.

```
sum_check(0, []).  
sum_check(Sum, [H|T]) :-  
    sum_check(TSum, T), Sum is H + TSum.
```

Problem 9 (5 points):

Write a Prolog predicate `find_missing/3` that can be called with any two arguments instantiated and if the two supplied arguments are equal, the uninstantiated argument is instantiated to the value of the other two.

```
three_eq(X,X,X).
```

Problem 10 (5 points):

- (1) Write a Prolog query that expresses *Is there is a person who knows both Bob and Mary?*:

```
knows(X,bob), knows(X,mary).
```

- (2) Write a Prolog query that expresses *Does Mary know anyone who works on a different shift than she?*:

```
knows(mary,X), shift(mary,S), \+shift(X, S).
```

- (3) Define a new clause for `knows/2` that expresses *A person knows everyone who works on the same shift.*

```
knows(X,Y) :- shift(X,S), shift(Y,S), X \== Y.
```

- (4) Define a predicate `by_shift` that prints a list of employees by shift.

```
by_shift :- report, fail.  
  
report :- write('Day:'), nl, shift(day), nl.  
report :- write('Night: '), nl, shift(night), nl.  
  
shift(X) :- shift(P,X), write('  '), write(P).
```

Problem 11 (3 points):

Write an ML function `allsame(L)` of type `'a list -> bool` that returns true if all the elements in a list are equal and false otherwise. `allsame([])` should return false.

```
fun allsame([]) = false
  | allsame([x]) = true
  | allsame(x1::x2::xs) = x1 = x2 andalso allsame(x2::xs)
```

Problem 12 (2 points):

Consider this function definition:

```
fun f(x,g) = x::g(x-1)
```

What types would ML infer for:

```
f?   int * (int -> int list) -> int list
```

```
g?   int -> int list
```

```
x?   int
```

Problem 13 (5 points):

Write an Icon program `tac` to read a text file on standard input and print on standard output the lines of the file in reverse order—last line first; first line last.

```
procedure main()
  lines := []

  while push(lines, read())
  while write(get(lines))
end
```

Problem 14 (20 points):

If you don't know this by now, I doubt that telling you one more time will help...

Extra Credit Problems

(1 point) Andrew Koenig's paper, *An Anecdote About ML Type Inference*, describes an incident in which ML's type inferencing system produced a surprising result. What was that result?

It was detected that a program would not terminate.

(2 points) Name five programming languages that originated before 1980.

ML, Icon, C, C++, and Prolog

(2 points) In C, write a recursive version of the library function `strlen(char*)`. You may not use any library functions, or perform any assignment, augmented assignment, or increment/decrement operations. In other words, write `strlen` using a functional style.

```
int strlen(char *p)
{
    if (!*p)
        return 0;
    else
        return 1 + strlen(p + 1);
}
```

(1 point) Who was the person that first described the notion of partially evaluated functions, such as that provided with currying in ML?

Schonfinkel. (Curry came along later.)

(1 point) Name a popular operating system in which Prolog is utilized.

Windows NT

(5 points) Do a great job on question 14.

Did you?

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Mid-Term Examination Solutions

Problem 1: (2 points each; 4 points total)

State the type of each of the two following expressions, or if the expression is not valid, state why.

```
(1, 2, (1=2, 1+2), "x")
```

```
int * int * (bool * int) * string
```

```
[[], [1], [1, 2]]
```

```
int list list
```

Problem 2: (2 points each; 8 points total)

Consider this ML function definition:

```
fun f(a,b,c) = (b, a(b), c(a)) = ("x", 2, [1])
```

State the type that will be deduced for each of the following: (2 points each)

```
a: string -> int
```

```
b: string
```

```
c: (string -> int) -> int list
```

```
The type of the result produced by f: bool
```

Problem 3: (4 points)

Write a function `f` that has the type `int -> int -> int -> int -> bool`. You may use literals (constants) but you may not use any explicit type specifications such as `x:int`.

```
fun f a b c d = a + b + c + d = 1 (* A. Freshwater *)
```

```
- or -
```

```
fun f 1 2 3 4 = true
```

Problem 4: (12 points)

Write a function `ints_to_strs(L, c)` that for the `int list L` and the `string c` produces a list of strings where the i th element in the resulting list is a string composed of N replications of `c` where N is the i th element in the input list.

Most solutions took this form:

```

fun repl(s, 0) = ""
  | repl(s, n) = s ^ repl(s, n-1);

fun ints_to_strs([], _) = []
  | ints_to_strs(x::xs, s) = repl(s, x) :: ints_to_strs(xs, s)

```

Problem 5: (12 points)

Write a function `len(L)` of type `string list list -> int` that produces the total number of characters in all the strings in the lists contained in `L`. (12 points)

```

fun len(L) = size(reduce(op^, reduce(op@, L))) (* P. Holland *)

```

Problem 6: (10 points)

Write a function `pair(L)` that accepts an 'a list as an argument and produces a list of tuples containing consecutive pairs of elements from the list `L`.

```

exception OddLength;

fun pair([]) = []
  | pair([x]) = raise OddLength
  | pair(x1::x2::xs) = (x1,x2)::pair(xs)

```

Problems 7 and 8: (26 and 10 points, respectively)

```

class Food {
public:
    virtual int GetUnits() = 0;
};

class Burger: public Food {
public:
    int GetUnits() { return 25; }
};

class Fries: public Food {
public:
    int GetUnits() { return 15; }
};

```

```

class Eater {
public:
    Eater(int capacity)
        : itsMax(capacity), itsBurps(0), itsValue(0) {}

    void Eat(int units) {
        itsValue += units;
        while (itsValue >= itsMax) {
            cout << "burp!" << endl;
            itsBurps++;
            itsValue -= itsMax;
        }
    }

    void Eat(Food *fp) {
        Eat(fp->GetUnits());
    }

    int BurpCount() const { return itsBurps; }

private:
    int itsMax, itsBurps, itsValue;
};

ostream& operator<<(ostream& o, Eater& E)
{
    o << "Eater at " << &E << " has burped " << E.BurpCount()
      << " times" << endl;

    return o;
}

```

Problem 9: (2 points each; 14 points total)

Answer each of the following questions related to object-oriented programming in general and C++ in particular.

What is the difference between a class and an object?

An object is an instance of a class.

What is the purpose of a constructor?

To initialize an object.

What is the purpose of a destructor?

To reclaim resources acquired during the lifetime of the object.

If a class has no member functions, how many data members should it have?

"Zero" is a reasonable answer, but with proper rationale the answer "any number" is also acceptable.

Challenge or defend this statement: In C++, one possible reason to have a public data member is to avoid the overhead of calling a function to access that data.

Using an inline member function maintains encapsulation but without any performance penalty.

Challenge or defend this statement: The purpose of member functions is to provide well-controlled access to data members.

No, the purpose of member functions is to provide the required behavior for the class. Data members merely support member functions.

Describe a benefit provided by using inheritance.

Being able to treat an object as being something more general than it really is.

Optional Extra Credit Problems:

What is a practical reason to prefer pattern matching rather than using the `hd` and `tl` functions in SML? (2 points)

With pattern matching a non-exhaustive match can indicate a situation where a usage of `hd` could produce an exception. Pattern matching can also be argued for on the basis of efficiency and clarity.

Write the minimum amount of code necessary to compile and run this code: (4 points)

The intended response was `"class X {};"` but a number of persons observed that `"typedef char X;"` or `"#define X char"` was enough.

Could C++ be used effectively for functional programming? (5 points)

This could be argued successfully either way.

Write in C a version of `int strcmp(char *, char *)` that uses no assignment operators of any form, nor the `++` or `--` operators. Recall that `strcmp` returns 0 if the strings are equal and a non-zero value if the strings are not equal. (3 points)

```
int strcmp(char *a, char *b)
{
    if (*a == '\0' && *b == '\0') return 0;
    else if (*a == '\0' || *b == '\0') return 1;
    else if (*a == *b) return strcmp(a+1, b+1);
    else return 1;
}
```

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Final Examination Solutions

Problem 1 (12 points):

For each of ML, C++, Icon, and Prolog, cite three elements in the language that are unique to that language among this group of four.

ML: Type deduction, partial application of functions, no variables

C++: Supports an object oriented paradigm, type extensibility, templated functions.

Icon: Expression failure, string scanning, a compact but expressive set of built-in functions.

Prolog: Procedures (predicates) with multi-faceted behavior, the notion of unification, expressions represented as trees that are evaluated on demand.

Problem 2 (8 points):

Select one element from EACH set of three in the previous problem and describe a benefit it provides to the programmer.

ML: A partial application can be used to create a more specialized function from a more general function.

C++: Encapsulation of data in objects allows the data to change without requiring modification to code that uses those objects.

Icon: The set of built-in functions is compact enough that I'm personally able to write Icon programs of a significant size without needing to consult any reference material.

Prolog: The multi-faceted behavior of predicates allows one predicate to serve several purposes. For example, `member/2` can be used to test for membership, generate elements, and more.

Problem 3 (5 points):

Write a predicate `permute(L, P)` that for a list `L` of 1, 2, or 3 elements instantiates `P` to each permutation of the elements of `L`.

```
permute([A], [A]).
permute([A, B], [A, B]).
permute([A, B], [B, A]).
permute([A, B, C], [A, B, C]).
permute([A, B, C], [A, C, B]).
permute([A, B, C], [B, A, C]).
permute([A, B, C], [B, C, A]).
permute([A, B, C], [C, A, B]).
permute([A, B, C], [C, B, A]).
```

Problem 4 (3 points):

The instructor's implementation of `roman/2` used a series of facts of this form:

```
rdval('I',1).
rdval('V',5).
rdval('X',10).
etc.
```

Consider an attempt at an ML function to provide the same functionality as `rdval/2`:

```
fun rdval("I") = 1
  | rdval("V") = 5
  | rdval("X") = 10
  etc.
```

Without particular regard to usage in `roman/2`, is the ML function a good approximation of the `rdval/2` predicate?

The ML function provides only half the functionality of the predicate, which can also map from given decimal numbers to their Roman equivalent.

Problem 5 (7 points):

Write a predicate `sum_ints(L, Sum)` that produces a sum of the integers in list `L`. `L` might contain things other than integers, but they should be ignored.

```
sum_ints([], 0).
sum_ints([H|T], Sum) :- integer(H), sum_ints(T, TSum),
                        Sum is H+TSum, !.
sum_ints([_|T], Sum) :- sum_ints(T, TSum), Sum is TSum.
```

Problem 6 (6 points):

Write a predicate `assemble(L, Segments)` that describes the relationship that the list `L` can be assembled from two of the lists in `Segments`.

```
assemble(L, Segments) :- member(A, Segments), member(B, Segments),
                          append(A, B, L).
```

Problem 7 (10 points):

```
cfa([], _, []).
cfa([Amt|Amts], Coins, [Change|MoreChange]) :-
    make_change(Coins, Amt, Change, Left),
    cfa(Amts, Left, MoreChange).
```

Problem 8 (8 points):

Write an Icon procedure `extract(s, m, n)` that extracts a portion of a string that represents a hierarchical data structure. `m` is a major index and `n` is a minor index. Major sections of the string are delimited by slashes and are composed of minor sections separated by colons. Here is a sample string:

```
/a:b/apple:orange/10:2:4/xyz/
```

It has four major sections which in turn have two, two, three and one minor sections.

```
procedure extract(s, i, j)
    return split(split(s, '/') [i], ':') [j]
end
```

Problem 9 (6 points)

Write an Icon program that reads, on standard input, a list of words, one per line, and prints the words that contain the letters a, b, and c in that order. The letters need not be consecutive and there may be more than one occurrence of each.

```
procedure main()
    while line := read() do
        line ? {
            tab(upto('a')) & tab(upto('b')) & tab(upto('c')) &
            write(line)
        }
end
```

Problem 10 (6 points)

Write an Icon procedure `revby2(s)` that reverses the string on a character pair-wise basis and returns the resulting string. **NOTE: Your solution must use string scanning. In particular you may not use string subscripting, sectioning, or the * operator.**

```
procedure revby2(s)
    r := ""

    s ? {
        tab(0)
        while r || := move(-2)
            pos(1) | fail
    }

    return r
end
```

Problem 11 (7 points):

Write an Icon program that prints on standard output, one per line, each minute of the day in the form 12:22pm.

```
procedure main()
  every f("am")
  every f("pm")
end

procedure f(m)
  every write(right(12 | (1 to 11), 2, " "), ":",
    right(0 to 59, 2, "0"), m)
end
```

More concisely:

```
procedure main()
  every m := ("am"|"pm") &
    write(right(12 | (1 to 11), 2, " "), ":",
      right(0 to 59, 2, "0"), m)
end
```

Problem 12 (4 points):

Write an Icon program `rev` that reads a file redirected to standard input and writes out the lines in the file in reverse order—last line first, first line last.

```
procedure main()
  L := []
  while push(L, read())
  while write(pop(L))
end
```

Problem 13 (9 points):

Write an ML function `samesums(L)` of type `(int * int * int) list -> bool` that tests whether all the 3-tuples in `L` have the same sum.

```
fun sum3(a,b,c) = a+b+c:int

fun samesums([]) = true
  | samesums([t]) = true
  | samesums(t1::t2::ts) =
    sum3(t1) = sum3(t2) andalso samesums(t2::ts);
```


Problem 14 (9 points)

Write code for a C++ class named X that exhibits the following elements...

```
#include <iostream.h>

class X {
public:
    X(int a, int b) : itsSum(a+b) {}
    int f() { return itsSum; }
    void make5();
private:
    X() :itsSum(0) {}
    int itsSum;
};

void X::make5()
{
    X a, xs[3];
    X *p = new X();

    cout << a.f() + p->f() + xs[0].f() + xs[1].f() + xs[2].f()
        << endl;
}

ostream& operator<<(ostream& o, X& x)
{
    o << "an X at " << &x;
    return o;
}
```

EC 1 (5 points):

Name five programming languages that originated before 1985.

ML, C++, Icon, Prolog, and C.

EC 2 (5 points max):

For one point each, name a programming language and the person generally credited as being the designer of the language.

ML—Robin Milner et al.
C++—Barne Stroustrup
Icon—Ralph Griswold
Prolog—Alain Colmeraurer
Java—James Gosling

EC 3 (1 point):

What is the instructor's favorite programming language?

I guess that if I've got a favorite it would have to be Icon, but it really depends on the

situation. Any answer here was worth a point.

EC 4 (1 point):

Name a popular operating system in which Prolog plays a role in system configuration.

Windows NT

EC 5 (2 points)

Languages can be grouped according to various aspects of the language. Group the languages we studied according to their type checking philosophy.

One possible grouping is that type-checking is done at compile time in ML and C++, but at run time in Icon and Prolog.

EC 6 (3 points)

Write an Icon program that reads a list of words like that described in problem 12 and prints out the words that consist of solely of the hex digits a-f. Examples of such words: added, beef, dead, facade.

```
procedure main()
  while line := map(read()) do
    if *(line -- 'abcdef') = 0 then
      write(line)
  end
```

EC 7 (1 point)

Among ML, C++, Icon, and Prolog, which is your favorite?

Any answer here was worth a point.

EC 8 (2 points)

Of all that we covered, which one language feature did you find most interesting?

For me, it's probably ML's ability to support partial applications of functions.

EC 9 (5 points)

In the same style as problems 1 and 2, name three differences between Java and C++ and for any one of those differences explain the benefit provided to the programmer.

Automatic memory management, function bodies must appear in the class definition, and there can be no global functions or data.

EC 10 (2 points)

Why are static class members an essential element of Java?

Because there are no global functions or global data.

EC 11 (1 point)

What is the Prolog 1000?

A compilation of applications implemented in Prolog.

CSc 372, Spring 1997

Mid-term Examination Solutions

Problem 1: (1 points each; 4 points total)

State the *type* of each of the following expressions, or if the expression is not valid, state why. For example, the type of the expression `3+4` is `int`.

```
([1, 2], [3.0, 4.0])
```

```
int list * real list
```

```
(map size) (explode "abcd")
```

```
int list
```

```
("x", (2, "y"), ([3, "z"]))
```

```
Invalid: [3, "z"] attempts to form a heterogeneous list
```

```
(length, [size, length o explode])
```

```
('a list -> int) * (string -> int) list
```

Problem 2: (2 points)

Consider this ML function definition: `fun f(x) = [x 1, 2]` What type will be deduced for `f`?

```
(int -> int) -> int list
```

Problem 3: (1 point each; 5 points total)

Consider these two ML function definitions:

```
fun f(_) = 1
fun g(a,b,c) = if a = f(c) then b else [c,a]
```

State the type that will be deduced for each of the following:

```
a: int
```

```
b: int list
```

```
c: int
```

```
The return type of f: int
```

```
The return type of g: int list
```

Problem 4: (3 points)

Write a function `f` that has the type `int -> int list -> bool`.

```
fun f l [1] = true
```

Problem 5: (9 points)

Write a function `tossbig(L,N)` of type `string list * int -> string list` that produces a list consisting of the elements in `L` that have a size less than `N`.

```
fun tossbig([], _) = []
  | tossbig(s::ss, n) =
      if size(s) < n then s::tossbig(ss, n)
      else tossbig(ss, n)
```

Or, a non-recursive solution using `filter` from the slides:

```
fun tossbig([], _) = []
  | tossbig(L, n) = filter(fn(s) => size(s) < n, L)
```

Problem 6: (9 points)

Write a function `samesums` of type `(int * int) list -> bool` that produces true if adding the two elements of each tuple in turn produce the same sum.

```
fun samesums [] = true
  | samesums [_] = true
  | samesums ((a,b)::(c,d:int)::ts) =
      a+b = c+d andalso samesums((c,d)::ts)
```

Problem 7: (12 points)

Write a function `block(w,h)` of type `int * int -> unit` that prints a block of `x`'s having a width of `w` and height of `h`. You may assume that `w` and `h` are greater than or equal to 1. **Your solution must be NON-RECURSIVE in nature.**

When this problem was written, an answer like this was envisioned:

```
fun block(w,h) =
  let
    fun row _ =
        implode (map (fn(x) => "x") (m_to_n(1,w))) ^ "\n"
  in
    print(implode ((map row) (m_to_n(1,h))))
  end
```

However, some persons observed that the solution could be simplified with `repl`, from the second assignment:

```
fun block(w, h) = print(repl(repl("x", w) ^ "\n", h))
```

If I had considered that `repl` might be used, I would have specifically excluded it, but I

since I did not, I considered solutions using `repl` to be perfectly acceptable, even though that essentially side-stepped the purpose of the problem.

Problem 8: (6 points)

Write a function `c_block` of type `int -> int -> unit` that behaves like `block`, but that allows partial application. You may use `block` in your solution.

```
fun c_block w h = block(w,h)
```

Problem 9: (30 points)

In this problem you are to implement a C++ class that models a television set that has a list of favorite channels, each with a preferred volume. ...

```
class TV {
    ...
private:
    int itsFavs[84];
    int itsCurChan;
    int itsCurVol;
};

TV::TV()
: itsCurChan(2), itsCurVol(5)
{
    for (int i = 2; i < 84; i++)
        itsFavs[i] = -1;
}

int ckRange(int low, int high, int val)
{
    if (val < low || val > high)
        return 0;
    else
        return 1;
}

void TV::SetVol(int vol)
{
    if (!ckRange(0, 10, vol))
        return;

    itsCurVol = vol;
}

void TV::SetChan(int chan)
{
    if (!ckRange(2, 83, chan))
        return;

    itsCurChan = chan;
}

void TV::SetFav()
{
```

```

        itsFavs[itsCurChan] = itsCurVol;
    }

void TV::SetFav(int vol)
{
    if (!ckRange(0, 10, vol))
        return;

    itsFavs[itsCurChan] = vol;
}

void TV::NextFav()
{
    int i;
    for (i = itsCurChan+1; i <= 83; i++)
        if (itsFavs[i] != -1) {
            SetVol(itsFavs[i]);
            SetChan(i);
            return;
        }

    for (i = 2; i < itsCurChan; i++)
        if (itsFavs[i] != -1) {
            SetVol(itsFavs[i]);
            SetChan(i);
            return;
        }
}

void TV::Status()
{
    cout << "Channel is " << itsCurChan << ", volume is "
         << itsCurVol << endl;
}

```

Problem 10: (5 points)

With our `String` class in mind, overload the `%` operator so that an expression such as `s % c` produces an `int` that is the zero-based position of the first occurrence of the character `c` in the `String s`.

```

int operator%(const String& s, char c)
{
    char *p = strchr(s.GetPtr(), c);

    if (p == 0)
        return -1;
    else
        return p - s.GetPtr();
}

```

Problem 11: (2 points each; 6 points total)

Briefly answer each of the following questions related to object-oriented programming in general and C++ in particular.

(a) What is the difference between a class and an object?

An object is an instance of a class.

(b) As you know, the destructor for a class X is a method named $\sim X$. The rationale for this choice of name is that "destruction is the complement of construction". However, the instructor has contended on several occasions that the relationship between constructors and destructors is in fact somewhat asymmetrical. Describe that asymmetry.

The responsibility of a constructor is to initialize an object. The destructor's responsibility is to surrender resources acquired during the lifetime of the object.

(c) What is the key benefit provided by in-line functions in C++?

In-line functions provide access that is just as fast as directly referencing data members, but without loss of encapsulation.

Problem 12: (9 points)

In this problem you are to implement a class called `Ring` that is a subclass of the `Shape` class described in the slides.

```
class Ring: public Shape {
public:
    Ring(double inner, double outer)
        : itsInner(inner), itsOuter(outer) {}

    double Area() {
        return itsOuter.Area() - itsInner.Area();
    }

    double Perimeter() {
        return itsOuter.Perimeter();
    }

    void Print(ostream& o) {
        o << "Ring; area = " << Area() << ", perim = "
          << Perimeter() << endl;
    }

private:
    Circle itsInner, itsOuter;
};
```

No changes are required in `SumOfAreas` or `Biggest`.

CSc 372, Spring 1997

Final Examination Solutions

Problem 1: (2 points each; 20 points total)

Based on the material covered in class, in what language is the expression `[10, 20 | 30]` valid? What does it mean?

That expression has no meaning in Prolog based on the material covered but in Icon it's an expression that has the result sequence $\{[10, 20], [10, 30]\}$.

What is the type of the following ML expression?

```
[([length], [1, 2, 3])]
```

```
(('a list -> int) list * int list) list
```

In ML, implement the well-studied `map` function in a way that yields the same type as the built-in version of `map`. This is the type desired:

```
('a -> 'b) -> 'a list -> 'b list
```

```
fun map F [] = []  
  | map F (x::xs) = F(x)::(map F xs)
```

In your own words, what does the term "object-oriented programming" mean?

A programming method where one creates a system of entities and orchestrates interaction between them.

Cite a fundamental benefit of inheritance in C++.

Objects can be treated as being something more general than they really are.

What's unusual about this Prolog predicate?

```
f(L) :- g(L), fail, !.
```

The cut comes after fail and is thus never reached.

Describe in English the form of the list `L` that would satisfy this predicate:

```
p(L) :- append(L1,L1,L) .
```

A list that can be divided into two identical lists. Here's one: [1,2,3,1,2,3].

Consider this version of `member` which has been instrumented with calls to `write/1`:

```
member(X,L) :- write('A'), L = [X|_].  
member(X,[_|T]) :- write('B'), member(X,T), write('C').
```

What would be printed in response to the following query?

```
| ?- member(3, [1,2,3]) .  
  
ABABACC  
yes
```

Write the `append/3` predicate.

```
append([], X, X) .  
append([X|L1], L2, [X|L3]) :- append(L1,L2,L3) .
```

Name two significant things that Prolog has in common with any one of the other languages that we studied.

Prolog and Icon have several things in common. Among them: automatic memory management, backtracking, a heterogeneous list type, and a FORTRAN-based first implementation.

Problem 2 (31 points):

Write an Icon program `ckconn` that analyzes test run output of `connect` from assignment seven and determines for each test case if the output shown is a suitable configuration of cables.

I was bit worried about putting a question of this size on the test and I tried to compensate for that with a very direct advance hint via mail and by citing a possible decomposition in the exam itself. I liked the fact that the problem required use of many elements of Icon and was practical rather than contrived. But, you know what's said about the best laid plans and the fact is that most persons didn't do very well on this problem.

To help you understanding the grading, I thought of it as thirty point problem with five parts: (1) parsing of the "case..." line, (2) parsing of the configuration, (3) verification of

the configuration's length and matings, (4) verification that the cables used were drawn from the ones supplied, (5) a main program to tie things together. Each part was worth six points and there was a one point bonus for writing down anything. When grading I deducted only for major flaws and omitted elements—code that appeared to be in the ballpark got full credit. Most persons ended up in the mid to low 20s. There was a 28, two 29s, and one 31.

```

link split

procedure do_case(s)
  cabs := []
  s ? {
    tab(upto('\['))
    pieces := split(tab(0), '[],\''')
    e2 := pull(pieces)
    len := pull(pieces)
    e1 := pull(pieces)

    every i := 1 to *pieces by 3 do
      put(cabs, pieces[i:i+3])
    }

  return [cabs,len,e1||e2]
end

procedure do_config(s)
  cabs := []

  s ? while e1 := move(1) do {
    len := *tab(many('-'))
    e2 := move(1)
    put(cabs, [e1,len,e2])
  }

  return cabs
end

procedure config_ok(cabs, len, ends)
  if (cabs[1][1] == ends[1]) | (cabs[-1][3] == ends[2]) then
    fail

  every len -=: (!cabs)[2]

  if len <= 0 then
    return
end

procedure sets_ok(In,Out)

```

```

t := table(0)
every t[c_to_rep(!In)] += 1
every t[c_to_rep(!Out)] -= 1

if !t < 0 then
    fail
else
    return
end

procedure c_to_rep(cable)
    cable := sort(cable)
    return map(cable[1] || cable[2] || cable[3])
end

procedure main()

    while data := do_case(write(read())) do {
        confln := write(read())
        if confln[1] ~= "C" then {
            config := do_config(confln)

            if not config_ok(config, data[2], data[3]) |
                not sets_ok(data[1], config) |
                find("MM"|"FF", confln) then
                write("***ERROR**")
            }
            write(read())
        }
    }
end

```

Problem 3 (8 points):

Write a Prolog predicate `sort(L, SortedL)` that describes the relationship that `SortedL` is a list that has the elements of `L` in ascending order. Both lists may be assumed to consist only of integers. The query `sort([], [])` should succeed.

```

sort([], []).
sort(L, [X|Sorted]) :-
    min(X, L),
    getone(X, L, Left),
    sort(Left, Sorted).

```

Problem 4 (6 points):

Write a Prolog predicate `hexprint/0` that prints, one per line, each of the hexadecimal numbers between `000` and `fff` inclusive but omitting those numbers where all the digits are the same (`000`, `111`, `222`, ..., `eee`, `fff`). In all, 4080 lines are to be printed (16^3 minus 16 is 4080). Note that `hexprint` ultimately succeeds.

```

notallsame([X,X,X]) :- !, fail.
notallsame(_).

hexdig(X) :- member(X,[0,1,2,3,4,5,6,7,8,9,a,b,c,d,e,f]).

hexprint :- hexdig(D1), hexdig(D2), hexdig(D3),
            notallsame([D1,D2,D3]),
            write(D1), write(D2), write(D3), nl, fail.
hexprint.

```

Problem 5 (6 points):

Write a Prolog predicate `palsum/1` that succeeds if a list of integer lists is palindromic with respect to the sums of the elements of the contained lists.

```

palsum([]).
palsum([_]).
palsum([H|T]) :- append(Middle,[Last],T), sum(H,Sum),
                sum(Last,Sum),
                palsum(Middle).

```

Problem 6 (6 points):

It was said in class that a single Prolog predicate can take the place of several functions in some other language. (1) Explain what's meant by that statement. (2) Write a Prolog predicate that exhibits that property. (3) In some other language write a set of routines to perform the various operations that the predicate can perform. NOTE: Don't get carried away on this problem—conserve your time by using a simple predicate that illustrates the point.

A predicate can perform different functions depending on what's instantiated. The member predicate is a simple example:

```

member(X, [X|_]).
member(X, [_|T]) :- member(X,T).

```

Member can (1) test to see if a value is in a list (2) generate all values in a list (3) generate lists containing a given value. The first two in Icon:

```

procedure is_member(x, L)
    if x == !L then return
    else fail
end

procedure members(L)
    suspend !L
end

```

Problem 7 (4 points):

Among ML, C++, Icon, and Prolog, which language did you find the most interesting, and why?

Answer-wise anything that was coherent earned all four points on this problem.

Personally, I find them all them pretty interesting, but if I had to pick one that's the most interesting to me at the moment it would have to be Prolog.

The responses:

<i>Icon</i>	<i>12.5</i>
<i>Prolog</i>	<i>11.5</i>
<i>C++</i>	<i>4</i>
<i>ML</i>	<i>0</i>

Problem 8 (4 points):

Among ML, C++, Icon, and Prolog, which language did you find the most difficult to learn. Cite an element of the language that you had particular difficulty with.

As in the last problem, any sort of coherent response got all four points.

Of the group I found Prolog to be the most difficult. For one thing, I have a hard time visualizing a Prolog computation that uses a lot of backtracking.

The responses:

<i>Prolog</i>	<i>21</i>
<i>C++</i>	<i>3</i>
<i>ML</i>	<i>3</i>
<i>Icon</i>	<i>1</i>

Historical note: Last semester a show of hands poll at the final showed about a 50/50 split between Icon and Prolog with one for ML and zero for C++ as the most difficult language.

Problem 9 (3 points):

Write an ML function f of type $a \rightarrow b \rightarrow a$ that exhibits the following behavior...

fun f x _ = x

Problem 10 (4 points):

Write an ML function `dups (s)` that removes sequences of duplicated characters from a string.

At the time of the test I hadn't written a solution for `dups` and while driving to campus I convinced myself that the problem was harder than I first thought it was. I therefore added `biggest (L)` as an alternative on the spot, but `dups` was actually very simple:

```
fun dups (s) =
  let
    fun dups1 ([]) = []
      | dups1 ([c]) = [c]
      | dups1 (c1::c2::cs) =
        if c1 = c2 then
          dups1 (c2::cs)
        else
          c1::dups1 (c2::cs)
  in
    implode (dups1 (explode (s)))
  end
```

Here's `biggest`:

```
exception Empty;
fun biggest [] = raise Empty
  | biggest [x] = x:int
  | biggest (x1::x2::xs) =
    if x1 > x2 then
      biggest (x1::xs)
    else
      biggest (x2::xs)
```

`biggest` can also be done with `reduce`, but I'll leave you to think about that one.

Problem 11 (8 points):

Implement two C++ classes: `MList` and `PrintableMList`. ...

```
#include <iostream.h>

class MList {
public:
  MList(int maxVal)
    : _maxVal(maxVal), _count(0), _closed(0) {}
  void operator<(int value) {
    if (!_closed && value <= _maxVal)
      _values[_count++] = value;
  }

  void close() { _closed = 1; }
```

```

    int size() { return _count; }

protected:
    int _maxVal, _count, _closed, _values[100];
};

class PrintableMList : public MList {
public:
    PrintableMList(int maxVal)
    : MList(maxVal) {}
    void print() {
        for (int i = 0; i < _count; i++)
            cout << _values[i] << " ";
        cout << endl;
    }
};

```

EXTRA CREDIT SECTION

EC 1 (1 point):

Two of the programming languages mentioned during lectures that were first publicly released after 1990. Name BOTH of them.

Limbo and Java

EC 2 (1 point):

Reigning world chess champion Garry Kasparov was recently defeated in a six game match by IBM's Deep Blue system. What language was used to implement Deep Blue?

According to an interview with A. Joseph Hoane, Jr. that can be found at www.chess.ibm.com/meet/html/d.4.5.a.html, it's written in C.

EC 3 (1 point):

Taking into account the syllabus, the slides for each language, homework assignments and solutions, and the mid-term exam and solutions, how many pages of handouts have been distributed in the course of this class? Your answer must be within 10% of the actual total. Note that a sheet printed on both sides counts as two pages.

```

% cd /home/cs372/Handouts
% grep ^%%Page: *.ps | wc -l
513
%

```

EC 4 (1 point):

Name a language that is an ancestor of Icon.

SNOBOL4

EC 5 (1 point):

How many applications are included in the Prolog-1000 list? Pick one: (a) Less than 1000
(b) Exactly 1000 (c) More than 1000.

The copy parked in /home/cs372/Prolog/Prolog-1000 appears to have 502 entries, but is said to be "preliminary". However, I think that in class I might have said that the list had more than one thousand entries and therefor, either (a) or (c) earned a point.

EC 6 (1 point):

What piece of sports equipment is on the instructor's desk?

A bowling pin. (I put this question here as a token reward for those students who kept me from being lonely during office hours!) Other responses were baseballs, footballs, and a tennis racket.

EC 7 (1 point):

Write an Icon expression that is exactly ten characters in length and that evaluates to the value "10" (a string). RESTRICTION: You may use no letters, digits, underscores, white space characters, or parentheses.

My answer:

**[[]] | | * []*

Mr. Klein was the only person who answered this question correctly. His answer:

**" \ \ " | | * " "*

EC 8 (1 point):

Finish this sentence as yourself: "If I only remember one thing from CSc 372 it will be _____."

If I only remember one thing from teaching CSc 372 this time around it will be nearly losing my mind trying to think up some decent problems for the first C++ assignment.

EC 9 (1 point):

Without using a control structure (such as `every` or `while`) write an Icon expression that prints the letters from "a" to "z".

This is a classic example of omitting a key element of a question. I should have said "...prints, one per line, the letters..." The answer I had in mind was this,

```
write(!&lcase) & 1 = 0
```

but a number of persons observed that the specifications could be met with this,

```
write(&lcase)
```

and that earned full credit.

EC 10 (1 point):

Write an Icon procedure `allsame(s)` that succeeds if all the characters in the string `s` are the same and fails otherwise. For example, `allsame("testing")` should fail, but `allsame("++++")` should succeed. `allsame("")` should fail.

```
procedure allsame(s)
  *cset(s) = 1 & return
end
```

EC 11 (1 point): (Written on the board...)

Sometimes in Tucson the only difference between the time and the temperature is a _____.

colon (For example, it might be 102 at 1:02.)

CSc 372, Fall 2001

ML Examination Solutions

Problem 1: (2 points each; 8 points total)

State the *type* of each of the following expressions, or if the expression is not valid, state why. For example, the type of the expression `3+4` is `int` and the type of the expression `length` is

`'a list -> int.`

`(1, [2,3], 4.0)`

`int * int list * real`

`(reduce op+)`

`int list -> int`

`explode o rev o implode`

Not valid – implode produces a string but rev requires an 'a list

`[[[size]]]`

`(string -> int) list list list`

Problem 2: (3 points each; 15 points total)

State the *type* of each of the following functions:

`fun a (w,h) = w * h * 1`

`int * int -> int`

`fun f(x) = f(1) + f(2)`

`int -> int`

`fun f(L, (a,b)) = L = (a,b)`

`(''a * ''b) * (''a * ''b) -> bool`

`fun f(3,4) = (size,length)`

`int * int -> (string -> int) * ('a list -> int)`

`fun x y z = (y z) + z`

`(int -> int) -> int -> int`

Problem 3: (3 points each, 9 points total)

Edit or rewrite the following functions to make better use of the facilities of ML:

```
fun f(a,b,c) = [a-c, a+c]
    fun f(a, _, c) = [a-c, a+c];

fun f(x,y) = x::y::1::2::[]
    fun f(x,y) = [x,y,1,2];

fun f(n) = if n = 10 then true else if n = 5 then true else false;

fun f2(10) = true
  | f2(5) = true
  | f2(_) = false
```

Problem 4: (5 points)

Write the map function. The type of map is ('a -> 'b) -> 'a list -> 'b list

```
fun map F [] = []
  | map F (x::xs) = F(x)::(map F xs)
```

Problem 5: (7 points)

Create a function `abslist(L)` of type `real list -> real list` that produces a copy of `L` with each value in the output list being the absolute value of the corresponding value in the input list. Assume there is NO function like Java's `Math.abs()` to compute absolute value—do the absolute value computation yourself.

```
fun abslist(L) = map (fn(x) => if x < 0.0 then ~x else x) L
```

Problem 6: (7 points)

Your instructor suffered the great embarrassment of distributing a version of `gather` that has a bug: If called with an empty list it should return `[]` but in fact it returns `[[]]`.

Example:

```
- gather([], 10);
val it = [[]] : int list list
```

Change this:

```
fun gather(L, limit) =
to this:
```

```
fun gather([], _) = []
  | gather(L, limit) =
```

Problem 7: (15 points)

In this problem you are to create TWO functions, `doubler` and `quadrupler`. `doubler` is of type `string list list -> string list list` and "doubles" each letter in the strings. `quadrupler` is of the same type, but quadruples each letter.

```
fun doubler L =
  let
    fun f([]) = []
      | f(c::cs) = c::c::f(cs)
  in
    (map (map (implode o f o explode))) L
  end

val quadrupler = doubler o doubler
```

Problem 8a: (7 points)

Create a function `genlist` that takes a list of integers and for each integer `N` in the list, produces a list with `N` instances of the number 1. You may assume that all the values are non-negative.

```
val genlist = map ((map (fn(_) => 1)) o iota)
```

Problem 8b: (7 points)

Create a function `genlist_inv` that performs the inverse operation of `genlist`. The only value appearing in the lists will be the integer 1 (one).

```
val genlist_inv = map sum
```

An acceptable answer is to use `length` instead of `sum`,

```
val genlist_inv = map length
```

but if you try it out with the interpreter, you'll find that you get an error about type variables not being generalized.

Problem 8c: (2 points)

What is the type of `genlist_inv o genlist o genlist_inv` ?

```
int list list -> int list
```

Problem 9: (18 points)

Create a function `tacdel (fname)` that reads the file named by `fname` and prints (using the `print` function) the lines in the file in reverse order, and if a line contains the character "@", the line "<D>" appears in its place.

```
fun tacdel (fname) =
  let
    val bytes = read_all_bytes (fname)
    fun lmapper (s) =
      if member ("@", explode s) then "<D>" else s
    val lines = map lmapper (rev (split #"\n" bytes))
  in
    print (concat (ien (lines, 1, "\n")))
  end
```

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Icon Examination Solutions

Problem 1: (15 points)

Write a program `tacdel` that reads lines from standard input and prints the lines in the file in reverse order. If a line contains the character "@", the line "<D>" appears in place of that line.

```
procedure main()
  L := []
  while line := read() do
    if line ? find("@") then
      push(L, "<D>")
    else
      push(L, line)
    every write(!L)
  end
```

Problem 2: (15 points)

Write a program `idiff` that examines two files named on the command line and if the files are not identical, prints "Diffs". If the files are identical, `idiff` produces no output.

```
procedure main(a)
  x := read_file(a[1])
  y := read_file(a[2])

  if *x ~= *y then stop("Diffs")
  every i := 1 to *x do
    if x[i] ~= y[i] then
      stop("Diffs")
  end
```

Problem 3: (15 points)

Write a program `paldate` that searches for palindromic dates between January 1, 2001 and December 31, 2099 and prints those dates. Represent a date such March 15, 2001 like this: 3/15/1.

A straightforward solution is this:

```
procedure main()
  t := table(31)
  every t[4|6|9|11] := 30
  t[2] := 28
  every m := 1 to 12 do
    every d := 1 to t[m] do
      every y := 1 to 99 do {
        s := m || "/" || d || "/" || y
        write(reverse(s) == s)
      }
  end
```

With a little thought about the possibilities, the program can be simplified:

```
procedure main()
  every m := 1 to 12 do
    every d := (1 to 9) | 11 | 22 do
      every y := 1 to 21 do {
        s := m || "/" || d || "/" || y
        write(reverse(s) == s)
      }
end
```

Problem 4: (24 points)

Write a program `total` that reads merchandise descriptions and prices and then computes the total for a list of items to purchase.

```
procedure main()
  p := table()
  while line := read() do {
    if line == "." then
      break
    reverse(line) ? {
      price := reverse(tab(upto(' ')))
      if price[-1] == "c" then
        price := price[1:-1] * .01
      else
        price := price[2:0] * 1.0
      tab(many(' '))
      item := reverse(tab(0))
      p[item] := price
    }
  }

  total := 0
  while total += p[read()]
  write("$", total)
end
```

Problem 5: (7 points)

Write a procedure `intmem(i, L)` that returns `&null` if the integer `i` is contained in the list `L` and fails otherwise. `L` may contain values of any type.

```
procedure intmem(i, L)
  return integer(!L) = i & &null
end
```


Problem 6: (10 points)

Write a program `sumints` that reads lines on standard input and prints the sum of all integers found.

Restriction: Your solution must be based on string scanning. The only types you may use are integers, strings, and character sets. You may not any comparison operators such as `==`.

```
procedure main()
  sum := 0
  while line := read() do
    line ? while tab(upto(&digits)) do
      sum += tab(many(&digits))

  write(sum)
end
```

Problem 7: (6 points)

According to the instructor, what is the unique aspect of Icon's expression evaluation mechanism?

Expressions can produce zero, one, or many results.

Name one thing that the instructor doesn't like about Icon or has identified as a problem with the language. Here's one thing you can't mention: unexpected failure.

Some examples:

*t := table([]) doesn't mix well with push and put
Semicolon insertion can lead to surprises
No well-defined and documented library to do things like reversing a list*

There are no built-in functions in Icon to do things like reverse lists, compare all elements of two lists, or do a "deep copy" of a list. What did the instructor cite as the likely reason for the absence of functions like that?

The limited memory space (< 64k of compiled code) for the initial UNIX implementation and relative difficulty of writing those functions in C.

Problem 8: (8 points)

Fill in the blanks:

The instructor described the function `move` as being a "lone wolf". He said that `tab` "works well with others".

The result of a successful comparison in Icon is the *right hand operand*.

We studied a total of `8` string scanning functions. Of those, two changed *the position* and `five` of them returned a *position*. `pos` is one-of-a-kind.

EXTRA CREDIT SECTION (one point each)

(a) Write the result sequence of `(?"xxx" || !"xxx" || *"xxx")`

```

][ .every (?"xxx" || !"xxx" || *"xxx");
  "xx3" (string)
  "xx3" (string)
  "xx3" (string)

```

(b) If the string `s` contains your login name, what is `string(cset(s[1:4]))[1:-2]`?

```

][ s := "whm" & string(cset(s[1:4]))[1:-2];
  r := "h" (string)

```

```

][ s := "yourname" & string(cset(s[1:4]))[1:-2];
  r := "o" (string)

```

(c) Which one of the following principal contributors to Icon have not been mentioned in class: Steve Wampler, Bob Alexander or Tim Korb?

(d) Cite up to three elements of Icon that are "syntactic sugar". (one point each)

The unary `\` and `/` operators

It can be argued that the augmented operators, such as `+=`, are syntactic sugar.

Two elements we didn't talk about, the `repeat` and `case` expressions, are reasonably thought of as syntactic sugar.

(e) Given this program, `args.icn`:

```

procedure main(args)
  every write(!args)
end

```

what does `args` print when run like this: `"args < in.dat >out.dat"`?

It produces no output.

(f) Describe a situation where `tab(n)` and `move(n)` produce the same result, for a particular subject, position, and value of `n`.

```

][ " " ? tab(2);
  Failure

```

```

][ " " ? move(2);
  Failure

```

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Prolog Examination Solutions

Problem 1: (5 points)

Show an example of each of the following:

A fact: `p.`

A rule: `p :- q.`

A query: `p.`

A clause: `p.`

An atom: `p`

Problem 2: (2 points)

What is the relationship between facts, rules, and clauses?

Facts and rules are clauses.

Problem 3: (5 points)

True or false: The following is a working implementation of the `member` predicate, as studied in class:

```
member(X, [X]).  
member(X, [_|T]) :- member(X, T).
```

False—it only succeeds if a value is the last element of the list.

Problem 4: (5 points)

True or false: The following is a working implementation of the `length` predicate, as studied in class:

```
length([], 0).  
length([_|T], Sum) :- length(T, Sum), Sum is Sum + 1.
```

False—Sum is Sum + 1 fails.

Problem 5: (12 points)

Write a predicate `sumval(+List, +Value, -Sum)` that produces the sum of all occurrences of `Value` in the list `List`. Assume that `Value` and all elements in `List` are integers.

```
sumval([], _, 0).  
sumval([X|T], X, Sum) :- sumval(T, X, TSum), Sum is X + TSum, !.  
sumval([_|T], X, Sum) :- sumval(T, X, Sum).
```

Problem 6: (4 points)

Write a predicate `sumvals(+List, +ListOfValues, -Sum)` that produces the sum of all occurrences of members of the list `ListOfValues` in the list `List`. Assume that `Value` and all elements in `List` are integers.

The order of values in `ListOfValues` is inconsequential. Note that a given value may appear multiple times in `ListOfValues` but that does not affect the result.

```
sumvals([], _, 0).
sumvals([H|T], L, Sum) :- member(H, L), sumvals(T, L, TSum),
                          Sum is H + TSum, !.
sumvals([_|T], L, Sum) :- sumvals(T, L, Sum).
```

Problem 7: (12 points)

Write a predicate `listeq(+L1, +L2)` that succeeds if the lists `L1` and `L2` are identical and fails otherwise. `L1` and `L2` may be arbitrarily complicated lists but all values will be either integers or lists.

```
listeq(L,L).
```

Problem 8: (15 points)

Write a predicate `consec(+Value, +N, +List)` that succeeds if and only if `List` contains `N` consecutive occurrences of `Value`. Assume that `Value` and all elements of `List` are atoms or integers. Assume `N > 0`.

```
consec(Val, N, List) :- repl(Val, N, Vals),
                        append(Vals, _, List), !.
consec(Val, N, [_|T]) :- consec(Val, N, T).
```

Problem 9: (15 points)

Write a predicate `order3(+L1, -L2)` that assumes that `L1` contains three integers and instantiates `L2` to be a list of those integers in ascending order:

```
order3(L, [A,B,C]) :-
    getone(A,L,R), getone(B,R,[C]), A =< B, B=< C, !.
```

Problem 10: (20 points)

In this problem you are to write a predicate `inventory/0` that does an inventory calculation for a fruit stand. [...]

```
inventory :- fruit(F), get_qty(F,Q), cost(F,C), TC is Q*C/100,
              format('~p: ~p at ~p = $~p~n', [F,Q,C,TC]), fail.
inventory.

get_qty(F,Q) :- qty(F,Q), !.
get_qty(_,0).
```

Problem 11: (5 points)

For each of the two following queries, write in the values computed for each variable. If a query fails, indicate it.

| ?- $X = [1, 2, 3]$, $Y = [4|X]$, $[A, B|C] = Y$.

$A = 4$
 $B = 1$
 $C = [2, 3]$

| ?- $A = []$, $B = 1$, $C = [A, B]$, $B = 2$, $[D, E] = C$.

This query fails because B can't be unified with both 1 and 2.

EXTRA CREDIT SECTION (one point each)

(a) What is the Prolog 1000?

A list of significant applications written in Prolog and related languages.

(b) In what country was Prolog developed?

France

(c) What country made a big investment in Prolog?

Japan, with its Fifth Generation project.

(d) What language was used for the first implementation of Prolog?

FORTRAN

(e) What is the sound of a combinatorial explosion?

Silence

(f) What is inaccurate about this specification: `append(+L1, +L2, -L3)`?

The correct specification is `append(?L1, ?L2, ?L3)`. All, some, or none of the arguments might be specified.

(g) Why is a warning about a singleton variable significant?

The variable in question is used only once. That might indicate a misspelled name or other error.

(h) In a Prolog library you see these two predicates: `get_chr(+Number, -Char)` and `get_ord(+Char, -Number)`. What's odd about that?

With Prolog, one predicate can perform both calculations.

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Final Examination Solutions

Problem 1: (7 points)

Write an Emacs Lisp function `change` that changes every letter in the current buffer to "x", and every decimal digit to "#".

```
(defun change ()
  (interactive)
  (goto-char 1)
  (let (ch)
    (while (not (eobp))
      (setq ch (char-after (point)))
      (delete-char 1)
      (cond
        ((letterp ch) (insert ?x))
        ((digitp ch) (insert ?#))
        (t (insert ch)))
      )
    )
  )
```

Problem 2: (15 points—do only two of problems 2, 3, and 4)

Write a function `ruler`, bound to ESC-R, that inserts a "ruler" before the current line.

```
(defun ruler ()
  (interactive)
  (let ((w (1- (window-width))) (current (point)) start end)
    (forward-line 0)
    (setq start (point))
    (let ((n (/ w 10)) (i 1))
      (while (<= i n)
        (insert "          " (int-to-string i))
        (setq i (1+ i)))
      (insert "\n")
      (setq i 1)
      (while (<= i w)
        (insert (int-to-string (% i 10)))
        (setq i (1+ i)))
      (insert "\n")
      )
    (read-char)
    (delete-region start (point))
    (goto-char current)
  )
  )

(global-set-key "\eR" 'ruler)
```

Problem 3: (15 points—do only two of problems 2, 3, and 4)

Write an Emacs Lisp function `longest` that positions the cursor at the beginning of the longest line in the current buffer. If there are ties for the longest line, choose the first one.

```
(defun longest()
  (interactive)
  (goto-char 1)
  (let ((max -1) (last (point)) (maxpos 1) len)
    (while (not (eobp))
      (forward-line 1)
      (setq len (- (point) last))
      (cond
        ((> len max) (setq max len)
                    (setq maxpos last)))
      (setq last (point)))
    )
  (goto-char maxpos)
  )
)
```

Problem 4: (15 points—do only two of problems 2, 3, and 4)

Write an Emacs Lisp function `marquee` that displays a horizontally scrolling line of text.

```
(defun marquee (text)
  (interactive "sText? ")
  (get-empty-buffer "*m*")
  (switch-to-buffer "*m*")
  (insert-char ?\n (/ (window-height) 2))
  (setq pos (point))
  (insert text)
  (let (ch)
    (while t
      (goto-char pos)
      (setq ch (char-after pos))
      (delete-char 1)
      (end-of-line)
      (insert ch)
      (sit-for 0 70)
    )
  )
)
```

Problem 5: (9 points)

Background: In Icon, built-in functions supply default values for omitted arguments when there's a reasonable default. Emacs Lisp is very inconsistent in this regard. For example, the count for `forward-line` is optional but the count for `delete-char` is required. The instructor believes that consistent use of reasonable defaults would be an improvement for Emacs Lisp.

Problem: Identify two more elements from ML, Icon, Prolog, and/or Java that would be improvements for Emacs Lisp. Briefly describe how Emacs Lisp would benefit from their inclusion. The elements may be from the same language or from different languages.

One thing that comes to mind for me is to add object-orientation so that instead of a big pile of functions we could have classes like `Buffer`, `Window`, etc. Buffer-specific operations might be methods of the `Buffer` class, for example. It is the case however, that a simpler module-based approach, somewhat like ML's structures, would provide sufficient grouping to make the task of finding functions more manageable.

For a second item, I think that Icon's idea of keywords—things like `&subject` and `&pos` might be useful. For example, imagine `&point`. To move forward one might say `&point += 1`. `&point := 1` would go to the beginning of the buffer and `&point := 0` would go to the end of the buffer. Instead of several functions to adjust the point, one would simply change the value of `&point`.

Problem 6: (6 points)

Write an ML function `rm_prefix(P, L)` that **ASSUMES** that `P` is a prefix of the list `L` and returns a copy of `L` with `P` removed.

```
fun rm_prefix([],L) = L
  | rm_prefix(_::ps, _::xs) = rm_prefix(ps, xs);
```

Problem 7: (2 points)

Write an ML function `listeq(L1, L2)` that returns true if the lists `L1` and `L2` are identical and returns false otherwise. Style does matter on this problem.

```
fun listeq(L1, L2) = L1 = L2;
```

Problem 8: (8 points)

Write an Icon procedure `extsort(L)` that accepts a list of file names and sorts them by their extension.

```
procedure extsort(L)
  return swap(sort(swap(L)))
end

procedure swap(L)
  L2 := []
  every w := split(!L, ".") do
    put(L2, w[2] || "." || w[1])
  return L2
```


end

Problem 9: (8 points)

Write a Prolog predicate `find(+N, [-A, -B, -C])` that produces all combinations of integers between 1 and N inclusive such that $N = A * B - C$.

```
find(N, [A, B, C]) :- iota(N, L), getone(A, L, R), getone(B, R, R2),
    getone(C, R2, _), N is A * B - C.
```

Problem 10: (10 points)

Pick one interesting element from any of the languages we have studied and, in the style of an e-mail note, describe that element to a colleague familiar only with Java programming. Be sure to talk about the syntactic form, the operation, and describe a practical usage of the element.

When describing the idea of this course to someone I often use `member` in Prolog as an example of an interesting way to do something in another language:

In Prolog I might define a *predicate* called `member` that tests for membership in a list. Here is the definition of `member`:

```
member(X, [X|_]).
member(X, [_|T]) :- member(X, T)
```

That says that X is a member of any list of which it is the first element or any list that it is a member of the tail. An interesting thing about Prolog is that because predicates describe relationships, we can use that same predicate to generate the elements in a list:

```
?- member(X, [1, 2, 3]).
X = 1? ;
X = 2? ;
X = 3?
```

Problem 11: (10 points)

Present an argument either for or against the prospect of a single language becoming dominant for the majority of software development. Here are some points to possibly consider: What major elements would a dominant language need to have? How might such a language come into existence? What are forces that would work in opposition to a language becoming dominant?

Before Java's quick rise to popularity I was more skeptical about the prospect of a single language being dominant but Java, with all its problems, has nonetheless transformed much of the programming landscape. I have to think that a language of comparable complexity that addresses Java's weaknesses might have a chance of becoming dominant across many, if not most application areas.

It seems that a language with a potential of dominance would have to come from academia or the open source community. Vendors have a bad track record of supporting ideas from other vendors, no matter how good they are. Ideas that emerge from neutral parties often have a greater likelihood of widespread adoption.

In terms of language characteristics, it seems that object-orientation, a conventional syntactic structure, automatic memory management, and the potential of efficient execution are all musts.

With regard to opposing forces, it seems to be the case that successful software systems grow and grow. A dominant language would probably grow and grow until at some point it became clear that a language with a subset of the capabilities would serve just as well in many cases and perhaps excel in other areas. A crisp new language would perhaps attract those who like to be different and perhaps the cycle would repeat itself.

Problem 12: (10 points)

For five points each, answer TWO of the following questions. If more than two questions are answered, only the first answers on the paper will be graded.

(A) In languages like Java, C++, and ML, words like "if", "fun", and "class" are called *reserved words*—they can't be used for variable or routine names. The PL/I language has no reserved words. One can write statements like `if = while + then(else)`. What are some advantages and/or disadvantages to having no reserved words? Disregard issues related to compiling languages with no reserved words.

A big advantage is that you don't have work around reserved words when choosing variable names. I've many times wanted to use the variable "to" in an Icon program but that conflicts with `to-by`.

In terms of negatives, there is the potential for writing code like the above, but that's rarely a problem in practice. Also, it's difficult to write ad-hoc source code analysis tools to deal with programs written in such languages.

(B) Icon has several polymorphic operators and functions. For example, the unary `*` operator returns the number of elements in an object. The `delete` function removes elements from sets and tables. What are some tradeoffs that a language designer must take into account when considering inclusion of a polymorphic operation in a language?

There can be a tendency to have a polymorphic operator cover too much ground. For example, should Icon's `!` operator handle numbers as well? Should the `delete` function operate on lists as well? There can also be a problem when it comes to naming an operation but using an operator instead of a function is one way to avoid the question of what-to-call-it.

(C) Imagine a language that has heterogeneous lists like Prolog, Icon, and Lisp, but that also has a tuple type that is very similar to ML. Present an argument either for or against the claim that if a language has heterogeneous lists, tuples provide no additional benefit.

Python is a language that has heterogeneous lists as well as tuples. Python's tuples are immutable—they can't be changed—and in *Learning Python* that immutability is cited as the best reason for the co-existence of the two mechanisms. I have used Icon's lists as tuples in various situations and there is something that feels a little bit uncomfortable about it, but I can't put my finger on it—maybe it is mutability.

(D) What do Java's exception handling mechanism and Icon's failure mechanism have in common?

The common element is the situation of an expression for which there's no reasonable result. In Icon an out of bounds array index fails; in Java an exception is thrown. Exceptions are far more general but much more cumbersome to use. It would be nice to have a mechanism with the generality of exceptions and Icon's conciseness of expression.

(E) The instructor said that "every programmer should have a language like Icon in their toolbox". What are the characteristics of Icon, and similar languages, that make it worthwhile to know such a language in addition to mainstream languages like Java and C++? (Or, argue that knowing a single language like Java or C++, and knowing it well, is all that's needed.)

The common elements that I see are (1) simple I/O, (2) good string handling, (3) data types like lists and tables, and (4) a library that's sufficiently well-designed that you don't need to look up the arguments for every other function.

(F) A language implemented in C, such as Emacs Lisp, typically has some library functions coded in C and the balance coded in the language itself. What factors influence whether a function is implemented in the language itself?

One way to think about built-in functions is which can be implemented in the language and which cannot. For example, there's no way to exactly implement Icon's `push/pop/pull/...` functions with the other mechanisms of the language—you can't write those functions in Icon.

Another consideration is efficiency. It may be possible to implement a function in Lisp, but if the function is long-running and heavily used, it might be better written in C.

A third issue is complexity. A function may be sufficiently complicated that it is impractical to write in the implementation language.

EXTRA CREDIT SECTION (one point each)

(a) What's the difference between a hack and programming technique?

When you do it, it's a programming technique. When somebody else does it, it's a hack.

(b) Order these languages from oldest to youngest: Icon, Java, Lisp, ML, Prolog.

Lisp, Prolog, ML, Icon, Java

(c) Write an expression that is valid in three of the languages we studied but with a notably

different interpretation in each.

Good question!

(d) As of midnight on December 12, how many messages have been sent to the CSc 372 mailing list? (Your answer must be within 10%.)

280 messages

(e) The instructor has immediate plans to rewrite the Icon assignments in another language to see how that language compares to Icon. What's the language?

Python

(f) What is the type of `rm_prefix` (problem 6)?

```
'a list * 'b list -> 'b list
```

CSc 372, Fall 2006
Mid-Term Examination Solutions

TOP SECRET

Circumstances have still not allowed two students to take a make-up for this exam. Guard these solutions and your exam closely.

A word about grading

The best way to be sure your work is scored equitably is get a problem right—there's no chance of being given the wrong amount of partial credit. We try very hard to make equivalent deductions for equivalent errors but it's very hard, especially with a large class. In some cases specific deductions and/or extra credit awards are cited below. If a mark on your exam differs from one of those you should definitely let me know. If you find that you got a lower mark than a colleague for a similar error, let me know. In some cases it might be that your friend got lucky. If so, I won't change your friend's mark but I also won't compound the error by making the same wrong deduction for you.

If you believe that an answer for one of the code-centric questions is correct then before coming to see me you should get on a machine and see if it actually works. If it does, come and see me. If it doesn't work then figure out the smallest change that makes it work. If you still think the deduction is inequitable then come and see me.

Please double-check that the scores written on each problem match the scores on the cover sheet.

As the syllabus states, you're encouraged to contest any score that you don't think is equitable.

Problem 1: (5 points; average 4.61, median 5)

The instructor often says "In ML we never change anything; we only make new things." What does he mean by that?

Here are my favorite complete answers:

"Everything is immutable."—Qiyam Tung

"There are no variables in ML, only aliases to unchangeable pieces of data."—Garrett Hoxie

A common error was to have a variable-centric answer, perhaps saying simply that a `val` might hide an earlier binding of the same name. That was a 1.5 point deduction.

Problem 2: (5 points; average 4.36, median 5)

(a) Write an ML function `fun firstLast(L)` that returns a tuple consisting of the first and last elements of the list `L`.

```
fun last [x] = x
  | last (_::xs) = last(xs)

fun firstLast(x::xs) = (x, last(x::xs))
```

(b) What is the type of `firstLast`?

```
'a list -> 'a * 'a
```

Problem 3: (5 points; average 2.28, median 1.5)

Flatten one-element lists.

```
val f = map hd
```

I was surely disappointed by the results on this one. I wish more students had put down something that worked, even if it was longer than I requested. Some students even erased answers and left it blank. Remember that on my exams something is no worse than nothing—give me a chance to give you partial credit. A blank is a zero, period.

Problem 4: (6 points; average 4.67, median 6)

Write an ML function `eo(L)` that returns a list consisting of every other element of the list `L`. (That is, the 2nd, 4th, 6th, 8th, ... elements.)

```
fun eo(x::y::more) = y::(eo more)
  | eo _ = []
```

Problem 5: (12 points; average 8.59, median 9)

Without writing a function that is directly or indirectly recursive, write an ML function `ints_to_string(L)` that produces a string representation of `L`, an `int list`.

```
fun ints_to_string [] = ""
  | ints_to_string L =
    let
      val almost =
        concat(map (fn(s) => ", " ^ Int.toString(s)) L)
    in
      implode(List.drop(explode almost, 2))
    end
```

I ended up working through a fairly similar problem—`printN`—during the Q&A session so I tried to compensate for that by saying a lot about it in a follow-up note to the list on Monday night.

Common errors were a trailing `", "` (-3); a `tl` too few (-1); producing just the integers, no commas (-5); and doing little more than `map Int.toString` (-8).

Problem 6: (15 points; average 13.03, median 15)

Without writing a function that is directly or indirectly recursive, write an ML function `show_lists(L)` of type `(string * int list) list -> unit` that prints the contents of `L`, prefixing each `int list` with the specified label.

```
fun its' [] = "<empty>"
  | its' L = ints_to_string L;

fun show_lists(L) =
  print(concat(map
    (fn(label, IL) => label ^ ": " ^ (its' IL) ^ "\n") L))
```

Many solutions for both problem 5 and problem 6 used folding instead of a `map` and `concat` (or folding with `op^`). I see that as good news and bad news: I think that shows great understanding of folding but always seek the simplest solution—it has the greatest chance of being correct.

We ended up grading this problem in a somewhat qualitative fashion. For the most part we classified solutions as "A", "B", "C", "D", or "F" and awarded 15, 12.5, 10, 5, or zero points, respectively. If you see something like "A-15" on yours, that's why.

A very common error was to return `unit list` instead of `unit`. We didn't deduct for that but did award a point of extra credit if `unit` was returned. (Be sure we gave it to you if that's what you did.)

Problem 7: (10 points; average 1.83, median 0)

Consider a folding that operates on an `int list` with an even number of values, all greater than zero, and produces a list of pair-wise sums: `[1st+2nd, 3rd+4th, ..., (N-1)th+Nth]`

A fair number of students solved this problem or got close enough to make me happy. Mr. Bressel's solution was surely the best. I'd like you to think more about this problem so I'm not going to publish a solution here but if you're dying to know, see me or get to know Mr. Stout, Mr. D. Nguyen, Mr. Ghigliotti, Mr. Shokirev, Mr. Patki, Mr. Sarando, Mr. Tung, Mr. Bressel, Mr. Sortelli, Mr. Wallis, or Mr. Nation. (alphabetical by login name)

Problem 8: (4 points; average 2.25, median 2)

(a) Is the following ML function declaration valid? If valid, what is the type of `f1`? If not valid, explain why it is not valid.

```
fun f1 () f2 () = [f2];
```

It's valid. The type is `unit -> 'a -> unit -> 'a list`

I posted a question very similar to this to the mailing list. Remember that I think of my postings to that list as part of the course material.

There were a few exceptions but if you put down any type we usually considered that as evidence that you viewed the declaration as being valid and gave you a point for that.

(b) Write an ML function `g` whose type is

```
int -> (int list * int) -> (string list) -> (bool * real)
```

```
fun f 1 ([1],1) [""] = (true,1.0);
```

Problem 9: (4 points; average 2.71, median 3.25)

(a) Using nothing but a `val` binding and the composition operator, create an ML function `f(s)` that returns a copy of the string `s` with the first and last characters removed. Assume that `size(s) >= 2`.

```
val f = implode o rev o tl o rev o tl o explode;
```

(b) As you've defined it, what is the type of `f`? (Don't forget to properly account for the intermediate functions in the composition.)

```
string -> string
```

A few students fell victim to the bum steer about the intermediate functions. I guess they overlooked slide 162 and missed the time or two in class when I specifically said to watch out for this on an exam.

Problem 10: (16 points; average 9.85, median 12)

Write a Ruby program that reads from standard input a script of interaction with `irb` and combines the expressions and results on a single line, vertically aligning the results, based on the longest input expression. Each combined line is followed by a blank line.

```
exprs = []
results = []

if ARGV.length != 0
  gap = ARGV[0].to_i
else
  gap = 1
end

while line = STDIN.gets
  exprs << line.chomp
  results << (STDIN.gets || (puts "Error: short input"; exit))
end

longest = exprs.max{|a,b| a.size <=> b.size }.size

for e in exprs
  printf("%s%s\n", e.ljust(longest) + (" " * gap), results.shift)
end
```

Common deductions: Doesn't handle command line option (-2); doesn't handle "short input" case (-2); doesn't bother at all with alignment (-4); gets alignment wrong (-2). A lot of solutions aligned columns based on the longest input line instead of only considering the expressions (-2).

Problem 11: (2 points; average 1.62, mean 2)

Write a Ruby program that reads all lines from standard input and prints them on standard output in reverse order, last line first, first line last. Assume there is at least one line and that the file ends with a newline.

For two points of extra credit, have less than 25 characters in your solution.

```
puts readlines.reverse
```

I figured this one would be a cream puff since (1) it was the first thing we wrote in Ruby (slide 9), (2) I posed an in-class challenge to do this, and (3) I wrote the above on the Elmo when discussing (2)!

Problem 12: (3 points; average 2.02, median 3)

Here is a line of code from a Ruby method:

```
line = (gets || return)
```

Imagining the reader to be a Java programmer with no knowledge whatsoever of Ruby, explain its operation in each of the possible cases that might arise when it executes. Ignore the open-command-line-arguments-as-files-and-read-them behavior of `gets`.

If `gets` produces a line then it is assigned to `line`. If not, the `return` terminates the current method.

Many students said mentioned something to the effect of "the value produced by `return` is then assigned to `line`". That resulted in a deduction of 1.5.

Problem 13: (8 points; average 5.48, median 6.25)

Write a Ruby iterator named `upto_limit(a, limit)`. The argument `a` is an array of integers; `limit` is an integer. `upto_limit` yields the values of `a` in turn (`a[0]`, `a[1]`, ...) continuing while the sum of the yielded values is less than or equal to `limit`. `upto_limit` returns `a`.

```
def upto_limit(a, limit)
  sum = 0
  for i in a
    sum += i
    if sum <= limit then
      yield i
    end
  end
  a
end
```

Common errors: Doesn't return `a` (-1.5); yields wrong values due to logic error (-1.5), prints instead of yielding—a fundamental misunderstanding (-2.5).

If a solution simply yielded the values in `a` we only gave it two points but at the moment seems like too big of a deduction. If you got that 2, see me and I'll change it to 3.5.

Problem 14: (5 points; average 2.85, median 4)

Write a Ruby method `extract(s, m, n)` that extracts a portion of a string that represents a hierarchical data structure. `m` is a major index and `n` is a minor index. Major sections of the string are delimited by slashes and are composed of minor sections separated by colons.

```
def extract(s,m,n)
  majors = s.split("/")
  majors.delete("")
  major = (majors[m-1] || return)

  minors = major.split(":")
  minors.delete("")
  minors[n-1]
end
```

A hint specified "Assume that `"|20|1|300|".split("/")` produces `["20", "1", "300"]`. With that in mind the `delete("")` calls above are not needed.

Common deductions: Using `m` and `n` instead of `m-1` and `n-1` (-0.5); not checking whether the major reference is out of bounds (-0.5).

Extra Credit Section (one point each unless otherwise indicated; average 2.86, median 2; high 8)

- (1) *Imagine that you have an ML function named `f` and a Ruby method named `f`. Does `[f]` produce an analogous result in both languages? If not, how do the results differ?*

The result is different. In ML it is a list containing the function `f`. In Ruby it is an array that contains the result of calling `f`.

- (2) *For up to three points name three programming languages developed at the University of Arizona and give an example of a valid expression in each that involves an operator.*

See slide 14 in `intro.sli.pdf`. I believe that `3+4` is a valid expression in all those languages except perhaps SIL2.

We went ahead and gave a point for just the language name. If you cited a valid expression it was worth

another half-point per language.

- (3) *For one point each, write `curry` and `uncurry` in ML.*

```
fun curry f x y = f (x,y)
```

```
fun uncurry f (x,y) = f x y
```

Very few got these right but quite a few got them reversed.

- (4) *Assuming that `s` is a string, what is a Ruby expression that produces the same effect as `s.dup` but is both shorter and more difficult to type?*

`s+" "` I believe that only one student, Mr. Tung, got this one.

- (5) *What element of Ruby most closely corresponds to an anonymous function in ML?*

Blocks.

- (6) *Simplify this Ruby expression: `if a[0] == nil then false else true end`*

The answer I had in mind was `a[0]` but that's a little inaccurate. Mr. Kovell and Mr. Maloney did better: `!!a[0]`. (Do you see the difference?)

I should have said "Greatly simplify..." but since I didn't I accepted any expression that produced the same result but that was simpler than the above.

- (7) *Cite a contribution to knowledge made by Ralph Griswold.*

I hope that somebody will take the time to write a biography about Ralph. Here are a few thoughts I've got.

At Bell Labs Ralph led development of four SNOBOL languages. I believe he said SNOBOL took a day to implement. SNOBOL2 took a week. SNOBOL3 took a month. SNOBOL4 took a year. SNOBOL4 was very popular both in industry and academia. It was written with portability in mind and coded in a macro language called SIL (SNOBOL Implementation Language). It was ported to dozens of different machines. Quite a few books were written about SNOBOL4 by both him and others. For many years it was by far the most popular unconventional language to use for non-numeric problems on mainframe computers.

A language that almost nobody's heard of is SL5—SNOBOL Language 5. Ralph led development of it here at the University of Arizona and, as the name implies, it was a follow-on in the SNOBOL line. Ralph once said, "SL5 had everything—you could even change the procedure call mechanism". But in the end the team didn't like the overall result and the language was never released. It is fading into the sands of time.

I asked Ralph what his first ideas about Icon were and he said, "I was in the hospital [I don't know for what] pondering SL5 and I kept thinking that there must be something simpler." That turned out to be Icon. Great effort was taken to make Icon small (conceptually) but powerful. I remember once that Ralph patiently listened while I rattled off a list of features that I thought would be good in Icon. He said "Go ahead, but for every one feature you add, first find one to remove." He was exaggerating, but by only a tiny amount.

Perl guru Damian Conway was asked in an interview, "What languages other than Perl do you enjoy programming in?" He replied, "I'm very partial to Icon. It's so beautifully put together, so elegantly proportioned, almost like a Renaissance painting." In the `digibarn.com` poster cited in the intro slides Icon is described as "A general purpose language known for its beauty and grace."

Ralph founded this department and served as department head for many years. It's hard to imagine how difficult it is to simultaneously and successfully teach classes, conduct original research and publish about it, write successful grant proposals, build from scratch a department that is internationally recognized, direct and coordinate the work of several graduate students, and on top of all that, keep an academic department

running smoothly, bearing in mind that a collection of professors, each with their own priorities and often-strong opinions, are not easy to keep happy.

When Ralph "retired" he quickly rose to prominence in the weaving community by virtue of his interest and pursuit of mathematical problems in weaving.

Here's a quote about Ralph from one of his graduate students who is now a professor: "As one of the founders of the Bell Labs software culture which spawned UNIX, C, and many other essential contributions to modern software, Ralph Griswold brought to his academic research not only brilliance, but also experience and a value system that demanded that research ideas be tested by fire and proven useful and usable by real users, not just good-looking diagrams in academic papers."—Clint Jeffery

When I started working for Ralph as a graduate student I discovered that my was education was just beginning. He was probably the smartest guy I've ever known and surely the wisest, at least in this field. One of the great fortunes of my life was working for him.

Things that Ralph clearly saw as good ideas over thirty years ago, such as run-time type checking, garbage collection, and a well-designed collection of datatypes are now becoming widely accepted.

- (8) *(Up to five points.) Offer some intelligent observations about the applicability of type deduction, or something similar, in Ruby.*

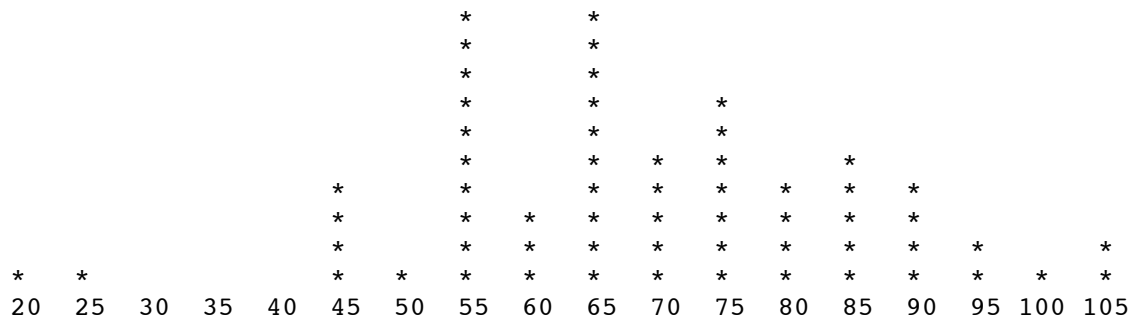
There has been quite a bit of research on various aspects of figuring out types in languages that don't use static typing, like Icon and Ruby. A fellow named Ken Walker wrote a type-inferencing Icon compiler about a decade ago for his dissertation. I believe he found that as a rule "type consistency" held in about 80% of the cases for the large body of Icon code that he tested with. You can read more here: www.cs.arizona.edu/icon/ftp/doc/tr93_32.pdf.

Ruby is more slippery than Icon however. For example, in Icon you can be sure that something like $x * 3.7$ is always going to produce a floating point value. That's not so in Ruby. In Ruby you can't even be sure that $2+2$ is 4! However, a user who's interested in speeding up a Ruby program might be willing to sacrifice mutability for performance.

Overall results

The average on the exam was 68.9 and the median was 67.25. Here is the full set of scores and a histogram:

106.00, 104.00, 102.00, 96.50, 96.00, 91.50, 91.00, 90.50, 89.50,
86.00, 85.00, 84.50, 84.50, 83.50, 82.00, 82.00, 81.00, 79.00,
76.50, 75.50, 75.50, 75.50, 75.50, 74.50, 74.50, 71.50, 69.50,
68.50, 67.50, 67.50, 67.00, 66.50, 66.50, 66.50, 66.00, 64.00,
64.00, 63.50, 63.00, 62.50, 62.00, 60.50, 57.50, 57.00, 56.00,
55.50, 55.50, 55.50, 55.50, 55.00, 53.50, 53.50, 53.50, 50.00,
46.50, 45.25, 43.50, 42.50, 23.75, 18.50



I want to think about it a little bit more but I'm currently leaning against any sort of class-wide adjustment of the scores. If that were to happen I believe the maximum I'd add would be 6 points.

CSc 372, Fall 2006
Final Examination Solutions

Problem 1: (13 points; average: 10.8)

In this problem you are to write a Ruby program `xref.rb` that prints a cross-reference table of what identifiers appear on which lines in a Ruby program.

```
ids = Hash.new([])
lnum = 1
while line = gets
  line.scan($id_re).each {|id| ids[id] += [lnum] unless $kwds.include? id }
  lnum += 1
end

ids.sort.each {
  |pair|
  id = pair[0]
  lines = pair[1].uniq
  printf("%s: %s\n", id, lines * ", ")
}
```

Problem 2: (8 points; average: 6.7)

The `connect` predicate on assignment 9 printed a representation of a sequence of cables. In this problem you are to write a Ruby method `parse_layout(s)` that parses such a representation and returns an array of arrays representing the cables.

```
>> parse_layout("M---MF-MF----M")
=> [{"m", 3, "m"}, {"f", 1, "m"}, {"f", 4, "m"}]
```

Here's what I thought of right off the bat:

```
def parse_layout(s)
  r = []

  s.downcase!
  while s =~ /([mf])(-+)([mf])/
    r << [$1, $2.size, $3]
    s[$&] = ""
  end

  r
end
```

Mr. Ghigliotti and Mr. Sortelli used an approach like this:

```
def parse_layout(s)
  s.downcase.scan(/([mf])(-+)([mf])/).map {|e1, ds, e2| [e1, ds.size, e2] }
end
```

Problem 3: (2 points; average: 1.1)

Specify the contents of a Ruby source file, `tptnf.rb`, such that after loading it, `2+2` is not 4.

```
class Fixnum
  def + rhs
    0
  end
end
```

Common errors were to omit `class Fixnum` and to specify more than one parameter for the `+` method. (Remember that `a+b` is like `a.+(b)`).

Problem 4: (4 points; average: 2.7)

(a) In a non-recursive way, implement `between(+Low, +High, -Value)`.

```
between(Low, High, Value) :- numlist(Low, High, List), member(Value, List).
```

(b) In a non-recursive way, implement `numlist(+Low, +High, -Value)`.

```
numlist(Low, High, List) :- findall(Value, between(Low, High, Value), List).
```

The answers for `between` were mostly correct but only about a dozen answers for `numlist` were correct.

Problem 5: (6 points; average: 4.1)

Write a Prolog predicate `idpfx(+List, -Prefix)` that instantiates `Prefix` to the longest prefix of `List` such that all elements of the prefix are identical.

```
idpfx(L,P) :- reverse(L,R), append(_, P, R), allsame(P), !.
```

Problem 6: (14 points; average: 12.9)

Write a predicate `show_cost(C)` that prints a description and cost of the cable `C`. Cables are represented using a structure with the functor `cable`. The structure `cable(m,2,f)` represents a 2-foot cable with a male connector on one end and a female connector on the other.

```
show_cost(Cable) :-
  order(Cable, cable(E1, Len, E2)),
  map(E1, E1nm),
  map(E2, E2nm),
  cost(E1nm, E1Cost),
  cost(E2nm, E2Cost),
  cost(foot, FootCost),
  Cost is FootCost * Len + E1Cost + E2Cost,
  format('~w-foot ~w to ~w: $~2f~n', [Len, E1nm, E2nm, Cost]).

order(cable(E1, Len, f), cable(f, Len, E1)).
order(X, X).

map(m, male).
map(f, female).
```

Problem 7: (7 points; average: 8.1)

Write a predicate `halves(+L, -H1, -H2)` that instantiates `H1` and `H2` to the first and second halves of the list `L`, respectively. `halves` fails if `L` has an odd number of elements.

```
halves(L, H1, H2) :- append(H1, H2, L), length(H1, Len), length(H2, Len).
```

When I wrote my first solution for this I checked for an even number and then used `length` to form a half-sized list. I then realized that a description of halving, "find a place to cut this so you get two equal parts", works in Prolog, too!

Problem 8: (8 points; average: 3.3)

Write a predicate `wseq(+Words, -Seq)` that finds a sequence of the atoms in `Words` such that the last character of each atom is the same as the first character of the next atom. Here is a simple example:

```
wseq([W], [W]).

wseq(Ws, [W1, W2|Sorted]) :-
    select(W1, Ws, Rest),
    wseq(Rest, [W2|Sorted]),
    pair(W1, W2).

pair(A1, A2) :-
    atom_chars(A1, C1),
    atom_chars(A2, [C1_]),
    last(C1, C).
```

Problem 9: (2 points each; 16 points total; average: 12.1)

The expression $(f\ 1\ 2)$ has meaning in both ML and Emacs Lisp. In Emacs Lisp it means to call the function f with the arguments 1 and 2. Does it mean the same thing in ML? If not, what does it mean?

In ML it means $((f\ 1)\ 2)$ — call f with the argument 1. Then call the function produced by $(f\ 1)$ with the argument 2.

It's well known that thinking up names for variables and functions is not always easy and that bad names make code harder to understand. This is sometimes called the "naming problem". It can be said that with respect to Java, one of our three primary languages makes the naming problem worse. Another of the three lessens the naming problem. The third is roughly neutral—it requires about as much naming as Java. Which language is which? Briefly state why.

I'd say that Prolog makes the naming problem worse because there's no nesting of expressions; ML makes things better thanks to partial applications and anonymous; Ruby is neutral.

With the Icon programming language in mind, what's meant by the term "failure"? Show two distinct examples of expressions that can fail or succeed depending on the values of the variables involved.

When an expression is evaluated in Icon it either succeeds and produces a result or it fails and produces no result. Failure propagates to enclosing expressions and they fail in turn.

Two examples of expressions that can fail are $x < y$ and $s[n]$.

Prolog has predicates for comparison like $>/2$ and $==/2$ but it does not have predicates for arithmetic like $+/2$ and $/2$. Why is that?*

Success or failure itself is a meaningful result that is manifested by control continuing through the goal (or not). Arithmetic expressions need to produce a result but an expression like $3 + 4$ simply doesn't provide a place to specify a result. Arithmetic predicates would need to look like `add(3, 4, R)` and things would get clumsy fast.

Which does Prolog use—compile-time type checking or run-time type checking? Or does the notion of type-checking not really apply to Prolog? Support your answer with a brief argument.

A number of students said that Prolog has no type checking—type mismatches simply produce "No" but that's incorrect. Consider `X is 3 + abc`. There's no error when that code is loaded but there is an error when that goal is evaluated.

Ruby's designer elected to have `string[n]` produce an integer character code instead of a one-character string. Ignoring possible performance considerations write a brief argument either in favor of this design decision or against it.

I personally think this is a terrible idea but that's perhaps because I'm used to Icon, which produces a one-character string for `string[n]`.

Write a simple Ruby method that takes advantage of duck typing and briefly explain how duck typing allows the code to be simpler, or more expressive, or etc.

The method

```
def double x
  return x + x
end
```

"doubles" `x` by adding it to itself. This has meaning for any type that has provided a meaning for addition.

The term "duck typing" appears to have originated in the Ruby community but the idea has been around for years; routines like `double` are said to be "polymorphic".

What is meant by the term "syntactic sugar"?

A syntactic construct that is not necessary but provides a more convenient way to express something.

Problem 10: (1 point each; 4 points total; average: 2.5)

Characterize each statement below as true or false.

F The instructor prefers the term "scripting language" to categorize languages like Icon, Perl, Python, and Ruby.

It's true that I made a practice of calling Ruby a "scripting language" but I also said that in general I don't like that term to describe languages like Icon, Perl, Python, and Ruby. The industry may well be stuck with "scripting language" by now but an alternative I prefer is "agile language". However, when you start trying to characterize agile languages you often end up with only one thing in common: dynamic typing, so maybe "dynamically typed language" is the best term.

Lisp is an interesting case: it's dynamically typed but I think its syntax is sufficiently cumbersome to make me hesitate saying it's agile.

I think the term "scripting language" should be reserved for languages that let one orchestrate a series of commands in another computational domain with little interaction between the domains and/or little knowledge of either domain in the other domain. For example, most shells support scripts that string together commands but the only communication between the two domains is via command line arguments, termination codes, and standard input/output. The shell has no knowledge of what `cat`, `ls`, `find`, etc. are doing and the programs have no knowledge of the shell—they simply take arguments, maybe handle standard input/output, and produce an exit code.

F In Icon, the expression `write(1 to 10)` prints the numbers from 1 through 10.

Just about everybody missed this one. When `write(1 to 10)` is evaluated the generator `1 to 10` produces 1,

the first value in its result sequence, and that is written out. To get all the numbers you need to put in a context where the generator is resumed until it is exhausted, like `every write(1 to 10)` or `write(1 to 10) & p()`, where `p` is a procedure that always fails.

F The Prolog fact $p([A,B,C])$ indicates that $p(X)$ is true iff X is a three-element list whose values are all different.

The use of three different variables allows unification with three different values but it does not require them to be different.

T The regular expression $/[a-z][x][123]/$ can be written more concisely.

$/[a-z]x[123]/$ (A one-character character class is equivalent to a single character.)

Problem 11: (18 points)

The average on the essay questions was 16.53.

Problem 12: (6 points, EXTRA CREDIT; average: 1.74)

Using the parsing idiom supported by Prolog's rule notation, write a predicate `parse(S)` that parses a simple Ruby string subscripting expression and outputs a line representing a method call that performs the same computation.

```
?- parse('s[1]').
s.charAt(1)
Yes
```

```
?- parse('line[10,20]').
line.substr(10,20)
Yes
```

```
parse(S) :- atom_chars(S,C), subexpr(R, C, []), show(R).

subexpr(sub(Id,D)) --> id(Id), lbrack, digits(D), rbrack.
subexpr(sub(Id,D1,D2)) --> id(Id), lbrack, digits(D1), [','], digits(D2), rbrack.

show(sub(Id,D)) :- format('~w.charAt(~w)~n', [Id, D]).
show(sub(Id,D1,D2)) :- format('~w.substr(~w,~w)~n', [Id, D1, D2]).

lbrack --> '['.
rbrack --> ']'.
```

In many answers the `format` calls were in the grammar rules. There was no deduction for that but it's not entirely correct. The problem with printing in the rules is that there may be trailing characters, like `'s[1]x'`. If so the printing is premature.

Extra Credit Section (one half-point each unless otherwise indicated; average: 4.0)

NOTE: In general, incorrect but humorous answers worked, too.

(1) What programming language in the SNOBOL/Icon family was developed between SNOBOL4 and Icon?

Lots of students said "SNOBOL5" but it was "SL5" (SNOBOL Language 5).

(2) Name a programming language that allegedly supports more than seven (7) programming paradigms.

I made the briefest mention of it while looking at the Wikipedia "Multi-Paradigm" page during the last class but Oz is claimed to support eight programming paradigms. It can also be argued that due to its flexibility Lisp can support any paradigm so I accepted Lisp as an answer as well.

- (3) *Order these languages by age, oldest to youngest: Java, Icon, Lisp, ML, Ruby, Scala.*

I'd say the order is Lisp, ML, Icon, Ruby, Java, Scala but Java and Ruby are very close. As long as those two were consecutive either order was acceptable for them. I counted an answer as correct if at most a single deletion yielded a valid ordering.

- (4) *(2 points) Write an ML function $eq(L1, L2)$ of type `'a list * 'a list -> bool` that returns true iff the lists $L1$ and $L2$ are equal. Be sure to accommodate lists that contain lists.*

It wasn't very conservation-minded to allow so much space for such a short answer but here's all you need:

```
fun eq(L1,L2) = L1 = L2
```

I should have deducted a little bit for `fun eq(L1,L2) = if L1 = L2 then true else false`, but I looked the other way.

- (5) *Imagining that Ruby has Icon's notion of failure, rewrite the following code to take advantage of failure:*

```
for i in 0...len
  c = self[start+i]
  if c then
    r += c.chr
  end
end
```

There would be no need to see if `c` was `nil`:

```
for i in 0...len
  r += self[start+i].chr
end
```

- (6) *What is a connection of sorts between Java and constraint programming?*

James Gosling's Ph.D. dissertation concerned the algebraic manipulation of constraints.

- (7) *In three words or less, describe Icon in terms of the languages we studied this semester.*

What I had in mind was "Ruby meets Prolog" but other answers worked, too.

- (8) *In three words or less, describe Scala in terms of the languages we studied this semester.*

What I had in mind was "Java meets ML".

- (9) *The names Java, Ruby and Icon are not acronyms. Create a humorous acronym for each that is somehow related to the language, like Lisp: *Lost In Stupid Parentheses*. (1/2 point each)*

I was surprised by the number of good ones that turned up. I wish I had time to quote them all.

- (10) *(1 point) In SWI-Prolog the query `?- X.` produces an "Easter Egg" that alludes to a well-known book. What is the title of that book?*

tHHGttG

(11) *Who was the central character in the short film Jarwars Episode III, Revenge of the <T>?*

Duke Vader

(12) *According to assigned reading, the only well-known scholarly paper published by Bill Gates concerned what problem?*

I believe that just about the only reading I assigned (rather than only suggested) was in the assignment 9 write-up: "There's even a Wikipedia article about pancake sorting. (Read it!)"

(13) *On every lecture day the instructor ate breakfast at Millie's Pancake House. Estimate the total number of pancakes he consumed at Millie's during those breakfasts.*

Zero. I prefer their waffles! I'll sometimes have the German Pancake but there was never enough time for one of those on lecture days.

Only Mr. Hoskins got this one, speculating that I was probably too busy flipping them to eat any.

(14) *(2 points) In any language you wish, write a program to read this exam as plain text on standard input and output the total number of points for all the regular problems, i.e., don't worry about this extra credit section.*

```
sum = 0
while line = gets
  if line.chomp! =~ /(\d+) points( total)?\)$/ then
    sum += $1.to_i
  end
end
puts sum
```

Mr. Merrill's solution was unique: The language he chose was English!

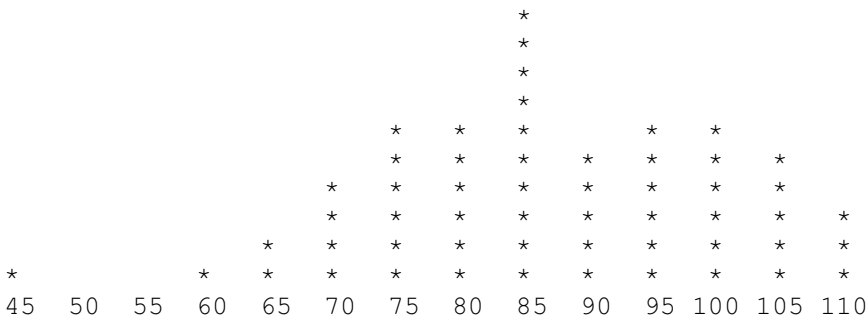
Overall statistics

The average on the exam was 86.57; the median was 85.5.

Here is the full set of scores:

110.00, 109.00, 108.00, 105.00, 104.50, 104.00, 103.00, 103.00, 102.00, 101.50,
99.00, 98.50, 98.00, 98.00, 97.00, 96.00, 95.00, 95.00, 94.50, 93.50, 92.00,
90.00, 90.00, 89.50, 87.50, 87.00, 87.00, 85.50, 85.50, 85.50, 84.50, 84.50,
83.50, 83.00, 82.50, 82.00, 82.00, 81.50, 81.00, 79.50, 78.50, 77.00, 76.00,
75.00, 75.00, 73.50, 73.50, 72.00, 70.50, 70.50, 69.50, 64.00, 64.00, 58.00,
46.50

Here is a histogram:



Solutions for
CSC 372 Haskell Mid-term Exam
February 28, 2014

Problem 1: (15 points) Mean and median: 10.8, 10.5

What is the type of the following values? If the expression is invalid, briefly state why.

Assume numbers have the type `Int`. Remember that the type of `True` is `Bool`.

`"x"`
[Char] or String

`(1, 'x', [True])`
(Int, Char, [Bool])

`["x":[]]`
[[[Char]]]
A little tricky, and gotten wrong by many, typically one set of brackets short. Think about turning `"x":[]` into `["x"]`, then `[['x']]` and then adding the outer brackets for `[[['x']]]`, to get `[[[Char]]]`.

`head`
[a] -> a

`not . not . isLetter`
Char -> Bool

`map not`
[Bool] -> [Bool]

`(+1) . (0<)`
Invalid, since `(0<)` produces a `Bool`, and `Bools` can't be added.

`\x -> x + 1`
Int -> Int

`[1, '2', "3"]`
Invalid, due to multiple types.

`isDigit . chr . head . (:[]) . (+3) . ord . chr`
Int -> Bool

As I mentioned at least a couple of times in class, if a composition is valid you only need to look at the input of the rightmost function and the output of the leftmost function to know the type of the full composition.

Problem 2: (12 points) (two points each) Mean and median: 10.7, 11

Using no functions other than helper functions you write yourself, implement the following Prelude functions.

Note: There will be a 1/2-point penalty for each case of not using the wildcard pattern (the underscore) where it would be appropriate.

I forgot to specify handling for empty lists for `head` and `tail` so we didn't take that case into account when grading.

```
head [] = error "empty"
head (h:_) = h

tail [] = error "empty"
tail (_:t) = t

length [] = 0
length (_:t) = 1 + length t

sum [] = 0
sum (h:t) = h + sum t

last [] = error "shortList"
last [x] = x
last (_:t) = last t

snd (_,x) = x
```

Problem 3: (10 points) Mean and median: 9.3, 10

Write a function `prswap` that swaps the elements of a list on a pair-wise basis. That is, the first and second elements are swapped, the third and fourth are swapped, etc.

ASSUME the list has an even number of elements but is possibly empty.

There are no restrictions on this problem.

A few approached this with a helper function for tracking the position and I think there were even a handful that used folding but my intention was a simple recursive solution:

```
prswap [] = []
prswap (a:b:xs) = b:a:prswap xs
```

Several students used a take 2/drop 2 approach, like this:

```
prswap [] = []
prswap list = reverse (take 2 list) ++ prswap (drop 2 list)
```

One of the general wisdoms I've learned for languages that support cons lists is that cons is always preferred over concatenation. Cons simply makes a new node but concatenation is done by making a series of cons nodes with each of the elements in the left operand. Here's the source for `++` from the Haskell Prelude:

```
(++) [] ys = ys
(++) (x:xs) ys = x : xs ++ ys
```

Something like `[1,2,3] ++ [4,5,6]` is effectively `1:2:3:[4,5,6]`

With all that in mind I'd think that the take 2, drop 2, concat version would be much slower and take far more memory but with `:set +s` in my `.ghci` I see the following.

```
% cat prswap.hs
prswap1 [] = []
prswap1 (a:b:xs) = b:a:prswap1 xs

prswap2 [] = []
prswap2 list = reverse (take 2 list) ++ prswap2 (drop 2 list)

m = [1..10000000]

run1 = length $ prswap1 m
run2 = length $ prswap2 m

% ghci prswap.hs
...
> run1
10000000
(3.87 secs, 1765864896 bytes)

% ghci prswap.hs (Fresh run of ghci, to get a clean slate.)
...
> run2
10000000
(4.97 secs, 3325445008 bytes)
```

The cons version is faster but only by about 20%. The cons version has half as much memory throughput but I imagined it'd be a smaller fraction of the concat version. Results were similar with repeated testing.

I've clearly got a lot to learn about Haskell!

This is also a good example of a bad assumption about performance. I've seen plenty of those in my career, both by myself and others, and I've learned that nothing takes the place of running cases and looking at the numbers. But even then, pitfalls abound!

Problem 4: (10 points) Mean and median: 9.5, 10

Write a function `rotabc` that changes `a`'s to `b`'s, `b`'s to `c`'s and `c`'s to `a`'s in a string. Only lowercase letters are affected.

There are no restrictions on this problem but it must be written out in full detail—no ditto marks, abbreviations, etc. It must be ready for an ASU or UNC-CH CS graduate to type in.

Here's a solution written by an N. C. State University grad:

```
rotabc = map f
  where
    f 'a' = 'b'
    f 'b' = 'c'
    f 'c' = 'a'
    f c = c
```

I'd hoped that most students would immediately see this as a mapping problem. Also, my hope in requiring the solution to be written out in full detail was to make people think in terms of low repetition but I suppose that once a solution is mind there's a strong temptation to just go with it.

Lots of solutions were recursive and repetitious, like this:

```
rotabc [] = []
rotabc (c:cs)
  | c == 'a' = 'b': rotabc cs
  | c == 'b' = 'c': rotabc cs
  | c == 'c' = 'a': rotabc cs
  | otherwise = c : rotabc cs
```

Problem 5: (20 points) (ten points each) Mean and median: 9.6, 10 for recursive; 8.3, 10 for non-recursive

For this problem you are to write two separate versions of a function named `bigTuples` (call it `bt`).

One version must not use any higher order functions (like assignment 1); the other version must not use any explicit recursion (like assignment 2, minus `warmup.hs`).

`bigTuples max tuples` produces a list of the 2-tuples in `tuples` whose sum is larger than `max`, i.e., for a tuple (a,b) , $a + b > \text{max}$.

```
bigTuples _ [] = []
bigTuples n ((x,y):ts)
  | x+y > n = (x,y):rest
  | otherwise = rest
  where
    rest = bigTuples n ts

bigTuples n tuples = filter (\(x,y) -> (x+y) > n) tuples
```

Problem 6: (6 points) (5 for function, 1 for type) Mean and median: 4.9, 6

Write a function `fml list` that returns a 3-tuple with the first, middle and last elements of a list. Assume the list is non-empty and has at least one element.

Restriction: You may not use the !! list indexing operator.

And, answer this question, too: What is the type of `fml`?

```
fml :: [a] -> (a,a,a)
fml x = (head x, middle, last x)
  where
    middle = last (take ((length x `div` 2) + 1) x)
```

Some students made this a little harder than necessary by writing a recursive function to find the middle element of a list, some with a counter and some with an `init` and `tail` combo to repeatedly take an element off both ends. I'll be honest and say that when grading we didn't take too close a look for off-by-one errors on the counter-based functions, figuring they were already self-penalizing by the amount of time they took.

Problem 7: (10 points) Mean and median: 6.9, 9.5

Consider a function `separate s` that returns a 2-tuple with the digits and non-digits in the string `s` separated, with the initial order maintained.

```
> separate "July 4, 1776"
("41776", "July , ")

> separate "Problem 7: (10 points)"
("710", "Problem : ( points)")
```

Here is a partial implementation of `separate`, using `foldr`:

```
separate s = foldr f ([],[]) s
```

Your task on this problem is to write the folding function `f`. Remember that for `foldr`, the type of the folding function can be described as `elem -> acm -> elem acm`. Use `isDigit` to test for a digit.

```
f elem (digs, non)
  | isDigit elem = (elem:digs, non)
  | otherwise = (digs, elem:non)
```

Here's a Thanks! and a Bug Bounty Point to Mr. Garcia for being the first to point out that I'd specified the wrong type for the folding function, ending with `elem` instead of `acm`! What a whopper!!

Problem 8: (5 points) Mean and median: 2.6, 3.5

Implement `map` in terms of a fold.

Your solution must look like this: `map f list = fold...`

```
map f list = foldr (\e acm -> f e:acm) [] list
```

Problem 9: (2 points) Mean and median: 0.6, 0.5

Without using explicit recursion, write `last` in point-free style. Hint: Tough, and easy to get backwards! Don't worry about handling empty lists.

Note: Wording changing at start of exam to "Write `last` in terms of a fold: `last = fold...`"

```
last = foldl1 (\_ e -> e)
```

Without that last minute wording change the problem had a trivial solution, but worth a ½ point of extra credit:

```
last = head . reverse
```

Problem 10: (10 points) (one point each unless otherwise indicated) Mean and median: 8.0, 8

Answer the following questions. Keep your answers brief for questions 4-10—assume that the reader is a 372 classmate who just needs a quick reminder.

- (1) Who founded the University of Arizona Computer Science department and when? (2 points)
Ralph Griswold, in 1971.

If you see this question again it might be worth zero points if correct but -2 points if wrong! Feel free to write this information on the back of your hand before future exams in 372.

- (2) Name two programming languages created **before 1990**.
See intro slide 20, but the first two that come to mind for me are FORTRAN and COBOL.
- (3) Name two programming languages created **after 1989**.
Lots on slide 20 but Java and Ruby are two I'd hope you know. Haskell was forming around this time, and counted as correct for this question. Another way to solve this would be "create" two languages on the spot, perhaps named after your goldfish. They'd be vaporware, but good enough!
- (4) Name one language feature you would expect to find in a language that supports imperative programming.
Looping control structures, variables.

- (5) *whm* often says "In Haskell we never change anything; we only make new things." What's an example of that?
A function like `reverse` builds a new list from the elements of an existing list. Another: A function to remove a value from a list builds a copy of the list, not including occurrence(s) of that value.
- (6) *Things like cons lists, recursion, curried functions, and pattern matching on data structures are commonly used in functional programming but there's another capability that without which it's hard to do anything that resembles functional programming. What's that capability?*
The ability to treat functions as values.
- (7) *What is relatively unique among programming languages about the way that Haskell handles strings and lists?*
Strings are simply lists of characters.
- (8) *What is a "partial application"?*
A call to a multiple-argument function that's given fewer parameters than it needs.
- (9) *What is "syntactic sugar"?*
A syntactic construct that makes a language more pleasant to use but that doesn't add a new capability.
- (10) *In general, what's something we can represent with a tuple that we can't represent with a list?*
A heterogenous collection of values, like a string and an integer.

Note: I originally wrote this with nine questions, allowing two points for the first question. Then while "proofreading" I noticed I was a question short, and added a question, for a total of 11 points instead of 10 points. Mr. Srivastava caught this during the exam. Let's think of the extra point as possible extra credit—we'll count the exam as 100 points for purposes of average.

Extra Credit Section (½ point each unless otherwise noted) Mean and median: 1.6, 1.5

- (1) *What is the type of `foldr`?*
I like to describe it as `foldr :: (val -> acm -> acm) -> acm -> [val] -> acm`
- (2) *What is the type of the composition operator?*
`(b -> c) -> (a -> b) -> a -> c`
- (3) *What's meant by "lexicographic comparison"? (Hint: Don't just say "dictionary order.")*
Pair-wise comparison of a sequence of values until a pair differs, with the difference deciding the ordering.
- (4) *Name a programming language created at the University of Arizona.*
Intro slide 31 names a number of them but Icon is one I'd hope you know of. A presentation on Icon that Griswold gave at N. C. State led me to come to graduate school here to work on Icon. (I got on their radar here, ultimately getting a research assistantship, by being the first person to get Icon working on IBM mainframes.)

Lots of people cited SNOBOL. Griswold continued work on SNOBOL4 here at The University of Arizona but SNOBOL through SNOBOL4 were created at Bell Labs. There was also SL5 (SNOBOL Language 5) but Griswold ultimately was not happy with it. It was never released to the public although many papers about it were published while it was being developed.

Mr. Garcia used the approach suggested on Problem 10(3) with "Grant++". I made it just now." That's good for an Original Thought!
- (5) *Haskell functions like `getLine` and `putStrLn` return an action. What does an action represent?*
An interaction with the outside world that happens when the action is evaluated.

- (6) What is the exact type of the list `[head, tail]`?
`[head, tail]` is an invalid list, since the types differ.
- (7) If you only remember one thing about the Haskell segment of 372, what will it be? (Ok to be funny!)
 If time permits I'll issue a revised version with some of the highlights of these but I'm short on time at the moment!
- (8) With Ruby in mind, cite an example of an imperative method and an example of an applicative method.
`reverse!` and `reverse` are the first two that came to mind for me.
- (9) Write a **Ruby** method `printN` that prints the numbers from 1 to N on a single line, separated by commas. (1 point)

```
def printN n
  (1..n).to_a * ", "
end
```

- (10) Predict the median score on this test. (The median is the "middle" value in a range of values.)

I was wondering if *The Wisdom of Crowds* (see Wikipedia) would apply here but not so. These were the predictions.

```
100, 100, 88, 86, 84, 84, 83.2, 83, 83, 82, 81, 81, 81, 80, 79, 79, 78, 78,
76, 76, 75, 75, 75, 75, 74, 74, 72, 72, 72, 72, 71, 71, 70, 70, 70, 68, 65,
65, 60, 50, 50, 50
```

The mean of those predicted medians is 75.2. Any prediction at all earned the ½ point.

Here are the actual scores:

```
102, 102, 101.5, 100.5, 100.5, 100, 99, 97.5, 97, 95.5, 95.5, 95, 95, 94.5,
94, 93, 92.5, 92, 92, 91, 91, 91, 90.5, 90, 90, 90, 89, 88.5, 88, 87, 86,
83.5, 83, 82.5, 81, 80.5, 79.5, 79, 78.5, 78, 78, 78, 77.5, 76.5, 76.5, 76,
75, 74.5, 73.5, 69.5, 68, 66, 64.5, 59, 58, 52, 49, 45, 29.5
```

Simple statistics:

```
n = 59
mean = 82.7542
median = 87
```

For the record, here are the changes/updates accumulated during the exam and shown on the screens:

Exam done: 10:52

Prob 2: `head, tail`: assume not empty

Prob 6 (fml): Assume odd number of elements

Prob 7: `foldr` is `elem` -> `acm` -> `acm` (not `elem`!!)

Problem 9 change:

Write `last` in terms of a fold, just like problem 8, but for last

Problem 10 (8) (9) Ok to just cite an example.

New EC: Answer Problem 9 in a different way, just following the instructions as written, which make it trivial! :(

Solutions for
CSC 372 Ruby Mid-term Exam
April 11, 2014

Problem 1: (21 points) Mean and median: 17.6, 19

In this problem you are to write a Ruby program `tail.rb` that prints the last N lines of standard input, just like the UNIX `tail` command. ...

The solution I wrote when timing myself was this:

```
if ARGV.length != 1 || (not ARGV[0] =~ /^-\d+$/)
  puts "Usage: tail -N"
  exit 1
end

n = -ARGV[0].to_i

lines = []
while line = STDIN.gets
  lines << line
end

if n > lines.size
  n = lines.size
end

(-n).upto(-1) { |i| puts lines[i] }
```

With some time to think and some good ideas from student solutions, I offer this simpler version:

```
if ARGV.length != 1 || (not ARGV[0] =~ /^-\d+$/)
  puts "Usage: tail -N"
  exit 1
end

n = -ARGV[0].to_i

lines = STDIN.readlines

n = lines.size if n > lines.size

puts lines[-n..-1]
```

Problem 2: (17 points) Mean and median: 13.5, 15.5

In this problem you are to write a method `load_facts(file_name)` that reads Prolog facts from the specified file and returns a Ruby hash that holds a representation of the facts.

```
def load_facts(file_name)
  facts = Hash.new []

  f = File.open(file_name)

  while line = f.gets
    line.chomp!
    if line =~ /^(\w+)\((.*)\)\.$/
      facts[$1] += [$2.split(",")]
    end
  end

  f.close
  facts
end
```

The combination of initializing the hash facts with `Hash.new []` and using `+=` allows avoiding a check to see whether `facts[$1]` already exists. (Using `<<` instead of `+=` would break it. Try it and be the first to explain why on Piazza!)

Because the input can be assumed to be valid, only processing lines that start with `/\w/` suffices to ignore empty and blank lines.

Common mistakes, shown as variations of the above, were these:

```
facts[$1] = $2.split(",")      # Doesn't build an array of arrays
facts[$1] += [$2]              # Doesn't split
```

Some students used various splits but here's the good one:

```
parts = "food(just,a,test,here)".split(/[,()]/)
```

The functor ends up in `parts[0]`; the terms are in `parts[1..-1]`.

Let's combine that with a variation of parallel assignment that we didn't study but that is similar to the mechanism for handling varying numbers of arguments:

```
>> head, *tail = "food(just,a,test,here)".split(/[,()]/)
>> head      => "food"
>> tail      => ["just", "a", "test", "here"]
```

Problem 3: (15 points) Mean and median: 9.3, 10.5

This problem is a partner to `load_facts`. You are to write a Ruby method `print_preds` that takes the hash produced by `load_facts` (the previous problem) and prints a list of predicate indicators.

My draft solution is below but Dennis noticed a bug in it. Cover the portion of the page the follows the code and play exam grader for a minute to see if you see it!

```
def print_preds h
  for k in h.keys.sort
    lens = h[k].collect {|a| a.size }
    for n in (lens.min)..(lens.max)
      puts "#{k}/#{n}"
    end
  end
  nil
end
```

The problem is that it assumes a contiguous range of "arities". For example, given `x(a)`. and `x(a,b,c)`., it'll output `x/1`, `x/2` (oops!), and `x/3`. That was true with the sample data I provided but not true in general.

If had recognized the potential of noncontiguous arities, I would have mentioned `Array#uniq`, which is similar to UNIX's `uniq` command, discarding non-unique values:

```
>> [3,1,2,3,1,3].uniq => [3, 1, 2]
```

`uniq` enables this concise solution:

```
def print_preds h
  for k in h.keys.sort
    for n in lens = h[k].collect {|a| a.size }.uniq.sort
      puts "#{k}/#{n}"
    end
  end
  nil
end
```

Without `uniq` you need some other way to compute the set of arities. The first thing that comes to mind based on what you've seen is using the `|` operator to form the union of two arrays:

```
>> [3,1]| [1]| [2] => [3, 1, 2]
```

The keys of a hash also constitute a set. A couple of students took that observation further and used the whole predicate indicator, like "food/1", as the key! Here's a solution based on that idea:

```
def print_preds h
  indicators = {}
  h.each { |k, arrays|
    arrays.each { |e| indicators["#{k}/#{e.size}"] = 1 }
  }
  puts indicators.keys.sort
  nil
end
```

There's a slight bug with that because, for example, "t/10" collates before "t/2". With these facts,

```
t(x).
t(x,x).
t(x,x,x,x,x,x,x,x,x,x,x).
```

you'll this output:

```
t/1
t/10
t/2
```

Also, I never mentioned it in lecture but Ruby does have a Set class:

```
>> require 'set'          => true

>> [3,1,3,4,2,1].to_set => #<Set: {3, 1, 4, 2}>
```

I apologize for the unintended difficulty due to my error when writing my own solution, but everybody was in the same boat.

Problem 4: (5 points) Mean and median: 4.0, 4.5

Write a method multstring(spec, s) that behaves like this:

```
>> multstring("3,1,5", "x")
=> "xxx,x,xxxxx"
```

Solution:

```
def multstring(spec,s)
  spec.split(",").map {|e| s*e.to_i} * ","
end
```

Problem 5: (4 points) Mean and median: 2.4, 2.5

Write a method `addrev` such that after calling `addrev`, the unary minus operator applicatively reverses a string.

```
def addrev
  eval("class String; def -@; self.reverse; end; end")
end
```

I didn't expect students to know it but that class declaration must be wrapped in an `eval(...)`. The error "class definition in method body" is produced by this version:

```
def addrev
  class String
    def -@; self.reverse; end; end
end
```

Problem 6: (11 points) (One point each unless otherwise indicated) Mean and median: 7.2, 8.5

(a) Write a regular expression that is equivalent to `/x+/` but that doesn't use the `+` operator.

`/xx*/`

(b) Write a regular expression that is equivalent to `/ax|bx|cx/` but that doesn't use the `|` operator.

`/[abc]x/`

(c) Describe in English the strings matched by `/a*b+c$/`

Strings containing zero or more "a"s immediately followed by one or more "b"s immediately followed by a "c" at the end of the string.

(d) (3 points) Write a regular expression that matches only strings that are binary constants like these:

```
"0b0"
"0B11111"
"0b01010101"
```

The first two characters are a "0" and an upper- or lower-case "B". One or more "1"s or "0"s follow.

Here are two non-matches: "00b1" (extra leading zero), "0b12" (trailing non-0/1).

`/^0[bB][01]+$/`

(e) (5 points) Write a regular expression that matches a string if and only if it is a comma-separated sequence of integers **greater than or equal to 10**. Examples of matches:

`"10, 11, 12"`

```
"30,200,500"  
"100"
```

One optional space may appear after each comma but that is the only place a space may appear.
Leading zeros are not permitted!

Here are three non-matches: "10, 020" (has a leading zero), "7,11" (7 is less than 10), "1x" (has a trailing "x").

```
/^[1-9][0-9]+(,[ ?[1-9][0-9]+)*$/
```

Problem 7: (7 points) Mean and median: 4.7, 6

Write an iterator `take_while(a)` that calls its block with each element of the array `a` in turn. As long as the block returns true, array elements are accumulated. When the block first returns a non-true value or when the array elements are exhausted, an array of the accumulated elements is returned.

```
def take_while a  
  r = []  
  a.each { |e|  
    if yield e  
      r << e  
    else  
      return r  
    end  
  }  
  return r  
end
```

Problem 8: (12 points) Mean and median: 7.9, 8.5

(a) Who invented Ruby? (1 point)

"Matz" is the answer I was hoping for, but "some Japanese guy" was counted as correct, too. Even "Some whack-a-doo! Monkey patching?!? really?" got a point!

(b) Consider a Ruby method `last(x)` that returns the last element of a string or array. Why would `last` be awkward to write and use in Java? (2 points)

Quite a few students pointed out that you'd need to do `length-1` to compute the position of the last element but I was looking for something a little deeper.

I wish I'd stipulated "without overloading" but since I didn't, pointing out that you'd need overloaded methods was counted as correct. However, `char last(String s)` is easy enough but how about the array case? `int last(int a[])` only covers ints, of course. Can it be done with generics?

(c) What's the effect of adding "include Enumerable" to a class definition? (2 points)

Assuming that the class implements each, including Enumerable gives your class all the methods in Enumerable, as you saw with XString.

(d) Cite one way in which Ruby's `if-then-else` is like Haskell's `if-then-else` and one way in which it is different. (2 points)

In both Haskell and Ruby `if-then-else` is an expression, producing a value. Haskell requires an `else` clause but Ruby does not.

(e) A Java newcomer to Ruby might think that `private` and `attr_reader` are keywords but they aren't. What are they? (2 points)

Methods

(f) What's the essential difference between dynamic typing and static typing? (3 points)
Hint: If your answer contains `/(interpret|compile)[rd]?/` there's a fair chance it'll be wrong.

In my mind the essential difference is that with static typing you can detect a particular class of type errors without executing the code but with dynamic typing you cannot.

A number of students had a successful answer that included `/(interpret|compile)[rd]?/` and that was fine but I suggested not using that because I feared answers like "Dynamically typed languages must be interpreted and statically typed languages must be compiled.", which is completely wrong!

Problem 9: (8 points) Mean and median: 4.8, 6

In this problem you are to create a subclass of Shape named Ring. An instance of Ring represents the region between two concentric circles (the black area in the drawing to the right). Along with a label that is passed to Shape's constructor, Ring's constructor takes the radii of the two circles but they may specified be in either order. If the two circles have the same radius, the area of the ring is zero.

Your implementation of Ring should have five methods: a constructor, `area`, `inner`, `outer`, and `inspect`. The methods `area`, `inner`, and `outer` return the area of the ring, the inner radius and the outer radius, respectively. `inspect` displays the inner (smaller) radius followed by the outer radius.

```
class Ring < Shape
  def initialize(label, r1, r2)
    super(label)
    if r1 < r2
      r1, r2 = r1, r2
    end
    @outer, @inner = r1, r2
  end

  attr_reader :inner, :outer
```



```

def area
  @outer**2*Math::PI - @inner**2*Math::PI
end

def to_s
  "Ring #{label} (#{@inner}-#{@outer})"
end
end

```

Extra Credit Section (½ point each unless otherwise noted) Mean and median: 3.0, 3.25

- (a) *What does whm consider to be the all-time greatest Original Thought ever put forth by one of his 372 students?*

Joe Astier, in my Fall 1996 class, likened a Prolog predicate to a motor: If you apply current to a motor, it turns the rotor; if you turn the rotor, current is produced.

Technical note: My understanding is that it must be a DC motor with a magnet.

- (b) *Based on the Prolog we've covered, is Prolog statically typed or dynamically typed? (And why?)*

Dynamically typed

- (c) *What thing in Ruby is closest to a Prolog atom?*

Symbols

- (d) *Which is the oldest of Java, Haskell, and Ruby?*

Haskell

- (e) *The term "mixin" came from a business that sold what to college students?*

The business was Steve's Ice Cream but I imagine that Steve sold other stuff, too.

- (f) *Regular expressions are Type 4 languages in the Chomsky hierarchy of languages.*

- (g) *Predict the median score on this exam. (The median is the "middle" value in a range of values.)*

Here are the predictions: (mean = 74.4, mode = 75, median = 75)

50, 50, 60, 65, 65, 67, 67, 70, 70, 70, 70, 70, 72, 72, 72, 72.71,
74, 74, 75, 75, 75, 75, 75, 75, 78, 78, 79, 79, 80, 80, 81, 82,
82, 82, 83, 83, 84, 84, 84.726953281, 85, 85

Here are the actual scores:

104, 103, 100.5, 100.5, 99, 98.5, 96, 96, 94.5, 93, 91.5, 91.5,
90, 90, 89, 89, 88.5, 88, 88, 86, 86, 85.5, 84, 83.5, 82.5, 82,
81.5, 79, 79, 78.5, 78.5, 78.5, 78.5, 78, 78, 78, 77, 75, 73.5,
70.5, 69.5, 69.5, 69, 68, 66.5, 65.5, 64.5, 63, 62.5, 60.5, 57,
53, 48.5, 44, 38.5, 38, 31.5, 28.5, 15.5

Simple statistics:

```
N = 59
mean = 75.8729
median = 78.5
```

If I had more time I'd compile the interesting answers from the following but alas I don't have that time to spare at the moment. If time permits, I'll issue an update.

One man's trash is another man's treasure so as you'd expect, what seemed stupidest to some, like monkey patching, seemed best to others.

(h) *If you only remember one thing about Ruby, what will it be? (Ok to be funny!)*

(i) *What's the stupidest thing in Ruby? Can't be the same as (h) or (j). (1 point)*

(j) *What's the best thing in Ruby? Can't be the same as (h) or (i). (1 point)*

(k) *Implement `attr_reader`. (1 point)*

```
def attr_reader *attrs
  attrs.each { |attr|
    eval("def #{attr}; @#{attr}; end")
  }
end
```

The real `attr_reader` is a method of `Module` but the above works as-is.

Solutions for
CSC 372 Final Exam
Wednesday, May 14, 2014

Problem 1: (6 points)

Mean and median: 5.1, 6

Cite three things about programming languages you learned by watching your classmates' video projects. Each of the three should be about a different language.

I tallied the languages cited in the responses and came up with these numbers:

Java	34
PHP	19
Lua	17
Python	15
Ruby	12
Lisp	8
C#	7
MATLAB	5
Haskell	5
C++	4
C	4
vimscript	3
R	3
Dart	3
JavaScript	2

The relatively high interest in Lisp reflected above reminds me that I should probably be whipped for not spending at least a little time on Lisp in this course. I did do a sidebar slide on Lisp in the Haskell set (#127) but ended up skipping it due to time. If you want to see a little bit of Lisp in the context of Emacs Lisp, see <http://www.cs.arizona.edu/~whm/352/elisp.sli.pdf>.

Problem 2: (6 points)

Mean and median: 5.1, 5.5

Write the following simple Prolog predicates. There will be a half-point deduction for each occurrence of a singleton variable or failing to take full advantage of unification.

Restriction: No library predicates may be used other than `is/2`.

`last(?List, ?Elem)` specifies the relationship that `Elem` is the last element of `List`, which is assumed to be non-empty.

`last([X], X).`

```
last([_|T], X) :- last(T,X).
```

member(?Elem, ?List) specifies the relationship that *Elem* is a member of *List*.

```
member(X,[X|_]).  
member(X,[_|T]) :- member(X,T).
```

length(?List, ?Len) specifies the relationship that *List* is *Len* elements in length.

```
length([],0).  
length([_|T],Len) :- length(T,N), Len is N+1.
```

Problem 3: (8 points)

Mean and median: 6.8, 7.5

Write a Prolog predicate *insrel(+List, -WithReIs)* that instantiates *WithReIs* to a copy of *List* with one of the atoms *<*, *>*, and *=* inserted between each pair of values to reflect the relationship between those values. Assume all values are numbers. Examples:

```
?- insrel([5,3,7,7,0],L).  
L = [5, >, 3, <, 7, =, 7, >, 0] .  
...
```

Solution:

```
insrel([],[]).  
insrel([X],[X]).  
insrel([X,Y|T], [X,Sym|R]) :- which(X,Y,Sym), insrel([Y|T], R).  
  
which(X,Y,'<') :- X < Y.  
which(X,X,'=') .  
which(X,Y,'>') :- X > Y.
```

Problem 4: (7 points)

Mean and median: 5.7, 7

Write a Prolog predicate *alltails(+List, -T)* that first instantiates *T* to the tail of *List*. If an alternative is requested, it generates the tail of the tail of *List*, and so forth, thus generating "all the tails".

```
alltails([_|T],T).  
alltails([_|T],R) :- alltails(T,R).
```

Problem 5: (10 points)

Mean and median: 8.2, 9

Write a Prolog predicate *pinch(+List, -Pair)* that instantiates *Pair* to a series of *pair/2* structures. The first *pair* structure has the first and last values of *List*. The second *pair* has the second and next-to-last values of *List*. And so forth. Example:

```
?- pinch([a,b,c,d,e,f],P).  
P = pair(a, f) ;  
P = pair(b, e) ;  
P = pair(c, d) ;  
false.
```

Solution:

```
head([H|_],H).
pinch(L, pair(First,Last)) :- head(L,First), last(L,Last).
pinch([_|T], pair(F,L)) :- append(Rest,[_],T), pinch(Rest,pair(F,L)).
```

Problem 6: (5 points)

Mean and median: 4.2, 5

Write a Prolog predicate `sumvals/0` that consolidates all `v/1` facts into a single fact that contains the sum of the terms of those facts. Assume all terms are numbers. There may be any number of `v/1` facts.

```
sumvals :- findall(Val, v(Val), Vals), sumlist(Vals,Sum), retractall(v(_)),
assert(v(Sum)).
```

The first version of my solution had the following no-facts case but just as I was about to deduct points for a solution not having it, I realized it wasn't needed!

```
sumvals :- \+v(_), assert(v(0)), !. % Not needed!
```

Problem 7: (12 points)

Mean and median: 9.2, 11.5

`path(+Start, +End, +Moves, -Path)` instantiates `Path` to a series of values from `Moves` that describe a path from `Start` to `End`, two points on a Cartesian plane. All alternatives are produced if requested. Each move can be used only once in a given path. Example:

```
?- path(p(0,0), p(3,4), [m(4,4),m(3,3),m(0,1),m(-1,0)], Moves).
Moves = [m(4, 4), m(-1, 0)] ;
Moves = [m(3, 3), m(0, 1)] ;
Moves = [m(0, 1), m(3, 3)] ;
Moves = [m(-1, 0), m(4, 4)] ;
false.
```

Solution:

```
path(p(X,Y),p(X,Y),_,[]).

path(p(X,Y), p(DX,DY), Moves, [m(MX,MY)|MoreMoves]) :-
select(m(MX,MY), Moves, Remaining),
NX is X + MX, NY is Y + MY,
path(p(NX,NY), p(DX,DY), Remaining, MoreMoves).
```

Problem 8: (10 points)

Mean and median: 6.4, 7.5

Using the parsing method supported by Prolog's grammar rule notation write a predicate `ptime(+Spec, -Mins)` that parses atoms that represent time durations, like `'10m'`, `'5h'` and `'10:20'`, and instantiates `Mins` to the number of minutes represented by `Spec`.

```
ptime(Spec,Mins) :- atom_chars(Spec,Chars), spec(Mins,Chars,[]).

spec(Mins) --> int(Hours), ['h'], { Mins is Hours * 60 }.
spec(Mins) --> int(Mins), ['m'].
spec(Mins) --> int(H), [':'], int(M), {Mins is H * 60 + M}.
```

Problem 9: (7 points)

Mean and median: 5.7, 6

Write a **Haskell** function `ckconn` that takes a list similar to that used by `a8's connect.pl` and returns `True` or `False`, depending on whether the exact sequence and orientation of cables represents a valid connection.

Example:

```
> ckconn 'm' [('f',10,'m'), ('f',7,'m')] 'f'
True
```

For the type, it was fine to have something like this:

```
ckconn :: Char -> [(Char,Int,Char)] -> Char -> Bool
```

but the type that Haskell infers is this:

```
ckconn :: Eq a => a -> [(a, t, a)] -> a -> Bool
```

Here's the executable code:

```
ckconn _ [] _ = False

ckconn from [(left,_,right)] to =
  from /= left && to /= right

ckconn from ((left,_,right):t) to =
  from /= left && ckconn right t to
```

Problem 10: (7 points)

Mean and median: 5.3, 6

Write a **Haskell** function `connlen` that takes a list of the same type as `ckconn` and **prints** either the length of the configuration, like `"25 feet"` or `"nope"`, if the configuration is not valid.

```
> connlen 'm' [('f',10,'m'), ('f',7,'m')] 'f'
17 feet

> connlen 'm' [('f',10,'m'), ('f',7,'m')] 'm'
nope
```

Solution:

```
connlen :: Char -> [(Char,Int,Char)] -> Char -> IO ()
connlen from cables to = putStr result
  where
    result =
      if ckconn from cables to then
        (show $ sum $ map ( \(_,len,_) -> len) cables)
          ++ " feet\n"
      else
        "nope\n"
```

Problem 11: (14 points)

Mean and median: 11.9, 14

Write a **Ruby program** `shuffle.rb` that reads lines from standard input, shuffles them, and then writes them to standard output.

`shuffle` requires one command line argument, `-N`, which specifies that lines are to be handled in blocks of `N` lines. Assume that standard input consists of a multiple of `N` lines.

Here's a "plug and chug" solution:

```

if ARGV.size != 1 || (not ARGV[0] =~ /^-\d$/)
  puts "Oops!"
  exit 1
end

n = -ARGV[0].to_i

blocks = []
while true do
  block = []
  1.upto(n) {
    line = STDIN.gets
    if !line then
      blocks.shuffle.each { |block|
        block.each { |line| puts line }
      }
      exit
    end
    block << line
  }

  blocks << block
end

```

Those nested each blocks for output can be replaced with just this:

```
puts blocks.shuffle
```

Note that I "punt" on getting out of the `1.upto(n)` block by printing and exiting in the middle of the block when end of file is reached.

If you lean on the library a little more you can come up with this:

```

if ARGV.size != 1 || (not ARGV[0] =~ /^-\d$/)
  puts "Oops!"
  exit 1
end

n = -ARGV[0].to_i

blocks = []

lines = STDIN.readlines.each_slice(n) { |slice| blocks << slice }

puts blocks.shuffle

```

My son pointed out that PHP has `array_chunk`. That suggests a one-liner like this,

```
puts STDIN.readlines.chunks(n).shuffle
```

but I can't find anything like `chunks` in Ruby, which PHP programmers know as `array_chunk`. However, we can correct that omission with this:

```
class Array
  def chunks(n)
    result = []
    self.each_slice(n) { |slice| result << slice }
    result
  end
end
```

I first encountered "shuffle" years ago as an Icon program. At the time I assumed that Ralph Griswold came up with that clever name but maybe it was somebody else. There's a `shuf` Linux command, too. It has the useful behavior of being able to shuffle command-line arguments as well but its `-i` and `-n` options make me wonder if the author knew of `seq` and `head`.

Problem 12: (8 points, one point each)

Mean and median: 5.7, 6

(a) *Who founded UA's CS department, and in what year?*

Ralph Griswold, in 1971. I hope the CS majors will always remember who got this program going.

Ralph once said that on his first day here, he arrived to find a number of students waiting in line outside his office, for advising. Once in his office, he found that he had a desk but no chair.

Ralph said he took the position here with the specific condition that he would not have to serve as department head but when no other suitable candidate was found, he took on that role.

A random memory about Ralph: A tradition started by his graduate students was showing up at his house on Halloween night, and inviting themselves in for a chat. Those Halloween visits by students and former students continued until his death, in 2006.

(b) *Why are Prolog warnings about singleton variables worth paying attention to?*

A singleton warning often indicates a misspelled variable name. In other cases it might indicate that a value is being computed but never used, so why compute it.

(c) *What's the fundamental difference between predicates like `member/2` and `append/3` in Prolog and their superficial analogs in other languages?*

Prolog's `member` predicate can be used to both test for membership in a list, generate all elements in a list and more.

(d) *Draw the box for Prolog's four-port model and label the ports.*

I'm lazy! See slide 55.

(e) *"cons" lists are found in many languages that make use of recursion. What is it about cons lists that makes them well-suited for recursive functions?*

Many problems have a natural recursive formulation of operating on the first element of the list and combining that with the result of the function on the rest of the list.

(f) *Consider this claim: Prolog's grammar rule notation, like `sentence --> article, noun, verb`, is an example of syntactic sugar. Present an argument that either supports that claim or refutes it.*

Grammar rules are a great example of syntactic sugar. Any grammar rule can be brainlessly rewritten by adding

"In" and "Out" arguments to each non-terminal, replacing terminals with list unifications, and removing curly braces around ordinary goals.

- (g) Write a simple **Haskell function** and show an example of using a partial application of that function.

```
> let add x y = x + y
> map (add 5) [1,2,3]
[6,7,8]
```

- (h) What's a very good reason that `ckconn` above uses tuples instead of lists to represent the cables?

Those Prolog lists are heterogeneous.

Extra Credit Section (½ point each unless otherwise noted)

Mean and median: 2.3, 2.5

- (a) What movie inspired the "Original Thought" bonus?

Broadcast News

- (b) *whm* came to graduate school here at UA specifically to join a research team developing a programming language. What was the language?

Icon

- (c) To what current CS faculty member does *whm* attribute the following quotation?

"When you come to a problem you can lean forward and type, or you can sit back and think."

Dr. Proebsting

- (d) *The Prolog 1000* is a compilation of applications written in Prolog and related languages. What's a little odd about it?

There are less than 1000 applications on the list.

- (e) *Jean Ichbiah*, Ada's designer, was said to have once predicted that in ten years only two programming languages would remain in use. Ada was one of the languages. What was the other?

Lisp

- (f) Cite a significant contribution to computer science made by Grady Booch.

He was one of the "Three Amigos"—along with James Rumbaugh and Ivar Jacobson—who created UML.

- (g) What's a language that has/had an "arithmetic if", one form of which looks like this:

```
IF (I-J) 100, 110, 120
```

FORTRAN. Control branches to the statement labeled 100, 110, or 120 respectively, depending on whether the result of $I-J$ is negative, zero, or positive.

- (h) In terms of creators, what do `vim` and Java have in common?

Bill Joy, later a founder of Sun Microsystems, wrote `vi`, which of course inspired `vim`. Joy was also involved with Java early on.

Several students found success with something like "They were both created by programmers."

- (i) *Market research has determined that the course title Comparative Programming Languages is dry and unappealing. Think up a new name for 372. It needn't be less dry but should be funny!*

The responses are below, in random order. It seems like not everybody got the "It needn't be less dry but should be funny!" part, but I suppose good humor is where you find it. I also posted the list on the board outside the 733 corridor. If you're in the building, go by and vote for your favorite.

Learn 3+ Languages in Too Short of Time
Brain Buster: The Class
So Much Recursion
Get Confused by Small Differences 101
372: Fiesta of Programming
Resume Booster
Why Ruby is So Much Better Than Haskell [Ed. note: That wasn't my intention!]
The Many Languages of Pancakes
Dr. Strangelanguage or: How I Learned to Stop Worrying and and Love Prolog
Super Comparative Programming Languages
Actually Learn Programming
372: The Wrath of Cons
More, Harder, and Funnier Homework Than You Could Hope For
Study of Mind-Warping
Trying to Keep 3 Languages Separate in Your Head
Multiple Languages Just in One Semester
Exploration into the World of Machine Languages
Heads and Tails, Let's Rock!
Three Fun Ways to Scramble Your Brains
Multiple Language Ingestion
How to Talk To Computers
Introduction to Different Styles of Thinking About Programming General Purpose Computing Devices
An Introduction to Remaining Competitive In Your Field, Good Luck.
Bunch of Random Languages
No Language to Beat 'em All
Learn to Hate Pancakes in 3 Different Languages
372: Too Much Information You Won't Retain
Learn All the Languages!!! or Just 3 More
Completely Pleasant Languages
Hardcore 3 Programming Language Learning in 3 Months
Learn You a Haskell /([Haskell|Ruby|Prolog]/ for Great Good
Foreign Languages for Programmers
Superfast Computer Language Learning Time
A Class About Not Java
whm and the 3 bears
Haskell, Ruby, Prolog! (so they know the languages we're learning)
Any Way You Want It: 3 Languages for the Programmer on the Go
A Programmer's Nightmare
1001 Ways to Write Fast
Wow So Many Languages in One Course
Too Many Languages!
Not Java—the Class!
French 102 and Other Languages (so us B.S. students wouldn't have to take Foreign Language in place of a CS elective!)
Pancake Hell
Programming in Latin
How Many Examples Can We Fit Into One Slideshow
Programming Languages: The Good, The Bad, and Haskell
Blow Your Mind With Unorthodox Programming Languages

Functional, Objective, Logical—A Plethora of Paradigms
Programming Languages, A Love Story
Learning How to Stroke Egos: New With Haskell!
Programming Paradigms Explored (not funny, but EC!)

- (j) *whm would like to recycle a8's buy.pl in a future semester but needs more dontmix facts with an element of humor. What's another pair he could use?*

My favorites of these were `dontmix('Godzilla', 'NYC')` and the classic but elegant `dontmix(oil, water)`.

- (k) *How many students earned the "close reading" bonus on assignment 8?*

Eleven.

Answers like "A few." were counted as correct, too.

Statistics

All scores:

100, 100, 99.5, 98.25, 98, 97.5, 97, 97, 96.75, 96.5, 96, 95, 94.5, 94.5, 93.5,
92.75, 91.75, 91, 91, 90.5, 90.5, 89.75, 89, 88, 87.5, 87, 86.75, 86.5, 84,
82.5, 82.5, 82.5, 81, 80.5, 80, 80, 77.5, 76.5, 76.25, 76, 75.5, 74.25, 72.5,
70, 65, 62, 61, 60, 59, 59, 58.25, 57.5, 54, 44.5, 41

N = 55

mean = 81.6136

median = 86.5

Solutions for
CSC 372 Mid-term Exam
Thursday, March 12, 2015

A note about grading mistakes

I wish I was perfect but I'm not. I do make mistakes when grading. I encourage you to double-check my work and let me know if you find any mistakes or disagree with any of my grading decisions, including deduction amounts.

I do regrading on a problem by problem basis; a regrade request for a single problem does not trigger an audit of the full exam.

There's no deadline for reporting grading mistakes aside from the filing deadline for final grades.

Unless there are exceptional circumstances I require regrading requests to be in person, not via email or IM.

Before asking me to revisit any problem involving code, first type in your code and see what it does.

I hate to have to mention it but note that all completed exams were scanned into a PDF, making it easy to catch post-grading alteration/addition of answers. Don't be tempted to add a couple of characters to get a point or two back!

Problem 1: (15 points) mean = 10.18, median = 11.00

What is the type of the following values? If the expression is invalid, briefly state why.

Assume numbers have the type `Int`. Remember that the type of `True` is `Bool`.

`'x'`

`Char`

`("len", "", "")`

`([Char], [Char], [Char])`

`(:)`

`a -> [a] -> [a]`

`[(1, 'a'), ('b', 2)]`

Invalid. The two tuples have different types.

`map length`

`[[a]] -> [Int]`

`(+1) . (0<)`

The composition is not valid. `(0<)` produces a `Bool` but `(+1)` requires a number.

`head`

`[a] -> a`

`(True, (False, "x"))`

`(Bool, (Bool, [Char]))`

`length . (\x -> [(x,x)]) . head . init . tail`

Hint: the composition is valid.

`[a] -> Int`

If you wrote `... -> ... -> ... -> ... -> ...`, see slide 252.

`[1..] < [2..]` (*Remember: I want the type!*)
 `Bool`

Problem 2: (12 points) (two points each) **mean = 9.92, median = 10.50**

This problem is like `warmup.hs` — write the following Haskell Prelude functions.

Each instance of poor style or needlessly using other Prelude or helper functions will result in a deduction.

Remember this order of preference for handling cases: patterns, guards, if-else. Be sure to use the wildcard pattern (underscore) when appropriate.

IGNORE empty list cases for `head`, `tail`, and `maximum`. There's no need to specify function types.

head

```
head (h:_) = h
```

tail

```
tail (_:t) = t
```

length

```
length [] = 0  
length (_:t) = 1 + length t
```

max (*Hint: max 2 3 is 3*)

```
max x y  
| x > y = x  
| otherwise = x
```

maximum (*maximum [5,2,3] is 5. Ok to abbreviate as mm.*)

```
mm [x] = x  
mm (x1:x2:xs)  
| x1 > x2 = mm (x1:xs)  
| otherwise = mm (x2:xs)
```

Another way. The explicit type specification avoids a "monomorphism restriction" error.

```
mm :: Ord a => [a] -> a  
mm = foldr1 max
```

A third: `mm [x] = x; mm (x:xs) = max x $ mm xs`

filter (*filter odd [1,2,3] is [1,3]. Ok to abbreviate as flt.*)

```
filter _ [] = []  
filter f (x:xs)  
| f x = x : filter f xs  
| otherwise = filter f xs
```

Problem 3: (14 points) (7 points each) **recursive: mean = 6.05, median = 6.00; non-recursive: mean = 4.64, median = 6.50**

For this problem you are to **write both recursive and non-recursive versions** of a function `tupruns` of type `[(Int, a)] -> [a]` that behaves like this:

```
> tupruns [(3, 'a'), (2, 'b'), (4, 'c')]  
"aaabbccccc"
```

```
> tupruns [(1, '#'), (0, '$')]
"#
"

> tupruns (zip [1..8] "abcdefgh")
"abccccddddeeeeefffffgggggghhhhhhhh"
```

Solutions:

```
tupruns [] = ""
tupruns ((n,c):ts) = replicate n c ++ tupruns ts

tupruns = concat . map (uncurry replicate)
```

A number of non-recursive solutions looked like this:

```
tupruns list = foldr (\(n,ch) acm -> r n ch ++ acm) "" list
```

It'd be in point-free style if only `list` weren't present on both sides.

A common mistake was mapping or folding with a non-function value, like this:

```
... concat . map (replicate x y) ...
```

Problem 4: (3 points) mean = 2.32, median = 3.00

Write a function `flattups` that "flattens" a list of 3-tuples into a list of the values in those tuples.

```
> :t flattups
f :: [(a, a, a)] -> [a]

> flattups [(10,20,30), (3,4,5), (1,2,3)]
[10,20,30,3,4,5,1,2,3]
```

Solution:

```
flattups = foldr (\(a,b,c) acm -> a:b:c:acm) []
```

A number of students had not wrong but long answers due to writing three helper functions to extract the first, middle, and last element from three tuples.

Problem 5: (7 points) mean = 4.18, median = 5.50

The following function removes consecutive duplicates from a list:

```
dropConsecDups list = foldr ff [] list
```

Usage:

```
> dropConsecDups [3,3,1,5,7,5,5,7,7,7]
[3,1,5,7,5,7]

> dropConsecDups "a loooooooooooooooooooooooooooooo one!"
"a long one!"
```

For this problem you are to write a folding function `ff` that will work with `dropConsecDups` as shown above.

```
ff val [] = [val]
ff val all@(a:_)
  | val == a = all
  | otherwise = val:a
```

Problem 6: (6 points) mean = 4.44, median = 5.50

Write a Haskell program that reads a file named on the command line and prints the mean (average) length of the lines in the file.

```
avglen bytes = (show $ totalChars / numLines) ++ "\n"
  where
    lineLengths = map length $ lines bytes
    totalChars = fromIntegral $ sum lineLengths
    numLines = fromIntegral $ length lineLengths
```

The version above breaks the input into a list of `lines`. I wondered how much faster it would be to just count newlines by filtering on them. The version below takes that approach.

```
avglen bytes = (show $ totalChars / numLines) ++ "\n"
  where
    numLines = fromIntegral $ length $ filter (=='\n') bytes
    totalChars = (fromIntegral $ length bytes) - numLines
```

I then tried simply counting newlines:

```
avglen bytes = (show $ totalChars / numLines) ++ "\n"
  where
    numLines = fromIntegral $ count '\n' bytes
    totalChars = (fromIntegral $ length bytes) - numLines
    count c s = foldr
      (\elem acm -> if elem == c then acm + 1 else acm) 0 s
```

The times for the three surprised me:

Use <code>lines</code> to break <code>bytes</code> into <code>lines</code> :	0.817s
<code>length \$ filter (=='\n') bytes</code> :	0.644s
Count with <code>foldr</code> :	1.160s

These solutions handle the integer division properly but that was not required of student solutions.

Very few students remembered to append a newline to the output. Those who did got a ¼-point bonus.

I wish I'd mentioned in the write-up that the value `bytes` produced by `readFile` is a string like `"xxx\ny\nzz\n"` but some assumed it was a list of lines. I also wish I'd reminded about the `lines` function in the Prelude; some students wrote their own version, and that wasn't my intention.

Problem 7: (7 points) mean = 6.38, median = 6.50

Write a Ruby version of the Haskell program in the previous problem. The Ruby version reads from standard input rather than opening a file specified on the command line. ... Unlike the Haskell version this Ruby version must properly handle the math to get a `Float` result, not a truncated value like `3/2 == 1`.

```
sum = n = 0
while line = gets
  line.chomp!
  sum += line.size
  n += 1
end

printf("%.1f\n", sum / n.to_f)
```

Several students approached the problem by building an array with line lengths and then summing the lengths. That seems like a Haskell solution written in Ruby!

The only common mistake was to not `chomp` or otherwise account for the line terminator(s) that `gets` leaves in place.

Problem 8: (7 points) mean = 5.51, median = 6.00

Write a Ruby program `nwords.rb` that reads lines from standard input and writes the first N words on each line to standard output. N is specified by a `-N` command line argument that is assumed to be present. If N is larger than the number of words on a line, all the words on that line are output.

```
n = -ARGV[0].to_i

while line = STDIN.gets
  line.chomp!
  puts line.split[0,n] * " "
end
```

A common assumption was an analog to Haskell's `concat` to join an array of strings together into a string but `concat` wouldn't put spaces between them. Something like `array * sep` (as shown above), or a loop was needed. Assuming something like Haskell's `unwords` was reasonable, if explicitly stated.

A common implied assumption was that `puts array[0,n]` would output blank-separated words but it actually outputs one array element per line.

A number of students assumed a single-digit N even though there is a `-100` example.

Lots of students wrote mysterious code to process multiple arguments and/or error checking code. None of that resulted in deductions but I imagine it ate up a lot of time. Avoid that on the final by taking advantage of what can be assumed.

Problem 9: (6 points) mean = 4.07, median = 5.00

Write Ruby method `chunkstr(s, n)` that returns an array of consecutive n -long substrings of the string `s`. Partial substrings are not included. Assume $n > 0$. `chunkstr` does not change `s`! (Maybe use `String#dup`.)

```
>> chunkstr("abcdef",3)
=> ["abc", "def"]
```

Here was my first solution. I forgot the return on the first run but it worked on the second run.

```
def chunkstr(s,n)
  r = []
  s = s.dup
  while s.size >= n
    r << s[0,n]
    s[0,n] = ""
  end
  r
end
```

I then wrote a more numeric solution:

```
def chunkstr(s,n)
  r = []
  pos = 0
  while pos + n <= s.size
    r << s[pos,n]
    pos += n
  end
  r
end
```


It took three runs to get right: (1) forgot `pos += n`, (2) used `s[0, n]`, (3) used `s.size + 1`. I might have also forgotten to return `r` on the first run if I'd started from scratch instead of hacking up my first solution.

Lots of student solutions did something like

```
a = []; apos = 0
...
a[apos] = str
apos += 1
```

but `a << str` or `a.push(str)` is simpler.

Problem 10: (6 points) (one point each unless otherwise indicated) **mean = 2.70, median = 2.50**

The following questions and problems are related to Haskell.

(1) Add parentheses to the following type to explicitly show the associativity of the `->` operator.

```
(Int -> Int) -> Int -> Int
```

It seems that only TODO students know that the type operator `->` is right associative.

```
(Int -> Int) -> (Int -> Int)
```

Expect to see a question like this on the final.

(2) Fully parenthesize the following expression.

```
f g a + x y z + f1 (a, b) c
```

Quite a few students got tripped up on this one but only two rules come into play: (1) two expressions side-by-side is function call. (2) function call has higher precedence than any operator.

```
((f g) a) + ((x y) z) + ((f1 (a, b)) c)
```

Expect to see a question like this on the final!

(3) Rewrite the following expression to use as few parentheses as possible.

```
len ((map f) (head (lines bs)))
```

Solution: `len $ map f $ head $ lines bs`

(4) Describe in English the data structure matched by this pattern: `[t:h]`

A list containing a single non-empty list.

A number of students got tripped by a head named `t` and a tail named `h` but those names mean no more to Haskell than do `ping` and `pong`!

(5) Consider the following definitions for a function that tests whether a list is empty. Each is shown with the types that Haskell infers for them:

```
empty1 :: [t] -> Bool
empty1 [] = True
empty1 _ = False

empty2 :: Eq a => [a] -> Bool
empty2 x
```

```
| x == [] = True
| otherwise = False
```

What's causing the type of the functions to differ? What's an example of a list that would work with `empty1` but not `empty2`? (Two points.)

The use of the `==` operator in `empty2` produces the added requirement that the type `a` must be in the `Eq` type class. `empty1 [length]` works but `empty2 [length]` produces a type error because function types aren't members of the `Eq` type class.

I'd initially planned each of the two questions to be worth a point each but few students got the second question right. I decided to score the first question as two points and the second question as a one-point bonus question.

An answer that was as little as `"=="` earned full credit on this problem.

Problem 11: (7 points) (one point each unless otherwise indicated) **mean = 3.07, median = 3.00**

The following questions and problems are related to Ruby.

(1) Write a Ruby iterator `itr` that behaves like this:

```
>> itr(3) {|x| puts x}
6
```

Solution:

```
def itr x
  yield x * 2
end
```

(2) In the Ruby code `$x = N * 5`, we know that `$x` is a global variable and `N` is a constant.

(3) Given `h = {}`, write an expression such that after it is evaluated, `h["x"]` is 10.

```
h["x"] = 10
```

(4) What's a big mistake in the following statement?

"The `if-else`, `while`, and `for` statements are examples of Ruby control structures."

`if-else`, `while`, and `for` are expressions—they all produce a value!

(5) A method named `show_match` is used extensively on the regular expression slides. Briefly, what does it do?

See slide 192!

`show_match` is in my `.irbrc`. To get a copy of my `.irbrc`, do the following `cp`, assuming you're in your `a4` directory:

```
$ cp a4/.irbrc ~
```

After copying it, browse it with `less ~/.irbrc` and see if you learn anything new.

(6) What are the minimum and maximum lengths of strings that can be matched by the following regular expression? (Be careful!)

```
[Aa]..[Zz]0x9?
```

Six or seven characters are matched: 'A' or 'a', then any two characters, then 'Z' or 'z', '0', 'x', and maybe a '9'.

- (7) Write a Ruby method that exemplifies duck typing. There's no need for any explanation!

I like the `double` example on slide 126 but most any method that invokes a method on an argument or applies an operator to an argument provides an example of duck typing.

Problem 12: (10 points) (one point each unless otherwise indicated) **mean = 6.48, median = 7.00**

Answer the following general questions. Keep your answers brief—assume that the reader is a 372 classmate who just needs a quick reminder.

- (1) Who founded the University of Arizona Computer Science department and when?

Ralph Griswold, in 1971. There was no partial credit on this one—you had get the year right, too. Here are two ways to remember 1971: (1) The decimal value for ASCII 'G' is 71. (2) There are 7+1 letters in "Griswold". Note that it's Griswold, not Griswald. (Remember the 'O's in SNOBOL.)

Good news: you'll have one more chance to get this right!

- (2) Name a language that was created before Ruby. Name a language that was created after Ruby.

Popular pre-Ruby examples were FORTRAN, COBOL, C, and Icon. Common post-Ruby examples were Java and Swift. Python was a common wrong answer for a language that came after Ruby.

Two students created a language on the spot.

- (3) *whm* believes the acronym LHiLaL appears nowhere on the web except in his slides. What does it stand for?

Learn(ing) How to Learn a Language

- (4) What are two aspects of a "paradigm", as described in Kuhn's *The Structure of Scientific Revolutions*? Here are two wrong answers: functional and object-oriented.

See Haskell slide 3 and following.

- (5) Perhaps the most fundamental characteristic of a functional programming language is that it permits higher-order functions to be written. What's the language feature that's required in order to write a higher-order function?

The ability to pass a function to a function as a parameter.

- (6) What's an important difference between an imperative method and an applicative method? (Hint: it doesn't concern the method name!)

An imperative method changes state in an object. An applicative method produces a new object.

- (7) *whm* often says "In Haskell we never change anything; we only make new things." What's an example of that?

To reverse a list we'd make a new list.

- (8) In general, every expression in a programming language has three aspects. What are those three? Hint: one of them starts with a "v". (1.5 points)

Type, value, side-effects

(9) Briefly define the term "programming language". (1.5 points)

Here are some of the answers I especially liked:

"A language that is used to communicate with a computer."—J. Naranjo

"A group of syntactic and semantic rules to tell a computer how to process input."—R. Storck

"A grammar and vocabulary for providing instruction in math and logic."—B. Whitely

"A collection of syntax and words which can be read by the machine."—J. Wolfe

"A compilation of syntax and semantics that supports a variety of computations."—A. Zarbock

Extra Credit Section (½ point each unless otherwise noted) mean = 2.03, median = 2.00

(1) Predict the median score on this test. (The median is the "middle" value in a range of values.)

All predictions:

90, 88, 86, 85, 84, 84, 84, 83, 83, 83, 83, 83, 83, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 81, 81, 81, 81, 81, 81, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 80, 78, 78, 78, 77, 77, 76, 76, 76, 76, 75, 75, 75, 74, 72, 72, 70, 70, 67, 65, 64

n = 58

mean = 79.22

median = 80

(2) Add a dunsel to the following function definition

```
f x = take 3 x ++ drop 3 x
```

Two common ones were ++ [] and ++ take 0 x

(3) Why was \ chosen for use in Haskell's lambda abstraction syntax?

It resembles λ .

(4) To whom does whm attribute the following quote?

"When you hit a problem you can lean forward and type or sit back and think."

Dr. Proebsting

(5) What's the basic idea of whm's so-called "O(1) navigation"?

Being able to hit a page with a short, fixed set of keystrokes.

(6) What is the exact type of the list [head, tail]?

The expression is invalid—head and tail have different types.

(7) What's interesting about the ASCII code sequence from 60 through 62?

They form the "spaceship" operator: <=>

(8) *What Ralph say when a young and eager graduate student put forth a list of potential new features for Icon?*

Roughly quoting, "Add all the features you want but for every feature you want to add, first find one to remove."

(9) *If you only remember one thing about the Haskell segment of 372, what will it be? (Ok to be funny!)*

"The compiler is always right but it will never tell you why."—B. Streeter

"Jeremiah going over my head in six words."—S. Stephens

"Haskell is really spelled 'Haskell'."—J. Scarim

"Higher-order functions are the bees knees."—C. Macdonald

"Pancakes"—A. Rane

"Typing errors, typing errors everywhere."—J. Naranjo

"Watch the types!!!"—J. Knott

"Pancakes are evil!"—K. Enami

"It's a (fun)ctional language"—S. Desai

(10) *What is Matz' full name?*

Yukihiro Matsumoto

(11) *Write a good extra credit question and answer it.*

Lots of good ones but I'm out of time to cite them here! :(

Statistics and an adjustment

Here are all scores, in order:

103.75, 101.25, 97.25, 97.25, 95.75, 94.00, 92.25, 92.00, 91.00, 90.50, 89.75,
88.75, 88.25, 88.25, 88.25, 87.00, 86.25, 83.00, 82.75, 82.50, 82.25, 81.75,
80.75, 80.50, 79.75, 78.25, 78.25, 78.25, 78.00, 77.75, 76.75, 76.25, 76.00,
75.25, 75.00, 74.50, 74.00, 73.50, 72.00, 71.25, 70.25, 69.50, 67.75, 67.25,
66.75, 66.75, 65.75, 65.50, 65.00, 64.50, 63.75, 63.75, 63.00, 61.00, 60.00,
59.75, 58.75, 57.75, 57.75, 57.50, 56.75, 56.25, 54.75, 54.00, 53.50, 53.25,
50.75, 50.50, 40.50, 40.25, 39.00, 36.25, 35.75

n = 73

mean = 71.9623

median = 74

The scores ran a little lower than I would have liked. After taking all factors into consideration **I've decided to add six points to all scores.** The score you'll see on D2L will be six points higher than the score written on the cover page of your exam.

CSC 372 Final Exam Solutions
Tuesday, March 12, 2015

Quiz 18, May 12, 2015
2 questions; 4 points

1. *For one point each, cite three things you learned from Dr. Proebsting's presentation in 372 on Tuesday, May 5, the last day of class.*

Here are some of my jots...

Story of Richard Hamming's three questions for new hires at Bell Labs.

"I think programming languages are the key to productivity."

"Perl is the only popular language I hold in lower esteem than C."

Recommended book *The Innovator's Dilemma*.

Academics are batting zero for popular languages. [But I'd say Haskell is a still-rising counter-example.]

Thinks Visual Basic was most influential language of the 1990s.

Statistics gathered by Microsoft's Watson tool (not to be confused with IBM's Watson!) show that about 50% of crashes are caused by 1% of the bugs.

His mention of "flight data recorders" for programs reminded me that Adobe had something like that in the works for its ActionScript/Flash Player stack. I've got a distinct memory of seeing a demo of it but a quick Google just now didn't turn up anything that looked familiar.

He said that Go is the fastest growing language right now. It was also interesting to hear about a single code formatting standard being enforced by the Go formatter. There are benefits to freedom from choice, and I sure like a one-for-all-formatter better than Python's enforcement of indentation rules.

And last but not least there was that incredible story about the birth of Erlang.

2. *On a scale of 1 to 5, with 1 being least important and 5 being most important, how would Dr. Proebsting rate the importance of language choice for a programming project?*

I believe he'd give it a 5, but I counted a 4 or 5 as correct.

Problem 1: (6 points) mean = 5.12, median = 6.00

Cite three things about programming languages you learned by watching your classmates' video projects. Each of the three should be about a different language.

I tallied the languages cited in the responses and came up with the numbers below. I believe Mr. Nelson's video is destined to become a cult classic, so I gave it its own category, and didn't count it toward Ruby. I especially loved how he fit ten minutes of video into seven minutes by simply speeding it up, taking a lesson from Alvin and the Chipmunks.

Swift	27
Python	26
Ruby	17
Go	14
The Hardest Unsolved Problem in Computer Science	12
Java	10
Haskell	8
PHP	8
Lisp	6
C++	6
C	5
JavaScript	4
Erlang	4
Icon	3
Lisp	3
Perl	3
io	2
MATLAB	2
C#	2
Mathematica	2
F#	1

Lots of people commented about the ability to have emojis in Swift but just like Swift, Java allows programs to be written in Unicode. You can thus use emojis in Java, too; the question is whether your IDE or editor displays the full Unicode character set properly.

Problem 2: (3 points) mean = 1.09, median = 1.00

- (1) (Two points) Imagine that a Haskell function f has the type $\text{Char} \rightarrow \text{Bool} \rightarrow \text{Char}$. Explain the meaning of that type in a way that demonstrates you have significant knowledge of Haskell.

Hint: here's an answer that's worth zero points: " f takes two arguments, a Char and a Bool , and returns a Char ."

Calling f with a Char produces a function that can be called with a Bool to produce a final result, of type Char . f is most likely defined in curried form.

- (2) (One point) Fully parenthesize the following Haskell expression.

$((((f\ 1)\ 2)\ g) + (x\ x)) + (((f\ g)\ f)\ 1)$

Problem 3: (6 points) mean = 2.48, median = 2.00

Write a Haskell function `longpos :: [String] -> Int` that returns the one-based position of the longest string in a list of strings. Assume the list has at least one string. Don't worry about ties.

```
longpos strings = snd $ head $ reverse $ sort $ zip (map length strings) [1..]
```

Problem 4: (9 points) mean = 6.82, median = 8.00

Write a Ruby program that reads integers, fractions, and mixed numbers, one per line from standard input, and prints their sum when end of file is reached.

```
sum = 0
while (print "Number? "; line = gets)
  line.chomp!

  if line =~ /^\\d+$/
    sum += $&.to_f
  elsif line =~ /^(\\d+)?(\\d+)\\/(\\d+)$/ then
    sum += $2.to_i + $3.to_f/$4.to_f
  else
    puts "Ignored: #{line}"
  end
end
puts "\\nTotal: #{sum}"
```

Problem 5: (9 points) mean = 7.24, median = 8.50

In this problem you are to write a Ruby version of `buy.pl` from assignment 9. The Ruby version reads a file named `buy.data` for information about items and discounts.

```
items = {}

f = File.open("buy.data")

while line = f.gets
  type,item,f3,f4 = line.chomp.split("|")
  if type == "item"
    items[item] = [f3, f4.to_f]
  else
    items[item][1] *= 1 - f3.to_f*0.01
  end
end
f.close
```



```

total = 0
for item in ARGV
  if !items[item]
    puts "Price check for #{item}!\n"
    exit(1)
  else
    cost = items[item][1]
    printf("%s...%.2f\n", items[item][0], cost)
    total += cost
  end
end

printf("Total: $%.2f\n", total)

```

I was appalled by the number of students who used this structure, which turns an $O(n)$ computation into an $O(n^2)$ computation:

```

for item in ARGV
  read buy.data, looking for item

```

Problem 6: (6 points) mean = 4.72, median = 6.00

Implement assignment 9's `outin` as a Ruby iterator. Assume its argument is always a non-empty array.

```

module Outin # as a mixin...
  def outin
    a = self.dup
    while a.size > 0
      yield a[0]
      a = a[1..-1].reverse
    end
    nil
  end
end

```

Some students imagined that an iterator can be called recursively but that doesn't work. However, I let those pass.

Problem 7: (5 points) mean = 2.87, median = 3.00

Ruby defines a meaning for `String * Fixnum` but the operation is not commutative—`Fixnum * String` produces an error:

```

>> 4 * "abc"
TypeError: String can't be coerced into Fixnum

```

For this problem you are to create a file named `symmul.rb` such that after `symmul.rb` is loaded, `Fixnum * String` works.

```

class Fixnum
  def *(rhs)
    if rhs.class == String
      rhs * self
    else
      self * rhs
    end
  end
end

```

Problem 8: (10 points) mean = 8.16, median = 9.00

Write the following simple Prolog predicates. There will be a half-point deduction for each occurrence of a singleton variable or failing to take full advantage of unification.

Restriction: No library predicates may be used other than `is/2`. (But note exception for `init!`)

(a) `f(?X)` expresses the relationship that `X` is 3 or 4.

```
f(3).  
f(4).
```

(b) `head2(?L, ?Heads)` expresses the relationship that `Heads` is a list that consists of two copies of the head of `L`.

```
head2([H|_],[H,H]).
```

(c) Write the library predicate `member/2`.

```
member(H,[H|_]).  
member(X,[_|T]) :- member(X,T).
```

(d) `sum(+L, -Sum)` instantiates `Sum` to be the sum of the elements in `L`, which are assumed to all be numbers.

```
sum([],0).  
sum([H|T],Sum) :- sum(T,Sum0), Sum is H + Sum0.
```

(e) `init(?L, ?Init)` is an analog to Haskell's `init`: the list `Init` is all but the last element of `L`. `init` fails if `L` is empty. **Restriction EXCEPTION: Your solution for `init` may use `append`.**

```
init(L,Init) :- append(Init,[_],L).
```

Problem 9: (4 points) mean = 2.91, median = 3.00

Write a Prolog predicate `zip(+L1, +L2, ?Pair)` that produces a series of `pair/2` structures:

```
?- zip([1,2,3,4],[a,b,c],R).  
R = pair(1, a) ;  
R = pair(2, b) ;  
R = pair(3, c) ;  
false.
```

```
zip([H1|_],[H2|_], pair(H1,H2)).  
zip([_|T1],[_|T2], R) :- zip(T1,T2,R).
```

Problem 10: (6 points) mean = 4.15, median = 5.00

Write a Prolog predicate `swapends(?L1, ?L2)` that expresses the relationship that `L1` is a copy of `L2` with the first and last elements swapped. `swapends` is only meaningful for lists with two or more elements.

```
?- swapends([a,b,c,d],L).
L = [d, b, c, a] ;
false.
```

```
?- swapends([1,2,3],L).
L = [3, 2, 1] ;
false.
```

```
?- numlist(1,7,Nums), swapends(Nums,R).
Nums = [1, 2, 3, 4, 5, 6, 7],
R = [7, 2, 3, 4, 5, 6, 1] ;
false.
```

```
swapends([First|T],[Last|Rest]) :-
    append(Middle,[Last],T), append(Middle,[First],Rest).
```

I was very impressed with the elegance and symmetry of answers by Mr. Britton,

```
swapends([H|T],[R|F]) :- reverse(T,[R|RS]), reverse([H|RS],F).
```

and Mr. S. Stephens:

```
swapends([X|T],[Y|S]) :- reverse(T,[Y|R]), reverse(S,[X|R]).
```

In case you're wondering, yes, I had to type those in to convince myself they worked.

Mr. Wolfe had an elegant recursive solution: (minus an overlooked unification)

```
swaphelp([X],[Y],Y,X).
swaphelp([X|XS],[Y|YS],In,Out) :- X = Y, swaphelp(XS,YS,In,Out).
swapends([X|XS],[Y|YS]) :- swaphelp(XS,YS,X,Y).
```

Problem 11: (6 points) mean = 2.98, median = 4.00

On assignment 9 you wrote `outin(+L, -R)`, which worked like this:

```
?- outin([1,2,3,4,5],R).
R = 1 ;
R = 5 ;
R = 2 ;
R = 4 ;
R = 3 ;
false.
```

On this problem you are write `inout(+L, -R)`, which generates elements in the opposite order from `outin`.

IMPORTANT: You may use `outin` in your solution! This problem is intended to be easy; don't make it hard!

```
inout(L,R) :-
    findall(Val, outin(L,Val), Vals), reverse(Vals,RVals), member(R,RVals).
```

A common short but wrong answer was to simply reverse the list and call `outin` on the reversed list.

Problem 12: (12 points) mean = 6.06, median = 7.00

In this problem you are to write a Prolog predicate `cross/3` that finds a way to cross over a series of pits using wooden planks as bridges. ...

```
cross(Planks,Distance,Solution) :-
    layplanks(Planks, 0, Distance, Solution).

layplanks(_,Current,Distance,[]) :- Current >= Distance.

layplanks(Planks, Current, Distance, [Plank|MorePlanks]) :-
    select(Plank, Planks, LeftOver),
    NewEnd is Current + Plank,
    \+overpit(NewEnd),
    layplanks(LeftOver,NewEnd,Distance,MorePlanks).

overpit(N) :- pit(Start,Width), End is Start + Width, N >= Start, N <= End.
```

A common mistake was to have code that looked like this,

```
..., pit(Start,Width), End is Start, NewEnd < Start, NewEnd >= End, ...
```

where I've got `\+overpit(NewEnd)` above. With code like that you're asking, "Is there is any pit that the joint is not over?"

Problem 13: (7 points) (one point each unless otherwise indicated) mean = 5.09, median = 5.00

The following questions and problems are related to Prolog.

- (1) *Haskell strings are actually just lists of characters. Similarly, Prolog lists are actually instances of a more basic element of Prolog. What's that element?*

Structures, but lots of people said "atoms".

- (2) *What's an appropriate situation in which to use the "cut-fail" combination?*

When a predicate detects a condition that guarantees the predicate should fail. Or, "My final answer is no!"

- (3) *Consider the following goal written by a novice Prolog programmer: `append(A,B,A)`. What's a likely problem with that goal?*

`append(A,B,A)` can only be true if B is an empty list. Perhaps the programmer thinks that `append` works like `A = A + B`.

- (4) *Consider this claim: Aside from what `is/2` provides, Prolog has nothing that corresponds to the concept of an expression like that found in Java, Haskell, and Ruby. Present an argument either in favor or against this claim. (2 points)*

The hallmark of an expression is that it produces a value but predicates can only succeed or fail. Any values produced by a predicate must be via instantiation.

In retrospect I decided this wasn't a very good question. Any non-trivial answer for it was counted as correct.

- (5) *What's the most important fundamental difference between a Prolog predicate like `member/2` and a function/method of the same name in Haskell, Ruby, or Java? (2 points)*

`member` can both test for membership and generate values.

Problem 14: (5 points) (one point each unless otherwise indicated) mean = 5.95, median = 6.00

The following is a Sather program, from http://rosettacode.org/wiki/Sum_of_squares#Sather

```
class MAIN is

  sqsum(s, e:FLT):FLT is
    return s + e*e;
  end;

  sum_of_squares(v :ARRAY{FLT}):FLT is
    return (#ARRAY{FLT}(|0.0|).append(v)).reduce(bind(sqsum(_,_)));
  end;

  main is
    v :ARRAY{FLT} := |3.0, 1.0, 4.0, 1.0, 5.0, 9.0|;
    #OUT + sum_of_squares(v) + "\n";
  end;

end;
```

Based on the code above, tell me five things about Sather. Excellent or additional observations may earn up to three points of extra credit.

Here's what I see:

The big one: Sather appears to be statically typed.

Types follow the entity whose type is being declared.

|val1, val2, ..., valN| appears to be array initializer syntax but there's also #ARRAY{FLT}(|0.0|); the distinction between the two is not clear. #ARRAY is apparently the same kind of thing that #OUT is.

reduce(bind(sqsum(_,_))) implies that reduce is a higher-order function, but bind is apparently needed to create an intermediate value that refers to sqsum.

Last value in method does not implicitly become return value; explicit return statement is used instead.

One form of initialization is :=.

#OUT is a special value that produces output when a value is concatenated with it.

String literals are enclosed in double quotes and have backslash escapes.

Semicolons are required to terminate statements.

class may imply that Sather is object-oriented. I believe that only Mr. Bernth mentioned that .append implies object-orientation, too.

A number of students said that the free-standing s in sqsum(s, e:FLT) implied that types need not be specified, but in fact the type simply follows the identifier(s). (Note that in the Java declaration int x, y; the type int applies to both x and y.)

A handful of students said that : was cons, but I see no grounds for that whatsoever.

Problem 15: (6 points) mean = 5.46, median = 6.00

Answer the following general questions.

- (1) *What is the fundamental characteristic of a statically typed language? (1 point)*

The type of every expression can be determined at compile time.

- (2) *A language designer must decide whether an operation is to have a symbolic form, like +, ==, and x[y] or an alphabetic form like length, insert, and charAt. What are some factors that must be considered when deciding between an symbolic or alphabetic form for an operation? (2 points)*

Symbolic forms allow more concise expression and that's good for common operations like concatenation and indexing.

Sometimes using a symbol avoids a naming problem. For example, Icon's unary * operator, which returns the length of a string or a list, the number of key/value pairs in a table, the numbers of characters in a character set, and more. Instead of deciding between length, size, count, cardinality (true story), etc., *x provides a helpful indefiniteness.

Designers must also consider whether there's a common underlying idea that makes a symbolic form appropriate, like using + for both addition and concatenation, although the latter is not commutative.

- (3) *Imagine that for some reason all your knowledge and memories of two of the three languages we covered this semester must be erased! Which of the three languages do you wish to retain your memories of, and why? (3 points)*

I tallied the answers. Here are the numbers:

Haskell:	16
Ruby:	24
Prolog:	28

The rationales for retention were myriad. Among them were which language was most interesting, which language would likely be most useful and/or marketable, which language had the most concepts useful in other settings, which language was least likely to be independently learned, and which language "I don't ever want to learn again."

Extra Credit Section (½ point each unless otherwise noted) mean = 2.85, median = 3.00

- (1) *What programming language had a typo in the first example of the first book published about the language?*

The first example in the *The Java Programming Language* by Ken Arnold and James Gosling had "Sytem.out.println(...)" in the first example.

- (2) *The first machine named lectura was a VAX-11/785. Who picked the name "lectura"?*

The first round of CS host names were font names. Dr. Peter Downey found "Lectura", and it seemed perfect for an instructional machine. Some others were Bocklin, Megaron, Caslon, and Bembo.

- (3) *What would be a better name for the Prolog 1000, and why?*

Maybe the Prolog 500—the list appears to have about 502 entries.

(4) *What does DWIM mean?*

"Do what I mean." Runner-up, by P. Martin: "Drunken whales injure millions."

(5) *What is the official name of Gould Simpson 942? (Ok to be funny!)*

"Programming Languages Lab" is on the plaque beside the door, and Mr. Hickey knew that, but here are other titles:

The Lion's Den
The Den of Crushed Freshmen
Ephiphany H.Q.
Home [two entries! — whm]
The Thunderdome
A long staircase away.
the Lab
CS Dungeon
The "Please Help me" Lab
"When you're desperate"
The Help me room
Late-night Debugging Center
Big Poppa's House
The Hurt Locker
Last minute disaster
Panic Bunker
The Romper Room
Where the Problems Are Solved
This is where you go to finish your program.
Buckle your Seat Belts Room
Help Center for Sick 372 Students
The Meat Grinder
A room where people inside cry 9 times a semester.
Help Center
think tank
The Simpsons
whm's coder clubhouse
The Cool Kids Club
Broken Elevators
Windowless Dungeon of Office Hours [submitted by a fellow correctional officer]
Office hours central
my second home
Mitchell's Lab (?) [that does have a nice ring!]
The Last Minute Help Room
"The assignment is due tonight?!"
The computer lab that eats all of your time away.
The "Help Me" group
The penthouse
my apartment
Gould Simpson 942 (spelling counts) [ouch!]

Names for the building, apparently:

My girlfriend calls it the "Nerd Palace".
Palace of Science

- (6) *Ralph Griswold is known for designing languages like SNOBOL4 and Icon but he's also known for his work related to the mathematical aspects of weaving. What's a one word connection between those two areas?*

My word is "strings", and Mr. Nelson came up with that, too.

J. Naranjo and T. Romero said "threading".

E. Harris, C. Jensen, C. Johnson, R. Macdonald, B. Streeter, and C. Troy all came up with "patterns", and that's surely true!

K. Enami pointed out that both SNOBOL4 and "weaving" have an "n" in them.

K. Hudspeth was creative with "weavemactical". (Zero Google hits just now.)

- (7) *In what year did Ralph Griswold found The U of A's Department of Computer Science?*

1971

- (8) *On Ralph's first day here he arrived to find a number of students waiting outside his office for advising. When he entered his office he found a common piece of office furniture was absent. What was it?*

Ralph had a desk, but no chair! However, any answer was counted as correct. Twenty-two said "desk", twenty-six said "chair(s)", and one said "coffee maker".

Here's one last story about Ralph. As dial-up modems started becoming popular the phone company started worrying about modem users monopolizing circuits. There was a Tucson TV news story about this in the early 70s in which a phone company representative talked about the problems that heavy modem users could create. As a case in point they cited a customer in town whose modem had been continuously connected for over a month! Ralph told me that story and added, "That customer was me."

- (9) *There are many measures of success. What do you think must be true in order for a programming language to be considered a success?*

The first answer I read was by Mr. Dimka: "One person considers it their favorite language." Interestingly, that's an answer I had in mind, too. I believe I mentioned in class that I discovered the language RATSNO (Rational SNOBOL) among the Icon stuff. Dave Hanson developed it as an experiment in software adaptability, to see how hard it would be to retarget the RATFOR preprocessor (about 1500 lines), which had a design principle of "RATFOR does not know any FORTRAN". Hanson completed the conversion in about 8 hours.

I loved RATSNO and used it for several projects as an undergraduate at N.C. State, including a Pascal compiler. I've never gone looking for other users (I should!), but as far as I know, I was the only regular user of RATSNO. But for me, RATSNO was a success. <http://www.cs.arizona.edu/classes/cs372/spring15/csc412project.pdf> is an example of some RATSNO code. It solves language equations using Arden's Lemma. You'll see that thirty-five years ago I wrote more comments than I do now.

Here are other answers that caught my eye:

"A successful language displaces a previous language." — S. Stephens

"It can solve a problem." — J. Weiser

"If a lot of people are using it without complaining." — N. Gelo

"People use it." — J. Tom

"Mother's approval." — M. Curry

"Helped solve one problem better than any other language."

(10) *Under what circumstances should a programming language be considered dead?*

I've pondered this question a fair amount over the years. During the Icon segment of 372 in Fall 1996, Larry Johnson said, "I'm just worried we're studying some dead language just because it was invented at the U of A."

As a practical matter I think it takes a lot to kill a programming language. One of my first thoughts was that if a language is written in assembler and no machines with that architecture still exist, that language is surely dead. However, one could write an emulator for that architecture and revive the language. Even if all implementations were lost but specifications or programs remained, again the language could be revived.

I think I may have mentioned that there was never a implementation of the Alphard language but several papers were published about it. (Ralph thought that was "nuts!")

Here are some of the many answers I enjoyed:

- "No one considers it their favorite."—A. Dimka
- "No one can write a program in it without Googling."—J. Wolfe
- "When there are no new programs being written in it."—C. Johnson
- "When you can't Google it."—M. Justice
- "When the tools to run the programming language no longer exist."—J. Wynne
- "When it has no more followers."—E. Saetren
- "They don't die; they just go to sleep for a very long time."—B. Hammond
- "When it has C in the name."

Statistics and an adjustment

While grading I ultimately came to not like problems/questions 2(1), 13(1), and 15(2). Five points were added to all scores to compensate for those questions. The scores written on your exams do not reflect that five-point adjustment.

Here are all scores, with that five-point adjustment applied:

107.00, 106.50, 106.50, 106.00, 105.25, 102.50, 100.50, 97.00, 96.50, 96.00,
93.00, 91.00, 90.50, 90.00, 89.50, 89.50, 89.50, 88.00, 87.50, 87.00, 87.00,
86.50, 86.50, 86.00, 84.50, 83.50, 83.00, 83.00, 83.00, 82.50, 82.00, 81.00,
80.50, 79.50, 78.00, 78.00, 76.50, 76.50, 76.00, 75.50, 74.50, 74.00, 73.50,
73.50, 72.00, 72.00, 69.50, 68.00, 66.00, 64.50, 64.50, 63.00, 62.50, 62.00,
62.00, 61.50, 61.50, 61.50, 60.50, 60.50, 57.75, 56.50, 54.50, 51.00, 37.50

n = 65
mean = 78.9615
median = 80.5

All overall final averages for the course are shown below, with grade lines drawn in. You can find your final letter grade in 372 by looking at your "Overall average" on D2L and seeing where you fall in the list below.

Drawing grade lines is always tough. For those just short of a letter grade I double-checked his/her exam for any additional possible points.

----- A's below
104.70
104.26
104.24
103.50
102.92
101.96
101.53
101.23
100.15
100.00
96.83
96.75

96.67
96.39
96.38
96.04
95.87
95.51
94.54
93.85
93.57
92.92
92.87
92.65
91.44
90.58
89.99
89.88
----- A's above; B's below
88.89
87.97
87.22
86.15
86.02
85.16
84.15
82.41
82.25
82.11
82.05
80.33
79.57
----- B's above; C's below
77.74
77.70
77.69
76.94
74.58
72.35
70.85
70.59
69.98
69.87
69.20
69.09
68.49
----- C's above; D's below
66.95
65.54
64.69
64.32
63.61
60.06
----- D's above; E's below
53.28
52.83
31.09
30.67

CSC 372 Mid-term Exam
Thursday, March 10, 2016
Solutions

Problem 1: (8 points) (mean = 5.6, median = 5.5)

What is the type of each of the following values? If the expression is invalid, briefly state why.

```
"abc"
    [Char]

('4', 52, [5,2])
    (Char, Int, [Int])

last
    [a] -> a

[[True]]
    [[Bool]]

filter even
    [Int] -> [Int]

map head
    [[a]] -> [a]

[head, head . tail]
    [[a] -> a]

(++"x")
    [Char] -> [Char]
```

Problem 2: (10 points) (two points each) (mean = 8.3, median = 8.5)

```
snd          (Returns second element of a two-tuple)
snd (_,x) = x

head         (Ignore empty-list case)
head (h:_) = h

last        (Ignore empty-list case)
last [x] = x
last (_:t) = last t

map
map _ [] = []
map f (h:t) = f h : map f t

zipWith     (Reminder: zipWith (+) [1,2,3] [10,20,30] is [11,22,33])
zipWith f (x:xs) (y:ys) = f x y : zipWith f xs ys
zipWith _ _ _ = []
```

Note the ordering of the clauses: The first clause handles the case that both lists have at least one element. If that's not true, we're done, and that's handled by the second clause.

Problem 3: (16 points) (8 points each) (recursive: mean = 6.2, median = 7; non-recursive: mean = 5.0, median = 6)

For this problem you are to write both recursive and non-recursive versions of a function `numlist`, with type `[[Char]]`
-> `IO ()`, that outputs a numbered list of the strings in a list:

```
> numlist ["just", "testing", "this"]
1. just
2. testing
3. this

> numlist []
[no items]
```

Solutions:

```
numlist [] = putStr "[no items]\n"
numlist items = putStr $ unlines $ helper 1 items
  where
    helper _ [] = []
    helper n (item:items) =
      (show n ++ ". " ++ item) : helper (n+1) items

numlist [] = putStr "[no items]\n"
numlist items = putStr $ unlines $ zipWith f [1..] items
  where
    f num s = show num ++ ". " ++ s
```

Problem 4: (4 points) (mean = 3.3, median = 4)

Consider the following interaction with `ghci`:

```
> map count [10,20,30]
[1,2,3]

> map count [7,8,9,10]
[1,2,3,4]
```

For this problem you are to either (1) write a function `count` that behaves as shown above or (2) explain why it is impossible to write such a function.

It's impossible. Functions always produce the same output for a given input but in the first case, `count 10` produces 1 and in the second case, `count 10` produces 4.

Problem 5: (8 points) (mean = 5.7, median = 7)

The following function, `revtups`, takes a list of two-tuples and produces a new list with the tuples' elements swapped and the order of the tuples reversed:

```
revtups list = foldl ff [] list
```

Usage:

```
> revtups [(1, 'a'), (2, 'b'), (3, 'c')]
[( 'c', 3), ( 'b', 2), ( 'a', 1)]

> revtups [("one", [1]), ("two", [2])]
[[2], "two"), ([1], "one")]
```

For this problem you are to:

1. State the type of `revtups` (1 point)
2. Write a folding function `ff` that will work with `revtups` as shown above.

1. `revtups :: [(a,b)] -> [(b,a)]`
2. `ff acm (a,b) = (b,a):acm`

Problem 6: (12 points) (mean = 8.2, median = 10)

Write a Haskell function `co chars string`, with type `[Char] -> [Char] -> Int`, that counts how many times the characters in `chars` occur in `string`.

Usage:

```
> co "aeiou" "just a test"
3

> co ['0'..'9'] "12:15pm"
4
...
```

My first solution was this:

```
co chars str = sum $ map (f str) chars
  where
    f str c = length $ filter (\e -> e == c) str
```

Of the non-recursive solutions I saw, I felt that Ms. McCabe's was the best:

```
co chars string = length $ filter (\x -> x `elem` chars) string
```

Several students wrote a non-recursive solution that was something like this:

```
co chars (c:cs)
  | c `elem` chars = 1 + co chars cs
  | otherwise     = co chars cs
co _ _ = 0
```

Problem 7: (22 points) (mean = 14.4, median = 18)

Write a Ruby program `adjcols.rb` that makes specified adjustments to columns of numeric values in a CSV (comma-separated values) file.

Adjustments are specified as command-line arguments. Here's a sample invocation:

```
ruby adjcols.rb 2:+10 3:=7 5:-1 < x.csv
```

Adjustments have the form `COLUMN-NUMBER:CHANGE`. Examples:

- `2:+10` means to add 10 to all values in column 2 (column numbers are 1-based and positive)
- `3:=7` means to change all values in column 3 to 7
- `5:-1` means to subtract 1 from all values in column 5

This is my solution:

```
puts STDIN.gets

while line = STDIN.gets
```

```

parts = line.split ","
for adj in ARGV
  col, delta = adj.split ":"
  col = col.to_i - 1
  if delta[0] == "="
    newval = delta[1..-1].to_i
  else
    newval = parts[col].to_i + delta.to_i
  end
  parts[col] = newval.to_s
end

puts parts * ","

end

```

I'd hoped that it would be quickly observed that lines could be processed one at a time, but a number of students read all the lines into an array and then iterated over the elements of that array. An attribute that I've found to be common among many long and/or wrong solutions on assignments and exams is this: creation of unnecessary data structures. It takes code to build those unnecessary structures and then code to get data out of those structures. For this problem it also turns a program that could process a file of unlimited size to one that's limited by available memory.

A minor thing that made me groan during grading was the use of a flag to indicate whether the input line at hand was the first line. It seems far simpler to just read and write that first line.

Problem 8: (5 points) (one point each unless otherwise indicated) (mean = 2.9, median = 3)

The following questions and problems are related to Haskell.

(1) Add parentheses to the following type to explicitly show the associativity of the `->` operator.

```
[Int] -> (Int -> Bool) -> [Bool]
```

```
[Int] -> ((Int -> Bool) -> [Bool])
```

(2) Fully parenthesize the following expression to show the order of operations.

```
f 2 g 3 + x f g [ a b c * 1 ]
```

```
((f 2) g) 3 + ((x f) g) [((a b) c) * 1]
```

(3) Rewrite the following function binding to use point-free style:

```
f1 x = f (g x)
```

```
f1 = f . g
```

(4) Briefly, how does Haskell's pattern matching contribute to the readability of Haskell code?

Patterns let us bind names to various elements of data structures, so that instead of writing code that digs into data structures, like

```
f x = g (head x) ++ h (tail x)
```

we can write

```
f (h:t) = g h ++ h t
```

(5) Once upon a time I had this line of code in a file:

```
f x y = x*3 + y
```

I wanted to produce an error on that line, so I typed some junk into the line:

```
asdsf sdfs 3 3 3 f x y = x*3 + y
```

But, that goofy code loaded without error! Why? (Hint: Be sure your answer is more than something like "It's still valid code.")

The junk I typed turned the two-argument function `f` into a seven-argument function named `asdsf`. Three of the arguments are literal pattern matches for the number 3.

Problem 9: (5 points) (one point each unless otherwise indicated) (mean = 2.3, median = 2)

The following questions and problems are related to Ruby.

- (1) *Aside from the fact that strings are mutable in Ruby and are immutable in Java, what's an important difference between the string-handling facilities in Ruby and Java?*

Ruby lets us specify portions of strings with `s[n]`, `s[start, length]`, and `s[Range]`. Additionally, those expressions can be targets of an assignment. Many other answers are valid, too.

- (2) *Imagine that a Ruby class has methods named `mudge` and `mudge!`. What does that imply?*

`mudge` has both an applicative and an imperative form. `mudge`, the applicative form returns a result but doesn't modify its receiver. `mudge!`, the imperative form modifies its receiver.

- (3) *What's a fundamental semantic (i.e., non-syntactic) difference between `if-else` in Ruby and `if-else` in Java?*

`if-else` is a statement in Java but in Ruby it's an expression. In Ruby I can say something like `val = if a > b then c end`.

- (4) *Aside from syntax, what's a fundamental difference between `:load x.hs` in `ghci` and `load "x.rb"` in `irb`?*

`:load` is implemented by the REPL that `ghci` provides; it's not Haskell code. Ruby's `load` is a method; `load "x.rb"` is a Ruby expression that has a side effect of loading the code in `x.rb`.

- (5) *What's the value of each of the two following Ruby expressions?*

```
"abc"[5] && false  
nil
```

```
0 || 1  
0
```

I was surprised by the number of students that missed this one.

Problem 10: (10 points) (one point each unless otherwise indicated) (mean = 6.1, median = 7)

Briefly answer the following general questions.

- (1) *Who founded The University of Arizona's Computer Science department and when?*
Ralph Griswold, in 1971.

- (2) *What are two aspects of a "paradigm", as described in Kuhn's *The Structure of Scientific Revolutions*? Here are two wrong answers: "functional" and "object-oriented". (Two points!)*

See Haskell slide 4.

- (3) *What's a fundamental characteristic of a language that uses static typing?*
Type errors can be detected without running any code or knowing what specific input values are.
- (4) *What's a fundamental characteristic of a language that uses dynamic typing?*
In the general case, type errors can't be detected until code is run.
- (5) *Show an example of syntactic sugar in any language you know.*
In Haskell, "abc" is syntactic sugar for ['a' , 'b' , 'c'].
- (6) *Aside from the intrinsic elements of a language, like its design and performance, what are two factors that can influence the popularity of a language?*
See intro slide 34.
- (7) *whm often says "In Haskell we never change anything; we only make new things." What's an example of that?*
If the first element of a list of integers was to be changed to zero, we'd do that by making a new list whose head is zero and whose tail is the of the list at hand.
- (8) *When a new graduate research assistant wanted to add a bunch of new features to Icon, what did the project's wise leader say?*
Ralph said I could all the features I wanted but for every feature I wanted to add, I first had to find a feature to remove.
- (9) *What's one way in which having a REPL available makes it easier to learn a programming language?*
It makes it easy to experiment with things.

Extra Credit Section (½ point each unless otherwise noted) (mean = 1.9, median = 2)

- (1) *whm believes the abbreviation LHiLaL appears nowhere on the web except in his slides. What does it stand for?*
Learning How to Learn a Language
- (2) *To whom does whm attribute the following quote?*
"When you hit a problem you can lean forward and type or sit back and think."
Dr. Proebsting
- (3) *Consider this Haskell function: `add x y = x + y`. What is the exact type of `add`?*
`Num a => a -> a -> a`
- (4) *Double tricky: What is the exact type of the Haskell list `[foldl, foldr]`?*
My first thought was that it would be a type error because the functions don't have the same type but when I saw that it worked, I realized that the types of the two can be unified:
`[(b -> b -> b) -> b -> [b] -> b]`
- (5) *The Haskell expression `[FROM..TO]` produces an empty list if `FROM > TO`. Write a non-recursive function `range from to` that's a little smarter: `range 1 5` returns `[1,2,3,4,5]`, and `range 5 1` returns `[5,4,3,2,1]`.*

```
range from to
| from <= to = [from..to]
| otherwise = reverse [to..from]
```
- (6) *Suppose the second example for problem 4 (page 5) had been this:*

```
> map count [6,7,8,9]
[1,2,3,4]
```


Briefly, how would that have changed your answer for that question?
It would now be possible to implement `count`.

Note: This question was ill-conceived—virtually any answer could be argued as being correct but it was only

marked as correct if you said that `count` could now be implemented. Consider a half-point of the 8-point adjustment as being compensation for any injustice on this question.

- (7) If you only remember one thing about the Haskell segment of 372, what will it be? (Ok to be funny!)
Presented anonymously and in random order, here's what was said:

Haskell has no debugger, and thus sucks.
functional programming can be very useful
That recursion is occasionally ok
maps & folds are useful!
Partial application
The power of cons.
I need to watch my types...
unhelpful error messages :(
It was (fun)ctional!
recursion is easier with patterns
Anonymous functions are beautiful.
The Friday Night Club isn't as fun as it sounds
Don't over think it!
I'm not good at it.
Patterns.
pancakes on the stack
Haskell functions seem to be redundant to death (having to write the function name again for every possibility of input)
I can't eat pancakes any more
putting the fun in FUNctional programming
So much recursion
mapping
You never change anything. Only make new things.
Haskell is short for HaskHell
higher order functions
expected `[Char]`, was instead `[[Char]]`
A whole lot of time spent to find a solution with very little code
Iteration is for the weak!
Recursion isn't complete hell
Pancake
Crying tears of blood when forgetting to add a base case in recursion problems
Type error everywhere
functions are values
higher order function
Matt Gautreau was right. Don't tell him I said that.
Patterns over guards over if-else.
Pancakes Toyota
There's probably a Prelude function to do something for you if you look hard enough
f this f that f it
variable state, why don't you change!
maps are crazy useful
Recursion is now my best friend haha
Know your recursion!
anonymous functions
recursion!

- (8) What is "duck typing"?
A style of programming/mindset for typing where we're only concerned about the operations provided by objects rather than their types.

(9) *With Ruby in mind, define the term "iterator".*
 An iterator is a method that can invoke a block.

(10) *Name a language other than Icon that was created at The University of Arizona.*
 See intro slide 38.

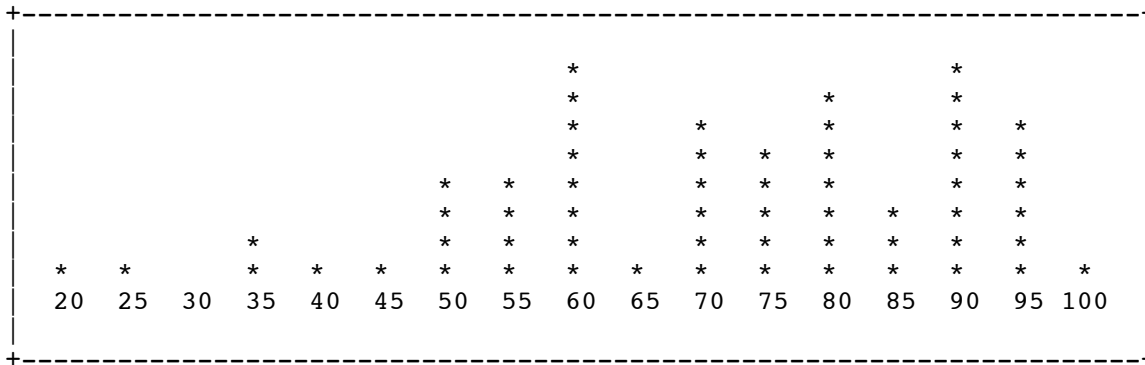
Statistics

Here are all scores:

98.5, 95.5, 94.5, 94, 94, 93, 92.5, 91, 91, 90, 89.5, 89.5, 88, 87.5, 87.5,
 84.5, 84, 82.5, 81.5, 81, 81, 79.5, 79.5, 78, 77.5, 76, 75, 74.5, 73.5, 73,
 71.5, 71.5, 69.5, 68.5, 68, 67.5, 63, 61.5, 61, 60.5, 60, 59, 58.5, 58.5, 58.5,
 53.5, 53.5, 53, 53, 49.5, 48.5, 48, 47.5, 46, 40.5, 37, 34.5, 22.5, 18.5

n = 59
 mean = 69.8
 median = 73

Here's a histogram of all scores. The five-point wide bins cover the interval $[X-2.5, X+2.5)$, where X is the label for a bin.



The mean and median were lower than I expected, so eight points were added to all scores before loading them on D2L.

CSC 372 Final Exam
Monday, May 9, 2016
Solutions

Problem 1: (6 points) (mean: 5.6, median: 6)

Cite three things about programming languages you learned by watching your classmates' video projects. Each of the three should be about a different language and have a bit of depth, as described in the Piazza post that announced this problem.

When grading I tallied the video topics that were cited and came up with the counts below, with a cut-off of five. In some cases I lumped together all topics for a language into a single count.

Magic Methods in Python	20
Ruby's method_missing	17
PHP	17
JavaScript	10
Character sets in Icon	9
R	9
Swift	9
Lambdas in Java 8	8
Threads in Ruby	8
Functors in Haskell	7
Arrays in Go	6
Randomness in Haskell	6
List comprehensions in Python	6
Hotswapping in Java	5

Videos excelled in different dimensions but if I had to pick an overall winner, it would be K. Taylor's [APL - The Implications of Unicode](#).

Here are some others that I felt were particularly outstanding for one reason or another. Authors are not cited because I promised the potential of anonymity.

[Closures in JavaScript](#)

[Introduction to Common Lisp: S-Expressions and list/quote/eval](#)

[Haskell Monads in 8 Minutes](#)

[Control Structures in bash](#)

[Magic Methods in Python](#)

[Introduction to Monoids](#)

[An Exploration of Channels in Go](#)

[A Little on Functors](#)

["Globals" in MUMPS](#)

[Python Asterisk\(*\) usage](#)

[Why Nobody Uses Go Arrays](#)

Problem 2: (1 point) (mean: 0.3, median: 0)

Write a Haskell function `doflip pancakes flip` that performs an `fsort`-style flip.

```
doflip pancakes n = reverse (take n pancakes) ++ (drop n pancakes)
```

I intended this one to be a dead-simple list-manipulation problem that leveraged a concept from `fsort` but only about a third of you attempted it. The rest perhaps instinctively recoiled as soon as they saw "pancakes".

Problem 3: (3 points) (mean: 2.3, median: 3)

Write a **recursive** Haskell function `totlen list` that returns the total length of the strings in `list`.

```
totlen [] = 0
totlen (h:t) = length h + totlen t
```

Problem 4: (4 points) (mean: 2.7 median: 4)

Write a Haskell function `xout string` that replaces every letter (a-z) in `string` with an "x" of the same case. Non-letters are unchanged.

```
xout = map f
  where
    f c
      | isLower c = 'x'
      | isUpper c = 'X'
      | otherwise = c
```

Problem 5: (2 points) (mean: 1, median: 0.75)

Write a folding function `f` such that the `foldr` call below behaves as shown, returning a list of the odd numbers in its last argument.

```
> foldr f [] [5,2,9,4,4,3,1]
[5,9,3,1]

f elem acm
| odd elem = elem:acm
| otherwise = acm
```

Problem 6: (5 points) (mean: 4.6, median: 5)

Write a Ruby iterator `sbl(a, max)` ("strings by length") that first yields each one-character string in the array `a`. It then yields each two-character string in `a`. The process continues up through strings of length `max`. Strings are yielded in the order they appear in `a`. `sbl` always returns `nil`.

```
def sbl(a,max)
  for i in 1..max
    for s in a
      if s.size == i
        yield s
      end
    end
  end
end
nil
end
```

Problem 7: (4 points) (mean: 2.9, median: 3)

Write a Ruby method `pages_re` that returns a regular expression that matches a string iff the string consists of one or more comma-separated page specifications. A page specification is one of these three:

- A number, such as "12".
- Two numbers separated by a dash, such as "1-3".
- A number followed by a dash, such as "2500-".

```
def pages_re
  num = /\d+|\d+-\d*/
  /^#{num}(,#{num})*$/
end
```

Problem 8: (11 points) (mean: 8.8, median: 10)

Write a Ruby program `mostfreq.rb` that reads lines on standard input and writes out each line followed by an annotation that shows which non-space character appears most frequently on the line, and how many times it appears.

```
def main
  while line = gets
    line.chomp!
    puts "#{line.ljust(30)}#{count line}"
  end
end

def count s
  counts = Hash.new(0)

  s.each_char {|c| counts[c] += 1 if c != " "}
  first = counts.sort_by_value[-1]

  if first
    " ('#{first[0]}': #{first[1]})"
  else
    ""
  end
end
```

```

        end
    end

    main

```

Problem 9: (8 points) (mean: 5.6, median: 6.5)

In this problem you are to implement a Ruby class named `Seq` that represents a sequence of values with a maximum length.

```

class Seq
  def initialize n
    @n = n
    @vals = []
  end

  def << rhs
    @vals << rhs
    if @vals.size > @n
      @vals.shift
    end
    self
  end

  def inspect
    "|" + @vals * "-" + "|"
  end
end

```

Problem 10: (6 points) (mean: 4.1, median: 5)

Write the following simple Prolog predicates. There will be a half-point deduction for each occurrence of a singleton variable or failing to take full advantage of unification.

- (a) `fl_same(?L)` expresses the relationship that the first and last elements of `L` are identical. It should be able to handle all possible combinations of instantiated and uninstantiated variables. `fl_same` fails if the list is empty. Examples:

```
fl_same(L) :- L = [H|_], last(L,H).
```

- (b) `revgen(+L,-X)` generates the elements of the list `L` in reverse order.

```
revgen(L,X) :- reverse(L,RL), member(X,RL).
```

- (c) Write the library predicate `member/2`. Examples:

```
member(X, [X|_]).
member(X, [_|T]) :- member(X,T).
```

Problem 11: (6 points) (mean: 3.2, median: 3)

`abl(+Atoms,+Max,-A)` first instantiates `A` to each one-character atom in `Atoms`, then each two-character atom in `Atoms`, etc. `abl` continues for atoms of lengths up through `Max`, if any are that long.

```
abl(Atoms,Max,A) :- between(1,Max,N), member(A,Atoms),
```

```
atom_chars(A, Chars), length(Chars, N).
```

Problem 12: (8 points) (mean: 4.1, median: 5)

Write a Prolog predicate `findrun(+L,+N,+X,-Pos)` that looks for N -long runs of X in L , instantiating Pos to the zero-based starting position of each run. Assume N is greater than zero.

```
findrun(L,N,X,Pos) :-
    repl(X,N,Mid), append(Pre,Rest,L), append(Mid,_,Rest),
    length(Pre,Pos).
```

Problem 13: (7 points) (mean: 5.1, median: 5.5)

Write a predicate `expand(+List,-Expanded)` that takes a list of (1) atoms and (2) structures of the form $Atom^*N$ and produces an "expanded" list. Assume the N terms are ≥ 0 .

```
expand([], []).
expand([Atom*N|T], R)
    :- repl(Atom,N,Rep), expand(T,More), append(Rep,More,R), !.
expand([H|T], [H|R]) :- expand(T,R).
```

Problem 14: (11 points) (mean: 6.6, median: 8)

Write a Prolog predicate `reach(+Destination,+Jumps,+Fences,-Solution)` that finds a sequence of "jumps" on a Cartesian plane from $(0,0)$ to the Destination (a $pos/2$ structure), being sure that no jump lands on a fence.

```
reach(Dest, Jumps, Fences, Solution) :-
    reach0(Dest, Jumps, Fences, pos(0,0), Solution).

reach0(pos(X,Y), _, _, pos(X,Y), []).

reach0(Dest, Jumps, Fences, pos(CX,CY), [Jump|MoreJumps]) :-
    select(Jump, Jumps, Remaining),
    Jump = jump(X,Y),
    NX is CX+X, NY is CY+Y,
    \+on_fence(pos(NX, NY), Fences),
    reach0(Dest, Remaining, Fences, pos(NX,NY), MoreJumps).

on_fence(pos(X,Y), Fences) :-
    (member(fence(x,X), Fences); member(fence(y,Y), Fences)).
```

Problem 15: (4 points) (one point each) (mean: 2.5, median: 2.5)

The following questions and problems are related to Prolog.

(1) When writing documentation for Prolog predicates, arguments are often prefixed with the symbols $+$, $-$, and $?$, such as $p(+X, ?Y, -Z)$. What does each of those three symbols mean?

plus: should be instantiated
minus: will be instantiated
question mark: either instantiated or uninstantiated

(2) Write a sentence that expresses the relationship between the terms "fact", "clause", and "rule".

Facts and rules are clauses.

(3) Consider the following goal written by a novice Prolog programmer:

```
X is X + length(List)
```

What are two misunderstandings evidenced by that goal?

(1) Seems to be treating `is` as assignment, not unification. `X is X + anything` won't succeed unless anything is zero.

(2) Seems to be thinking of `length` not as a predicate but an arithmetic function that `is/2` knows about.

(4) What's the most important fundamental difference between a Prolog predicate like `append/3` and a function/method of the same name in Haskell, Ruby, or Java?

Prolog's `append/3` can be used to perform many operations, like taking a list apart.

Problem 16: (7 points) (mean: 6.2, median: 7)

Below is a transcript of interaction with Standard ML of New Jersey, a functional programming language. Annotate the transcript with seven significant observations about Standard ML. Excellent or additional observations may earn up to a total of three points of extra credit.

```
$ sml
Standard ML of New Jersey v110.69 [built: Mon Jun  8 23:24:21 2009]
  A few students said, "sml starts a REPL". That was a little thin, but good enough!
```

```
- 5 + ~7;
val it = ~2 : int
```

Tilde is the unary negation operator.

Some said that tilde indicates an approximate value, and although 5 plus around 7 wouldn't be around 2, we took it, on grounds of creativity.

`int` is SML's name for an integer type.

The name `it` is bound to the last value produced.

Semicolons are required after an expression.

```
- (1, 2.0, "three");
val it = (1,2.0,"three") : int * real * string
```

There are tuples.

Tuples can be heterogenous.

`real` and `string` are names for types.

The type of tuples is shown as `TYPE1 * TYPE2 * ... * TYPEN`.

An ML programmer would read that type as "int cross real cross string", by the way.

```
- explode "test";  
val it = [#"t",#"e",#"s",#"t"] : char list  
string and char are distinct types. (Worth two points.)
```

char literals are #"c".

List types are shown with the suffix `list`, in contrast to Haskell's `[TYPE]` notation.

Juxtaposition is function call.

```
- implode it;  
val it = "test" : string  
implode and explode are inverses.  
  
- map (fn(n) => n * 3) [3, 1, 5, 9]; {- See above re map -}  
val it = [9,3,15,27] : int list  
Anonymous functions are supported.
```

Higher-order functions are supported.

{- ... -} is a comment

[...] is a list literal

```
- it::[];  
val it = [(1,2.0,"three")] : (int * real * string) list  
:: is a "cons" operation.
```

```
- fun f1 a b = [a,b];  
val f1 = fn : 'a -> 'a -> 'a list  
fun is used to declare a function.
```

An equals sign separates the "parameters" (which could be patterns, just like Haskell) from the expression that specifies the value.

Functions are curried.

Type variables are denoted with an apostrophe. (An ML programmer would read 'a as "alpha" and 'b as "beta". You might have occasionally heard me inadvertently use "alpha" and "beta" when reading a type variable in Haskell.)

```
- fun f2 a b = [a = b];  
val f2 = fn : ''a -> ''a -> bool list  
The boolean type is named bool.
```

= is an equality operator.

If memory serves, only 2-3 students observed that the type variables for `f2` are preceded with two apostrophes instead of only one. I believe only student went further and correctly guessed that the double apostrophes rose from the comparison. That observation was surely

worth two points.

Background: Standard ML doesn't have the notion of type classes like Eq , but it does distinguish types whose values can be compared for equality, and ' ' a would be recognized as an *equality type*.

```
- 3 + 4.5;  
stdIn:1.1-1.6 Error: operator and operand don't agree [literal]  
operator domain: int * int  
operand:          int * real  
"Mixed-mode" arithmetic is not allowed.  
  
- (hd [1,2,3], tl [1,2,3]);  
val it = (1,[2,3]) : int * int list  
hd and tl are "head" and "tail"
```

I last taught Standard ML in 372 in Fall 2006. My slides are here:

<http://cs.arizona.edu/classes/cs372/fall06/sml.sli.pdf> You'll see that a lot of ML examples translate well into Haskell examples...

Problem 17: (7 points) (one point each unless otherwise indicated) (mean: 3.1, median: 3.5)

Answer the following general questions.

- (1) What's something significant related to programming languages that you remember from the *JarWars* video we viewed and discussed during the second-to-last class?

Tiger was the code name for Java 5, which introduced generics.

- (2) Ralph Griswold said, "If you're going to invent a language, be sure to invent a language that you want to use."

- (3) What is the fundamental characteristic of a dynamically typed language?

In general, the type of an expression can't be known without executing the code.

- (4) How does *Icon* avoid the "to versus through" problem that plagues string indexing in many languages and libraries?

String positions are considered to be between characters.

- (5) What's something significant about *Icon* you recall from the *Icon by Observation* exercise during the last class? (Hint: Don't cite your answer for the previous question!)

*x produces the number of elements in x.

- (6) With programming languages in general, what's the fundamental difference between a statement and an expression?

Expressions produce a value; statements don't. Typically the only reason to execute a statement is to produce a side-effect.

- (7) Which of the three languages we covered this semester are you most glad we covered, and why?

Haskell	22
Prolog	20
Ruby	9

Extra Credit Section (½ point each unless otherwise noted) (mean: x, median: y)

- (1) In as few words as possible, what is "The Cathedral and the Bazaar"? (Mentioned in a 7 solutions.)
Book

- (2) In what month of the year 1891 were classes first held at The University of Arizona?
October. See also

<http://www.arizona.edu/topics/about-university/about-university-arizona/ua-history-and-traditions>

- (3) With Prolog in mind, why is "camelcase variable" an oxymoron?
Something like `maxValue` would be an atom!

- (4) The technology known as Leda was mentioned on Piazza. What is Leda?
A multi-paradigm programming language created by Tim Budd.

- (5) Draw an appropriate avatar for any one of the three languages we covered.
My favorite was Mr. Ferra's "Haskell-Guy", but I'm inclined to call him Lambda Man.



- (6) Name a language that was once studied in depth in 372 but isn't any more.
C++, Icon, Standard ML, Lisp, Emacs Lisp are five I know of.

- (7) Who do you think whom will vote for in November's presidential election?
There was a lot of variety here, including "nobody", "not Trump", Ralph Griswold, Mickey Mouse (an always popular write-in, election after election), and "self".

Popular guesses were these:

Bernie	9
Hillary	12
Trump	6

Early on I liked Fiorina, Cruz, Rubio, and Trump; I later came to like Kasich. But Trump's getting my vote in November!

- (8) Why did whm's solution for `pipes.pl` have the following line? `do(p) :- do(pipes).`
So the pipes could be shown with just `p..`

- (9) (1 point) `mostfreq.rb` says to assume that `Hash` has a `sort_by_value` method. Write Ruby code that makes that be true.

```
class Hash
  def sort_by_value
    self.sort {|a,b| a[1] <=> b[1]}
  end
end
```

```
    end
end
```

(10) *What did Knuth say about premature optimization?*
It's the root of all evil.

(11) (1 point) *Using only `append` and `length`, and no recursion, write a Prolog predicate `longer(A,B)`, which is true iff list A is longer than list B.*

```
longer(A,B) :- length(A,N), length(X,N), append(B,[_|_],X).
% by Patrick
```

(12) (1 point) *In SNOBOL4, how do you indicate where control should go if a statement fails?*
... `:F(LABEL)`

(13) *whm hates writing up Piazza posts with suggested readings! They usually don't align well with his slides and he wonders if anybody actually does any of the readings. Over the course of the full semester, how many hours do you estimate you spent doing the suggested readings? (This is just data collection, no right/wrong.)*

```
N = 43
mean = 3.670
median = 1.000
```

(14) *Write a joke about programming languages.*

A number of students expressed their true feelings about various languages with these one-word offerings:
C, Java, JavaScript, Perl, and Prolog.

I believe these are original and worth repeating:

"Prolog was invented by aliens, it's more logical than life."

"I just made a new programming language called FUN (Fantastically Underachieving Newbie!)"

"It won't right on the first run, or the second, or the third, but it might eventually."

"Prolog should be called Prolonger than Haskell."

"What did Ruby say to her boyfriend Prolog on Valentine's Day? You better HAS something good for me or I'll KELL you!"

"Why are Java programmers wealthy? Inheritance. [crickets]"

"Knock, knock.

Who's there?

Haskell.

Go away."

"My love for Prolog is TRUE."

(15) Finish this sentence: "If I only remember one thing about 372 it will be ...".

Here are a few:

"To start early."

"the FRIDAY NIGHT CLUB"

"That logic programming is virtually impossible."

"Pancakes" [several of these]

"The day you almost lost your voice during the first week of lecture." [almost?]

"Ruby is a cool language and to stay away from Prolog."

"If you are looking for a job, everyone should know [you are looking for a job]."

"append in Prolog is amazing"

"Programming problems are better when they have pancakes/food in them."

"p a n c a k e s"

"The horror of pancakes."

"Prolog programmers think Haskell is a cute toy."

"How much I love quizzes."

"1000+ slides"

"Haskell sucks"

"Ralph Griswold founded the CS department in 1971."

Statistics

All scores, in order:

104.00, 95.50, 95.00, 92.00, 92.00, 92.00, 91.50, 90.50, 88.50, 88.50,
87.50, 87.50, 87.50, 86.50, 86.00, 86.00, 85.00, 83.00, 81.50, 81.00, 80.50,
80.50, 79.50, 79.00, 79.00, 77.50, 77.00, 76.50, 75.00, 74.50, 74.00, 72.00,
71.50, 71.00, 70.50, 70.00, 69.50, 69.00, 68.50, 68.50, 67.50, 62.50, 62.50,
62.50, 61.00, 58.00, 58.00, 58.00, 57.50, 57.25, 57.00, 56.50, 55.50, 54.00,
50.50, 39.00, 39.00, 31.00

N = 58

mean = 73.306

median = 74.75

CSC 372 Mid-term Exam Solutions
Monday, March 19, 2018

Problem 1: (5 points) (one point each) (mean: 3.72, median: 4, 3rd quartile: 4)

What is the **type** of each of the following values? If the expression is invalid, briefly state why.

Assume integers have the type `Int`. Remember that `String` is a type synonym for `[Char]`—the two can be used interchangeably.

```
'a'
    Char
```

```
("a", ['a'])
    ([Char], [Char])
```

```
snd (Reminder: snd produces the second element of a 2-tuple.)
    (a, b) -> b
```

```
map snd
    [(a, b)] -> [b]
```

```
fold . length (3 + 4)
    Error! length wants a list (actually a Foldable).
```

Problem 2: (3 points) (mean: 1.7, median: 2, 3rd quartile: 2)

This problem is like `ftypes.hs` on `a3`. Write functions `f1`, `f2`, and `f3` having each of the following types. There are no restrictions other than you may not use an explicit type declaration. (e.g. `f1 :: ...`)

```
f1 :: (a,b) -> (b,a,b)
    f1 (a,b) = (b,a,b)
```

```
f2 :: [a] -> [b] -> (b,a)
    f2 [a] [b] = (b,a)
```

```
f3 :: (a -> b) -> a -> b -> b
    f3 f a b = head [f a, b]
```

Problem 3: (7 points, as indicated) (mean: 4.93, median: 5.5, 3rd quartile: 6.5)

This problem is like `warmup.hs` on the assignments—write the following Haskell Prelude functions.

Instances of poor style or needlessly using other Prelude or helper functions will result in deductions.

Be sure to use the wildcard pattern (underscore) when appropriate.

There's no need to specify function types.

`snd` (Returns second element of a two-tuple) [1 point]

```
snd (_,b) = b
```

`not` [1 point]

```
not False = True
```

```
not _ = False
```

`at list n` (Like `list!!n`. Assume `n` is in-bounds.) [2 points]

```
at (h:_) 0 = h
```

```
at (_:t) n = at t (n-1)
```

`map` [2 points]

```
map _ [] = []
```

```
map f (h:t) = f h : map f t
```

`flip` (Reminder: `flip take "abc" 2 == "ab"`) [1 point]

```
flip f x y = f y x
```

Problem 4: (12 points) (6 points each) (recursive—mean: 5.55, median: 6, 3rd quartile: 6)
(non-recursive—mean: 4.82, median: 6, 3rd quartile: 6)

For this problem you are to write both recursive and non-recursive versions of a Haskell function `sumexcl nums exclude`, having type `[Int] -> Int -> Int`, that returns the sum of the values in `nums`, excluding all occurrences of the value `exclude`.

```
> sumexcl [1,10,2,3,10] 10
6
```

Recursive

```
sumexcl :: [Int] -> Int -> Int
```

```
sumexcl [] _ = 0
```

```
sumexcl (x:xs) e
```

```
  | x == e = sumexcl xs e
```

```
  | otherwise = x + sumexcl xs e
```

Non-recursive:

```
sumexcl :: [Int] -> Int -> Int
```

```
sumexcl list e = sum $ filter (e /=) list
```

Problem 5: (6 points) (mean: 5.40, median: 6, 3rd quartile: 6)

Certain conditional code in Haskell can be written in three different ways:

- with `if-else`
- with `guards`
- with `patterns`

Imagine a function `f` that returns `'a'` if called with `1` or `2` but if called with any other number, it returns `'b'`.

For this problem you are to write three versions of `f`: one using `if-else`, one using `guards`, and one using `patterns`.

With if-else:

```
f x = if x == 1 || x == 2 then 'a' else 'b'
```

With guards:

```
f2 x
  | x == 1 || x == 2 = 'a'
  | otherwise = 'b'
```

With patterns:

```
f3 1 = 'a'
f3 2 = 'a'
f3 _ = 'b'
```

Problem 6: (6 points) (mean: 4.18, median: 5, 3rd quartile: 5.5)

The Haskell function `evenwords s` returns a string containing only the even-length words in the string `s`. Here is an incomplete solution for `evenwords`:

```
evenwords s = unwords (foldr ff [] (words s))
```

What's missing is the folding function `ff`. Your task for this problem is to write the function `ff`.

```
ff w acm
  | even $ length w = w : acm
  | otherwise = acm
```

Problem 7: (18 points) (7 and 11 points, respectively) (recursive—mean: 6.19, median: 6.5, 3rd quartile: 7)
(non-recursive—mean: 5.21, median: 5, 3rd quartile: 10.5)

For this problem you are to **write both recursive and non-recursive versions** of a function `deo` having type `[Int] -> [Int]`, that doubles every other number in a list.

Recursive:

```
deo [] = []
deo [x] = [x]
deo (x1:x2:xs) = x1:(x2 * 2):deo xs
```

This is the non-recursive solution I initially wrote:

```
deo list = result
  where
    double = cycle [False, True]
    result = map f $ zip double list
    f (True, x) = x * 2
    f (_, x) = x
```

But Mr. McClean showed me the right way to do it:

```
deo_mc nums = zipWith (*) nums $ cycle [1, 2]
```


Problem 8: (5 points) (one point each unless otherwise indicated) (mean: 3.54, median: 3.5, 3rd quartile: 4.5)

The following questions and problems are related to Haskell.

(1) *In Haskell, as in many functional languages, the list type is a "cons list". Using the style shown in the slides, draw a diagram of the list [10, 20, 30].*

I'm lazy! See b on slide 140.

(2) *What's wrong with the following statement regarding a Haskell function named f ?
"The type of f is (Int, Char)."*

If f is a function, there should be a \rightarrow in the type.

(3) *What is the essential idea of lazy evaluation?*

Expressions are not evaluated until their value is needed.

(4) *In Haskell, what's the difference between a type and a type class?*

A type is a set of values. A type class is a set of types.

(5) *If a Haskell function requires three parameters but is called with only two parameters, what happens?*

A partial application is produced.

Problem 9: (15 points) (mean: 12.23, median: 14.5, 3rd quartile: 15)

Write a Ruby program that reads lines from standard input and upon end of file writes the longest line and its line number to standard output. If there are ties for the longest line, the program writes out all the lines that tie. If there is no input, the program produces no output.

```
longest = -1
num = 1
result = []

while line = gets do
  line.chomp!
  len = line.size
  if len > longest then
    result = [[num, line]]
    longest = len
  elsif len == longest then
    result << [num, line]
  end
  num += 1
end

for num, line in result do
  puts "#{num}: '#{line}'"
end
```

I have to admit there was some fantasy in the assignment 5 solutions. In the assignment 5 write-up I mentioned

that I'd used `longest.rb` a number of times but over time enough students had become unduly frustrated with it that I decided to make it a zero-pointer this semester. Nobody turned in a solution for it this semester, but nonetheless I recycled the detailed story about student encounters from the Spring 2016 solutions since I felt it had some good lessons. But since nobody turned in a solution for it, I felt ok about putting a simple version of it on the exam.

Quite a few exam solutions stored the full input in an array, noting the length of the longest line in the process, and then making a second pass over the array, printing lines of that length. Memory is really cheap these days but I think there's still merit in algorithms that are conservative with memory.

Here's a slightly different version of the main loop, based on several solutions:

```
while line = gets do
  line.chomp!
  len = line.size
  if len > longest then
    result = []
    longest = len
  end
  if len == longest then
    result << [num, line]
  end
  num += 1
end
```

BEFORE READING FURTHER, see if you can find the bug in the loop above.

At first glance I thought that the code above was buggy but in fact it works just fine. It took me a second look to realize that the first `if` sets `longest` to `len`, which makes the second `if`'s condition be true. Which of the two forms do you prefer?

Problem 10: (9 points) (mean: 6.8, median: 8, 3rd quartile: 8.5)

Write a Ruby program whose command-line arguments are pairs of counts and strings. For each pair, the string is replicated by the associated count and written to standard output. All strings are output on a single line with no separation, but that line does end with a newline.

If run with no arguments or an odd number of arguments, the program prints a question mark on a line by itself. Assume counts are always non-negative integers.

This was my first solution:

```
a = ARGV

if a.empty? || a.size.odd? then
  puts "?"
  exit
end

while !a.empty? do
  n, s = a[0,2]
  print s * n.to_i
  a.slice!(0,2) # Why not: drop!(2) would be nice here.
end
```

```
puts
```

I generally avoid indexing when I can, but in the process of grading this problem I came to like better a loop that uses indexing:

```
i = 0
while a[i]
  n, s = a[i,2]
  print s * n.to_i
  i += 2
end
```

However, `Enumerable.each_slice` lets us replace the loop with a one-liner:

```
a.each_slice(2) {|n,s| print s * n.to_i}
```

Problem 11: (5 points) (one point each unless otherwise indicated) (mean: 2.75, median: 3, 3rd quartile: 3)

The following questions and problems are related to Ruby.

(1) *In class it's been said that some Ruby methods are applicative and others are imperative. What's the difference between the two?*

Applicative methods never modify their receiver but imperative methods might in some cases.

(2) *What is the value of the following Ruby expression? `""[0] || [""][0]`*

`""` (empty string)

(3) *What is a major way in which Ruby arrays differ from Java arrays? (OR, What is a major way in which Ruby arrays differ from Java lists?)*

Ruby arrays differ from Java arrays in many ways. Ruby arrays...

- Are heterogeneous
- Allow negative indexing
- Can be concatenated
- Can have elements inserted or deleted
- And more!

A fundamental difference between Ruby arrays and Java's `List` hierarchy is that Ruby arrays can be accessed with symbolic syntax like `a[n]`, `a[start, len]` and more.

(4) *What is the value of the following Ruby expression? `[1,2,3,3] <=> [1,2,3,5]`*

- (a) -1
(b) 0
(c) 1
(d) 2

(5) *With duck typing in mind, what are two things that must be true for `x[y]` to be a valid expression?*

`x` must have a `.[]` method for which `y` is a valid argument.

As mentioned at the start of the exam, this question was out of bounds wrt. the material I said the exam would

cover. To compensate for that, the score written on the front of your exam is your actual score plus one point. If you went ahead and correctly answered this question, you got a point for that, too.

Problem 12: (9 points) (one point each unless otherwise indicated) (mean: 4.63, median: 5, 3rd quartile: 6.5)

Briefly answer the following general questions.

- (1) *Who founded The University of Arizona's Computer Science department and when? (Hint: the ASCII code for 'D' is 68.)*

One student wrote, "1791". Dr. Ralph Griswold was certainly a pioneer but he didn't found our department until 1971.

For years I had trouble remembering whether it was 1971 or 1972 but when I learned the ASCII codes I noticed that the code for 'G', like in Griswold, was 71, and I never had trouble with that again.

I hinted that 'D' was 68 to help those who might have remembered the connection to ASCII from intro slide 39 but didn't know the code for any uppercase letter.

- (2) *Circle the best answer:*

Ralph Griswold said that if you're going to design a language it should be...

- (a) A language you want to use*
- (b) A language that is easy to use*
- (c) A language that many people will want to use*
- (d) A language that professional developers will want to use*

- (3) *In general, which is larger and why, the mental footprint required to be able to write code in a language or the mental footprint required to be able to read code in a language?*

As discussed in class, the reading footprint is bigger because while you can solve any problem using only a small, *Turing complete* subset of a language, to read an arbitrary program, you might need to any or all parts of the language.

- (4) *In class it was said that some language designers have an attitude of "Why?" and others have an attitude of "Why not?" What's the difference in those two attitudes? Support your answer with a brief example.*

I felt Mr. Chipman said it best:

"Why?—you need a good reason to add a feature.

"Why not?—you need a good reason to not add a feature.

We've seen lots of examples of how Matz seems to tend toward "Why not?" with Ruby.

- (5) *As it relates to this class, what's a dunsel?*

The answer to this can be found in any of the assignment solutions that have been distributed.

- (6) *Specifications for programming languages generally focus on two areas, syntax and semantics. With respect to programming languages what does "semantics" mean?*

The meaning of a sequence of symbols.

- (7) We've talked about three aspects of expressions: value, type, and side effect. For each of the three, write a

sentence or two that describes the concept (i.e, value, type, or side effect), being sure to cite an example. (1 point each)

Extra Credit Section (½ point each unless otherwise noted) (mean: 0.67, median: 0.25, 3rd quartile: 1)

- (1) *What's the value of the following Ruby expression? `[1,2,3].each { puts 1 } [1,2,3]`*
- (2) *In Ruby, what is the output produced by `"abc".each { |s| puts s[0].size.class }`?
It's an error. The String class doesn't have an each method, to my dismay.*
- (3) *Write a Haskell function with the following type: $(a, b, a) \rightarrow (b, a, b)$*

`f (a,b,a) = (b,a,b)` was a common answer but you'll need to wait for Prolog if you want to name a parameter more than once in the argument list. Meanwhile, you can do this:
`f (a,b,_) = (b,a,b)`
`f (_,b,a) = (b,a,b)`
- (4) *What is the name of the Ruby operation performed by `[1,2,3] * "x"`?
Intercalation*
- (5) *Fill in the blanks below to produce a Haskell expression whose value is a function.*
`take $ 5`
- (6) *In `ghci`, what's something `:info` will show me that `:type` won't?
For one thing, `:info +` will show the precedence of that operator.*
- (7) *What's wrong with the following statement? "Java is an interpreted language."
Slide 76: "Interpretation and compilation are attributes of an implementation of a language, not the language itself!"*
- (8) *Fill in the blanks: Cells in a cons list comprise a/an head and a/an tail.*
- (9) *As a Ruby programmer, tell me what MRI is.
Matz Ruby Implementation*
- (10) *Honor system: If you've created at least two Chrome (or Firefox, etc.) search engines, as described in cs.arizona.edu/~whm/o1nav.pdf and suggested on on Ruby slide 9, what are their keywords? (i.e., What do you type in the address bar to invoke them?)*

I was disappointed that only six students earned this easy half-point. I wonder if the class will fare any better on the final exam.

Here are all scores, in descending order:

100.25, 98.75, 95, 92.25, 90.5, 90, 89.5, 88.75, 88, 85.75, 83.5, 83, 82.5, 82.5, 81.5, 80, 79.75, 79, 79, 79, 78.75, 78.25, 78, 77.25, 76, 75, 74.5, 73.5, 73, 71.75, 71.25, 70.5, 67.25, 64.75, 64.25, 63.5, 62, 60, 59.5, 58.5, 58.5, 57, 56, 55, 53.5, 52, 49.25, 49, 41.5, 39.5

To see your rank, put the lines above in a file `x` and do this: `tr , \\n < x | cat -n`

N = 50, mean = 72.7, median = 75.5, 3rd quartile: 82.5

CSC 372 Final Exam Solutions
Tuesday, May 8, 2018

Problem 1: (6 points) (mean: 5.58, median: 6)

Cite three things about programming languages you learned by watching your classmates' video projects. Each of the three should be about a different language and have a bit of depth, as described in the Piazza post that announced this problem.

When grading I tallied the video topics that were cited and came up with the counts below, with a cut-off of three. There were multiple videos on some topics; a combined total is shown for those.

Python Magic Methods (combined)	15
PHP Arrays (combined)	11
Optionals in Swift	11
Tables in Lua	10
Java Lambdas and Streams (combined)	10
Bash Arrays (combined)	10
For-else clause in Python	9
Ownership in Rust	7
String Scanning in Icon	6
LINQ (Language Integrated Query) in C#	6
Functors in Haskell	5
Lambdas + Macros in Clojure	4
C++ Classes and Objects	3
INLINE X86 in C: A New Hope	3
Ruby Threads (combined)	3

There were four videos that I felt were particularly outstanding for one reason or another. Authors are not cited because I promised the potential of anonymity. In alphabetical order, here are those four videos:

[Constraint Logic Programming Over Finite Domains](#)

[Feature and Usage of java.util.stream](#)

[Optionals in Swift](#)

[Ownership in Rust](#)

Problem 2: (6 points) (mean: 4.62, median: 6)

Given the following Haskell function definition,

```
f xs ys = foldr (++) [] (map m (zip xs ys))
  where
    m (a,b) = [a,b]
```

What does the following expression produce?

```
f ['h','e','l','l','o'] "hello"
```

- a) "hellohello"
- b) ["hh", "ee", "ll", "oo"]
- c) [('h','h'), ('e','e'), ('l','l'), ('o','o')]
- d) "hheellllloo"**
- e) A type error of some sort.

Michael wrote this question for the mid-term. I ended up without a good place for it then but I found it perfect for the final, both due to its use of higher-order functions and a well-designed set of distractors.

Problem 3: (4 points) (mean: 3.53, median: 4)

Write a Haskell function `again`, of type `Eq t => [t] -> Bool`, that returns `True` if and only if the first element of `list` appears again elsewhere in the list.

`again` returns `False` if `list` has less than two elements.

This problem can be solved in many ways but here's a solution facilitated by the higher-order function `any`, of type `Foldable t => (a -> Bool) -> t -> Bool`:

```
again (x:xs) = any (==x) xs
again _ = False
```

Problem 4: (3 points) (mean: 2.68, median: 3)

Write a Ruby iterator `inorder(x,y,z)` that yields the values `x`, `y`, and `z` in ascending order. Assume that `x`, `y`, and `z` can be sorted with Ruby's `Enumerable#sort` method. `inorder` always returns `nil`.

```
def inorder(x,y,z)
  [x,y,z].sort.each { |x| yield x }
  nil
end
```

Problem 5: (6 points) (mean: 4.85, median: 5.75)

This *Ruby* problem is similar to `btw.pl` from assignment 9. Write a *Ruby* *iterator* `btw(a, sep)` that yields copies of the array `a` with `sep` inserted between each element of `a` in turn. `btw(a, sep)` returns `a`.

My first solution was this,

```
def btw(a, sep)
  for i in 1...(a.size)
    yield a[0...i] + [sep] + a[i..-1]
  end
  a
end
```

but it took me a little time to convince myself that the subscripts were right. Both Mr. Duvall and Mr. Wan used `Array`'s `take` and `drop` instead, and I found that far easier to reason about. Here's an example of that approach:

```
def btw(a, sep)
  for n in 1...(a.size)
    yield a.take(n) + [sep] + a.drop(n)
  end
  a
end
```

A simpler solution that might well run as fast as the above two is to repeatedly make a copy of the array `a`, and insert the separator at the appropriate position for each `yield`:

```
def btw(a, sep)
  for i in 1...(a.size)
    a2 = a.dup
    a2.insert(i, sep)
    yield a2
  end
  a
end
```

A common error was to end up with multiple copies of `sep` in the yielded array.

Problem 6: (5 points) (mean: 4.24, median: 5)

This problem is similar to `re.rb` on assignment 7. Write a method `zip_re` that returns a regular expression that matches the city/state/zip line of postal addresses, like these:

```
Tucson, AZ 85750
Beverly Hills, CA 90210
Walkertown, NC 27051
```

Solution:

```
def zip_re
  /^(?<city>[A-Z][A-Za-z ]*[a-z]), (?<state>[A-Z]{2}) (?<zip>\d{5})$/
end
```


Problem 7: (9 points) (mean: 7.80, median: 8.5)

For this problem you are to write a Ruby program that implements a very simple simple line-oriented calculator. It supports three commands/operations:

```
variable=integer
    Assigns the integer value to the specified variable.
```

```
var1=var2+var3
    Assigns the sum of var2 and var3 to var1.
```

```
/vars
    Print all variables and their values. Simplification: Variables can be printed in any order.
```

A number of students used regular expressions and/or `split` to parse the commands but I'd written the problem with the intention of simple string indexing being sufficient, like this:

```
vars = {}
while line = (print "calc> "; gets)
  line.chomp!
  if line == "/vars"
    for var,val in vars
      print("#{var}: #{val}\n")
    end
  elsif line =~ /\+/
    vars[line[0]] = vars[line[2]] + vars[line[4]]
  elsif
    vars[line[0]] = line[2..-1].to_i
  end
end
```

Problem 8: (5 points) (mean: 4.8, median: 5)

In this problem you are to implement a Ruby class named `Rope` that represents a length of rope that can be cut into two pieces.

```
class Rope
  def initialize(len)
    @pieces = [len]
  end

  def cut(len)
    if @pieces.size == 1 and len < @pieces[0]
      @pieces = [@pieces[0] - len, len]
      true
    else
      false
    end
  end

  attr_reader :pieces
end
```

Most students used two or three instance variables, but as you can see above, one is all you need.

Problem 9: (3 points) (mean: 2.40, median: 3)

Write a Prolog predicate `ints_atoms(+L, -E)` that first instantiates `E` to each integer in `L`, and then instantiates `E` to each atom in `L`.

```
ints_atoms(L,E) :- member(E,L), integer(E).
ints_atoms(L,E) :- member(E,L), atom(E).
```

Problem 10: (5 points) (mean: 3.39, median: 4.5)

Write a predicate `middle(+List, -M)` that instantiates `M` to the middle element of the list `L`. `middle` fails if the list has an even number of elements.

RESTRICTIONS:

- Just like on `append.pl` on assignment 9, **the only predicates you can use are `length` and `append`.**
- `middle` cannot be recursive.

```
middle(L,M) :-
    append(First,Rest,L), append([M],Last,Rest),
    length(First,Len), length(Last,Len).
```

Problem 11: (7 points) (mean: 5.44, median: 6.5)

For this problem you are to write a Prolog predicate `sumneq(+L, -Sum)`. The first argument, `L`, is a list of `vp/2` structures where both terms are integers. `sumneq` looks for `vp` structures with unequal terms, like `vp(3,4)` and `vp(-10,2)`, but not `vp(3,3)`. For each `vp` structure with unequal terms, `sumneq` computes the product of those two integer terms and then instantiates `Sum` to the sum of all those products.

```
sumneq(L,Sum) :-
    findall(Sum, (member(vp(X,Y),L), X\==Y, Sum is X*Y), Sums),
    sumlist(Sums,Sum).
```

Problem 12: (7 points) (mean: 5.32, median: 6.5)

Write a predicate `updown(+Ints, -Atom)` that instantiates `Atom` to a series of atoms in turn, based on the integers in `Ints`. Example:

```
?- updown([3,1,5], A).
A = 'up three' ;
A = 'down three' ;
A = 'up one' ;
A = 'down one' ;
A = 'up five' ;
A = 'down five'.
```

My solution:

```
updown(Nums, A) :-
    member(Num, Nums), member(UD, ['up ', 'down ']),
    n(Word, Num), atom_concat(UD, Word, A).
```

Problem 13: (10 points) (mean: 6.24, median: 8)

Write a Prolog predicate `seating(+Host, +Guests, -Seating)` that determines the seating for a dinner party to be attended by some number of conservatives and liberals.

```
seating(Host, Guests, [Host|Seating]) :-
    seatingH(Host, Guests, Seating),
    append(_, [Last], Seating), ok(Host, Last), !.

seatingH(_, [], []).
seatingH(Seated, People, [Person|Seating]) :-
    select(Person, People, Remaining),
    ok(Seated, Person),
    seatingH(Person, Remaining, Seating).

ok(lib(_, _), lib(_, _)).
ok(con(_, _), con(_, _)).
ok(con(_, D1), lib(_, D2)) :- D1 + D2 =< 4.
ok(lib(_, D1), con(_, D2)) :- D1 + D2 =< 4.
```

`ok/2` can be reduced to three clauses by using a cut in a way we barely discussed, to prevent later clauses from being tried if we simply unify with the head in either of the first two clauses:

```
ok(con(_, D1), lib(_, D2)) :- !, D1 + D2 =< 4.
ok(lib(_, D1), con(_, D2)) :- !, D1 + D2 =< 4.
ok(_, _).
```

The predicate `=.. /2`, mentioned in the extra credit section, can be used to produce a less repetitious `ok/2` that is perhaps also less readable:

```
ok(P1, P2) :-
    P1 =.. [T1, _, D1], P2 =.. [T2, _, D2], T1 \== T2, !, D1 + D2 =< 4.
ok(_, _).
```

Problem 14: (10 points) (one point each unless otherwise indicated) (mean: 7.71, median: 8)**The following questions and problems are related to Prolog.**

- (1) *Write a sentence that expresses the relationship between the terms "fact", "clause", and "rule".*
Both facts and rules are clauses.
- (2) *Prolog goals were modeled using the "Four port model". What are the four ports?*
call, exit, redo, fail
- (3) *If a predicate with three clauses is being evaluated and the first clause fails, what does Prolog do?*
It tries the second clause.
- (4) *What's the most important fundamental difference between a Prolog predicate like `length/2` and a function/method of the same name in Haskell, Ruby, or Java?*
In Haskell, Ruby, Java, and other conventional languages, `length` simply returns the length of a list. In Prolog, `length(?List, ?Len)` can (1) produce the length of `List`, (2) produce a list of `Len` uninstantiated variables, (3) see if the length of `List` is `Len`, (4) produce all `List/Len` pairs.

- (5) *What did you find hardest to understand about Prolog?*
- (6) *In your mind, what's the most interesting thing about Prolog?*
A wide variety of answers earned points on these two questions.
- (7) *What does the predicate `trace/0` do?*
Turns on tracing.
- (8) *Write a Prolog clause that would generate a singleton warning.*
`f(X) .`
- (9) *(Two points) What does the `findall` predicate do?*
Evaluates a query and for each result produced adds an instance of a template to a list that is ultimately produced as the result of `findall`.

Problem 15: (2 points) (mean: 1.21, median: 1)

The following questions about SNOBOL4 are one point each. You may answer as many as you want but the maximum score on this problem is 2 points.

- (1) *Write a SNOBOL4 program that copies standard input to standard output, just like the `cat` command. (For a point of extra credit, implement `tac` instead, copying lines in reverse order—last line first, first line last. Hint: remember that `char(10)` produces a newline character.)*

```
$ cat cat.sno
loop output = input      :s(loop)
end

$ cat tac.sno
loop result = input char(10) result      :s(loop)
  output = result
end
```

Note: The `tac.sno` above is acceptable but in fact it produces an extra newline at end of the output. We can avoid that by using `rtab` (tab to from-right position) to match all but the last character and assign it to output.

```
loop result = input char(10) result      :s(loop)
  result rtab(1) . output
end
```

- (2) *Write a SNOBOL4 expression that concatenates the strings held in the three variables `x`, `y`, and `z`.*
`x y z`
- (3) *In the following SNOBOL4 statement, which would start in column 1, what does the "`. x`" mean?*

```
loop   line span(&digits) . x           :f(p)
```

Assign the spanned digits to the variable `x`.

- (4) *In the SNOBOL4 statement above, what does `:f(p)` mean?*
If the pattern match fails, go the statement whose label is `p`.
- (5) *Tell me something else of significance about SNOBOL4.*

Lots of answers sufficed here, but a common one was that Ralph Griswold played a central role in the creation of the SNOBOL family.

One student wrote, "This is the language that Mr. Mitchell coded in during his prime."

Problem 16: (2 points) (mean: 1.33, median: 2)

The following questions about Icon are one point each. You may answer as many as you want but the maximum score on this problem is 2 points.

- (1) *Briefly describe Icon.*
Ruby meets Prolog
- (2) *What is the output of the following Icon expression? `write(2 > 3, 2+3, !"abc")`*
The expression `2 > 3` fails. That failure propagates and causes the `write` to fail, in turn causing no output whatsoever to be produced.
- (3) *What was a fundamental design goal of Icon's string scanning mechanism?*
Be able to interleave string matching operations with regular computation—compute a little, match a little, ...
- (4) *What's something that Prolog and Icon have in common?*
Backtracking
- (5) *Tell me something else of significance about Icon.*
Just like in the SNOBOL4 section, a common answer was that Ralph Griswold played a central role in the creation of Icon.

Problem 17: (10 points) (one point each unless otherwise indicated) (mean: 6.9, median: 7)

Answer the following general questions.

- (1) *This is a "matching" problem. Draw a line connecting each of the following language facilities on the left with the best characterization of primitives vs. idioms/techniques for that language on the right.*
Here are the correspondences:

Icon's string scanning:	Few primitives but many idioms/techniques
Regular expressions in Ruby:	Many primitives but few idioms/techniques
SNOBOL4 patterns:	Few primitives and few techniques
- (2) *What is a fundamental characteristic of a statically typed language?*
The type of every expression can be determined by analyzing the code.
- (3) *What is the essence of the duck typing mindset?*
Writing code that is concerned only with whether a value supports the operations that are used, not the type of the value.
- (4) *With programming languages in general, what's the fundamental difference between a statement and an expression?*
Expressions produce values; statements don't.

- (5) *What is the basic idea of type inferencing?*
Mr. Chambers wrote the following, which I considered to be an Original Thought:
"You act like this type, so you must be it."
- (6) *In any language you know, write an expression that has both a value and a side-effect. Cite the language, too.*
In C and Java, `x=1` and `x++` are two examples. In Python, `x=1` is statement, not an expression.
- (7) *What is a fundamental benefit provided by a REPL?*
I failed to note who wrote it, but I loved this answer: "Fun"
- (8) *Tell me something about the concept of paradigms that is unrelated to programming paradigms in particular.*
A paradigm has a vocabulary.
- (9) *(Two points) Which of the three main languages we covered this semester are you most glad we covered, and why?*
Some students answered with multiple languages; I divided such "votes" accordingly. The counts:
Haskell: 11.33
Ruby: 11.33
Prolog: 24.17

Extra Credit Section (½ point each unless otherwise noted) (mean: 3.59, median: 4)

- (1) *The slides had some quotes from prior 372 students. What's something you remember about one of them?*
Eleven students cited Astier's Analogy—Prolog predicates are like D/C motors. Others cited Swartz re append, Nguyen re expressions vs. statements, and Sleiman re findall.
- (2) *What does the Prolog predicate `=..(?Struct, ?List)` do?*
It expresses an equivalence between lists and structures:


```
?- con(david,3) =.. L.
L = [con, david, 3].
```
- (3) *What is the Chomsky hierarchy a hierarchy of?*
Languages
- (4) *What's an example of a list that Prolog can sort but that Ruby and Python 3 can't?*
[1, "two"]
- (5) *(One point) Present a brief argument either in favor of keeping Prolog as a 372 language or replacing it.*
The count was 27 to 2 in favor of keeping Prolog.
- (6) *Pick a nickname for one of the five languages we studied and explain why it's appropriate.*
Mr. Morgan wrote,
"Truth or Dare: Prolog. Either check and see if it is true or I dare you to try and make it so."
That looks like an Original Thought to me!

Here are the others: (apologies if I overlooked any!)

"Haskiller"

"Haskill, it will kill your fear of recursion."

"Truly Functional Fun = Haskell"

"Pro-long for Prolog because most of the clauses in Prolog are really long."

"Haskell -> Lazy Language"

"Prolog = Lil Logic. The Lil makes it cool, and Logic because Prolog is a fact based language."
 "Haskell -> Nightmare. Enough said."
 "Hask(hell) because it is hell to learn"
 "Ruby = Diamond. More pretty."
 "Prolog = APE. I chose this nickname because I feel we use append in the all the programs. :)"
 "Mathskell, relation to math functions"
 "It might be Ruby but it's a diamond in the rough..."
 "Husky for Haskell 'coz both are fun."
 "SNOBOL4 = Out-dated regEx's, typically new languages provide great libraires and regExs in place of SNOBOL4 features."
 "Stupid - Haskell, name fits."
 "Prolog: "Just the facts, ma'am." Entirely logic based."
 "Haskell - recursion hell"
 "Prolog - One liners—mostly gigantic single line expression"
 "Friendly: Ruby = so many options; friendly to old and new programmers"
 "Ruby: Typing Ducks"
 "Ruby - Shape Shifter—it looks familiar but it's not as easy as it looks"
 "Haskell -> Hasl-ALL, everything is a hassle"

(7) Put the five languages we studied in order by their age, oldest first.
 SNOBOL4, Prolog, Icon, Haskell, Ruby. When grading, any order for the five was accepted.

(8) *What's a piece of wisdom from Ralph Griswold that whm passed along to you?*
 Eight students cited some form of "If you're going to design a language, design a language you want to use."

Six students remembered that Ralph said I could add some number of features to Icon if I could find a corresponding number of features to remove.

Others:

"Humans start counting at 1."
 "Simplicity is important."
 "Less is more in a language."

(9) *What is a non-control, non-alphanumeric character and its ASCII code?*
 Results on this question were disappointing. Do man ascii on lectura.

If you ever take time to memorize the ASCII character set, wait a year or two, and then let me know whether you thought the effort was worthwhile.

(10) *Where in Gould-Simpson could leftover 372 handouts be found?*
 On the shelves at the 8th floor freight elevator.

(11) *The TAs were required to learn all of your names. What are the TAs' names? (First and last!)*
 Alex Koltz and Michael Ordaz

(12) *Late in the semester the class was invited to a sporting outing. What was the sport?*
 Bowling. Other answers: soccer, riding, "drinking and talking".

(13) *Finish this sentence: "If I only remember one thing about 372 it will be ...". (apologies if I overlooked any!)*
 "Haskell is not the language for me!"
 "Haskell"
 "To always appreciate a REPL."

"Prolog"
 "Spending 20+ hours on an assignment and feeling very proud/accomplished despite wanting to pull my hair out."
 "the night club on every fridays"
 "The University of Arizona was well-known by creating programming languages like Icon."
 "The reason I no longer eat pancakes."
 "Pancakes"
 "Haskell's a pain / take all time"
 "long office hours"
 "Pancakes"
 "Prepare for Prolog"
 "Always have office hour in 914 until midnight."
 "How great it was."
 "How it feels to turn in this final."
 "That some languages can handle tasks much more concisely than mainstream languages."
 "Haskell gave me scars."
 "Pancakes"
 "Prolog is hard."
 "Being surprised on day 1 when whm knew my name."
 "Pancakes"
 "Mr. Mitchell"
 "That Java and Python and the other imperatives are computing but computing is not imperative. I.e., there are other ways to think about computation than imperatively."
 "The huge assignment 9"
 "Bowling is a sport."
 "Putting the fun in functional programming."
 "The size of the spec as I awake from my nightmare."
 "Mr. Mitchell's handouts"
 "Haskell will kick your butt and laugh at you while you cry."
 "How much whm cares for the success of his students."
 "STAY AWAY FROM HASKELL"
 "The importance of choosing the right language for a task."
 "What it's like to be a good teacher."
 "How much time I spent on open frames in bowl.rb."
 "whm worked on Icon."
 "That I am not a fan of Prolog."
 "whm"
 "Haskell is hard."
 "Maybe I should stick to Java."

(14) (Zero points) whm booked his best of time of the semester ascending the steps to the eighth floor before Sunday's practice session! What was his time? (a) 25 seconds (b) 50 seconds (c) 1:40 (d) 3:20 (e) 6:40

Overall statistics

For the record, the exam started with a twelve minute walk-through that ended at 3:42pm. The exam ran until 5:40pm, a total of 118 minutes.

All final exam scores, in order:

104.50, 102.00, 100.00, 98.25, 98.00, 96.75, 96.75, 96.50, 95.00, 94.00, 93.50, 92.25, 91.50, 91.00, 90.75, 90.50, 90.00, 87.25, 86.50, 86.00, 85.50, 85.00, 85.00, 83.50, 83.00, 83.00, 82.50, 81.25, 80.75, 79.75, 79.25, 78.50,

76.25, 76.00, 74.75, 72.25, 71.25, 69.00, 68.25, 66.00, 65.00, 62.00, 51.00,
46.50, 45.00, 44.25

N = 46
mean = 81.6
median = 84.25

CSC 372 Midterm Exam Solutions
Wednesday, November 2, 2022

Problem 1: (5 points) (one point each) (mean: 3.4, median: 3.5, 3rd quartile: 4)

What is the **type** of each of the following Haskell expressions? If the expression is invalid, briefly state why.

```
[1..3]
  [Int]

('x', ['x'])
  (Char, [Char])

length
  [a] -> Int

tail "head"
  [Char] (or String)

map isDigit
  [Char] -> [Bool]
```

Problem 2: (6 points) (mean: 4.5, median: 5.3, 3rd quartile: 5.5)

This problem is like `ftypes.hs` on a3. Write functions `f1`, `f2`, and `f3` having each of the following types. There are no restrictions other than you may not use explicit type declarations. (e.g. `f1 :: ...`)

```
f1 :: [a] -> Int
  f1 [a] = length [a]

f2 :: a -> b -> c -> [b]
  f2 a b c = [b]

f3 :: [(a, b)] -> ([b], [c])
  f3 [(a,b)] = ([b], [])
```

Problem 3: (4 points, as indicated) (mean: 2.75, median: 3, 3rd quartile: 4)

This problem is like `warmup.hs` on the assignments—write the following Haskell Prelude functions.

```
tail      [1 point] (Assume the list is never empty.)

tail (_:t) = t
```

last [1 point] (*Assume the list is never empty.*)

```
last [x] = x
last (_:t) = mylast t
```

zip [2 points] (*Remember that the length of the shorter list is the length of the result.*)

```
zip (a:as) (b:bs) = (a,b) : zip as bs
zip _ _ = []
```

Problem 4: (18 points) (8 points each + 2 points for types)

(recursive—mean: 6.1, median: 8, 3rd quartile: 8)

(non-recursive—mean: 6.2, median: 8, 3rd quartile: 8)

(types—mean: 1.8, median: 2, 3rd quartile: 2)

For this problem you are to **write both recursive and non-recursive versions** of a Haskell function `mkintlists` that takes a list of strings of digits and returns a list of `Ints` with corresponding values.

```
> mkintlists ["315", "91", "", "713"]
[[3,1,5], [9,1], [], [7,1,3]]
```

In the recursive version **ONLY**, use error "even!" to produce an error if an even digit is encountered:

```
> mkintlists ["31", "12"]
*** Exception: even! (Non-recursive version would produce [[3,1], [1,2]]).
```

BEFORE writing your two versions of `mkintlists`, what is the type of..

```
mkintlist?  [[Char]] -> [[Int]]
digitToInt? Char -> Int
```

Recursive:

```
mkintlists [] = []
mkintlists (s:ss) = doStr s : mkintlists ss

doStr [] = []
doStr (d:ds)
  | even val = error "even!"
  | otherwise = val : doStr ds
  where
    val = digitToInt d
```

Non-recursive:

```
mkintlists strings = map (map digitToInt) strings
```

Problem 5: (15 points) (mean: 10.1, median: 14, 3rd quartile: 15)

Without writing any recursive code, write a Haskell function `vcnp :: String -> Int` that counts the number of vowels in a string that are not immediately preceded by a vowel. Vowels may be in upper or lower case. Examples:

```
> vcnp "ate"
2

> vcnp "Oopsie!"
2

> vcnp "a-e-i-o-u-A-E-I-O-U"
10
```

Solution:

```
isv c = toLower c `elem` "aeiou"

f (last,count) c
  | isv last = (c, count)
  | isv c = (c, count+1)
  | otherwise = (c, count)

vcnp s = snd $ foldl f ('x',0) s
```

I was dismayed by the number of students who wrote out `['a','e','i','o','u']` instead of `"aeiou"`. And, at least one student, wrote that out twice.

Problem 6: (17 points) (mean: 10.7, median: 15.5, 3rd quartile: 16.5)

Write a Haskell function `coords rows cols` with type `Int -> Int -> IO ()` that PRINTS row and column coordinates for a grid with the given number of rows and columns. Example:

```
> coords 3 4
(0,0) (0,1) (0,2) (0,3)
(1,0) (1,1) (1,2) (1,3)
(2,0) (2,1) (2,2) (2,3)
```

Solution:

```
-- my first version of mkrc:
-- mkrc row col = concat ["(", show row, ",", show col, ")"]
mkrc row col = show (row, col)

mkrow cols row = unwords $ map (mkrc row) [0..cols-1]

coords rows cols =
  putStr $ unlines $ map (mkrow cols) [0..rows-1]
```

Problem 7: (5 points) (one point each unless otherwise indicated) (mean: 2.9, median: 3, 3rd quartile: 4)

The following questions and problems are related to Haskell.

- (1) *The Haskell expression below has more parentheses than are needed! Mark **ALL** the parentheses that can be removed without changing the value of the expression.*

Before: (take 3) (show x) ++ (replicate 5) (chr 66)

After: take 3 (show x) ++ replicate 5 (chr 66)

- (2) *Given the type of a function, how can we quickly tell if the function is polymorphic?*

A function is polymorphic if any parameter has a type variable.

- (3) *Add parentheses to the type below to fully show the right-associativity of the `->` type operator.*

Before: Int -> [Int] -> (Char -> Bool -> Bool) -> String

After: Int -> ([Int] -> ((Char -> (Bool -> Bool)) -> String))

- (4) *Briefly explain how the following `map` works, paying particular attention to the function being mapped. (That function is the result of **(uncurry \$ flip replicate)**.)*

```
> map (uncurry $ flip replicate) [('a',3),('b',2)]
["aaa","bb"]
```

`flip replicate` creates a version of `replicate` with the parameters swapped:

```
> flip replicate
<function>

> :type it
it :: a -> Int -> [a]
```

Then, uncurrying the result function produces a function that can be applied to an `(a, Int)` tuple:

```
> uncurry it
<function>
> :type it
it :: (a, Int) -> [a]

> it ('a',3)
"aaa"
```

It was sufficient to say something like, "flip swaps the order of replicate's arguments and then uncurrying it lets it be mapped onto the tuples."

This question was mentioned as a possible midterm question in the a5 solution write-up for `rtext.hs`.

- (5) Consider the Haskell expression below. Does it have any partial applications? If so, briefly describe what constitutes each of the partial applications.

```
map (take 5)
```

First, `take 5` produces a partial application. Then `map` is applied to that function, producing a second partial applications.

Most students identified `take 5` as a partial application but only a few recognized that there is also a partial application of `map`.

Problem 8: (7 points) (mean: 5.1, median: 6.5, 3rd quartile: 7)

Using our DIY cons lists, write a Prolog predicate `eqalen/2` that succeeds iff its two arguments are lists that consist entirely of atoms **and** the length of all atoms in corresponding positions are equal. Examples:

```
?- eqalen(a:test:now:empty, i:went:too:empty).
true.      (Atoms in both lists have lengths of 1, 4, and 3, respectively.)

?- eqalen(a:test:now:empty, i:went:too:far:empty).
false.     (Four atoms in second list.)
```

RESTRICTION: The symbol = may NOT APPEAR in your solution! (This rules out == and \==, too, for example.)

Solution:

```
eqalen(empty, empty).
eqalen(A1:T1,A2:T2) :-
    atom(A1), atom_length(A1,L),
    atom(A2), atom_length(A2,L),
    eqalen(T1,T2).
```

Problem 9: (12 points) (mean: 6.4, median: 7.5, 3rd quartile: 10)

Write a Prolog predicate `lines(+Pairs, +Separator)` with this behavior:

```
?- lines(three-x:five-ok:four-oops:empty, '.').
x.x.x
ok.ok.ok.ok.ok
oops.oops.oops.oops
true.

?- lines(four-four:five-[:empty,<>).
four<>four<>four<>four
[]<>[]<>[]<>[]<>[]
true.

?- lines.
Usage: lines(+Pairs,+Sep)
true.
```

Solution:

```
lines(Pairs,Sep) :-
    member_cl(English-Atom,Pairs), n(English,N),
    print(N,Atom,Sep), fail.
lines(_, _).

lines :- writeln('Usage: lines(+Pairs,+Sep)').

print(N,Atom,Sep) :-
    between(2,M,_),
    format('~w~w~w', [Atom, Sep]), fail.
print(_,Atom,_) :- writeln(Atom).
```

Problem 10: (5 points) (one point each unless otherwise indicated) (mean: 2.7, median: 3, 3rd quartile: 4)

The following questions and problems are related to Prolog.

- (1) $x(3, 4)$ is an example of a Prolog structure. Without using any parentheses, commas, or square brackets, write another example of a Prolog structure.

3+4

- (2) Prolog anatomy question: What are the three parts of a Prolog rule? (½ point)

head, neck, and body

- (3) What are three distinct ways in which `length/2` can be used? (1½ points)

Get the length of a list.

See if a list has a specific length.

Make a list with a specific number of uninstantiated variables.

- (4) What is the **output** of the following query?

```
?- between(1,3,A), writeln(A), A > 5,  
   between(5,7,B), writeln(B), B < 10,  
   writeln('Done!').
```

The output is:

```
1  
2  
3
```

It was also fine to include the result, "false.", but that's not part of the output.

- (5) How do the following two goals differ in meaning?

$A+B == 5$

Compares the structure $3+5$ to the number 5; always fails.

$A+B =:= 5$

Evaluates $A+B$ as an arithmetic expression and tests whether the result is equal to 5.

Problem 11: (6 points) (one point each unless otherwise indicated) (mean: 3, median: 3, 3rd quartile: 4)

Briefly answer the following general questions.

- (1) *Who founded The University of Arizona's Computer Science department and when?*

Ralph Griswold, in 1971

- (2) *What is the value and side effect of the following Python expression?*

```
print("testing")
```

The value is None. The side effect is that "testing" is printed on standard output.

- (3) *What's the one feature/property that a language must have in order to do anything that even remotely resembles functional programming?*

Functions must be first-class values. In general, it must be possible to use a function value in all the contexts where values of others types can be used—be held in variables and data structures, be passed as parameters and returned as results, etc.

- (4) *Which one of the following language elements is most essential for imperative programming AND why? (2 points)*

(a) *some sort of looping construct like a while or a for*

(b) an assignment operation

(c) *some sort of "print" statement*

(d) *procedures*

Much of imperative programming is basically orchestration of changes to the value of variables but without an assignment operation, the value of a variable can't be changed.

- (5) *Early in the semester we talked about three aspects of expressions that are often important to understand and reason about. What are those three aspects?*

Value, type, and side effect

Extra Credit Section (½ point each unless otherwise noted) (mean: 0.8, median: 0.5, 3rd quartile: 1.5)

- (1) *Collectively, the body of facts and rules that implement a Prolog predicate is known as the procedure for the predicate.*

Note: "clauses" (**plural**) was also counted as correct.

- (2) *Sadly, I never got around to answering this Haskell puzzle posed on 284:
Make the list [take, tail, init] valid by adding two characters.
Answer it now!*

My thought was [take_5, tail, init] but Mr. Fielding came up with [(take, tail, init)]. Mr. Meyer, Ms. Rahman, and Mr. Waugaman came up with ["take, tail, init"]

- (3) *What's a fundamental difference between using >>> type(x) in the Python shell and using > :type x in ghci?*

type is a Python function—we can use it in a Python program—but :type is a ghci command, and not an element of Haskell itself. Similarly, help is a Python function but :help is a ghci command. **This distinction—whether something is part of a language or part of a tool—is important to understand!**

- (4) *Write our beloved map function in Python. (1 point)*

Here are two versions; the second uses a list comprehension.

```
def map(f, L):
    result = []
    for e in L:
        result.append(f(e))
    return result

def map(f, L):
    return [f(e) for e in L]
```

- (5) *Several places in the Haskell slides mention "H10". Example: "Lambda abstraction (H10)". What is H10?*

The Haskell 2010 Report. (Slide 37)

Lots of students said that "H10" referred to a version of Haskell but only Ms. Saran correctly identified it as my shorthand for a document.

(6) *What would be a big simplification in the following Haskell code?*

```
g list = foldl1 (\acm elem -> f acm elem) list
```

The anonymous function does nothing but pass its two arguments to `f`, so we could just call `f` directly, and that's the big simplification:

```
g list = foldl1 f list
```

A minor improvement is that we could also turn `g` into a partial application:

```
g = foldl1 f
```

(7) *Write a non-imperative version of C's `strcpy(...)` function. (If you haven't had 352 nor are taking it now, plead ignorance for a half-point!)*

Nobody recognized that this is simply impossible. At the heart of `strcpy` is copying characters from one location in memory to another, and without assignment—essential for imperative programming—that's impossible

(8) *Once `whm` decided he should teach Racket instead of Ruby, he held onto Racket like a monkey holding onto a piece of fruit! [See also [youtube.com/watch?v=9jBgo7UipqY](https://www.youtube.com/watch?v=9jBgo7UipqY).]*

(9) *Write a good extra credit question related to the course material and answer it. (1 point)*

There were several good ones but relatively few students responded to this question.

Statistics

Here are all fifty scores, in descending order:

98.50, 97.00, 95.50, 95.50, 92.50, 91.50, 91.50, 89.00, 89.00,
 88.00, 85.00, 84.00, 83.50, 79.00, 78.00, 78.00, 76.00, 75.50,
 75.00, 74.00, 74.00, 74.00, 73.50, 72.50, 71.50, 70.00, 68.50,
 67.50, 66.50, 66.00, 65.50, 65.00, 60.00, 60.00, 59.50, 58.00,
 53.00, 53.00, 52.50, 52.50, 52.00, 48.50, 43.00, 41.00, 39.00,
 31.50, 24.50, 21.00, 20.00, 3.00

Mean: 66.45
 Median: 70.75
 3rd Quartile: 82.38

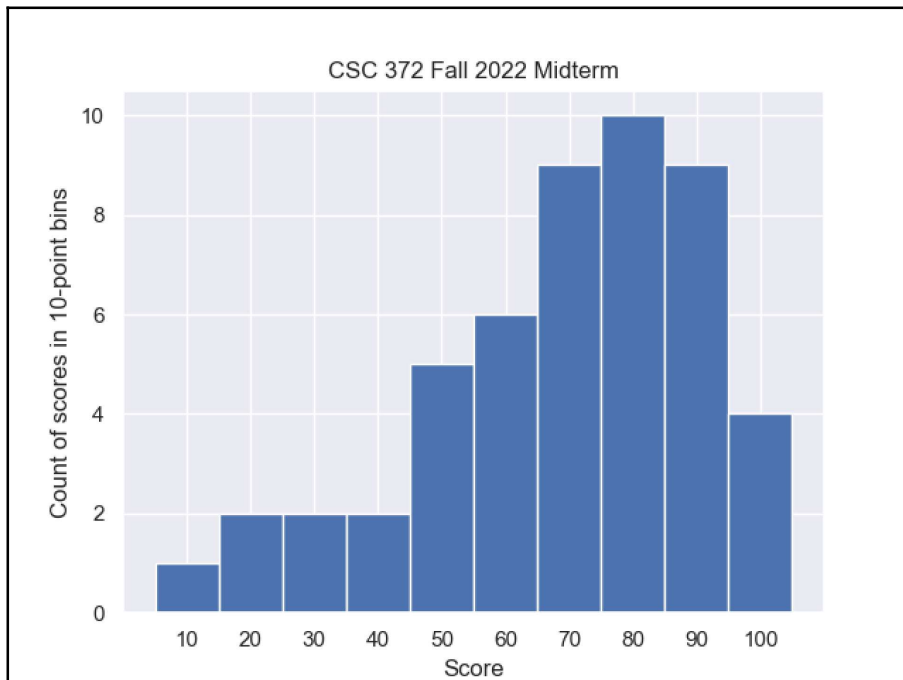
Here's a table with per-problem statistics. **Median/possible** shows per-problem median scores divided by possible points, expressed as a percentage.

	exprtypes	ftypes	simple	mkints rec	mkints nr	mkints type	vcnp	coords	Haskell S/A	equalen	lines	Prolog S/A	Gen S/A	EC	Total
Mean	3.41	4.46	2.75	6.08	6.2	1.83	10.11	10.74	2.91	5.04	6.38	2.72	2.99	0.83	66.45
Median	3.5	5.25	3	8	8	2	14	15.5	3	6.5	7.5	3	3	0.5	70.75
3rd quartile	4	5.5	4	8	8	2	15	16.5	4	7	10	4	4	1.5	82.375
Median/possible	70.0	87.5	75.0	100.0	100.0	100.0	93.3	91.2	60.0	92.9	62.5	60.0	50.0	11.1	

Adjustment

I'm thinking the exam was perhaps a half-problem too-long, and some of the short answer questions perhaps took a little longer to answer than I'd anticipated. Taking all things into account, I've decided to add seven points to all scores.

With that adjustment applied, here's a histogram of scores:



CSC 372, Fall 2022

Final Exam Solutions

Thursday, December 15, 2022

Problem 1: (6 points) (mean: 5.38, median: 6, 3rd quartile: 6)

Cite three things about programming languages you learned by watching your classmates' video projects. Each of the three should be about a different language and have a bit of depth, as described in the Piazza post that announced this problem.

All the videos this semester were good and some were great. Videos are great in different ways. It'd be pretty hard for me to pick a best video but I will pick an All-Star team, and in alphabetic order by title, here it is:

== in JavaScript

<https://www.youtube.com/watch?v=8m3DWtounNs>

Coding your own Music w/ Sonic Pi

<https://youtu.be/DRmJVM9iY3E>

Bash Arrays

<https://drive.google.com/file/d/1kp9K3JHY5Z5SarV-Bi3KPSPP55v15w1n>

Goroutines and Channels: Concurrency in Go

<https://youtu.be/ZwY3kRmlenw>

How I Typed "Toy Story 3" Without Any Characters in JavaScript: Automatic Type Conversion By Chase K

<https://youtu.be/zjC7jfyROZc>

Make a Class Really Easy to Use in Python with Magic Methods by Amber Converse

https://drive.google.com/file/d/1jVgayWJ69iEP8_i1OIYBKobKojIOHrhb/view

A number of students made their YouTube videos "Unlisted" but I encourage all to list them—they might accumulate an interesting number of views over time. For example, Ryan Melzer's Spring 2016 video, *Haskell Monads in 8 Minutes*, has accumulated 53k views! You can see Ryan's video here: <https://www.youtube.com/watch?v=gEoruozy3mk>

Problem 2: (10 points) (mean: 8.9, median: 10, 3rd quartile: 10)

The following program is in Tcl and was adapted from rosettacode.org/wiki/Ordered_words#Tcl. Read through the code and then for one point each, briefly answer the questions that follow below the code.

```
1      # Return a list of the ordered words (of maximal length) in a list
2      proc chooseOrderedWords list {
3          set maxlen 0
4          set orderedOfMaxlen {}
5          foreach word $list {
6              # Condition to determine whether a word is ordered;
7              # are its characters in sorted order?
8              if {$word eq [join [lsort [split $word ""]] ""]} {
9                  set wordlen [string length $word]
10                 if {$wordlen > $maxlen} {
11                     set maxlen $wordlen
12                     set orderedOfMaxlen {}
13                 }
14                 if {$wordlen == $maxlen} {
15                     lappend orderedOfMaxlen $word
16                 }
17             }
18         }
19         return $orderedOfMaxlen
20     }
21     # Get the dictionary and print the ordered words from it
22     set t [http::geturl "http://cs.arizona.edu/classes/cs372/fall122/web2"]
23
24     set result [chooseOrderedWords [http::data $t]]
25
26     puts "Longest ordered words:"
27     for {set i 0} {$i < [llength $result]} {incr i} {
28         puts [lindex $result $i]
29     }
```

- (1) What does the syntax for procedure definitions seem to be?
`proc NAME PARAMS { ... }`
- (2) How does one apparently create and initialize a variable?
`set VAR VALUE`
- (3) What appears to be the rule about when a variable name needs a sigil?
When we want the value of the variable.
- (4) What purpose do square brackets (`[` and `]`) seem to serve?
They indicate a procedure call, and enclose both the procedure's name and its arguments, a bit like Lisp S-expressions.
- (5) At line 8, `eq` is used to test equality but at line 14, `==` is used to test for equality. Why are two different operators used?
Looks like perhaps `eq` is numeric equality and `==` is string equality.
- (6) What does the `{}` in line 4 apparently represent?
An empty list.
- (7) Roughly translate line 5 (`foreach...`) into Ruby code that uses an iterator.
`for word in list do`

(8) Roughly translate line 28 (`puts [lindex $result $i]`) into Ruby.
`puts result[i]`

For one point each, **make up to four more significant observations** about the code, but maximum score for the problem is 10.

Here are a few more observations:

- Tcl seems to be dynamically typed.
- The for-loop at 27 seems to have init/condition/advance elements just like Java, C, and others.
- "`http::...`" seems to reference elements in an `http` package/module.
- The `return` at line 19 implies that Tcl doesn't have "last value return" like Ruby.
- Indexing seems to be zero-based.
- `incr VAR` apparently increments the value of `VAR`.
- `#` is comment to end of line.

I wish I'd thought to include a question that asked whether you'd seen Tcl before, but I didn't!

You'll see on its [Wikipedia page](#) that Tcl, pronounced "tickle", was created in 1988 and its latest release was less than a month ago. I see about ten Tcl books on [learning.oreilly.com](#) at the moment.

<https://wiki.tcl-lang.org/page/Applications+in+Tcl+and+Tcl%2FTk> lists a number of large applications written in Tcl. At a Usenix conference years ago I remember a speaker mentioning a 250,000 line Tcl application that was integral to the operation of an oil rig in the Gulf of Mexico.

If you've done any graphics in Python with `tkinter`, take a look at <https://docs.python.org/3/library/tk.html>. It says, "The `tkinter` package is a thin object-oriented layer on top of Tcl/Tk."

Problem 3: (11 points) (mean: 6.95, median: 7, 3rd quartile: 10.125)

Write a Haskell function `avgvows` of type `[String] -> Double` that returns the average (mean) number of vowels per word in a body of text, ignoring one-letter words. Assume all letters are lower-case. Examples:

```
> avgvows ["what a", "treat"]
1.5

> avgvows ["ouch oops", "my bad"]
1.25

> avgvows ["my my"]
0.0
```

My solution:

```
avgvows lns = fromIntegral total_vowels / fromIntegral (length keepers)
  where
    all_words = words $ unwords lns
    keepers = filter (\w -> length w > 1) all_words
    vowel_counts = map (filter (\c -> c `elem` "aeiou")) keepers
    total_vowels = sum $ map length vowel_counts
```

Problem 4: (8 points) (mean: 5.43, median: 6, 3rd quartile: 7.625)

Write a Prolog predicate `all_atoms(+L)` that succeeds iff the list `L` is not empty and all its values are atoms. Examples:

```
?- all_atoms([just,a,test]).
true.

?- all_atoms([just,1,test]).
false.

?- all_atoms([]).
false.
```

This problem is a good example of the hazard of looking for a problem with a solution in hand! I was looking for a `findall` problem and, sure enough, the problem can be solved like this:

```
all_atoms(L) :-
    findall(A, (member(A,L),atom(A)), Atoms), length(Atoms,N),
    length(L,N), N > 0.
```

However, if you approach the problem without a hammer that's looking for a nail, you'll see a simple recursive solution:

```
all_atoms([X]) :- atom(X).
all_atoms([H|T]) :- atom(H), all_atoms(T).
```

Problem 5: (20 points) (mean: 14.3, median: 17, 3rd quartile: 18)

This is the Prolog problem like `connect` and `pit-crossing` that you were told to expect.

Write a Prolog predicate `makepath/1` that takes a list of "layers" and prints a sequencing of **ALL** of them that has a continuous path of asterisks from top to bottom. Here's an example of a path through five layers:

```
?- makepath(['----*-','--*--','-----*','--*--','----*-']).
----*-
--*--
--*--
----*-
-----*
true.

?- makepath(['*--','--*','--*']).
No sequencing for those 3 layers
true.
```

My solution:

```
findseq([],_,[]).
findseq(Layers,N,[Layer|Seq]) :-
    select(Layer, Layers, Remaining),
    atom_chars(Layer, Chars),
    nth0(Pos, Chars, '*'),
    fit(N,Pos),
    findseq(Remaining, Pos, Seq).

fit(N,_) :- N < 0.
fit(N, Pos) :- abs(N-Pos) =< 1.
```



```

makepath(Layers) :-
  findseq(Layers, -1, Seq), print_layers(Seq), !.
makepath(Layers) :-
  length(Layers,N),
  format('No sequencing for those ~a layers~n', N).

print_layers(Layers) :- member(Layer, Layers), writeln(Layer), fail.
print_layers(_).

```

Problem 6: (15 points) (mean: 13.34, median: 15, 3rd quartile: 15)

Write a Ruby program `hmt.rb` that, based on command-line arguments, prints the "head", "tail" and/or "middle" of its input lines, possibly multiple times. This problem was inspired by the `head` and `tail` UNIX commands.

The command

```
$ ruby hmt.rb ht 5 < x.txt
```

specifies that the "head" (`h`) and "tail" (`t`) of the input are to be printed. This causes the first five lines and then the last five lines of `x.txt` to be printed; a total of ten lines.

The command

```
$ ruby hmt.rb tth 20 < x.txt
```

causes the last twenty lines of `x.txt` to be printed twice, followed by the first twenty lines; a total of sixty lines.

If the number of lines to print is not specified, it defaults to three.

My solution:

```

if ARGV.size == 2
  n = ARGV[1].to_i
else
  n = 3
end

lines = STDIN.readlines

ARGV[0].each_char do
  |c|
  if c == "h"
    puts lines[0...n]
  elsif c == "t"
    puts lines[-n..-1]
  elsif c == "m"
    start = lines.size/2 - n/2
    puts lines[start,n]
  end
end
end

```

Problem 7: (9 points) (mean: 7.04, median: 8, 3rd quartile: 9)

Write a Ruby method `lc_occurs(s, n)` that returns a string of the lower-case letters that occur **n or more** times in the string `s`. Characters in the result are in alphabetical order.

Examples:

```
>> lc_occurs("just a test", 1)
=> "aejstu"

>> lc_occurs("just a test", 3)
=> "t"

>> lc_occurs("", 0)
=> "abcdefghijklmnopqrstuvwxyz"
```

RESTRICTION: You may not use 'for' or 'while' statements in your solution.

My solution:

```
def lc_occurs(s, n)
  counts = Hash.new 0
  s.each_char {|c| counts[c] += 1 }
  result = ""
  ('a'..'z').each {|c| result += c if counts[c] >= n}
  return result
end
```

Problem 8: (12 points) (mean: 10.43, median: 11, 3rd quartile: 12)

In this problem you are to implement a Ruby class named `IntRange` that represents a non-empty range of integers.

```
>> r = IntRange.new(3, 7)

>> r.inspect
=> "3 4 5 6 7 (5 values)"

>> r.size
=> 5

>> r.bounds
=> [3, 7]

>> r[1]
=> 3

>> r[5]
=> 7

>> [r[0], r[6]]
=> [nil, nil]
```

Earn a point of extra-credit by not having return appear in your code!

```
class IntRange
  def initialize first, last
    @first = first
    @last = last
  end

  def size
    @last - @first + 1
  end

  def inspect
    "#{(@first..@last).to_a * " "}" (#{size}
values)"
  end

  def bounds
    [@first, @last]
  end

  def [](i)
    if i > 0 && i <= size
      @first + (i - 1)
    else
      nil
    end
  end
end
```

Problem 9: (5 points) (one point each unless otherwise indicated) (mean: 3.22, median: 3.5, 3rd quartile: 4)

The following questions and problems are related to Ruby.

- (1) *What are two examples of sigils in Ruby and what does each indicate?*
- | | |
|----|-------------------|
| \$ | global variable |
| @ | instance variable |
| @@ | variable |

Several students cited the ! and ? method suffixes but I don't believe I ever described those as sigils, nor did I find anything on the net that suggests they, too, should be considered sigils.

- (2) *A novice programmer might simply understand that the following loop terminates when end of file is reached on standard input. What's a more thorough explanation of what happens when end of file is reached on standard input?*

```
while line = STDIN.gets
  puts line
end
```

At end of file, `STDIN.gets` returns `nil`. `nil` gets assigned to `line` and the value produced by the assignment operator is the value assigned, `nil` in this case. That causes the `while` to reduce to `while nil`, and because `nil` is regarded as "falsey", the `while` terminates.

- (3) *For any Ruby Integer n , I'd like $n.big?$ to return a "truthy" value if n is greater than 1000 and a "falsey" value if not. Write Ruby code to fulfill my wish.*

```
class Integer
  def big?
    self > 1000
  end
end
```

A lot of students got this half-right but both `class Integer` and `self > 1000` were required for full credit.

- (4) *What is the essence of the duck typing mindset?*

A few students simply used James Whitcomb Riley's quote from Ruby slide 134. That made me wish I'd prohibited the word "duck" in the answer, but having failed to do that, I counted those recitations as correct.

I'd say that Mr. Ricci's answer was perhaps the most concise:

"I don't care if you have the right type. Can you do this method?"

- (5) *If you only remember one thing about Ruby, what will it be?*

I was hoping for some interesting things here but the most common answer by far was something about the `end` keyword—needing it, frequently forgetting it, etc.

Problem 10: (2 points) (mean: 0.89, median: 0, 3rd quartile: 2)

Write a SNOBOL4 program `twice.sno` that prompts for the user for a number and then prints twice that number, like this:

```
$ snobol4 twice.sno
Number?
7
Twice 7 is 14
```

For a point of extra credit, make it loop until the user hits ^D (end-of-file) to terminate it.

```
loop    output = "Number?"
        n = input                                :f(end)
        output = "Twice " n " is " (n * 2)      :s(loop)
end
```

Problem 11: (2 points) (mean: 0.84, median: 1, 3rd quartile: 1.5)

The following questions about Icon are worth one point each. You may answer as many as you want but the maximum score on this problem is 2 points.

(1) Write two distinctly different Icon expressions that fail to produce a value.

```
2 < 3
"x"[2]
```

(2) Write an expression that produces the length of `s`, where `s` is an Icon string.

```
*s
```

(3) Write an expression that produces the sum of the first and last elements of `L`, where `L` is a list of strings that represent integers. If `L` is `["7", "45", "8"]` the sum would be 15. Assume that `L` has at least one element.

```
L[1] + L[-1]
```

(4) What is a major aspect of Icon that Ralph Griswold was disappointed with?

String scanning

(5) Regarding language design, what was Ralph Griswold's opinion about whether a language should be easy to implement?

Icon slide 5 mentions that there was generally a "disregard for implementation problems and efficiency".

Extra Credit Section (½ point each unless otherwise noted) (mean: 1.99, median: 2, 3rd quartile: 2.5)

- (1) *With respect to programming languages, the term "mixin" was said to have been borrowed from the product line of a Somerville, Massachusetts business. What was the primary product of that business?*

I assume that ice cream was the primary product of Steve's Ice Cream in Somerville. When grading I got a smile from these guesses: cement, blenders, and cocktails.

- (2) *What's the language in the SNOBOL family that was developed between SNOBOL4 and Icon and that "had everything".*

Lots of students said SNOBOL5 but it was SL5, short for SNOBOL Language 5.

- (3) *Brooks Law says that "Adding manpower to a late software project makes it later."*

- (4) *To the best of whom's knowledge, what was the size of the RATSNO (Rational SNOBOL4) user community at its peak?*

My search for other RATSNO users continues but to the best of my knowledge, I was the only regular user of RATSNO. I used it for several undergraduate projects including a compiler for a subset of Pascal, an information retrieval system, and an extra-credit project involving Arden's Lemma/Rule. I couldn't even get my partner on the Arden's project to use RATSNO; he did his portion in plain old SNOBOL4!

Here is Dr. David R. Hanson's RATSNO paper: <https://drhanson.s3.amazonaws.com/storage/documents/ratsno.pdf>. Dr. Hanson was CS department head here for a time. When the question of "What's the best class you ever had?" comes up, my answer is Hanson's CSC 453—we wrote a C compiler, a linker, and a debugger. They were simplified in various ways, but they were also very "real".

- (5) *Write the Prolog predicate `member/2` in terms of `nth0/3`.*

```
member(E,L) :- nth0(_,L,E).
```

- (6) *Write a SNOBOL4 pattern that would match decimal fractions like `123.45`, `0.789`, and `1000.1`.*

```
decfrac = span(&digits) "." span(&digits)
```

- (7) *Among Haskell, Icon, Java, Prolog, Python, Ruby, and SNOBOL4, which are the three oldest languages?*

SNOBOL4, Prolog, and Icon

- (8) *What's relatively unique about when Ruby was created?*

I don't know of any other language that has an exact date cited for its "birth" but Matz wrote, "Well, Ruby was born on February 24, 1993."

- (9) *Is Java a compiled language or an interpreted language? Briefly justify your answer. (1 point)*

See Ruby slide 132. I say that compilation or interpretation is an attribute of an implementation of a language, not the language itself. For any language, one can write a compiler or an interpreter; a great number of language implementations use a mix of compilation and interpretation techniques.

- (10) *Write a good extra credit question related to the course material and answer it. (1 point)*

Many answers were very creative but I'll say that I like Ms. Ying's best:

Q: Who would win in a fight: Haskell, Prolog, or Ruby?

A: Haskell be on the defense and guard itself.

Prolog would logic its way out of the fight.

Ruby could win in multiple ways.

The non-lazy side of me aspires to add a few more notable answers here. Check back to see if that ever happens.

Statistics

Here are all 48 scores, in descending order:

103.50, 100.50, 100.00, 99.50, 97.50, 97.00, 97.00, 94.00, 92.50, 92.00, 90.50,
 89.50, 89.50, 87.00, 86.00, 86.00, 85.50, 85.00, 85.00, 84.00, 82.50, 81.50,
 81.50, 80.50, 80.50, 80.00, 80.00, 79.50, 79.50, 78.50, 78.00, 76.50, 76.00,
 75.00, 73.50, 73.50, 70.50, 70.00, 69.00, 69.00, 64.50, 62.50, 60.00, 57.00,
 54.50, 51.50, 43.00, 8.00

Mean: 78.70
 Median: 80.50
 3rd Quartile: 89.5

Here's a table with per-problem statistics. Median/possible shows per-problem median scores divided by possible points, expressed as a percentage.

Last Name	Videos	Tcl	avgvows	all_atoms	makepath	hmt	lc_occurs	IntRange	Ruby s/a	SNOBOL	Icon	EC
Mean	5.38	8.90	6.95	5.43	14.30	13.34	7.04	10.43	3.22	0.89	0.84	1.99
Median	6	10	7	6	17	15	8	11	3.5	0	1	2
3rd quartile	6	10	10.125	7.625	18	15	9	12	4	2	1.5	2.5
Median/possible	100.0	100.0	63.6	75.0	85.0	100.0	88.9	91.7	70.0	0.0	50.0	

Here's a histogram of scores:

