`$Id: cmps112-2015q4-exam3.mm,v 1.108 2015-12-01 20:00:12-08 - - $`

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1. Define `gcd` which uses Euclid's algorithm to find the greatest common divisor for two integers $x > 0$ and $y > 0$. The C version is given. Example : gcd(111, 259) = gcd(111, 148) = gcd(111, 37) = gcd(74, 37) = gcd(37, 37) = 37.

```
int gcd (int x, int y) {
   while (x != y) if (x > y) x -= y; else y -= x;
   return x;
}
```

(a) ***Scheme.*** Use tail recursion. **[2✓]**
Example call : `(define g (gcd 111 259))`.

```
(define (gcd x y)
   (cond ((> x y) (gcd (- x y) y))
         ((< x y) (gcd x (- y x)))
         (else x)))
```

(b) ***Ocaml.*** Use tail recursion and curried format. **[2✓]**
Example call : `let d = gcd 111 259;;`.

```
let rec gcd x y =
   if x > y then gcd (x - y) y
   else if x < y then gcd x (y - x)
   else x
```

(c) ***Smalltalk.*** Extend class `Integer` with a keyword method `gcd:`. Use a loop. **[2✓]**
Example call : `g := 111 gcd: 259.`

```
Integer extend [
   gcd: n [ |x y| x := self. y := n.
      [x = y] whileFalse: [
            (x > y) ifTrue: [x := x - y]
                    ifFalse: [y := y - x]
      ]. ^x]]
```

(d) ***Perl.*** Use a loop or tail recursion. Properly prototype the function. **[2✓]**
Example call : `$g = gcd 111, 259;`

```
sub gcd ($$) {
   my ($x, $y) = @_;
   while ($x != $y) {
         if ($x > $y) {$x -= $y} else {$y -= $x}
   }
   return $x }
```

(e) ***Prolog.*** **[2✓]**
Example call : `gcd( 111, 259, G ).`

```
gcd(X, Y, Z) :- X>Y, T is X-Y, gcd(T, Y, Z).
gcd(X, Y, Z) :- X<Y, T is Y-X, gcd(X, T, Z).
gcd(X, X, X).
```

2. ***λ-calculus.*** Given the expression in the λ-calculus shown at the top of each box, show the derivation order to the number 25 for each of normal order and applicative order evaluation. **[1✓]**

normal order evaluation	applicative order evaluation
$(\lambda x\,.\,*\,x\,x)\ (+\,2\,3)$ = = (* (+ 2 3)(+ 2 3)) = (* 5 5) = 25	$(\lambda x\,.\,*\,x\,x)\ (+\,2\,3)$ = = (λx.* x x) 5 = * 5 5 = 25

3. ***Scheme.*** Using `apply`, `map`, `max`, and `cons`, define the function `depth` for any argument. If it is `null?`, its depth is 1. Otherwise, if it is not a `pair?`, its depth is 0. The depth of anything else (a list) is one more than the maximum depth of the elements of the list. **[2✓]**

```
> (depth '(1 2 (3 4 (5 6)) 88))
3
> (depth '(a b c))
1
> (depth '())
1
> (depth 7)
0
```

```
(define (depth list)
   (cond ((null? list) 1)
         ((not (pair? list)) 0)
         (else (+ 1 (apply max (cons 0
                  (map depth list)))))))
```

4. ***Ocaml.*** Define `drop`, which returns its argument list without the first *n* elements. If *n* is larger than the length of the list, it returns a null list. If *n* is not positive, it just returns the list. Use a tail call. Do not compute the length of the list. **[2✓]**

```
# drop;;
- : int -> 'a list -> 'a list = <fun>
# drop 3 [1;2;3;4;5;6;7];;
- : int list = [4; 5; 6; 7]
# drop 10 [1;2;3;4];;
- : int list = []
# drop (-5) [1;2;3;4];;
- : int list = [1; 2; 3; 4]
# drop 5 [];;
- : 'a list = []
```

```
let rec drop n list =
   if n <= 0 then list
   else match list with
        | [] -> []
        | _::t -> drop (n - 1) t
```

5. ***Smalltalk.*** Extend class `Array` with an instance method `find:` whose argument is a value which is searched for in the array. If the value is present in the array, return the index of the first position where it is. If not found, return `nil`. **[2✓]**

```
st> a := #(5 6 7 8 9).
(5 6 7 8 9 )
st> a find: 6
2
st> a find: 99
nil
```

```
Array extend [
   find: key [
      1 to: self size do: [:i|
         ((self at: i) = key) ifTrue: [^ i].].
      ^ nil.]].
```

6. ***Perl.*** Write a program which prints out the file size, modification time, and filename for each file mentioned in `@ARGV`. Hints: The result of the `stat` function is an array where `$stat[7]` is the file size and `$stat[9]` is the modification time. Use the `strftime` format `"%b %e %H:%S"` to print out the time. Print a suitable error message if `@stat` has length 0. **[3✓]**

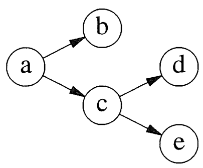
```
-bash-60$ ls.perl *.perl
     84 Nov 12 13:37 count.perl
    240 Nov 16 12:39 euclid.perl
    253 Nov 25 19:03 ls.perl
    110 Dec  5 17:53 range.perl
     91 Mar 14 21:31 wc.perl
```

```
for $file (@ARGV) {
   @stat = stat $file;
   print "$0: $file: $!\n" and next
      unless @stat;
   $date = strftime "%b %e %H:%S",
         localtime $stat[9];
   printf "%8d %s %s\n",
         $stat[7], $date, $file;
}
```

7. Write the name of a programming language associated with each of the following people. Score 1/4 point for each correct answer, but not more than 2 points total. Choose answers from: AWK, BASIC, C, C++, COBOL, FORTRAN, Java, Lisp, Perl, Python, Scheme, λ-calculus. **[2✓]**

Alfred Aho	AWK	John Backus	FORTRAN	Alonzo Church	λ-calculus
James Gosling	Java	Grace Hopper	COBOL	John Kemeny	BASIC
John McCarthy	Lisp	Dennis Ritchie	C	Guy Steele	Scheme
Bjarne Stroustrup	C++	Larry Wall	Perl	Guido van Rossum	Python

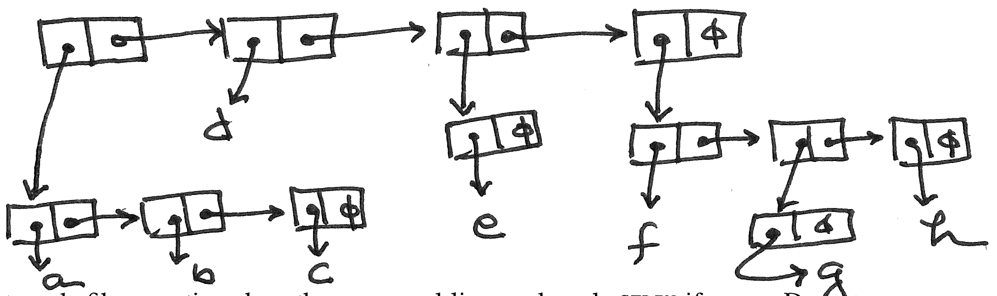
8. ***Prolog.*** Write facts in Prolog to describe the graph at left. Use the term `arrow` whose first argument is the tail of the arrow and whose second argument is the head of the arrow, i.e., `arrow(X,Y)` means that node `X` points directly at node `Y`. Write a rule `arrow2(X,Y)` which finds out if it is possible to get from `X` to `Y` by following exactly two `arrows`. **[2✓]**



```
arrow(a,b).        arrow2(X,Y) :- arrow(X,Z),
arrow(a,c).                       arrow(Z,Y).
arrow(c,d).
arrow(c,e).
```

9. ***Scheme.*** Draw a picture of the following Scheme expression. For each `cons` cell, draw a rectangular box divided into to parts, and draw an arrow from each of the `car` and the `cdr` fields to the cell or object pointed to. **[2✓]**

`((a b c) d (e) (f (g) h))`



10. ***Perl.*** Write a program that reads files mentioned on the command line, and reads `STDIN` if none. Do not open files — use the `<>` operator. At the end of the last file, print each word followed by the number of times it appears. Print the words lexicographically. A word is any sequence of characters that matches `m/\w+/`. An example is given. **[2✓]**

example input	example output

`This is a test.`
`test is a This.`
`is this a test?`
`testing this.`
	`This 2`
	`a 3`
	`is 3`
	`test 3`
	`testing 1`
	`this 2`

```
while ($line = <>) {
    ++$hash{$_} while $line =~ s/\w+//;
}
print "$_ $hash{$_}
    for sort keys %hash;
```

11. ***Ocaml.*** Write a function `eval` which takes an `expr` as an argument and returns a `float` result. An `expr` is either a `Number` or an `Expr` with a `char` operator and two `exprs`. The only operators recognized are `'+'` and `'*'`. **[2✓]**

Definitions:

```
type expr = Number of float
          | Expr of char * expr * expr;;
let a = Expr ('+',
        Expr ('*', Number 6.0, Number 7.2),
        Expr ('*', Number 1.5, Number 2.7));;
```

Interaction:

```
# eval;;
- : expr -> float = <fun>
# eval a;;
- : float = 47.25
```

```
let rec eval e = match e with
|Number f -> f
|Expr (op, x, y) -> match op with
    |'+' -> eval x +. eval y
    |'*' -> eval x *. eval y
    |_ -> failwith "eval error"
```

Multiple choice. To the *left* of each question, write the letter that indicates your answer. Write ***Z*** if you don't want to risk a wrong answer. Wrong answers are worth negative points. **[12✓]**

number of correct answers		× 1 =	$= a$
number of wrong answers		× ½ =	$= b$
number of missing answers		× 0 =	0
column total $c = \max(a - b, 0)$	12		$= c$

C 1. If `a` is a valid list, what is equal to `a` itself?
   (A) `(car (cdr (cons a)))`
   (B) `(cons (car (cdr a)))`
   (C) `(cons (car a) (cdr a))`
   (D) `(cons (cdr a) (car a))`

A 2. What is the Perl equivalent to `strerror(errno)`?
   (A) `"$!"`
   (B) `"$0"`
   (C) `"$?"`
   (D) `"$_"`

C 3. In Perl, how can `$p` be made to be a reference to an array containing some integers?
   (A) `$p = (1, 2, 3, 4);`
   (B) `$p = <1, 2, 3, 4>;`
   (C) `$p = [1, 2, 3, 4];`
   (D) `$p = {1, 2, 3, 4};`

A 4. What is the Ocaml type signature for the definition: `let f x = x;;`
   (A) `val f : 'a -> 'a = <fun>`
   (B) `val f : 'a -> 'b -> 'b * 'a = <fun>`
   (C) `val f : 'a -> 'b -> 'b = <fun>`
   (D) `val f : int -> int = <fun>`

A 5. Passing a parameter by _____ means that it is passed in unevaluated and then evaluated only if needed.
   (A) name
   (B) reference
   (C) value
   (D) value-result

D 6. An object-oriented language like C++ does dynamic dispatching of method calls using a:
   (A) friend function
   (B) heap-allocated closure
   (C) template declaration
   (D) virtual function table

D 7. The Perl pattern equivalent to `[a-zA-Z0-9_]` is:
   (A) `\d+`
   (B) `\s+`
   (C) `\t+`
   (D) `\w+`

A 8. If we have a function `not` (`bool -> bool`) and a function `even` (`int -> bool`), how might the function `odd` be defined?
   (A) `let odd = compose not even`
   (B) `let odd = map not even`
   (C) `let odd = not even`
   (D) `let odd x = not even x`

C 9. A closure is:
   (A) A special field of a structure or class used to point at a base class when implementing shared multiple inheritance.
   (B) A special type declaration in Ocaml used to distinguish sum types from product types.
   (C) A structure on the heap, used to hold variables of an outer function when referenced by an inner function.
   (D) A table used to dynamically dispatch virtual functions in an object-oriented environment.

B 10. In Perl, what command will put the names of files in the current directory in the variable `@files`?
   (A) `@files = <ls>;`
   (B) `@files = `ls`;`
   (C) `@files = glob "ls";`
   (D) `@files = system 'ls';`

C 11. What is the type of `car` in the following?
   `let car s = match s with | x::xs -> x`
   (A) `val car : 'a -> 'a = <fun>`
   (B) `val car : 'a -> 'a list = <fun>`
   (C) `val car : 'a list -> 'a = <fun>`
   (D) `val car : 'a list -> 'a list = <fun>`

D 12. What is the type of ~~tail~~ cdr in the following?
   `let cdr s = match s with | x::xs -> xs`
   (A) `val cdr : 'a -> 'a = <fun>`
   (B) `val cdr : 'a -> 'a list = <fun>`
   (C) `val cdr : 'a list -> 'a = <fun>`
   (D) `val cdr : 'a list -> 'a list = <fun>`

Multiple choice. To the ***left*** of each question, write the letter that indicates your answer. Write ***Z*** if you don't want to risk a wrong answer. Wrong answers are worth negative points. **[12✓]**

number of correct answers		× 1 =	= a
number of wrong answers		× ½ =	= b
number of missing answers		× 0 =	0
column total $c = \max(a - b, 0)$	12		= c

D
1. The basic algorithm used in type inference is :
   (A) code replication
   (B) interpretation
   (C) overloading
   (D) unification

A
2. If `guess` finds something in a sequence of facts, and `verify` checks to see if it is a good one, then `find` can be defined in Prolog as :
   (A) `find(X) :- guess(X), verify(X).`
   (B) `find(X) :- guess(X).`
       `find(X) :- verify(X).`
   (C) `find(X) :- guess(X), !, verify(X).`
   (D) `guess(X), verify(X) := find(X).`

A
3. What is 6 ?
   (A) `(apply + '(1 2 3))`
   (B) `(cons + '(1 2 3))`
   (C) `(list + '(1 2 3))`
   (D) `(map + '(1 2 3))`

A
4. Which will unexpectedly start a comment ?
   (A) `let f = (*);;`
   (B) `let f = (+);;`
   (C) `let f = (-);;`
   (D) `let f = (/);;`

D
5. What Perl statement will open a pipe to a subprocess and allow writing to its standard input ?
   (A) `open my $file, "$name|"`
   (B) `open my $file, "<$name"`
   (C) `open my $file, ">$name"`
   (D) `open my $file, "|$name"`

A
6. Which language uses lazy evaluation by default ?
   (A) Haskell
   (B) Lisp
   (C) Ocaml
   (D) Scheme

B
7. In Ocaml, what is 7 ?
   (A) `(+) (3, 4);;`
   (B) `(+) 3 4;;`
   (C) `(+) 3, 4;;`
   (D) `3 (+) 4;;`

B
8. What function is called immediately after `d()` if `d()` is true ?
```
for (a(); b(); c()){
   if (d()) continue;
   e();
   if (f()) break;
   g();
}
h();
```
   (A) `b()`
   (B) `c()`
   (C) `e()`
   (D) `h()`

D
9. The following interaction indicates what kind of polymorphism ?
```
# List.length;;
- : 'a list -> int = <fun>
```
   (A) conversion
   (B) inclusion
   (C) overloading
   (D) parametric

10. If `$key` is a key, what is the value associated with it in a hash ? [✓ $hash{$key}] %hash{$key} &hash{$key} @hash{$key}

A
11. What kind of function is
`let f x y z = x + y + z;;`
   (A) curried
   (B) thunked
   (C) tupled
   (D) unified

C
12. Go To Statement Considered Harmful
   (A) Corrado Böhm & Giuseppe Jacopini
   (B) Donald E. Knuth
   (C) Edsger W. Dijkstra
   (D) Niklaus Wirth