

Name: _____

CSE341, Spring 2013, Final Examination
June 13, 2013

Please do not turn the page until 8:30.

Rules:

- The exam is closed-book, closed-note, except for **both sides** of one 8.5x11in piece of paper.
- **Please stop promptly at 10:20.**
- You can rip apart the pages, but please staple them back together before you leave.
- There are **100 points** total, distributed **unevenly** among **8** questions (many with multiple parts).
- When writing code, style matters, but do not worry much about indentation.

Advice:

- Read questions carefully. Understand a question before you start writing.
- Write down thoughts and intermediate steps so you can get partial credit.
- The questions are not necessarily in order of difficulty. **Skip around.** Make sure you get to all the problems.
- If you have questions, ask.
- Relax. You are here to learn.

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1. (16 points)

- (a) Without using any helper functions, write a Racket function `filter-increasing`, which works as follows:
- It takes three arguments (recall Racket supports multi-argument functions directly): (1) a function `f` that takes list elements and, we assume, returns numbers, (2) a number `i`, and (3) a list `xs`.
 - It returns a list that contains a subset of the elements in `xs` in the same order they appear in `xs`.
 - An element of `xs` is in the output if and only if `f` applied to the element produces a number greater than `i` and greater than the number produced by `f` for all elements earlier (closer to the head) in the list.
- (b) Write a Racket function `filter-function-maker` that takes two arguments that are the same as `f` and `i` in part (a) and returns a *function* that takes a list `xs` and returns the result of `filter-increasing` with `f`, `i`, and `xs`. Use your answer to part (a) as appropriate.
- (c) Write a call to `filter-function-maker` that returns a function that works as follows:
- It filters out any list element that is not a positive number.
 - It includes any positive numbers that are greater than previous positive numbers in the list.
 - For example, the result for `(list 0 3 2 5 (list 19 24) #f 7 3)` would be `'(3 5 7)`.

Solution:

- (a)

```
(define filter-increasing
  (lambda (f i xs)
    (if (null? xs)
        null
        (let ([j (f (car xs))])
          (if (> j i)
              (cons (car xs) (filter-increasing f j (cdr xs)))
              (filter-increasing f i (cdr xs))))))
```
- (b)

```
(define (filter-function-maker f i)
  (lambda (xs) (filter-increasing f i xs)))
```
- (c)

```
(filter-function-maker
  (lambda (j) (if (number? j) j -1))
  0)
```

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2. (11 points) For each of the following programs, indicate what would be printed. Notice that in each program there are two print expressions and there are two calls to the function.

- (a) `(define (f1 x)`
 `(begin`
 `(print x)`
 `(set! x (+ x 7))`
 `(print x))`
- `(f1 12)`
 `(f1 12)`
- (b) `(define f2`
 `(let ([x 5])`
 `(lambda (a)`
 `(begin`
 `(print x)`
 `(set! x (+ x 7))`
 `(print x))))`
- `(f2 12)`
 `(f2 12)`
- (c) `(define f3`
 `(let ([x 5])`
 `(begin`
 `(print x)`
 `(lambda (a)`
 `(begin`
 `(set! x (+ x 7))`
 `(print x))))`
- `(f3 12)`
 `(f3 12)`

Solution:

(There would not actually be spaces between the numbers, but we include them here for readability and did not grade on this detail.)

- (a) 12 19 12 19
(b) 5 12 12 19
(c) 5 12 19

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3. (13 points) Write a Racket function `some-multiple-of-n` that works as follows:

- It takes a stream `s` and a number `n`. (Remember a stream is a thunk that returns a pair where the `cdr` is a stream.)
- It returns a list. The length of the list will be k times `n` for some $k \geq 1$.
- The returned list contains elements from the stream in order. It always contains the first `n` elements. If the n^{th} element is `#f`, then the list contains the `#f` and another `n` elements. This continues until the first k for which the $k \cdot n^{\text{th}}$ stream element is *not* `#f`, in which case this stream element is in the returned list as the last element.

Hint: You will need a recursive helper function that takes either two or three arguments, depending on how you organize your code.

Solution:

```
(define (some-multiple-of-n s n)
  (letrec ([f (lambda (s m)
                (let ([pr (s)])
                  (cons (car pr)
                        (if (= m 1)
                            (if (car pr) null (f (cdr pr) n))
                            (f (cdr pr) (- m 1)))))))]
    (f s n)))
```

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4. (14 points) Here is the skeleton of the MUPL language and interpreter, including all the struct definitions that define the syntax of the language:

```
(struct var (string) #:transparent) ;; a variable, e.g., (var "foo")
(struct int (num) #:transparent) ;; a constant number, e.g., (int 17)
(struct add (e1 e2) #:transparent) ;; add two expressions
(struct ifgreater (e1 e2 e3 e4) #:transparent) ;; if e1 > e2 then e3 else e4
(struct fun (nameopt formal body) #:transparent) ;; a recursive(?) 1-argument function
(struct call (funexp actual) #:transparent) ;; function call
(struct mlet (var e body) #:transparent) ;; a local binding (let var = e in body)
(struct apair (e1 e2) #:transparent) ;; make a new pair
(struct fst (e) #:transparent) ;; get first part of a pair
(struct snd (e) #:transparent) ;; get second part of a pair
(struct aunit () #:transparent) ;; unit value -- good for ending a list
(struct isaunit (e) #:transparent) ;; evaluate to 1 if e is unit else 0
(struct closure (env fun) #:transparent)

(define (envlookup env str) ...)
(define (eval-under-env e env) ...)
(define (eval-exp e)
  (eval-under-env e null))
```

Below are four wrong calls to the MUPL interpreter. For each, identify which of these choices best describes what goes wrong and **explain your answer** in 1-3 English sentences by explaining what happens when the program runs. (There is room on the next page for your answers.)

- A. Racket will raise an error before `p` is defined, so `eval-exp` will never get called.
 - B. `eval-exp` will get called, but with something that is not a legal MUPL program.
 - C. `eval-exp` will get called with a legal MUPL program, but evaluation will encounter a MUPL dynamic type-error.
- (a) `(define p (isaunit (ifgreater (int 1) (aunit) (int 3) (aunit))))`
`(eval-exp p)`
 - (b) `(define p (isaunit? (ifgreater (int 1) (aunit) (int 3) (aunit))))`
`(eval-exp p)`
 - (c) `(define p (aunit (ifgreater (int 1) (aunit) (int 3) (aunit))))`
`(eval-exp p)`
 - (d) `(define p (aunit? (ifgreater (int 1) (aunit) (int 3) (aunit))))`
`(eval-exp p)`

Solution:

See next page

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Extra room for answers to Problem 4.

Solution:

- (a) (C) This is a legal MUPL program that tries to determine if the result of the `ifgreater` expression is `(aunit)`. But `ifgreater` requires its first two subexpressions to evaluate to MUPL integers, so a dynamic type-error occurs from the second `ifgreater` subexpression.
- (b) (B) `isaunit?` is a Racket function that returns `#f` if passed anything not created by the `isaunit` constructor. So `p` is `#f`, which is not a MUPL program.
- (c) (A) `aunit` is a Racket constructor that requires 0 arguments, but here is given 1, so the definition of `p` fails.
- (d) (B) `aunit?` is a Racket function that returns `#f` if passed anything not created by the `aunit` constructor. So `p` is `#f`, which is not a MUPL program.

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5. (12 points) In this problem, we assume the purpose of the Java type system is to prevent “method missing” errors at run-time. We consider what would happen if we *removed interfaces from the language*, i.e., the language still had classes but there is simply no notion of interfaces or classes implementing them. For each answer below, explain your answer in 1–3 English sentences.
- (a) Would this revised language have a sound type system?
 - (b) Would this revised language have a complete type system?
 - (c) Are interfaces enough like Ruby mixins that implementing something like Ruby’s `Comparable` or `Enumerable` in Java is easier with interfaces in the language than without?
 - (d) If we added multiple inheritance at the same time we removed interfaces, how could we encode the same concept as interfaces?

Solution:

- (a) Yes, Java starts with a sound type system and without interfaces only fewer programs would type-check, so we would still not accept any programs that cause method-missing errors.
- (b) No, there would still be plenty of safe programs that would not type-check, such as one with a statement like `if(false) { x.m(); /* x has no m method */ }`
- (c) No, mixins are not well-supported in Java with or without interfaces. Mixins define methods, but interfaces indicate only the types of methods.
- (d) Each interface can become a class with all abstract methods (with one abstract method for each method signature in the interface). Then a class can extend the abstract class instead of implementing the corresponding interface.

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6. (6 points) Write a Ruby method called `curry` that takes one argument and works as follows:

- We assume the argument is an instance of `Proc` with a `call` method that expects two arguments.
- It returns an instance of `Proc` that is a curried version of the argument: it takes one argument and returns another `Proc`.
- For example, this use of `curry` should assign 16 to `v3`:

```
v1 = curry (lambda {|a,b| a + b})
v2 = v1.call 7
v3 = v2.call 9
```

Solution:

```
def curry p
  lambda {|x| lambda {|y| p.call(x,y)}}
end
```


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7. (15 points) Consider the following silly ML code:

```
datatype the_type = A of string | B of int | C of int * int
```

```
fun f x =  
  case x of  
    A s => s ^ " is coming!"  
  | _ => ""
```

```
fun g (x,y) =  
  case x of  
    B i => i + y  
  | C(i,j) => i + j + y  
  | A _ => y
```

```
val foo = (f(A "summer"), g(A "winter",7))
```

- (a) What is `foo` bound to after this program is evaluated?
- (b) Port this code to Ruby as follows:
- Use an OOP style with multiple class definitions. Do not define methods outside of these classes.
 - Use `initialize` methods, other methods, and instance variables as appropriate.
 - Have `foo` hold a two-element array.

(There is more room on the next page in case you need it.)

Solution:

- (a) ("summer is coming!",7)
- (b) See next page

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Extra room for answers to Problem 7.

Solution:

(b)

```
class TheType
  def f # also fine to duplicate this in B and C, in which case do not need
    "" # a TheType class (grading flexible)
  end
end
```

```
class A < TheType
  def initialize s
    @s = s
  end
  def f
    @s + " is coming!"
  end
  def g y
    y
  end
end
```

```
class B < TheType
  def initialize i
    @i = i
  end
  def g y
    @i + y
  end
end
```

```
class C < TheType
  def initialize (i,j)
    @i = i
    @j = j
  end
  def g y
    @i + @j + y
  end
end
```

```
foo = [A.new("summer").f, A.new("winter").g(7)]
```

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8. (13 points) In this problem, we consider a language like in lecture containing (1) records with mutable fields, (2) higher-order functions, and (3) subtyping. We do *not* require explanations for your answers.
- (a) For each of the following questions, answer “yes” if and only if the proposed subtyping relationship is sound, meaning it would not allow a program to type-check that could then try to access a field in a record that did not have that field.
- i. Is `{f1 : string, f2 : string}` a subtype of `{f1 : string, f2 : string, f3 : string}`?
 - ii. Is `{f1 : string, f2: {g1 : string, g2 : string} }` a subtype of `{f1 : string, f2 : {g1 : string} }`?
 - iii. Is `string -> {f1 : string, f2 : int, f3 : int}` a subtype of `string -> {f3 : int, f2 : int}`?
 - iv. Is `{f1 : string, f2 : int, f3 : int} -> string` a subtype of `{f3 : int, f2 : int} -> string`?
 - v. Is `int -> {f1 : string, f2 : {g1 : string} }` a subtype of `int -> {f1 : string, f2 : {g1 : string, g2 : string} }`?
- (b) If we change the language so that records are immutable (you cannot update contents of a field), which, if any, of your answers to part (a) change?

Solution:

- (a) i. No
ii. No
iii. Yes
iv. No
v. No
- (b) Part (ii) only