Compiler Construction
Professor Jeremy Siek

Midterm Exam
October 29, 2012

Name: ____________________

This exam has 7 questions, for a total of 100 points.

1. 10 points Give the output of the following Python program:

```
x = [1, [2]]
y = x + x
x[0] = 3
x[1][0] = 6
print y[0] + y[1][0]
```

Solution:

```
7
```

2. 10 points Give the output of the following Python program:

```
print ([0] and [1])[0] and not ([] or [1])
```

Solution:

```
False
```

3. 10 points Give the output of the following Python program:

```
d = { 0: 1 }
d[d[0]] = d
i = 0
x = d
while i != 2:
  x[0] = x[0] + x[0]
  x = x[1]
  i = i + 1
print d[0]
```

Solution:

```
4
```

4. 20 points Perform heapification and closure conversion, as taught in class, on the following program to obtain an equivalent program that does not include any lambdas and in which all functions are global definitions.

```
def c(f):
    def d(x):
        def e(y):
            return f(x,y)
        return e
    return d
print c(lambda a, b: a + b)(4)(2)
```

Write your answer using Python syntax, but using the following primitive functions:

- `create_closure` takes two arguments, a function pointer and a list of values for the free variables, and allocates a closure on the heap.
- `get_function` takes one argument, a closure, and returns the function pointer contained in the closure.
- `get_free_vars` takes one argument, a closure, and returns the list of values for the closure's free variables.

Instead of using `Let`, use a sequence of assignments.

Solution:

```
def fun0(fvs, y):
    f = fvs[0]
    x = fvs[1]
    tmp = f[0]
    return get_function(tmp)(get_free_vars(tmp), x[0],y)

def fun1(fvs, x):
    f = fvs[0]
    x = [x]
    e = create_closure(fun0, [f,x])
    return e

def fun2(fvs, f):
    f = [f]
    d = create_closure(fun1, [f])
    return d

def fun3(fvs, a, b):
    return a + b

c = create_closure(fun2, [])
tmp1 = get_function(c)(get_free_vars(c), create_closure(fun3, []))
tmp2 = get_function(tmp1)(get_free_vars(tmp1), 4)
print get_function(tmp2)(get_free_vars(tmp2), 2)
```

5. 15 points Give the LALR(1) parse table (state transition diagram) for the following grammar. For each state, list the items (grammar rules with dots) for that state and the actions (shift, goto, and reduce).

```
(1) start ::= A "."
(2) A ::= "a"
(3) A ::= A "+" B
(4) B ::= "b"
```

Solution:

```
state 0
   start ::= . A "."
   A ::= . "a"
   A ::= . A "+" B
   on "a" shift to state 2
   on A goto state 1

state 1
   start ::= A . "."
   A ::= A . "+" B
   on "+" shift to state 3
   on "." shift to state 6

state 2
   A ::= "a" .
   on any reduce by rule 2

state 3
   A ::= A "+" . B
   B ::= . "b"
   on "b" shift to state 5
   on B goto state 4

state 4
   A ::= A "+" B .
   on any reduce by rule 3

state 5
   B ::= "b" .
   on any reduce by rule 4

state 6, accept
   S ::= A "." .
```

6. 20 points Translate the following AST

```
Module(Stmt([Printnl(Not(CallFunc(Name('input'), [])))]))
```

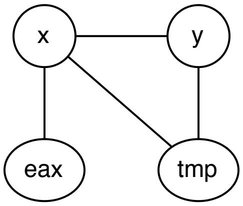
into the monomorphic intermediate representation given by the following grammar. The only kinds of values in this subset of Python that you need to deal with are integers, booleans (no lists or dictionaries), and pyobj (which is the tagged union of integers and booleans). Recall that the tag for integers is 0, the tag for Booleans is 1, and the tag for big objects is 3. You may use any of the functions from `runtime.c`.

```
type ::= int | bool
boolean ::= True | False
integer ::= 0 | 1 | 2 | ...
identifier = [a-zA-Z0-9_]+
value ::= boolean | integer
op ::= "==" | "!="
expr ::= Name(identifier) | Input() | Const(value)
       | Let(identifier, expr, expr) | IfExp(expr, expr, expr)
       | InjectFrom(type, expr) | ProjectTo(type, expr) | GetTag(expr)
       | Compare(expr, op, expr) | CallFunc(expr, [expr,...,expr])
stmt ::= Stmt([stmt,...,stmt]) | Printnl(expr)
module = Module(stmt)
```

Solution:

```
Module(Stmt([Printnl(InjectFrom(bool,
    Compare(Const(0), '==',
      Let(0_letify, CallFunc(Name('input_int'), []),
        IfExp(Compare(GetTag(Name('0_letify')), '==', Const(3)),
          CallFunc(Name('is_true'), [Name('0_letify')]),
          Compare(Const(0), '!=', ProjectTo(int, Name('0_letify'))))))))]))
```

7. 15 points Given the following interference graph, perform register allocation for an x86 processor, but restrict yourself to use just `eax` and `ebx` for general purpose allocation. Record your register allocation decisions in the following table. On each line, record which registers are still available for use for each variable. Also record which variable you choose to color and the chosen location.



avail. for x	avail. for y	avail. for tmp	variable chosen to color	chosen location

Solution: One solution is

avail. for x	avail. for y	avail. for tmp	variable	location
ebx	eax,ebx	eax, ebx	x	ebx
-	eax	eax	y	eax
-	-	none	tmp	-4(%ebp)

and another is

avail. for x	avail. for y	avail. for tmp	variable	location
ebx	eax,ebx	eax, ebx	x	ebx
-	eax	eax	tmp	eax
-	none	-	y	-4(%ebp)