CS 558 Programming Languages Fall 2023 – Practice Final Exam Sample Solutions

1. (a) `a`: 40, `b`: 21

(b) `f`

(c) `f`:`c`, `g`: `x`

(d)

```
y=20
g=clos
x=20
f=clos
c=20
```

(e)

```
y=1
h=clos
f=clos
c=20
```

There is no value for `x` available at the point where it is referenced in the body of `g`. (`g` is not available either, which could be a problem if it were recursive.)

2. (a)

```
def f(x0:Int) : Int = {
  var x = x0    // only needed because parameters are vals, not vars
  while (x <= 100)
    x = f(x+11)
  x - 10
}
```

(b)

```
def g[A](x:Int,k:Int => A) : A = {
  if (x > 100)
    k(x-10)
  else g(x+11, y => g(y,k))
}
```

3.(a) `int`

(b) $(a_1 \to (a_2 \to a_1))$

(c) $((\texttt{bool} \to a_1) \to a_1)$

(d) Not typable: `x` cannot be both a function and an integer.

(e) $((a_1 \to \texttt{bool}) \to (a_1 \to \texttt{bool}))$

4.

$$\frac{TE \vdash e : (\texttt{list}\ \ t_e) \quad TE \vdash e_n : t \quad TE + \{x_h \mapsto t_e, x_t \mapsto (\texttt{list}\ \ t_e)\} \vdash e_c : t}{TE \vdash (\texttt{match}\ \ e\ \ e_n\ \ x_h\ \ x_t\ \ e_c) : t}\ \text{(Match)}$$

5.

```
case class P(i:Int, u:T, v:T) extends T {
  def f() = i * u.f() + v.f()
}

case class Q(b:Boolean) extends T {
  def f () = if (b) 1 else 0
}
```

6.a. f: x,z. g: y.

(b)

```
def M2(x:Boolean,y:Int,z:Int) =
  R(w => if (x) z + w else w - 42,
    w => w + y)
```