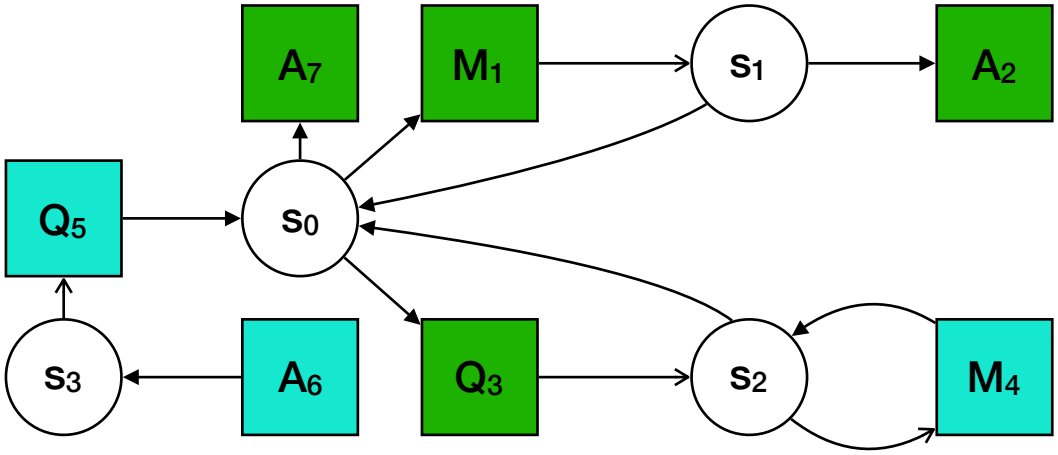
EXERCISES

Exercise 1: Name Resolution

a) Explain the main aspects of name resolution with scope graphs.

b) Given the following scope graph, list all reachability paths for reference A_6. Also indicate the path that is chosen according to the visibility rules.



c) Given the following Java program, give a scope graph that describes its name binding structure. Use the subscripts on identifiers to distinguish different occurrences of the same name.

```
public class A1 {
    int f2;
}

public class B3 {
    int m4(A5 obj6) {
        return obj7.f8;
    }
}
```

Exercise 2: Typing Constraints

a) Explain the main aspects of type checking with constraints. Discuss how the different parts of your answer are related to the language the checker is for.

b) Explain the concepts of soundness and completeness in terms of your previous answer.

c) Given the following type equalities, give a substitution that satisfies the equalities.

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

d) Explain the concept of principality in terms of your previous answer. Illustrate your answer with a different unifier that would also satisfy the constraints of (c).

Exercise 3: Constraint Semantics

Consider the constraint `d : t` that gives the type of a declaration. The semantic rule for this constraint is given by

T,G,s |= `d : t` where T(s(d)) = s(t)

where T is a function that gives the type for a declaration.

a) Given the following constraints, give a substitution `s` such that the constraints are not satisfiable.

```
Var{“a” @1} : ty1, ty1 == INT(), Var{“a” @1} : ty2
```

b) We specify the following rule to solve these type-of constraints

```
type-of(d,ty1), type-of(d, ty2) <=> ty1 == ty2
```

Show using a counter-example that this rule is unsound. Explain how the rule is applied in your example.

c) Modify the rule above so that your counter-example is rejected.

Exercise 4: Constraint Rules

a) Given the following constraint rules and program, show the constraints that would be generated by applying these rules to the program. Feel free to rename variables if necessary to avoid capture.

```
[[ LetRec(binds) ^ (s) : ty ]] :=
  new s_let,
  s_let ---> s,
  Map1[[ binds ^ (s_let) ]].

[[ Bind(x, e) ^ (s) ]] :=
  Var{x} <- s,
  Var{x} : ty,
  [[ e ^ (s) : ty ]].

[[ IntLit(_) ^ (s) : INT() ]].

[[ VarRef(x) ^ (s) : ty ]] :=
  Var{x} -> s,
  Var{x} |-> d,
  d : ty.
```

```
LetRec([
  Bind("x"₁,IntLit(42)),
  Bind("y"₂,VarRef("x"₃)),
], VarRef("y"₄))
```

b) Give a solution for the constraints you generated in (a), or explain why a solution is not possible.

c) The rules from (a) model a recursive let. The parallel let is a let where the bodies of the bindings cannot refer to the variables that are defined in the let, but only to variables defined outside the let. Give a set of modified rules that implement these semantics.