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Exercise 1 (Possibly Available Expression Analysis): (1 + 3 Points)

The goal of Possibly Available Expression Analysis (PEVA) is to determine, for each program point, which (complex) expressions *may* have been computed, and not later modified, on some path to that program point.

a) Give a formal description of the dataflow system (i.e. of E, F, D, $\sqsubseteq$, $\sqcup$, $\bot$, ι, φ_ℓ, $\text{kill}_{\text{PEVA}}$, and gen_{PEVA}) for PEVA!

b) Perform PEVA on the following program using the worklist algorithm!

```
[x := a * 2]^1;
[x := b + c]^2;
while [y > a * 2]^3 do
    [a := a * 2]^4;
    [x := a * 2 - (b + c)]^5;
```

Exercise 2 (Widening): (2+2+2 Points)

Consider the domain $D = (\mathbb{N} \times \{0, 1\}) \cup \{\infty\}$.

a) Define a relation $\sqsubseteq \subset D \times D$ such that $(D, \sqsubseteq)$ is a complete lattice which posesses both infinite ascending chains as well as infinite descending chains! Justify your answer!

b) Define a relation $\preceq \subset D \times D$ such that $(D, \preceq)$ is a complete lattice which posesses both infinitely many pairwise disjoint infinite ascending chains as well as infinitely many pairwise disjoint infinite descending chains! Justify your answer!

c) Define widening operators for both $(D, \sqsubseteq)$ and $(D, \preceq)$! Justify your answer!