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Problem Set 15
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Verification

Problem 1: Weakest precondition [4 Points]

Compute the following formulae:

1. $\mathsf{wp}(x \geq 0,\ x := x - k; \texttt{assume}\ k \leq 1)$
2. $\mathsf{wp}(x \geq 0,\ \texttt{assume}\ k \leq x; x := x - k)$
3. $\mathsf{wp}(x \geq 0,\ x := x - k; \texttt{assume}\ k \leq x)$
4. $\mathsf{wp}(x + 2y \geq 3,\ x := x + 1; \texttt{assume}\ x > 0; y := y + x)$

Problem 2: Factorial [4 Points]

Prove the partial correctness of fact. Annotate the function with an inductive loop invariant; visualize the basic paths in a diagram; list the basic paths and corresponding verification conditions and prove that all verification conditions are valid.

```
@pre n ≥ 0
@post rv = n!
int fact(int n) {
  int f := 1;
  for
    @ ⊤
    (int i := 1; i ≤ n; i := i + 1) {
    f := f * i;
  }
  return f;
}
```

Figure 1: Computing the factorial of n

The following exercises belong to the afternoon session.

Problem 3: Absolute values [6 Points]

Prove the total correctness of abs. Annotate the function with an inductive loop invariant; visualize the basic paths in a diagram; list the basic paths and corresponding verification conditions and prove that all verification conditions are valid. Furthermore, give a ranking function to prove termination.

```
@pre ⊤
@post ∀i.0 ≤ i < |rv|  →  rv[i] ≥ 0
int[] abs(int[] a_0) {
  int[] a := a_0;
  for
    @ ⊤
    (int i := 0; i < |a|; i := i + 1) {
    if (a[i] < 0)  {
      a[i] :=  − a[i];
    }
  }
  return a;
}
```

Figure 2: Computing the absolute values of an array