Task 1.1

$$i=0; while (i < size(a))\{x=x+a[i]; i=i+1\}$$

Task 2.1

(a) $\langle s, n = 5 \rangle$ \rightarrow $\langle b; s, n = 5 \rangle$ \rightarrow < n = 3 * n + 1; s, n = 5 > \rightarrow $\langle s, n = 16 \rangle$ \rightarrow $\langle b; s, n = 16 \rangle$ $\rightarrow < n = n/2; s, n = 16 >$ $\rightarrow \langle s, n = 8 \rangle$ \rightarrow $\langle b; s, n = 8 \rangle$ $\rightarrow < n = n/2; s, n = 8 >$ \rightarrow < s, n = 4 > \rightarrow $\langle b; s, n = 4 \rangle$ \rightarrow < n = n/2; s, n = 4 > $\rightarrow \langle s, n = 2 \rangle$ \rightarrow $\langle b; s, n = 2 \rangle$ $\rightarrow < n = n/2; s, n = 2 >$ $\rightarrow \langle s, n = 1 \rangle$ $\rightarrow \langle skip, n = 1 \rangle$

Task 2.2

- (a) $M(s,\sigma) = \{\bot_d\}$
- (b) $M(s, \sigma) = \{\{n = 0\}\}\$

(b) $M(s,\sigma) = \{\{n=1\}\}\$

- (c) $M(s, \sigma) = \{\{n = -1\}\}$
- (d) $M(s,\sigma) = M(y := a[x], \sigma) = \{\{x = 1, a = [0, 3, 2, 1], y = 3\}\}$
- (e) $M(s,\sigma) = M(z := 0,\sigma) = \{\{x = -1, a = [0,3,2,1], z = 0\}\}$
- (f) $M(s,\sigma) = M(y := a[x], \{x = 5, a = [0,3,2,1], z = 0\}) = \{\bot_e\}$

Task 3.1

- (a) **Unsatisfied**. Post-condition is false, as i becomes 0.
- (b) **Satisfied**. Pre-condition and post-condition passes. $i = 0 \land i \ge 0$ and $x = 6 \land x \ge 1$.
- (c) Satisfied. Same reason as above. Program doesn't terminate and errors.
- (d) **Satisfied**. Pre-condition is false thus, the triple is satisfied.
- (e) **Satisfied**. Same reason as above.
- (f) **Unsatisfied**. Post-condition is false, as x = 0.
- (g) **Unsatisfied**. Post-condition is false, since i is updated throughout the program. At the end, i = 0, x = 6, and thus, $x \neq 0$! or $x \neq 1$.
- (h) **Satisfied**. Fixes the previous problem by saving i in another variable, k. Precondition and post-condition passes. At the end, $i = 0 \land x = 6 \land k = 3$ and thus, x = k!.

Task 3.2

- (a) Valid. If y = 0 then causes an error which is fine for partial correctness. For all other states, they terminate in a state satisfying the post-condition.
- (b) Not valid since with y=0 leads to runtime error, x/0. Fixed: $[x \ge 0 \land y > 0]z := x/y[z \ge 0]$
- (c) Valid
- (d) Not valid, since we don't know the contents of array, a. They can be negative which makes the post condition false. So, I changed the program and to make it use the absolute value instead. Fixed: $\{i \ge 0 \land i < |a|\}x := |a[i]|\{x \ge 0\}$

Task 3.3

Since r := r*(-2), we need to make n be even so that it ends on a positive and passes the post-condition. $[r = 1 \land \exists k \in \mathbb{Z}. n = 2 * k]m := n$; while $n \neq 0 \{r := r*(-2); n := n-1\}[r = 2^m]$

Task 4.1

I spent about 3 hours on this.