1. Problem 1

- Draw the first 3 levels of the search tree
  \[ 5 \text{ points} \]

\[
\begin{align*}
&[S,0] \ f = 8 \\
&[B,S,1] \ f = 2 \\
&[C,B,3] \ f = 6 \\
&[C,S,5] \ f = 8 \\
&[F,B,3] \ f = 8 
\end{align*}
\]

- A* search
  \[ 5 \text{ points} \]

Note: the notation used [Node,Parent, Path-cost]

Here, \( f() = g() + h() \) (students may or may not write that)

\[
\begin{align*}
&[S,0] \ f = 8 \\
&[B,S,1] \ f = 2 \\
&[C,B,3] \ f = 6 \\
&[C,S,5] \ f = 8 \\
&[F,B,3] \ f = 8 
\end{align*}
\]
\[D, F, 4\] \( f = 8 \)
\[B, D, 8\] \( f = 9 \)
\[G2, D, 9\] \( f = 9 \)

1 points
Solution path: \( S \rightarrow B \rightarrow F \rightarrow D \rightarrow G2 \)

1 points
Solution cost 9

1 points
A* is optimal

1 points
Time Complexity: \( b^d \)

1 points
Space Complexity: \( b^d \)

- “greedy best first search”

5 points
\[S, 0\]
\[C, S, 5\]
\[G3, C, 16\]
Or
\[S, 0\]
\[B, S, 1\]
\[C, B, 3\]
\[G3, C, 14\]

1 points
Solution path: \( S \rightarrow C \rightarrow G3 \)

Or

Solution path: \( S \rightarrow B \rightarrow C \rightarrow G3 \)

1 points
Solution cost 16

or

Solution cost 14

1 points
In general it is not optimal

1 points

Time complexity: $b^m$

1 points

Space complexity: $b^m$

- depth-first search

5 points

Note: assuming expansion from left to right. Right to left is also possible

$[S, 0]$

$[A, S, 3]$

$[G1, A, 13]$

1 points

Solution path $S \rightarrow A \rightarrow G1$

1 points

Solution cost 13

1 points

In general not optimal

1 points

Time complexity: $b^m$

1 points

Space complexity: $bm$

- uniform cost search

5 points

$[S, 0]$

$[B, S, 1]$

$[A, S, 3]$

$[C, B, 3]$

$[F, B, 3]$

$[D, F, 4]$

$[C, S, 5]$

$[B, D, 8]$

$[G2, D, 9]$
1 points
Solution: $S \rightarrow B \rightarrow F \rightarrow D \rightarrow G2$

1 points
Solution cost 9

1 points
Optimal: yes

1 points
Complexity Time: Nr. of nodes w. path cost $\leq$ cost of optimal path (in this case 7)

1 points
Complexity Space: Nr. of nodes w. path cost $\leq$ cost of optimal path (in this case 7)
2)

a) 10 points
\[ \forall \text{white squares } j, \sum_i E(i, j) = 1 \]

b) 5 points

**Unary**
\[ E(1,5)=1, E(3,4)=1, E(11,12)=1 \]

**Binary**
\[ E(3,4) + E(3,7) = 1 \]
\[ E(1,5) + E(5,6) = 1 \]
\[ E(5,9) + E(9,10) = 1 \]
\[ E(1,5) + E(5,9) = 1 \]
\[ E(5,6) + E(6,7) = 1 \]

**Tertiary**
\[ E(5,6) + E(6,10) + E(6,7) = 1 \]
\[ E(6,7) + E(3,7) + E(7,11) = 1 \]

**Quadruple**
\[ E(9,10) + E(6,10) + E(10,11) + E(10,14) = 1 \]
\[ E(10,11) + E(7,11) + E(11,12) + E(11,15) = 1 \]

c) 5 points
d) **10 points**

**NOTE:** They must pick a variable that is most constrained and use the degree heuristic to break ties. If there is still a tie after applying the degree heuristic, they can select the variables arbitrarily. Thus, they do not have to use the $\min_{x,y} E(x,y)$ as stated in the question.

**One possible order:**

- $E(1,5) = 1$
- $E(5,6) = 0$
- $E(6,7) = 1$
- $E(3,4) = 1$
- $E(3,7) = 0$
- $E(5,9) = 0$
- $E(6,10) = 0$
- $E(7,11) = 0$
- $E(9,10) = 1$
- $E(11,12) = 1$
E(10,11) = 0
E(10,14) = 0
E(11,15) = 0

e) 5 points
**Time:** O(b^m)
**Space:** O(b^m)

f) 5 points
No, arc-consistency does NOT imply that the CSP has a solution (it might or it might not) because arc-consistency does not detect every possible inconsistency.

g) 5 points
Polynomial
Problem 3

- tic-tac-toe

  2.5 points - gift. everyone gets this credit
  No it is possible to have a tie (tie is not a win)

- chess against a human

  2.5 points - gift. everyone gets this credit
  No yet, DeepBlue did not always beat Kasparov

- a game of poker

  2.5 points
  No. To some degree poker is a random game, which implies that even the best computer may loose a round.

- Alpha-beta prunning is an exact algorithm

  2.5 points
  Yes