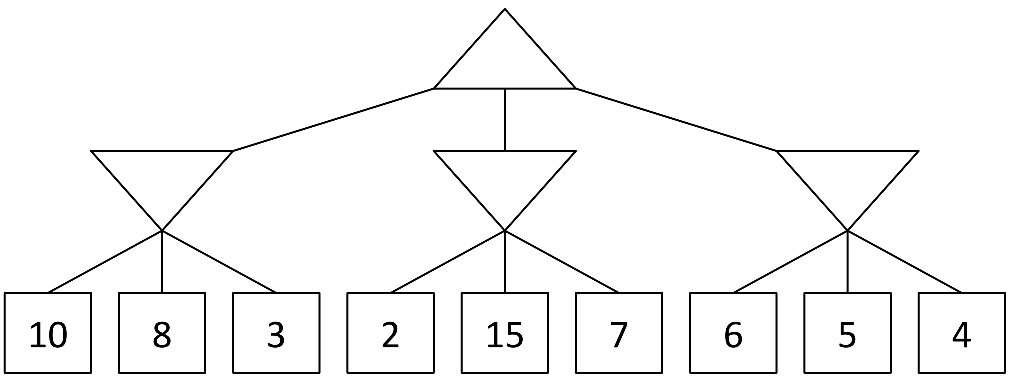
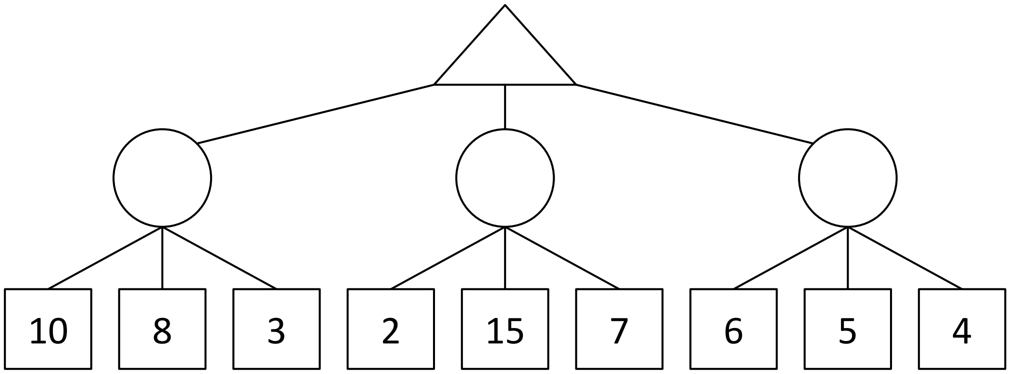
(a) Consider the zero-sum game tree shown below. Triangles that point up, such as at the top node (root), represent choices for the maximizing player; triangles that point down represent choices for the minimizing player. Assuming both players act optimally, fill in the minimax value of each node.



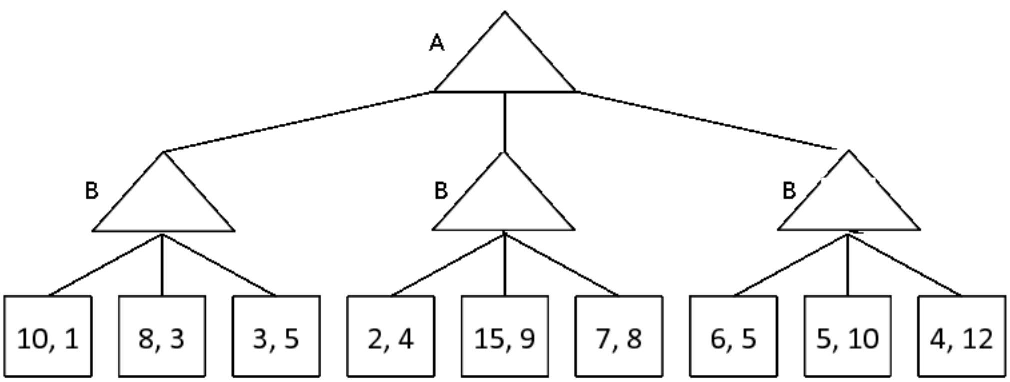
(b) Which nodes can be pruned from the game tree above through alpha-beta pruning? If no nodes can be pruned, explain why not. Assume the search goes from left to right; when choosing which child to visit first, choose the left-most unvisited child.

(c) Again, consider the same zero-sum game tree, except that now, instead of a minimizing player, we have a chance node that will select one of the three values uniformly at random. Fill in the expectimax value of each node. The game tree is redrawn below for your convenience.



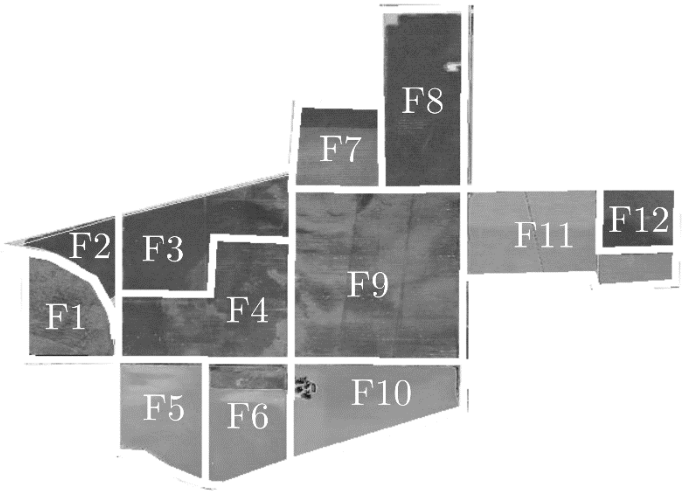
(d) Which nodes can be pruned from the game tree above through alpha-beta pruning? If no nodes can be pruned, explain why not.

1. Let's look at a non-zero-sum version of a game. In this formulation, player A's utility will be represented as the first of the two leaf numbers, and player B's utility will be represented as the second of the two leaf numbers. Fill in this non-zero game tree assuming each player is acting optimally.



2. Which nodes can be pruned from the game tree above through alpha-beta pruning? If no nodes can be pruned, explain why not.

Section 2 (8 points)



The figure to the left illustrates a parcel of arable land on planet AIMaL (see Section 1 for more information). The AIMaL Farming Cooperative wants to apply a three-field crop rotation scheme this autumn. The parcel is divided in twelve fields, which we indicate with $F1, \dots, F12$.

Every field can be used for one and only one of the following three purposes:
b: planted with *b*eans;
r: planted with *r*ye;
w: left fallo*w* (to allow for recovery).

No pair of neighbouring fields can be used for the same purpose. Fields are neighbouring if segments of their respective sides touch one another (in the figure, e.g., notice that it is the case for $F1$ and $F4$, as well as for $F3$ and $F7$, whereas neither $F1$ and $F5$ nor $F6$ and $F9$ are neighbours).

There are a few additional details to consider, though:

- Field $F5$ is low with organic matter and has to be left fallow (w).
- Field $F12$ have a fertile soil and should not be left fallow (so they can be assigned with either b or r, but not with w).
- The other fields can be used for any of the above purposes.

Our objective is to find a configuration that implements the three-field crop rotation described thus far. Considering this as a Constraint Satisfaction Problem, please carry out the following tasks.

1. Write down the set of variables and domains.
2. Represent the problem as a constraint (hyper-)graph ensuring node consistency.
3. Show a run of AC-3, explaining the operations.
4. Solve the problem via backtracking, using the Maintaining Arc Consistency inference propagation technique with the Minimum Remaining Value, max-degree (as a tie-breaker), and least-constraining value heuristics. In case of equal priority, use the increasing alphanumeric order for variables and values (e.g., $F1$ precedes $F2$, and b precedes r). Make sure to motivate the passages and explain the heuristics that determine the runtime choices.
5. At the end of step 3., are all variables node-consistent and arc-consistent? If so, explain the reason for it. If there are nodes that do not enjoy any of those properties, please indicate which they are. In both cases, make sure to clarify what these properties mean.