first name _____ **last name** _____ **std.id#** _____

12 marks **30 min (× 1.5)** **closed book** **no devices** **1 page**

Recall • *game tree* is tree of all continuations of the game, different nodes can have same position

• *game graph* is graph of all continuations of the game: different nodes have different positions • $3^9 = 19683$

1. [3 marks] For tic-tac-toe, there are about **(circle one)** 10^{11000} 12675 **500,000** 3^9 nodes in the game tree.

   For 3×3 go, there are about **(circle one)** 500,000 3^9 **10^{1100}** 12675 nodes in the game tree.

   To solve 2×2 go with python3 minimax in under 2 seconds, it is necessary to **(circle all that apply)**

   i) check pass moves after stone moves **ii) use alpha-beta cutoffs**

   iii) check pass moves before stone moves iv) use negamax.

2. [3 marks] Find all winning moves for nim position (26, 11, 20, 14): for each pile with a winning move, fill in the blanks.

```
26-pile  1 1 0 1 0          reduce 26-pile to  17-pile: remove   9 stones
11-pile    1 0 1 1          reduce 11-pile to   0-pile: remove  11 stones
20-pile  1 0 1 0 0          reduce 20-pile to ___-pile: remove ___ stones
14-pile    1 1 1 0          reduce 14-pile to   5-pile: remove   9 stones
```

3. [3 marks] Here is output from recursive nim solver `nimsimp.py`. Fill in each blank: **False** or **False dict** or **True losing child** or **True dict**. Also, below, give the

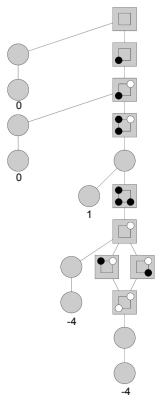
   number of states: 4

```
(1, 1, 1)
  (0, 1, 1)
    (0, 0, 1)
      (0, 0, 0) False dict
    (0, 0, 1) True losing child
    (0, 0, 1) True dict
  (0, 1, 1) False
(1, 1, 1) True losing child
```

4. In this White 2×2 go strategy diagram, some symmetric subtree(s) was(were) pruned. **Label each leaf** of the diagram with Black score +4, +1, 0, −1 or −4. Let m be the minimax score for Black for 2×2 go.

   Based on this diagram only, what can you conclude about m (answer like this: $m = 2$ or $m \geq -3$ or $m \leq 5$ etc.)? **answer:** $m \leq 1$

   Explain. **This strategy shows that White loses by at most one, so Black cannot win by more than 1, so $m \leq 1$.**



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Recall • *game tree* is tree of all continuations of the game, different nodes can have same position

• *game graph* is graph of all continuations of the game: different nodes have different positions • $3^9 = 19683$

1. [3 marks] For 3×3 go, there are about **(circle one)** 500,000 3^9 **10^{1100}** 12675 nodes in the game tree.

   For tic-tac-toe, there are about **(circle one)** 10^{11000} 12675 **500,000** 3^9 nodes in the game tree.

   To solve 2×2 go with python3 minimax in under 2 seconds, it is necessary to **(circle all that apply)**

   i) use negamax **ii) check pass moves before stone moves**

   iii) use alpha-beta cutoffs iv) check pass moves after stone moves.

2. [3 marks] Find all winning moves for nim position (25, 11, 20, 13): for each pile with a winning move, fill in the blanks.

```
25-pile  1 1 0 0 1          reduce 25-pile to  18-pile: remove   7 stones
11-pile    1 0 1 1          reduce 11-pile to   0-pile: remove  11 stones
20-pile  1 0 1 0 0          reduce 20-pile to ___-pile: remove ___ stones
13-pile    1 1 0 1          reduce 13-pile to   6-pile: remove   7 stones
```

3. [3 marks] Here is output from recursive nim solver `nimsimp.py`. Fill in each blank: **False** or **False dict** or **True losing child** or **True dict**. Also, below, give the

   number of states: 4

```
(1, 1, 1)
  (0, 1, 1)
    (0, 0, 1)
      (0, 0, 0) False dict
    (0, 0, 1) True losing child
    (0, 0, 1) True dict
  (0, 1, 1) False
(1, 1, 1) True losing child
```

4. In this White 2×2 go strategy diagram, some symmetric subtree(s) was(were) pruned. **Label each leaf** of the diagram with Black score +4, +1, 0, −1 or −4. Let m be the minimax score for Black for 2×2 go.

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   Explain. **This strategy shows that White loses by at most one, so Black cannot win by more than 1, so $m \leq 1$.**