first	name										
each	page 8 mai	rks 40 min	closed book	no de	evices 3	pages	page 1				
0.	On page 0, On pages 0	in the bubbles, write , 1, 2, 3, write your fi	your <b>*** CCID *</b> rst name, last name a	** . and student	id.						
1.	. [2 marks] in tic-tac-toe program tt24.py, about how many nodes are in each of the following? For each answer, use one of these numbers: 1000, 4000, 8000, 16000, 32000, 600000, 300000, 600000, 900000.										
	a) tree of a	ll continuations of the	e game								
	b) tree of all continuations of the game if we prune isomorphic positions										
	c) dag of al	l continuations of the	game if we prune isc	morphic po	ositions						
	d) dag of al	l continuations of the	game								
2.	[4 marks] a so that <b>neg</b>	) In this tic-tac-toe amax() is still correct	e code, where can you ?	ı insert line	e if so_far = answer: imme	== 1: bre diately aft	ak er line				
	5) def ne	egamax(d, psn, ptm)	): # 1/0/-1 win/dr	aw/loss							
	6) ii	f psn.has_win(oppo)	nent(ptm)): return	n <b>-</b> 1							
	7) L	= psn.legal_moves	()								

```
so_far = max(so_far, -nmx)
            psn.brd[cell] = Cell.e
14)
```

 $so_far = -1$ for cell in L:

8) 9)

10)

11) 12)

13)

if len(L) == 0: return 0

psn.brd[cell] = ptm

```
15)
        return so_far
```

b) From the empty board position, what is the ratio (calls made after making change in a) //(calls made before change)? Circle only one answer.

1/21/31/65/62/3

nmx = negamax(d+1, psn, opponent(ptm))

3. [2 marks] x-bias tic-tac-toe (xttt) is this game: x gets 3-in-a-row: x win, o loss, game ends; o gets 3-in-a-row: game continues; board full and x did not win: draw. Modify this function (from tt24.py) (insert/delete/change one or more lines) so that tt24.py plays xttt.

```
def has_win(self, z):
0)
                                                      explain your changes here
1)
      for t in Win_lines:
        if (self.brd[t[0]] == z and
2)
            self.brd[t[1]] == z and
3)
4)
            self.brd[t[2]] == z):
5)
          return True
6)
      return False
```

first	name			last name		$\mathbf{student}$	id	
each	page 8	8 marks	40 min	closed	book	no devices	3 pages	page 2
4.	[4 mai	rks] For t	the nim position	n below,				
	i) the	number	of winning mov	es is	_			
	ii) one	e winning	g move is to ren	nove	_ stones f	rom pile		
	pile	size	binary	SHOW YOUR	WORK FO	R ii) HERE		
	а	15	1 1 1 1					
	b	27	1 1 0 1 1					
	с	14	1 1 1 0					
	d	25	1 1 0 0 1					

5. [2 marks] Here is the end condition for the game of nim:

if it is your turn and the total number of stones left is 0 then you lose.

**Pim** is similar to nim, except it has this end condition:

if it is your turn and the total number of stones left is 0 or 1 then the game ends and you lose, e.g.  $pim(0\ 0\ 0)$  and  $pim(0\ 0\ 1)$  are losing positions.

For pim, give the player-to-move win/loss value ( $\mathbf{W}$  or  $\mathbf{L}$ ) for each position below. We have done the first one for you.

position	value	position	value	position	value	position	value
(0 0 0)	L	(0 1 1)		$(1 \ 1 \ 1)$		(0 2 2)	
(0 0 1)		(0 0 3)		(0 0 4)		(1 1 2)	
(0 0 2)		(0 1 2)		(0 1 3)			

6. [2 marks] Find a 3-pile nim position with exactly 2 winning moves or explain why no such position exists.

first name		last na	me	st			
each page 8 ma	arks 4	40 min	closed book	no devi	ces a	B pages	page 3
7. $[2 \text{ marks}]$ ]	For each tic-t	ac-toe position	with <b>x</b> to play,	give $\mathbf{x}$ 's minim	ax score x (-	-1/0/1 lose/draw	$v/{ m win}$ ).
ο.				• •	0		
		ο	хо.	х.	X	x	
	x.	. x .		. 0		0	
score							

8. [6 marks] Here is a go position after 1.B[b1] 2.W[a2] 3.B[b2] 4.W[c3] 5.B[b3] 6.W[a1] 7.B[c2] 8.W[pass]. a) From this position for black to play, draw a strategy tree for black with minimax score B - W = +9.



. x . o x x o x .

b) After move 1 above, give a move 2 that is better for white than move 2 above.

your move: 2.W[\_\_\_]

your move's B - W minimax score

c) After move 5, black knew that it could score +9 by a theoretical property discussed in the lectures. Explain the property.

first	name										
each	page 8 marks	40 min	closed book	no de	evices	3 pages	page 1				
0.	On page 0, in the b On pages $0, 1, 2, 3,$	ubbles, write yo write your first	our <b>*** CCID **</b> t name, last name a	** . nd student	; id.						
1.	[2 marks] in tic-tac-toe program tt24.py, about how many nodes are in each of the following? For each answer, use one of these numbers: 1000, 4000, 8000, 16000, 32000, 600000, 300000, 600000, 900000.										
	a) dag of all continu	ations of the g	ame								
	b) dag of all continuations of the game if we prune isomorphic positions										
	c) tree of all continu	uations of the g	ame if we prune iso	morphic p	ositions						
	d) tree of all contin	uations of the g	game								
2.	[4 marks] a) In this so that negamax()	tic-tac-toe o is still correct?	code, where can you	insert line	e if so_far answer: imm	== 1: brea nediately after	ak er line				
	3) def negamax(	l, psn, ptm):	# 1/0/-1 win/dra	aw/loss							
	4) if psn.ha	as_win(oppone	nt(ptm)): return	-1							
	5) $L = psn.2$	legal_moves()									

- 6) if len(L) == 0: return 0
  7) so\_far = -1
- for cell in L:
- 9) psn.brd[cell] = ptm
- 10) nmx = negamax(d+1, psn, opponent(ptm))
- 11) so\_far = max(so\_far, -nmx)
- 12) psn.brd[cell] = Cell.e
- 13) return so\_far

b) From the empty board position, what is the ratio(calls made after making change in a) //(calls made before change)? Circle only one answer.

3/5 4/5 1/2 1/5 2/5

3. [2 marks] x-bias tic-tac-toe (xttt) is this game: x gets 3-in-a-row: x win, o loss, game ends; o gets 3-in-a-row: game continues; board full and x did not win: draw. Modify this function (from tt24.py) (insert/delete/change one or more lines) so that tt24.py plays xttt.

```
19) def has_win(self, z): explain your changes here
20) for t in Win_lines:
21) if (self.brd[t[0]] == z and
22) self.brd[t[1]] == z and
23) self.brd[t[2]] == z):
24) return True
25) return False
```

first	name			last name		$\mathbf{student}$	id	
each	page 8	8 marks	40 min	closed	book	no devices	3 pages	page 2
4.	[4 mai	rks] For	the nim position	n below,				
	i) the	number	of winning mov	es is	_			
	ii) one	e winning	g move is to ren	nove	_ stones f	rom pile		
	pile	size	binary	SHOW YOUR	WORK FO	R ii) HERE		
	a	27	1 1 0 1 1					
	b	3	1 1					
	С	25	1 1 0 0 1					
	d	7	1 1 1					

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For pim, give the player-to-move win/loss value ( $\mathbf{W}$  or  $\mathbf{L}$ ) for each position below. We have done the first one for you.

position	value	position	value	position	value	position	value
(0 0 0)	W	(0 1 1)		$(1 \ 1 \ 1)$		(0 2 2)	
(0 0 1)		(0 0 3)		(0 0 4)		(1 1 2)	
(0 0 2)		(0 1 2)		(0 1 3)			

6. [2 marks] Find a 3-pile nim position with exactly 2 winning moves or explain why no such position exists.

first name		la	st name		student id		
each	page 8 marks	<b>40 min</b>	closed book	no de	vices 3 pa	ges page 3	
7.	[2 marks] For eac	ch tic-tac-toe po	sition with $\mathbf{x}$ to pla	ay, give <b>x</b> 's mini	max score x $(-1/0)$	$0/1 \log/draw/win).$	
		0				0	
			. x .	. x .	. 0 .		
	. X O	. X .	0	. 0 .	х	х	
	score						

8. [6 marks] Here is a go position after 1.B[b1] 2.W[c2] 3.B[b2] 4.W[a3] 5.B[b3] 6.W[c1] 7.B[a2] 8.W[pass]. a) From this position for black to play, draw a strategy tree for black with minimax score B - W = +9.



•	x	
х	x	0
	х	0

b) After move 1 above, give a move 2 that is better for white than move 2 above.

your move: 2.W[\_\_\_]

your move's B - W minimax score \_\_\_\_\_

c) After move 5, black knew that it could score +9 by a theoretical property discussed in the lectures. Explain the property.

first	name	udent id								
each	page 8 m	arks 4	0 min	closed book	no devic	es 3 page	s page 1			
0.	On page On pages	$0, \text{ in the bubbl} \\ 0, 1, 2, 3, \text{ writ}$	les, write your te your first na	*** CCID *** . ame, last name and	student id.					
1.	[2 marks] answer, u	in tic-tac-toe $\mathbf{I}$ use one of these	program tt24 e numbers: 100	.py, about how man 00, 4000, 8000, 1600	y nodes are 0, 32000, 6	e in each of the fol 0000, 300000, 600	llowing? For each 0000, 900000.			
	a) dag of all continuations of the game if we prune isomorphic positions									
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2.	[4 marks] so that <b>n</b>	a) In this tic egamax() is sti	-tac-toe cod ill correct?	e, where can you ins	sert line i an	f so_far == 1: swer: immediatel	break y after line			
	0) def	negamax(d, p	osn, ptm): #	1/0/-1 win/draw/	loss					
	1)	if psn.has_w	in(opponent	(ptm)): return -1						
	2)	L = psn.lega	l_moves()							
	3)	if len(L) ==	0: return 0	C						
	4)	$so_far = -1$								
	5)	for cell in	L:							

```
6) psn.brd[cell] = ptm
```

```
7) nmx = negamax(d+1, psn, opponent(ptm))
```

```
8) so_far = max(so_far, -nmx)
9) psn.brd[cell] = Cell.e
```

```
10) return so_far
```

b) From the empty board position, what is the ratio(calls made after making change in a) //(calls made before change)? Circle only one answer.

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```

first	name			last name		$\operatorname{student}$	id	
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(0 0 2)		(0 1 2)		(0 1 3)			

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first name		la	ist name		student id	
each	page 8 marks	40 min	closed boo	ok no de	evices 3 pa	nges page 3
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			. x o	. X .	x	X
	. x .	. x .			. 0 .	
	0	. 0 .		0		0
	score					

8. [6 marks] Here is a go position after 1.B[a2] 2.W[b3] 3.B[b2] 4.W[c1] 5.B[c2] 6.W[a3] 7.B[b1] 8.W[pass]. a) From this position for black to play, draw a strategy tree for black with minimax score B - W = +9.



0	0	•
х	х	х
	х	

b) After move 1 above, give a move 2 that is better for white than move 2 above.

your move: 2.W[\_\_\_]

your move's B - W minimax score \_\_\_\_\_

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