Question 1

State Space:

The problem consists of 2 jugs containing varying amounts of water. 2 fractions can be used to indicate the portion of the jug that contains water. For example,

3 gallon jug: 1
4 gallon jug: ½

means the 3 gallon jug is full and the 4 gallon jug is half full (contains 2 gallons of water).

Initial State:

3 gallon jug: 0
4 gallon jug: 0

because both jugs are empty, holding no water.

Goal State:

3 gallon jug: ⅔
4 gallon jug: X (can hold any amount of water)

because the 3 gallon jug holds 2 gallons of water. The amount of water in the 4 gallon jug does not matter.

Set of Actions:

- Fill the 3 gallon jug, setting **3 gallon jug: 1** (does nothing if the jug is already full)
- Fill the 4 gallon jug, setting **4 gallon jug: 1** (does nothing if the jug is already full)
- Empty the 3 gallon jug, setting **3 gallon jug: 0** (does nothing if the jug is already empty)
- Empty the 4 gallon jug, setting **4 gallon jug: 0** (does nothing if the jug is already empty)
- Pour water from the 3 gallon jug into the 4 gallon jug (does nothing if the 4 gallon jug is already full or the 3 gallon jug is empty)
    - Let **x** be the portion of the 4 gallon jug that is empty (1 - **4 gallon jug**)
    - **4 gallon jug += min(x, 3 gallon jug)**
    - **3 gallon jug -= min(x, 3 gallon jug)**
- Pour water from the 4 gallon jug into the 3 gallon jug (does nothing if the 3 gallon jug is already full or the 4 gallon jug is empty)
    - Let **y** be the portion of the 3 gallon jug that is empty (1 - **3 gallon jug**)
    - **3 gallon jug += min(y, 4 gallon jug)**
    - **4 gallon jug -= min(y, 4 gallon jug)**

Actions to achieve Goal State:

1. Fill 3 gallon jug

3 gallon jug: 1
4 gallon jug: 0

2. Pour 3 gallon jug into 4 gallon jug
   3 gallon jug: 0
   4 gallon jug: ¾

3. Fill 3 gallon jug
   3 gallon jug: 1
   4 gallon jug: ¾

4. Pour 3 gallon jug into 4 gallon jug
   3 gallon jug: ⅔ **Goal State**
   4 gallon jug: 1

Question 2

State Space:

The problem consists of 3 poles that behave like stacks (lists) of discs. There are 64 discs, which can be labelled with numbers 1 to 64, which larger numbers representing larger discs. For example:

A: [64, 63, 61, 58, …]
B: [62, 60, 59, …]
C: [ ]

represents 2 non-empty poles and 1 empty pole. Discs are added and removed from the right side of the list, and the lists must maintain a decreasing order.

Initial State:

A: [64, 63, 62, 61, 60, 59, 58, 57, 56, 55, 54, 53, 52, 51, 50, 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1]
B: [ ]
C: [ ]

because all the discs are stacked correctly (descending order) on one pole.

Goal State:

A: [ ]
B: [64, 63, 62, 61, 60, 59, 58, 57, 56, 55, 54, 53, 52, 51, 50, 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1]

C: []

Or

A: [ ]
B: [ ]
C: [64, 63, 62, 61, 60, 59, 58, 57, 56, 55, 54, 53, 52, 51, 50, 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1]

because all the discs are stacked correctly (descending order) on a different pole.

Set of Actions:

- Remove a disc from a list (list must be non-empty)
- Add a disc to a list (list must be empty, or the new disc must be smaller than the right-most disc in the list)

  (this assumes that only one disc can be moved at a time, otherwise, one can pick up the the entire stack of 64 discs and move then to another pole)

Question 3

BFS			**DFS**		
Expanded Node	*Open Queue*	*Closed Queue*	*Expanded Node*	*Open Queue*	*Closed Queue*
	{ A }			{ A }	
A	{ B D E }	A	A	{ B D E }	A
B	{ D E G }	A B	B	{ G D E }	A B
D	{ E G C F }	A B D	G	{ I D E }	A B G
E	{ G C F H I }	A B D E	I	{ D E }	A B G I
G	{ C F H I }	A B D E G			
C	{ F H I }	A B D E G C			
F	{ H I }	A B D E G C F			
H	{ I }	A B D E G C F H			
I	{ }	A B D E G C F H I			

BFS Path: A E I

DFS Path: A B G I

Question 4

BFS		
Expanded Node	*Open Queue*	*Closed Queue*
	{ S^0 }	
S^0	{ A^3 D^4 }	S^0
A^3	{ D^4 B^7 D^8 }	S^0 A^3
D^4	{ B^7 D^8 E^6 }	S^0 A^3 D^4
B^7	{ D^8 E^6 C^{10} H^{11} }	S^0 A^3 D^4 B^7
D^8	{ E^6 C^{10} H^{11} E^{10} }	S^0 A^3 D^4 B^7 D^8
E^6	{ C^{10} H^{11} E^{10} B^{11} C^{10} F^{10} }	S^0 A^3 D^4 B^7 D^8 E^6
C^{10}	{ H^{11} E^{10} B^{11} C^{10} F^{10} }	S^0 A^3 D^4 B^7 D^8 E^6 C^{10}
H^{11}	{ E^{10} B^{11} C^{10} F^{10} G^{12} }	S^0 A^3 D^4 B^7 D^8 E^6 C^{10} H^{11}
E^{10}	{ B^{11} C^{10} F^{10} G^{12} B^{15} C^{14} F^{14} }	S^0 A^3 D^4 B^7 D^8 E^6 C^{10} H^{11} E^{10}
B^{11}	{ C^{10} F^{10} G^{12} B^{15} C^{14} F^{14} C^{14} H^{15} }	S^0 A^3 D^4 B^7 D^8 E^6 C^{10} H^{11} E^{10} B^{11}
C^{10}	{ F^{10} G^{12} B^{15} C^{14} F^{14} C^{14} H^{15} }	S^0 A^3 D^4 B^7 D^8 E^6 C^{10} H^{11} E^{10} B^{11} C^{10}
F^{10}	{ G^{12} B^{15} C^{14} F^{14} C^{14} H^{15} H^{15} }	S^0 A^3 D^4 B^7 D^8 E^6 C^{10} H^{11} E^{10} B^{11} C^{10} F^{10}
G^{12}	{ B^{15} C^{14} F^{14} C^{14} H^{15} H^{15} }	S^0 A^3 D^4 B^7 D^8 E^6 C^{10} H^{11} E^{10} B^{11} C^{10} F^{10} G^{12}

BFS Path: S^0 A^3 B^7 H^{11} G^{12} (cost is 12)

DFS		
Expanded Node	*Open Queue*	*Closed Queue*
	{ S^0 }	
S^0	{ A^3 D^4 }	S^0
A^3	{ B^7 D^8 D^4 }	S^0 A^3
B^7	{ C^{10} H^{11} D^8 D^4 }	S^0 A^3 B^7

C^{10}	{ H^{11} D^{8} D^{4} }	S^{0} A^{3} B^{7} C^{10}
H^{11}	{ G^{12} D^{8} D^{4} }	S^{0} A^{3} B^{7} C^{10} H^{11}
G^{12}	{ D^{8} D^{4} }	S^{0} A^{3} B^{7} C^{10} H^{11} G^{12}

DFS Path: S^{0} A^{3} B^{7} H^{11} G^{12} (cost is 12)

UCS		
Expanded Node	*Open Queue*	*Closed Queue*
	{ S^{0} }	
S^{0}	{ A^{3} D^{4} }	S^{0}
A^{3}	{ D^{4} B^{7} D^{8} }	S^{0} A^{3}
D^{4}	{ E^{6} B^{7} D^{8} }	S^{0} A^{3} D^{4}
E^{6}	{ B^{7} D^{8} C^{10} F^{10} B^{11} }	S^{0} A^{3} D^{4} E^{6}
B^{7}	{ D^{8} C^{10} C^{10} F^{10} B^{11} H^{11} }	S^{0} A^{3} D^{4} E^{6} B^{7}
D^{8}	{ C^{10} C^{10} E^{10} F^{10} B^{11} H^{11} }	S^{0} A^{3} D^{4} E^{6} B^{7} D^{8}
C^{10}	{ C^{10} E^{10} F^{10} B^{11} H^{11} }	S^{0} A^{3} D^{4} E^{6} B^{7} D^{8} C^{10}
C^{10}	{ E^{10} F^{10} B^{11} H^{11} }	S^{0} A^{3} D^{4} E^{6} B^{7} D^{8} C^{10} C^{10}
E^{10}	{ F^{10} B^{11} H^{11} C^{14} F^{14} B^{15} }	S^{0} A^{3} D^{4} E^{6} B^{7} D^{8} C^{10} C^{10} E^{10}
F^{10}	{ B^{11} H^{11} C^{14} F^{14} B^{15} H^{15} }	S^{0} A^{3} D^{4} E^{6} B^{7} D^{8} C^{10} C^{10} E^{10} F^{10}
B^{11}	{ H^{11} C^{14} C^{14} F^{14} B^{15} H^{15} H^{15} }	S^{0} A^{3} D^{4} E^{6} B^{7} D^{8} C^{10} C^{10} E^{10} F^{10} B^{11}
H^{11}	{ G^{12} C^{14} C^{14} F^{14} B^{15} H^{15} H^{15} }	S^{0} A^{3} D^{4} E^{6} B^{7} D^{8} C^{10} C^{10} E^{10} F^{10} B^{11} H^{11}
G^{12}	{ C^{14} C^{14} F^{14} B^{15} H^{15} H^{15} }	S^{0} A^{3} D^{4} E^{6} B^{7} D^{8} C^{10} C^{10} E^{10} F^{10} B^{11} H^{11} G^{12}

UCS Path: S^{0} A^{3} B^{7} H^{11} G^{12} (cost is 12)

Question 5

BFS		
Expanded Node	*Open Queue*	*Closed Queue*
	{ A^0 }	
A^0	{ S^{140} T^{118} Z^{75} }	A^0
S^{140}	{ T^{118} Z^{75} F^{379} R^{360} }	A^0 S^{140}
T^{118}	{ Z^{75} F^{379} R^{360} L^{347} }	A^0 S^{140} T^{118}
Z^{75}	{ F^{379} R^{360} L^{347} T^{221} }	A^0 S^{140} T^{118} Z^{75}
F^{379}	{ R^{360} L^{347} T^{221} }	A^0 S^{140} T^{118} Z^{75} F^{379}
R^{360}	{ L^{347} T^{221} C^{696} P^{677} }	A^0 S^{140} T^{118} Z^{75} F^{379} R^{360}
L^{347}	{ T^{221} C^{696} P^{677} M^{646} }	A^0 S^{140} T^{118} Z^{75} F^{379} R^{360} L^{347}
T^{221}	{ C^{696} P^{677} M^{646} }	A^0 S^{140} T^{118} Z^{75} F^{379} R^{360} L^{347} T^{221}
C^{696}	{ P^{677} M^{646} }	A^0 S^{140} T^{118} Z^{75} F^{379} R^{360} L^{347} T^{221} C^{696}

BFS Path: A^0 S^{140} R^{360} C^{696} (cost is 696)

DFS		
Expanded Node	*Open Queue*	*Closed Queue*
	{ A^0 }	
A^0	{ S^{140} T^{118} Z^{75} }	A^0
S^{140}	{ F^{379} R^{360} T^{118} Z^{75} }	A^0 S^{140}
F^{379}	{ R^{360} T^{118} Z^{75} }	A^0 S^{140} F^{379}
R^{360}	{ C^{696} P^{677} T^{118} Z^{75} }	A^0 S^{140} F^{379} R^{360}
C^{696}	{ P^{677} T^{118} Z^{75} }	A^0 S^{140} F^{379} R^{360} C^{696}

DFS Path: A^0 S^{140} R^{360} C^{696} (cost is 696)

UCS		
Expanded Node	*Open Queue*	*Closed Queue*
	{ A^0 }	
A^0	{ Z^{75} T^{118} S^{140} }	A^0
Z^{75}	{ T^{118} S^{140} T^{221} }	A^0 Z^{75}
T^{118}	{ S^{140} T^{221} L^{347} }	A^0 Z^{75} T^{118}
S^{140}	{ T^{221} L^{347} R^{360} F^{379} }	A^0 Z^{75} T^{118} S^{140}
T^{221}	{ L^{347} R^{360} F^{379} }	A^0 Z^{75} T^{118} S^{140} T^{221}
L^{347}	{ R^{360} F^{379} M^{646} }	A^0 Z^{75} T^{118} S^{140} T^{221} L^{347}
R^{360}	{ F^{379} M^{646} P^{677} C^{696} }	A^0 Z^{75} T^{118} S^{140} T^{221} L^{347} R^{360}
F^{379}	{ M^{646} P^{677} C^{696} }	A^0 Z^{75} T^{118} S^{140} T^{221} L^{347} R^{360} F^{379}
M^{646}	{ P^{677} C^{696} }	A^0 Z^{75} T^{118} S^{140} T^{221} L^{347} R^{360} F^{379} M^{646}

UCS Path: A^0 T^{221} L^{347} M^{646} (cost is 646)

IDS		
Limit	*Expanded Node*	*Open Queue*
1		{ A^0 }
	A^0	{ }
2		{ A^0 }
	A^0	{ S^{140} T^{118} Z^{75} }
	S^{140}	{ T^{118} Z^{75} }
	T^{118}	{ Z^{75} }
	Z^{75}	{ }
3		{ A^0 }

	A^0	{ S^{140} T^{118} Z^{75} }
	S^{140}	{ F^{379} R^{360} T^{118} Z^{75} }
	F^{379}	{ R^{360} T^{118} Z^{75} }
	R^{360}	{ T^{118} Z^{75} }
	T^{118}	{ L^{347} Z^{75} }
	L^{347}	{ Z^{75} }
	Z^{75}	{ T^{221} }
	T^{221}	{ }
4		{ A^0 }
	A^0	{ S^{140} T^{118} Z^{75} }
	S^{140}	{ F^{379} R^{360} T^{118} Z^{75} }
	F^{379}	{ R^{360} T^{118} Z^{75} }
	R^{360}	{ C^{696} P^{677} T^{118} Z^{75} }
	C^{696}	{ P^{677} T^{118} Z^{75} }

IDS Path: A^0 S^{140} R^{360} C^{696} (cost is 696)