Question 1: Optimizing the Toronto Maple Leafs [100]

a) Line Combinations [60]

The Toronto Maple Leafs, a hockey team in the NHL, needs your help to get into the final playoff spot. The general manager and the coach of the Leafs have hired you, an operations research expert, to improve the chemistry of the teammates and their on-ice performance.

As an operations research scientist, you are asked to help the coach to further optimize the hockey team's line combinations. A line is composed of five skaters: one left wing, one centre, one right wing and two defensemen. It is well known that physical play (*P*) and skating speed (*S*) are essential attributes for a hockey team. The values of *P* and *S* are recorded in Table 1. After comprehensive research, you have come to a conclusion that the performance of a line is solely dependent on the three most physical players of the line and the three slowest skaters on the line.

Hence, the overall performance of a line can be calculated with the following equation:

Performance = ∑ (Highest 3 (*P*)) + ∑ (Lowest 3 (*S*))

> *For example:*
>
> *A line of MacArthur-Grabovski-Brown-Lebda-Schenn has the following performance score: Highest 3* P *(77+71+58) + Lowest 3* S *(76+72+61) = 415*

Create three line combinations for the Toronto Maple Leafs based on Table 1 to maximize the total performance score of the entire team. A player can be on one line only. Total performance score is the sum of the individual line performances.

	LW	C	RW	D	D	Performance
Line 1						
Line 2						
Line 3						

Total Performance _____

Question 1: Optimizing the Toronto Maple Leafs

b) Trade Scenario [10]

On the trade deadline, the GM of the Toronto Maple Leafs had received the following intriguing trade offer from the Atlanta Thrashers: Clarke MacArthur + 2 Draft Picks for Zach Bogosian. As the operations research expert, you are only interested with the current state of the hockey team in order to reach the final playoff spot this year. (The success of the current hockey team is directly related to your bonus at year end.) **Not concerned with the draft picks, would Bogosian improve the overall team performance (MacArthur would not be part of the team in this case)?**

MacArthur (LW) *P*: 71 *S*: 86

Bogosian (D) *P*: 70 *S*: 72

	LW	C	RW	D	D	Performance
Line 1						
Line 2						
Line 3						

Total Performance with MacArthur replaced by Bogosian _____

For the following questions, assume that the GM decided to decline the trade offer because he felt that the drafts picks were too much too give up.

Question 1: Optimizing the Toronto Maple Leafs

c) Double Shifting [20]

Double shifting is a concept of asking a player to play on more than one line (at most two lines). However, if a player plays on more than one line, his *S* and *P* values are reduced by 10% *on both lines* due to fatigue. For example, if Phil Kessel is double shifted and plays on both line 1 and 3, the *P* value is reduced from 72 to 64.8 and the *S* value from 92 to 82.8 for both lines. **If double shifting is allowed, what are the line combinations and the new total performance?**

	LW	C	RW	D	D	Performance
Line 1						
Line 2						
Line 3						

Total Performance _____

d) Nazem Kadri [10]

Nazem Kadri is a young and promising prospective player currently in the minor league for the Toronto Maple Leafs. **Would Kadri improve the current state of the Toronto Maple Leafs team? If so, what is the new total performance?** Assume double shifting is not allowed.

Kadri (LW) *P*: 52 *S*: 79

Total Performance _____ (write "N/A" if Kadri does not improve the team)

Table 1: Hockey Team Attributes

Player #	Player Name	Position	Physical Play (*P*)	Skating Speed (*S*)
84	Mikhail Grabovski	C	55	86
47	Darryl Boyce	C	62	71
37	Tim Brent	C	69	77
42	Tyler Bozak	C	63	84
16	Clarke MacArthur	LW	71	86
41	Nikolai Kulemin	LW	55	90
11	Fredrik Sjostrom	LW	64	79
19	Joffrey Lupul	LW	75	81
38	Jay Rosehill	LW	89	59
18	Mike Brown	RW	58	72
81	Phil Kessel	RW	72	92
46	Joey Crabb	RW	60	70
9	Colby Armstrong	RW	80	72
28	Colton Orr	RW	87	58
23	Brett Lebda	D	53	61
2	Luke Schenn	D	77	76
36	Carl Gunnarsson	D	73	82
3	Dion Phaneuf	D	95	76
8	Mike Komisarek	D	90	68
59	Keith Aulie	D	83	70

Question 2: Spices [50]

You are cooking and you need to decide which spices to include in your recipe. You can choose from *four* kinds of spices. However, you know that mixing some of these spices without some others is poisonous!! Table 2 shows the spices that cannot be mixed. Each item in the list represents a combination that should NOT be used, so, for example, (1, 2, -3) means you cannot include spices #1 and #2 without including spice #3. (-1, -2, 3) means you cannot leave out #1, leave out #2 and include #3. In other words, you cannot have #3 without including #1 and #2 as well. (1, 2, 4) means you cannot use #1, #2 and #4 all together. (-2, -3, -4) does not allow you to leave out #2, #3 and #4; you must include one of them. **Which spices will you include in your recipe?** _____

Table 2: Forbidden Spice Combinations

(1, 2, -3)
(-1, -2, 3)
(1, -2, -3)
(-1, -2, -3)
(1, 2, 4)
(-1, -2, 4)
(-1, 2, -4)
(-1, -2, -4)
(1, 3, 4)
(1, -3, 4)
(1, 3, -4)
(-1, -3, -4)
(-2, 3, 4)
(2, 3, -4)
(-2, -3, 4)
(2 -3 -4)
(-2 -3 -4)

Question 3: Disney's Fast Pass [150]

a) The Magic Kingdom [100]

The reward of the 10th Annual Operations Research Challenge is a vacation to Disneyworld's Magic Kingdom, where dreams come true. Researching the theme park, you soon find out that all of Disney's theme parks have a special queueing system called the Fast Pass. On selected rides, a customer has the choice to enter the regular queue line or to take a Fast Pass, so that he/she can come back after a certain time printed on the Fast Pass and join an express line.

From Disney's perspective, incorporating a Fast Pass system implies that the load of a high demand ride can be diverted by encouraging customers to come back at a later time. From your perspective, the Fast Pass system can be utilized to ride as many fun and interesting rides as possible in a day.

An in-depth research reveals the complicated nature of the Fast Pass in the Magic Kingdom. The popular rides have a regular line, express line and the Fast Pass return time, which allows you to join the express line after the printed time on the Fast Pass. However, a customer can have only one Fast Pass at a time. Once a Fast Pass is used to enter the express line of a particular ride, the customer can retrieve another Fast Pass on the completion of the current ride. To further complicate matters, the regular wait time, express wait time and the Fast Pass return time are all dependent on the time of the day. Table 3 shows the ride information of all the rides at the Disneyworld's Magic Kingdom. Note that only the popular rides have Fast Pass. These are marked with a star (*) in Table 3.

Your day at Disney's Magic Kingdom, where dreams come true, begins at 10 a.m. and finishes at 6 p.m. You gain satisfaction points equal to the rating of the ride after completing the ride. In Table 3, the rating of the ride is given in brackets beside the ride's name. If you choose not to ride the same ride more than once, **find the optimal schedule to maximize the satisfaction points**.

For example:

You retrieve a Fast pass for the Big Thunder Mountain Railroad *at 10 a.m. sharp, which tells you to return after 120 minutes. In the meantime, you choose to ride the* Small World *and the* Liberty Square Riverboat, *which is exactly 120 minutes in total. Now, it is 12 p.m. (noon), 120 minutes after 10 a.m. You submit your Fast Pass and enter the express line for the* Big Thunder Mountain Railroad *that requires you to wait for only 50 minutes. Now you can take another fast pass. After the 3 rides, your satisfaction points are (3+5+8=16).*

Big Thunder Mountain Railroad *10 a.m. (Fast Pass)*
Small World *(3) 10 a.m. – 11 a.m. (Regular Line)*
Liberty Square Riverboat *(5) 11 a.m. – noon (Regular Line)*
Big Thunder Mountain Railroad *(8) noon – 12:50 p.m. (Express Line)*

Please write your schedule here:

Question 3: Disney's Fast Pass

b) Three Day Schedule [50]

Winning the prestigious TORC award three years in a row, you've accumulated a 3-day ticket to the Disneyworld's Magic Kingdom. (Each day is 10 a.m. - 6 p.m.) Based on Table 3 and assuming that the information for all three days remains the same, **find a three-day schedule to maximize the overall satisfaction**. (It is rather boring to ride the same ride again and hence you choose not to do that.)

Please write your schedule here:

Table 3: Disneyworld's Magic Kingdom Rides
(Ride names with Fast Pass are marked with * . All wait times are in minutes.)

Name of the Ride (Rating)	**Morning**	**Noon**	**Afternoon**
Astro Orbiter (4 Stars)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 5:59 p.m.
Regular Wait Time	40	50	60
**Big Thunder Mountain Railroad* (8)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	70	80	120
Express Wait Time	50	50	50
Fast Pass Return Time Period	(+120)	(+140)	
**Buzz Lightyear's Space Ranger Spin* (10)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	120	160	180
Express Wait Time	60	60	60
Fast Pass Return Time Period	(+200)	(+240)	
**Jungle Cruise* (7)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	50	60	70
Express Wait Time	40	40	40
Fast Pass Return Time Period	(+90)	(+100)	
Liberty Square Riverboat (3)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	60	60	60

Mad Tea Party (4)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	30	40	30
Mickey's PhilharMagic (5)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	60	60	60
Monsters, Inc. Laugh Floor (6)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	60	60	60
**Peter Pan's Flight* (6)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	70	80	120
Express Wait Time	50	50	50
Fast Pass Return Time Period	(+120)	(+140)	
**Pirates of the Caribbean* (9)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	90	100	140
Express Wait Time	50	50	50
Fast Pass Return Time Period	(+160)	(+180)	
Small World (5)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	60	80	80

Snow White's Scary Adventures (4)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	40	50	60
**Space Mountain* (8)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	50	60	80
Express Wait Time	30	30	30
Fast Pass Return Time Period	(+90)	(+100)	
**Splash Mountain* (8)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	50	60	80
Express Wait Time	30	30	30
Fast Pass Return Time Period	(+90)	(+100)	
Stitch's Great Escape (2)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	40	60	80
The Enchanted Tiki Room (3)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	40	60	60
The Hall of Presidents (3)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	40	60	60

The Haunted Mansion (9)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	120	160	200
The Magic Carpets of Aladdin (4)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	30	40	50
**The Many Adventures of Winnie the Pooh* (6)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	30	50	70
Express Wait Time	20	20	20
Fast Pass Return Time Period	(+50)	(+90)	
Walt Disney's Carousel of Progress (4)	10 – 11:59 a.m.	12 – 1:59 p.m.	2 – 6 p.m.
Regular Wait Time	40	60	60

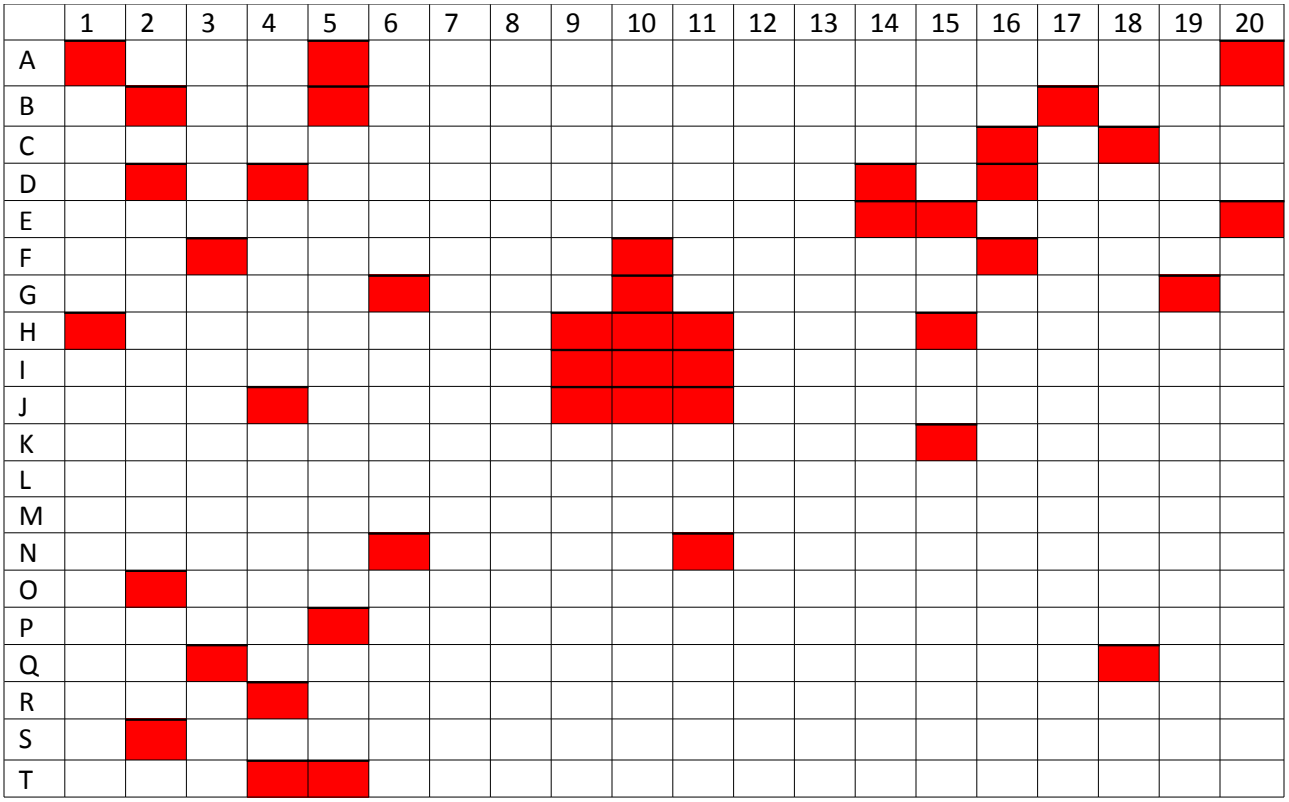
Question 4: Prime and Unique [30]

Select a prime number between 2 and 30 (inclusive). The selected prime number will be the number of marks awarded to your group if no other group selects the same prime number. If two or more groups select the same prime number, all of these groups will receive no marks. **What will your prime and unique choice be?** _____

Question 5: When Zombies Attack [150]

a) Outbreak!!! [115]

Zombies have come and they are real! Toronto is currently under quarantine as pockets of crazed zombies run amok. You are to take control of the Zombie Outbreak Marine Group (ZOMG) and slow the zombie infestation in order for the scientists at University of Toronto to create a cure.



The map above is a section of Toronto that you are in charge of saving. The black squares represent any areas that are infested with zombies. You are in charge of 5 squads of marines.

These squads will be key players as they are able to clear out all zombies in the area that they are occupying as well as all adjacent squares.

For example, if one of your squads is at position B2, the positions A1, A2, A3, B1, B2, B3, C1, C2 and C3 will all be changed to white.

Each turn, you may move each of your squads up to two squares in any direction (diagonally included) where they will continue to clear out all infestations in that area.

Example of a squad moving for 4 turns is: Start (B2)->(B4)->(D2)->(F3)->(G3)

However, the zombies aren't just going to sit around and let you kill them all. Zombies will, during each turn, infest all squares adjacent to them. Therefore, if a position B2 is infested, then A1, A2, A3, B1, B2, B3, C1, C2 and C3 will become infested (black) in the following turn if those positions are not adjacent to one of your ZOMG squads. During each turn, you make your move before the zombies do.

Please help us stop the spread of the living dead. **You have 5 turns to do your best and control the level of zombies.** You can start your 5 squads anywhere on the grid that you like for turn 1.

Tips for the best answer format:

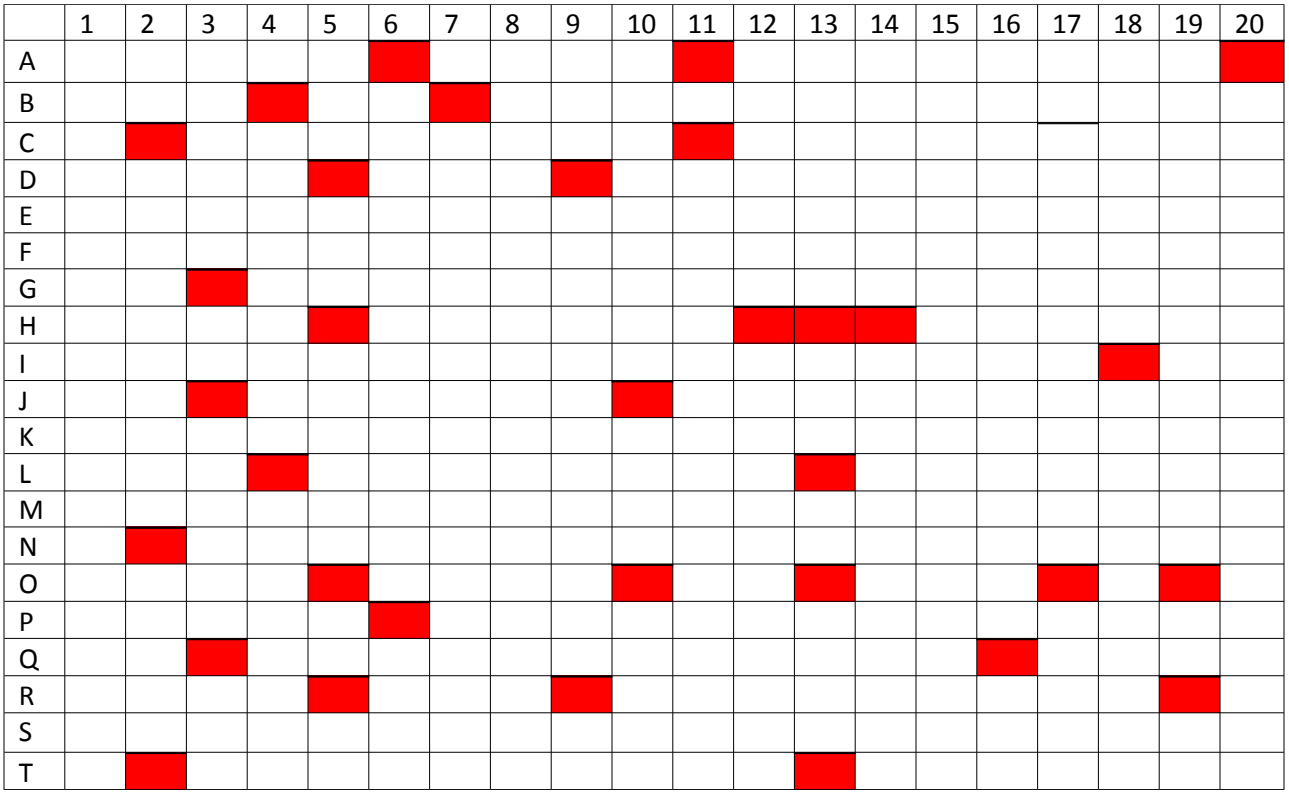
- indicate the initial location of the 5 squads on the map
- indicate the move you decide to make for each of your squads for each turn
- represent squad moves as follows: *Start (B2)->(B4)->(D2)->(F3)->(G3)*

Please write your answer on this page and the back of this page:

Question 5: When Zombies Attack

b) The Aftermath [35]

You have successfully slowed down the infestation of zombies long enough for the scientists at the University of Toronto to create a cure. The government is now looking to administer the cure to all communities that still have infections. However, the cost of deploying the Zombie Outbreak Marine Group has been large on the city. Government officials have asked you to cure all infections at minimal cost.



The map above shows the communities still containing zombies. You are to choose locations to build medical centres and train medics to go and cure these communities. A medical centre can be built at any location except for those infested with zombies. Each facility will cost you $75,000. Medics must start at a facility and move towards a zombie infested community. Once all the zombies in a community are cured, the medics must head back to the medical centre they started from to restock their supplies before they are able to venture out again to cure another community. Training medics costs the city $10,000 and each medic can move at most 10 squares each time. All medics must return back to their original medical centres by the end of the 10 movements.

For example, assume you have chosen to build a medical centre on square A1 with a single medic. This medic has been assigned to infested communities B4 and C2. The medic must start at square A1, move to C2, move back to A1, then move to B4, and then back to A1. This gives the medic a total movement of 10 if they take the path (A1)->(B2)->(C2)->(B2)->(A1)->(A2)->(B3)->(B4)->(B3)->(A2)->(A1).

You must determine how many medical centres to build and where to locate them along with the number of medics to be trained at each facility and which communities they are responsible for. If your medics fail to cure a community, the city will be forced to take emergency procedures which will cost an extra $90,000 per infected community. Therefore, it is important that all communities are serviced properly.

Tips for the best answer format:

- State the number of medical centres you decide to build
- State the location of each medical centre
- Create a list of medics along with their assigned communities
- State the costs

Example:

There are ... medical centres.

Medical Centre at A1
- medic 1 assigned to B4, C2
- medic 2 assigned to D5
* cost = $95,000

Medical Centre at ...
- medic 1 assigned to ...
- medic 2 ...
- medic 3 ...
- medic 4 ...
* cost = $115,000

....

Total Cost: $ ...

Please write your answer to Question 5 b) (When Zombies Attack, The Aftermath) on this page:

Question 6: Transporting Food [100]

Prior to being delivered to the Bahen Centre, the food for the Operations Research Challenge had to be transported and stored at different locations. Suppose there are 6 locations, Maher-town, TK-ville, Daria Village, Tony City, Maliheh-land and Christianton with 3, 1, 5, 4, 1 and 0 units of fuel, respectively. These locations are connected by roads in a ring shape so that Maher-town is connected to TK-ville, TK-ville is connected to Daria Village, Daria Village is connected to Tony City, Tony City to Maliheh-land, Maliheh-land to Christianton, and Christianton to Maher-town. There is one truck at Maliheh-land and no trucks at any other locations. The truck has to transport food between locations, and can carry at most 1 type of food at a time. When a truck moves from one location to another, it consumes 1 unit of fuel. Assume the locations are connected by pipes, so that it is possible to move fuel from any location to another: one unit of fuel can be donated from a source location to any other destination location (not necessary adjacent) at any time, unless the unit is the last unit of fuel in the source location.

Initially, *water* and *pop* are in Maher-town, *rice crispies* in TK-ville, *pizza* in Daria Village, *cookies* in Tony City, *chips* and *juice* in Maliheh-land. The goal is to have *water, juice* and *pop* in Maher-town, *chips* in TK-ville, *rice crispies* in the Daria Village, *cookies* in Tony City, *pizza* in Christianton. To achieve the goal we need to take some actions.

The possible actions are: moving a truck from one location to another adjacent location (consuming fuel from the source location), loading food into a truck, unloading food from a truck, and donating fuel from one location to another. A plan is a sequence of these actions.

> *For example, if you would like to move* juice *from Maliheh-land to Maher-town, one possible plan is:*
>
> *Action 0: DONATE 1 unit of fuel from Tony City to Christianton*
> *Result: there are 3 units of fuel at Tony City and 1 unit of fuel at Christianton*
>
> *Action 1: LOAD* juice *onto the truck at Maliheh-land*
> *Result:* juice *is in the truck*
>
> *Action 2: MOVE truck from Maliheh-land to Christianton*
> *Result: truck is at Christianton, the fuel level at Maliheh-land is 0*
>
> *Action 3: DONATE 1 unit of fuel from Maher-town to Christianton*
> *Result: there are 2 units of fuel at Maher-town and 2 units of fuel at Christianton*

Action 4: MOVE truck from Christianton to Maher-town
Result: truck is in location Maher-town, there is 1 unit of fuel left at Christianton

Action 5: UNLOAD juice at Maher-town
Result: juice *is at Maher-town, truck is empty*

Find the optimal plan (sequence of actions) that achieves the goal. In this case, "optimal" means using as few actions as possible.
Please write your plan here, in the format used in the above example.

Question 7: Investment Company [20]

You are in charge of an investment company and have characterized the four important properties of your investments:

1. High Risk / Low Risk
2. Long Term / Short Term
3. Diversify / Intensify
4. NA / ASIA / EU

You have characterized each of your previous investments according to the four properties.

The following investments made a profit:
1. High Risk – Long Term – Diversify – NA
2. Low Risk – Short Term – Intensify – ASIA
3. Low Risk – Short Term – Diversify – EU
4. Low Risk – Long Term – Intensify – ASIA

The following investments incurred a loss:
1. High Risk – Long Term – Intensify – EU
2. High Risk – Short Term – Intensify – ASIA
3. High Risk – Short Term – Diversify – EU
4. Low Risk – Long Term – Intensify – EU

You are about to make a new investment. **Based on your previous investment experience, what is the best investment option to maximize the company's profit?**

Circle Your New Investment Option		
High Risk	Low Risk	
Long Term	Short Term	
Diversify	Intensify	
NA	ASIA	EU