- **Due:** Tuesday 9/10 at 11:59pm.

- **Policy:** Can be solved in groups (acknowledge collaborators) but must be submitted individually.

- **Make sure to show all your work and justify your answers**.

- **Note:** This is a typical exam-level question. On the exam, you would be under time pressure, and have to complete this question on your own. We strongly encourage you to first try this on your own to help you understand where you currently stand. Then feel free to have some discussion about the question with other students and/or staff, before independently writing up your solution.

- **Note:** Leave the self-assessment sections blank for the original submission of your homework. After the homework deadline passes, we will release the solutions. At that time, you will review the solutions, self-assess your initial response, and complete the self-assessment sections below. The deadline for the self-assessment is 1 week after the original submission deadline.

- Your submission on Gradescope should be a PDF that matches this template. Each page of the PDF should align with the corresponding page of the template (page 1 has name/collaborators, question begins on page 2.). **Do not reorder, split, combine, or add extra pages**. The intention is that you print out the template, write on the page in pen/pencil, and then scan or take pictures of the pages to make your submission. You may also fill out this template digitally (e.g. using a tablet.)

First name	Yuchuan
Last name	Mao
SID	304 0807955
Collaborators	Xuanwei Liang

Q1. [6 pts] Robot in a Factory

Suppose a factory floor has width W and length L. There are P packages on the factory floor at the start. The robot is able to move North, South, East, or West on the floor.

(a) [3 pts] For this subquestion only, the position of the robot is known, and it wants to pick up all P packages in the factory. However, the robot can move North at most 2 times overall.

What is the minimal size of the state space for this problem? Write your answer in the box as a product of terms that reference problem quantities (such as, but not limited to, W, L, and P). You may also use constants as part of your expression. For each term in your expression, also state the information it encodes. For example, you might write "4×WL" and write "number of directions" under the first term and "robot's position" under the second term. You will receive partial credit for a complete but non-minimal state space.

$$ML \times P \propto (1 + ML - 1)$$

robot's position

packages picked up or not? : 1

if not, packages position : $ML - 1$

$$= ML \times PML$$

$$ML \times 2^P \times 3$$

Q1(a) Self-Assessment - leave this section blank for your original submission. We will release the solutions to this problem after the deadline for this assignment has passed. After reviewing the solutions for this problem, assess your initial response by checking one of the following options:

○ I fully solved the problem correctly, including fully correct logic and sufficient work (if applicable).

● I got part or all of the question incorrect.

If you selected the second option, explain the mistake(s) you made and why your initial reasoning was incorrect (do not re-iterate the solution. Instead, reflect on the errors in your original submission). Approximately 2-3 sentences.

I didn't notice that there are multiple packages need to pick up. Just because of carelessness.

Correct solution: $ML \times 2^P \times 3$ — how many times left the the robot can move North. which could be $(0, 1, 2)$

position of Robot

wether a square have packages

(b) [3 pts] In this subquestion, the robot is lost on the factory floor and does not know its location. However, the robot wants to visit every single square (it does not care about collecting the packages anymore). The robot's task is to find a sequence of actions that guarantees it will visit every single square.

What is the size of a minimal state space for this problem? As in part **(a)**, give your answer as a product of terms along with the information encoded by each term. You will receive partial credit for a complete but non-minimal state space.

$$ML \times 2^{ML}$$

Robot's position · Is the square visited?

ML squares total

Q1(b) Self-Assessment - leave this section blank for your original submission. We will release the solutions to this problem after the deadline for this assignment has passed. After reviewing the solutions for this problem, assess your initial response by checking one of the following options:

- ● I fully solved the problem correctly, including fully correct logic and sufficient work (if applicable).
- ○ I got part or all of the question incorrect.

If you selected the second option, explain the mistake(s) you made and why your initial reasoning was incorrect (do not re-iterate the solution. Instead, reflect on the errors in your original submission). Approximately 2-3 sentences.

Q2. [10 pts] Pacman Goes to School!

Pacman lives far from his university, so he decides to model his daily commute as a search problem. He imagines the city of Berkeley as an M by N square grid, where his apartment is the top left square; his goal is to reach Dwinelle Hall, located in the bottom right square in the fewest number of timesteps. He can move *left, right, up,* or *down,* as long as he stays within the grid.

There is a single fixed bus route on the grid, where a bus travels in a loop at a constant rate of three squares per timestep. Any square along this route is a valid bus stop. Pacman knows the bus route, and if he's on the same square as the bus, **he can hop on and travel at a rate of three squares per timestep along the bus route.** He can stay on the bus for any number of timesteps and get off at any square adjacent to the route. However, Pacman's Clipper card only allows one ride per commute, so he can only board and disembark from the bus route at most once during his trip.

Below is an example initial state on a 6 by 6 grid. The arrows represent the bus route. Note that this is just an example route, and the actual bus route may vary. For the following questions, consider the general case, **not** this specific example. **Additionally, consider each part separately (i.e., do not carry over assumptions).**
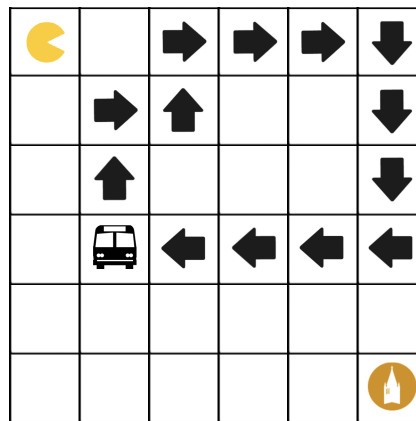
(a) [2 pts] Which of the following are admissible heuristics? Select all that apply.

- ☐ The Manhattan distance between Pacman and the university.
- ☑ The Manhattan distance between Pacman and the university divided by 4.
- ☐ The Manhattan distance between Pacman and the bus.
- ☐ The Manhattan distance between the closest bus stop to Pacman and the university.
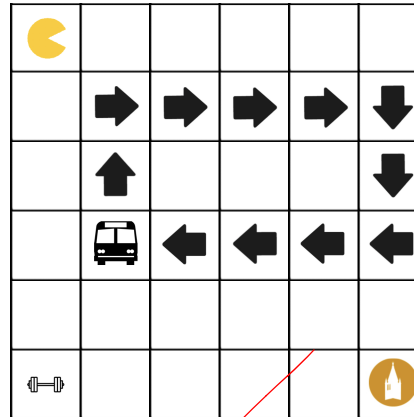- ☐ None of the above.

(b) [2 pts] Suppose Pacman knows there is at least one bus stop adjacent to the university. Which of the following are admissible heuristics? Select all that apply.

- ☐ The Manhattan distance between Pacman and the bus.
- ☑ The Manhattan distance between the bus and the stop next to the university divided by 3.
- ☐ $\frac{1}{7}$ for all states.
- ☑ The minimum of the above heuristics.
- ☐ None of the above.

(c) [2 pts] Suppose that there are B different buses with their own routes. Pacman can now ride the bus multiple times, but he must also ride a bus at least once. Which of the following are admissible heuristics? Select all that apply.

- ☑ The minimum of the Manhattan distances between every bus stop and the university, and Pacman and the university.
- ☐ The number of times Pacman has ridden the bus so far.
- ☑ The Manhattan distance from Pacman to the closest bus stop plus the distance from that bus stop to the university divided by three.
- ☐ None of the above.

(d) [2 pts] Suppose Pacman now wants to work out at the RSF (the campus gym), located in the bottom left square of the grid. It doesn't matter if he goes before or after reaching the university, but he must visit both locations. Below is an example initial state with the RSF represented by a dumbbell in the bottom left corner:
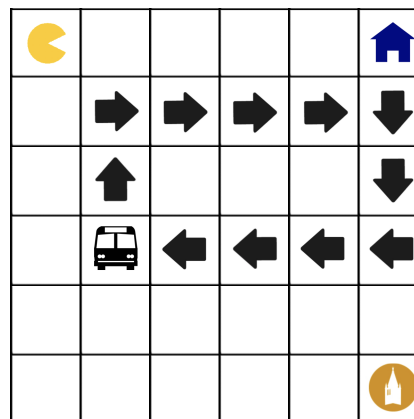

Which of the following are admissible heuristics? Select all that apply.

- [x] The minimum of the Manhattan distances between Pacman and the RSF, the RSF and the university, and Pacman and the university, divided by 3.
- [ ] The sum of the Manhattan distances between Pacman and the RSF, the RSF and the university, and Pacman and the university, divided by 3.
- [ ] The maximum of the above heuristics.
- [ ] None of the above.

(e) [2 pts] Suppose Pacman and his friend Xavier want to go to the university together today. Xavier lives in an apartment in the top right corner of the grid and wants to meet up with Pacman somewhere before they move together to the university. Assume that Xavier moves independently from Pacman, one space per timestep, and that they must meet in another square before either of them can go to the university. Xavier cannot take the bus, with or without Pacman (although Pacman can still take it alone). In this updated search problem, you can control both Pacman and Xavier.

Below is an example initial state with Xavier's apartment in the top right corner. Xavier is currently in his apartment:

Which of the following are admissible heuristics? Select all that apply.

- [ ] The Manhattan distance between Pacman and Xavier divided by 2.
- [x] The Manhattan distance from Xavier to the university.
- [x] The Manhattan distance from Pacman to the university divided by 3.
- [ ] None of the above.

Q2 Self-Assessment - leave this section blank for your original submission. We will release the solutions to this problem after the deadline for this assignment has passed. After reviewing the solutions for this problem, assess your initial response by checking one of the following options:

○ I fully solved the problem correctly, including fully correct logic and sufficient work (if applicable).

● I got part or all of the question incorrect.

If you selected the second option, explain the mistake(s) you made and why your initial reasoning was incorrect (do not re-iterate the solution. Instead, reflect on the errors in your original submission). Approximately 2-3 sentences for *each* incorrect sub-question.

For question (a), I am confuse by the number of 4, because divide 3 is enough. It doesn't violate the nature of heuristics , so I still make the right choice even it seems weird.
For question (b), I misunderstood the nature of heuristics "how close a state is to a goal". Because the route of bus is fixed, there is no difference between the different states of Pac-Man.
For question(c), I don't think A is admissible because if Pac-Man was already take the bus once, we shouldn't consider the distance between Pac-Man and the bus stop. And I realized that C is not admissible either because of the same reason.