Problem 1. (4 points)

Which of the following statements are true about a message marshalling system like LCM? (Circle all that apply)

A) Using an LCM-like system encourages developers to standardize on a single computational platform and programming language.

B) Encoding and decoding functions are generated automatically, saving developer effort.

C) Formal message specifications encourage modularity and abstraction.

D) Developers can easily add new fields to previously defined types without modifying the formal declaration.

Problem 2. (10 points)

Consider the magnetic-lift crane below, which we first looked at in Quiz 1. Its base is on a railway that allows the whole crane to move in along the X axis. The crane itself has a rotational joint whose theta is measured with respect to the +X axis; i.e., in the figure below, theta is about +15 degrees.
The forward kinematics for the end effector can be written as:

\[ x = L_1 + L_2 \cos(\theta) \]
\[ y = L_2 + L_3 \sin(\theta) - L_4 \]

A. Write the Jacobian for the position of the arm in terms of the controllable parameters \( L_1, \theta, \) and \( L_4. \) (We will assume that \( L_2 \) and \( L_3 \) cannot be changed).

B. Suppose \( L_2 = L_3 = 1 \) and that, due to a mechanical failure, \( L_4 \) is stuck at 1. Write closed-form expressions for \( L_1 \) and \( \theta \) that will position the end-effector at an arbitrary \((x, y)\) location. (You do not need to address the case where no solution is possible.)
Problem 3. (6 points)

A homogeneous 3D rigid-body transformation (circle all that apply):

A) Is an orthonormal matrix
B) Is symmetric
C) Is full rank
D) Is 4x4
E) Combines translation and rotation in a single matrix
F) Can represent the perspective projection of a camera.

Problem 4. (12 points)

For each of the motion planning algorithms below, put an X next to each of its properties.

A) Depth-First search
   Deterministic: ___ Complete: ____ Optimal: _____

B) Wavefront motion planner:
   Deterministic: ___ Complete: ____ Optimal: _____

C) A*:
   Deterministic: ___ Complete: ____ Optimal: _____

D) RRT:
   Deterministic: ___ Complete: ____ Optimal: _____

E) BUG 0 (see reminder below)
   Deterministic: ___ Complete: ____ Optimal: _____

F) BUG 1 (see reminder below)
   Deterministic: ___ Complete: ____ Optimal: _____

Reminders:

Bug 0: The algorithm that drives towards the goal when possible, otherwise follows obstacles around the left.

Bug 1: The algorithm in which the robot circles any obstacles it encounters completely.
Problem 5. (4 points)

Describe an application for which you would prefer a range sensor with a narrow field of view.

Describe an application for which you would prefer a range sensor with a wide field of view.

Problem 6. (6 points)

In class, we described four invariance properties that are desirable for feature descriptors List three:

1. 
2. 
3. 
4. (+1 extra credit)
Problem 7. (10 points)

A) The robot is at the position marked “S” and wants to get to either of the destinations marked “G”. Using the wavefront motion planning algorithm, fill in the distance-to-goal function for each grid cell, assuming the robot can go up/down or right/left (but not diagonally), and that the robot cannot travel through black cells.

B) Would A* (using a Euclidean distance heuristic) be faster or slower on this problem? Explain.
Problem 8. (5 points)

Recall the infrared range finders that we discussed in class.

A) Write an expression giving the output voltage as a function of the distance to the nearest object and the parameters f and b.

B) Provide a qualitative sketch of your function. (+1 extra credit if you include the potentially-problematic real-world non-ideality.)

C) Assume that the voltage is read using an analog-to-digital converter with Gaussian noise with standard deviation 0.01V. Will distance estimates (as a function of voltage) be more accurate at short or long ranges? (circle one)

Short ranges
Long ranges
Problem 9. (10 points)

Match the terms (letters on left) with the most appropriate phrase on the right:

______ A) Axis/Angle 1. Full resolution, half resolution, quarter resolution...
______ B) Bayer Pattern 2. Measures time-of-flight of pulse
______ C) Biased Sampling 3. Robust feature descriptor
______ E) Harris Corner 5. Covariance matrix of gradient has large eigenvalues
______ F) Heuristic function 6. High-torque motor without feedback
______ G) Image Pyramid 7. 2x2 grid of Red, Green, Green, and Blue.
______ H) Lens 8. Light focusing device
______ I) Low-pass filtering 9. Color sensing cells on retina
______ J) Servo 10. Can be expressed as a quaternion
______ K) SIFT 11. Invertible mapping over all real numbers
______ L) Ultrasound ranger 12. Motor that seeks a specified angle

13. Brightness sensing cells on retina
14. Prevents aliasing when down sampling an image
15. Deterministic variant of RRT
16. Cost-to-go under-estimate