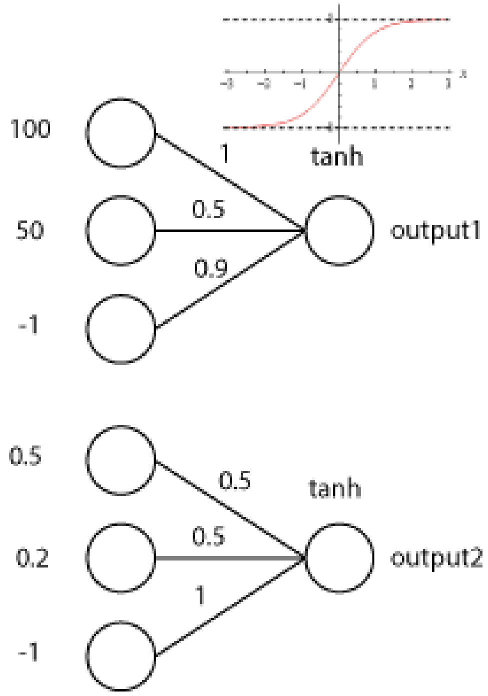
Q1. Neural Networks

(a) Approximate the values output1 and output2 in these artificial neural networks.



output1:

output2:

(2 marks)

(b) For each of the following problems, draw the simplest neural network architecture that can solve it. Also give the output function (e.g linear, sigmoid, step-function).

- predict the sum of 3 numbers.
- predict the output of XOR

  0 XOR 0 = 0

  0 XOR 1 = 1

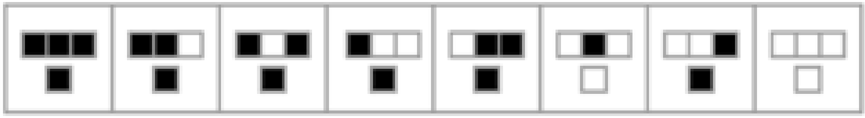
  1 XOR 0 = 1

  1 XOR 1 = 0
- predict a heart attack given 2 minutes of electrocardiogram (ECG) time-series with one measurement every second.

(3 marks)

Q2. Cellular Automata

(a) Follow the rules pictured below for a cellular automata initialised with the following line[000010000]. Perform 4 iterations and make sure to specify the boundary conditions.



(2 marks)

(b) Which one of these applies:

1. Uniform final state
2. Simple stable or periodic final state
3. Chaotic, random, nonperiodic patterns
4. Complex, localized, propagating structures

(1 mark)

(c) What problems could you theoretically compute using a cellular automaton? Say why in a couple words.

(1 mark)

Q3. Artificial Evolution

(a) Design an evolutionary algorithm that allows a two-wheeled robot to fully explore an environment while avoiding obstacles. The robot has two obstacle sensors each covering 180° mounted on both sides.

In a couple of words, describe how you would set the following elements of the algorithm:

- genotype
- phenotype
- fitness
- initial population
- selection operator

(5 marks)

(b) Imagine that your evolutionary algorithm converges to a sub-optimal solution (for example turning on the spot). What can you do to help the evolutionary algorithm find better solutions? Provide two ideas with short explanations.

(2 marks)

Q4. Biomimetic Robotics

(a) You're a researcher building a tiny flying robot the size of a fly. In a couple of words, what source of inspiration could you use and why?

- for the sensors
- for the flying mechanism
- for the control of individual robots
- for the control of many robots working together
- itemize

(4 marks)

(b) What could this flying robot teach biologists?

(1 mark)

(c) Draw a subsumption controller for the fly robot to navigate its environment. The robot has two behaviours move straight and avoid obstacle.

(2 marks)

(d) How would you change this controller to use a map as an input to navigate the environment? Make sure the robot is safe and doesn't collide with obstacles.

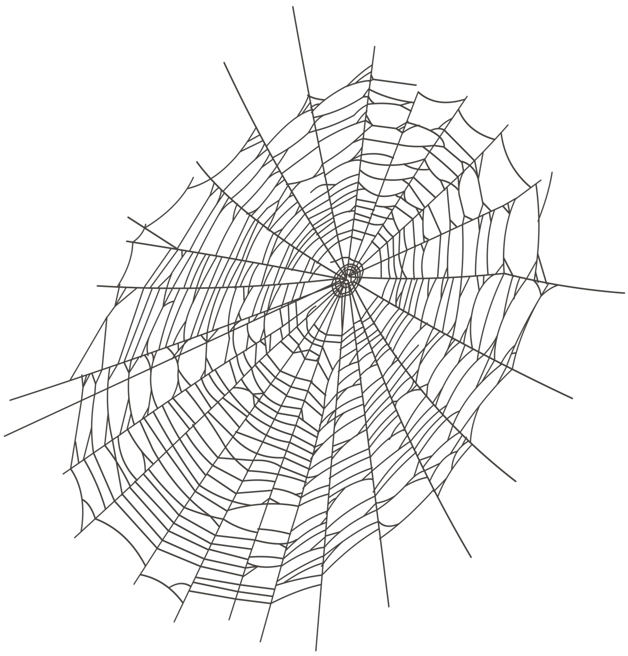
(1 mark)

Q5. Morphological Computation

(a) You are given the two following options regarding the purchase of a robot manipulator. List two pros and two cons about the controllability of each of these robots.

(2 marks)

(b) Give one example of what type of computation may be embedded in the spider web?



(1 mark)

Q6. Chemical Computing

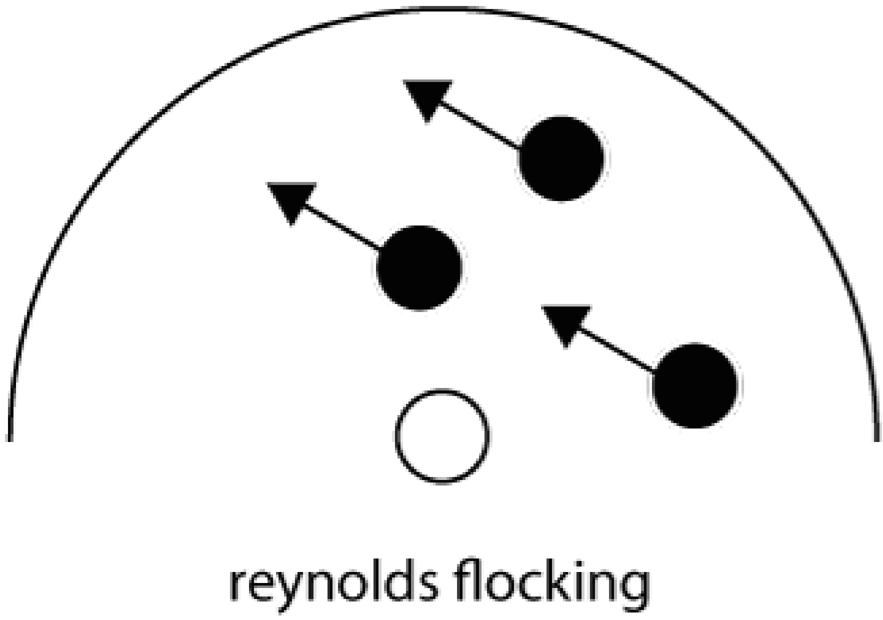
(a) Given the chemical species X_1, X_2, Y (fluorescent red), and N (fluorescent green), what reaction networks (there can be more than one) give you the following functions.

1. $f(x_1)$: parity of x_1 - initial state:$x_1 X_1, 1N$
2. $f(x_1, x_2)$: $x_1 > x_2$? - initial state:$x_1 X_1, x_2 X_2, 1N$
3. $f(x_1) = 2x_1$ - initial state:$x_1 X_1$
4. $f(x_1) = x_1/2$ - initial state:$x_1 X_1$
5. $f(x_1, x_2) = x_1 + x_2$ - initial state:$x_1 X_1, x_2 X_2$
6. $f(x_1, x_2) = min(x_1, x_2)$ - initial state:$x_1 X_1, x_2 X_2$

(6 marks)

Q7. Swarm Intelligence

(a) Draw the resulting velocity vector applied to the agent in white in the case of Reynolds Flocking.



(1 mark)

(b) Assuming there are 10 robots per flock, write pseudo code for a simulator that would model Reynolds flocking.

(2 marks)

(c) Briefly describe two techniques to design a controller for a robot that will give you a desired swarm behaviour.

(2 marks)

(d) Imagine you are artificially evolving a swarm of robots, name two conditions that improves the evolution of cooperative, rather than deceptive or individualistic behaviour?

(2 marks)