Q1. Backpropagation

(a) Perform forward propagation on the neural network below for \( x = 1 \) by filling in the values in the table.

Note that (i), . . . , (vii) are outputs after performing the appropriate operation as indicated in the node.

\[
\begin{array}{ccccccc}
(i) & (ii) & (iii) & (iv) & (v) & (vi) & (vii) \\
\hline
\hline
\end{array}
\]

\[
\begin{array}{cccccccc}
 x & \cdot 2 & (i) & \sum & (iv) & \max & \max & (vii) \\
 x & \cdot 3 & (ii) & \max & (v) & \min & (vi) \\
 x & \cdot 4 & (iii) & & & & & \\
 a & b & c & d & e & f & & \\
\end{array}
\]

(b) Below is a neural network with weights \( a, b, c, d, e, f \). The inputs are \( x_1 \) and \( x_2 \).

The first hidden layer computes \( r_1 = \max(c \cdot x_1 + e \cdot x_2, 0) \) and \( r_2 = \max(d \cdot x_1 + f \cdot x_2, 0) \).

The second hidden layer computes \( s_1 = \frac{1}{1+\exp(-a \cdot r_1)} \) and \( s_2 = \frac{1}{1+\exp(-b \cdot r_2)} \).

The output layer computes \( y = s_1 + s_2 \). Note that the weights \( a, b, c, d, e, f \) are indicated along the edges of the neural network here.

Suppose the network has inputs \( x_1 = 1, x_2 = -1 \).
The weight values are \( a = 1, b = 1, c = 4, d = 1, e = 2, f = 2 \).

Forward propagation then computes \( r_1 = 2, r_2 = 0, s_1 = 0.9, s_2 = 0.5, y = 1.4 \). Note: some values are rounded.

Using the values computed from forward propagation, use backpropagation to numerically calculate the following partial derivatives. Write your answers as a single number (not an expression). You do not need a calculator. Use scratch paper if needed.

Hint: For \( g(z) = \frac{1}{1+\exp(-z)} \), the derivative is \( \frac{\partial g}{\partial z} = g(z)(1 - g(z)) \).