Question 1:
What function $\psi_p^{(1)}$ does the following program compute?

IF $X \neq 0$ GOTO A
Z ← $Z + 1$
IF $Z \neq 0$ GOTO B
[A] $X ← X − 1$
$Y ← Y + 1$
$Y ← Y + 1$
IF $X \neq 0$ GOTO A
[B] $Y ← Y + 1$
$Y ← Y + 1$
$Y ← Y + 1$
$Y ← Y + 1$

Question 2:

a) Write a program $\varphi$ in the language $\mathcal{L}$ that computes the following function $\psi_p^{(1)}(r)$:

$$\psi_p^{(1)}(r) = \begin{cases} \uparrow, & \text{if } r = 0 \\ r + 3, & \text{otherwise} \end{cases}$$

Here, “$\uparrow$” stands for “undefined,” that is, the program will never terminate. You cannot use any macros at all, but only the three types of instructions in the original definition of the language. The input value $X_1$ does not have to be conserved.

b) Write down the complete list of snapshots that occur during the computation of $\psi_p^{(1)}(1)$. Use the format shown on page 29 in the textbook.
Question 3:

Now you want to write a program in your favorite language $\mathcal{L}$ that computes the factorial function.

a) Write down the program using macros. You are allowed to use the macros $V \leftarrow V$, $V \leftarrow m$, GOTO $L$, and $W \leftarrow f(V_1, \ldots, V_n)$. Use at least one macro of the form $W \leftarrow f(V_1, \ldots, V_n)$, and whenever you do so, provide a program that computes $f(V_1, \ldots, V_n)$.

b) In your program, pick one of the macros of the form $W \leftarrow f(V_1, \ldots, V_n)$ and expand it using the convention given in Section 2.5 in the textbook. Write down the version of your program with this one macro expanded.