Problem 1: Write the series of homogeneous transforms associated with each link in the manipulator shown above. Write the transform describing the end effector of the manipulator in the base reference frame (i.e. the 0th reference frame).
**Problem 2:** (Spong, Problem 2-15) If the coordinate frame A is obtained from the coordinate frame B by a rotation of $\pi/2$ about the $x$-axis followed by a rotation of $\pi/2$ about the fixed $y$-axis, find the rotation matrix $R$ representing the composite transformation. Sketch the initial and final frames.

![Figure 2: Used in Problem 3](image)

**Problem 3:** (Spong, Problem 2-37) Consider the diagram above. A robot is set up 1 meter from a table. The table top is 1 meter high and 1 meter square. A frame $o_1 x_1, y_1, z_1$ is fixed to the edge of the table as shown. A cube measuring 20 cm on a side is placed in the center of the table with frame $o_2 x_2, y_2, z_2$ established at the center of the cube as shown. A camera is situated directly above the center of the block 2m above the table top with frame $o_3 x_3, y_3, z_3$ attached as shown. Find the homogeneous transformations relating each of these frames to the base frame $o_0 x_0, y_0, z_0$. Find the
homogeneous transformation relating the frame $o_2 x_2, y_2, z_2$ to the camera frame $o_3 x_3, y_3, z_3$.

**Problem 4:** (Spong, Problem 2-38) In problem 3, suppose that, after the camera is calibrated, it is rotated 90 degrees about $z_3$. Recompute the above coordinate transformations.

**Problem 5:** (Spong, Problem 2-39) If the block on the table is rotated 90 about $z_2$ and moved so that its center has coordinates $(0, .8, .1)^T$ relative to the frame $o_1 x_1, y_1, z_1$, compute the homogeneous transformation relating the block frame to the camera frame; the block frame to the base frame.