Planning:

Stepper Motor Movement:

Since we are using stepper motors we must calculate # of steps to get to desired angles.

Yaw is easy.

Since a nema 23 turns $9/5^\circ$ per step have a 5:1 gear ratio:

$$(\#\text{ of steps}) = 9 \cdot \Delta\theta = 9 \cdot (\theta_d - \theta_i)$$

Due to the sliding movement on the pitch assembly, we note that the following calculation will be much more difficult. In particular, it will be dependent on current angle.

We know the pitch, h, of our screw, the steps per deg, s, of our motor and our current and desired angles. We want to find #num of steps. We note:

$$\theta_{sc} \cdot h = d$$

θ_{sc}: degrees our screw turns

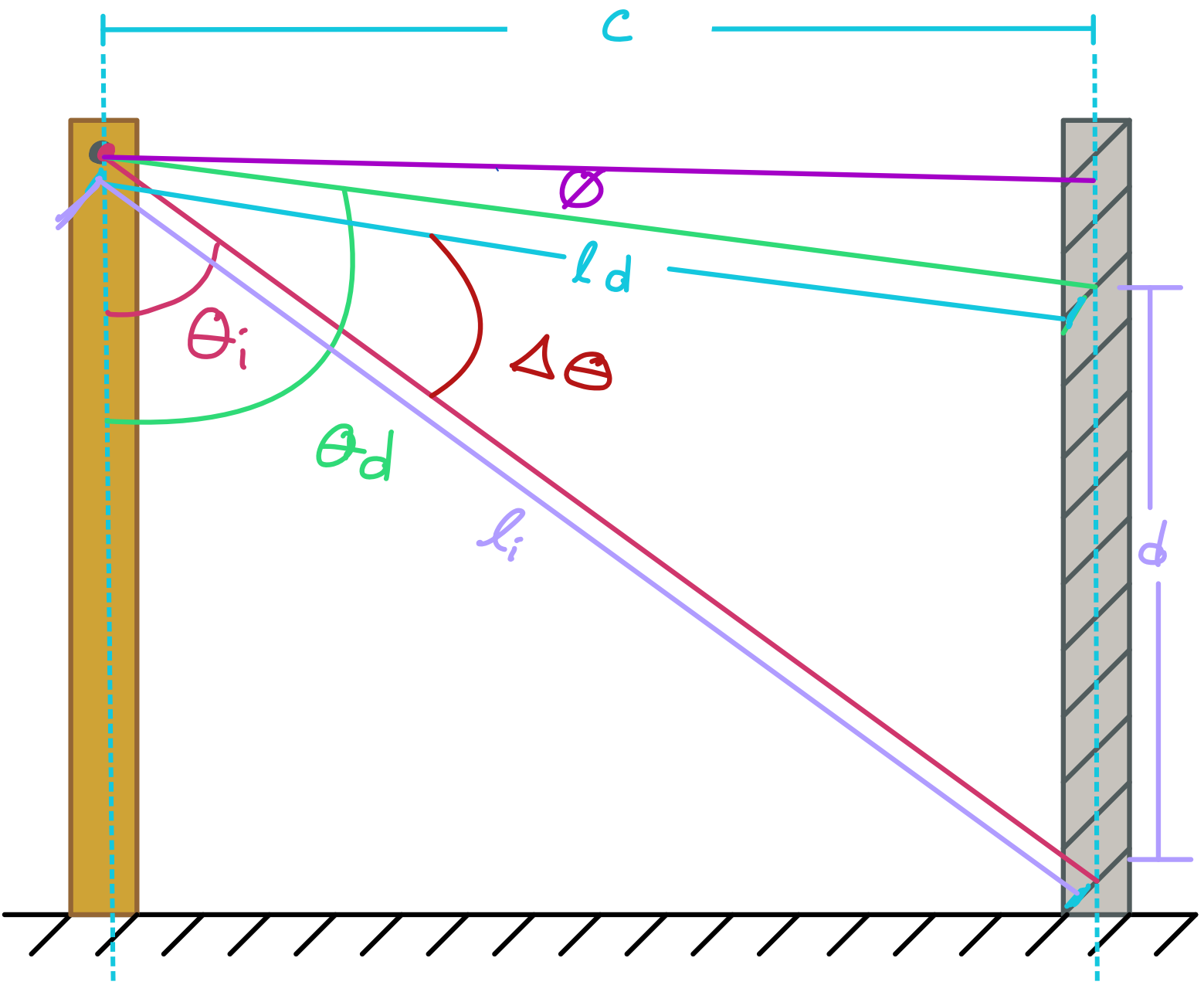
d: distance we travel up.

and # of steps $= s \cdot \theta_{sc}$

Thus our problem reduces to solving for d. Consider c to be the horizontal dist. between attachment points.

This is a constant dictated by the assembly

if we analyze the geometry of our robot:

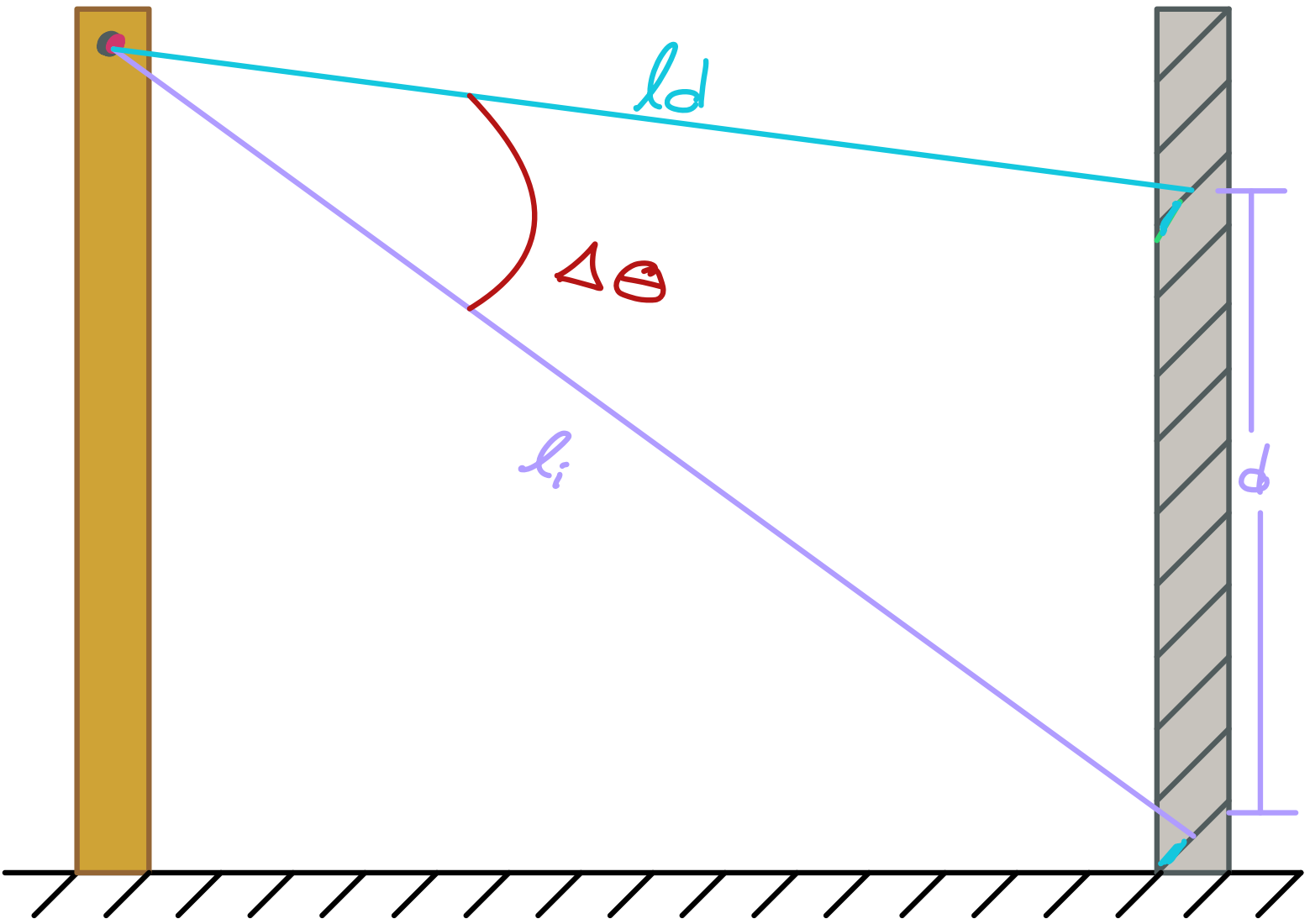


We see that:

$$l_i = \frac{c}{\sin(\theta_i)} \qquad l_d = \frac{c}{\cos\phi}$$

$$\Delta\theta = \theta_d - \theta_i \qquad \phi = 90 - \theta_d$$

From here we analyze the triangle:



Using law of cosines we get:

$$d^2 = l_d^2 + l_i^2 - 2 l_i l_d \cos \Delta\theta$$

Once we take the square Root we can solve for # of steps using d!