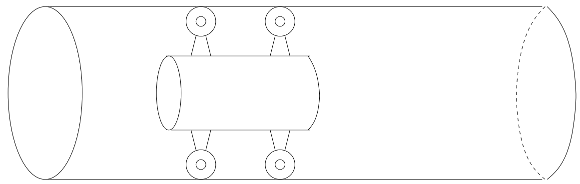
6. [10]

The robot pictured below has the job of cleaning a 100 m long pipe. It can only travel forward or backward within the pipe. The robot's wheels are pressed tight against the pipe. Thus, the robot only moves when its motors are driving it. The robot has four identical fixed standard wheels of radius r.



(a) [3] The robot's control signal, u_t, gives the change in roll angle of its wheels, $\Delta\phi$. The system state vector x_t gives the robot's position within the pipe, ranging from 0 - 100 m. Show the system update equation for a Kalman filter and determine the matrices A_t and B_t which are part of this equation.

(b) [6] Assume that the equation from (a) is corrupted by zero-mean Gaussian noise with a standard deviation of 1 m. Assume also that the robot has no sensors. Apply the Kalman filter to determine μ_{10} and σ_{10} with initial belief given by $\mu_0 = 10$ and $\sigma_0 = 0$. The first five control signals are $u_1 = u_2 = u_3 = u_4 = u_5 = 5$. Thereafter, the control signals are all zero. Assume the wheel radius r is 1 m.

(c) [1] Is this robot holonomic (yes or no):