1. I believe that the lowest duty factor for a multi-legged robot is one that creates a support polygon that contains the center of gravity and/or the zero-moment point. This means that ideally 3 legs should be on the ground at one time, but in some cases (as shown in the biped example in the zmp lecture) 2 supporting legs will suffice if they are opposing feet (i.e on a quadruped, the front left and back right, and vice versa). The absolute lower limit would be 1/n, where n is the number of legs, because anything lower would imply that there are times where zero legs are supporting the robot. However, given what I discussed above, the ideal limit for 3 supporting legs at one time would be 3/n, which would mean that each leg would be supporting the robot at the same time as 2 other legs.

2. Assuming my answer to the previous question is correct, that u = 1 m/s, and that I am using a symmetric hexapod robot, the lower limit for beta would be 0.5 because at every moment, 3 out of 6 legs will be on the ground at a time. Therefore, the maximum velocity of the body would be 1 m/s. See work below.

$$V(t) = \frac{(1-\beta(t))}{\beta(t)} U(t)$$

If $\beta \geq \frac{3}{n} = \frac{3}{6} = 0.5$

$$V(t) = \left(\frac{1-0.5}{0.5}\right) \cdot 1 m/s = 1 m/s$$

If $\beta \geq \frac{2}{n} = \frac{2}{6} = \frac{1}{3}$

$$V(t) = \frac{(1-\frac{1}{3})}{\frac{1}{3}} \cdot 1 m/s = 2 m/s$$

3. See attached zip file. The scripts use a beta of 0.5 and assume that the robot will be stable if 2 legs are on the ground at a time. Rather than using DH convention and geometric jacobian for the relevant calculations, I used screw theory and the relevant derivation of the jacobian.

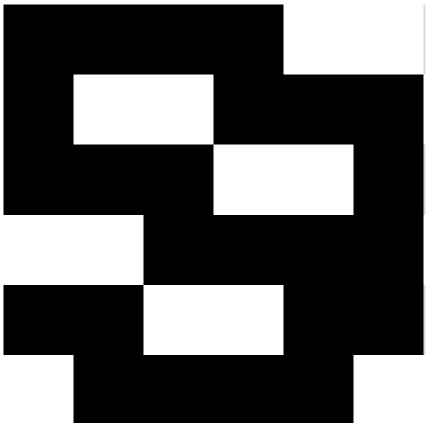
4.1

$$U_{f/b} = \frac{\frac{2}{3}}{1-\frac{2}{3}} \cdot 0.01 m/s = \frac{\frac{2}{3}}{\frac{1}{3}} \cdot 0.01 m/s = 0.02 m/s$$

4.2

$$U_{f/g} = \frac{0.01\,m/s}{1-\frac{2}{3}} = \frac{0.01\,m/s}{\frac{1}{3}} = 0.03\,m/s$$

4.3 For a symmetric gait, 6x6 grid with leg 1 at the top and leg 6 at the bottom.



4.4 Based on the above kinematic diagram, when leg 1 starts supporting the robot, legs 2, 3, and 5 are also supporting, leg 4 is beginning to transfer, and leg 6 is halfway through transferring. Given the half-cycle offset between opposing legs, 2 is 3/6 through its relative kinematic phase, leg 3 is $\frac{1}{6}$, leg 4 is 4/6, leg 5 is $\frac{1}{3}$, and leg 6 is $\frac{5}{6}$ through its relative kinematic phase.

4.5

$$L = 0.03m,\ V = 0.01\,m/s$$

$$\frac{L}{V} = \frac{0.03m}{0.01\,m/s} = 3s$$