3.

\subsection\*{Predicting the Range of Controllability}

In our system, we use reference position commands instead of voltage commands because it makes semantic sense. For our physical system, the original set point was 3.23mm, and we found the controllable position command ranged from 3.03mm to 3.53mm. For the linear model, the control range goes from 2.53mm to 5.23mm. The non-linear model is controllable from 0mm to 5.13mm.

We see overlapping agreement between the virtual models and the physical system around the set point. The physical system has the least range of controllability. The difference between our models and the real system arise due to a range of factors that we did not take into account such as op-amp short-comings, air viscosity, heating in the electromagnet’s coil causing a change in properties, etc. We additionally see that our non-linear model has higher fidelity in predicting what the system would do compared to the linear model, but both grossly optimistically over-estimate the range of controllability. We could not have gauged

(2) The frequencies used in the empirical observations started from 0.01Hz and went all the up to 13Hz. A total of 19 data points were sampled. More samples were selected at higher frequencies since the behavior of the system was more interesting behavior was predicted by the linear model. However, the physical system became unstable at higher frequencies and we were limited by this. The bode plot for these data is shown in figure \ref{Q3\_1}. Compared to the one generated from our linear theoretical model, we see that the predicted magnitude change is similar to the actual change in magnitude: as the frequency of input signals increases, they start steadily, decrease and then increases a little bit. However, when we look at the phase, although the trends for both diagrams are similar, they have some noticeable difference. This is probably due to non-linearity in the system and some factors that we have not modelled. This can also account for why our observed bandwidth and predicted bandwidth vary.

