MAE 106 Laboratory Exercise #3 (Solution)
Feedback I: P-type Velocity Control of a Motor

Q1 Op-amp 1 inverts ω_d to $-\omega_d$. This is necessary to get the correct sign for ω_d on the controller. Op-amp 2 adds ω_{actual} and $-\omega_d$ and multiplies by a gain. Op-amp 3 is a buffer, necessary so that little current is drawn from the tachometer. K = Rf/Rin. The Km/s term represents the dynamics of the amplifier and motor, and relates input voltage to the motor to output speed of the motor. The amplifier produces a current proportional to its input voltage I = Av, and the motor produces a torque proportional to its input current, τ = BI, and the motor accelerates proportional to its torque $\alpha = \tau/J = B/J*I = B/J*A*v \equiv K_m v$. Taking the Laplace transform gives $\omega/v = K_m/s$.The 1/s term is an integration term, and represents the fact that the motor integrates torque to get angular velocity.

Q2

	R_f = 10 KΩ	R_f = 1 KΩ
f_{3db}	~30-40 Hz	~2-4 Hz
$\tau = 1/\omega_{3db}$	~5 ms	~50 ms
τ	~5-10 ms	~50-60 ms
e_{ss}	~0	~1.3V
K_m	~10-20	~10-20
Gain	~100-200	~10-20

$K_m = 1/\tau K$

Gain = K K_m

Q3 The small DC voltage has commanded the motor to move slowly. When you try to move the motor shaft by hand, you create a disturbance, which the controller tries to compensate for. At a lower feedback gain (Rf = 1k), the controller is less sensitive to disturbance, so you are able to disturb the shaft more easily.

Q4 The lower feedback gain resulted in a more sluggish controller: the –3dB point is difficult to find, as the motor does not follow the desired velocity profile well. The time constant is larger for small gain, and the steady state error is larger.

Q5 The steady state error was caused by coulomb friction.

Q6 The voltage controller controls velocity because motor speed is proportional to velocity for an inertially loaded motor. The velocity controller explicitly tries to control velocity based on sensing from the tachometer. The voltage controller is cheaper because you do not need a tachometer, but would not perform well if there are external disturbances such as the wind since it does not sense velocity changes. (i.e. as long as the motor voltage is at the desired value, the circuit is “happy” and doesn’t try to change anything).