Each of the following five questions is worth 20 points, for a total of 100 on the exam.

1. Answer the following questions with **TRUE** or **FALSE**.

   (a) The phase crossover frequency $\omega_p$ is the frequency at which the open loop transfer function’s phase response equals 0 radians.

   (b) The bandwidth $\omega_{BW}$ of a closed loop system is a measure of the speed of response.

   (c) Phase margin is measured at the gain crossover frequency.

   (d) If phase crossover occurs at a lower frequency than gain crossover, then the closed loop system will be stable.

   (e) If the low frequency slope of the magnitude Bode plot is -20db per decade, then the closed loop system is type 1.
2. Consider the block diagram shown below.

With $D(s) = D_1(s)$, the closed loop system is type 1 with $K_v = 10$ and with dominant closed loop poles at $s = -5 \pm j3$. Augment $D(s)$ with a lag compensator to increase $K_v$ to 150, while leaving the dominant closed loop poles close to $s = -5 \pm j3$. 
3. Sketch straight line approximations for the magnitude and phase Bode plots for

\[ G(s) = \frac{16s + 5}{s + 20} \]
4. The transfer function $G(s)$ has Bode plot given below. $G(s)$ has no right half plane poles.

For the closed loop system

$$\frac{K G(s)}{1 + K G(s)}$$

(a) determine an upper bound on $K$ for closed loop stability;
(b) determine the crossover frequency, phase margin, and velocity error constant $K_v$ when $K = 1$
(c) determine the crossover frequency, phase margin, and velocity error constant $K_v$ when $K = 10$
5. Consider the Nyquist plot for $G(s)$ shown below. Assuming that $G(s)$ has one right half plane pole, determine for what values of $K$ the closed loop system

$$\frac{KG(s)}{1 + KG(s)}$$

is stable.
EXTRA WORKSHEET. Indicate problem number clearly.