Guidelines:

- Part I is closed book. Part II is open book, open notes.
- You will receive Part II after you submit Part I. It is recommended that you spend no more than 30 minutes on Part I.
- Time limit: 3 hours total.
- 90 points possible.
- Show all your work.
- Complete the test independently.

I agree to complete this exam without unauthorized assistance from any person, materials, or device. ________________________

Part I (Closed Book) [32 pts]: Consider use of an equation or sketch whenever that might make your answer more clear.

1. [4 pts] Give an advantage and a disadvantage of I mode control.

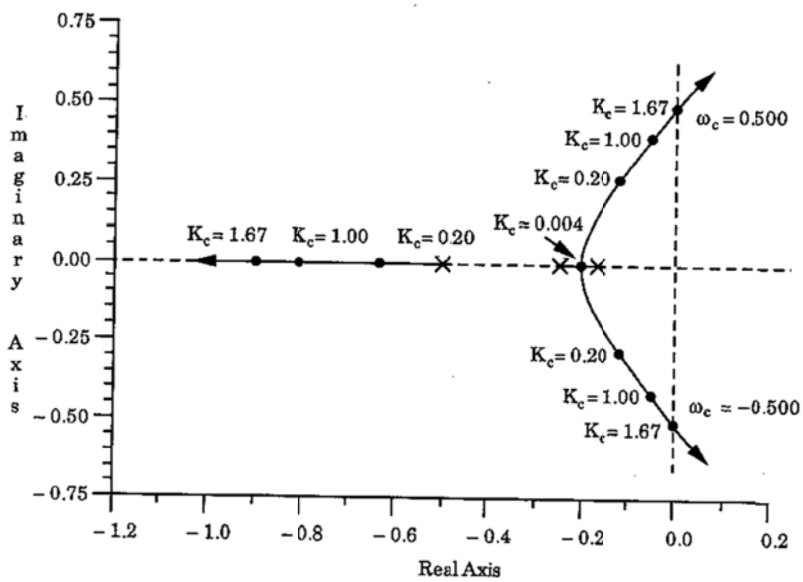
2. [3 pts] Define stability.

3. [3 pts] What is an operon?

4. [6 pts] Give three desirable qualities for a controller.

5. [6 pts] What quantities are plotted in a set of Bode plots?

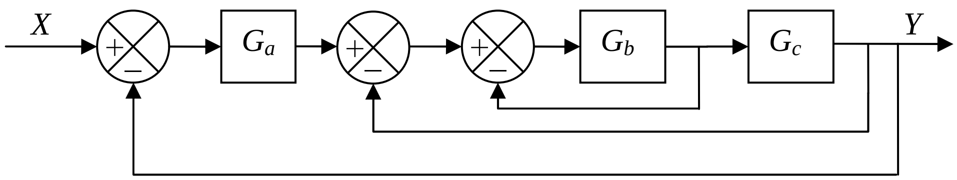
6. [4 pts] For the system with the following root locus diagram, at what values of K_c will the closed-loop process be stable?



7. [6 pts] Identify (with an arrow and a brief description) three components which are part of the *control loop* in this level control system.

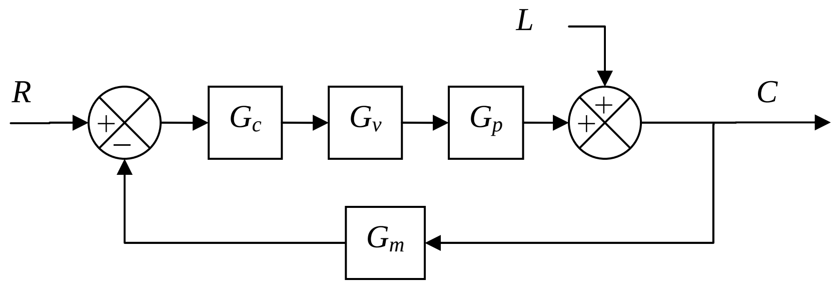
Part II (Open Book) [58 pts]:

1. [14 pts] Consider the following block diagram:



a. [10 pts] Find a general expression for $Y(s)/X(s)$.
b. [4 pts] Evaluate $Y(s)/X(s)$ for $G_a = 5$, $G_b = \frac{1}{2s}$, and $G_c = 3$.

2. [22 pts] Consider the standard process control loop below with $G_m = 1$, $G_p = \frac{2}{(5s+1)(7s+1)}$, $G_v = \frac{1}{s+1}$.



a. [10 pts] For a P controller with $K_c = 3$, what is the percent offset after a setpoint change?

b. [12 pts] Use direct synthesis to create a different controller for this process. Design the new closed loop transfer function to be $G_{CL} = \frac{1}{(\tau_c s+1)^2}$ and choose τ_c to create a pole-zero cancellation to remove the lag in the G_v term.

3. [22 pts] Consider the second-order process with one zero, $G(s) = \frac{s+2}{(s+1)^2}$, in a feedback loop with measurement device and actuator with negligible dynamics and a P-only controller.

   a. [8 pts] Theoretically, for what range of K_c will the closed-loop process be stable?

   b. [14 pts] Sketch a root-locus diagram for values of $K_c > 0$. Use the diagram to note ranges of K_c where the process is stable/unstable and where the response will be oscillatory.