I. Given the following plant (20%)

$$G(s)=\frac{20(s+5)}{s(s+1)(s+4)}$$

1. Please find the system's state space equation, i.e.,
   $\dot{x}=Ax+Bu$
   $y=Cx$
2. Please find a state feedback $u=Kx$ to yield a 9.48% overshoot and a settling time of 0.74 seconds (Hint: the closed loop system has a desired characteristic equation $s^3+15.9s^2+136.08s+413.1=0$).

II. A controlled process is modeled by the following state equations: (20%)

$$\dot{x}_1(t)=-x_1(t)+5x_2(t)$$
$$\dot{x}_2(t)=-6x_1(t)+u(t)$$

where $u(t)$ is the input. The output equation is $y(t)=x_1(t)$.

1. Design a state-feedback control so that the closed-loop system has a damping ratio of 0.707 and a natural undamped frequency of 10 rad/s.
2. Design a PD controller cascaded with the controlled process so that the closed-loop poles of the unity feedback system are at $s=-4$ and $s=-8$.

III. Given a system with the following loop transfer function (20%)

$$G(s)H(s)=\frac{k[(s+3)^2+2^2]}{s(s+1)(s+6)}$$

1. Find the angle of arrival at the complex zeros. (Hint: $\tan^{-1}2/3=33.7^o$)
2. Find the value of k that gives a closed-loop pole at $s=-10$.
3. Where are the other closed-loop poles at the gain obtained in (b)?
4. Please draw the root locus for the system as shown above.

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IV. For a unity negative feedback system with the open loop transfer function (20%)

$$G(s)=\frac{k}{s(s+2)(s+5)} \quad , \quad k>0$$

1. Please sketch the Nyquist plot of this system with brief explanation.
2. Use the Nyquist stability criterion to find the range of gain k , such that the closed-loop system is stable.

V. Given a unity feedback system with open-loop transfer function (20%)

$$G(s)=\frac{K(s+3)}{s(s+4)(s+10)}$$

1. What is the value of the gain K that is required if the steady-state error to an input $r(t)=5tu(t)$ is to be 0.05.
2. What is the value of K_v for the value K found in part (a)?
3. What is the steady-state error to a step input $r(t)=5u(t)$?