1. (15%) Consider the electrical system shown in Fig. 1.
   (a) (10%) Please find the transfer function from the input voltage e_i to the output voltage e_o, i.e., $E_o(s)/E_i(s)$.
   (b) (5%) Please find the DC gain of the system.

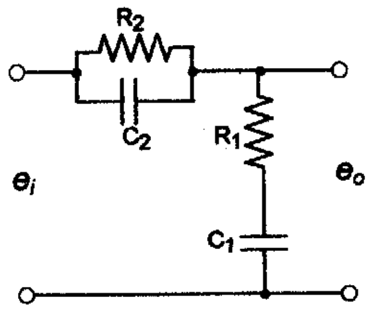

Fig. 1

2. (15%) Consider the system shown in Fig. 2(a).
   (a) (5%) What is the steady-state error e_{ss} due to the unit ramp input i.e., $r(t) = t, t \geq 0$.?
   (b) (10%) Now, a proportional-plus-derivative filter $(1+ks)$ is introduced to the above system, as shown in Fig. 2(b). By properly setting the value of *k*, we could eliminate the steady-state error when the input is still the unit ramp function. What is the value of *k* that yields zero steady state error? Note that the error is defined by $r(t)-c(t)$.

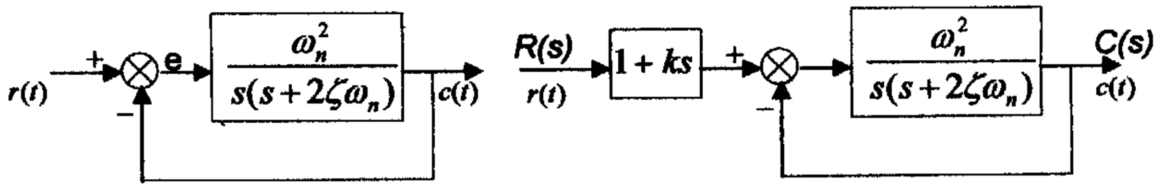

Fig. 2(a)　　Fig. 2(b)

3. (30%) Consider the tracking problem of the unity negative feedback system, as shown in Fig. 3, where the plant $G(s) = \dfrac{1}{s(s+2)}$ and feedback controller $H(s) = 1$.
   (a) (10%) Determine the type of the system. Also, determine the position and velocity constants of the system in term of tracking performance. Remember to first check if the unknown system type and static error constants are well-defined in this case.
   (b) (5%) Show that we have a non-zero asymptotic (steady-state) tracking error for the ramp command, i.e., $r(t) = t, t \geq 0$.
   (c) (5%) In order to have zero asymptotic tracking error for the ramp input, discuss why simply adding an integral control, i.e., $H(s) = 1/s$, CANNOT do the job.
   (d) (10%) Use the root locus method to show that it is possible to use a PI, proportional-integral, control to achieve zero asymptotic tracking error for the ramp input.

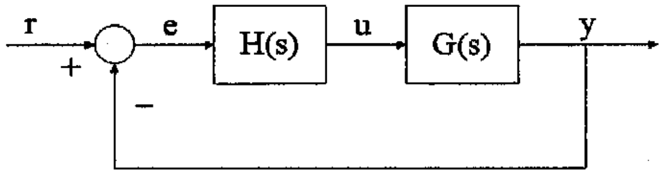

Fig. 3

4. (25%) Consider a unity negative feedback control system as shown in Fig. 4(a). The Bode plot of the plant $G(s)$ is shown in Fig. 4(b).
   (a) (5%) Suppose that $K = 1$. What is the steady state error of the closed-loop system due to the unit step input?
   (b) (10%) Suppose that we require the steady state error of the closed-loop system due to the unit ramp input to be less than 10%. Please estimate the range of the feedback gain K that meets the requirement.
   (c) (10%) Suppose now that we require the damping ratio of the closed-loop system to be greater than 0.5. Please estimate the range of the feedback gain K that meets the requirement.

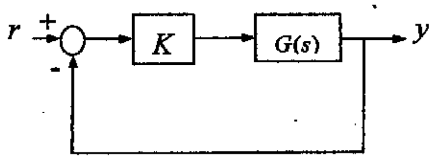

Fig. 4(a)

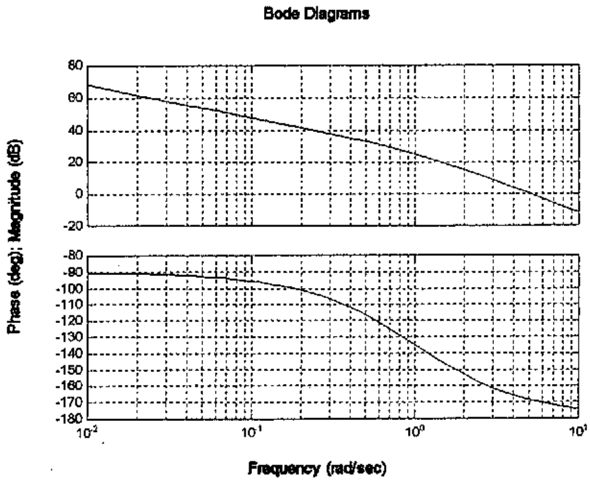

Fig. 4(b)

5. (15%) Consider a unity negative feedback system, as shown in Fig. 5(a). Suppose that two open-loop systems are considered, denoted as system A and system B, whose Bode plots are given in Fig. 5(b) and Fig. 5(c) respectively. Please answer the following questions regarding the performance of the closed-loop systems. (Note: you will not get any scores if no reasons are given to your answers.)
   (a) (5%) Which system will have a smaller steady-state error due to the unit ramp input? Why?
   (b) (5%) Which system will have a larger damping ratio? Why?
   (c) (5%) Which system will have a larger bandwidth? Why?

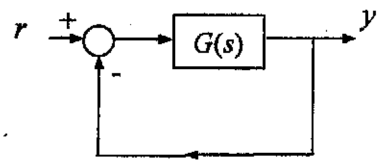

Fig. 5(a)

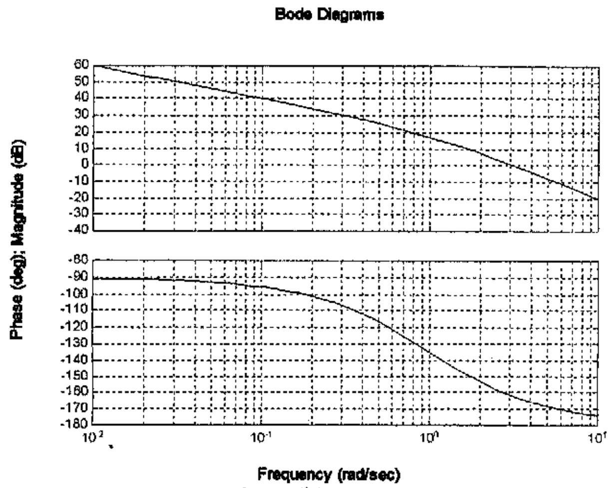

Fig. 5(b)　System A

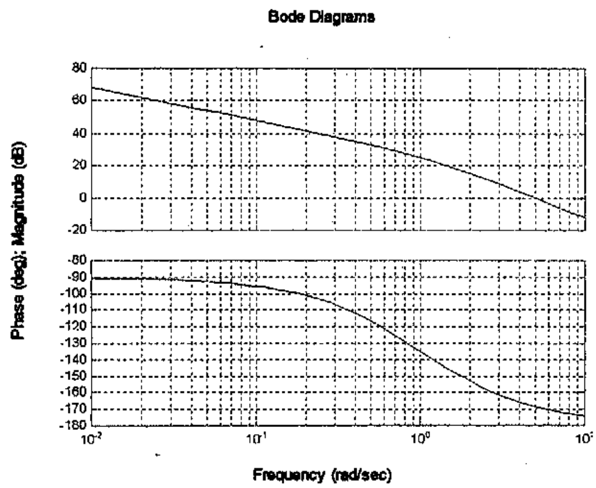

Fig. 5(c)　System B