UNIVERSITY OF VICTORIA

EXAMINATIONS, DECEMBER 1995

ELEC 360 – **CONTROLTHEORY AND SYSTEMS I**

(SECTION F01)

TO BE ANSWERED IN BOOKLETS

DURATION: 3 HOURS

INSTRUCTOR: H. W. SMITH

Students must count the number of pages in this examination paper before beginning to write, and report any discrepancy immediately to the invigilator.

This question paper has 3 pages. Special graph paper will be supplied.

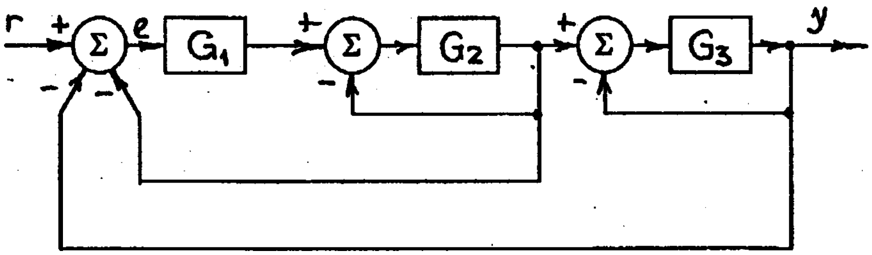
NOTES

1. **A single aid sheet (two sides) is permitted.**
2. **Any silent, self-powered non-printing calculator may be used.**
3. **Marks for each question are as indicated. Total marks 100. The final examination has a value of 50 percent of the course mark.**

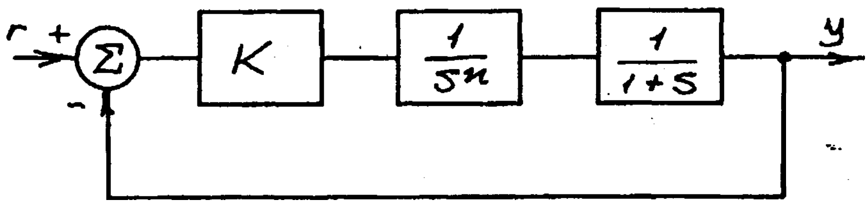
1 **(10 marks)** A **block** diagram for a linear system is shown below. Find (by any means you choose) **the** following transfer functions;

a. $Y(s)/R(s)$ **(7)**

b. $E(s)/R(s)$ **(3)**



2. **(6 marks)** In the system shown below,



find the smallest values of the gain K and number of integrators ***n*** which will give the steady state error coefficients

a. $K_p = 100$ **(2)**

b. $K_v = 25$ **(2)**

c. $K_v = \infty$ **(2)**

3. (9 **marks) A** second order linear system has a unit step response with peak overshoot $M_p = 20\%$ and settling time $t_s = 1$ **sec (2%** error). The final value of the step response is 5 units. Find the following:

a. The real and imaginary parts of the system poles, $s = -\sigma \pm j\omega_d$ (4)

b. the damping factor ζ and undamped natural frequency ω_n (2)

c. the system's transfix function (3)

4. (15 **marks) Carefully** sketch, approximately to scale, the root locus of the characteristic equation

$$1 + \frac{K}{s(s^2 + 2s + 10)} = 0$$

Explicitly calculate the value of the centroid, the asymptotes, the departure angles from the complex poles, the gain and frequency at which the locus crosses the imaginary axis, and the position of the real pole at this gain. **(10)**

Explain, using a rough sketch and the minimum necessary calculations, how adding a zero at s = -2 will alter the root locus, (5)

5. (15 marks) A unity-feedback system has-the **forward** path transfer function

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

a. Plot a Nyquist diagram for the system (approximately to scale)_ and determine the range of values of K for which the system is stable. **(12)**

b. For K giving a pole pair on the imaginary axis, at what frequency will the system oscillate? (3)

6. (15 **marks) A** process has the transfer function

$$G(s) = \frac{0.5}{(1+2s)(1+0.5s)}$$

It **is** to be connected in a unity-feedback control loop with a standard PI controller having the transfer function

$$C(s) = \frac{K(1+T_i s)}{s}$$

Determine **a** set of values for K and T_i that will (approximately) maximize the closed loop bandwidth while limiting the **peak** magnitude of the sensitivity function

$$S(s) = \frac{1}{1+KC(j\omega)G(j\omega)}$$

to **less than** about 3 db. Estimate the bandwidth of **the** closed-loop system.

7. **(30 marks)** The fixed elements of a **servomechanism** have the transfer **function**

$$G(s) = \frac{5}{s(1+0.5s)}$$

a. Use frequency-domain design techniques (Bode diagram) to design a **lead compensator C(s) so** that the closed **loop** system satisfies the following specifications:

$$K_v = 20\ \text{sec}^{-1} \quad M_p\ \text{SO.15} \quad \omega_{\text{gain crossover}} \le 10\ \text{rad / sec}$$

(Explain your design procedure clearly; use the least compensation needed. (20)

b. Sketch a root locus for the system, and estimate the closed loop poles. (5)

c. Describe the main features of the system step response (approximate sketch). (5)

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