※ 考生請注意：本試題可使用計算機。　請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. A linear system not described in phase-variable form is expressed as the following:

$$\begin{cases} \dot{z} = Az + Bu \\ y = Cz \end{cases}$$

Assume that this system has the controllability matrix C_{Mz} and can be transformed into the phase-variable (x) representation with a controllability matrix C_{Mx} by using the following transformation

$$z = Px$$

(i) Derive the transformation matrix P based on the controllability matrices C_{Mz} and C_{Mx}. (15%)

(ii) Find the transformation P for the following transfer function (10%)

$$G(s) = \frac{(s+4)}{(s+1)(s+2)(s+5)}$$

2. Design an integral controller to let the following system have a zero steady-state error, 10% overshoot and a settling time of 0.5 second with respect to a unit step input. (25%)

$$\begin{cases} \dot{z} = \begin{bmatrix} 0 & 1 \\ -3 & -5 \end{bmatrix} z + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u \\ y = \begin{bmatrix} 1 & 0 \end{bmatrix} z \end{cases}$$

3. A mathematical model for HIV infection is described as

$$\frac{dT}{dt} = s - nT - (1-u_1)\beta T v$$

$$\frac{dT^*}{dt} = (1-u_1)\beta T v - \mu T^*$$

$$\frac{dv}{dt} = (1-u_2)\kappa T^* - cv$$

The interested number of free HIV viruses v is selected as the system output. Besides, n, κ, s, β, c, and μ are constant system parameters, and u_1 and u_2 are control inputs.

(i) Derive the linearized state-space form of this nonlinear HIV model with the operation point $(T_0, T_0^*, v_0) = (\frac{c\mu}{\beta\kappa}, \frac{s}{\mu} - \frac{cd}{\beta\kappa}, \frac{s\kappa}{c\mu} - \frac{d}{\beta})$ and ($u_{10} = u_{20} = 0$) as

$$\begin{cases} \dot{z} = Az + Bu \\ y = Cz \end{cases}$$

and express A, B, and C. (10%)

(ii) Find the closed-loop transfer function (10%)

$$T(s) = \frac{Y(s)}{U(s)}$$

(iii) Replace n=0.021/day, κ=100 counts/cell, s=10/mm^3/day, β=2.4×10^{-5}/mm^3/day, c=2.4/day, and μ=0.24/day in T(s), and show the exact form of T(s) with these system parameters. (5%)

4. Implement the PID controller expressed as the following transfer function via using only one operational amplifier, some capacitors, and some resistors. (25%)

$$G_{PID}(s) = \frac{(s+55.92)(s+0.5)}{s}$$