1. Given the block diagram model as shown in the following figure,

(a) Find the system transfer function. (10%)

(b) Using the Routh-Hurwitz criterion, find out how many closed-loop poles of the system lying in the left half-plane, in the right half-plane, and on the \( j\omega \)-axis. (15%)

2. For the system represented by the differential equation

\[
c^{(3)}(t) + 3c^{(2)}(t) + 2c^{(1)}(t) + 4c(t) = 4r(t),
\]

where \( r(t) \) represents the reference input.

(a) By means of the signal-flow graph and Mason's theorem, find the transfer function of the closed-loop system, \( C(s)/R(s) \). (16%).

(b) Also determine the phase-variable form of the state and output vector equations for the system. (9%)

3. Given the feedback control system:

(a) Find the range of the gain \( K \) for stability of the closed-loop system. (10%)

(b) If \( K=2 \), what is the frequency (rad/sec) of the oscillation for transients? (5%)

(c) If \( K=1 \), find the steady-state error (i.e. input minus output) when the input \( r \) is a unit step function. Does this unit step response exhibit an overshoot of the steady state output? (5%)

(d) If \( K=1 \), find the steady-state error for a unit ramp input. (5%)

4. Given an unity feedback system

\[
KG(s) = \frac{K}{s(s^2 + 6s + 12)}
\]

(a) Sketch the Bode plot (10%)

(b) Determine the range of the gain \( K \) which can make the system stable. (5%)

(c) Determine \( K \) and the natural frequency \( \omega_n \) if the damping ratio \( (\xi) \) is 0.5 of the closed-loop system. (10%)