School of Electrical and Information Engineering
University of the Witwatersrand, Johannesburg
ELEN3016 Control I

# Test

**(Closed-book; One double-sided A4 formula sheet allowed.)**

**Time: 80 minutes** **Total: 30** **Date: 8 September 2010**

## Question 1 [10 marks]

Use block diagram algebra to derive the overall transfer function for the system in Figure 1. **Important:** Marks will only be awarded if the quotients are simplified as far as possible.

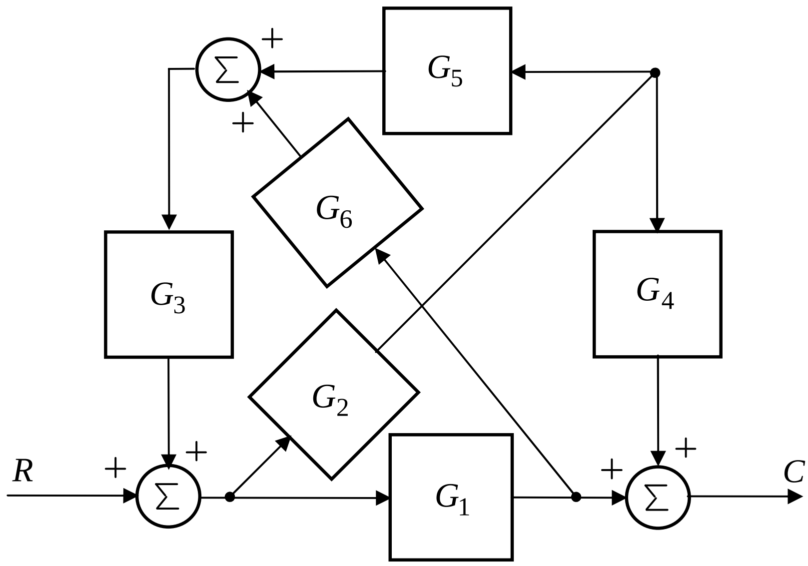


Figure 1. Block diagram of a complex system.

## Question 2 [20 marks]

For small-signal analysis the circuit of a phase-shift oscillator effectively reduces to that shown in Figure 2(a). (The assumptions here are that the effective resistance of the biasing network is significantly greater than the value of R and that all bypass capacitors, blocking capacitors and coupling capacitors are effectively short circuits at the frequency of interest.) With the small-signal analysis model of a bipolar junction transistor shown in Figure 2(b) the phase-shift oscillator's circuit reduces to that shown in Figure 2(c). An additional simplifying assumption made here is that each of the resistances of the phase-shift network and the transistor's base-emitter junction resistance are all equal as are the capacitors in the phase-shift network.

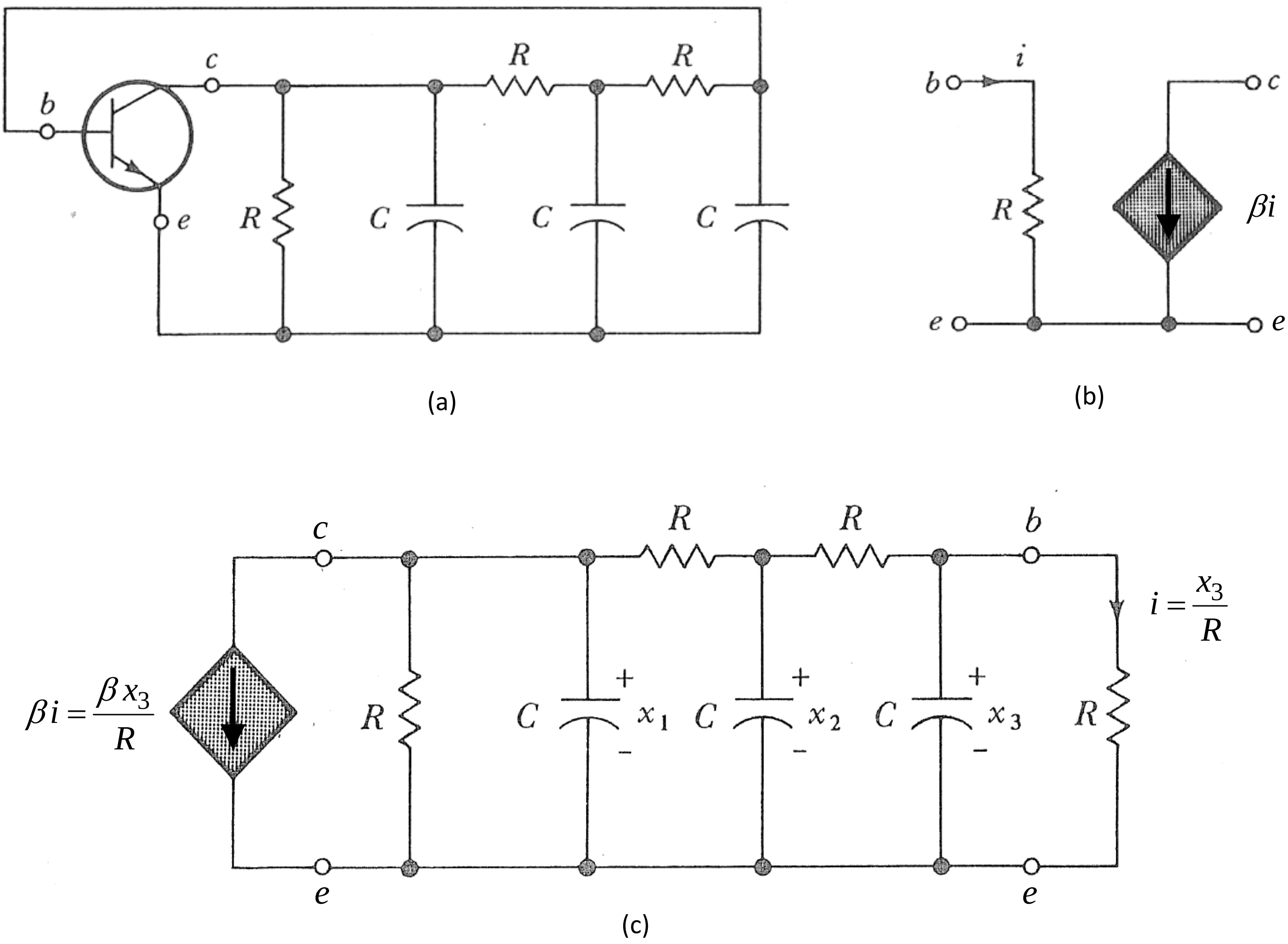


Figure 2. Phase-shift oscillator.

a. Derive the dynamical equation for the phase-shift oscillator.
b. From the dynamical equation determine the parameter values $\beta$ and $a = 1/RC$ for which the circuit will oscillate as well as the frequency at which it will oscillate.

Hints:

1. Choose the voltages across the capacitors as state variables (as indicated in Figure 2(c)) to obtain the state space representation for this circuit.
2. Next, derive the system's characteristic equation namely $s^3 + 6as^2 + 10a^2 s + (\beta + 4)a^3 = 0$ and then use the Routh-Hurwitz stability criterion for determining the conditions for which the circuit will oscillate.