# UNIVERSITY OF VICTORIA

## FINAL EXAMINATION - Dec 2017

## ELEC 360 – Control Theory and Systems I

## SECTION - A01 (CRN: 11250)

**TO BE ANSWERED IN BOOKLETS** **Duration:** 3 hours (7 PM to 10 PM)

Instructor: Ilamparithi Thirumarai Chelvan

**This question paper has 5 pages including this page.**

**Students must count the number of pages in this question paper before commencing the exam and report any discrepancy immediately to the invigilator.**

Instructions:

1) Please write your V number in the answer booklet.
2) Please verify if your question paper has 5 pages including this page.
3) Any type of calculator can be used.
4) Hand written formulae sheets can be used during exam. However, they must be submitted along with the answer booklets.
5) Please write all the assumptions/approximations made.
6) Please return the answer sheet and the formula sheet at the end of the exam.
7) Please answer all questions given in the three sections.
   (i) Section A comprises of eight questions each of 1 mark.
   (ii) Section B comprises of four questions each of 5 marks.
   (iii) Section C comprises of one question worth 10 marks.
   (iv) Legible presentation carries 2 marks.

   *Legible presentation*

   - Numbers and symbols should be easy to read.
   - All steps of an answer must be one below another and should be clear.
   - Avoiding margin spaces to write answers.
   - For section A, the question number & the option in block letter must be clear.
   - In diagrams, axes should be labelled.
   - Representing fractions using two decimal places and appropriate units

## Section A (8 x 1 = 8 marks)

1) For a system described by the differential equation given below, the number of states required for state space model would be

$$\dddot{y} + a_1\ddot{y} + a_2\dot{y} + a_3 y = b_0\dddot{u} + b_1\ddot{u} + b_2\dot{u} + b_3 u$$

(1 mark)

(A) 4
(B) 3
(C) 2
(D) 1

$s(s+1)+1=0$
$s^2+s+1$

2) A system has two open loop poles at s = 0 and s = -1. The desired location of a dominant closed loop pole is given as s = -1.5 + j 2.5981. If the angle formed by the open-loop pole at s = 0 to the desired dominant closed loop pole is 120°, then the angle formed by the open-loop pole at s = -1 to the desired dominant closed loop pole would be

(1 mark)

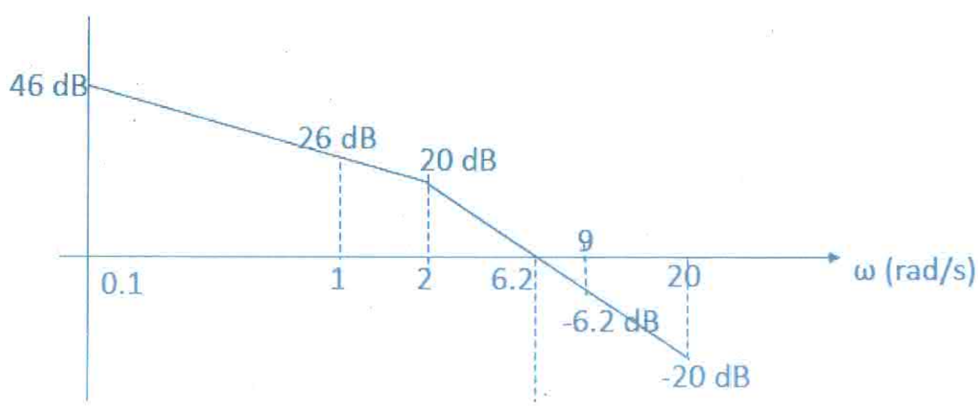
(A) 100°
(B) 90°
(C) 80°
(D) 40°

$\frac{1}{(s+1)s}$

$180-120-$ $180-120-$

3) If the Magnitude plot (Bode plot) of a system is as given below, then

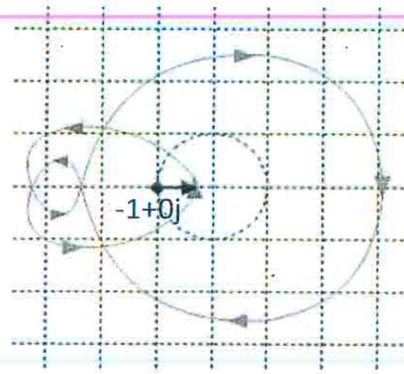
(1 mark)




(A) The system has no zero and one pole
(B) The system has one zero and one pole
(C) The system has one zero and two poles
(D) The system has no zero and two poles

4) Nyquist plot of a system is given below. The condition for stability would be

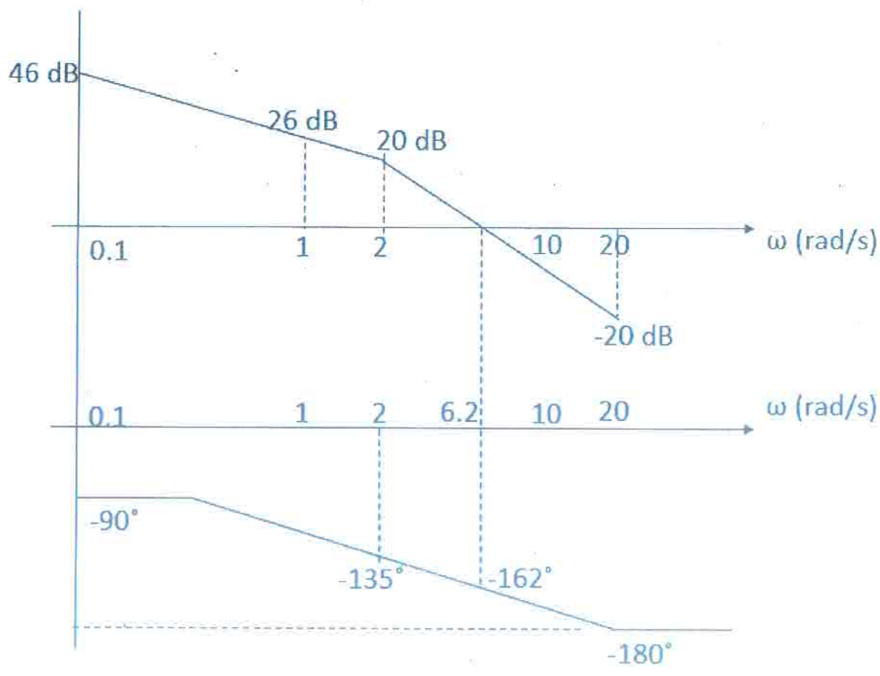
(1 mark)




(A) There should be no open loop poles in right half of s-plane
(B) There should be one open loop pole in right half of s-plane
(C) There should be two open loop poles in right half of s-plane
(D) None of the above

5) If the Bode plot of a system is as given below, then

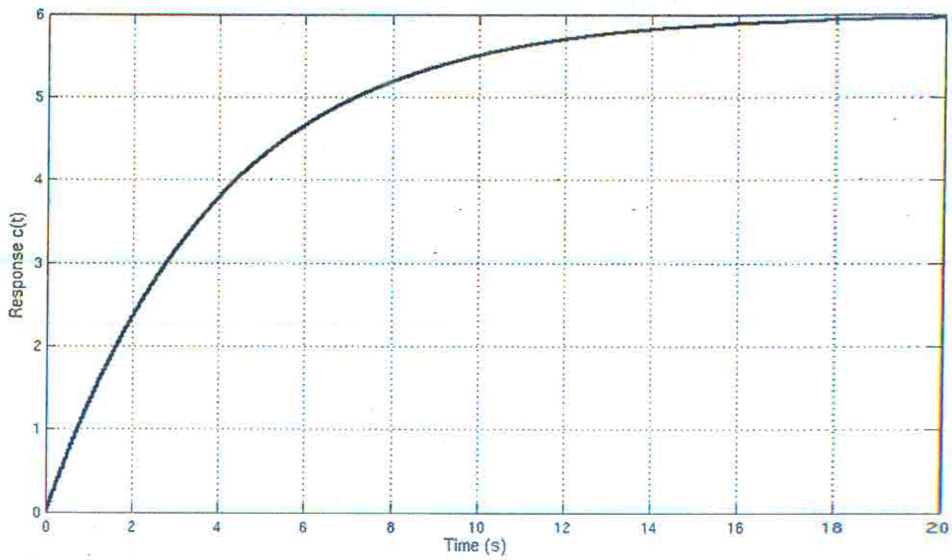
(1 mark)




(A) Phase margin of the system is -45° and the system is unstable
(B) Phase margin of the system is +45° and the system is stable
(C) Phase margin of the system is +18° and the system is stable
(D) Phase margin of the system is -18° and the system is unstable

6) Bump test conducted on a system using a step input of magnitude 3 V, gave the following result. Then the approximate gain of the system would be

(1 mark)




(A) Gain = 3
(B) Gain = 2
(C) Gain = 6
(D) None of the above

7) Root locus is

(1 mark)

(A) A plot of closed loop poles and zeros as gain is varied from zero to infinity
(B) A plot of open loop poles and zeros as gain is varied from zero to infinity
(C) A plot of open loop poles but not zeros as gain is varied from zero to infinity
(D) A plot of closed loop poles but not zeros as gain is varied from zero to infinity

8) For a second order system with damping ratio of 0.707 and undamped natural frequency of √2 rad/s,

(1 mark)

(A) The settling time corresponding to a 2% tolerance band will be lesser than the settling time corresponding to a 5% tolerance band
(B) The settling time corresponding to 2% tolerance band will be equal to the settling time corresponding to a 5% tolerance band
(C) The settling time corresponding to a 2% tolerance band will be greater than the settling time corresponding to a 5% tolerance band
(D) None of the above

$t_{s,2\%} = \frac{4}{\zeta\omega_n} = \frac{4}{(0.707)\sqrt{2}} = 4$

$t_{s,5\%} = \frac{3}{\zeta\omega_n} = \frac{3}{(0.707)\sqrt{2}} = 3$

## Section B (4 x 5 = 20 marks)

9) Open-loop transfer function is given by the expression $G(s)H(s) = \frac{K(s+2)(s+3)}{s(s+1)}$.
   (a) (1 mark) Plot the root locus
   (b) (1 mark) Mark the breakaway or break-in points
   (c) (2 marks) Identify the values of gain at the breakaway or break-in points.
   (d) (1 mark) For $K$=10, comment on the nature of the transient response (underdamped, critically damped or over-damped) exhibited by the closed loop system?

10) If open loop transfer function of a system is given as G(s) = 10/(s-2), then
   (a) (3 marks) Check the stability of the closed loop system using Nyquist plot
   (b) (2 marks) Check the stability of the system using Routh Hurwitz criterion
   Assume unity negative feedback

11) A system is described by the equation $m\ddot{y} + b\dot{y} + ky = u$.
   (a) (1 mark) Identify the number of inputs, number of outputs and number of states for the system
   (b) (3 marks) Represent the system using a state space model
   (c) (1 mark) Represent the system using its transfer function model
   Assume the system is initially at a relaxed state.

12) Open loop transfer function of a system is given as $G(s) = \frac{K}{s(Js+F)}$.
   (a) (3 marks) Plot the Bode plot
   (b) (1 mark) Compute the steady state velocity error constant for the system
   (c) (1 mark) Assuming unity negative feedback, compute the damping ratio of the system

## Section C (1 x 10 = 10 marks)

13) (10 marks) A plant has an open-loop transfer function $G(s) = \frac{5}{s(0.5s+1)}$. It is known that the phase margin of the system is related to its closed loop damping ratio by the relation given below

$$Phase\ Margin = \tan^{-1}\left[\frac{2\zeta}{\sqrt{\left(\sqrt{1+4\zeta^4}\right) - 2\zeta^2}}\right]$$

Design a controller that would ensure a phase margin of at least 51.8° and an undamped natural frequency of 4 rad/s for the closed loop system.

END