UTHM
Universiti Tun Hussein Onn Malaysia

# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER II
## SESSION 2018/2019

| | | |
|---|---|---|
| COURSE NAME | : | CONTROL SYSTEM |
| COURSE CODE | : | DAE 32103 |
| PROGRAMME CODE | : | DAE |
| EXAMINATION DATE | : | JUNE / JULY 2019 |
| DURATION | : | 2 HOURS 30 MINUTES |
| INSTRUCTION | : | ANSWER **FOUR (4)** QUESTIONS ONLY |

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

**Q1** (a) Control system is an important part of technology nowadays. Its application can range from house appliances to large industrial machines.

(i) Define control system.

(2 marks)

(ii) List two types of control system configuration.

(2 marks)

(iii) Give **one (1)** example for each of the system configuration answered in **Q1(a)(ii).**

(2 marks)

(iv) For each example in **Q1(a)(iii),** briefly explain its operation in term of control system.

(6 marks)

(b) Feedback is a system that maintains a relationship between the output and some reference input by comparing them and using the difference as a means of control.

(i) List **two (2)** effects of adding a feedback in the performance of control system.

(2 marks)

(ii) **Figure Q1(b)(ii)** shows a block diagram of a control system with feedback system. Find its transfer function, *M(s)*.

(7 marks)

(iii) If the system in **Q1(b)(ii)** feedback is replace with a unity feedback, find its new transfer function.

(2 marks)

(iv) Differentiate between controlled variable and manipulated variable.

(2 marks)

**Q2** (a) In order to compute the time response of a dynamic system, laplace transform technique is used to solve the differential equation for a given inputs. For each differential equation below, find the laplace transform

(i) $f(t) = e^{-2t}$

(5 marks)

(ii) $f(t) = e^{-2t} + 2e^{-4t}$

(7 marks)

(b) To determine the output response of a transfer function, there are commonly 3 types of input function used.

(i) List down all the **three (3)** inputs function.

(3 marks)

(ii) Sketch the signal of the **three (3)** inputs function.

(3 marks)

(iii) Find the output response, *c(t)* to an input of unit ramp, *r(t)* for the following transfer function. Assume that the initial condition is zero.

$$\frac{d}{dt}c(t) + 8c(t) = \frac{d}{dt}r(t)$$

(7 marks)

**Q3** (a) **Figure Q3(a)** shows a diagram of a spring-mass-damper system.

(i) Draw the free body diagram of the system in t-domain and s-domain.

(4 marks)

(ii) Derive the system transfer function, $G(s) = X_0(s) / X_i(s)$.

(3 marks)

(b) Given a block diagram as shown in **Figure Q3(b).**

(i) Find the equivalent single block that represents the transfer function, $T(s) = C(s) / R(s)$. Show your calculation.

(9 marks)

(ii) Calculate the damping ratio ($\zeta$), rise time ($t_r$), peak time ($t_p$) and damping response type.

(7 marks)

(iii) State the other **two (2)** types of damping response in second order system.

(2 marks)

**Q4** (a) The use of digital control systems have grown significantly over the past three decades as the price and reliability of digital computers have improved dramatically.

(i) Explain the advantages of digital control system.

(4 marks)

(ii) Name **four (4)** types of signals involved in digital control system.

(4 marks)

(iii) **Figure Q4(a)(iii)** shows the general block diagram of a digital control system. Sketch the signals *r(t)*, *u(t)*, *y(t)*, *u(k)* and *y(k)*.

(5 marks)

(b) Data acquisition is the process of automatically importing data from an instrument into a computer.

(i) Draw the complete block diagram of data acquisition system.

(8 marks)

(ii) Signal conditioning is an important step in data acquisition. Describe the steps involved in signal conditioning.

(4 marks)

**Q5** (a) An analog to digital converter (ADC) is a very useful device that converts an analog voltage to a digital number. By converting from the analog world to the digital world, we can begin to use electronics to interface to the analog world around us.

(i) Name **two (2)** common methods used in ADC.

(2 marks)

(ii) ADC performs three main operations. Briefly explain each operation.

(6 marks)

(iii) Suppose we were measuring the height of water in a 20-ft tall storage tank using an instrument with an 8-bit ADC. Determine how much physical water level will be represented in each *step* of the ADC.

(2 marks)

(iv) If the 8-bit ADC in **Q5(a)(iii)** has a maximum range of 12V. Calculate the input voltage of the ADC and height of the water in the tank (in ft) if the output of the ADC is 1000 1111.

(5 marks)

(b) In process control system, input signal is converted from continuous-varying physical value into a continuously varying electrical signal. List **four (4)** physical values commonly measured in process control.

(4 marks)

(c) Describe the differences between sequential process control and continuous process control.

(6 marks)

**Q6** (a) Explain why instrumentation such as indicators, annunciators and alarms are very important in process control.

(4 marks)

(b) **Figure Q6(b)** shows a water level control system using cascade controller.

(i) Draw the block diagram of the system.

(7 marks)

(ii) Name **two (2)** other types of process control loop apart from open loop and closed loop.

(2 marks)

(c) Proportional-Integral-Derivative (PID) controller are used in most automatic process control applications in the industry.

(i) Briefly describe the function of 'P', 'I' and 'D' component.

(6 marks)

(ii) **Figure Q6(c)(ii)** shows a closed loop control system using PID controller. Given the transfer function for the PID controller, $G_c(s)$ and also the plant's transfer function, G(s):

$$G_c(s) = K_p + \frac{K_i}{s} + K_d s \qquad G(s) = \frac{1}{s+a}$$

Derive the expression for $M(s) = \frac{Y(s)}{R(s)}$ in terms of parameters a, $K_d$, $K_i$ and $K_p$.

(6 marks)

**- END OF QUESTION –**

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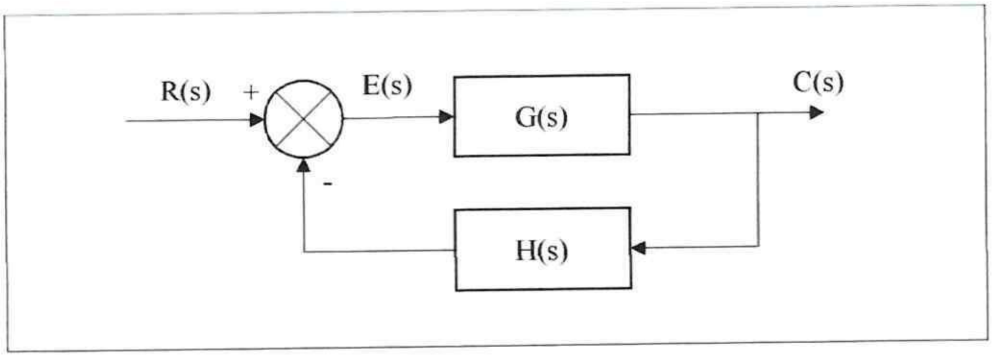


**FIGURE Q1(b)(ii)**

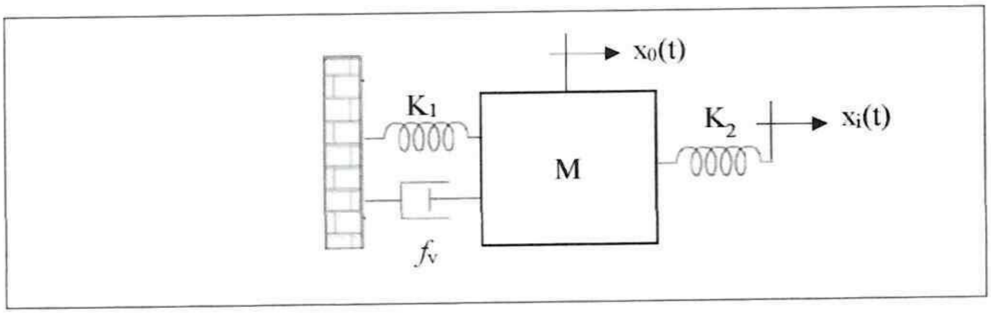


**FIGURE Q3(a)**

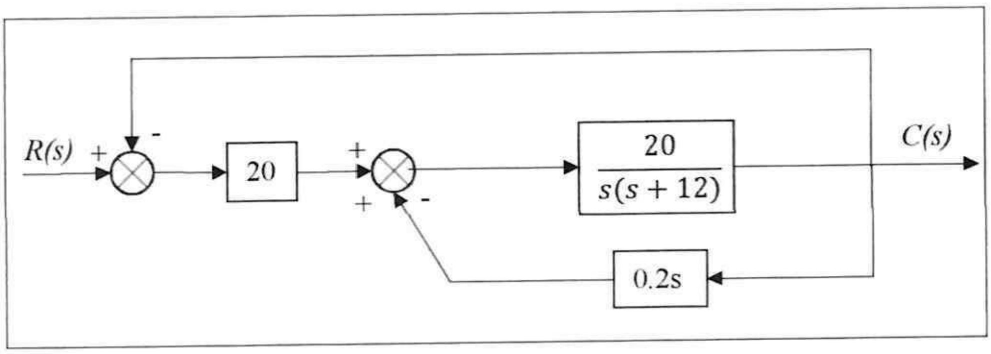


**FIGURE Q3(b)**

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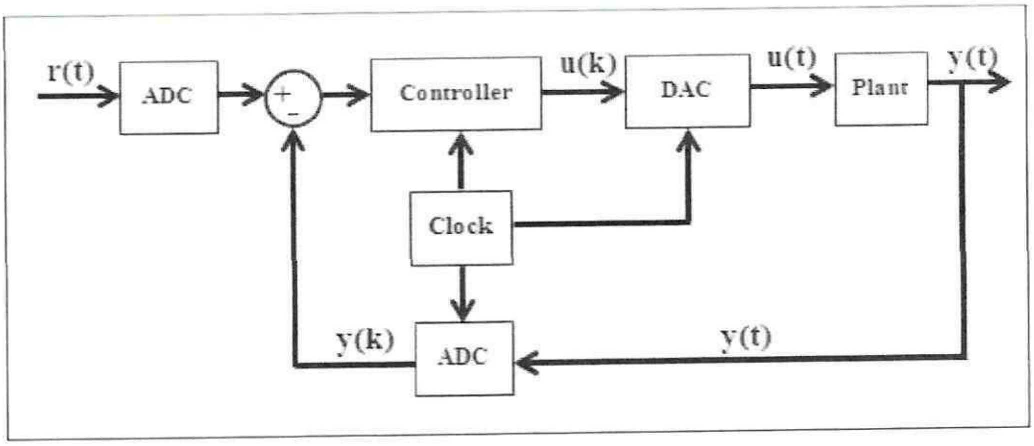


**FIGURE Q4(a)(iii)**

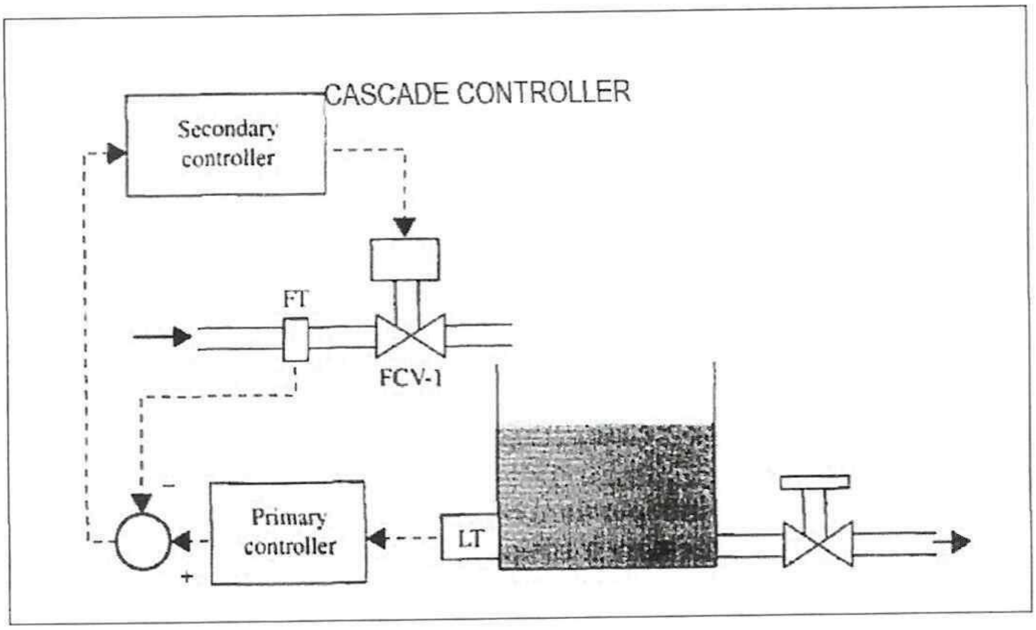


**FIGURE Q6(b)**

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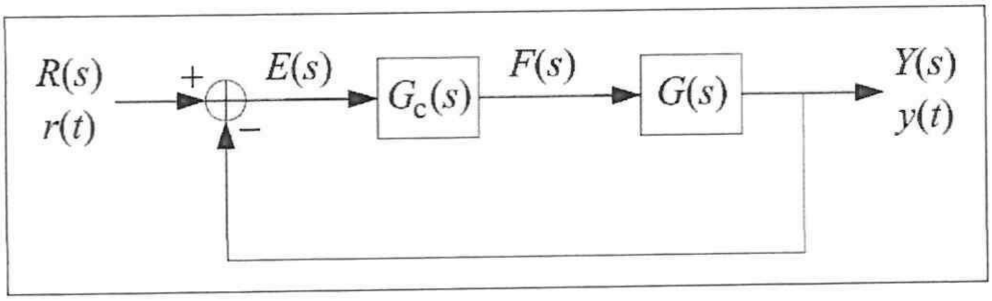


**FIGURE Q6(c)(ii)**

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## LAPLACE TRANSFORM TABLE

| Item no. | $f(t)$ | $F(s)$ |
|---|---|---|
| 1. | $\delta(t)$ | $1$ |
| 2. | $u(t)$ | $\frac{1}{s}$ |
| 3. | $tu(t)$ | $\frac{1}{s^2}$ |
| 4. | $t^n u(t)$ | $\frac{n!}{s^n + 1}$ |
| 5. | $e^{-at}u(t)$ | $\frac{1}{s+a}$ |
| 6. | $\sin \omega t u(t)$ | $\frac{\omega}{s^2+\omega^2}$ |
| 7. | $\cos \omega t u(t)$ | $\frac{s}{s^2+\omega^2}$ |

## LAPLACE TRANSFORM THEOREM

| Item no. | Theorem | Name |
|---|---|---|
| 1. | $\mathscr{L}[f(t)] = F(s) = \int_{0-}^{\infty} f(t)e^{-st}dt$ | Definition |
| 2. | $\mathscr{L}[kf(t)] = kF(s)$ | Linearity theorem |
| 3. | $\mathscr{L}[f_1(t) + f_2(t)] = F_1(s) + F_2(s)$ | Linearity theorem |
| 4. | $\mathscr{L}[e^{-at}f(t)] = F(s+a)$ | Frequency shift theorem |
| 5. | $\mathscr{L}[f(t-T)] = e^{-sT}F(s)$ | Time shift theorem |
| 6. | $\mathscr{L}[f(at)] = \frac{1}{a}F\left(\frac{s}{a}\right)$ | Scaling theorem |
| 7. | $\mathscr{L}\left[\frac{df}{dt}\right] = sF(s) - f(0-)$ | Differentiation theorem |
| 8. | $\mathscr{L}\left[\frac{d^2f}{dt^2}\right] = s^2F(s) - sf(0-) - f'(0-)$ | Differentiation theorem |
| 9. | $\mathscr{L}\left[\frac{d^nf}{dt^n}\right] = s^nF(s) - \sum_{k=1}^{n} s^{n-k}f^{k-1}(0-)$ | Differentiation theorem |
| 10. | $\mathscr{L}\left[\int_{0-}^{t} f(\tau)d\tau\right] = \frac{F(s)}{s}$ | Integration theorem |
| 11. | $f(\infty) = \lim_{s\to 0} sF(s)$ | Final value theorem[1] |
| 12. | $f(0+) = \lim_{s\to\infty} sF(s)$ | Initial value theorem[2] |

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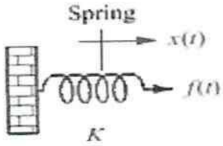
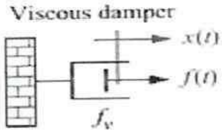
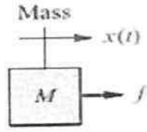
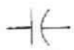
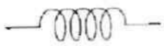
**LIST OF FORMULAE**: Mechanical Components Table

| Component | Force-velocity | Force-displacement | Impedance $Z_M(s) = F(s)/X(s)$ |
|---|---|---|---|
| Spring  | $f(t) = K\int_0^t v(\tau)\,d\tau$ | $f(t) = Kx(t)$ | $K$ |
| Viscous damper  | $f(t) = f_v v(t)$ | $f(t) = f_v \frac{dx(t)}{dt}$ | $f_v s$ |
| Mass  | $f(t) = M\frac{dv(t)}{dt}$ | $f(t) = M\frac{d^2x(t)}{dt^2}$ | $Ms^2$ |

**LIST OF FORMULAE**: Electrical Components Table

| Component | Voltage-current | Current-voltage | Voltage-charge | Impedance $Z(s) = V(s)/I(s)$ | Admittance $Y(s) = I(s)/V(s)$ |
|---|---|---|---|---|---|
|  Capacitor | $v(t) = \frac{1}{C}\int_0^t i(\tau)\,d\tau$ | $i(t) = C\frac{dv(t)}{dt}$ | $v(t) = \frac{1}{C}q(t)$ | $\frac{1}{Cs}$ | $Cs$ |
|  Resistor | $v(t) = Ri(t)$ | $i(t) = \frac{1}{R}v(t)$ | $v(t) = R\frac{dq(t)}{dt}$ | $R$ | $\frac{1}{R} = G$ |
|  Inductor | $v(t) = L\frac{di(t)}{dt}$ | $i(t) = \frac{1}{L}\int_0^t v(\tau)\,d\tau$ | $v(t) = L\frac{d^2q(t)}{dt^2}$ | $Ls$ | $\frac{1}{Ls}$ |

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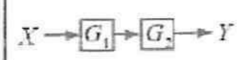
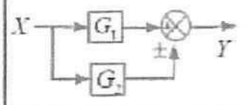
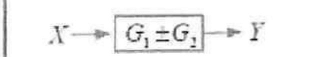
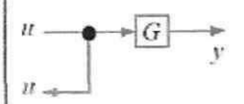
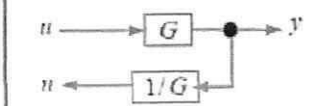
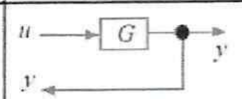
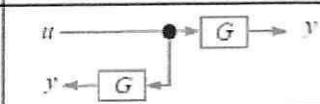
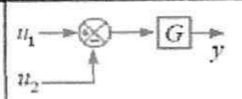
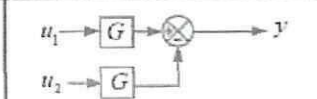
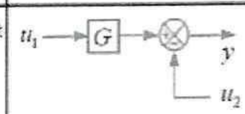
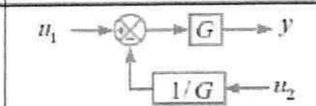
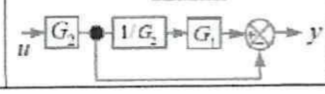
## LIST OF FORMULAE: Block Diagram Tranformations

| | Manipulation | Original Block Diagram | Equivalent Block Diagram | Equation |
|---|---|---|---|---|
| 1 | Combining Blocks in Cascade |  |  | $Y=(G_1G_2)X$ |
| 2 | Combining Blocks in Parallel; or Eliminating a Forward Loop |  |  | $Y=(G_1 \pm G_2)X$ |
| 3 | Moving a pickoff point behind a block |  |  | $y = Gu$<br>$u = \frac{1}{G}y$ |
| 4 | Moving a pickoff point ahead of a block |  |  | $y = Gu$ |
| 5 | Moving a summing point behind a block |  |  | $e_2 = G(u_1 - u_2)$ |
| 6 | Moving a summing point ahead of a block |  |  | $y = Gu_1 - u_2$ |
| | | |  | $y=(G_1 - G_2)u$ |

## LIST OF FORMULAE: Second Order System Parameters

| | |
|---|---|
| Rise time, $$t_r = \frac{\pi - \cos^{-1}\zeta}{\omega_n\sqrt{1-\zeta^2}}$$ | Peak time, $$t_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$$ |
| Percentage overshoot, $$\%M_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$$ | Settling time, $$t_s = \frac{4}{\zeta\omega_n} \text{ (2\% criterion)}$$ $$t_s = \frac{3}{\zeta\omega_n} \text{ (5\% criterion)}$$ |