Second Semester Examination
Academic Session 2017/2018

May/June 2018

EMC322 – Automatic Control
[Kawalan Automatik]

Duration : 3 hours
Masa : 3 jam

Please check that this examination paper consists of SEVEN [7] printed pages before you begin the examination.

[Sila pastikan bahawa kertas soalan ini mengandungi TUJUH [7] mukasurat bercetak sebelum anda memulakan peperiksaan.]

INSTRUCTIONS : Answer **ALL FIVE [5]** questions.
*[**ARAHAN** : Jawab **SEMUA LIMA [5]** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

1. [a] **Figure Q1[a] shows a DC motor which drives a spring loaded pointer, to return it to the reference position. If K_b = back e.m.f. constant, K_T = torque constant, K_s = spring constant and J = moment of inertia, find the transfer function $\frac{\theta(s)}{V_a(s)}$.**

Given the Laplace transform $f^{(k)}(t) = \frac{d^k f(t)}{dt^k}$ is $F(s) = s^k F(s) - s^{k-1} f(0^-) - s^{k-2} f^{(1)}(0^-) - \cdots - s^0 f^{(k-1)}(0^-)$. Assume all the initial conditions are zero.

Rajah S1[a] menunjukkan sebuah motor DC memandu petunjuk yang dimuatkan pegas, untuk kembali kepada kedudukan rujukan. Jika K_b = pemalar e.m.f. bertentangan, K_T = pemalar tork, K_s = pemalar pegas dan J = momen inersia, cari fungsi pemindahan $\frac{\theta(s)}{V_a(s)}$.

Diberi penjelmaan Laplace $f^{(k)}(t) = \frac{d^k f(t)}{dt^k}$ adalah $F(s) = s^k F(s) - s^{k-1} f(0^-) - s^{k-2} f^{(1)}(0^-) - \cdots - s^0 f^{(k-1)}(0^-)$. Andaikan semua keadaan awal adalah sifar.

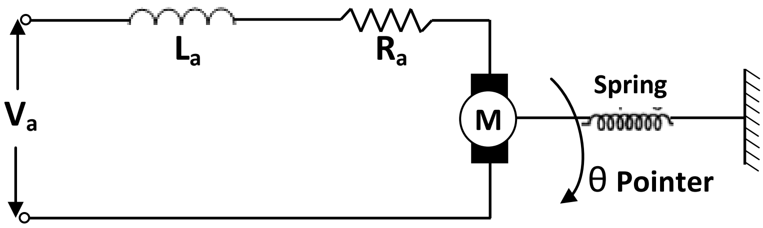

Figure Q1[a]
Rajah S1[a]

(**40 marks**/*markah*)

[b] **An electrical system is shown in Figure Q1[b].**
Satu sistem elektrik ditunjukkan dalam Rajah S1[b].

(i) **Find the mathematical model for the system.**
Carikan model matematik untuk sistem tersebut.

(ii) **Obtain its block diagram.**
Dapatkan rajah bloknya.

(iii) **Determine the transfer function using block diagram reduction technique.**

Tentukan fungsi pemindahan dengan menggunakan kaedah pengurangan rajah blok.

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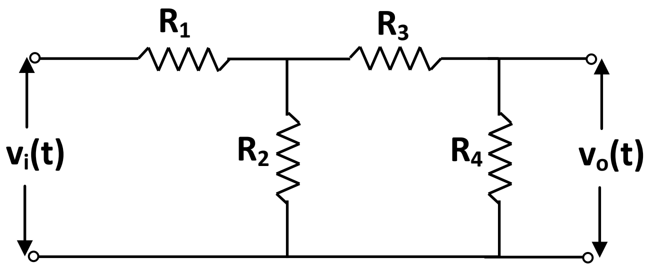

Figure Q1[b]
Rajah S1[b]

(**60 marks**/*markah*)

2. **Consider a speed control system shown in Figure Q2.**
Pertimbangkan sistem kawalan kelajuan yang ditunjukkan dalam Rajah S2.

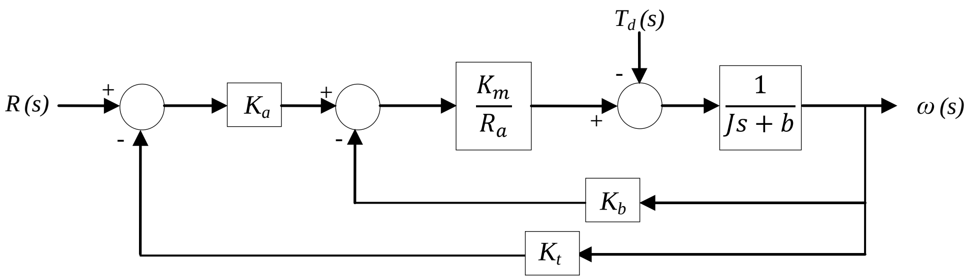

Figure Q2
Rajah S2

[a] **Find the sensitivity of the close loop transfer function to changes in K_m.**

Dapatkan kepekaan fungsi pemindahan gelung tertutup terhadap perubahan dalam K_m.

(**40 marks**/*markah*)

[b] **Calculate the steady state response of the closed loop system due to unit step disturbance $T_d(s) = 1/s$. Assume R(s) = 0.**

Kirakan sambutan keadaan mantap sistem gelung tertutup akibat satu gangguan pelangkah unit $T_d(s)=1/s$. Anggap R(s) = 0.

(**40 marks**/*markah*)

[c] **Calculate the steady state error of the closed loop system due to unit step input $R(s) = 1/s$. Assume there is no disturbance.**

Kirakan ralat keadaan mantap sistem gelung tertutup akibat satu masukan pelangkah unit R(s)=1/s. Anggap tiada gangguan.

(**20 marks**/*markah*)

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3. [a] **A feedback control system is shown in Figure Q3[a].**
Sistem kawalan suap-balik ditunjukkan dalam Rajah S3[a].

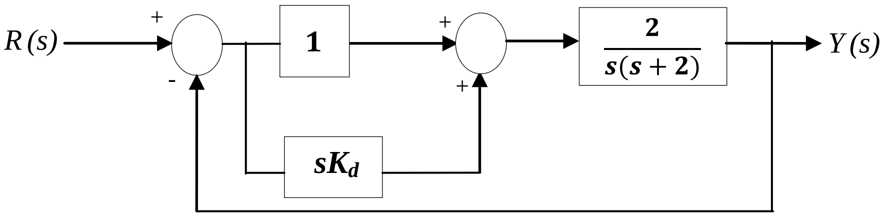

Figure Q3[a]
Rajah S3[a]

[i] **Determine the steady state error of the closed loop system response to a unit ramp input.**

Tentukan ralat keadaan mantap sambutan sistem gelung tertutup terhadap input unit tanjakan.

(**30 marks**/*markah*)

[ii] **Determine the value of K_d so that system will be critically damped.**
Tentukan nilai K_d supaya sistem itu akan teredam secara kritikal.

(**15 marks**/*markah*)

[iii] **Calculate its settling time (based on 2% criterion) when $\zeta = 0.7$.**
Kirakan masa penetapannya (berdasarkan 2% kriteria) apabila $\zeta = 0.7$.

(**15 marks**/*markah)*

[b] **For a control system shown in Figure Q3[b], find the values of gain K_1 and K_2 so that percent overshoot, *P.O* = 20% and peak time, T_p = 5s. Assume unit step input.**

Untuk sistem kawalan yang ditunjukkan dalam Rajah S3[b], cari nilai gandaan K_1 dan K_2 supaya peratusan lajakan, P.O = 20% dan masa memuncak, T_p = 5s. Anggapkan input langkah seunit.

…5/-

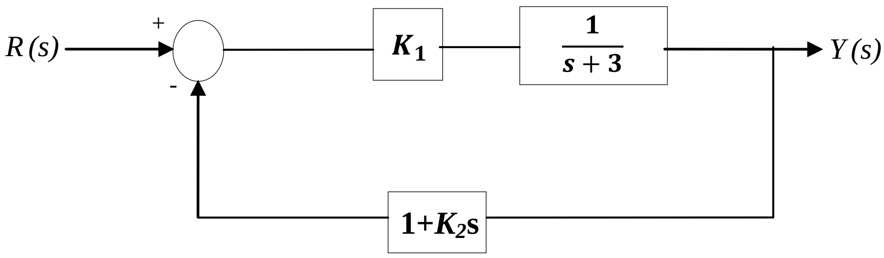

Figure Q3[b]
Rajah S3[b]

(**40 marks**/*markah)*

4. [a] A mobile robot has a feedback control system with the transfer function given below. Analyze the location of the poles in *s*-plane to determine the stability of the robot.

Sebuah robot bergerak mempunyai satu sistem kawalan suap-balik dengan rangkap pindahnya diberi di bawah. Analisa kedudukan kutub-kutubnya dalam satah-s untuk menentukan kestabilan robot tersebut.

$$\frac{Y(s)}{R(s)} = \frac{48}{(s^2+3s+6)(s^2-4s+8)}$$

(25 marks/*markah)*

[b] Figure Q4[b] shows the block diagram of an inverted pendulum unity feedback control system. The system has been designed to use proportional integral derivative (PID) controller. Analyze the Routh-Hurwitz criterion to determine the stability of the inverted pendulum.

Rajah S4[b] menunjukkan rajah blok bagi sebuah sistem kawalan suap-balik seunit bandul terbalik. Sistem tersebut telah direkabentuk untuk menggunakan pengawal berkadaran kamiran kebezaan (PID). Analisa kriteria Routh-Hurwitz untuk menentukan kestabilan bandul terbalik tersebut.

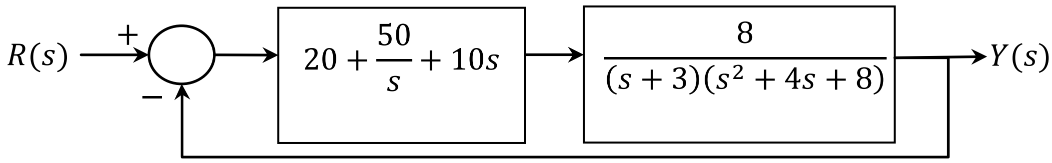

Figure Q4[b]
Rajah S4[b]

(35 marks/*markah)*

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[c] A microwave oven has a feedback control system with the transfer function given below. Analyze the Routh-Hurwitz criterion to find the range of gain K for a stable system and to determine the imaginary roots that result in marginal stability.

Sebuah ketuhar gelombang-mikro mempunyai satu sistem kawalan suap-balik dengan rangkap pindahnya diberi di bawah. Analisa kriteria Routh-Hurwitz untuk mendapatkan julat gandaan K bagi satu sistem yang stabil dan untuk menentukan punca-punca khayalan yang mengakibatkan kestabilan marginal.

$$\frac{\boldsymbol{Y(s)}}{\boldsymbol{R(s)}} = \frac{\boldsymbol{K}}{\boldsymbol{s^4 + 6s^3 + 11s^2 + 6s + K}}$$

(**40 marks**/*markah*)

5. A unity feedback system as shown in Figure Q5 is used to control the speed of an electric train using proportional integral derivative (PID) controller.

Satu sistem kawalan suap-balik seunit seperti ditunjukkan dalam Rajah S5 digunakan bagi mengawal kelajuan sebuah keretapi elektrik menggunakan pengawal berkadaran kamiran kebezaan (PID).

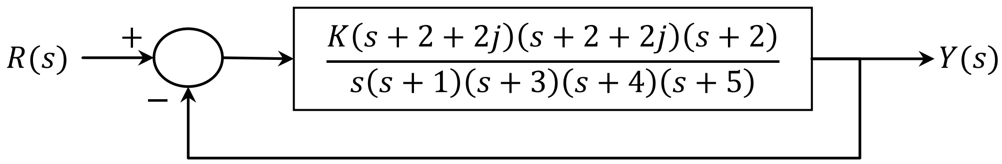

Figure Q5
Rajah S5

[a] Sketch the segments of the root locus on real axis by locating the poles and zeros on *s*-plane.

Lakarkan segmen-segmen londar punca pada paksi nyata dengan meletakkan lokasi kutub-kutub dan sifar-sifarnya pada satah-s.

(**20 marks**/*markah*)

[b] Plot the root locus by determining the asymptote center $\boldsymbol{\sigma_A}$ and angles $\boldsymbol{\phi_A}$, the breakaway points, and the arrival angles given $\boldsymbol{\sigma_A = \frac{\sum_{i=1}^{n}(-p_i) - \sum_{j=1}^{M}(-z_j)}{n-M}}$ and $\boldsymbol{\phi_A = 180^\circ\left(\frac{2k+1}{n-M}\right)}$.

Plot londar puncanya dengan menentukan pusat σ_A dan sudut-sudut ϕ_A asimptotnya, titik-titik berpisahnya dan sudut-sudut ketibaannya diberi $\sigma_A = \frac{\sum_{i=1}^{n}(-p_i) - \sum_{j=1}^{M}(-z_j)}{n-M}$ *dan* $\phi_A = 180^\circ\left(\frac{2k+1}{n-M}\right)$.

(**50 marks**/*markah*)

…7/-

[c] **From the root locus in Q5[b], determine the gain K so that the percent overshoot PO of the response is less than 16% and the settling time T_s (based on 5 % criterion) is less than 3 seconds. Given $P.O = 100e^{-\pi\zeta/\sqrt{1-\zeta^2}}$, $\theta = \cos^{-1}\zeta$ and $T_s = 3/(\zeta\omega_n)$.**

Dari londar punca dalam S5[b], tentukan gandaan K supaya peratusan lajakan sambutannya PO kurang dari 16% dan masa enapannya T_s (berdasarkan kriteria 5%) kurang dari 3 saat. Given $PO = 100e^{-\pi\zeta/\sqrt{1-\zeta^2}}$, $\theta = cos^{-1}\zeta$ and $T_s = 3/(\zeta\omega_n)$.

(**30 marks**/*markah*)

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