UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2011/2012

Jun 2012

EEM 232 – Sistem Mekatronik

Masa : 3 jam

ARAHAN KEPADA CALON:

Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA BELAS muka surat termasuk SATU muka surat Lampiran bercetak dan **ENAM** soalan sebelum anda memulakan peperiksaan ini.

Jawab **LIMA (5)** soalan.

Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru.

Agihan markah bagi soalan diberikan disudut sebelah kanan soalan berkenaan.

Jawab semua soalan di dalam Bahasa Malaysia atau Bahasa Inggeris atau kombinasi kedua-duanya.

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

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

…2/-

1. (a) Pengerak, penderia dan kawalan digital adalah komponen di dalam satu sistem mekatronik yang tipikal. Lukis carta alir yang mengandungi semua komponen bagi satu sistem mekatronik yang tipikal. Beri dua contoh peranti bagi setiap komponen.

Actuators, sensors and digital control are components of a typical mechatronics system. Draw a flow chart which consists of all the components for a typical mechatronics system. Give two (2) examples of device for each component.

(30 markah/*marks*)

(b) Terangkan tentang pembinaan sistem pengukuran berat menggunakan dua tolok teriakan aktif dengan paparan ialah meter gelung bergerak.

Describe the construction of weight measurement system using two active strain gauges with the display is the moving coil meter.

(40 markah/*marks*)

(c) Kenyataan – Kaedah yang selalu digunakan bagi membetulkan elemen tak-lelurus ialah memperkenalkan satu pampasan elemen tak-lelurus ke dalam sistem tersebut.

Statement - The most common method of correcting a non-linear element is to introduce a compensating non-linear element into the system.

Terangkan kenyataan di atas menggunakan thermistor sebagai contoh.
Explain the above statement by using thermistor as your example.

(30 markah/*marks*)

2. (a) Rajah 2(a) menunjukkan satu gambarajah blok bagi satu transduser daya menggunakan suapbalik negatif.

Figure 2(a) shows a block diagram of a force transducer using negative feedback.

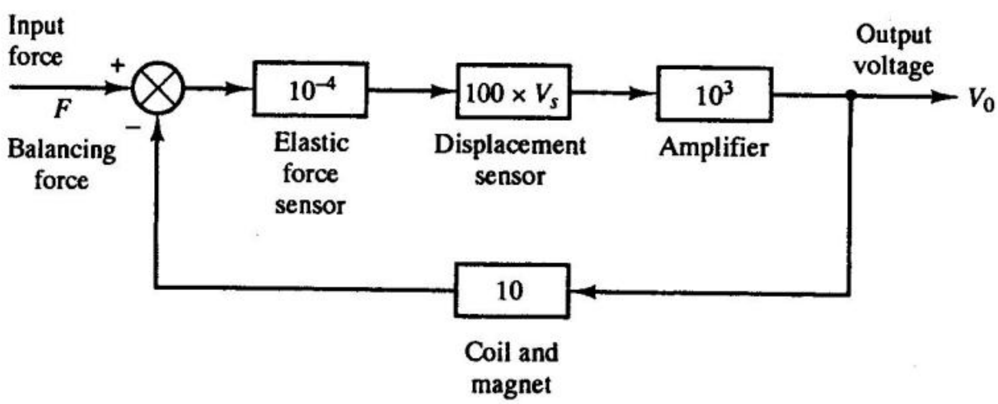
Kira voltan keluaran apabila:-

Calculate the output voltage when:-

(i) V_s =1.0 volt, F=50 N

(ii) V_s =1.5 volt, F=50 N

(iii) Comment on the variation of output voltage with respect to the variation of supply voltage, V_s



Rajah 2(a)

Figure 2(a)

(30 markah/*marks*)

(b) Satu sistem pengukuran daya mengandungi elemen-elemen lelurus dan mempunyai kepekaan keadaan-tetap keseluruhan bernilai satu. Sistem dinamik ditentukan oleh fungsi tertib kedua bagi elemen pengesan yang mempunyai frekuensi semulajadi, ω_n = 30 rad/s dan nisbah rendaman, ξ=0.2.

A force measurement system consists of linear elements and has an overall steady-state sensitivity of unity. The dynamics of the system are determined by the second order transfer function of the sensing element which has a natural frequency ω_n = 30 rad/s and a damping ratio ξ=0.2.

(i) Jika fungsi pindah tertib kedua diberikan sebagai ________,

tunjukkan bahawa $\left|G(j\omega)\right| = \frac{1}{\sqrt{\left[\left(1-\frac{\omega^2}{\omega_n^2}\right)^2 + 4\xi^2\frac{\omega^2}{\omega_n^2}\right]}}$

If the second order transfer function is given as ________, show that $\left|G(j\omega)\right| = \frac{1}{\sqrt{\left[\left(1-\frac{\omega^2}{\omega_n^2}\right)^2 + 4\xi^2\frac{\omega^2}{\omega_n^2}\right]}}$

(ii) Kira keluaran sistem sekiranya isyarat daya masukan berkala:

Calculate the system output corresponding to the periodic input force signal:

$$F(t) = 20\left\{\sin 10t + \frac{1}{3}\sin 30t\right\}$$

Diberikan:

Given:

$$\Delta O(t) = \sum_{n=1}^{n=\infty} \hat{I}_n \left|G(jn\omega_1)\right| \sin(n\omega_1 t + \phi_n)$$

Amplitude ratio= $|G(j\omega)| = \dfrac{1}{\sqrt{\left[\left(1-\dfrac{\omega^2}{\omega_n^2}\right)^2 + 4\xi^2 \dfrac{\omega^2}{\omega_n^2}\right]}}$

Phase difference= $\arg G(j\omega) = -\tan^{-1}\left[\dfrac{2\xi\omega/\omega_n}{1-\omega^2/\omega_n^2}\right]$

(40 markah/*marks*)

(c) *Explain the followings:-*

(i) Perisai elektromagnet

Electromagnetic Shielding

(15 markah/*marks*)

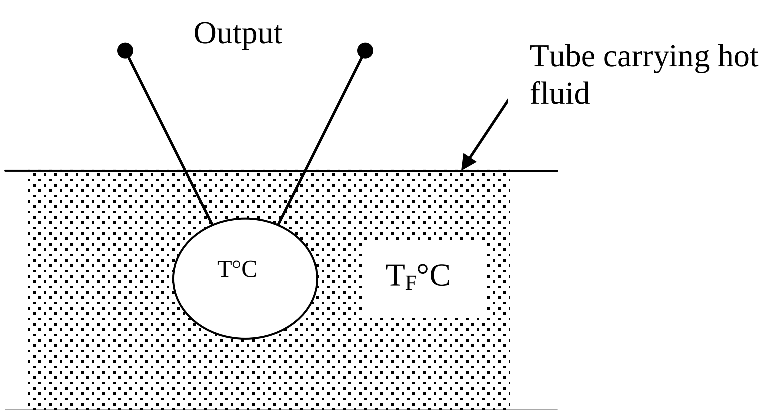
(ii) Penolakan voltan ganguan mod biasa menggunakan penguat pembezaan.

Rejecting common mode interfering voltages using differential amplifier.

(15 markah/*marks*)

3. (a) Terbitkan persamaan untuk sambutan dinamik bagi sistem yang ditunjukkan dalam Rajah 3(a).

Derive equation to estimate the dynamic response of the system shown in Figure 3(a).



Thermocouple sensor in fluid

Rajah 3(a)

Figure 3(a)

(b) Satu sistem pengukuran suhu mengandungi kepekaan keadaan mantap bernilai satu dan dinamik sistem tersebut ditentukan oleh fungsi pindah tertib pertama bagi elemen penderia. Pada t=0, elemen penderia dipindahkan dari udara bersuhu 20°C ke air yang mendidih. Satu minit kemudian, elemen tersebut dipindahkan kembali ke udara. Menggunakan data yang diberikan di bawah, kira ralat dinamik sistem pada masa: t=10, 20, 50, 120 and 300 s.

A temperature measurement system consists of steady-state sensitivity of unity and the dynamics of the system is determined by the first-order transfer function of the sensing element. At t=0, the sensing element is suddenly transferred from air at 20°C to boiling water. One minute later the element is suddenly transferred back to air. Using the data given below, calculate the system dynamic error at the following times: t=10, 20, 50, 120 and 300 s.

Data penderia:
Sensor data:

Jisim = 5×10^{-2} kg
Mass = 5×10^{-2} kg

Luas permukaan =10^{-3} m^2
Surface area = 10^{-3} m^2

Haba tentu = 0.2 $kg^{-1}{}^\circ C^{-1}$
Specific heat = 0.2 $kg^{-1}{}^\circ C^{-1}$

Pekali pemindahan haba bagi udara = 0.2 $Wm^{-2}{}^\circ C^{-1}$
Heat transfer coefficient for air = 0.2 $Wm^{-2}{}^\circ C^{-1}$

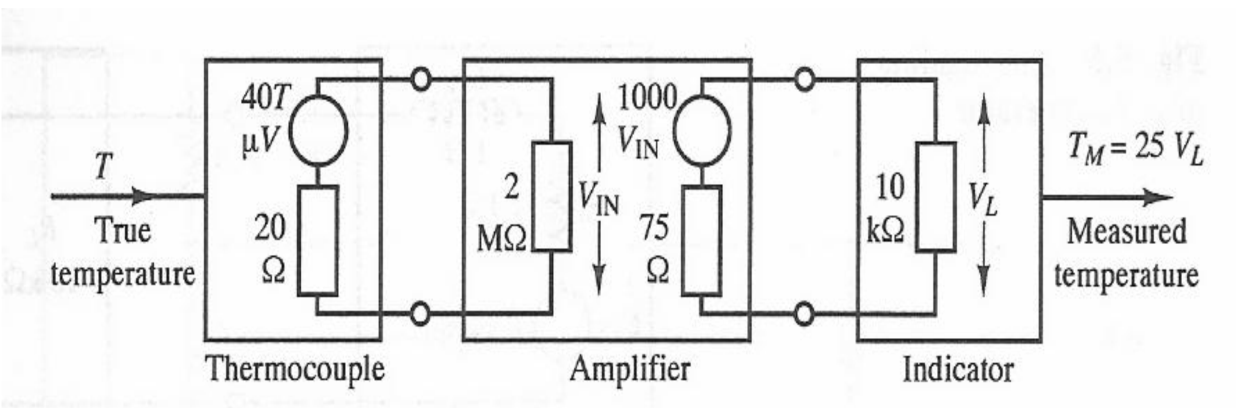
Pekali pemindahan haba bagi air =1.0 $Wm^{-2}{}^\circ C$
Heat transfer coefficient for water = 1.0 $Wm^{-2}{}^\circ C$

(50 markah/*marks*)

(c) Rajah 3(b) menunjukkan bebanan antara-elemen bagi satu system pengukuran
Figure 3(b) shows the inter-element loading of a measurement system

(i) Kira ralat sistem tanpa mempertimbangkan kesan bebanan
Calculate the system error without considering the loading effect

(ii) Kira ralat sistem bersama kesan bebanan
Calculate the system error with the loading effect



Rajah 3(b)
Figure 3(b)

(50 markah/*marks*)

4. (a) Pertimbangkan bendalir hidraulik dengan modulus pukal β = 250,000 psi, jumlah nominal V_o = 100 in^3. Jika bendalir dimampatkan daripada tahap tekanan atmosfera sehingga 2500 psi, cari perubahan isipadu bendalir.

Consider a hydraulic fluid with bulk modulus of β = 250,000 psi, a nominal volume of V_o = 100 in^3. If the fluid is compressed from atmospheric pressure level to 2500 psi level, find the change in the fluid volume.

(30 markah/*marks*)

(b) Pertimbangkan takometer dengan perolehan sebanyak 2 V / 1000 rpm. Ia diantaramukakan dengan sistem perolehan-data melalui penukar analog-ke-digital (ADC), yang mempunyai resolusi 12-bit dan julat masukan ± 10V. Spesifikasi sensor menyatakan bahawa voltan riak disebabkan oleh penukar tertib pada takometer adalah 0.25% daripada keluaran voltan maksimum.

Consider a tachometer with a gain of 2 V / 1000 rpm. It is interfaced to a data-acquisition system through a analog-to-digital converter (ADC), which has 12-bit resolution and ±10V input range. The sensor specifications state that the ripple voltage due to commutators on the tachometer is 0.25% of the maximum voltage output.

(i) Tentukan kelajuan maksimum yang boleh diukur oleh sistem sensor dan sistem perolehan-data.

Determine the maximum speed that the sensor and data-acquisition system can measure.

(ii) Apakah ralat-ralat pengukuran yang disebabkan oleh voltan riak dan resolusi ADC.

What are the measurement errors due to the ripple voltage and due to ADC resolution.

(iii) Jika ADC 8-bit digunapakai, sumber ralat yang manakah lebih nyata? Voltan riak atau resolusi ADC?

If the ADC was 8-bit, which error source is more significant? Ripple or ADC resolution?

(70 markah/*marks*)

5. (a) Pertimbangkan pam yang membekalkan Q_P = 60 liter / min aliran malar kepada silinder dwi-tindakan. Diameter lubang silinder d_1 = 6 cm dan diameter rod d_2 = 3 cm. Andaikan rod dipanjangkan melalui kedua-dua hujung silinder. Beban yang disambungkan pada rod silinder ialah F = 10000 N. Aliran diarahkan di antara pam dan silinder oleh injap empat-hala kawalan berkadar. Abaikan penurunan dan kehilangan tekanan pada injap. Tentukan tekanan dalam silinder, halaju dan kuasa yang disampaikan oleh silinder semasa kitaran lanjutan. Dengan mengandaikan kecekapan keseluruhan pam adalah 80%, tentukan kuasa yang diperlukan untuk memacu pam tersebut.

Consider a pump that supplies Q_P = 60 liter/min constant flow to a double-acting cylinder. The cylinder bore diameter is d_1 = 6 cm and rod diameter d_2 = 3 cm. Assume the rod is extended through both sides of the cylinder. The load connected to the cylinder rod is F = 10000 N. The flow is directed between the pump and the cylinder by a four-way proportional control valve. Neglect the pressure drop and losses at the valve. Determine the pressure in the cylinder, velocity and power delivered by the cylinder during extension cycle. By assuming 80% overall pump efficiency, determine the power necessary to drive the pump.

(60 markah/*marks*)

(b) Pertimbangkan satu pengekod tokokan dengan resolusi 2500-garisan/putaran dan penyahkod yang menggunakan ×4 penyahkodan logik. Kemudian, resolusi pengekod adalah 10,000 kiraan / putaran. Andaikan bahawa pengesan-foto dalam litar penyahkod boleh mengendali isyarat saluran A dan B sehingga frekuensi 1Mhz.

Consider an incremental encoder with 2500-lines/rev resolution and a decoder which uses ×4 decoding logic. Then the resolution of the encoder is 10,000 counts/rev. Assume that the photodetectors in the decoder circuit can handle A and B channel signals up to 1Mhz frequency.

(i) Tentukan kelajuan maksimum yang boleh dikendalikan oleh litar pengekod dan penyahkod.

Determine the maximum speed the encoder and decoder circuit can handle.

(ii) Jika resolusi tersebut adalah 25,000 garisan / putaran dan penyahkod yang sama digunakan, apakah kelajuan maksimum yang boleh dikendalikan oleh litar penyahkod.

If the resolution was 25,000 lines/rev and the same decoder is used, what is the maximum speed that can be handled by the decoder circuit.

(40 markah/*marks*)

6. (a) Pertimbangkan satu sensor suhu jenis RTD digunakan untuk mengukur suhu suatu lokasi. Kedua-dua terminal sensor disambung pada kedudukan R_1 pada litar titi-Wheatstone. Hubungan sensor suhu-perintang adalah seperti berikut:

Consider that an RTD type temperature sensor is used to measure the temperature of a location. The two terminals of the sensors are connected to the R_1 position of a Wheatstone bridge circuit. The sensor temperature-resistance relationship is as follows:

$$R = R_o\,(1 + \alpha\,(T - T_o))$$

Daripada data kalibrasi sensor, $\alpha = 0.004\ ^oC^{-1}$, suhu rujukan $T_o = 0\ ^oC$, dan $R_o = 200\ \Omega$ pada suhu T_o. Andaikan bahawa $V_i = 10$ VDC, dan $R_2 = R_3 = R_4 = 200\ \Omega$. Apakah suhu apabila $V_o = 0.5$ VDC?

From the sensor calibration data, $\alpha = 0.004\ ^oC^{-1}$, $T_o = 0\ ^oC$ reference temperature, and $R_o = 200\ \Omega$ at temperature T_o. Assume that $V_i = 10$ VDC, and $R_2 = R_3 = R_4 = 200\ \Omega$. What is the temperature when the $V_o = 0.5$ VDC?

(60 markah/*marks*)

(b) Pertimbangkan suatu pam bersesaran tetap $D_P = 100\ cm^3$/putaran dan mematuhi syarat operasi nominal berikut: kelajuan aci input $w_{shaft} = 1200$ rpm, kilasan pada masukan aci T = 250 N•m, tekanan keluaran $P_{out} = 12$ MPa, dan kadar aliran keluaran $Q_{out} = 1750\ cm^3/s$. Tentukan isipadu, mekanikal dan kecekapan keseluruhan pam pada keadaan operasi ini.

Consider a pump with fixed displacement $D_P = 100\ cm^3$/rev and following nominal operating conditions: input shaft speed $w_{shaft} = 1200$ rpm, torque at the input shaft T = 250 N•m, the output pressure $P_{out} = 12$ MPa, and output flow rate $Q_{out} = 1750\ cm^3/s$. Determine the volumetric, mechanical and overall efficiencies of the pump at this operating condition.

(40 markah/*marks*)

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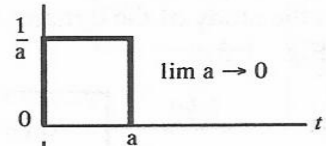
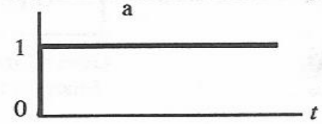
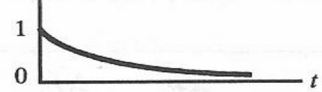
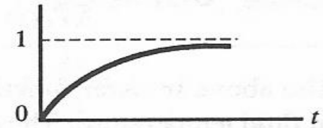
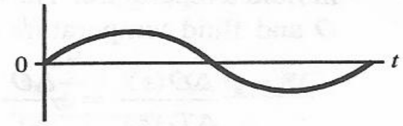
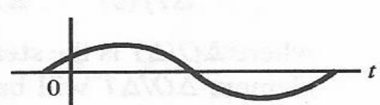
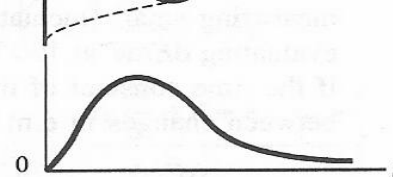
Table 4.1 Laplace transforms of common time functions $f(t)$

$$\mathscr{L}[f(t)] = \bar{f}(s) = \int_0^\infty e^{-st} f(t)\,dt$$

Function	Symbol	Graph	Transform
1st Derivative	$\frac{d}{dt} f(t)$		$s\bar{f}(s) - f(0-)$
2nd Derivative	$\frac{d^2}{dt^2} f(t)$		$s^2\bar{f}(s) - sf(0-) - \dot{f}(0-)$
Unit impulse	$\delta(t)$		1
Unit step	$\mu(t)$		$\frac{1}{s}$
Exponential decay	$\exp(-\alpha t)$		$\frac{1}{s+\alpha}$
Exponential growth	$1 - \exp(-\alpha t)$		$\frac{\alpha}{s(s+\alpha)}$
Sine wave	$\sin \omega t$		$\frac{\omega}{s^2+\omega^2}$
Phase shifted sine wave	$\sin(\omega t + \phi)$		$\frac{\omega \cos\phi + s \sin\phi}{s^2+\omega^2}$
Exponentially damped sine wave	$\exp(-\alpha t)\sin \omega t$		$\frac{\omega}{(s+\alpha)^2+\omega^2}$
Ramp with exponential decay	$t\exp(-\alpha t)$		$\frac{1}{(s+\alpha)^2}$

* Initial conditions are at $t = 0-$, just prior to $t = 0$