UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2004/2005

Mac 2005

EEM 232 – SISTEM MEKATRONIK

Masa : 3 Jam

ARAHAN KEPADA CALON:-

Sila pastikan kertas peperiksaan ini mengandungi **DUA BELAS** **(12)** muka surat beserta **(Lampiran 1 muka surat)** bercetak dan **ENAM** **(6)** soalan sebelum anda memulakan peperiksaan ini.

Jawab **LIMA** **(5)** soalan.

Agihan markah diberikan di sudut sebelah kanan soalan berkenaan.

Semua soalan hendaklah dijawab di dalam Bahasa Malaysia.

1. (a) Konsep impedan boleh digunakan kepada sistem elektrik,mekanik, bendalir dan terma. Bagi sistem mekanik, jisim adalah setara dengan induktan, pemalar redaman setara dengan rintangan elektrik dan 1/kekakuan setara dengan kapasitan elektrik.

Buktikan kenyataan di atas dengan bantuan lakaran yang sesuai.

The concept of impedance can be applied to electrical, mechanical, fluidic and thermal systems. For a mechanical system, mass is analogues to electrical inductance, damping constant is analogues to electrical resistance and 1/stiffness is analogues to electrical capacitance.

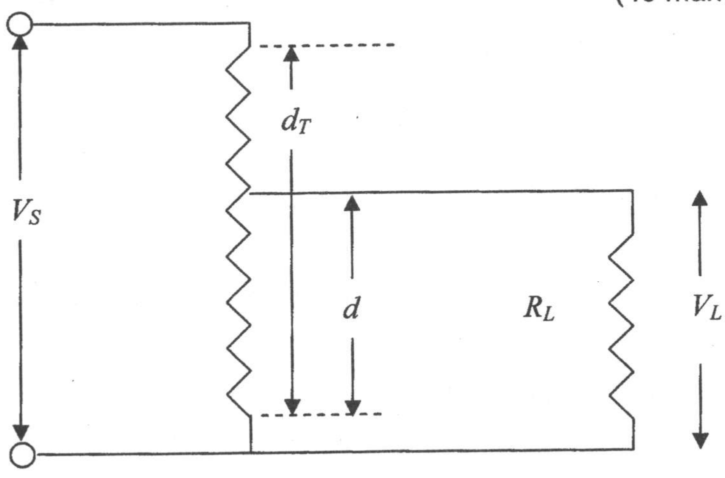
Prove the above statement with the help of suitable sketches.

(30 markah/*marks*)

(b) Terbitkan persamaan yang memberikan hubungan antara voltan dan sesaran (V_L dan d) bagi satu meter-upaya yang disambungkan kepada satu beban seperti yang ditunjukkan dalam Rajah 1(b).

Derive the equation that gives the relationship between voltage and displacement (V_L and d) for a potentiometer connected to a load shown in Figure 1(b).

(40 markah/*marks*)



Rajah 1(b)
Figure 1(b)

...3/-

(c) Bezakan antara transduser aktif dan pasif. Beri dua contoh untuk setiap transduser tersebut.

Differentiate between active transducers and passive transducers. Give two examples for each type of the transducers.

(30 markah/*marks*)

2. (a) Buktikan bahawa pembebanan dinamik bagi sistem mekanikal yang ditunjukkan di dalam Rajah 2(a) ialah seperti berikut:-

Prove that the dynamic loading for mechanical system shown in Figure 2(a) is given by:

$$F_S(s) = \frac{Z_{MS}(s)}{Z_{MS}(s) + Z_{MP}(s)} F(s)$$

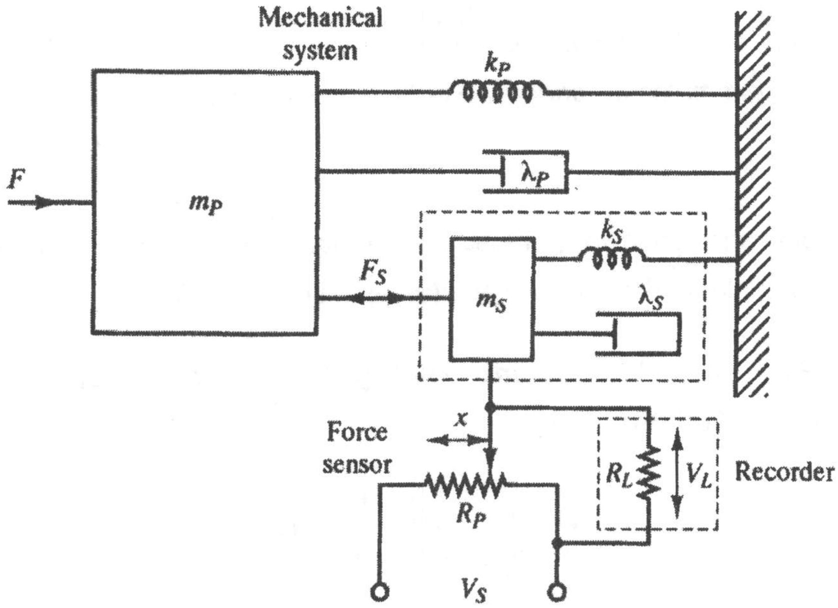
Di mana
Where

F ialah daya sebenar
is the true force

F_S ialah daya yang diukur
is the measured force

Z_{MP} ialah impedan proses
is process impedance

Z_{MS} ialah impedan penderia
is sensor impedance



Rajah 2(a)
Figure 2(a)

(30 markah/*marks*)

(b) Apakah yang dimaksudkan dengan pengenalpastian sistem ukuran? Terangkan bagaimana sistem tertib pertama dan sistem tertib kedua dapat dicamkan.

What is meant by the identification of measurement system? Explain on how to identify first order and second order system.

(30 markah/*marks*)

(c) Satu penderia sesaran mempunyai julat input di antara 0.0 cm sehingga 6.0 cm apabila dibekalkan dengan voltan bekalan piawai V_S = 5 volt. Menggunakan data penentuukuran di dalam Jadual 2(c), kira

A displacement sensor has an input range from 0.0 cm to 6.0 cm when supplied with standard voltage supply, V_S = 5 volts. Using calibration data in Table 2(c), calculate

[i] Tak-lineariti maksimum pada pesongan skala penuh.
Maximum nonlinearity at full scale deflection.

[ii] Kepekaan linear ideal sistem pengukuran.
Ideal linear sensitivity measurement system.

[iii] Pemalar gandingan alam sekitar K_I dan K_M yang berkaitan dengan perubahan voltan bekalan.
Environmental coupling constants K_I and K_M related to the change in voltage supply.

Jadual 2(c)
Table 2(c)

Sesaran (cm)	0	1.0	2.0	3.0	4.0	5.0	6.0
Voltan output, mV (V_S =5 volt)	0	33	64	88	102	111	116
Voltan output, mV (V_S = 6 volt)	15	75	100	123	140	142	155

(40 markah/*marks*)

3. (a) Terangkan dengan bantuan lakaran yang sesuai, kaedah perisaian elektromagnet dan perisaian elektrostatik yang boleh mengurangkan isyarat hingar di dalam sistem pengukuran.

Explain with the help of suitable sketches, electromagnetic shielding and electrostatic shielding methods which can reduce noise signal in measurement system.

(40 markah/*marks*)

(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 daripada 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 dan 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 $Wm^{-2}{}^{\circ}C$

(60 markah/*marks*)

4. (a)

[i] Rintangan bagi kebanyakan logam meningkat secara linear dengan perubahan suhu dalam julat yang tertentu. Tuliskan dan terangkan faktor dalam suatu siri kuasa yang boleh dijadikan model am bagi kaitan rintangan $R_T\ \Omega$ bagi suatu logam dengan suhu T^oC.

The resistance of most metals increases reasonably linearly with temperature in certain ranges. Write and explain the factors of a power series that can be used to model the general relationship between the resistance $R_T\ \Omega$ of a metal and temperature T^oC.

(10 markah/*marks*)

[ii] Suatu penderia rintangan platinum digunakan untuk mengukur suhu di antara 0°C dan 200°C. Dengan menggunakan persamaan dari [i], tentukan pekali siri kuasa tersebut sehingga faktor tertib kedua. Rintangan sensor platinum pada 0°C, 100°C, dan 200°C adalah, masing-masing,

A platinum resistance sensor is used to measure temperature between 0°C and 200°C. By using the equation in (i), find the coefficients of the power series up to the second order factor. Note that the resistance of the platinum sensor at 0°C, 100°C, and 200°C are, respectively,

$$R_0 = 100.0\ \Omega\ , R_{100} = 138.5\ \Omega\ , R_{200} = 175.83\ \Omega\ .$$

(20 markah/*marks*)

(b)

[i] Dengan menggunakan gambarajah yang sesuai, terangkan konsep tegasan, terikan, dan *modulus Young.*

By using suitable diagrams, explain the concepts of stress, strain, and Young's modulus.

(15 markah/*marks*)

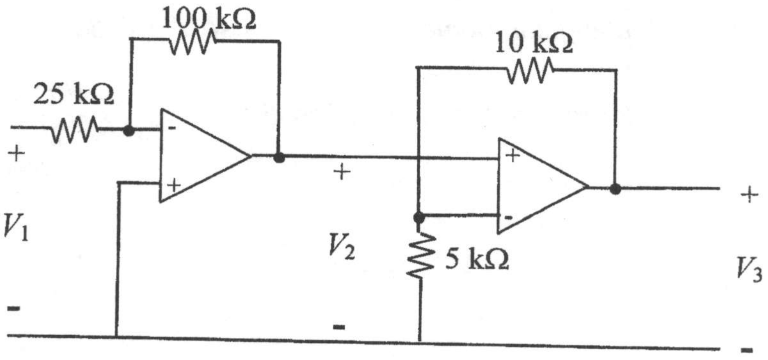
[ii] Apa itu suatu "strain gauge"? Dengan menggunakan suatu gambarajah yang sesuai, huraikan kaitan antara perubahan dalam rintangan dengan strain bagi suatu "strain gauge". Tentukan faktor gauge bagi "strain gauge" tersebut.

What is a strain gauge? By using a suitable diagram, derive the relationship between changes in resistance and strain for a strain gauge. Determine that gauge factor of the strain gauge.

(25 markah/*marks*)

(c) Cari persamaan pindahan voltan dengan input V_1 dan output V_3 bagi litar yang ditunjukkan dalam Rajah 4. Gunakan model penguat voltan yang ideal bagi "op amps" tersebut.

Find the voltage transfer equation with input V_1 and output V_3 for the circuit shown in Figure 4. Use the ideal voltage amplifier model for the op amps.



Rajah 4
Figure 4

(30 markah/*marks*)

5. (a) Nyatakan teori kegagalan tegasan normal maksimum.

State the maximum-normal-stress failure theory.

(10 markah/*marks*)

(b) Rod bergarispusat 50 mm yang diperbuat daripada keluli karbon biasa (S_y = 250 MPa) menyokong beban 9 kN, dan dikenakan momen kilasan 100 Nm seperti yang ditunjukkan dalam Rajah 5(b). Tentukan

A 50 mm diameter rod made from plain carbon steel (S_y = 250 Mpa) supports a 9 kN load, and is subjected to a torsional moment of 100 Nm as shown in Figure 5(b). Determine

[i] tegasan tegangan maksimum,
the maximum tensile stress,

[ii] *tegasan ricih maksimum,*
the maximum shear stress,

[iii] *margin keselamatan.*
The margin of safety.

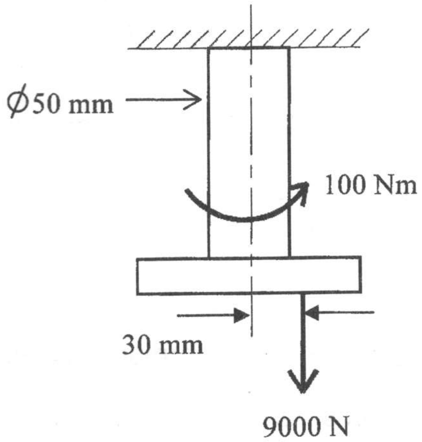
Cadangkan **satu** cara untuk mengurangkan margin keselamatan.

*Suggest **one** method of reducing the margin of safety.*

Given: *Rectangular moment of inertia of solid cylinder,* $I = \frac{\pi d^4}{64}$

Polar moment of inertia of solid cylinder, $I = \frac{\pi d^4}{32}$

(90 markah/*marks*)



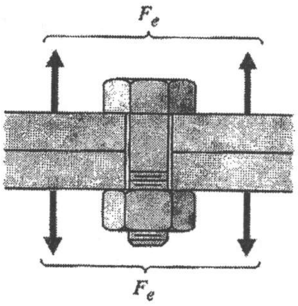
Rajah 5(b)
Figure 5(b)

6. (a) Beri **dua** sebab bagi menggunakan tegangan awal yang tinggi apabila mengetatkan bolt dan nat.

*Give **two** reasons for using high initial tension during tightening of bolts and nuts.*

Bolt yang ditunjukkan dalam Rajah 6(a) diperbuat daripada keluli SAE gred 5.8 yang mempunyai kekuatan 'proof' S_p = 250 Mpa. Bahagian-bahagian yang dikepilkan mempunyai kekakuan k_c enam kali kekakuan bolt k_b. Apakah beban awal minimum yang diperlukan untuk mengelakkan pengasingan plat-plat apabila daya luar F_e = 35 kN dikenakan?
Berasaskan nilai faktor keselamatan sebanyak 2.5, apakah luas tegasan minimum yang diperlukan pada bolt supaya kegagalan dapat dielakkan?

The bolt shown in Figure 6(a) is made from SAE class 5.8 steel having proof strength S_p = 250 MPa. The clamped parts have a stiffness k_c six times the bolt stiffness k_b. What is the minimum initial preload required to prevent separation of the plates when an external load F_e = 35 kN is applied? Based on a safety factor of 2.5, what minimum stress area is required on the bolt to avoid failure?



Rajah 6(a)
Figure 6(a)

(50 markah/*marks*)

(b) Namakan **empat** bahagian utama pada sebuah galas elemen guling.

*State the **four** main parts of a rolling element bearing.*

Galas bebola jejari mempunyai kapasiti kadaran 3.35 kN bagi hayat 90 × 10^6 putaran dengan kebolehpercayaan 90%. Galas tersebut digunakan dalam suatu aplikasi kejutan ringan-hingga-sederhana (K_a = 1.5). Syaf berputar pada 2500 psm dan galas tersebut dikenakan beban setara 1000 N. Tentukan

A radial ball bearing has a rated capacity of 3.35 kN for 90 × 10^6 revolution life with 90% reliability. The bearing is used in an application having light-to-moderate shock (K_a = 1.5). The shaft rotates at 2500 rpm and the bearing is subjected to an equivalent load of 1000 N. Determine

[i] hayat dalam jam bagi kebolehpercayaan 90%,
the life in hours for 90% reliability,

[ii] hayat dalam jam bagi kebolehpercayaan 99%,
the life in hours 99% reliability,

[iii] *kapasiti sebenar bagi operasi 2000 jam pada kebolehpercayaan 90%.*
the actual capacity for a 2000 hour operation at 90% reliability.

Faktor pelarasan kebolehpercayaan hayat K_r diberikan oleh carta dalam Rajah 6(b).

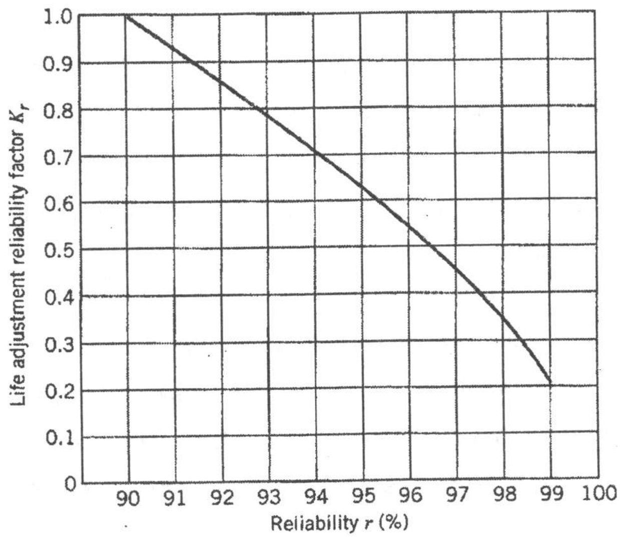
The life adjustment reliability factor K_r is given by the chart in Figure 6(b).

Diberi: Persamaan hayat galas:

Given: *Bearing life equations:*

$$L = K_r L_R \left(\frac{C}{F_e K_a} \right)^{10/3} \quad \text{dan/and} \quad C_{req} = F_e K_a \left(\frac{L}{K_r L_R} \right)^{0.3}$$

(50 markah/*marks*)



Rajah 6(b)
Figure 6(b)

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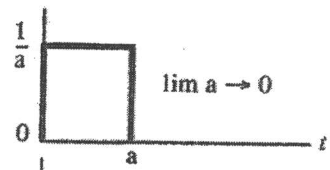
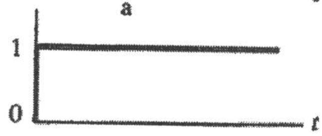
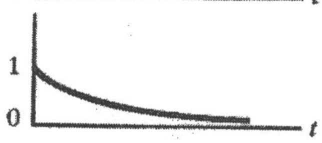
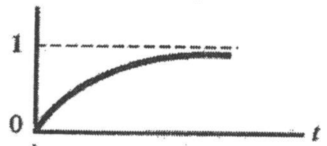
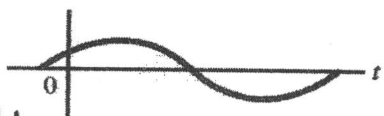
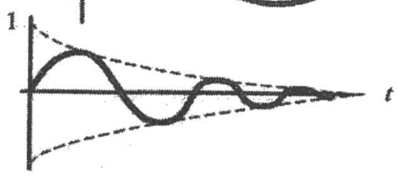
Lampiran 1
Appendix 1

[EEM 232]

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 $t = 0$