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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2011/2012

COURSE NAME	:	INSTRUMENTATION AND CONTROL SYSTEMS
COURSE CODE	:	BEH 22003
PROGRAMME	:	BEB / BEC / BED / BEU
EXAMINATION DATE	:	JUNE 2012
DURATION	:	2 ½ HOURS
INSTRUCTION	:	ANSWER **FOUR** (4) QUESTIONS ONLY

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

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Q1 (a) Explain the basic principle of d'Arsonval meter operation and discuss the modifications need to be made with appropriate diagram in order to measure AC current or voltages by using the same d'Arsonval meter.

(5 marks)

(b) Manufacturers of instruments may state that the instrument is accurate within certain percentage of a full scale reading. This specification is called as the limiting error. Given that the instruments listed in Table Q1 (b) are used to determine the power dissipation in a resistor where both are guaranteed to provide reading accurate within certain percentage at full scale.

Table Q1 (b)

Instrument	**Meter Range**	**Accuracy reading at full scale**
Voltmeter	200 V	$\pm 1\%$
Ammeter	150 mA	$\pm 2\%$

Determine;

(i) The limiting error of the voltmeter when it reads a 150 V DC source.

(2 marks)

(ii) The limiting error of the ammeter when it reads a 120 mA DC source.

(2 marks)

(iii) The limiting error of the power calculation dissipated in the resistor.

(3 marks)

(c) Solar power is one of the main alternative energy sources. It is a solid state device that converts the energy of sunlight directly into electricity by the photovoltaic effect. One of the modern solar panel used in UTHM is a *cadmium telluride* solar cell type as shown in Figure Q1 (c) (i). The solar energy from the solar cell will charge battery bank with a value of V_m. However, the storage voltage, V_m depends on the sunlight intensity. In order to study the pattern of current at load from the solar panel source, the d'Arsonval meter as shown in Figure Q1 (c) (ii) is connected in series with R_{Load}.

(i) Calculate the value of shunt resistors, R_a, R_b and R_c. Given that $R_m = 1\ k\Omega$, $I_m = 100\ \mu A$, $I_1 = 1$ A, $I_2 = 5$ A, $I_3 = 10$ A.

(10 marks)

(ii) Determine the most suitable full scale range of meter to measure the current at R_{Load}. Given that $R_{Load} = 15\ \Omega$ and $R_S = 10\ \Omega$. The maximum voltage in the solar curve data (V_m versus Time) is 20V.

(3 marks)

Q2 (a) The development of electronic television systems was based on the development of the cathode ray tube (CRT) as in Figure Q2 (a). Although the size and shape are different, the operating principle is the same where there is a vacuum inside the tube. The electron beam emitted by the heated cathode at the rear end of the tube is accelerated and focused by one or more anodes, and strikes the front of the tube, producing a bright spot on the phosphorescent screen.

(i) Name all the major components labeled in Figure Q2 (a).

(4 marks)

(ii) State four (4) basic parts of a CRT.

(4 marks)

(b) An experiment was conducted to make two LED flash briefly once every 5 seconds to imitate the indicator light of a real alarm. The waveform for both LED voltages was displayed on the screen of the oscilloscope as shown in Figure Q2 (b) (i). If the volts/div knob and times/div knob are set as in Figure Q2 (b) (ii), compute;

(i) The peak to peak voltage, $V_{p\text{-}p}$ of waveform A and waveform B.

(2 marks)

(ii) The frequency, f for each waveform.

(2 marks)

(c) An oscillator is a mechanical or electronic device that works on the principles of oscillation which is a circuit that generates an AC output signal without requiring any externally applied input signal. An audio oscillator is useful for testing equipment that operates in the audio frequency range. Name two (2) most common audio oscillator circuits.

(2 marks)

(d) Radio frequency (RF) oscillator must satisfy the Barkhausen criteria for oscillation. Hartley oscillator as shown in Figure Q2 (d) is one of standard RF oscillator and it is designed to be resonant at the desired frequency of oscillation when the inductive and capacitive reactances are equal, X_L=X_C. If the desired frequency of the sustained oscillation is 100 kHz, determine;

(i) Value of inductor, L_2.

(6 marks)

(ii) Minimum value of resistor, R_f.

(5 marks)

Q3 (a) A feedback loop is a common and powerful tool when designing a closed-loop control system. Feedback loop takes the system output into consideration, which enables the system to adjust its performance to meet a desired output response. Identify the unknown blocks, A and B, in the block diagram of a closed-loop control system in Figure Q3 (a).

(2 marks)

(b) Explain five (5) differences between the open-loop and closed-loop control systems.

(5 marks)

(c) (i) In order to understand and control a complex system, a control and instrument engineer needs to obtain quantitative mathematical models of the control system. It is necessary to analyze the relationships between the system variables and to obtain its mathematical model. Figure Q3 (c) shows the schematic of a closed-loop position control for an electro-mechanical system. Construct its block diagram with description of each component and variables.

(5 marks)

(ii) The transfer function of the motor connected to the load through the gears in Figure Q3 (c) can be simplified to be

$$\frac{\theta_o(s)}{V_a(s)} = \frac{10}{s(2s+1.5)},$$

while the potentiometer constant, $K_{p1} = K_{p2} = 5$ and the amplifier gain, $K_s = 10$. Determine the transfer function of the system, $\frac{\theta_o(s)}{\theta_i(s)}$.

(6 marks)

(d) Solve the transfer function, *C(s)/R(s)*, from the block diagram in Figure Q3 (d) using the block diagram reduction technique.

(7 marks)

Q4 (a) A control system is represented by the following transfer function

$$\frac{C(s)}{R(s)} = \frac{1}{s^2 + 3s + 2}.$$

Determine the response of the system in time domain to a unit step input.

(10 marks)

(b) A drive shaft or Cardan shaft is a mechanical component for transmitting torque and rotation which is usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them. Figure Q4 (b) shows a rotational mechanical drive shaft system.

(i) Derive the differential equations of the system with the free body diagram.

(7 marks)

(ii) Determine the transfer function, $\dfrac{\theta(s)}{T(s)}$.

(8 marks)

Q5 (a) The DC motor will be used in three-axis pick and place robot for flexible manufacturing system (FMS). The robot are simultaneously controlled and driven by a DC motor in movement of each axis with fast acceleration, deceleration and reasonable precision. A robot which has a block diagram as shown in Figure Q5 has to be designed. Determine the range of K_a for the system to be stable if $K_f = \dfrac{1}{(s+1)(s+5)}$.

(7 marks)

(b) If the system in Figure Q5 has unity feedback, categorize the system type and calculate steady state error for inputs of 4 $u(t)$, 4 $tu(t)$ and 4 $t^2u(t)$.

(4 marks)

(c) If the system in Figure Q5 has unity feedback and is required to obtain system response with 10% of maximum overshoot, determine the following performance specification for a unit step input.

(i) Possible value for gain, K_a

(4 marks)

(ii) The rise-time, T_r

(2 marks)

(iii) The settling-time, T_s for ±2%

(2 marks)

(iv) The peak-time, T_p

(2 marks)

(v) Sketch the system transient response in time domain.

(4 marks)

Q6 (a) In an industrial process, sensors and transducers are crucial elements in obtaining the information from the plant. Briefly describe the definition of sensors and transducers.

(4 marks)

(b) Typical manufacturing factories require various sensors to control process plant. Describe any two (2) examples for level measurement (sensor/transducer).

(8 marks)

(c) As an instrumentation engineer in UTHM Holdings Bhd, you are assigned to select and install several sensors for a new process that involve mixing a liquid with two dry materials to make a polymer additive used in making rubber product. One of the transducers to be installed is a J-type thermocouple with ice bath reference junction as shown in Figure Q6 (c). After the completion of installation, a measurement on the liquid heated by the steam jacket is to be made using the installed thermocouple sensor and circuit configuration in Figure Q6 (c).

Let the thermocouple constant $c=3.75x10^{-2}\ mV/^{o}C$ and $k=4.5x10^{-5} mV/^{o}C^{2}$ with ammeter showing a reading of 5 mA. Determine:

(i) The output voltage, V_o of the thermocouple.

(5 marks)

(ii) The temperature of the liquid after heated by the steam jacket.

(8 marks)

(Assume that ideal instruments are used and no power dissipation to the air)

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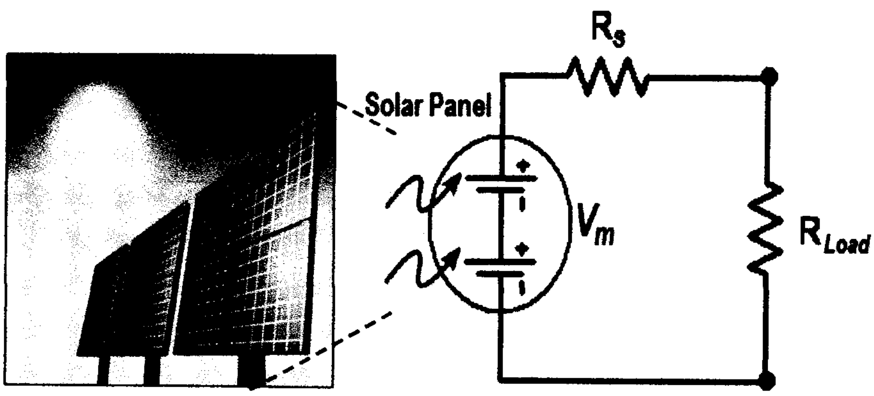

FIGURE Q1 (c) (i)

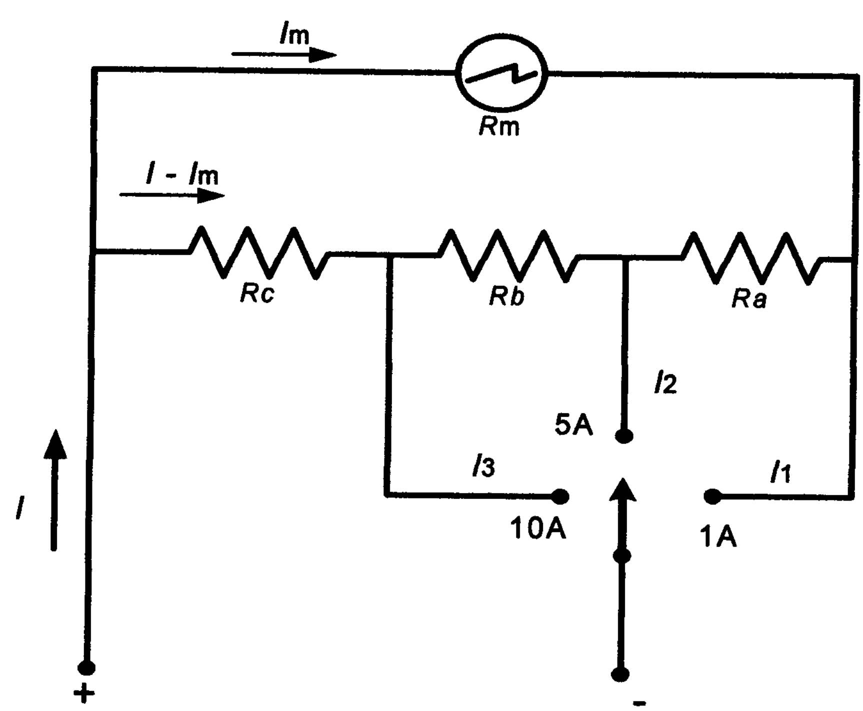

FIGURE Q1 (c) (ii)

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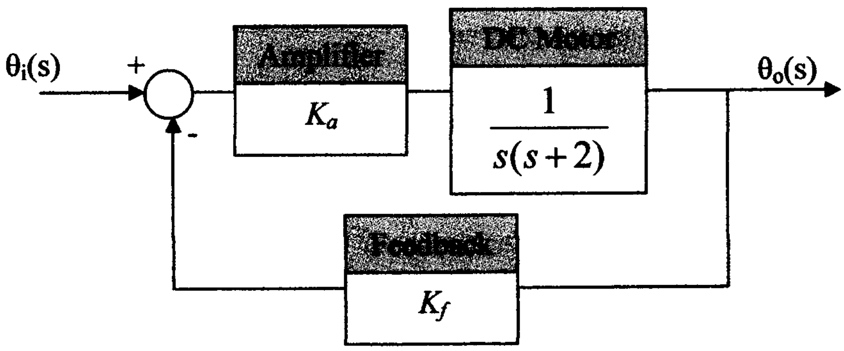
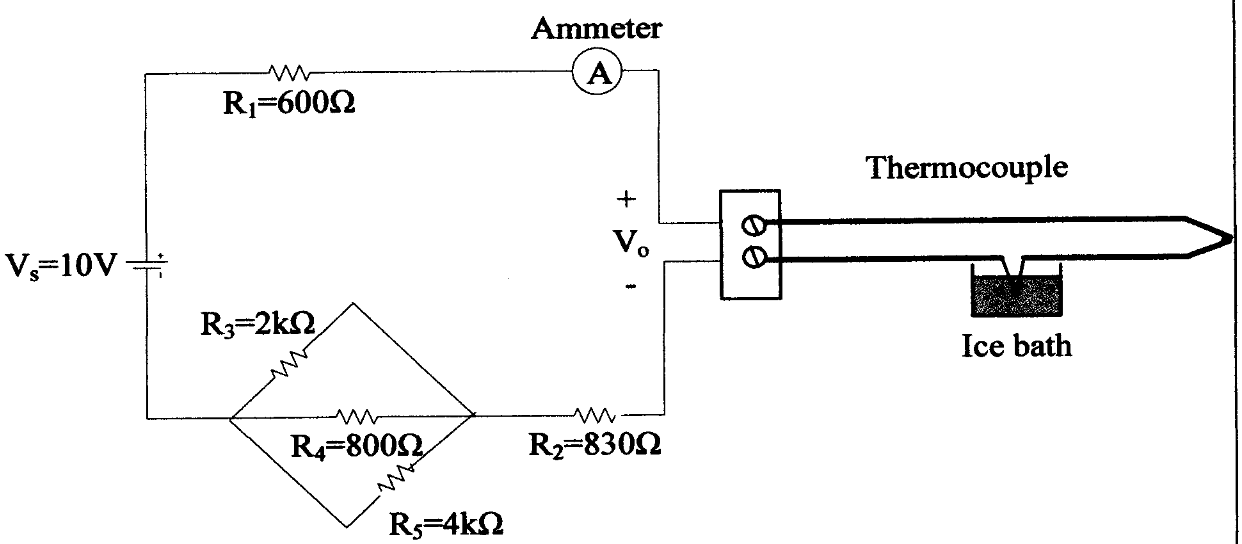


FIGURE Q5



$$V_o = c(T_1 - T_2) + k(T_1^2 - T_2^2)$$

FIGURE Q6 (c)

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TABLE 1
Laplace Transform Table

$f(t)$	$F(s)$
$\delta(t)$	1
$u(t)$	$\frac{1}{s}$
$tu(t)$	$\frac{1}{s^2}$
$t^n u(t)$	$\frac{n!}{s^{n+1}}$
$e^{-at}u(t)$	$\frac{1}{s+a}$
$\sin \omega t u(t)$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t u(t)$	$\frac{s}{s^2+\omega^2}$

TABLE 2
Laplace Transform Theorems

Name	Theorem
Frequency shift	$\mathscr{L}\left[e^{-at}f(t)\right]=F(s+a)$
Time shift	$\mathscr{L}\left[f(t-T)\right]=e^{-sT}F(s)$
Differentiation	$\mathscr{L}\left[\frac{d^n f}{dt^n}\right]=s^n F(s)-\sum_{k=1}^{n} s^{n-k} f^{k-1}(0^-)$
Integration	$\mathscr{L}\left[\int_{0^-}^{t} f(\tau)d\tau\right]=\frac{F(s)}{s}$
Initial value	$\lim_{t\to 0} f(t)=\lim_{s\to\infty} sF(s)$
Final value	$\lim_{t\to\infty} f(t)=\lim_{s\to 0} sF(s)$