UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION
SEPTEMBER 2014 SESSION

SUBJECT CODE : FAB30503 / FAB30903
SUBJECT TITLE : MECHATRONICS SYSTEM DESIGN
MECHATRONICS DESIGN PROJECT
LEVEL : BACHELOR
TIME / DURATION : 9.00 AM – 12.00 PM
(3 HOURS)
DATE : 07 JANUARY 2015

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. Please write your answers on the answer booklet provided.
4. Answer should be written in blue or black ink except for sketching, graphic and illustration.
5. This question paper consists of TWO (2) sections. Section A and B. Answer all questions in Section A. For Section B, answer THREE (3) questions only.
6. Answer all questions in English.

THERE ARE 9 PAGES OF QUESTIONS AND 3 PAGES OF APPENDICES, EXCLUDING THIS PAGE.
SECTION A (Total: 40 marks)

INSTRUCTION: Answer all the questions.
Please use the answer booklet provided.

Question 1

(a) Describe the four (4) key elements of mechatronics. (4 marks)

(b) Explain the differences between open-loop control system and closed-loop control system and give one (1) example of each system. (4 marks)

(c) Refer to Figure 1, name and explain the elements of 1, 2, 3 and 4. (6 marks)

(d) The mechatronic design process consists of three phases. List all three (3) phases. (3 marks)

(e) Describe three (3) types of controller that are normally used in control system. (3 marks)
Question 2

(a) The design level can be divided into three (3) categories, which are adaptive design, development design and new design. Describe adaptive design and give an example.

(2 marks)

(b) List four (4) discrete activities that are considered under the conceptual design.

(4 marks)

(c) Figure 2 shows the Humanoid Robot that Company A plan to introduce in the fourth quarter of year 2014. The mission statement of the product planning is shown in Figure 3.

i. List five (5) steps of product planning activities to produce the mission statement

(5 marks)

ii. Describe the meaning of stakeholders

(2 marks)
(d) Product design can be classified into industrial design and engineering design. Explain the meaning of industrial design and engineering design.

(4 marks)

(e) There are five (5) levels of innovation in design process and list three (3) of them.

(3 marks)
SECTION B (Total: 60 marks)

INSTRUCTION: Answer only THREE (3) questions.
Please use the answer booklet provided.

Question 3

(a) **Figure 4** shows the operational amplifier that is used to convert voltage to current. Answer the following question:-

i. Give **two (2)** examples of application that used this circuit.  
   
   (2 marks)

ii. Determine the range of input voltage that produces the current output range of 4mA to 20mA. 
   
   (3 marks)

(b) Illustrate with a block diagram, a step by step of signal conditioning process and provide an example of each step. 
   
   (5 marks)

(c) Selecting the right sensors depends on the particular need for the parameter being measured. Before considering the criteria of the sensor, the engineer should select the right sensor based on the applications. List **four (4)** sensor selection criteria. 
   
   (4 marks)

(d) Explain the differential sensor and give an example of the usage in industry. 
   
   (3 marks)
(e) Capacitive and inductive sensor is a type of proximity sensor. Discuss the principle of operation of capacitive sensor.

(3 marks)

Question 4

(a) Consider compound gear train A, B, C and D in Figure 5. If there are 15 teeth on wheel A, 30 teeth on wheel B, 18 teeth on wheel C and 36 teeth on wheel D, find the overall gear ratio of the angular velocities at the input and output shafts.

(6 marks)

Figure 5: Compound Gear Train

(b) Illustrate a diagram of four bar chain for double lever mechanism, lever crank mechanism and double crank mechanism.

(6 marks)

(c) Draw a pneumatic circuit for extend and retract cylinder by using 3/2 way valve.

(4 marks)

(d) Identify a type of cam follower based on Figure 6.

(4 marks)

Figure 6: Cam Follower
Question 5

(a) List two (2) key steps of modeling methodology.

(b) Initially, there is no current flow in the circuit and the switch is in open position. At time $t=0$, the switch is placed in closed position and voltage $e$ is applied. Current starts to build up in the circuit and starts charging the capacitor. The voltage in the circuit at time $t$ is given by:

$$\text{resistor voltage} + \text{inductor voltage} + \text{capacitor voltage} = \text{applied voltage}$$

Determine the transfer function for output current $I(s)$ and applied input $E(s)$ for the following circuit:

(c) Figure 8 shows the two (2) tanks connected in series where fluid level in downstream tank does not affect the fluid-level dynamics of the upstream tanks.
Variables used:
\[ z_1 = \text{fluid level in the upstream tank (1)} \]
\[ z_2 = \text{fluid level in the upstream tank (2)} \]
\[ q_0 = \text{fluid flow rate into tank 1} \]
\[ q_1 = \text{fluid flow rate out of tank 1 and into tank 2} \]
\[ q_2 = \text{fluid flow rate out of tank 2} \]
\[ R_1 = \text{resistance of the tank 1 outlet} \]
\[ R_2 = \text{resistance of the tank 2 outlet} \]

Find the transfer function; \( \frac{Z_1(s)}{Q_0(s)} \) of tank 1.

(d) A spring mass damper system is shown in Figure 9. The system is fixed at ends between two supports. Mass is supported by the spring and is free to oscillate about the position of rest. An equation of motion relating vertical motion of mass to applied force will be developed.

(5 marks)

\[ F = \text{External Force} \]
\[ M = \text{Mass Force} \]
\[ B = \text{Damping force} \]
\[ K = \text{Spring Force} \]

Where mass force + damping force + spring force = External Force

\[ M \frac{d^2 x(t)}{dt^2} + B \frac{dx(t)}{dt} + Kx(t) = F(t) \]

The differential equation above describes the behavior of spring, mass and damper system, where;

\[ F = \text{External Force} \]
\[ M = \text{Mass Force} \]
\[ B = \text{Damping force} \]
\[ K = \text{Spring Force} \]

Find the Transfer Function of the system where \( X(s) = \) Mass movement and \( F(s) = \) Applied Force.

And \[ TF(s) = \frac{X(s)}{F(s)} \]

All the initial condition = 0
Question 6

**Figure 10** shows a schematics diagram of PIC 16F877A. This is a simple application on how to start a basic PIC programming.

(a) Determine the inputs and outputs of the PIC.  
(2 marks)

(b) Describe the functionality of the component label X1, CRYSTAL, 20MHz.  
(2 marks)

(c) Construct a program for pin configuration of PIC 16F877A.  
(2 marks)
(d) Construct a program for pwm initialization with a frequency 1 KHz of DC motor. Please refer appendices to configure the CCP1 pin for pwm mode. 

(4 marks)

(e) Create a program of a DC motor by pressing a SW1 the motor will activate with 40% speed in a direction, SW2 to activate motor with a speed of 70% in another direction and SW3 is used to stop motor by giving 0% speed. You may start by giving CCPR1L=0 for 0% speed of duty cycle. The header file for the program should be as follows:

```c
// Push button on PIC16F877A, pull high
#define PB1 RA0
#define PB2 RA1
#define PB3 RA2

// L293B, H-Bridge IC to drive either DC brush
#define L293_EN RC2
// this pin is connected to Enable of L293 H-bridge driver, it is being use for speed control (PWM)

// L293 pin for DC Brushed Motor
#define M1 RB4
#define M2 RB5
```

(12 marks)

END OF QUESTION
APPENDIX A

EXAMPLE PWM FREQUENCIES AND RESOLUTIONS (Fosc = 20 MHz)

<table>
<thead>
<tr>
<th>PWM Frequency</th>
<th>1.22 kHz</th>
<th>4.88 kHz</th>
<th>19.53 kHz</th>
<th>78.12 kHz</th>
<th>150.3 kHz</th>
<th>208.3 kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timer Prescale (1, 4, 16)</td>
<td>16</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PR2 Value</td>
<td>0xFF</td>
<td>0xFF</td>
<td>0xFF</td>
<td>0x3F</td>
<td>0x1F</td>
<td>0x17</td>
</tr>
<tr>
<td>Maximum Resolution (bits)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>6.6</td>
</tr>
</tbody>
</table>

CCP1CON REGISTER/CCP2CON REGISTER (ADDRESS 17h/1Dh)

<table>
<thead>
<tr>
<th>U-0</th>
<th>U-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
<th>R/W-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>—</td>
<td>CCPxX</td>
<td>CCPxY</td>
<td>CCPxM3</td>
<td>CCPxM2</td>
<td>CCPxM1</td>
<td>CCPxM0</td>
</tr>
</tbody>
</table>

bit 7: Unimplemented: Read as ‘0’

bit 5-4

CCPxX:CCPxY: PWM Least Significant bits

Capture mode:
Unused.

Compare mode:
Unused.

PWM mode:

These bits are the two LSbs of the PWM duty cycle. The eight MSbs are found in CCPRxL.

bit 3-0

CCPxM3:CCPxM0: CCPx Mode Select bits

0000 = Capture/Compare/PWM disabled (resets CCPx module)
0100 = Capture mode, every falling edge
0101 = Capture mode, every rising edge
0110 = Capture mode, every 4th rising edge
0111 = Capture mode, every 16th rising edge
1000 = Compare mode, set output on match (CCPxIF bit is set)
1001 = Compare mode, clear output on match (CCPxIF bit is set)
1010 = Compare mode, generate software interrupt on match (CCPxIF bit is set, CCPx pin is unaffected)
1011 = Compare mode, trigger special event (CCPxIF bit is set, CCPx pin is unaffected); CCP1 resets TMR1; CCP2 resets TMR1 and starts an A/D conversion (if A/D module is enabled)
11xx = PWM mode

Legend:

R = Readable bit
W = Writable bit
U = Unimplemented bit, read as ‘0’
- n = Value at POR
‘1’ = Bit is set
‘0’ = Bit is cleared
x = Bit is unknown
APPENDIX B

REGISTER 8-1: T2CON: TIMER2 CONTROL REGISTER (ADDRESS 12h)

<table>
<thead>
<tr>
<th>U-0</th>
<th>RW-0</th>
<th>RW-0</th>
<th>RW-0</th>
<th>RW-0</th>
<th>RW-0</th>
<th>RW-0</th>
<th>RW-0</th>
<th>RW-0</th>
<th>RW-0</th>
<th>RW-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>TOUTPS3</td>
<td>TOUTPS2</td>
<td>TOUTPS1</td>
<td>TOUTPS0</td>
<td>TMR2ON</td>
<td>T2CKPS1</td>
<td>T2CKPS0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

bit7

bit 7: Unimplemented: Read as '0'

bit 6-3: TOUTPS3-TOUTPS0: Timer2 Output Postscale Select bits

- 0000 = 1:1 Postscale
- 0001 = 1:2 Postscale
- ...
- 1111 = 1:16 Postscale

bit 2: TMR2ON: Timer2 On bit

- 1 = Timer2 is on
- 0 = Timer2 is off

bit 1-0: T2CKPS1-T2CKPS0: Timer2 Clock Prescale Select bits

- 00 = Prescaler is 1
- 01 = Prescaler is 4
- 1x = Prescaler is 16