Student Number: ....

THE UNIVERSITY OF MELBOURNE

Semester 2 Assessment
November 2011

Melbourne School of Engineering
ENGR10003 ENGINEERING SYSTEMS DESIGN 2

Time allowed: 180 minutes
Reading time: 15 minutes

This paper has 35 pages

Authorised materials:
Electronic calculators approved by the Melbourne School of Engineering.

Instructions to invigilators:
All examination material is to be collected at the end of the exam including the multiple choice answer sheet.

Instruction to students:
Put your student number at the top of this and every other page.
Attempt **ALL** questions.
The questions carry weight in proportion to the marks in brackets after the question numbers.
- **PART A** contains 40 multiple choice questions and totals 40 marks.
  These MUST be answered on the provided answer sheet.
- **PART B** contains 3 extended answer questions and totals 60 marks.
  These MUST be answered in the spaces provided on this paper.

Use unprinted page sides for all rough work.

For examiners' use only.

PART A	PART B				EXAM
TOTAL (/40)	Q1	Q2	Q3	TOTAL (/60)	TOTAL (/100)

PART B - extended answer (60 marks)

Answer all Part B questions in the spaces provided on this paper.

Question 1 (20 marks)

1. [**2 marks**] "Digital circuits are really analog, it is just that we can pretend that they are not." Use your understanding of the way binary quantities are represented in digital circuits to support this statement.

2. **[3 marks]** The (7,4) Hamming code takes four information bits $(b_4\, b_3\, b_2\, b_1)$ and adds three parity check bits $(p_3\, p_2\, p_1)$ to give a codeword

$$(c_7\, c_6\, c_5\, c_4\, c_3\, c_2\, c_1) = (b_4\, b_3\, b_2\, p_3\, b_1\, p_2\, p_1).$$

The check bits $(p_3\, p_2\, p_1)$ are chosen as follows: p_3 is chosen so as to give an even number of 1s in the group $(c_7\, c_6\, c_5\, c_4) = (b_4\, b_3\, b_2\, p_3)$; p_2 is chosen so as to give an even number of 1s in the group $(c_7\, c_6\, c_3\, c_2) = (b_4\, b_3\, b_1\, p_2)$; and p_1 is chosen so as to give an even number of 1s in the group $(c_7\, c_5\, c_3\, c_1) = (b_4\, b_2\, b_1\, p_1)$.

After transmission across a communications channel, a single error occurs in a transmitted codeword leading to the 7-bit string 1110111 being received. What codeword was transmitted?

3. [**2 marks**] State the principle of duality and use it to obtain a new theorem of Boolean algebra given the theorem $\overline{X}\,1 = \overline{X}$.

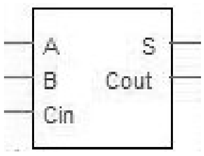
4. [**2 marks**] Sketch a circuit to implement $Y = \overline{A}\,B + \overline{C}$ using only NAND gates.

5. [**3 marks**] Construct a truth table for a circuit with one output, Z, and three inputs A, B and C. The output should be 1 if and only if C is 1 and A is 0 or when B is 0 and A is 1. Also express Z as a sum of product terms.

6. [**8 marks**] You are to design a circuit that calculates the Hamming distance between two 5-bit numbers. It takes two 5-bit binary numbers $A_4A_3A_2A_1A_0$ and $B_4B_3B_2B_1B_0$ as inputs and returns the number of bits that are different between the two numbers as the 3-bit binary output $O_2O_1O_0$. For example:

   - If the two input numbers were 10111 and 00001 then the output would be 011 as there are 3 bits different between them.
   - If the two input numbers were 11111 and 11111 then the output would be 000 as there are no bits different.
   - If the two input numbers were 11111 and 00000 then the output would be 101 as all 5 bits are different.

   (a) [**2 marks**] A full adder will be useful in your design of the Hamming distance calculator. It has 3 inputs A, B and C_{in} and 2 outputs C_{out} and S. It can be represented by the logic block:



   Construct the truth table for a full adder.

(b) [**6 marks**] Design the circuit for the Hamming distance calculator. Your design can make use of AND gates, OR gates, NOT gates, XOR gates, and Full Adders as required.

More space is provided for your answer on the following page.

Question 2 (20 marks)

1. [**12 marks**] An ice-cream shop wants to work out how much each ice-cream costs to produce in order to set an appropriate price to sell to their customers. The ice-cream can be modelled as a perfectly solid sphere of vanilla ice-cream with volume

$$V = \frac{4}{3}\pi r^3$$

sitting on a hollow cone of radius r and height h with surface area

$$S = \pi r^2 + \pi r\sqrt{r^2 + h^2}$$

The radius of the sphere and cone are assumed to be equal so that the vanilla ice-cream sits perfectly in the cone.

The cost of the vanilla ice-cream is $\$400/m^3$ and the cost of the cone is $\$8/m^2$.

(a) [**3 marks**] Write a MATLAB function `ice_cream_vol(r)` that calculates and returns the volume of ice-cream with radius `r`.

(b) [**3 marks**] Write a MATLAB function `cone_area(r,h)` that takes a radius `r` and height `h` and returns the surface area of the cone.

(c) [**6 marks**] Write a MATLAB function `total_cost(r,h)` that takes a radius `r` and height `h` (in metres) and prints the total cost of the ice-cream per cone (in dollars) on the screen. For example, running `total_cost(0.05,0.10)` MUST output the following format :

```
The cost to make the ice-cream is 0.4128 dollars.
```

You MUST call your `ice_cream_vol(r)` and `cone_area(r,h)` functions from parts (a) & (b).

2. [**8 marks**] The j-th *cumulative product* of a vector $x = (x_1, x_2, \ldots, x_n)$, for $j \leq n$ is defined by

$$p_j = x_1 \cdot x_2 \cdots x_j.$$

The cumulative product vector P contains all of the cumulative products as its elements, i.e.

$$P = [p_1\ p_2\ \ \ldots p_n]$$

where n is the number of elements in the vector x .

For example, the cumulative product vector P of the vector `x=[3 5 8 1 2 7]` is

```
P = [ 3 15 120 120 240 1680]
```

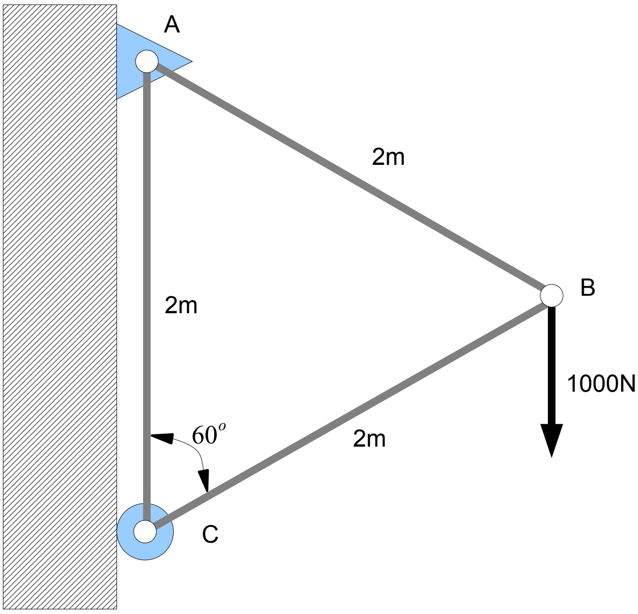
Write a MATLAB function `calc_prod(x)` that computes and returns the cumulative product vector of the vector `x`. You must make sure that the vector `x` contains only numbers and if not return an appropriate error message.

Hint : The MATLAB function `isnumeric(A)` returns 1 if `A` is a numeric array and 0 otherwise.

More space is provided for your answer on the following page.

Question 3 (20 marks)

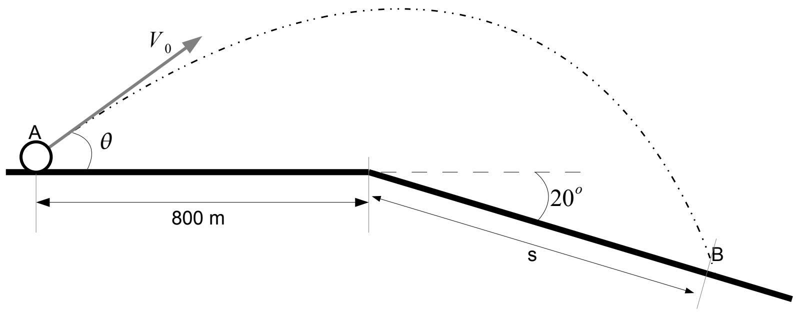
1. [**10 marks**] For the figure shown below, use the method of joints to calculate the components of the reaction forces at joints A and C and also the force in each member of the loaded truss. In order to get full marks, you need to specify whether each member is in compression or in tension.



More space is provided for your answer on the following page.

Even more space is provided for your answer on the following page.

2. **[10 marks]** A ball is to be launched at an angle θ to the horizontal and you would like to calculate the trajectory (motion) of the ball as shown below.



The drag force acting on the ball is given by

$$F_D = \frac{C_D}{2}\rho V^2 A \tag{1}$$

where V is the velocity of the ball, C_D is the coefficient of drag, ρ is the density of air and $A = \pi r^2$. The mass of the ball is m and its radius r.

(a) **[4 marks]** Derive the governing equations that define the 2-dimensional motion of the ball.

More space is provided for your answer on the following page.

(b) **[6 marks]** By neglecting aerodynamic drag (i.e. set $C_D = 0$), solve the set of ordinary differential equations that you derived in Part (a) and calculate the slant distance, s, which locates the point of impact B. Calculate also the time of flight, t. You are given that the ball is launched at velocity $V_0 = 120$ m/s at an angle $\theta = 40^o$.

More space is provided for your answer on the following page.

END OF EXAMINATION