Student Number: ....

THE UNIVERSITY OF MELBOURNE

Semester 2
November 2012

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.

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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**] Describe the principle of duality with respect to Boolean algebra.

2. [**2 marks**] Use perfect induction to prove $X + \overline{X}Y = X + Y$.

3. [**8 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:

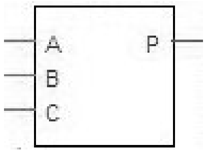
- p_3 is chosen so as to give an even number of 1s in the group $(c_7\, c_6\, c_5\, c_4) = (b_4\, b_3\, b_2\, p_3)$;
- p_2 is chosen so as to give an even number of 1s in the group $(c_7\, c_6\, c_3\, c_2) = (b_4\, b_3\, b_1\, p_2)$; and
- p_1 is chosen so as to give an even number of 1s in the group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

(a) [**2 marks**] Construct the truth table for the parity bit p_2 in terms of the input bits b_4, b_3, b_2, and b_1.

(b) [**2 marks**] Use your truth table from (a) to give a sum of products expression for p_2.

(c) **[2 marks]** Draw a digital circuit to generate p_2 using only XOR gates. We will call this the parity bit generator.

(d) **[2 marks]** The (7,4) Hamming encoder has four inputs $b_4\, b_3\, b_2\, b_1$ and seven outputs $c_7\, c_6\, c_5\, c_4\, c_3\, c_2\, c_1$. The parity bit generator (the circuit you created in the previous sub-question) can be represented by the logic block:



Draw the circuit for a complete Hamming encoder using these logic blocks.

4. [**8 marks**] A half-adder is a circuit that takes two binary inputs, X and Y, and that outputs the arithmetic sum of X and Y as the 2-bit output Z_1Z_0. In this question you will construct a half-adder and then use it as a building block for some larger designs.

   (a) [**2 marks**] Construct a truth-table for the half-adder circuit. The inputs are X and Y and the outputs are Z_1 and Z_0.

   (b) [**3 marks**] Using the truth-table, write down logic expressions for Z_1 and Z_0 and then sketch a circuit diagram for a half-adder. You are free to use AND, OR, NOT and XOR gates as you see fit.

(c) **[3 marks]** Now show how a full-adder can be built using two half-adders and an OR gate. You should label the full-adder inputs A, B and C_{IN} and label the outputs S and C_{OUT}.

Question 2 (20 marks)

1. [**10 marks**] An engineer wants to work out how much fuel a 4-cylinder internal combustion engine uses per hour, as a function of the speed of the engine in revolutions per minute and the dimensions of the cylinders in centimetres.

   An engine cylinder of radius r can be modelled as a perfect cylinder of height, h, thus each cylinder has a maximum volume (when the piston is at the bottom of its stroke) of

   $$v = \pi r^2 h$$

   The volume of fuel f (in litres) used per revolution in practice is based on the fuel-air ratio and can be simply modelled using a constant factor, C, multiplied by the maximum cylinder volume, v, (in litres) as follows

   $$f = Cv$$

   In answering this question, assume a fuel-air ratio constant of $C = 0.0001$.

   (a) [**2 marks**] Write a MATLAB function `cylinder_vol(r,h)` that calculates and returns the volume (in litres) of the engine cylinders of height `h` and radius `r` (in centimetres). Keep in mind that 1 $litre = 1000cm^3$.

   (b) [**2 marks**] Write a MATLAB function `fuel_per_rev(v)` that takes the volume `v` of a cylinder (in litres) and returns the fuel used for one revolution (in litres).

(c) **[6 marks]** Write a MATLAB function `litres_per_hour(rpm,r,h)` that takes the revolutions per minute `rpm` (in *rpm*), the height of the cylinders `h` (in centimetres) and the radius of the cylinders `r` (in centimetres) and prints the total fuel used per hour by a 4-cylinder engine (in litres) on the screen.
For example, running `litres_per_hour(2000,3,10)` MUST output the following format:

```
The fuel used at 2000 rpm is 13.5717 litres per hour.
```

You MUST call your `cylinder_vol(r,h)` and `fuel_per_rev(v)` functions from parts (a) & (b).

2. [**10 marks**] In this question you must write a MATLAB function that removes duplicate values from a vector resulting in a new vector containing only unique values.

   For example, the unique element vector E of the vector `x=[2 3 2 4 5 6 5 2 1 1]` is

   ```
   E = [2 3 4 5 6 1]
   ```

   Note that the unique vector does not need to be sorted in any particular order, however it must contain only one of every distinct value of the input vector.

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

   NOTE : You may NOT use the MATLAB function `unique` in your answer.

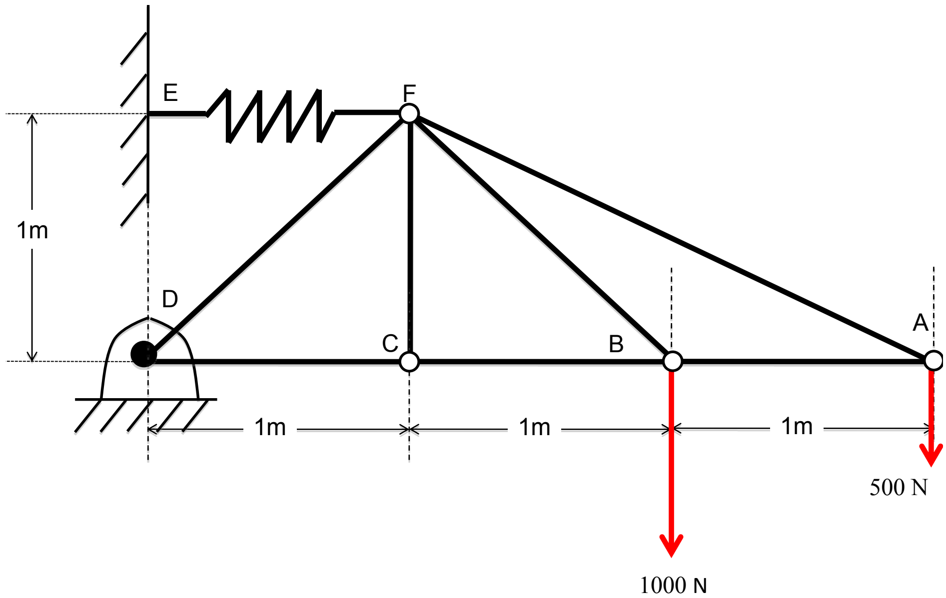
   Hints :

   - The MATLAB function `isnumeric(A)` returns 1 if `A` is a numeric array and 0 otherwise.
   - The MATLAB function `ismember(A,B)` where `A` is a number and `B` is a vector, returns 1 if `A` is contained in `B` and 0 otherwise.

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

Question 3 (20 marks)

1. **[10 marks]** In many Derrick crane designs, the crane is anchored to the ground at one point and held upright by a flexible cable at another point. The figure below illustrates a simplified Derrick crane design with a 500 N weight at point A and another 1000 N point load applying at point B. To simplify the analysis, the flexible cable is modelled by a linear spring with spring constant, k = 17,500 N/m.



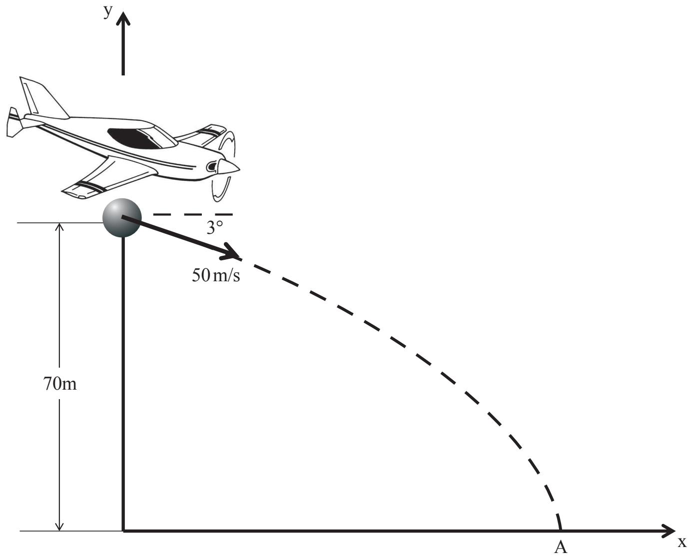
(a) **[1 marks]** Sketch the free body diagram of the system described above.

(b) **[3 marks]** Calculate the reaction forces at both points D and E. Express the reaction forces as vectors.

(c) **[5 marks]** Using the 'Method of Joints', evaluate the force in 3 truss members BC, FC and FD. In order to get full marks, you need to specify whether each member is in 'Compression' or in 'Tension'.

(d) **[1 marks]** Given $k = 17{,}500$ N/m, find the **natural length** of the spring if the system is in equilibrium. Note that the spring is a linear spring.

2. [**10 marks**] A pilot releases a spherical object 70 m above the ground. The object has an initial velocity 50 m/s at an angle of 3° to the horizontal as illustrated in the figure below.



The pilot is aiming the spherical object at point A in the figure. The aerodynamic drag of the spherical object is

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

where V is the velocity of the aeroplane, C_D is the coefficient of aerodynamic drag, ρ is the density of air and A is the spherical object's frontal surface area. The mass of the object is m.

(a) [**4 marks**] Derive the governing equations that define the 2-dimensional motion of the spherical object under the effects of aerodynamic drag and gravity.

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

(b) [**4 marks**] Assume ZERO aerodynamic drag in the set of ordinary differential equations that you derived in part (a). Calculate the drag-free (and hence approximate) landing point of the spherical object and the duration time of the flight of the spherical object. The initial velocity of the spherical object is 50 m/s at an angle of 3° to the horizontal.

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

(c) **[2 marks]** Using your result from part (b), calculate the magnitude and the angle of the final velocity of the spherical object when it hits the ground in the absense of aerodynamic drag.

END OF EXAMINATION