UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
MAY 2012 SEMESTER

COURSE : **MBB3043 / MCB3083 – MECHANICAL ENGINEERING DESIGN**

DATE : **6TH SEPTEMBER 2012 (THURSDAY)**

TIME : **9.00 AM – 12.00 NOON (3 hours)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in from the Question Booklet.
2. Begin **ALL** answers on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions.
5. Do not open this Question Booklet until instructed.

Note : There are **ELEVEN (11)** pages in this Question Booklet including the cover page and appendices.

1. A helical compression spring is made of ASTM A228 music wire. The wire diameter is 8 mm and the outside diameter of the spring is 120 mm. The ends are plain and ground, and there are 32 total coils. The spring is wound to a free length, which is largest possible with a solid-safe property.

   a. Interpret "solid-safe property" in the context of spring design.

   [5 marks]

   b. Evaluate

      i. the force needed to compress the spring to its solid length.

      [8 marks]

      ii. the spring rate, the free length and the pitch of the spring.

      [3 marks]

   c. Justify with calculation whether the spring might buckle in service.

   [4 marks]

2. The power from the engine of a front wheel drive car is transmitted to the gearbox by a chain drive as shown in **FIGURE Q2**. The two sprockets are of the same size. The chain transmits 120 kW of power at the chain speed of 54 m/s when the engine speed is 6000 rpm. The shafts are made of AISI1080 steel. The yield strength of AISI1080 is 380 MPa.

   a. Sketch the free body diagram indicating the forces on the driven shaft.

   [4 marks]

   b. Evaluate the reaction forces at the supports A and B.

   [8 marks]

   c. Assess the required diameter of the driver shaft using Distortion Energy Theory (DET) assuming the safety factor is 2.

   [8 marks]

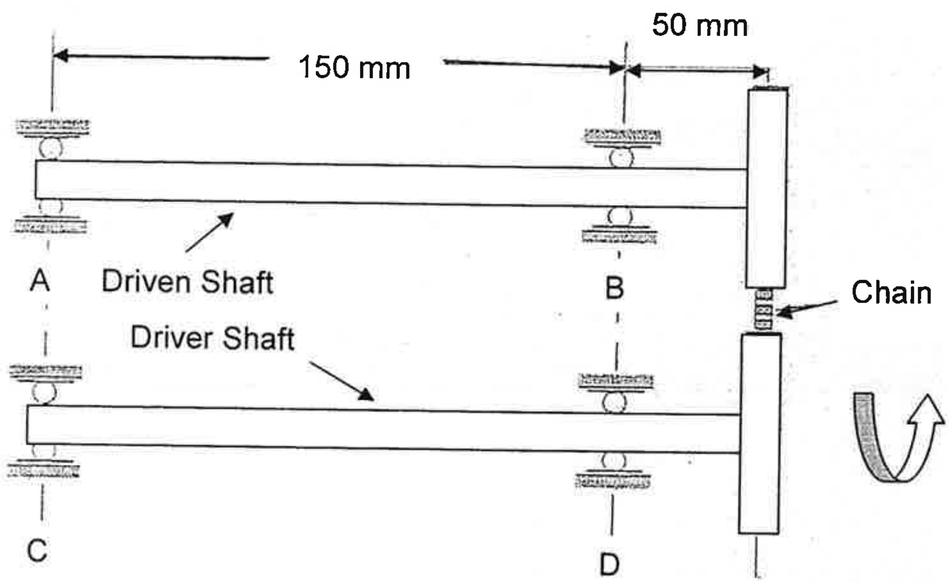

FIGURE Q2

3. The worm gear screw jack has a rated vertical load of 9 kN. The screw has single square threads with a major diameter of 0.04 m and a pitch of 0.006 m. Coefficients of friction are 0.07 for the threads and 0.08 for the collar bearing. The diameter of the collar is 0.15 m. The worm gear has a transmission efficiency of 82% and a speed ratio of 12:1. The speed of the motor driving the worm is 2200 rpm.

   a. Formulate an expression for obtaining the torque required to rotate against the axial load.

   [10 marks]

   b. Evaluate the linear speed of the screw in metres per second and the required power rating of the motor.

   [10 marks]

4. **FIGURE Q4** shows a schematic representation of the water sprinkler system in case of fire in the building. When the smoke sensor is triggered, a signal is sent to the motor driving the water pump. When the pump starts working, water is drawn through valves V1 and V2 from tanks Tank1 and Tank2. The water outlet pipe in each tank is fitted with a Filter F1 and F2, to prevent sediment and other debris being drawn into the system. Water from pump is forced along pipe P6 to the Nozzle, where it emerges as spray. The design engineer feels the need to construct the Fault Tree diagram for the system.

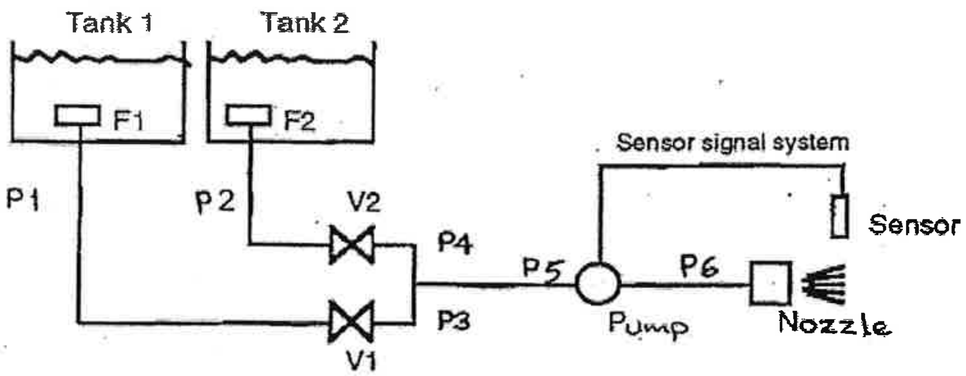

FIGURE Q4

a. Justify the need to construct the Fault Tree diagram for this system.

[6 marks]

b. Construct the Fault Tree diagram for the entire system.

[14 marks]

5. A cantilever beam as shown in **FIGURE Q5** is loaded with force "*P*" at its free end to produce a deflection. The cantilever beam has a circular cross section. Properties and cost of candidate materials for the beam are given in **TABLE Q5**.

Note: Deflection, $\delta = \frac{PL^3}{3EI}$, Moment of Inertia of circular cross section cantilever beam, $I = \frac{\pi r^4}{4}$

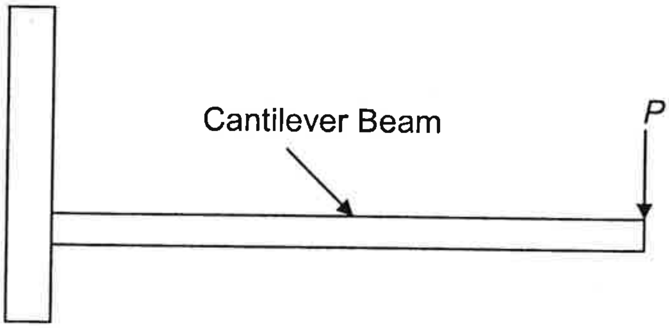

FIGURE Q5

TABLE Q5

Material	GNm^{-2}	ρ Mgm^{-3}	Approximate Cost. $/ton (1980)
Steel	200	7.8	450
Wood	12.5	0.6	450
Concrete	50	2.6	300
Aluminum	69	2.7	2,000
Carbon-fibre-reinforced plastic (CFRP)	135	1.5	200,000

a. Formulate a performance index for selecting a material that minimizes the weight of a beam for a given stiffness, which is $\frac{P}{\delta}$.

[10 marks]

b. Select the best material on the basis of performance by using the properties of candidate materials in **TABLE Q5**.

[5 marks]

c. Select the best material on the basis of cost and performance by using the properties and cost of candidate materials in **TABLE Q5**.

[5 marks]

- END OF PAPER –

APPENDIX I

Helical Compression Spring:

Spring index, $C = \dfrac{D}{d}$

Minimum tensile strength, $S_{ut} = \dfrac{A_p}{d^m}$

Shear stress, $\tau = K_B \dfrac{8FD}{\pi d^3}$

Shear stress correction factor, $K_B = \dfrac{4C+2}{4C-3}$

Spring constant, $k = \dfrac{d^4 G}{8D^3 N_a}$

The condition for absolute stability is: free length, $L_o < 2.63\dfrac{D}{\alpha}$, (Where $\alpha = 0.5$)

Shaft:

Shear stress, $\tau_{xy} = \dfrac{cT}{J}$, where $J = \dfrac{\pi d^4}{32}$

Bending stress, $\sigma_x = \dfrac{cM}{I}$, where $I = \dfrac{\pi d^4}{64}$

Principal stress, $\sigma_1, \sigma_2 = \dfrac{\sigma_x}{2} \pm \sqrt{\tau_{xy}^2 + \dfrac{\sigma_x^2}{4}}$

Von Mises Stress, $\sigma_e = \left(\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2\right)^{0.5}$

The Distortion Energy Theory predicts that failure will not occur if:

$\sigma_e < \dfrac{S_y}{n_s}$

Power Screws:

Mean or pitch diameter, $d_m = d - \frac{p}{2}$

Lead, $l = np$

Minor diameter, $d_r = d - p$

The torque required by the square thread power screw to raise the load (i.e. to rotate against the load),

$$T = \frac{Fd_m}{2}\left[\frac{l + \pi\mu d_m}{\pi d_m - \mu l}\right] + \frac{F\mu_c d_c}{2}$$

Power transmitted in kW, $P(\text{kW}) = \frac{Tn}{9549}$ (Where T is in Nm and n is in rpm)

APPENDIX II

TABLES FOR MECHANICAL ENGINEERING DESIGN

Table 1: Formulas for the Dimensional Characteristics of Compression-Spring

Material	Type of Spring Ends			
	Plain	**Plain & Ground**	**Squared or closed**	**Squared & Ground**
End coils, N_e	0	1	2	2
Total coils, N_t	N_a	$N_a + 1$	$N_a + 2$	$N_a + 2$
Free length, L_o	$pN_a + d$	$p(N_a + 1)$	$pN_a + 3d$	$pN_a + 2d$
Solid length, L_s	$d(N_t + 1)$	dN_t	$d(N_t + 1)$	dN_t
Pitch, p	$(L_o - d)/N_a$	$L_o/(N_a + 1)$	$(L_o - 3d)/N_a$	$(L_o - 2d)/N_a$

Table 2: Constants A and m of $S_{ut} = A/d^m$ for Estimating Minimum Tensile Strength of Common Spring Wires (Source From Design Handbook, 1987, Associated Spring.

Material	ASTM No.	Exponent m	Diameter, mm	A, MPa . mm^m	Relative Cost of Wire
Music Wire	A228	0.145	0.10 – 6.5	2211	2.6
OQ & T Wire	A229	0.187	0.5 – 12.7	1855	1.3
Hard drawn wire	A227	0.190	0.7 – 12.7	1783	1.0
Chrome-vanadium wire	A232	0.168	0.8 – 11.1	2005	3.1
Chrome-silicon wire	A401	0.108	1.6 – 9.5	1974	4.0

Table 3: Maximum Allowable Torsional Stresses for Helical Compression Springs in Static Applications

Material	Maximum Percentage of Tensile Strength Before Set Removed (includes K_w or K_B)	After Set Removed (includes K_s)
Music wire (A228) and cold-drawn carbon steel	45	60 – 70
Hardened and tempered carbon and low-alloy steel	50	65 – 75
Austenitic stainless steels	35	55 – 65
Nonferrous alloys	35	55 – 65

Table 4: Mechanical Properties of Some Spring Wires

Material	Elastic Limit, Percent of S_{ut}, Tension	Torsion	Diameter, d, mm	E, GPa	G, GPa
Music wire A228	65 - 75	45 - 60	< 0.8	203.4	82.7
			0.8 – 1.6	200	81.7
			1.61 – 3	196.5	81.0
			> 3	193	80.0
HD spring A227	60 – 70	45 – 55	< 0.8	198.6	80.7
			0.8 – 1.6	197.9	80.0
			1.61 – 3	197.2	79.3
			> 3	196.5	78.6
Oil tempered A239	85 – 90	45 – 50		196.5	77.2
Valve Spring A230	85 – 90	50 – 60		203.4	77.2