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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAM
SEMESTER 2
SESSION 2014/2015

COURSE NAME	:	TRIBOLOGY
COURSE CODE	:	BDC 40503
PROGRAMME	:	4 BDD
EXAMINATION DATE	:	JUNE / JULY 2015
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **5 (FIVE)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

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Q1 (a) List the **SEVEN (7)** assumptions are made in Reynolds' equation derivation.

(4 marks)

(b) Derive the equation for long bearing from the following Reynolds' equation,

$$\frac{\partial}{\partial x}\left[\frac{h^3}{\eta}\frac{\partial p}{\partial x}\right] + \frac{\partial}{\partial z}\left[\frac{h^3}{\eta}\frac{\partial p}{\partial z}\right] = 6\left[\frac{\partial}{\partial x}\{h(U_1 + U_2)\} + \frac{\partial}{\partial z}[h\{W_1 + W_2\}\right] + \cdots$$

$$\ldots. + \frac{2d}{dt}(\rho h)$$

(10 marks)

(c) Describe and illustrate with the drawing of Couette shear flow and Poiseuille pressure flow for the following lubricant velocity equation in *x* direction:

$$u = \frac{1}{2\eta}\frac{\partial p}{\partial x}\,(y^2 - hy) + \frac{y}{h}\,(U_1 - U_2) + U_1$$

(6 marks)

Q2 In Nano-tribology cases, a roller with 2 mm radius and 5 mm length is coated with Diamond Like Carbon Coating (DLC) and rolls without sliding with a speed of 60 rpm on a flat surface also coated with DLC, using a nano-lubricant as intervening fluid with viscosity of 0.00035 Pa.s. Load of 2 mN is applied. The composite roughness is 100 nm.

(a) (i) Explain the meaning of Diamond Like Carbon Coating (DLC)
(ii) Describe the types of nano-lubricant commonly used
(iii) List **FIVE (5)** examples where nano-tribology are applied

(9 marks)

(a) Calculate the regime film thickness of lubricant.

(6 marks)

(b) Determine the coefficient of friction if friction force required to break the bond (F_a) is 3.16×10^{-6} N and the meniscus force (F_m) is 0.5 mN.

(5 marks)

Q3 (a) An Oswald tube glass viscometer shown as in **FIGURE Q3**, has been used to analyze the viscosity of a certain lubricant with the following **Table Q1** .

Table Q1

Parameters	**Symbol**	**Value**	**Unit**
Tube radius	R	1.8	mm
Hydrostatic height	h_m	130	mm
Lubricant height	L	90	mm
Gravity (in Chicago)	g	9.8	m/s^2
Lubricant density	ρ	890	Kg/m^3
Volume of lubricant from level M1 to M2	V	5.7	mL
Flowing time from level M1 to M2	t	200	second

(i) Calculate the dynamic viscosity of this lubricant

(ii) Calculate the kinematic viscosity of this lubricant

(iii) Find the size and factor K of this viscometer

(12 marks)

(b) In order to investigate the viscosity of a an engine lubricant, the falling ball viscometer is used. The diameter of the ball is 15 mm, with 2500 kg/m3 in density. The lubricant density is 890 kg/m3. The ball falls down along the tube of 400 mm in 20 seconds.

(i) Calculate the dynamic viscosity of this lubricant if the gravity is 9.82 m/s^2.

(ii) What is the viscosity of this lubricant in the unit of *reyn* .

(8 marks)

Q4 A turbine engine is running at 6000 rpm, under load of 60 kN. The dimension of the journal bearing is 20 cm in diameter, and 15cm in length. The oil temperature is 30 °C with density of 860 kg/m³. The coefficient of specific heat of lubricant is 1880 J/kg°C and the constant of heat removal k_1 is 0.75, with reciprocal Sommerfeld number is 0.7855. The film thickness is estimated not more than 40 micron. The flow rate constant is 0.751 and friction constant is 17.1. The eccentricity ratio is 0.35.

(a) Demonstrate by drawing how the lubricant pressure distributed around the journal and define also the clearance and eccentricity ratio.

(4 marks)

(b) Calculate the radial clearance of the journal

(4 marks)

(c) Find the increase of the lubricant temperature

(4 marks)

(d) What is the Lubricant viscosity under this temperature (c)

(4 marks)

(e) Calculate the temperature at both side of the lubricant inflow if: a = 0.2 cP, b = 800 °K and c = 200° K.

(4 marks)

Q5 Machine with thrust bearing is rotating at 2000 rpm and carrying load of 4kN. The dimension of the journal bearing is 20 cm in diameter , and 16 cm in length. The inner pad length is 40 mm with inclined ratio K is 1. The oil temperature is 40 °C with density of 850 kg/m³. The coefficient of specific heat of lubricant is 1880 J/kg°C and constant of heat removal k_1 is 0.8, with constant mean temperature is 0.5.

(a) Describe the mechanism of thrust bearing and illustrate with drawing (3 marks)

(b) What is the increase of the lubricant temperature (3 marks)

(c) Find the effective temperature (2 marks)

(d) Calculate the effective viscosity if a = 0.18 cP, b =700 ° K and c = 200° K. (3 marks)

(e) What is the thickness of lubricant film (3 marks)

(f) Find the lubricant flow rate (2 marks)

(g) Determine the friction force and coefficient of lubricant friction (2 marks)

(h) Calculate the power consumption of this bearing (2 marks)

Q6 In order to analyze the synovial joint of a man with 100 Kg weight, the medical doctor consult with an engineer of UTHM to investigate the bio-tribology parameters of the patient. It is found that the femoral head diameter is 60 mm, clearance 2 mm, viscosity of the joint fat is 0.002 Pa.s. This patient use to walk with joint speed of 1.5 radial per second. It is also found that the elastic modulus of the bone is 25 MPa.

(a) If you are the engineer to assist this medical doctor, calculate the minimum film thickness of this lubricant joint to support the weight of this man.

(8 marks)

(b) The doctor recommended that the minimum film thickness is 8 micron, what shall be the normal weight of this man .

(6 marks)

(c) After few years the man come back to the doctor because of his joint suffered pain, the doctor analyze and found that the viscosity has been reduced to 0.0015 Pa.s. Calculate the film thickness of this new condition, assume the parameter given are the same.

(6 marks)

END OF QUESTIONS

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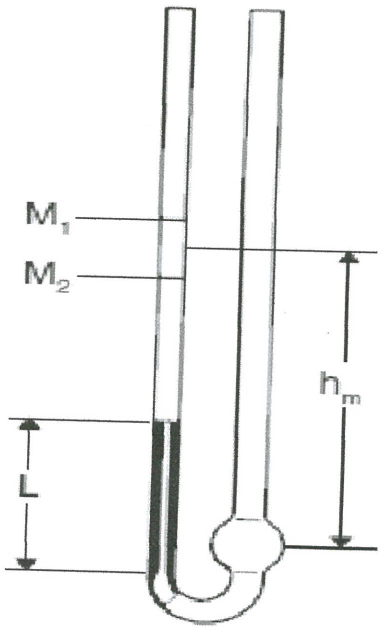

FIGURE Q3

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USEFUL FORMULAS

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$$\eta = (\pi R^4 g h_m t)(8LV)$$

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$$c = \frac{h_o}{(1-\varepsilon)}$$

$$K_1 = \frac{k_1}{\rho\, cp}$$

$$\Delta\theta_s = \frac{2\, U^*\, K_1\, W}{Q^* R\, L}$$

$$\eta = \frac{1}{S}\left(\frac{W}{\pi NDL}\right)\left(\frac{c}{R}\right)^2$$

$$\Delta\theta_{s1} = \theta_0 + \Delta\,\theta_s$$

$$\ln\eta = \ln a + \frac{b}{(\theta_{s2}-c)}$$

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$$K_1 = \frac{k_1}{\rho\, cp}$$

$$\theta_s = \frac{F^*\, K_1\, W\,(K+2)}{W^* B\, L\,(K+1)}$$

$$\Delta\theta_e = \theta_0 + \Delta k_2\, \theta_s$$

$$\ln\eta_e = \ln a + \frac{b}{(\theta_e - c)}$$

$$h_o^2 = \frac{k_1\, U\, B\, \eta_e\, \theta^*}{\Delta\theta_s\, \rho\, cp}$$

$$F^* = \frac{4\ln(K+1)}{K} - \frac{6}{K+2}$$

$$\theta^* = \frac{4\ln(K+1)}{K} - \frac{6}{K+2}$$

$$W^* = \frac{6\ln(K+1)}{K^2} - \frac{2K}{K+2}$$

$$Q^* = \frac{K+1}{K+2}$$

$$F = \frac{F^*\,(LBU\eta_e)}{h_o}$$

$$Q = Q^*\, UL\, h_o \qquad P = F\,U \qquad \mu = \frac{F}{W}$$

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$$h_o = 1.4\left(\frac{D^2}{c}\right)\left(\eta\,\Omega\,\frac{c}{2E'\,D}\right)^{0.65}\left(4\,W\,\frac{c^2}{E'\,D^4}\right)^{-0.21}$$

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$$U = 2\pi RN$$

$$h_o = \frac{2\;B\,U\,\eta_o\,R}{W}$$

$$F_n = F_m + W$$

$$\mu = \frac{F_a}{F_n}$$

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$$\nu = \frac{\pi R^4\, g\, h_m\, t}{8\, L\, V}$$

$$\eta = \frac{\pi R^2\, g(\rho_p - \rho_f)}{9\, V_s}$$