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CONFIDENTIAL

SET A

UNIVERSITI KUALA LUMPUR
Malaysia France Institute

FINAL EXAMINATION
JANUARY 2010 SESSION

SUBJECT CODE	:	FCB 40403
SUBJECT TITLE	:	AIR DISTRIBUTION AND SECONDARY FLUIDS
LEVEL	:	BACHELOR
TIME / DURATION	:	9.00am – 1.00pm (4 HOURS)
DATE	:	28 MAY 2010

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 questions paper consists of TWO (2) sections. Answer ALL questions in section A and B.
6. Answer ALL questions in English.
7. All documents authorized. (OPEN BOOK examination)
8. In the event of graphic resolution of a problem, return e graph and write down your ID on each return sheet.

THERE ARE 4 PAGES OF QUESTIONS, EXCLUDING THIS PAGE.

SECTION A (Total 20 marks)

INSTRUCTION: Answer ALL questions.

Please use the answer booklet provided.

In all problems, we will suppose that the density of the air is of 1,2 kg/m ^{3}.

Question 1

We wish to select a fan allowing to circulate an air flow of 3000 m ^{3} / h for an air distribution network presenting a pressure drop of 340 Pa.

From manufacturers documents, we plans to use a fan pertaining to a series of fans whose non-dimensional characteristics (Rateau coefficients) are given in Table I (in the form of numerical values) and Figure 1 (in the form of graphs traced using the values of Table I).

The manufacturer of fans proposes two solutions to ensure the desired flow and the total head, at relatively comparable costs:

solution 1 : a fan of radius 0,5 m turning at a speed of 750 tr/min

solution 2 : a fan of radius 0,31 m turning at a speed of 1450 tr/min

(a) From the provided Rateau coefficients, determine the best efficiency η_{max} and to deduce the values of coefficients μ_{opt}, δ_{opt} and τ_{opt} leading to this efficiency.

(2 marks)

(b) From the values determined in question (a), evaluate the radius and the number of revolutions optima and to compare them with the radius and the speed proposed in solution 1 and solution 2. To indicate which is the best solution.

(1 mark)

(c) For the solution chosen, to evaluate the efficiency and the power absorbed by the fan.

(2 marks)

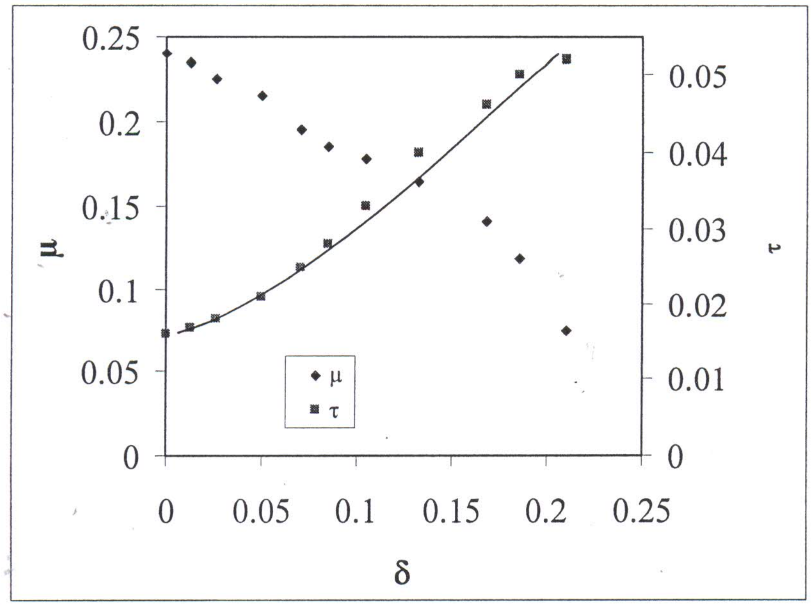


Figure 1 : Non-dimensional characteristics of the series of fans

δ	μ	τ
0	0,24	0,016
0,013	0,235	0,0169
0,026	0,225	0,018
0,0498	0,215	0,021
0,071	0,195	0,025
0,085	0,1857	0,028
0,105	0,178	0,033
0,1327	0,165	0,04
0,168	0,141	0,046
0,1854	0,119	0,05
0,21	0,075	0,052

Table I : Numerical values of figure 1

Question 2

We study a glycol system used as secondary fluid of a refrigerating unit. The circuit is represented in Figure 2.

Some data :

- for glycol water, ρ= 1090 kg/m ^{3} and μ=7.10 $^{-3}$ Pa.s
- the elbows are with R/D=1 of the type 3-1 (ASHRAE nomenclature)

- angle of the elbows C1 and C2 = 45° and angle of the elbow C3 = 90°
- derivation D of the type 5-33 (ASHRAE) with an angle of 45°
- the exchangers E1 and E2 involve a pressure drop of 0,1 bar each
- pressure drop at the exit of each negligible branch
- Main: diameter 7 cm and flow 15 m^3/h - total pressure drop of 5000 Pa
- Branch A: diameter 5,5 cm - length 32 m (except exchanger) - flow 7,5 m^3/h
- Branch b: diameter 5,5 cm - length 18 m (except exchanger) - flow 7,5 m^3/h
- roughness: 80 µm

(a) Calculate the pressure drop in each branch without taking account of the valve V For the calculation of the linear loss ratio of load, we will use the correlation of Colebrook.

(3 marks)

(b) The valve V has as a function to balance the network. What pressure drop does it have to induce?

(3 marks)

(c) To determine the total head of the pump to install to ensure the operation of the installation after adjustment of the valve V.

(2 marks)

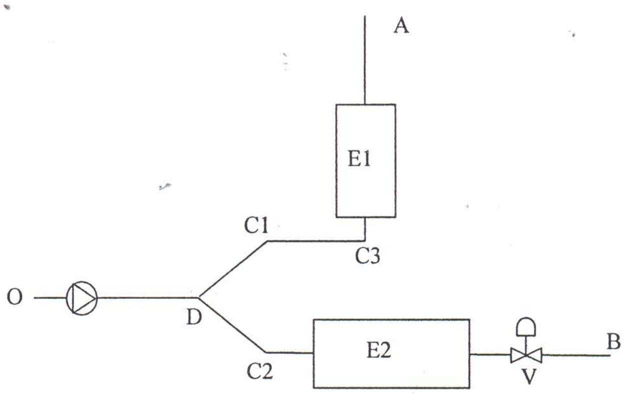
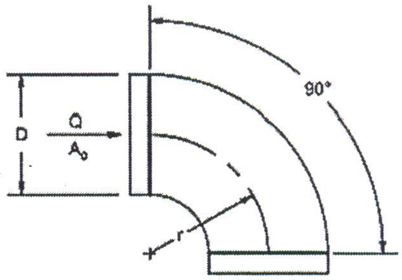


Figure 2: Glycol system – plan view - all the elements are in a horizontal plane.

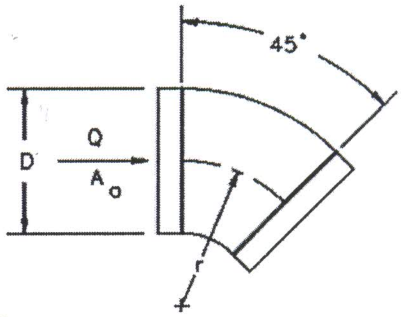
CD3-1 Elbow, Die Stamped, 90 Degree, r/D = 1.5

D, mm	75	100	125	150	180	200	230	250
C_o	0.30	0.21	0.16	0.14	0.12	0.11	0.11	0.11

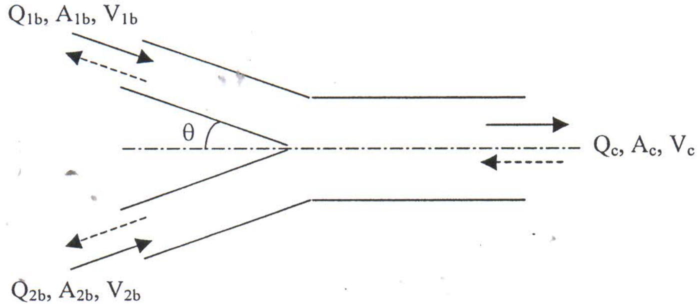


CD3-3 Elbow, Die Stamped, 45 Degree, r/D = 1.5

D, mm	75	100	125	150	180	200	230	250
C_o	0.18	0.13	0.10	0.08	0.07	0.07	0.07	0.07



Derivation of the type 5-33



where, A is the section (m ^{2}), Q the volume flow rate (m ^{3} / s) and V speed (m/s).

Converging

θ deg	ζ_{1b} or ζ_{2b} — Q_{1b}/Q_c or Q_{2b}/Q_c: 0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
15	-2.6	-1.9	-1.3	-0.77	-0.30	0.10	0.41	0.67	0.85	0.97	1.0
30	-2.1	-1.5	-1.0	-0.53	-0.10	0.28	0.69	0.91	1.1	1.4	1.6
45	-1.3	-0.93	-0.55	-0.16	0.20	0.56	0.92	1.3	1.6	2.0	2.3

Diverging

θ deg	ζ_{1b} or ζ_{2b} — V_{1b}/V_c or V_{2b}/V_c: 0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
15	0.81	0.65	0.51	0.38	0.28	0.20	0.11	0.06	0.14	0.30	0.51	0.76	1.0
30	0.84	0.69	0.56	0.44	0.34	0.26	0.19	0.15	0.15	0.30	0.51	0.76	1.0
45	0.87	0.74	0.63	0.54	0.45	0.38	0.29	0.24	0.23	0.30	0.51	0.76	1.0
60	0.90	0.82	0.79	0.66	0.59	0.53	0.43	0.36	0.33	0.39	0.51	0.76	1.0
90	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Question 3

We consider the air distribution network represented on Figure 3. The desired flows are 5000 m ^{3} / h in the main duct (diameter 500 mm), 3200 m ^{3} / h, in branch A (diameter 300 mm - length 25 m) and 1800 m ^{3} / h in the branch B (diameter 250 mm - length 28 m). We wish to use the fan, to ensure this flow rate. The fan characteristics are given on Figure 4 and in Table II.

All calculations done, it is shown that for the flows chosen, the pressure drop in the main and all of its various components (filters, AHU, inlet...) is 300 Pa. The pressure-drop in branch A is 157 Pa and that in the branch B of 154 Pa (except diffusers in both cases). Lastly, the pressure drop induced by each diffuser (in A and B) is of 15 Pa.

(a) Calculate the total pressure drop of the network.

(2 marks)

(b) Determine the point of operation of the installation if the fan feeds the network of Figure 3. This operation is it as per the specification?

(1 mark)

(c) To ensure the required values of flow, we proceeds to the installation of a register. Indicate the pressure drop which the register must induce. Calculate the power consumption by the fan.

(1 mark)

At the end of a certain time of use, the filters of the AHU are clogged so that they induce an additional pressure drop of 50 Pa, being added to the pressure drop specified initially (300 Pa). We maintain moreover the adjustment of the register determined at question 3(c).

(d) To show that because of the additional pressure drop related to clogging, the flow in branch A is established as 2777 m ^{3} /h and that of the branch B as 1568 m ^{3} /h, is a total flow in the root as 4345 m ^{3} /h.

(Note: To answer this question, it will be checked that with these new flows, the network is balanced and that the profit of pressure of the fan for the total flow is quite equal to the pressure drop induced by the network).

(1 mark)

Complementary data for the new mode :

- linear pressure losses for each branch: λ_A = 0,01742 and λ_B = 0,01858
- singularities: ζ_A = 0,2 and ζ_B = 0,4 (with reference to at the velocity upstream as per usual convention)
- $\Delta P_{diffuser}$ unchanged

(e) To calculate the power consumption by the fan under these new conditions

(1 mark)

(f) To compare operation with a clean filter and a clogged filter (variation of the flows, power consumption, etc...)

(1 mark)

(g) We decide then, to guarantee the flows given in the specification, to increase the speed of the fan. The adjustment of the register remains identical and the filters are not cleaned. To explain, qualitatively, the effect of such a modification on the power consumption of the installation compared to the situation obtained with question 2 (filter clean and installation of the register).

(1 mark)

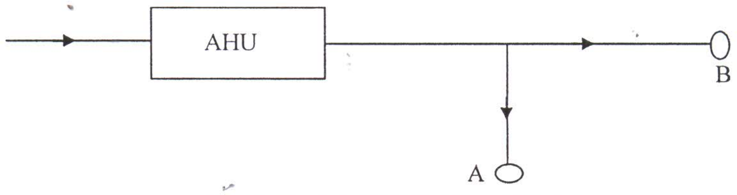


Figure 3: Air distribution network

V (m^3/h)	ΔP (Pa)	W (kw)	η
0	783	0,503	0,00
358	737	0,521	0,14
912	742	0,538	0,35
1710	715	0,628	0,54
2541	703	0,660	0,75
3065	680	0,740	0,78
3648	630	0,774	0,83
4264	604	0,903	0,79
5172	543	1,180	0,66
6182	460	1,528	0,52
7267	298	1,667	0,36

Table II: Characteristics of the selected fan (problem 3)

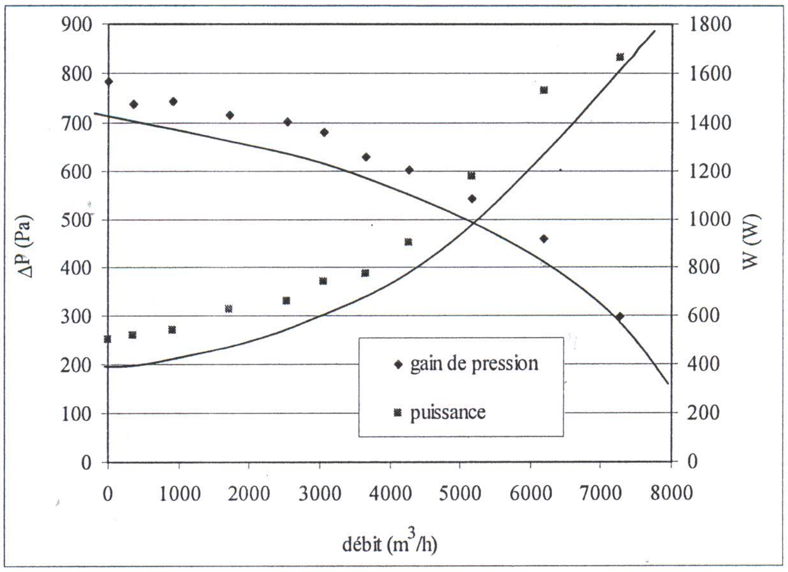


Figure 4: Characteristics of the selected fan (problem 3)

SECTION B (Total 10 marks)

INSTRUCTION: Answer ALL questions.

Please use the answer booklet provided.

Question 4

A dairy uses chilled water (+1°C) produced by means of a refrigerating machine of 150 kW whose control is staged at 33%, 66% and 100%. Chilled water is produced by a plate type heat exchanger which is then directed towards a tank before use. It returns from the load at +5°C.

The analysis of the histogram of the load requirements this application is summarized in the following table:

	Schedule times	Refrigerating needs
Milked reception of the morning	08h00 - 09h00	250 kW
Day time operation	09h00 - 19h00	100 kW
Milked reception of the evening	19h00 - 20h00	250 kW
Night operation	20h00 - 08h00	50 kW

(a) Is the system, correctly sized to ensure the refrigerating needs for this dairy?

(0.5 mark)

(b) Calculate the volume of the tank so that the system can meets the needs.

(1 mark)

(c) Is the refrigerating machine, enough powerful to re-charge the tank in the time section 09h00 – 19h00?

(0.5 mark)

One of the outlets of the tank supplies a heat exchanger of 80 kW located at 50 meters from there.

(d) What volume flow rate of chilled water you would use (one will take one $\Delta\theta$ of 4K)

(0.5 mark)

(e) By neglecting the effects of the temperature of water between the supply and the return, and by supposing a turbulent flow in pipings of connection, what diameter of piping would you use?

(1 mark)

(f) If would the diameter selected were 65 mm (DN65), what will be the pressure loss in pipe?

(0.5 mark)

The exchanger consists of 10 rows of tubes (smooth tubes) 1.5 cm in diameter.

(g) Give the coefficient of heat transfer at the side of chilled water.

(1 mark)

(h) By supposing that external side transfers are of the same order of magnitude as the coefficients of internal side transfer ($h_{total} = \frac{h_{internal}}{2}$) and by knowing that the LMTD is 10.8 K for this application, what length of tubes is necessary to heat transfer the required 80 kW?

(1 mark)

(i) By neglecting the singular pressure losses, which will be the pressure loss in this exchanger?

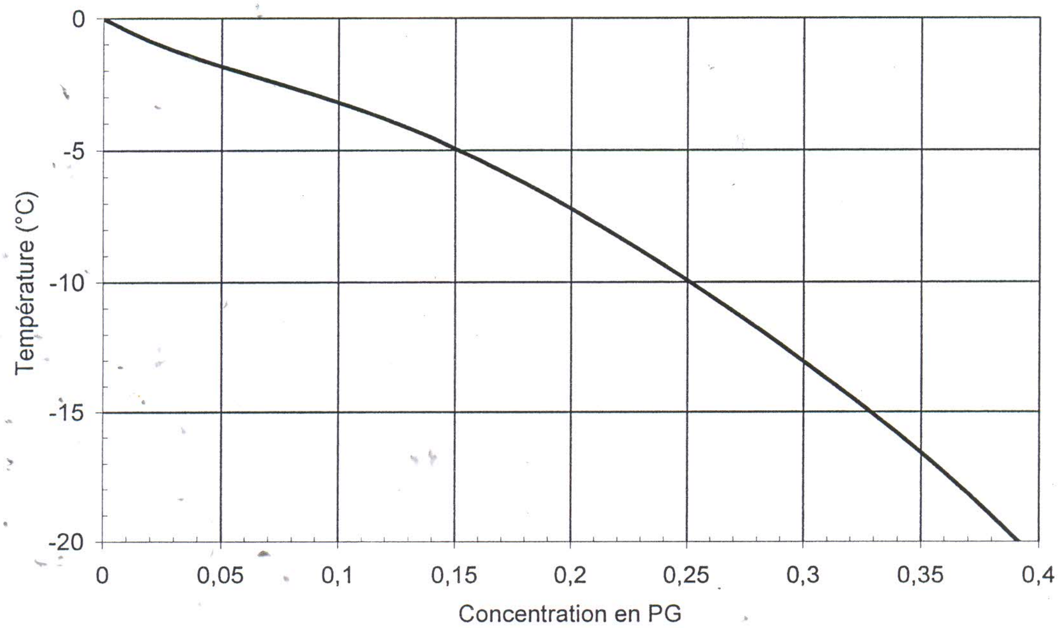
(1 mark)

(j) What will be the pressure loss in the whole of the circuit (pipings + exchanger; The possible presence of valves and singular pressure losses will not be taken into account)?

(1 mark)

Question 5

The figure below represents the equilibrium curve solid/liquid of a mixture of water and mono propylene glycol.



One has a mixture with an initial concentration of 15% in PG

(a) What is the starting temperature of freezing for this mixture?

(0.5 mark)

One leads this mixture to a temperature of –10 °C: a slurry of ice is obtained.

(b) What is the concentration in PG of the residual liquid (liquid phase).

(0.5 mark)

(c) What is the concentration in ice of this slurry?

(0.5 mark)

(d) While taking into account only the latent heat of the ice (333 kJ kg^{-1}), what volume of this slurry is necessary to store 100 kWh necessary for the application as obtained at the time of problem 1? (Note: The density of the slurry is: 980 kg m^{-3}).

(0.5 mark)

END OF QUESTION