Mansoura University
Faculty of Engineering
Mechanical Power Eng. Dept.
Fourth Year
Fluid Machines

First Semester (Jan. 2012)
Final Exam
21 January 2012
Time Allowed: 3 hr

Closed Book Examination. Assume any Missing Data.

Answer the Following Questions:

(1) (a) Show that for a centrifugal fan with zero whirl at inlet:

$$H_0 = \frac{U_2^2}{g} \cdot \frac{\tan\beta_2}{\tan\beta_2 - \tan\alpha_2} = \frac{U_2^2}{g} \cdot (1 + \phi \cot\beta_2)$$

where $\phi = C_{r2} / U_2$. (6 Marks)

(b) A backward-swept centrifugal fan is required to provide a supply of pressurized air to a furnace. The specification requires that the fan produce a total pressure rise equivalent to 7.5 cm of water at a volume flow rate of 0.2 m^3/s. At the impeller exit, the ratio of the passage width to perimeter being specified as 1/60, and the ratio of the radial velocity to peripheral velocity as 0.1. The blade angle at exit is 135°. Assuming that the efficiency of the fan is 0.75, determine:

(a) the peripheral velocity,
(b) the rotational speed and diameter of the impeller,
(c) the power required to drive the fan if the mechanical efficiency is 0.95.

For air, assume the pressure is 10^5 Pa and the temperature is 20°C. (10 Marks)

---

(2) (a) Draw an illustrative diagram of a centrifugal compressor stage indicating the names of its principal parts. What is the purpose of inducer blades? (3 Marks)

(b) For a radial tipped impeller of a centrifugal compressor, show that the impeller total-to-total efficiency can be expressed as:

$$\eta = \frac{c_p T_{o1} (p_{ro}^{\frac{\gamma-1}{\gamma}} - 1)}{\mu U_2^2 - U_1 C_{u1}}$$

where $p_{ro} = p_{02ss} / p_{01}$ is the pressure ratio and μ the slip factor. (7 Marks)

(c) The inlet of a centrifugal air compressor has a tip diameter of 0.2 m and a hub diameter of 0.105 m. Free-vortex guide vanes are fitted in the duct upstream of the impeller so that the flow on the tip of the impeller inlet has a relative Mach number, $M_{1,rel}$ = 1.0, an absolute flow angle of α_1 = 70°, and a blade angle β_1 = 145°. At inlet the stagnation conditions are 288 K and 10^5 Pa. At exit from the radially vaned impeller, the vanes have a radius of 0.16 m and a slip factor of 0.9. Assuming an impeller total-to-total efficiency of 0.9 and frictionless flow into the inlet, determine:

(a) the rotational speed of the impeller,
(b) the air mass flow rate,
(c) the shaft power input,
(d) the impeller pressure ratio. (10 Marks)

---

(3) (a) For a centrifugal compressor without inlet guide vanes, show that the axial velocity at inlet ($C_{a1} = C_1$) can be expressed as:

P.T.O.

$$C_{a1} = \frac{\dot{m} R T_{01}}{A_1 p_{01}} \cdot \left(1 - \frac{C_1^2}{2 c_p T_{01}}\right)^{\frac{-1}{\gamma-1}}$$ (5 Marks)

(b) An aircraft engine is fitted with a single-sided centrifugal compressor. The aircraft flies at an altitude where the stagnation pressure is 0.23 bar and the stagnation temperature 217 K. The compressor without inlet guide vanes has a radial tipped impeller. The inner and outer diameters of the eye are 180 mm and 330 mm respectively. The diameter of the impeller tip is 540 mm and the stagnation pressure ratio is 4. Estimate the blade angle at inlet and the static temperature at the compressor outlet when the mass flow rate is 216 kg/min and the air angle at outlet is 30°. Assume that the total-to-total efficiency is 0.8 and the slip factor is 0.9. (10 Marks)

---

(4) (a) Describe the construction of a horizontal axis wind turbine. Why a tall tower is essential for mounting it? (3 Marks)

(b) Derive the expressions for the power coefficient, axial thrust and power of a horizontal axis wind turbine:

$$C_P = \frac{1}{2}\left(1+\frac{C_d}{C_u}\right)^2\left(1-\frac{C_d}{C_u}\right), \quad F_x = \frac{1}{2}\rho A\, C_u^2\left(1+\frac{C_d}{C_u}\right)\left(1-\frac{C_d}{C_u}\right), \quad \text{Power} = C_p \eta \left(0.5\, \rho A \bar{C}_u^{\,3}\right)$$

where C_u, C_d are the upwind and downwind velocities and η is the efficiency. (7 Marks)

(c) A wind turbine has power coefficient and efficiency computed as a function of the ratio of the blade tip speed to wind speed with the following equations:

$$C_p = 0.06\,\sigma^2 - 0.008\,\sigma^3 \qquad \text{for} \qquad \sigma < 7.5$$

$$\eta = 0.5 - 0.02\,(\sigma - 5)^2$$

The daily variation of the wind speed (in m/s) is approximated by:

$$C_u = 0.00022\,t^4 - 0.0092\,t^3 + 0.098\,t^2 - 0.044\,t + 3.91$$

where t is the time in hours. The density of air is 1.2 kg/m^3. The propeller diameter is 25 m. Calculate:

(a) the maximum generated power by the wind turbine.
(b) the maximum rotational speed (rpm),
(c) the maximum axial thrust.

Hint: For the equation: $x^3 + x^2 - x - A = 0$, and $0 < A < 1$, the required root can be approximated by: $x = -0.1513A^2 + 0.5133A + 0.6355$. (10 Marks)

---

(5) (a) Explain briefly with neat sketches the working of the following hydraulic devices: (i) Hydraulic intensifier, (ii) Hydraulic crane, (iii) Hydraulic jack. (9 Marks)

(b) An intensifier receives water from an overhead tank through a pipeline and supplies high pressure water to a hydraulic press. The frictional loss at each packing of the intensifier and the press is k % of the total pressure on each piston.

(a) Prove that the force F_p which the press exerts and the velocity V_p of the press ram is related as: $F_p = a \frac{\eta}{1-\eta} V_p^2$, where H is the level of the tank above the intensifier level and η is the efficiency of transmission of the pipeline [= $(H - h_f)/H$, h_f is the loss of head in pipe]. What is the value of a ?

(b) Prove that the overall efficiency of the machine is given as: $\eta_{ov} = b\,\eta$. What is the value of b ? (10 Marks)

Good Luck, B. DJEBEDJIAN

Mansoura University
Faculty of Engineering
Mech. Power Eng. Dept.
Fourth Year

Final Semester Exam
Engines Performance-MPE4415
January 21, 2012 Time: 3 hours
Full Mark: 90

Answer the following questions. Assume any necessary assumptions.

Question (1) **[15 marks]**

1.1 What are the factors important to an engine user? [2 marks]

1.2 How are dynamometers classified? and explain briefly with aid of a neat sketch the basic principle of a dynamometer. [7 marks]

1.3 A gasoline engine working on 4-stroke develops a brake power of 25 kW. A Morse test was conducted on this engine and the brake power (kW) obtained when each cylinder was made inoperative by short circuiting. The spark plugs are 17.2, 17.4, 17.3 and 17.5 respectively. The test was conducted at constant speed. Find the indicated power, mechanical efficiency and bmep when all the cylinders are firing. The bore of engine is 8.5 cm and stroke is 9cm. The engine is running at 1500 rpm. [6 marks]

Question (2) **[30 marks]**

2.1 Describe with neat sketches the operation of: [15 marks]

a- Electromagnetic tachometer,
b- Rope brake-dynamometer,
c- Burette tube with electronic timing,
d- Air intake measurement by a tank and orifice plate, and
e- Water supply measurement by a rotameter.

[15 marks]

2.2 A 4-cylinder, four stroke gasoline engine gave the following results on the test bed: cylinder diameter=10cm, piston stroke=9cm, shaft speed 1400 rpm, brake drum diameter = 120 cm, dead weight on brake = 350 N, Spring balance reading = 50 N, Area of positive loop of the indicator diagram = 5.5 cm^2, Area of the negative loop of the indicator diagram = 0.25 cm^2, length of indicator diagram = 4.5 cm, pressure scale = 8.0 bar/cm, exhaust gas temperature 510 °C, mass flow rate of cooling water 200 kg/hr, water outlet temperature 70 °C, water inlet temperature 17 °C, ambient pressure 1.01 bar, ambient temperature 15 °C, time for consumption 70 ml of fuel (s.g=0.82, heating value 42000 kJ/kg) 30 sec, pressure drop across orifice 25mm H_2O (m_{air}[kg/sec]=0.0056 $\sqrt{\Delta H \times \rho_{air}}$, where ΔH in mm, ρ_{air} inlet air density kg/m^2), specific heat of exhaust gases 1.17 kJ/kg. °C. Determine the brake power, indicated power, bmep, bsfc, equivalence ratio, brake thermal efficiency, mechanical efficiency, volumetric efficiency and draw up the heat balance sheet.

Question (3) [20marks]

3.1 Explain briefly the operation of an electronic stroboscope and what are the main advantages of it? [3 marks]

3.2 Explain briefly the following tests: [9 marks]

a- Morse test.

b- Motoring test.

c- Deceleration method.

3.3 Willan's line test for single cylinder 1400 cc, 4 stroke compression ignition engine running 1400 rpm. The test data are shown in table. Torque arm=0.25m. [8 marks]

Brake load [N]	Time for 50 ml of fuel s.g=0.85, [sec]
37	184.8
74	141.5
118	106
163	90.5
212	72
302	56.5
367	18.5

Calculate the friction power, bmep and mechanical efficiency.

Question (4) [25 marks]

4.1 State two methods of temperature measurements and discuss their theory of operation. [5 marks]

4.2 During a test on a four stroke cycle diesel engine the following reading were obtained:

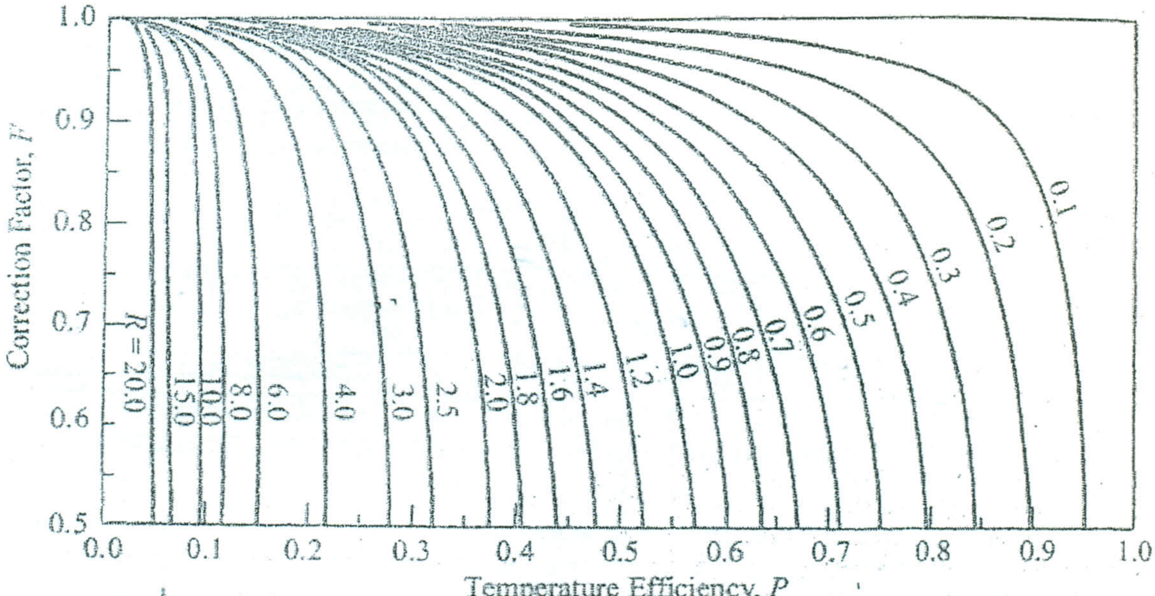
[20 marks]

Engine speed [rpm]	Brake load [N]	Brake load [N] motoring test	Time for 100ml of fuel s.g=0.85, [sec]
1000	1440	270	24
2000	1690	263	11
2500	1570	231	9.2
3000	1470	207	8

Torque arm=0.3m, heating value of fuel 41000 kJ/kg.

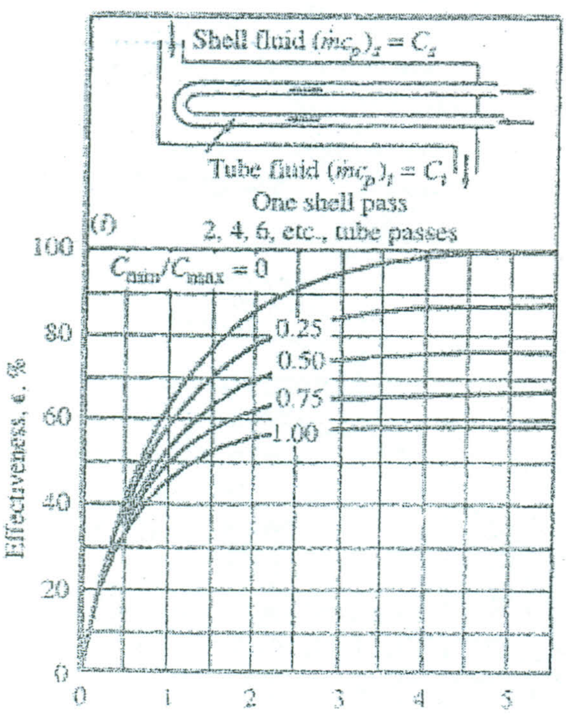
Draw performance curves (bp, ip, fp, η_{mech}, bsfc, η_{thb}) of engine against engine speed.

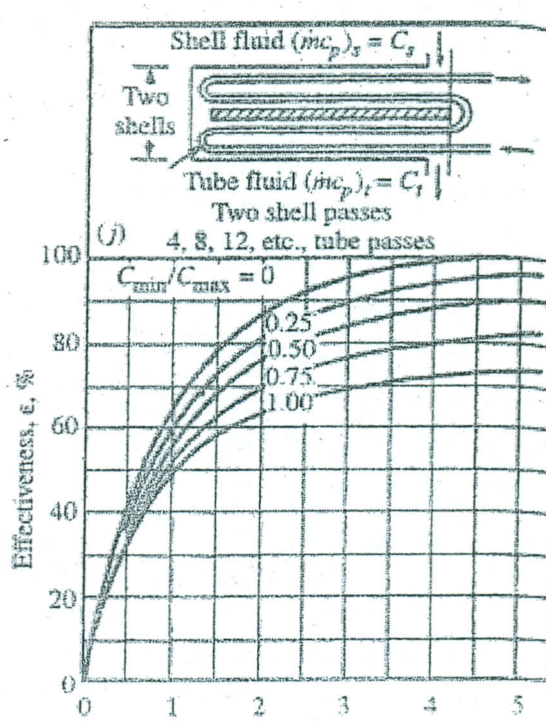
Good luck, **Dr. Ahmed Abd Elsalam**



$$P = \frac{t_2 - t_1}{T_1 - t_1} \qquad R = \frac{T_1 - T_2}{t_2 - t_1}$$

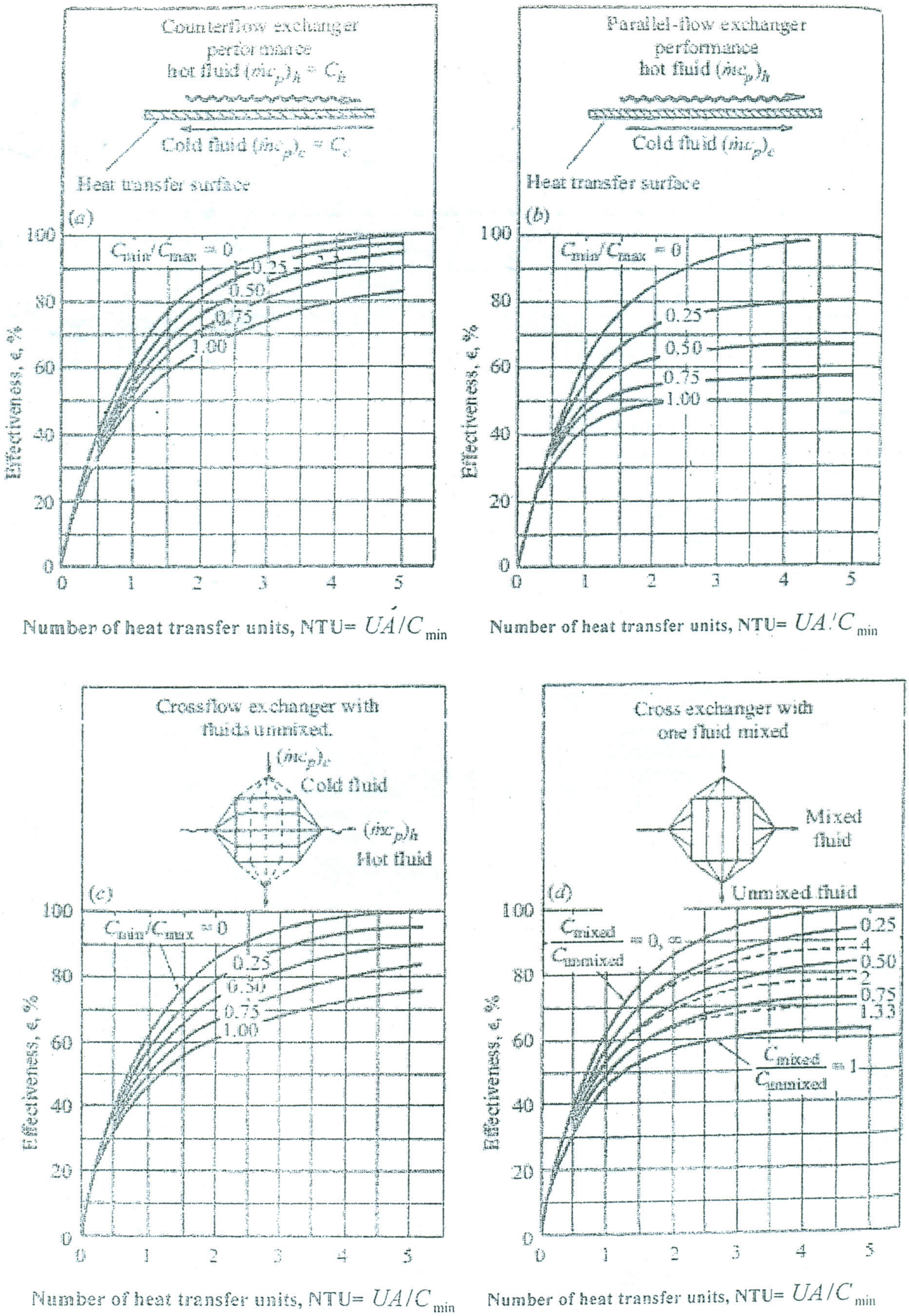
L.M.T.D correction factor for the shell-and-tube heat exchanger





Number of heat transfer units, NTU= UA/C_{min} Number of heat transfer units, NTU= UA/C_{min}

Heat exchanger effectiveness as a function of *NTU* for the shell-and-tube heat exchanger



Heat exchanger effectiveness as a function of *NTU* for several heat exchanger flow arrangements

The concoctive heat transfer coefficients are 15000 $W/m^2.K$ and 6000 $W/m^2.K$ on the steam side and water side, respectively. Fouling factors for condensate and cooling water inside tubes is 0.00012 $m^2 \cdot K/W$ and 0.00045 $m^2 \cdot K/W$, respectively. The water tubes are so thin that its wall thermal resistance can be neglected. Sketch the temperature distribution of both fluids along the condenser length and find:

i) the rate of heat exchanged between the two fluids.

ii) the mass flow rate of cooling water.

iii) the number of water tubes /pass and

iv) the required surface area and tube length per pass.

v) the percentage over surface of heat exchanger due to the presence of fouling (for water; C_p=4200 J/kg K, ρ = 1000 kg/m^3) (12 marks)

Question No. 4 (18 marks):

a) What is fouling? Mention its mechanisms and how much its effect on both heat transfer and pressure drop with respect to the types of hot and cold side fluids ?

(8 marks)

b) One important design features for automobile radiator is to cool the engine. Your responsibility as a design engineer is to make sure that the coolant (50% water-50% glycol, at the radiator inlet (top tank) does not exceed 110°C temperature at 100 k a guage radiator cap pressure. Determine the radiator top tank temperature (T_{hi}) for the following conditions:

Engine heat rejection rate; Q = 40 kW, air flow rate, $\dot{m}_a$ = 0.75 kg/s, air inlet temperature of 40°C, and water glycol mixture flow rate of $\dot{m}_{wg}$ =1.4 kg/s. For the radiator, UA = 1200 W/K. The specific heats for the air and the water glycol mixture are 1010 and 3700 J/kg K, respectively. What will be the outlet temperatures of both water glycol mixture and air? (10 marks)

Question No. 4 (18 marks):

a)Discuss the advantages and limitations of plate-type heat exchangers. (4 marks)

b) How to control fouling in heat exchangers operations? Discuss the different methods for cleaning heat exchangers if fouling control is not effective. (4 marks)

c) Which of the following dimensionless groups can have values ranging from 0.0 to 1.0 only?

(a) ε (b) NTU (c) correction factor; F (d) C^* (C_{min}/C_{max})

(e) P (t_o-t_i/ T_i-t_i), and (f) R (T_i-T_o/t_o-t_i) (2 marks)

d) In a heat exchanger, the effectiveness; ε generally increases with

(a) Increasing NTU (b) increasing C^* (c) increasing F

(d) Increasing the mixing of fluids at cross section. (2 marks)

e) Which of the following are all prime surface heat exchanger?

(1) double-pipe H.Ex. (2) automobile radiator (3) spiral plate exchanger

(4) plate type H.Ex. (5) strip-fin gas turbine regenerator (2 marks)

f) Fins are used primarily to:

(a) Increase heat transfer area; *A* (b) increase heat transfer coefficient; *h*

(c) Increase both *h* and *A*, and (d) increase neither *h* nor *A* (2 marks)

g) Which of the following are compact heat exchangers?

(a) Double-pipe exchanger (b) automobile radiator

(c) Stirling engine regenerator, and (d) plate-type exchanger (2 marks)

Good Luck

Prof. S. Elshafei

Mansoura University
Faculty of Engineering
Mech. Power Engng. Dept.

4th Year Student
Final Exam., Jan., 2012
Time: 3 hours

Elective 3 Heat Exchangers (MPE 4415)

Note: Tables and charts are not allowed; assume any missing data.
Answer only four of the following questions: (70 marks)

Question No. 1: (18 marks)

a) Classify the heat exchangers according to flow arrangements. Sketch the temperature distribution along the counter-flow H. Ex. with the length of single-phase fluids according to the ratio of C_h/C_c. (6 marks)

b) A double-pipe heat exchanger has the following data:

Oil is the hot fluid, flows through the inner tube (of inside diameter D_i= 10 cm and 2 mm thick) at a rate of 2.0 kg/s. The oil is cooled from 80°C to 50°C by water at a rate of 1.8 Kg/s flows in the same direction through the annular space with inlet temperature of 20°C. The oil side and water side convective heat transfer coefficients are 3000 W/m^2.K and 5000 W/m^2.K, respectively. The inner pipe is made of copper (k = 320 W/m K). Based on the outside surface area of the inner tube, calculate the following:

i) the length of the tube required ii) the %age reduction of that length if both fluids are arranged to flow in the opposite direction (counter-flow).

Properties of fluids are :

water: c_p = 4200 J/kg. K, ρ = 995 kg/m^3.
oil: c_p = 2500 J/kg. K, ρ = 1200 kg/m^3 (12 marks)

Question No. 2 (18 marks) :

a) Mention the major design considerations for a new heat exchanger and briefly discuss the rating and sizing heat exchanger problems (8 marks)

b) Hot exhaust gases flow over a finned-tube, cross-flow heat exchanger. The exchanger has an overall heat transfer coefficient of 200 W/m^2.K and with a surface area of 30 m^2. The exhaust gases are used to heat pressurized water which enters the heat exchanger at a temperature of 30°C with a flow rate of 0.8 kg/s. Meanwhile, gases enter the exchanger with a flow rate of 2.5 kg/s and a temperature of 250°C. Determine:

i) the rate of heat transfer by the exchanger, and
ii) the gas and water outlet temperatures.

(For water; c_p = 4200 J/kg. K, and for exhaust gases; c_p = 1000 J/kg. K)

(10 marks)

Question No. 3 (18 marks) :

a) a) Classify the heat exchanger according to surface compactness. Mention its main characteristics and discuss the important design and operating considerations for such heat exchangers. (6 marks)

b) A shell-and-tube type condenser (with one shell pass and two water tube passes) has N number of tubes/pass of 4 cm inside diameter. Dry saturated steam at 0.28 bar is to be condensed at a rate of 1.0 kg/s (t_{sat} = 68°C, L.H = 2340 kJ/kg). Cooling water is pumped from a river at 22°C enters the condenser and suffers a temperature rise of 8° C. The mean velocity of water flowing through the tubes is not exceeding 0. 5 m/s.

P.T.O