KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 407: HEAT TRANSFER

DATE: **Friday 13th April 2012** **TIME:** **8.00a.m – 10.00a.m**

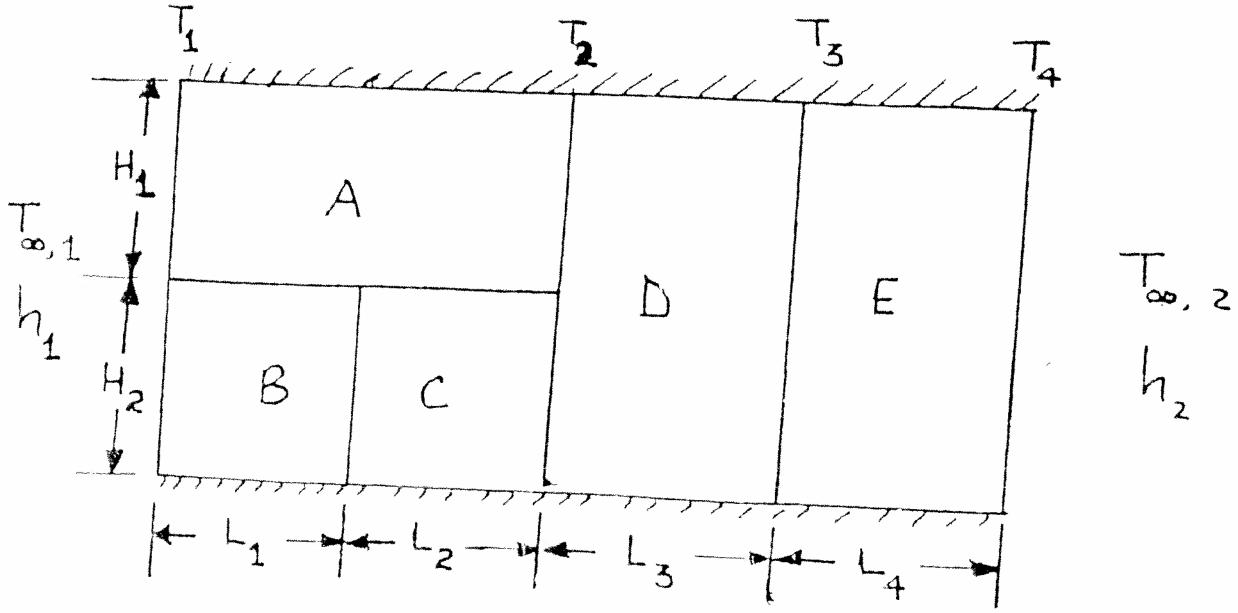
INSTRUCTIONS

Do any THREE (3) questions.

All questions carry equal marks.

Stefan-Boltzman constant $\sigma = 5.67 x 10^{-8} Wm^{-2} K^{-4}$

Q.1A composite solid wall is arranged as shown below Figure Q.1:-



The upper and lower surfaces as well as the two surfaces parallel to the plane of the page are insulated so that heat transfer within the composite is from right to left or left to right only. The composite has unit thickness in the direction normal to the page. Outer surfaces of layers A and B are exposed to a fluid at temperature $T_{\infty,1}$ and a convective heat coefficient h_1. For steady – state conditions use the data:

$H_1 = H_2 = 1.25m$; $L_1 = L2 = 10$ cm; $L_3 = L_4 = 15$ cm

$K_A = 20Wm^{-1}K^{-1}$; $K_B = 15Wm^{-1}K^{-1}$; $K_C = 5Wm^{-1}K^{-1}$

$K_D = 2Wm^{-1}K^{-1}$; $K_E = 0.5Wm^{-1}K^{-1}$

$T_{\infty,1} = 10^oC$ $\quad\quad$ $T_{\infty,2} = 160^o$

$h_1 = 60Wm^{-2}K^{-1}$ $\quad\quad$ $h_2 = 40Wm^{-2}K^{-1}$

a) Sketch the thermal circuit of the wall and show how the resistances can be determined. [6marks]

b) Determine:-

i) The rate of heat transfer across the wall.

ii) The temperatures T_1 and T_4 [14marks]

Q.2 a) Show that for purely radial conduction of heat in a right circular cylinder of thermal conductivity K that

$$T_1 - T_2 = \frac{Q}{2\pi K}\log_e\left(\frac{r_2}{r_1}\right)$$

Where T is the temperature at a corresponding radius r, and Q is the rate of heat transmission. (6 marks)

b) A cylindrical conductor of radius r, which is at a uniform temperature, is covered with electrical insulation of thermal conductivity K. The heat transfer coefficient between the surface of the insulation and the surrounding air is h:-

i) Determine the outside radius of the insulation for the heat transfer from the conductor to be a maximum for the given conductor and the air temperature. (6 marks)

ii) Show that the insulation will act as thermal insulation only if its outside radius is greater than the value of r_2 given by

$$\frac{r_1}{r_2} + \left(\frac{hr_1}{K}\right)\ln\left(\frac{r_2}{r_1}\right) = 1$$ (5 marks)

iii) If $r_1 = 3$mm, $h = 10$W/ (m^{2}K) and
K = 0.1 W/(mk);
Find the value of r_2. (3 marks)

Q.3 a) It is desired to cut down the radiation loss between two parallel surfaces by inserting a sheet of aluminium foil midway between them. The temperatures of the two surfaces are maintained at 40°C and 5°C, and the emissivities of both surfaces is 0.85. The emissivity of aluminium foil is 0.05. Calculate the percentage reduction in heat loss by radiation using the aluminium foil, assuming that the surface temperatures are the same in both cases and that all surfaces are grey. Neglect end effects.

(10 marks)

b) Two parallel plates 0.5m by 1m are spaced 0.5m apart. One plate is maintained 1000°C and the other at 500°C. The emissivities of the plates are 0.2 and 0. 5 respectively. The plates are located in a very large room, the walls of which are maintained at 27°C. The plates exchange heat with each other and with the room, but only the plate surfaces facing each other are to be considered in the analysis.
Find the net transfer of heat to each plate and to the room. (10 marks)

Q.4 a) Show that in Natural Convection heat transfer that NU = $\phi(Gr.\Pr)$ using variables $\mu, \rho, K, Cp, \theta, \beta g, L$ where β is the coefficient of cubical expansion,

$\beta = \frac{1}{dT}\frac{dv}{v}$ and g is the gravitational acceleration. (6marks)

b) For forced-convection heat transfer problems the heat transfer coefficient h is found to depend only on the fluid viscosity $\mu, density \rho$, the thermal conductivity of the fluid K, the specific heat capacity of the fluid C, a characteristic dimension of the solid surface L, the temperature difference between the surface and the fluid θ, and the fluid velocity U.

i) Show, by method of dimensions, that one form of relationship may be expressed as $h = \frac{K}{l}\Phi\left[\frac{\mu c}{K}, \frac{\rho u l}{\mu}, \frac{u^2}{c\theta}\right]$

or Nu = $\Phi(\Pr, \mathrm{Re}, Ec)$

Nu = Nusselt Number = $\frac{hl}{K}$

Pr = Prandtl Number = $\mu c / K$

Re = Reynolds Number = $\frac{\rho u l}{\mu}$

Ec = Eckert Number = u^2 / c

(7 marks)

ii) The heat transfer coefficient for a forced-convection air cooler system is to be estimated from a test on a one third scale model using air. If the velocity of the air in the cooler is to be 12 m/s, calculate the corresponding air velocity in the model test.
If, in the model test, the heat transfer rate is measured as 33.33 KW when the cooling surface area is $4m^2$ and the temperature difference between the air and the surface is 25K, calculate the heat transfer coefficient for the prototype cooler.
Assume that compressibility effects are negligible and that fluid properties are the same for both model and prototype.

[7marks]

Q.5 a) Heat flows through a bar whose surface is insulated. In this boundary – value problem the bar has a length of 3 units and a diffusivity of 2 units. Its ends are kept at temperature zero units and its initial temperature U (x, o) is given. By method of separation of variables or otherwise, using the equation.

$$\frac{\partial u}{\partial t} = 2\frac{\partial^2 u}{\partial x^2}, \quad 0 < x < 3,\ t > 0$$

Find the temperature at position x at time t i.e. find $U(x,t)$

Given that $U(O,t) = U(3,t) = 0$

$U\,(x,0) = 5\,Sin\,4\,\pi x - 3\,Sin\,8\pi x + 2Sin\,10\pi x\ for$

$|u(x,t) < M|$. (10 marks)

b) Derive the finite difference scheme for the heat flow in a body of homogeneous material which is governed by the equation

$$\frac{\partial^2 u}{\partial y^2} = 4\frac{\partial^2 u}{\partial x^2}, \quad 0 \le x \le 1$$

with boundary conditions $\left.\begin{matrix} U\,(0,\,y) = 0 \\ U\,(1,\,y) = 2y \end{matrix}\right\} y > 0$

and initial conditions $U(x,0) = Sin\,\pi\,x$

$\left(\partial u/\partial y\right) x,o = x$

Take the x – step h = 0.2, the y – step

K = 0.01 and find the solution along y = 0.03. (10 marks)

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