KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

SECOND SEMESTER EXAMINATION FOR THE DEGREE OF MASTER OF SCIEN(

SET 602: ADVANCED HEAT TRANSFER

DATE: Wednesday 18th April, 2012 **TIME:** 11.00 a.m. – 1.00 p.m.

INSTRUCTIONS

Answer any Three questions

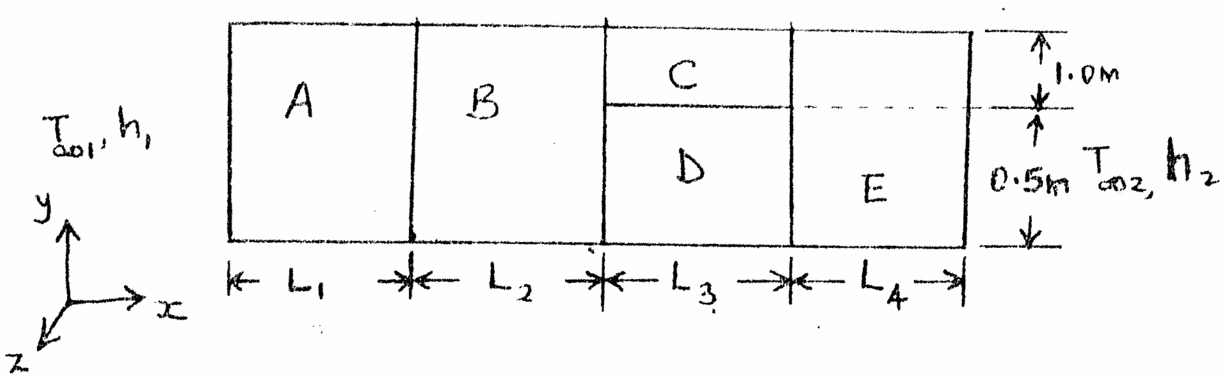
Use the following constants (where necessary)

Gravitational acceleration, g=10ms^{-2}

Stefan-Boltzmann constant = 5.67×10^{-8}wm^{-2}K^{-4}

All questions carry 20 equal marks each

Q1 (a) A composite wall is arranged as shown below



The layers have thermal conductivities

$K_A = 10, K_B = 40, K_c = 30, K_D = 35, K_E = 2.5,$

(each in Wm-1K-1), and lengths L1 = 7.5

L_2=5, L_3=2.5, L_4 = 1.5 (each in cm)

Layer B has a uniform internal thermal generation q_B (wm^{-3})caused by an electric voltage applied between its left and right surfaces. Top and bottom surfaces as well as surfaces parallel to the plane of the page are all insulated so that temperature gradients occur in x-direction only. Both left and right exposed surfaces are exposed to fluids at temperatures.

$T_{\infty 1} = T_{\infty 2} = 30^0 C.$

The left surface experiences a convection coefficient h_1=600Wm^{-2} K^{-1} while the right surface experiences coefficient h_2=950Wm^{-2}K^{-1}. The interface between A and B has contact thermal resistance R''_{c1}=0.003m^{2}KW^{-1}while the interface between C, D and E has contact resistance R''_{c2}=0.002m^{2}KW^{-1}. The surface of B in contact with A is at a temperature of 300^{0}C while the surface of B in contact with C and D has a temperature of 200°C.

For a unit thickness in a direction normal to the page,

i) Draw an equivalent thermal circuit of the wall (2 marks)

ii) Determine q_B (2 marks)

iii) Temperature on external surfaces of layers A and E (2 marks)

iv) Location of the plane of maximum temperature in layer B. (4 marks)

a) A hollow cylindrical pipe with internal radius r_i=1cm and external radius r_o carries hot water at a temperature of 95°C. The external surface of the pipe is exposed to air at a temperature of 25°C. The external surface of the pipe is exposed to air at a temperature of 25°C and a convection coefficient h=10Wm^{-2}K^{-1};

i) Describe the competing effects that occur when thickness (r_o-r_1) of the pipe is increased. (3marks)

ii) In a project to maximize the rate of heat flow from water to air, two alternatives are possible.

(1) Construct the pipe from a very thin sheet of steel with thermal conductivity K = 5Wm^{-1}K^{-1} then place a shell of vermiculate insulation round the pipe. Vermicular has thermal conductivity K=0.15Wm^{-1}K^{-1}

(2) Construct a thick-walled steel pipe

Determine the critical radius for each alternative and indicate, the better alternative, giving two reasons for your choice (3marks)

Q2 (a) For forced-convection heat transfer problems the heat transfer coefficient h is found to depend only on the fluid viscosity μ and fluid density ρ, 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 viscosity μ.

Show by, dimensimal analysis that one form of the relationship may be expressed:

$$h = \frac{K}{L}\phi\left(\frac{MC}{K}, \frac{\rho u l}{\mu}, \frac{\mu^2}{C\theta}\right)$$

or (10 marks)

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

(b) 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 12m/s, calculate the corresponding air velocity in the model test. If, in the model test, the heat transfer rate is measured as 33.33KW 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 third properties are the same for both the model and prototype.

Q3 (a) Show that in natural-convention heat transfer

Nu= $\phi(G\nu, \Pr)$

Using variables $\mu \ell, k, Cp, \theta, \beta g, L$ where β is the coefficient of cubical expansion.

$$\beta = \frac{1}{dT}\frac{dv}{v}$$

And g is the gravitational acceleration. (10 Marks)

(b) Calculate the heat loss by natural convention per meter length from horizontal pipe of 150mm diameter, the surface of which is at 277°C. The room temperature is 17°C.

For a horizontal cylinder:

$Nu=0.527/(\Pr)^{1/2}(\Pr+0.952)^{-1/4}(Gr)^{1/4}$

Where the properties are evaluated at the surface temperature.

Take the coefficient of cubical expansion, $\beta, as \frac{1}{T}$ where T Kelvin is the absolute temperature of the air.

$$Gr = \frac{\beta(g\theta)d^3}{\nu^2}$$

G=9.81m/s^2

Nu=nusselt number =h ℓ / κ

Gr=Grash of number =

Pr=prandtl number = μ c/k

Re = Reynold's number = ρu ℓ / μ

Ec = Eckert number = μ^2/C

Q4 It is required to reduce the rate of heat transfer through the plasterboard ceiling of a bedroom by the use of a layer of fiberglass insulation materials on the upper surface of the plasterboard.

The area of the ceiling is 10m^2, the plasterboard is 12mm thick, its thermal conductivity is 0.08W/(mk) and the surface heat transfer coefficient for both upper and lower surfaces is 3.25W/(m^{2}K).

(a) Calculate the rate of heat transfer through the uninsulated ceiling when the temperature difference between the air above and the air below the ceiling is 20K (10 marks)

(b) What thickness of fiberglass must be added to reduce the rate of heat transfer to one quarter of that through the un insulated plasterboard? (10 marks)

The thermal conductivity of the fiberglass is 0.0433 W/(mk) and the surface heat transfer coefficient is 1.05 W/(m^{2}k)

Q5 (a) It is desired to cut down the radiation loss between two parallel surfaces by inserting a sheet of aluminium foil mid-way between them. The temperature of the two surfaces are maintained at 40^0C and 5^0C, and the emissivity of both surfaces is 0.885. The emissivity of aluminum 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)

(c) Two rectangles 50cm by 50cm are placed perpendicularly with a common edge. One surface has T1=1000K, ε_1=0.6, while the other surface is insulated and in radiant balance with a large surrounding room at 300K.

Determine:

(i) The temperature of the insulated surface and

(ii) The heat lost by the 1000K (10marks)