Prof. F.K. FORSON Detailed Solution for AME 365 Mid-Semester Paper

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

FIRST SEMESTER MID-SEMESTER EXAMINATION, 2020/21 ACADEMIC YEAR

(Third ~~Second~~ Year)

AME 365 HEAT TRANSFER AND COMBUSTION ANALYSIS

MARCH 04, 2021 **DURATION: 1 HOUR**

INSTRUCTIONS: Study the following instructions carefully and apply them

1. This examination paper consists of **two compulsory** sections.

   Section A (questions 1 — 14) comprises 14 MCQs involving no calculations for 14 marks.

   Section B (questions 15 — 17) comprises 3 MCQs involving calculations for a maximum of 6 marks

2. In Section A, you are to choose the option that most appropriately answers a question or completes a statement by selecting and placing a ring around the letter that corresponds to the most appropriate option you have chosen.
3. In Section B, you are required to show detailed working in the space provided on the question paper to arrive at the answer for the problem and then select from among the options listed, the most appropriate answer by placing a ring around the letter corresponding to that option. A correct answer selected in **Section B** without detailed working will attract only 1 mark instead of the maximum of 2 marks.
4. Answer all questions in PEN and on the question paper.
5. Indicate your index number and Department on page 1 and on the other pages as demanded.

INDEX NUMBER: Detailed Solutions

Programme: Automobile Engineering

DEPARTMENT: [redacted]

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MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) Consider system A at uniform temperature t and system B at another uniform temperature T (t > T) as depicted in **Figure 1**. Let the two systems be brought into contact and be thermally insulated from their surroundings but not from each other. Heat (energy) will flow from system A to system B because of 1) _____

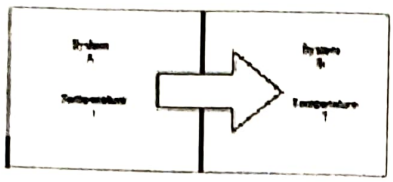

Figure 1

(A) Temperature difference
B) Energy difference
C) Mass difference
D) Volumetric difference

2) The literature of heat transfer generally recognizes distinct modes of heat transfer. How many modes are there? 2) _____

A) One
B) Two
(C) Three
D) Four

Modes of Heat Transfer:
Conduction, Convection, Radiation

3) The unit of the rate of heat transfer is 3) _____

A) Joule
B) Newton
C) Pascal
(D) Watt

Unit Energy/Unit time
Joule/second ≡ Watt

4) Convective heat transfer coefficient **doesn't** depend on 4) _____

A) Surface area
B) Space
(C) Time
D) Orientation of the surface

Dependants: Surface Area, Space, Orientation of Surface

5) Regarding one-dimensional heat transfer, choose the correct statement 5) _____

(A) Steady — f (x), Unsteady — f (x, t)
B) Steady — f (x, t), Unsteady — f (x)
C) Steady — f (x, y, t), Unsteady — f (x)
D) Steady — f (y, z), Unsteady — f (y)

Steady not dependant on time
unsteady a function of time
one-dimensional - function of one space coordinate

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6) Which statement is true regarding steady-state condition in heat transfer studies? 6) _____

A) There is a variation in temperature in the course of time

B) Heat exchange is constant

C) It is a function of space and time coordinates

D) Internal energy of the system changes

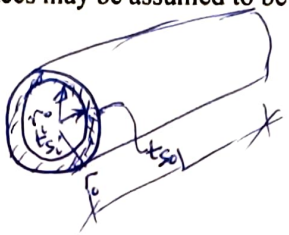
7) Heat transfer in a long, hollow cylinder which is maintained at uniform but different temperatures on its inner and outer surfaces may be assumed to be taking place in which direction? 7) _____

A) Axial only

B) Unpredictable

C) Radial only

D) No heat transfer takes place



8) Consider the following parameters 8) _____

(i) Composition

(ii) Density

(iii) Porosity

(iv) Structure

Then, thermal conductivity of glass wool varies from sample to sample because of variation in

A) i and ii only

B) i, ii, iii and iv

C) i and iii only

D) i, ii and iii only

9) In the Cartesian coordinates, the heat general conduction equation is given by: 9) _____

A) $d^2t/dx^2 + d^2t/dy^2 + d^2t/dz^2 + q_g = (1/\alpha)\ (d\ t/d\ T)$

B) $2d^2t/dx^2 + d^2t/dy^2 + d^2t/dz^2 + 34q_g = (d\ t/d\ T)$

C) $d^2t/dx^2 + 3d^2t/dy^2 + d^2t/dz^2 = (1/\alpha)\ (d\ t/d\ T)$

D) $4d^2t/dx^2 + d^2t/dy^2 + d^2t/dz^2 + 1/2q_g = (1/\alpha)\ (d\ t/d\ T)$

10) The diffusion equation 10) _____

$\nabla^2 t + q_g = (1/\alpha)\ (d\ t/d\ r)$

Governs the temperature distribution under unsteady heat flow through a homogeneous and isotropic material. The Fourier equation follows from this expression when:

A) Temperature doesn't depend on time only

B) There is no internal heat generation only

C) Steady state conditions prevail only

D) There is no internal heat generation but unsteady state condition prevails

Fourier Equation, same as the Diffusion Equation.

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11) For the same type of shapes, the value of radiation shape factor will be **higher** when 11) _____

A) Surfaces are closer
B) Surfaces are moved further apart
C) Surfaces are smaller and held closer
D) Surfaces are larger and held closer

12) The ratio of the Emissive Power of a body at a given temperature to that of a black body at the same temperature is constant all wavelengths. Such a body is called: 12) _____

A) Opaque body
B) Grey body
C) Transparent body
D) Diathermanous body

13) The **reciprocity theorem** states that 13) _____

A) $F_{12}=F_{21}$
B) $A_1F_{12}=A_2F_{21}$
C) $\alpha_1F_{12}=\alpha_2F_{21}$
D) $A_2F_{12}=A_1F_{21}$

14) Which of the following is a **wrong** statement in relation to the preamble below? 14) _____

The shape factor is equal to one

A) For any surface completely enclosed by another surface
B) For infinite parallel planes radiating only to each other
C) For a flat or convex surface with respect to itself
D) For inner cylinder to outer cylinder of a long co-axial cylinder

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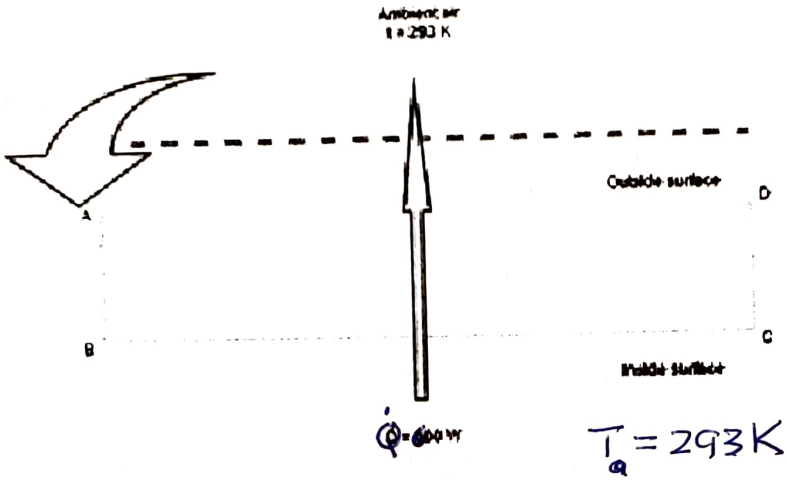
SECTION B [6 MARKS]. In this section you are required to show detailed working to arrive at the solution the problem in the space provide on the question paper and then select from among the options provided the most appropriate answer to the problem. A correct answer selected without the detailed correct working will attract only 1 mark instead of 2 marks. Write your answer in the space provided in PEN.

15) The oven of an electric store, of total outside surface area 2.9 m^2 dissipates electric energy at the rate of 600 W. The surrounding room air is at 20 degree Celsius and the surface coefficient of heat transfer between the room air and the surface of the oven is estimated to be 11.35 W/m^2 degree. Determine the average steady state temperature of the outside surface of the store



$T_a = 293K$

a) 38.23 degree Celsius
b) 48.23 degree Celsius
c) 58.23 degree Celsius
d) 68.23 degree Celsius

$\dot{Q} = h_c A_s (t_o - T_a)$

$t_o = \frac{\dot{Q}}{h_c A_s} + T_a = \frac{600}{11.35 \times 2.9} + 293 = 311.23 (38.23^\circ C)$

$\frac{1}{R_{eq}} = \frac{1}{R_2} + \frac{1}{R_3} \Rightarrow R_{eq} = \frac{R_2 R_3}{(R_2 + R_3)} = \frac{0.089 \times 0.018}{0.107} = 0.01497\ ^\circ C/W$

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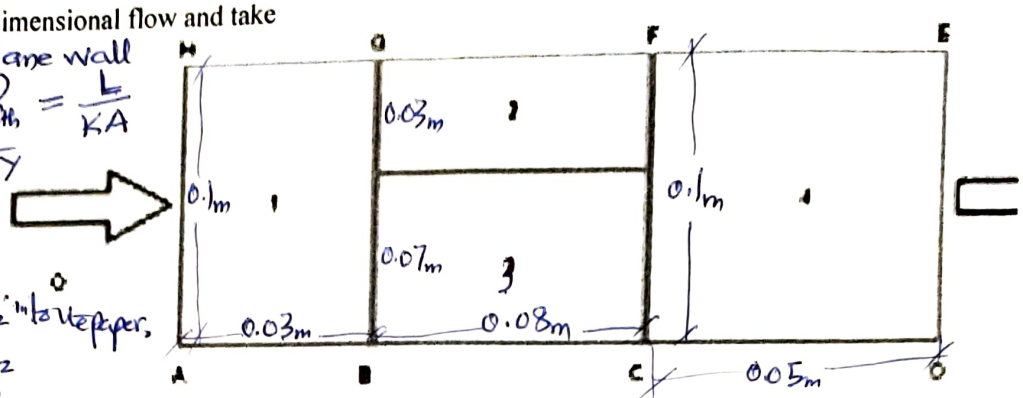
16) Find the heat flow rate through the composite wall as shown in figure. Assume one dimensional flow and take

For a plane wall $R_{th} = \frac{L}{KA}$

L = thickness
K = thermal conductivity
A = Area.



Assume depth = 1m. into the paper.

$A_1 = 0.1 \times 1 = 0.1 m^2$
$A_2 = 0.03 \times 1 = 0.03 m^2$
$A_3 = 0.07 \times 1 = 0.07 m^2$
$A_4 = 0.1 \times 1 = 0.1 m^2$

$R_1 = \frac{0.03}{150 \times 0.1} = 0.02\ ^\circ C/W$

$R_2 = \frac{0.08}{30 \times 0.03} = 0.089\ ^\circ C/W$

$R_3 = \frac{0.08}{65 \times 0.07} = 0.018\ ^\circ C/W$

$R_4 = \frac{0.05}{50 \times 0.1} = 0.01\ ^\circ C/W$

and $dt = 44.548\ ^\circ C$

k_1 = 150 W/m degree
k_2 = 30 W/m degree
k_3 = 65 W/m degree
k_4 = 50 W/m degree

AB = 3 cm, BC = 8 cm and CD = 5 cm. The distance between middle horizontal line from the top is 3 cm and from the bottom is 7 cm

a) 1173.88 W
b) 1273.88 W
c) 1373.88 W
d) 1473.88 W

$R_{total} = R_1 + R_{eq} + R_4 = 0.02 + 0.01497 + 0.01$
$= 0.03497\ ^\circ C/W$

$\dot{Q} = \frac{dt}{R_{total}} = \frac{44.548\ ^\circ C}{0.03497\ ^\circ C/W} = 1273.89 W$

17) A radiator in a domestic heating system operates at a surface temperature of 60 degree Celsius. Calculate the heat flux at the surface of the radiator if it behaves as a black body

a) 697.2 W/m^2
b) 786.9 W/m^2
c) 324.7 W/m^2
d) 592.1 W/m^2

$T_s = 273 + 60 = 333 K$

$\left(\frac{\dot{Q}_s}{A_s}\right)_{blackbody} = \sigma T_s^4 = 5.67 \times 10^{-8} \frac{W}{m^2 K^4} \times (333)^4 K^4$

heat flux $= 697.2 W/m^2$

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