K.L.N. College of Engineering

(An Autonomous Institution Affiliated to Anna University, Chennai)

Accredited by National Assessment and Accreditation Council (NAAC)
Pottapalayam – 630612.(11 km From Madurai City)TamilNadu, India.

Department of Mechanical Engineering

Accredited by NBA, New Delhi
Approved Research Center by Anna University, Chennai

Regulations – KLNCE-2020

20ME5L3
HEAT AND MASS TRANSFER LABORATORY MANUAL

Lab In charge

Dr. M.R.Thansekhar, Professor / Mech.,

Prepared by
Dr. M.R.Thansekhar, Professor / Mech.
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Approved by
Dr. P. Udhayakumar
HOD / Mech. Engg.

DEPARTMENT OF MECHANICAL ENGINEERING

VISION

To become a Centre of excellence for Education and Research in Mechanical Engineering.

MISSION

- **Attaining academic excellence through effective teaching learning process and state of the art infrastructure.**
- **Providing research culture through academic and applied research.**
- **Inculcating social consciousness and ethical values through co-curricular and extra-curricular activities.**

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO I	**Graduates will have successful career in Mechanical Engineering and service industries.**
PEO II	**Graduates will contribute towards technological development through academic research and industrial practices.**
PEO III	**Graduates will practice their profession with good communication, leadership, ethics and social responsibility.**
PEO IV	**Graduates will adapt to evolving technologies through lifelong learning.**

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1	**Derive technical knowledge and skills in the design, develop, analyze and manufacture of mechanical systems with sustainable energy, by the use of modern tools and techniques and applying research based knowledge.**
PSO 2	**Acquire technical competency to face continuous technological changes in the field of mechanical engineering and provide creative, innovative and sustainable solutions to complex engineering problems.**
PSO 3	**Attain academic and professional skills for successful career and to serve the society needs in local and global environment.**

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20ME5L3
HEAT AND MASS TRANSFER LABORATORY MANUAL

Lab In charge

Dr. M.R.Thansekhar, Professor / Mech.,

Name : ***Roll No. :***

Year / Sem. / Sec : ***Reg. No :***

General Instructions for Laboratory Classes

- Students must attend the lab classes with **ID cards**
- Enter Lab with **CLOSED FOOTWEAR**
- Boys should **"TUCK IN"** the shirts
- Students should wear **uniform only**
- **LONG HAIR** should be protected
- Any other machines / equipment's **should not be operated** other than the prescribed one for that day.
- POWER SUPPLY to your test table should be obtained only through the **LAB TECHNICIAN**
- Do not **LEAN** and do not be **CLOSE** to the machine components.
- **TOOLS, APPARATUS & GUAGE** Sets are to be returned before leaving the Lab.
- **Any damage** to any of the equipment/instrument/machine caused due to carelessness, the **cost** will be fully recovered from the individual (or) group of students.

University Examination

The examination will be conducted for 100 marks. Then the marks will be calculated to 80 marks.

Split up of Practical Examination Marks

Aim and Apparatus Required	***Tabulation & Calculation***	***Procedure***	***Results***	***Graph***	***Viva***	***Total***
15	*30*	*15*	*20*	*10*	*10*	*100*

Contents

Name: …………………………………….……… Batch……………………..………….

Roll No.:…………… Year ……..… Semester……..… Section: ………….....

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S. No.	Date	Name of the Experiment	Page	Marks	Staff Signature
1.					
2.					
3.					
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7.					
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10.					
11.					
12.					
13.					
14.					
15.					

Completed date:

Average Mark: **Staff - in – charge**

K.L.N. COLLEGE OF ENGINEERING, POTTAPALAYAM – 630 612
(An Autonomous Institution Affiliated to Anna University, Chennai)

20ME5L3 HEAT AND MASS TRANSFER LABORATORY L T P C
0 0 3 1.5

OBJECTIVES:

- To learn to measure thermal conductivity of materials
- To study the free and forced convective heat transfer
- To study condensation heat transfer
- To study the performance of Heat exchangers
- To study the applicability of Stefan – Boltzmann law

PREREQUISITE:

Course Code: 20ME302, 20ME304, 20ME403
Course Name: Fluid Mechanics and Machinery, Engg Thermodynamics, Thermal Engg.

LIST OF EXPERIMENTS

1. Thermal conductivity measurement of pipe insulation using lagged pipe apparatus.
2. Determination of Thermal conductivity of insulating powder, liquid and composite wall
3. Heat transfer from pin-fin apparatus (natural & forced convection modes)
4. Determination of heat transfer coefficient under natural convection from a vertical cylinder.
5. Determination of heat transfer coefficient under forced convection from a tube.
6. Determination of heat transfer coefficient in film wise and drop wise condensation.
7. Effectiveness of double pipe heat exchangers.
8. Effectiveness of cross flow heat exchanger.
9. Determination of Stefan – Boltzmann constant.
10. Determination of emissivity of a grey surface.

TOTAL: 45 PERIODS

OUTCOMES: AT THE END OF THE COURSE, LEARNERS WILL BE ABLE TO:

CO-01: Determine thermal conductivity of materials by conducting tests on heat conduction apparatus.
CO-02: Determine heat transfer rate and fin efficiency of a pin fin under natural/forced convective mode.
CO-03: Calculate natural/forced convective heat transfer coefficient by conducting tests on convective heat transfer apparatus.
CO-04: Determine the performance of parallel/counter/cross flow heat exchangers.
CO-05: Calculate the Stefan-Boltzmann constant by conducting tests on radiative heat transfer apparatus.
CO-06: Calculate the Emissivity of a gray surface.

S.No.	**NAME OF THE EQUIPMENT**	**Qty**
1	Guarded plate apparatus	1
2	Lagged pipe apparatus	1
3	Composite wall apparatus	1
4	Thermal conductivity of insulating powder apparatus	1
5	Pin-fin apparatus	1
6	Natural convection-vertical cylinder apparatus	1
7	Forced convection inside tube apparatus	1
8	Parallel flow heat exchanger apparatus	1
9	Counter flow heat exchanger apparatus	1
10	Cross flow heat exchanger apparatus	1
11	Stefan-Boltzmann apparatus	1
12	Emissivity measurement apparatus	1

Ex No: 1 ***Date:***

Thermal conductivity measurement using guarded plate apparatus

Aim:

To determine the thermal conductivity of given insulating material in the form of slab using guarded plate apparatus.

Apparatus Required:

1. Guarded plate apparatus

Procedure:

1. Ensure proper electrical connections and zero position of the variac.
2. Switch on both central and guard heaters.
3. Slowly rotate knob of variac 1, clockwise to set 40 volts, this is central heater and note down its current value in one ammeter.
4. Slowly rotate knob of variac 2, clockwise to set 50 volts, this is guard heater and note down its current value in another ammeter.
5. Note down all temperatures (temperatures between hot guard plate and specimen similarly temperatures between cold guard plate and specimen), using selector switch.
6. Note down all reading once in 15 minutes, until steady state condition is reached.

Formula Used:

$$k = \frac{Q \times L}{A_s \times (T_h - T_c)}$$

Where

k = Thermal conductivity of given insulating material in $\frac{W}{mK}$

Q = Heat energy supplied in W

L = Thickness of the given specimen in m

A_s = Surface area of the given specimen in m^2

T_h = Hot side temperature (average of central and guard heaters temperatures) in ^0C

Tc = Cold side temperature in ^0C

Observation:

Diameter of Central Heater - D = m

Diameter of Specimen (Slab) - d = m

Thickness of Specimen (Slab) - t = L = m

Tabulation:

S. No.	Heat Input				Temperature ° C						
	Central Heater		Guard Heater		Central Heater			Guard Heater			Cold side
	V_1 Volts	I_1 Amps	V_2 Volts	I_2 Amps	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1.											
2.											
3.											
4.											
5.											
6.											
7.											
8.											
9.											
10.											

Model Calculation:

Heat energy supplied to central heater = $Q_1 = V_1 \times I_1$

$$Q_1 = \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$$

$$Q_1 = \ldots\ldots\ldots\ldots \text{ W}$$

Heat energy supplied to Guard heater = $Q_2 = V_2 \times I_2$

$$Q_2 = \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$$

$$Q_2 = \ldots\ldots\ldots\ldots \text{ W}$$

Net heat energy supplied = $Q = \frac{Q_1 + Q_2}{2}$

$$Q = \frac{\ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots}{2}$$

$$Q = \ldots\ldots\ldots\ldots \text{ W}$$

L = Thickness of the specimen = ……………….. m

A_s = Surface area of the specimen

$$A_s = \frac{\pi}{4} \times d^2$$

Where

d = diameter of specimen = ………………. m

$$A_s = \frac{\pi}{4} \times \ldots\ldots\ldots\ldots^2$$

$$A_s = \ldots\ldots\ldots\ldots\ldots\ldots \text{ m}^2$$

T_h = Hot side temperature = Average of central and guard heater temperatures

$$T_h = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6}{6}$$

$$T_h = \frac{\ldots\ldots + \ldots\ldots + \ldots\ldots + \ldots\ldots + \ldots\ldots + \ldots\ldots}{6}$$

$$T_h = \ldots\ldots\ldots\ldots\ldots\ {}^{o}C$$

T_c = Cold side temperature

$$T_c = T_7$$

$$T_c = \ldots\ldots\ldots\ldots\ldots\ {}^{o}C$$

Thermal conductivity of given insulating slab specimen = $k = \dfrac{Q \times L}{A_s \times (T_h - T_c)}$

$$k = \frac{\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots)}$$

$$k = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{m^{o}C} \text{ (or) } \frac{W}{mK}$$

Result:

Thermal conductivity of given Insulating slab $k = \quad \frac{W}{mK}$

Inference:

I have learnt how to measure thermal conductivity of a solid insulating material.

Applications:

1. Comparison of thermal conductivity of different building materials (wood, asbestos, brick etc.)

2. Comparison of thermal conductivity of different plastics.

Ex No : 2 ***Date :***

Thermal conductivity measurement of pipe insulation using lagged pipe apparatus

Aim:

To determine the thermal conductivity of sawdust and Sand by using lagged pipe apparatus.

Apparatus Required:

Lagged Pipe apparatus

Procedure:

1. Ensure proper electrical connections and zero position of the variac.
2. Switch on the unit.
3. Rotate knob of the variac to give the heat input.
4. Note down Voltmeter and Ammeter readings.
5. Note down the Temperature values in all channels, for every 15 minutes until steady state condition is reached.
6. Conduct the experiment further by varying flow rate and different heat input values.

Formula used:

Thermal conductivity of saw dust = $k_1 = \dfrac{Q \times \ln \frac{r_2}{r_1}}{2\pi \times L \times \Delta T_1}$

Where

- Q = Heat energy supplied in W
- r_2 = radius of saw dust packing from centre in m
- r_1 = radius of heater pipe from centre in m
- L = Length of the pipe in m
- ΔT_1 = Temperature difference between inner heater pipe and saw dust packing in ^{o}C

Thermal conductivity of sand = $k_2 = \dfrac{Q \times \ln \frac{r_3}{r_2}}{2\pi \times L \times \Delta T_2}$

Where

- Q = Heat energy supplied in W
- r_3 = radius of sand packing from centre point in m
- r_2 = radius of saw dust packing from centre point in m
- L = Length of the pipe in m
- ΔT_2 = Temperature difference between saw dust packing and sand packing in ^{o}C

Observation:

Length of cylinder = L = m

Radius of heater pipe = r_1 = m

Radius of heater with saw dust = r_2 = m

Radius of heater with saw dust and Sand (Dry) = r_3 = m

Tabulation:

S.No.	**V (Volts)**	**I (Amps)**	**Temperature at heater pipe surface °C**		**Temperature at saw dust packing °C**		**Temperature at sand packing °C**	
			T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								

Model Calculation:

Thermal conductivity of saw dust = $k_1 = \dfrac{Q \times \ln \frac{r_2}{r_1}}{2\pi \times L \times \Delta T_1}$

Heat energy supplied by heater = $Q = V \times I$

$Q = \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$

$Q = \ldots\ldots\ldots\ldots\ \mathrm{W}$

r_2 = radius of saw dust packing from centre point = ……………… m

r_1 = radius of heater pipe from centre point = ……………… m

L = Length of the pipe = ……………… m

ΔT_1 = Temperature difference between inner heater pipe and saw dust packing in ^oC

$$\Delta T_1 = \left(\frac{T_1 + T_2}{2}\right) - \left(\frac{T_3 + T_4}{2}\right)$$

$$\Delta T_1 = \left(\frac{\ldots\ldots\ldots + \ldots\ldots\ldots}{2}\right) - \left(\frac{\ldots\ldots\ldots + \ldots\ldots\ldots}{2}\right)$$

$$\Delta T_1 = \ldots\ldots\ldots\ldots\ ^oC$$

$$k_1 = \frac{Q \times \ln \frac{r_2}{r_1}}{2\pi \times L \times \Delta T_1}$$

$$k_1 = \frac{\ldots\ldots\ldots\ldots \times \ln \frac{\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots}}{2\pi \times \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots}$$

$$k_1 = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \frac{W}{m^oC}\ (\text{or})\ \frac{W}{mK}$$

Thermal conductivity of sand = $k_2 = \dfrac{Q \times \ln \frac{r_3}{r_2}}{2\pi \times L \times \Delta T_2}$

Heat energy supplied to heater = $Q = V \times I$

$Q = \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$

$Q = \ldots\ldots\ldots\ldots\ W$

r_3 = radius of sand packing from centre point = ………………. m

r_2 = radius of saw dust packing from centre point = ………………. m

L = Length of the pipe = ……………… m

ΔT_2 = Temperature difference between saw dust packing and sand packing in ^oC

$$\Delta T_2 = \left(\frac{T_3 + T_4}{2}\right) - \left(\frac{T_5 + T_6}{2}\right)$$

$$\Delta T_2 = \left(\frac{\ldots\ldots\ldots + \ldots\ldots\ldots}{2}\right) - \left(\frac{\ldots\ldots\ldots + \ldots\ldots\ldots}{2}\right)$$

$$\Delta T_2 = \ldots\ldots\ldots\ldots\ ^oC$$

$$k_2 = \frac{Q \times \ln \frac{r_3}{r_2}}{2\pi \times L \times \Delta T_2}$$

$$k_2 = \frac{\ldots\ldots\ldots\ldots \times \ln \frac{\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots}}{2\pi \times \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots}$$

$$k_2 = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{m^oC} \text{ (or) } \frac{W}{mK}$$

Result:

Thermal conductivity of saw dust $k_1 = \qquad \frac{W}{mK}$

Thermal conductivity of sand $k_2 = \qquad \frac{W}{mK}$

Inference:

I have gained knowledge of measuring thermal conductivity of powder materials by applying the concept of one dimensional heat conduction through hollow cylinders.

Applications:

1. Comparison of thermal conductivity of different powder materials
2. Selection of material for piping insulation

Ex No: 3 ***Date :***

Determination of Thermal conductivity of composite wall

Aim:

To determine the thermal conductivity of Composite Wall using composite wall apparatus.

Apparatus Required:

Composite wall apparatus

Procedure:

1. Ensure proper electrical connection and ensure zero position of variac.
2. Switch on the heater and set the voltage (say 80 V) using the Variac.
3. Note down the ammeter and voltmeter readings.
4. Wait for reasonable time to allow the system to reach steady state.
5. Note down all temperatures using temperature indicator.

Formula used:

Heat transfer rate through composite wall =

$$Q = \frac{k_m A_m (T_h - T_m)}{L_m} = \frac{k_w A_w (T_m - T_w)}{L_w} = \frac{k_a A_a (T_w - T_a)}{L_a}$$

Where,

K_m, k_w and k_a = Thermal conductivity of mild steel, wood and asbestos respectively in $\frac{W}{mK}$

A_m, A_w and A_a = Surface area of mild steel, wood and asbestos respectively in m^2

T_h = Temperature of the heater in ^oC

T_m, T_w and T_a = Surface temperature of mild steel, wood and asbestos respectively in ^oC

L_m, L_w and L_a = Thickness of mild steel, wood and asbestos respectively in m

Observation:

Thickness of mild steel layer	= L_m	=	m
Diameter of mild steel layer	= d	=	m
Thickness of wood layer	= L_w	=	m
Diameter of wood layer	= d	=	m
Thickness of asbestos layer	= L_a	=	m
Diameter of asbestos layer	= d	=	m

Tabulation:

S. No.	Heat Input		Temperature ° C							
	V (Volts)	I (Amps)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8

From the above equation it is possible to find out thermal conductivity of individual materials by the following equations

$$k_m = \frac{Q \times L_m}{A_m (T_h - T_m)}$$

$$k_w = \frac{Q \times L_w}{A_w (T_m - T_w)}$$

$$k_a = \frac{Q \times L_a}{A_a (T_w - T_a)}$$

Model Calculation:

Heater temperature = $T_h = \frac{T_1 + T_2}{2}$

$$T_h = \frac{\text{...........} + \text{...........}}{2}$$

$$T_h = \text{..................}\ ^oC$$

Surface temperature of mild steel = $T_m = \frac{T_3 + T_4}{2}$

$$T_m = \frac{\text{...........} + \text{...........}}{2}$$

$$T_m = \text{..................}\ ^oC$$

Surface temperature of wood = $T_w = \frac{T_5 + T_6}{2}$

$$T_w = \frac{\text{...........} + \text{...........}}{2}$$

$$T_w = \text{..................}\ ^oC$$

Surface temperature of asbestos = $T_a = \frac{T_7 + T_8}{2}$

$$T_a = \frac{\text{...........} + \text{...........}}{2}$$

$$T_a = \text{..................}\ ^oC$$

Heat energy supplied by heater = $Q = V \times I$

$$Q = \text{...........} \times \text{...........}$$

$$Q = \text{...........}\ W$$

Surface are of mild steel, wood and asbestos = $A_m, A_w, A_a = \frac{\pi}{4} \times d^2$

$$A_m, A_w, A_a = \frac{\pi}{4} \times \text{..................}$$

$$A_m, A_w, A_a = \text{..................}\ m^2$$

Thermal conductivity of mild steel = $k_m = \dfrac{Q \times L_m}{A_m (T_h - T_m)}$

$$k_m = \frac{\ldots\ldots\ldots\ldots\ldots\times\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots\times(\ldots\ldots\ldots\ldots\ldots-\ldots\ldots\ldots\ldots\ldots)}$$

$$k_m = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{mK}$$

Thermal conductivity of wood = $k_w = \dfrac{Q \times L_w}{A_w (T_m - T_w)}$

$$k_w = \frac{\ldots\ldots\ldots\ldots\ldots\times\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots\times(\ldots\ldots\ldots\ldots\ldots-\ldots\ldots\ldots\ldots\ldots)}$$

$$k_w = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{mK}$$

Thermal conductivity of mild steel = $k_a = \dfrac{Q \times L_a}{A_a (T_w - T_a)}$

$$k_a = \frac{\ldots\ldots\ldots\ldots\ldots\times\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots\times(\ldots\ldots\ldots\ldots\ldots-\ldots\ldots\ldots\ldots\ldots)}$$

$$k_a = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{mK}$$

Result:

Thermal conductivity of mild steel	=	k_m	=	$\frac{W}{mK}$
Thermal conductivity of wood	=	k_w	=	$\frac{W}{mK}$
Thermal conductivity of asbestos	=	k_a	=	$\frac{W}{mK}$

Inference:

I have gained knowledge of measuring thermal conductivity of composite (group of materials) materials.

Applications:

Design of multilayer insulation for furnaces, pipings, etc.

Ex No: 4 ***Date :***

Determination of Thermal Conductivity of Insulating Powder

Aim:

To determine the thermal conductivity of given insulating powder (Saw dust) using insulating powder apparatus.

Apparatus Required:

Insulating powder apparatus

Procedure:

1. Ensure proper electrical connection and ensure zero position of variac.
2. Switch on the heater and set the voltage (say 40 V) using the Variac.
3. Note down the ammeter and voltmeter readings.
4. Wait for reasonable time to allow the system to reach steady state.
5. Note down all temperatures using temperature indicator.

Formula used:

We know that heat transfer in sphere = $Q = \dfrac{(T_i - T_o)}{\left(\dfrac{r_o - r_i}{4\pi \times k \times r_i \times r_o}\right)}$

Where,

T_i = Inner surface temperature of the sphere in ^{o}C

T_o = Outer surface temperature of the sphere in ^{o}C

r_i = Inner radius of the sphere in m

r_o = Outer radius of the sphere in m

k = Thermal conductivity of the insulating powder (Saw dust) in $\dfrac{W}{mK}$

From the above equation, it is possible to determine the thermal conductivity of the insulating powder

Thermal conductivity of insulating powder = $k = \dfrac{Q \times (r_o - r_i)}{(T_i - T_o) \times 4\pi \times r_i \times r_o}$

Observation:

Inner diameter of the sphere = d_i = m

Outer diameter of the sphere = d_o = m

Inner radius of the sphere = r_i = m

Outer radius of the sphere = r_o = m

Tabulation:

S.No.	Heater Input		Surface Temperatures of sphere °C							
			Inner surface				Outer surface			
	V (Volts)	I (Amps)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										

Formula used:

We know that heat transfer in sphere = $$Q = \frac{(T_i - T_o)}{\left(\frac{r_o - r_i}{4\pi \times k \times r_i \times r_o}\right)}$$

Where,

T_i	=	Inner surface temperature of the sphere in ^oC
T_o	=	Outer surface temperature of the sphere in ^oC
r_i	=	Inner radius of the sphere in m
r_o	=	Outer radius of the sphere in m
k	=	Thermal conductivity of the insulating powder (Saw dust) in $\frac{W}{mK}$

From the above equation, it is possible to determine the thermal conductivity of the insulating powder

Thermal conductivity of insulating powder = $$k = \frac{Q \times (r_o - r_i)}{(T_i - T_o) \times 4\pi \times r_i \times r_o}$$

Model Calculation:

Heat energy supplied by heater = $Q = V \times I$

$Q = \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$

$Q = \ldots\ldots\ldots\ldots\ W$

Inner surface temperature of sphere = $T_i = \dfrac{T_1 + T_2 + T_3 + T_4}{4}$

$$T_i = \frac{\ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots}{4}$$

$T_i = \ldots\ldots\ldots\ldots\ldots\ldots\ {}^{o}C$

Outer surface temperature of sphere = $T_o = \dfrac{T_5 + T_6 + T_7 + T_8}{4}$

$$T_o = \frac{\ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots}{4}$$

$T_o = \ldots\ldots\ldots\ldots\ldots\ldots\ {}^{o}C$

Thermal conductivity of insulating powder = $k = \dfrac{Q \times (r_o - r_i)}{(T_i - T_o) \times 4\pi \times r_i \times r_o}$

$$k = \frac{\ldots\ldots\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots\ldots)}{(\ldots\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots\ldots) \times 4\pi \times \ldots\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots\ldots}$$

$$k = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{mK}$$

Result:

Thermal conductivity of insulating powder (Saw dust) = k = $\frac{W}{mK}$

Inference:

I have gained knowledge of measuring thermal conductivity of powder materials by applying the concept of one dimensional heat conduction through spheres.

Applications:

1. Determination of thermal conductivity of different materials in powder form.
2. Design of spherical containers for thermal applications.

Ex No: 5 a ***Date :***

Heat transfer from pin-fin apparatus (natural convection mode)

Aim:

To determine the heat transfer rate, intermediate temperature distributions and fin efficiency of Pin-Fin in natural convection mode using pin-fin apparatus.

Apparatus Required:

Pin-fin apparatus

Procedure:

1. Ensure proper electrical connections and zero position of the variac.
2. Slowly rotate variac to desired values, say 100 V
3. Note down the readings of Voltmeter and Ammeter.
4. Note down the temperatures by channel selector for every 15 minutes until steady state conditions reached.

Formula used:

Heat transfer with fin = $Q_{fin} = \sqrt{hpkA} \times (T_b - T_a) \times \tanh(mx)$

Where,

h = Heat transfer Coefficient in $\frac{W}{m^2K}$

p = Perimeter of the cross section of the fin in m

k = Thermal conductivity of the fin material in $\frac{W}{mK}$

A = Cross sectional area of the fin in m^2

T_b = Base temperature of the fin in ^oC

T_a = Ambient or atmospheric temperature in ^oC

Observation:

Material of the pin-fin =

Diameter of the fin = d_{fin} = m

Length of the fin = L = m

Thermal conductivity of fin material = k = $\frac{W}{mK}$

Tabulation:

S.No.	Heat Input		Surface temperature of the fin °C					Ambient Temperature °C T_a
	V (Volts)	I (Amps)	T_1=T_b	T_2	T_3	T_4	T_5	
1.								
2.								
3.								
4.								
5.								

S.No.	Heat Input		x (m)	Tthe oC	Tact oC	Error (%)	ηf (%)	Qfin (W)
	V (Volts)	I (Amps)						
1.								
2.								
3.								
4.								
5.								

$$m = \sqrt{\frac{hp}{kA}} \text{ in } \frac{1}{m} \text{ (or) } m^{-1}$$

x = Length of the fin from base in m

Heat transfer coefficient can be determined by the following way

Film temperature = T_f $= \dfrac{T_m + T_a}{2}$

Where,

T_m = Mean surface temperature of fin $\dfrac{T_2 + T_3 + T_4 + T_5}{4}$

T_a = Ambient or Atmospheric temperature

Choose the following properties of air from HMT data book corresponding to film temperature T_f.

Density (ρ), Kinematic viscosity (ν), Prandtl number (Pr) and thermal conductivity (k)

Grash of number = Gr $= \dfrac{g \times \beta \times {d_{fin}}^3 \times (T_m - T_a)}{\nu^2}$

Where

g = gravity value (constant) in $\dfrac{m}{s^2}$ $(g = 9.81 \dfrac{m}{s^2})$

β = Coefficient of thermal expansion =

$\dfrac{1}{T_f}$ (T_f should be substituted in Kelvin)

d_{fin} = Diameter of fin in m

v = Kinematic viscosity in $\dfrac{m^2}{s}$

Then find out the product of (Gr × Pr)

Model Calculation:

Mean temperature of the fin surface $= \quad T_m = \dfrac{T_2 + T_3 + T_4 + T_5}{4}$

$$T_m = \frac{\ldots\ldots\ldots + \ldots\ldots\ldots + \ldots\ldots\ldots + \ldots\ldots\ldots}{4}$$

$$T_m = \ldots\ldots\ldots\ldots\ldots\ldots \ {}^{o}C$$

Ambient temperature of air = T_a

$$T_a = \ldots\ldots\ldots\ldots\ldots\ldots \ {}^{o}C$$

Film temperature = $T_f = \dfrac{T_m + T_a}{2}$

$$T_f = \frac{\ldots\ldots\ldots + \ldots\ldots\ldots}{2}$$

$$T_f = \ldots\ldots\ldots\ldots\ldots\ldots \ {}^{o}C$$

Choose the following properties of air from HMT data book corresponding to film temperature T_f.

$$\rho = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ \frac{kg}{m^3}$$

$$v = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ \frac{m^2}{s}$$

$$Pr = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$k = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ \frac{W}{mK}$$

β = Coefficient of thermal expansion = $\dfrac{1}{T_f}$ (T_f should be substitute with Kelvin)

$$\beta = \frac{1}{\ldots\ldots\ldots}$$

$$\beta = \ldots\ldots\ldots\ldots\ldots\ldots \ \frac{1}{K}$$

Then Nusselt number is determined by the following formula

$$Nu = C \times (Gr \times Pr)^{m}$$

C and m values can be chosen from HMT data book corresponding to natural convection from horizontal cylinder

Then general form for Nusselt number is

$$Nu = \frac{h \times d_{fin}}{k}$$

$$h = \frac{Nu \times k}{d_{fin}}$$

Fin efficiency = $\eta_{fin} = \frac{\tanh(m \times x)}{m \times x}$

Theoretical intermediate temperature = $T_{the} = \left[(T_b - T_a) \times \frac{\cosh m(L - x)}{\cosh(mL)} \right] + T_a$

Where,

L = Total length of the fin in m

Actual intermediate temperature = T_{act} = Surface temperature of fin indicated by digital thermometer corresponding to x

Error percentage in intermediate temperature =

$$Error = \frac{\text{Difference between } T_{the} \text{ and } T_{act}}{T_{the}} \times 100$$

Grash of number = $Gr = \frac{g \times \beta \times d_{fin}^{3} \times (T_m - T_a)}{\nu^{2}}$

$$Gr = \frac{\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots)}{\ldots\ldots\ldots\ldots\ldots}$$

$$Gr = \ldots\ldots\ldots\ldots\ldots\ldots$$

$$Gr \times Pr = \ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$$

$$Gr \times Pr = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Then Nusselt number is determined by the following formula

$$Nu = C \times (GrPr)^m$$

C and m values can be chosen from HMT data book corresponding to natural convection form horizontal cylinder

$$Nu = ... \times (..................)^{.........}$$

$$Nu = ...$$

Then general form for Nusselt number is

$$Nu = \frac{h \times d_{fin}}{k}$$

$$h = \frac{Nu \times k}{d_{fin}}$$

$$h = \frac{.............. \times ....}{..............}$$

$$h = ... \frac{W}{m^2 K}$$

Perimeter of the cross section of the fin = p = $\pi \times d_{fin}$

$$p = \pi \times ....$$

$$p = ... m$$

Cross sectional area of fin = A = $\frac{\pi}{4} \times d_{fin}{}^2$

$$A = \frac{\pi}{4} \times ....$$

$$A = ... m^2$$

T_b = Base temperature = T_1

$T_b = \ldots\ldots\ldots\ldots\ldots\ldots\ \,^oC$

T_a = Ambient temperature

$T_a = \ldots\ldots\ldots\ldots\ldots\ldots\ \,^oC$

$$m = \sqrt{\frac{hp}{kA}}$$

$$m = \sqrt{\frac{\ldots\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots\ldots}}$$

$$m = \ldots\ldots\ldots\ldots\ldots\ldots \frac{1}{m}$$

For a given intermediate position, $x = \ldots.m$

Heat transfer in fin = $Q_{fin} = \sqrt{hpkA} \times (T_b - T_a) \times \tanh(mx)$

$$Q_{fin} = \sqrt{\ldots\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots} \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots) \times \tanh(\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots)$$

$$Q_{fin} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \,W$$

Fin efficiency = $\eta_{fin} = \dfrac{\tanh(m \times x)}{m \times x} \times 100$

$$\eta_{fin} = \frac{\tanh(\ldots\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots\ldots)}{\ldots\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots\ldots} \times 100$$

$$\eta_{fin} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \%$$

Theoretical intermediate temperature = $T_{the} = \left[(T_b - T_a) \times \dfrac{\cosh m(L - x)}{\cosh(mL)} \right] + T_a$

$$T_{the} = \left[(\ldots\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots\ldots) \times \frac{\cosh \ldots\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots)}{\cosh(\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots)} \right] + \ldots\ldots\ldots\ldots$$

$$T_{the} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \,^oC$$

Actual intermediate temperature = T_{act} = Surface temperature of fin indicated by digital thermometer corresponding to x

T_{act} = ... ^{o}C

Error percentage in intermediate temperature =

$$\text{Error} = \frac{\text{Difference between } T_{the} \text{ and } T_{act}}{T_{the}} \times 100$$

$$\text{Error in intermediate temperature} = \frac{\ldots\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots\ldots} \times 100$$

Error in intermediate temprature = ...%

Result:

Corresponding to x = m,

Heat transfer by fin = Q_{fin} = W

Fin efficiency = η_{fin} = %

Theoretical intermediate temperature = T_{the} = ^{o}C

Actual intermediate temperature = T_{act} = ^{o}C

Percentage error in intermediate temperature = %

Inference:

I have gained knowledge of measuring efficiency and heat transfer rate of fins under natural convection.

Applications:

1. Design of fins for compressors, I.C. Engines.
2. Design of fins for motors, condensers.

Ex No: 5 b ***Date:***

Heat transfer from pin-fin apparatus (forced convection mode)

Aim:

To determine the heat transfer rate, intermediate temperature distributions and fin efficiency of Pin-Fin in forced convection mode using pin-fin apparatus.

Apparatus Required:

Pin-fin apparatus

Procedure:

1. Ensure proper electrical connections and zero position of the variac.
2. Slowly rotate variac to desired values, say 100 V
3. Note down the readings of Voltmeter and Ammeter.
4. Close control valve & switch on Toggle switch for blower. Later adjust gate valve by seeing manometer level.
5. Note down the temperature by channel selector for every 15 minutes until steady state condition is reached.

Formula used:

Heat transfer in fin = $Q_{fin} = \sqrt{hpkA} \times (T_b - T_a) \times \tanh(mx)$

Where,

h = Heat transfer Coefficient in $\frac{W}{m^2K}$

p = Perimeter of the cross section of the fin in m

k = Thermal conductivity of the fin material in $\frac{W}{mK}$

Observation:

Material of the pin-fin =

Diameter of the fin = d_{fin} = m

Length of the fin = L = m

Thermal conductivity of fin material = k = $\frac{W}{mK}$

Diameter of the orifice = m

Tabulation:

S. No.	Manometer Reading		Heat Input		Temperature of Surface°C					Ambient Temp°C T_a
	h_1 cm	h_2 cm	V (Volts)	I (Amps)	$T_1=T_b$	T_2	T_3	T_4	T_5	
1.										
2.										
3.										
4.										
5.										
6.										

S. No.	Heat Input		*x* (m)	T_{the} °C	T_{act} °C	Error (%)	η_f (%)	Q_{fin} (W)
	V (Volts)	I (Amps)						
1.								
2.								
3.								
4.								
5.								
6.								

A = Cross sectional area of the fin in m^2

T_b = Base temperature of the fin in ^oC

T_a = Ambient or atmospheric temperature of the air in ^oC

m $= \sqrt{\frac{hp}{kA}}$ in $\frac{1}{m}$ (or) m^{-1}

x = Length of the fin from base in m

Heat transfer coefficient can be determined by the following way

Film temperature = $T_f = \frac{T_m + T_a}{2}$

Where,

T_m = Mean surface temperature of fin $\frac{T_2 + T_3 + T_4 + T_5}{4}$

T_a = Ambient or Atmospheric temperature of air

Choose the following properties of air from HMT data book corresponding to film temperature T_f.

Density (ρ), Kinematic viscosity (ν), Prandtl number (Pr) and thermal conductivity (k)

Reynolds number = $Re = \frac{u \times d_{fin}}{\nu}$

Where,

u = Velocity of air in $\frac{m}{s}$ which can be determine by the following formula

$$u \text{ in } \frac{m}{s} = \frac{\text{Quantity of air discharged in } \frac{m^3}{s}}{\text{Cross sectional area of the fin in } m^2}$$

$$u = \frac{C_d \times a \times \sqrt{2gh}}{\frac{\pi}{4} \times d_{fin}^{\ 2}}$$

Model Calculation:

Mean temperature of the fin surface $= T_m = \dfrac{T_2 + T_3 + T_4 + T_5}{4}$

$$T_m = \frac{..........+..........+..........+..........}{4}$$

$$T_m = ...\ ^oC$$

Ambient temperature of air = T_a

$$T_a = ...\ ^oC$$

Film temperature = $T_f = \dfrac{T_m + T_a}{2}$

$$T_f = \frac{..........+..........}{2}$$

$$T_f = ...\ ^oC$$

Choose the following properties of air from HMT data book corresponding to film temperature T_f.

$$\rho = ...\ \frac{kg}{m^3}$$

$$v = ...\ \frac{m^2}{s}$$

$$Pr = ...$$

$$k = ...\ \frac{W}{mK}$$

$$\text{Air head} = h = \frac{(h_1 - h_2)}{100} \times \frac{\rho_w}{\rho_a}$$

$$\text{Air head} = h = \frac{(............-............)}{100} \times \frac{1000}{1.293}$$

$$\text{Air head} = h = ...\ \text{m of air}$$

Where,

C_d = Coefficient of discharge = 0.62

a = Cross sectional area of the orifice = $\frac{\pi}{4} \times d_{ori}{}^2$ in m^2

g = gravity value = 9.81 $\frac{m}{s^2}$

h = air head in m = $(h_1 - h_2) \times \frac{\rho_w}{\rho_a}$

Where,

ρ_w = density of water = 1000 $\frac{Kg}{m^3}$

ρ_a = density of air = 1.293 $\frac{Kg}{m^3}$

Then Nusselt number is determined by the following formula

$$Nu = C \times Re^m \times Pr^{0.333}$$

C and m values can be chosen from HMT data book corresponding to forced convection from vertical cylinder (Flow over cylinders)

Then general form for Nusselt number is

$$Nu = \frac{h \times d_{fin}}{k}$$

$$h = \frac{Nu \times k}{d_{fin}}$$

Fin efficiency = $\eta_{fin} = \frac{\tanh(m \times x)}{m \times x}$

Theoretical intermediate temperature = $T_{the} = \left[(T_b - T_a) \times \frac{\cosh m(L - x)}{\cosh (mL)} \right] + T_a$

$$Nu = \frac{h \times d_{fin}}{k}$$

From that

$$h = \frac{Nu \times k}{d_{fin}}$$

$$h = \frac{\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots}$$

$$h = \ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{m^2K}$$

Perimeter of the cross section of the fin = p = $\pi \times d_{fin}$

$$p = \pi \times \ldots\ldots\ldots\ldots\ldots\ldots$$

$$p = \ldots\ldots\ldots\ldots\ldots\ldots\ m$$

Cross sectional area of fin = A = $\frac{\pi}{4} \times d_{fin}{}^2$

$$A = \frac{\pi}{4} \times \ldots\ldots\ldots\ldots\ldots\ldots$$

$$A = \ldots\ldots\ldots\ldots\ldots\ldots\ m^2$$

T_b = Base temperature = T_1

$$T_b = \ldots\ldots\ldots\ldots\ldots\ldots\ {}^oC$$

T_a = Ambient temperature

$$T_a = \ldots\ldots\ldots\ldots\ldots\ldots\ {}^oC$$

$$m = \sqrt{\frac{hp}{kA}}$$

$$m = \sqrt{\frac{\ldots\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots\ldots}}$$

$$m = \ldots\ldots\ldots\ldots\ldots\ldots \frac{1}{m}$$

Actual intermediate temperature

= T_{act} = Surface temperature of fin indicated by digital thermometer corresponding to x

Error percentage in intermediate temperature

$$= \text{Error} = \frac{\text{Difference between } T_{the} \text{ and } T_{act}}{T_{the}} \times 100$$

$$m = \ldots\ldots\ldots\ldots\ldots\ldots \frac{1}{m}$$

For any one intermediate position = $x = \ldots\ldots\ldots\ldots\ldots\ldots\ldots$

Heat transfer in fin = $Q_{fin} = \sqrt{hpkA} \times (T_b - T_a) \times \tanh(mx)$

$$Q_{fin} = \sqrt{\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots \times \ldots\ldots\ldots \times \ldots\ldots\ldots} \times (\ldots\ldots\ldots - \ldots\ldots\ldots) \times \tanh(\ldots\ldots\ldots \times \ldots\ldots\ldots)$$

$$Q_{fin} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ W}$$

Fin efficiency = $\eta_{fin} = \dfrac{\tanh(m \times x)}{m \times x} \times 100$

$$\eta_{fin} = \frac{\tanh(\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots)}{\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots} \times 100$$

$$\eta_{fin} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \%$$

Theoretical intermediate temperature = $T_{the} = \left[(T_b - T_a) \times \dfrac{\cosh m(L - x)}{\cosh(mL)} \right] + T_a$

Where, L=Total length of the fin in m

$$T_{the} = \left[(\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots) \times \frac{\cosh \ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots)}{\cosh(\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots)} \right] + \ldots\ldots\ldots\ldots$$

$$T_{the} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ {}^{o}C$$

Actual intermediate temperature = T_{act} = Surface temperature of fin indicated by digital thermometer corresponding to x

$$T_{act} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ {}^{o}C$$

Error percentage in intermediate temperature

$$= \text{Error} = \frac{\text{Difference between } T_{the} \text{ and } T_{act}}{T_{the}} \times 100$$

$$\text{Error in intermediate temperature} = \frac{\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots} \times 100$$

$$\text{Error in intermediate temprature} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \%$$

Result:

Corresponding to x	=		m,
Heat transfer by fin	=	Q_{fin} =	W
Fin efficiency	=	η_{fin} =	%
Theoretical intermediate temperature	=	T_{the} =	^oC
Actual intermediate temperature	=	T_{act} =	^oC
Percentage error in intermediate temperature	=		%

Inference:

I have gained knowledge of measuring efficiency and heat transfer rate of fins under forced convection.

Applications:

1. Design of fins for automobiles.

Ex No : 6 ***Date :***

Determination of heat transfer coefficient under natural convection from a vertical cylinder

Aim:

To determine the actual and theoretical heat transfer coefficient from the surface of the vertical tube using natural convection apparatus.

Apparatus Required:

1. Natural Convection apparatus

Procedure:

1. Switch on CONSOLE.
2. Switch on the heater and set the voltage (say 40 V) using Variac.
3. Note down the ammeter and voltmeter readings.
4. Wait for sufficient time for the system to reach steady state.
5. Note down the Temperatures 1 to 4 using the channel selector and digital temperature indicator.
6. Calculate the convection heat transfer co-efficient using the procedure given below.
7. Repeat the experiment for different heat inputs.

Observation:

Material of the vertical tube =

Inner diameter of the vertical tube = d_i = m

Outer diameter of the vertical tube = d_o = m

Length of the vertical tube = L = m

Tabulation:

S.No.	**Temperatures °C**				**Ambient Temperature (°C)**	**Heater Input**	
	T_1	**T_2**	**T_3**	**T_4**	**T_5=T_a**	**V (Volts)**	**I (Amps)**
1.							
2.							
3.							
4.							
5.							

Formula used for Actual heat transfer Coefficient (h_a):

Actual heat transfer Coefficient $= h_a = \dfrac{Q}{A_s \times (T_m - T_a)}$

Where

h_a = Actual heat transfer Coefficient in $\dfrac{W}{m^2K}$

Q = Heat energy Supplied in W

A_s = Surface area of the Vertical tube in m^2

T_m = Mean temperature of the surface of the vertical tube in ^oC

T_a = Ambient or Atmospheric temperature in ^oC

Formula used for Theoretical method:

Film temperature $= T_f = \dfrac{T_m + T_a}{2}$

Choose the following properties of air from HMT data book corresponding to film temperature T_f.

Density (ρ), Kinematic viscosity (ν), Prandtl number (Pr) and thermal conductivity (k)

Grash of number $= Gr = \dfrac{g \times \beta \times L^3 \times (T_m - T_a)}{\nu^2}$

Where

g = gravity value (constant) in $\dfrac{m}{s^2}$ $(g = 9.81 \dfrac{m}{s^2})$

β = Coefficient of thermal expansion = $\dfrac{1}{T_f}$ (T_f should be substituted in Kelvin)

L = Length of the vertical tube in m

v = Kinematic viscosity in $\dfrac{m^2}{s}$

Then find out the product of (Gr × Pr)

If Gr × Pr < 10^4 Use the following Nusselt number (Nu) formula

Model Calculation:

Actual heat transfer Coefficient (h_a)

Heat energy supplied by heater = $Q = V \times I$

$Q = \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$

$Q = \ldots\ldots\ldots\ldots\ W$

A_s = Surface area of the vertical tube

$A_s = \pi \times d_o \times L$

Where d_o = Outer diameter of vertical tube = ………………. m

$A_s = \pi \times \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$

$A_s = \ldots\ldots\ldots\ldots\ldots\ m^2$

Mean temperature of the vertical tube surface = T_m = $\dfrac{T_1 + T_2 + T_3 + T_4}{4}$

$$T_m = \frac{\ldots\ldots\ldots + \ldots\ldots\ldots + \ldots\ldots\ldots + \ldots\ldots\ldots}{4}$$

$T_m = \ldots\ldots\ldots\ldots\ldots\ {}^oC$

Ambient or Atmospheric air temperature = $T_a = T_5$

$T_a = \ldots\ldots\ldots\ldots\ldots\ {}^oC$

Actual heat transfer Coefficient = $h_a = \dfrac{Q}{A_s \times (T_m - T_a)}$

$$h_a = \frac{\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots)}$$

$$h_a = \ldots\ldots\ldots\ldots\ldots \frac{W}{m^2K}$$

$$Nu = 0.68 + \frac{0.67(GrPr)^{0.25}}{\left\{1 + \left[\frac{0.492}{Pr}\right]^{0.5625}\right\}^{0.444}}$$

If $10^4 < Gr \times Pr < 10^9$ then use the following Nusselt number formula

$$Nu = 0.59\,(GrPr)^{0.25}$$

Then use the following expression to find out theoretical heat transfer Coefficient

$$Nu = \frac{h_t \times L}{k}$$

$$h_t = \frac{Nu \times k}{L}$$

Where

h_t = Theoretical heat transfer Coefficient in $\frac{W}{m^2K}$

Theoretical heat transfer Coefficient (ht)

Film temperature = T_f = $\frac{T_m + T_a}{2}$

$$T_f = \frac{\text{..........} + \text{..........}}{2}$$

T_f = ... ^oC

Choose the following properties of air from HMT data book corresponding to film temperature T_f.

ρ = …………………….. $\frac{kg}{m^3}$

ν = …………………….. $\frac{m^2}{s}$

Pr = ……………………..

k = …………………….. $\frac{W}{mK}$

β = Coefficient of thermal expansion = $\frac{1}{T_f}$ (T_f should be substituted in Kelvin)

$$\beta = \frac{1}{\text{...........}}$$

$$\beta = \text{...................}\ \frac{1}{K}$$

Grashof number = Gr = $\frac{g \times \beta \times L^3 \times (T_m - T_a)}{\nu^2}$

$$Gr = \frac{\text{............}\times\text{............}\times\text{............}\times(\text{............}-\text{.............})}{\text{................}}$$

$$Gr = \text{...................}$$

$$Gr \times Pr = \text{................}\times\text{..............}$$

$$Gr \times Pr = \text{..............................}$$

If Gr×Pr < 10^4 Use the following Nusselt number (Nu) formula

$$Nu = 0.68 + \frac{0.67(GrPr)^{0.25}}{\left\{1 + \left[\frac{0.492}{Pr}\right]^{0.5625}\right\}^{0.444}}$$

$$Nu = 0.68 + \frac{0.67(\text{.....................})^{0.25}}{\left\{1 + \left[\frac{0.492}{\text{.....................}}\right]^{0.5625}\right\}^{0.444}}$$

$$Nu = \text{..............................}$$

(or)

Else if 10^4 < Gr×Pr < 10^9 then use the following Nusselt number formula

$$Nu = 0.59\,(GrPr)^{0.25}$$

$$Nu = 0.59\,(.....................)^{0.25}$$

$$Nu = ...$$

Theoretical heat transfer Coefficient = $h_t = \dfrac{Nu \times k}{L}$

$$h_t = \frac{...............\times............}{..............}$$

$$h_t = ...\frac{W}{m^2K}$$

Result:

Actual heat transfer Coefficient = h_a = $\frac{W}{m^2K}$

Theoretical heat transfer Coefficient = h_t = $\frac{W}{m^2K}$

Inference:

I have gained knowledge of measuring heat transfer coefficient between a vertical cylinder and atmospheric air under natural convection mode.

Applications:

1. Design of air cooling system for I.C. engines.
2. Design of air cooling system for compressors.
3. Design of natural draught cooling towers.

Ex No: 7 ***Date:***

Determination of heat transfer coefficient under forced convection from a tube

Aim:

To determine the actual and theoretical heat transfer coefficient of a horizontal tube using forced convection apparatus.

Apparatus Required:

1. Forced Convection apparatus

Procedure:

1. Switch on the CONSOLE to activate the control panel.
2. Switch on the blower unit first and adjust the flow of air using wheel valve of blower to a desired difference in manometer.
3. Switch on the heater and set the voltage (say 80 V) using the Variac.
4. Note down the ammeter and voltmeter readings.
5. Wait for reasonable time to allow the system to reach steady state.
6. Measure the temperatures from T_1 to T_5 using the channel selector and digital temperature indicator.
7. Calculate the convective heat transfer co-efficient using the procedure given below.
8. Repeat the experiment for different values of power input to the heater and blower air flow rates.

Observation:

Material of the tube =

Inner diameter of the tube = d_i = m

Outer diameter of the tube = d_o = m

Length of the vertical tube = L = m

Diameter of the orifice = d_{ori} = m

Tabulation:

S.No.	Manometer Reading, (m of water)		Heat Input		Surface Temperature of the tube			Air temperature °C	
	h_1	h_2	V (Volts)	I (Amps)	T_1	T_2	T_3	T_4	T_5

Formula used for Actual heat transfer Coefficient:

Actual heat transfer Coefficient = $h_a = \dfrac{Q}{A_s \times (T_m - T_a)}$

Where

h_a = Actual heat transfer Coefficient in $\dfrac{W}{m^2K}$

Q = Heat energy Supplied in W

A_s = Surface area of the tube in m^2

T_m = Mean temperature of the surface of the tube in ^oC

T_a = Forced air temperature in ^oC

Formula used for Theoretical method:

Film temperature = $T_f = \dfrac{T_m + T_a}{2}$

Choose the following properties of air from HMT data book corresponding to film temperature T_f.

Density (ρ), Kinematic viscosity (ν), Prandtl number (Pr)

and thermal conductivity (k)

Reynolds number = $Re = \dfrac{u \times d_o}{\nu}$

Where, u = Velocity of air in $\dfrac{m}{s}$ which can be determine by the following formula

$$u \text{ in } \frac{m}{s} = \frac{\text{Quantity of air discharged in } \frac{m^3}{s}}{\text{Cross sectional area of the tube in } m^2}$$

$$u = \frac{C_d \times a \times \sqrt{2gh}}{\frac{\pi}{4} \times d_o^2}$$

Where,

C_d = Coefficient of discharge = 0.62

a = Cross sectional area of the orifice = $\dfrac{\pi}{4} \times d_{ori}^2$ in m^2

g = gravity value = 9.81 $\dfrac{m}{s^2}$

h = air head in m = $(h_1 - h_2) \times \dfrac{\rho_w}{\rho_a}$

Model Calculation:

Actual heat transfer Coefficient (h_a)

Heat energy supplied by heater = $Q = V \times I$

$$Q = \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$$

$$Q = \ldots\ldots\ldots\ldots\ W$$

A_s = Surface area of the tube

$$A_s = \pi \times d_o \times L$$

Where

d_o = Outer diameter of tube = ……………… m

$$A_s = \pi \times \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$$

$$A_s = \ldots\ldots\ldots\ldots\ldots\ldots\ m^2$$

Mean temperature of the vertical tube surface = $T_m = \dfrac{T_1 + T_2 + T_3}{3}$

$$T_m = \frac{\ldots\ldots\ldots + \ldots\ldots\ldots + \ldots\ldots\ldots}{3}$$

$$T_m = \ldots\ldots\ldots\ldots\ldots\ldots\ {}^oC$$

Forced air temperature = $T_a = \dfrac{T_4 + T_5}{2}$

$$T_a = \frac{\ldots\ldots\ldots + \ldots\ldots\ldots}{2}$$

$$T_a = \ldots\ldots\ldots\ldots\ldots\ldots\ {}^oC$$

Actual heat transfer Coefficient = $h_a = \dfrac{Q}{A_s \times (T_m - T_a)}$

$$h_a = \frac{\ldots\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots)}$$

$$h_a = \ldots\ldots\ldots\ldots\ldots\ldots\ \frac{W}{m^2K}$$

Where,

ρ_w = density of water = 1000 $\frac{kg}{m^3}$

ρ_a = density of air = 1.293 $\frac{kg}{m^3}$

Then Nusselt number is determined by the following formula

$$Nu = C \times Re^m \times Pr^{0.333}$$

C and m values can be chosen from HMT data book corresponding to forced convection from vertical cylinder (Flow over cylinders)

Then general form for Nusselt number is

$$Nu = \frac{h_t \times d_0}{k}$$

$$h_t = \frac{Nu \times k}{d_o}$$

Theoretical heat transfer Coefficient (ht)

Film temperature = T_f = $\frac{T_m + T_a}{2}$

$$T_f = \frac{..........+..........}{2}$$

$$T_f = ... \,^oC$$

Choose the following properties of air from HMT data book corresponding to film temperature T_f.

ρ = …………………….. $\frac{kg}{m^3}$

v = …………………….. $\frac{m^2}{s}$

Pr = ……………………..

k = …………………….. $\frac{W}{mK}$

Air head = h = $(h_1 - h_2) \times \frac{\rho_w}{\rho_a}$

$$\text{Air head} = h = (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots) \times \frac{1000}{1.293}$$

$$\text{Air head} = h = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ m of air}$$

$$\text{Velocity of air} = u = \frac{C_d \times a \times \sqrt{2gh}}{\frac{\pi}{4} \times d_o^2}$$

$$u = \frac{0.62 \times \frac{\pi}{4} \times d_{ori}^2 \times \sqrt{2gh}}{\frac{\pi}{4} \times d_o^2}$$

$$u = \frac{0.62 \times \frac{\pi}{4} \times \ldots\ldots\ldots\ldots \times \sqrt{2 \times 9.81 \times \ldots\ldots\ldots\ldots}}{\frac{\pi}{4} \times \ldots\ldots\ldots\ldots}$$

$$u = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{m}{s}$$

$$\text{Reynolds number} = Re = \frac{u \times d_o}{\nu}$$

$$Re = \frac{\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots}$$

$$Re = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Then Nusselt number is determined by the following formula

$$Nu = C \times Re^m \times Pr^{0.333}$$

C and m values can be chosen from HMT data book corresponding to forced convection form cylinder (Floe over cylinders)

$$Nu = \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots^{\ldots\ldots} \times \ldots\ldots\ldots\ldots^{0.333}$$

$$Nu = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Then general form for Nusselt number is

$$Nu = \frac{h_t \times d_0}{k}$$

From that

$$h_t = \frac{Nu \times k}{d_o}$$

$$h_t = \frac{\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots}$$

$$h_t = \ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{m^2K}$$

Result:

Actual heat transfer Coefficient	=	h_a	=	$\frac{W}{m^2K}$
Theoretical heat transfer Coefficient	=	h_t	=	$\frac{W}{m^2K}$

Inference:

I have gained knowledge of measuring heat transfer coefficient for forced convection through a tube.

Applications:

1. Design of forced draught cooling towers.

Design of tubes of boilers, refrigerators and air-conditioners

Ex No: 8 **Date :**

Effectiveness of Parallel flow heat exchanger

Aim:

To determine the rate of heat transfer, overall heat transfer coefficient and effectiveness of the parallel flow heat exchanger.

Apparatus Required:

1. Parallel flow heat exchanger apparatus
2. Thermometer
3. Stop watch
4. Measuring container

Procedure:

1. Open the Main valve and allow the water to flow through the geycer and ensure that water flows through the inner pipe of the apparatus.
2. In order to make the parallel flow between hot water and cold water open valve numbers 1, 2 and 4, and close the valve numbers 3 and 5.
3. Measure flow rate of both hot and cold water.
4. Note down temperatures at inlet and outlet for both fluids.

Formula used:

Heat transfer rate = $Q = \dfrac{m_h c_{ph}(T_1 - T_2) + m_c c_{pc}(t_2 - t_1)}{2}$ in W

Where,

m_h = Mass flow rate of hot water in $\dfrac{kg}{s}$

Observation:

Diameter of the inner tube = d = m

Length of the heat exchanger = L = m

Specific heat of hot fluid = c_{ph} = $\frac{J}{kgK}$

Specific heat of cold fluid = c_{pc} = $\frac{J}{kgK}$

Tabulation:

S. No.	**Hot water**			**Cold water**		
	Time for 200 ml of hot water collection (sec)	**Inlet temp. T_1 °c**	**Outlet temp. T_2°c**	**Time for 200 ml of cold water collection (sec)**	**Inlet temp. t_1 °c**	**Outlet temp. t_2 °c**
1.						
2.						
3.						
4.						
5.						

c_{ph} = Specific heat of hot water in $\frac{J}{kgK}$

T_1 = Inlet temperature of hot water in ^oC

T_2 = Outlet temperature of hot water in ^oC

m_c = Mass flow rate of cold water in $\frac{kg}{s}$

c_{pc} = Specific heat of cold water in $\frac{J}{kgK}$

t_1 = Inlet temperature of cold water in ^oC

t_2 = Outlet temperature of cold water in ^oC

We know that

$$Q = U \times A \times (LMTD)$$

Hence Overall heat transfer Coefficient = $U = \frac{Q}{A \times LMTD}$ in $\frac{W}{m^2K}$

Where,

A = Surface area of the inner tube = $\pi \times d \times L$ in m^2

LMTD = Logarithmic mean temperature difference = $\dfrac{(T_1 - t_1) - (T_2 - t_2)}{\ln \dfrac{T_1 - t_1}{T_2 - t_2}}$ in ^oC (or) K

C_h = $m_h c_{ph}$

C_c = $m_c c_{pc}$

If C_h is minimum assign $C_h = C_{min}$ and $C_c = C_{max}$ and use the following formula for determining effectiveness

$$\varepsilon = \frac{m_h C_{ph} (T_1 - T_2)}{C_{min} (T_1 - t_1)}$$

Else If C_c is minimum assign $C_c = C_{min}$ and $C_h = C_{max}$ and use the following formula for determining effectiveness

$$\varepsilon = \frac{m_c C_{pc} (t_2 - t_1)}{C_{min} (T_1 - t_1)}$$

Model Calculation:

Mass flow rate of hot water =

$$m_h = \frac{200\text{ml}}{\text{Time for 200ml of hot water collection in seconds} \times 1000} \text{ in } \frac{\text{kg}}{\text{s}}$$

$$m_h = \frac{200\text{ml}}{\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \times 1000}$$

$$m_h = \ldots\ldots\ldots\ldots\ldots\ldots \frac{\text{kg}}{\text{s}}$$

Mass flow rate of cold water =

$$m_c = \frac{200\text{ml}}{\text{Time for 200ml of cold water collection in seconds} \times 1000} \text{ in } \frac{\text{kg}}{\text{s}}$$

$$m_c = \frac{200\text{ml}}{\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \times 1000}$$

$$m_c = \ldots\ldots\ldots\ldots\ldots\ldots \frac{\text{kg}}{\text{s}}$$

$$Q = \frac{m_h c_{ph}(T_1 - T_2) + m_c c_{pc}(t_2 - t_1)}{2} \text{ in W}$$

$$Q = \frac{\ldots\ldots \times \ldots\ldots \times (\ldots\ldots - \ldots\ldots) + \ldots\ldots \times \ldots\ldots \times (\ldots\ldots - \ldots\ldots)}{2}$$

$$Q = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{W}$$

$$\text{LMTD} = \frac{(T_1 - t_1) - (T_2 - t_2)}{\ln \dfrac{T_1 - t_1}{T_2 - t_2}} \text{ in } {}^{o}\text{C (or) K}$$

$$\text{LMTD} = \frac{(\ldots\ldots - \ldots\ldots) - (\ldots\ldots - \ldots\ldots)}{\ln \dfrac{\ldots\ldots - \ldots\ldots}{\ldots\ldots - \ldots\ldots}}$$

$$\text{LMTD} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{K}$$

A = Surface area of the inner tube = $\pi \times d \times L$ in m^2

$$A = \pi \times \ldots\ldots\ldots \times \ldots\ldots\ldots$$

$$A = \ldots\ldots\ldots\ldots\ldots\ldots\ldots m^2$$

Overall heat transfer Coefficient = $U = \frac{Q}{A \times LMTD}$ in $\frac{W}{m^2K}$

$$U = \frac{\ldots\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots}$$

$$U = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{m^2K}$$

$$C_h = m_h \times c_{ph}$$

$$C_h = \ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$$

$$C_h = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{K}$$

$$C_c = m_c \times c_{pc}$$

$$C_c = \ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots$$

$$C_c = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{K}$$

If C_h is minimum assign $C_h = C_{min}$ and $C_c = C_{max}$ and use the following formula for determining effectiveness

$$\varepsilon = \frac{m_h c_{ph} (T_1 - T_2)}{C_{min} (T_1 - t_1)}$$

$$\varepsilon = \frac{\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots)}{\ldots\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots)}$$

$$\varepsilon = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Else If C_c is minimum assign $C_c = C_{min}$ and $C_h = C_{max}$ and use the following formula for determining effectiveness

$$\varepsilon = \frac{m_c c_{pc} (t_2 - t_1)}{C_{min} (T_1 - t_1)}$$

$$\varepsilon = \frac{\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots)}{\ldots\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots)}$$

$$\varepsilon = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Result:

Rate of heat transfer = Q = W

Overall heat transfer Coefficient = U = $\frac{W}{m^2K}$

Effectiveness of heat exchanger = ε =

Inference:

I have gained knowledge of measuring heat transfer rate and effectiveness of parallel flow heat exchangers.

Applications:

1. Design of Heat exchangers.
2. Dairy plants.
3. Oil refineries.

Ex No:9 **Date :**

Effectiveness of Counter flow heat exchanger

Aim:

To determine the rate of heat transfer, overall heat transfer coefficient and effectiveness of the counter flow heat exchanger.

Apparatus Required:

1. Counter flow heat exchanger apparatus
2. Thermometer
3. Stop watch
4. Measuring container

Procedure:

1. Open the Main valve and allow the water to flow through the geycer and ensure that water flows through the inner pipe of the apparatus.
2. In order to make the parallel flow between hot water and cold water open valve numbers 1, 3 and 5, and close the valve numbers 2 and 4.
3. Measure flow rate of both hot and cold water.
4. Note down temperatures at inlet and outlet for both fluids.

Formula used:

$$\text{Heat transfer rate} = Q = \frac{m_h c_{ph}(T_1 - T_2) + m_c c_{pc}(t_2 - t_1)}{2} \text{ in W}$$

Where,

m_h = Mass flow rate of hot water in $\frac{kg}{s}$

Observation:

Diameter of the inner tube = d = m

Length of the heat exchanger = L = m

Specific heat of hot fluid = c_{ph} = $\frac{J}{kgK}$

Specific heat of cold fluid = c_{pc} = $\frac{J}{kgK}$

Tabulation:

S. No.	Hot water			Cold water		
	Time for 200 ml of hot water collection (sec)	**Inlet temp. T_1 °c**	**Outlet temp. T_2°c**	**Time for 200 ml of cold water collection (sec)**	**Inlet temp. t_1 °c**	**Outlet temp. t_2 °c**
1.						
2.						
3.						
4.						
5.						

c_{ph} = Specific heat of hot water in $\frac{J}{kgK}$

T_1 = Inlet temperature of hot water in ^oC

T_2 = Outlet temperature of hot water in ^oC

m_c = Mass flow rate of cold water in $\frac{kg}{s}$

c_{pc} = Specific heat of cold water in $\frac{J}{kgK}$

t_1 = Inlet temperature of cold water in ^oC

t_2 = Outlet temperature of cold water in ^oC

We know that $Q = U \times A \times (LMTD)$

Hence Overall heat transfer Coefficient = $U = \frac{Q}{A \times LMTD}$ in $\frac{W}{m^2K}$

Where,

A = Surface area of the inner tube = $\pi \times d \times L$ in m^2

LMTD = Logarithmic mean temperature difference =

$$\frac{(T_1 - t_2) - (T_2 - t_1)}{\ln \frac{T_1 - t_2}{T_2 - t_1}} \text{ in } ^oC \text{ (or) } K$$

C_h = $m_h c_{ph}$

C_c = $m_c c_{pc}$

If C_h is minimum assign $C_h = C_{min}$ and $C_c = C_{max}$ and use the following formula for determining effectiveness

$$\varepsilon = \frac{m_h c_{ph}(T_1 - T_2)}{C_{min}(T_1 - t_1)}$$

Else If C_c is minimum assign $C_c = C_{min}$ and $C_h = C_{max}$ and use the following formula for determining effectiveness

$$\varepsilon = \frac{m_c c_{pc}(t_2 - t_1)}{C_{min}(T_1 - t_1)}$$

Model Calculation:

Mass flow rate of hot water =

$$m_h = \frac{200\text{ml}}{\text{Time for 200ml of hot water collection in seconds} \times 1000} \text{ in } \frac{\text{kg}}{\text{s}}$$

$$m_h = \frac{200\text{ml}}{\dots\dots\dots\dots \times 1000}$$

$$m_h = \dots\dots\dots \frac{\text{kg}}{\text{s}}$$

Mass flow rate of cold water =

$$m_c = \frac{200\text{ml}}{\text{Time for 200ml of cold water collection in seconds} \times 1000} \text{ in } \frac{\text{kg}}{\text{s}}$$

$$m_c = \frac{200\text{ml}}{\dots\dots\dots\dots \times 1000}$$

$$m_c = \dots\dots\dots \frac{\text{kg}}{\text{s}}$$

$$Q = \frac{m_h c_{ph}(T_1 - T_2) + m_c c_{pc}(t_2 - t_1)}{2} \text{ in W}$$

$$Q = \frac{\dots\dots \times \dots\dots \times (\dots\dots - \dots\dots) + \dots\dots \times \dots\dots \times (\dots\dots - \dots\dots)}{2}$$

$$Q = \dots\dots\dots\dots \text{W}$$

$$\text{LMTD} = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln \frac{T_1 - t_2}{T_2 - t_1}} \text{ in } {}^{o}\text{C (or) K}$$

$$\text{LMTD} = \frac{(\dots\dots - \dots\dots) - (\dots\dots - \dots\dots)}{\ln \frac{\dots\dots - \dots\dots}{\dots\dots - \dots\dots}}$$

$$\text{LMTD} = \dots\dots\dots\dots \text{K}$$

A = Surface area of the inner tube = $\pi \times d \times L$ in m^2

$$A = \pi \times .... \times ....$$

$$A = ...m^2$$

Overall heat transfer Coefficient = $U = \dfrac{Q}{A \times LMTD}$ in $\dfrac{W}{m^2K}$

$$U = \frac{..................}{............ \times ....}$$

$$U = ... \frac{W}{m^2K}$$

$$C_h = m_h \times c_{ph}$$

$$C_h = ... \times ....$$

$$C_h = ... \frac{W}{K}$$

$$C_c = m_c \times c_{pc}$$

$$C_c = ... \times ....$$

$$C_c = ... \frac{W}{K}$$

If C_h is minimum assign $C_h = C_{min}$ and $C_c = C_{max}$ and use the following formula for determining effectiveness

$$\varepsilon = \frac{m_h c_{ph} (T_1 - T_2)}{C_{min} (T_1 - t_1)}$$

$$\varepsilon = \frac{............... \times .... \times (.............. - ....)}{................ \times (............. - ....)}$$

$$\varepsilon = ...$$

Else If C_c is minimum assign $C_c = C_{min}$ and $C_h = C_{max}$ and use the following formula for determining effectiveness

$$\varepsilon = \frac{m_c c_{pc}(t_2 - t_1)}{C_{min}(T_1 - t_1)}$$

$$\varepsilon = \frac{\ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots)}{\ldots\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots)}$$

$$\varepsilon = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Result:

Rate of heat transfer	=	Q	=	W
Overall heat transfer Coefficient	=	U	=	$\frac{W}{m^2K}$
Effectiveness of heat exchanger	=	ε	=	

Inference:

I have gained knowledge of measuring heat transfer rate and effectiveness of counter flow heat exchangers.

Applications:

1. Design of Heat exchangers.
2. Dairy plants.
3. Oil refineries.

Ex No :10 ***Date :***

Effectiveness of Cross Flow Heat Exchanger

Aim:

To determine the effectiveness of a given cross flow heat exchanger

Apparatus Required:

1. Cross flow heat exchanger apparatus
2. Stop watch
3. Measuring container

Procedure:

1. Connect water pipes from the sources to geycer and to heat exchanger and clamp the hoses to prevent water leakage.
2. Provide 220 volts, AC, 15 power supply to the unit.
3. Fix the hose for hot water coming out from the geycer to entering on the side of the shell.
4. Also, fix the hose for cold water coming out from the source to entering on the bottom side of the shell.
5. Now put on geycer & adjust the flow rate of entering water into geycer for required hot water temperature.
6. Adjust flow rate of cold water also and should be lower than that of hot water.
7. Switch on digital temperature indicator & note down all four temperatures. Once the steady state is reached note down flow rate of hot water & cold water with the help of measuring container.

Tabulation:

S.No.	Time for 100ml hot water collection (Sec.)	Time for 100ml cold water collection (Sec.)	Temperature in ^{0}C			
			Hot water		Cold Water	
			T_3	T_4	T_2	T_1

Formula Used:

$$m_h = \frac{100\text{ml}}{\text{Time for 100ml hot water collection in seconds} \times 1000} \text{ in } \frac{kg}{s}$$

Where

m_h = Mass flow rate of hot water in $\frac{kg}{s}$

$$m_c = \frac{100\text{ml}}{\text{Time for 100ml cold water collection in seconds} \times 1000} \text{ in } \frac{kg}{s}$$

Where

m_c = Mass flow rate of cold water in $\frac{kg}{s}$

$$Q_h = m_h \times c_{ph} \times (T_1 - T_2)$$

Model Calculation:

Mass flow rate of hot water =

$$m_h = \frac{100\text{ml}}{\text{Time for 100ml of hot water collection in seconds} \times 1000} \text{ in } \frac{kg}{s}$$

$$m_h = \frac{100\text{ml}}{\text{.........................} \times 1000}$$

$$m_h = \text{................} \frac{kg}{s}$$

Mass flow rate of cold water =

$$m_c = \frac{100\text{ml}}{\text{Time for 100ml of cold water collection in seconds} \times 1000} \text{ in } \frac{\text{kg}}{\text{s}}$$

$$m_c = \frac{100\text{ml}}{\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \times 1000}$$

$$m_c = \ldots\ldots\ldots\ldots\ldots \frac{\text{kg}}{\text{s}}$$

$$Q_h = m_h c_{ph}(T_1 - T_2) \text{ in W}$$

$$Q_h = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \times 4183 \times (\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots)$$

$$Q_h = \ldots\ldots\ldots\ldots\ldots\ldots \text{W}$$

$$Q_c = m_c c_{pc}(T_3 - T_4) \text{ in W}$$

$$Q_h = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \times 4183 \times (\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots)$$

$$Q_c = \ldots\ldots\ldots\ldots\ldots\ldots \text{W}$$

$$\varepsilon = \frac{Q_c}{Q_h}$$

$$\varepsilon = \frac{\ldots\ldots\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots\ldots\ldots}$$

$$\varepsilon = \ldots\ldots\ldots\ldots\ldots\ldots$$

Where

Q_h = Heat transfer rate from hot water in Watts.

C_{ph} = Specific heat of hot water = 4183 $\frac{\text{J}}{\text{kgK}}$

T_1 = Inlet temperature of hot water in K.

T_2 = Outlet temperature of hot water in K.

Q_c = $m_c \times c_{p_c} \times (T_3 - T_4)$

Where

Q_c = Heat transfer rate to cold water in Watts.

C_{pc} = Specific heat of cold water = 4183 $\frac{J}{kgK}$

T_4 = Inlet temperature of cold water in K.

T_3 = Outlet temperature of cold water in K.

$$\varepsilon = \frac{Q_c}{Q_h}$$

Where

ε = Effectiveness of heat exchanger

Result:

Effectiveness of cross flow heat exchanger = ε =

Inference:

I have gained knowledge of determining effectiveness of cross flow heat exchangers.

Applications:

Design of Heat exchangers.

Dairy plants.

Oil refineries.

Ex No: 11 **Date :**

Determination of Stefan – Boltzmann constant

Aim:

To determine the Stefan Boltzmann Constant of thermal radiation using Stefan Boltzman apparatus.

Apparatus Required:

1. Stefan Boltzmann Apparatus
2. Stop watch

Procedure:

1. Ensure that water is filled in the geyser, open the outlet gate valve, allow water to flow through the hemisphere.
2. Switch on the heater and allow the hemisphere to reach a steady temperature.
3. Once steady state is achieved, insert the disc in the bracket, note down the time in seconds for every degree rise in temperature.
4. Continue the experiment until steady state condition is reached in the inserted disc.
5. Plot the curve of Time increment Vs Temperature increment for the disc.
6. Determine Stefan Boltzmann's constant analytically and graphically.

Formula used:

Stefan Boltzmann Constant = $$\sigma = \frac{Q}{A \times (T_h^4 - T_d^4)}$$

Where

Q	=	Heat transfer takes place in disc in W
A	=	Surface area of the disc in m2.
Th	=	Surface temperature of the hemisphere in K
Td	=	Surface temperature of the disc in K

$$Q = m \times c_p \times \frac{dT}{dt}$$

Where

m	=	Mass of the disc in Kg
c_p	=	Specific heat of disc material in $\frac{J}{kgK}$
dt	=	Rise in time in seconds
dT	=	Corresponding rise in Temperature of the disc in ^oC

Observation:

Material of the Disc =

Diameter of the disc = d = m

Mass of the disc = m = kg

Specific heat of the disc material = c_p = $\frac{J}{kgK}$

Tabulation:

S.No.	Temp. of hemisphere °C			Temperature of disc °C	Time in seconds for Every Degree Rise in disc
	T_1	T_2	T_3		
1.					
2.					
3.					
4.					
5.					

Model Calculation:

Stefan Boltzmann Constant determined by analytical formula

Heat transfer takes place in disc = $Q = m \times c_p \times \frac{dT}{dt}$

$$Q = \ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots \times \frac{\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots}$$

$$Q = \ldots\ldots\ldots\ldots\ldots \text{ W}$$

Surface area of the disc = $A = \frac{\pi}{4} \times d^2$

$$A = \frac{\pi}{4} \times \ldots\ldots\ldots\ldots$$

$$A = \ldots\ldots\ldots\ldots\ldots \text{ m}^2$$

Surface temperature of the hemisphere = $T_h = \frac{T_1 + T_2 + T_3}{3}$

$$T_h = \frac{\ldots\ldots + \ldots\ldots + \ldots\ldots}{3}$$

$$T_h = \ldots\ldots\ldots\ldots\ldots \, ^{o}C$$

$$T_h = \ldots\ldots\ldots\ldots\ldots + 273 = \ldots\ldots\ldots\ldots\ldots K$$

Surface temperature of the disc = T_d = Steady state temperature of the disc

$$T_d = \ldots\ldots\ldots\ldots\ldots \, ^{o}C$$

$$T_d = \ldots\ldots\ldots\ldots\ldots + 273 = \ldots\ldots\ldots\ldots\ldots K$$

Stefan Boltzmann Constant = $\sigma = \frac{Q}{A \times (T_h^{\,4} - T_d^{\,4})}$

$$\sigma = \frac{\ldots\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots\ldots)}$$

$$\sigma = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{m^2K^4}$$

Stefan Boltzmann Constant determined by graph

Plot the curve of Time increment Vs Temperature increment for a disc in graph.

Determine the slope of the curve $\frac{dT}{dt}$

From the slope, calculate the following.

Heat gained by the disc = $Q = m \times c_p \times \frac{dT}{dt}$

$$Q = \ldots\ldots\ldots\ldots\ldots \times \ldots\ldots\ldots\ldots\ldots \times \frac{\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots}$$

$$Q = \ldots\ldots\ldots\ldots\ldots\ldots \; W$$

Stefan Boltzmann Constant = $\sigma = \frac{Q}{A \times (T_h - T_d)}$

$$\sigma = \frac{\ldots\ldots\ldots\ldots\ldots\ldots}{\ldots\ldots\ldots\ldots\ldots\ldots \times (\ldots\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots\ldots)}$$

$$\sigma = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{W}{m^2K^4}$$

Result:

Stefan Boltzmann Constant determined by analytical formulas = $\sigma = \qquad \frac{W}{m^2K^4}$

Stefan Boltzmann Constant determined by graph = $\sigma = \qquad \frac{W}{m^2K^4}$

Inference:

I have learnt how to measure Stefan-Boltzmann constant for thermal radiation.

Applications:

1. Solar Collectors
2. Solar power plants
3. Radiant super-heaters
4. Radiation heat exchange between two surfaces.

Ex No : 12 ***Date :***

Determination of emissivity of a gray surface

Aim:

To determine the emissivity of the gray surface using emissivity measurement apparatus

Apparatus Required:

Emissivity Measurement Apparatus

Procedure:

1. Give necessary electrical connections and switch on the CONSOLE ON to activate the control panel.
2. Switch on the heater of the Gray body and set the voltage (say 45 V) using the Variac
3. Switch on the heater of the Black body and set the same voltage (say 45 V) using the Variac.
4. Wait to attain the steady state condition.
5. Note down the temperatures at different points and also the voltmeter and ammeter readings.
6. Tabulate the readings and calculate the surface emissivity of the gray surface.

Formula used:

$$\text{Emissivity of gray surface} = \varepsilon = \frac{\text{Emisive power of gray surface}}{\text{Emissive power of black surface}} = \frac{\sigma \times A \times (T_g{}^4 - T_a{}^4)}{\sigma \times A \times (T_b{}^4 - T_a{}^4)}$$

$$\varepsilon = \frac{(T_g{}^4 - T_a{}^4)}{(T_b{}^4 - T_a{}^4)}$$

Where,

Tg	=	Surface temperature of the gray surface in K
Tb	=	Surface temperature of the black surface in K
Ta	=	Ambient or Atmospheric air temperature in K

Observation:

Material of the gray and black surfaces =

Diameter of the gray and black surfaces = d = m

Tabulation:

S. No.	Heater input				Temperature°C				
	Black body		Gray body						
	V Volts	I Amps	V Volts	I Amps	T_1	T_2	T_3	T_4	T_5
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

Model Calculation:

Temperature of gray surface = $T_g = \dfrac{T_3 + T_4}{2}$

$$T_g = \frac{\ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots}{2}$$

$$T_g = \ldots\ldots\ldots\ldots\ldots\ldots {}^oC$$

$$T_g = \ldots\ldots\ldots\ldots\ldots\ldots\ldots + 273 = \ldots\ldots\ldots\ldots\ldots\ldots\ldots K$$

Temperature of black surface = $T_b = \dfrac{T_1 + T_2}{2}$

$$T_b = \frac{\ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots}{2}$$

$$T_b = \ldots\ldots\ldots\ldots\ldots\ldots {}^oC$$

$$T_b = \ldots\ldots\ldots\ldots\ldots\ldots\ldots + 273 = \ldots\ldots\ldots\ldots\ldots\ldots\ldots K$$

Ambient or Atmospheric air temperature = $T_a = T_5$

$$T_a = \ldots\ldots\ldots\ldots\ldots\ldots {}^oC$$

$$T_a = \ldots\ldots\ldots\ldots\ldots\ldots\ldots + 273 = \ldots\ldots\ldots\ldots\ldots\ldots\ldots K$$

Emissivity of gray surface = $\varepsilon = \dfrac{\text{Emisive power of gray surface}}{\text{Emissive power of black surface}} = \dfrac{\sigma \times A \times (T_g^{\ 4} - T_a^{\ 4})}{\sigma \times A \times (T_b^{\ 4} - T_a^{\ 4})}$

$$\varepsilon = \frac{(T_g^{\ 4} - T_a^{\ 4})}{(T_b^{\ 4} - T_a^{\ 4})}$$

$$\varepsilon = \frac{(\ldots\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots\ldots)}{(\ldots\ldots\ldots\ldots\ldots\ldots - \ldots\ldots\ldots\ldots\ldots\ldots)}$$

$$\varepsilon = \ldots\ldots\ldots\ldots\ldots\ldots$$

Result:

Emissivity of the gray surface = ε =

Inference:

I have gained knowledge of measuring emissivity of gray surfaces.

Applications:

1. Design of solar equipments

2. Shape factor analysis

PROGRAM OUTCOMES (POs)

Mechanical Engineering Graduates will be able to

1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to solution of complex engineering problems.
2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3	**Design / development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5	**Modern tool usage:** Create, select and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10	**Communication:** Communicate effectively on complex engineering activities withtheengineering communityandwithsociety atlarge, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11	**Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects in multidisciplinary environments.
12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

K.L.N. COLLEGE OF ENGINEERING

VISION

To become a Centre of Excellence in Technical Education and Research in producing Competent and Ethical professionals to the Society.

MISSION

To impart Value and Need based curriculum to the students with enriched skill development in the field of Engineering, Technology, Management and Entrepreneurship and to nurture their character with social concern and to pursue their career in the areas of Research and Industry.

Principal **Secretary &Correspondent** **President**