G.S.Mandal's

Maharashtra Institute of Technology, Aurangabad

Department of Plastics and Polymer Engineering

LABORATORY MANUAL

ACADEMIC YEAR:	**PART: I**
COURSE: HEAT TRANSFER	**COURSE COORDINATOR: MS. P. N. SHINDIKAR**

Experiment No. - 01

1. **Aim: Determination of thermal conductivity of a composite wall.**
2. **Theory:**

   Reference books: Heat Transfer – K. A. Gavhane
   Heat Transfer – R. K. Rajput
   Heat Transfer – S. P. Sukhatme

3. Apparatus:

The apparatus consists of central heater sand witched between two sheets .Three types of slabs are provided on both sides of heater which forms a composite structure. A small hand press frame is provided to ensure the perfect contact between the slabs. A dimmer stat is provided for varying the input to heater and measurement of heat input is carried out by a voltmeter, ammeter. Thermocouples are embedded between interfaces of the slab and connected to multichannel digital temperature indicator to read the temperature at the surfaces.

4. Specifications

Heater	: nichrome heater wound on mice former Insulator
Heater control unit	: 230 V
Voltmeter	: 100-200V
Ammeter	: 2 A
Dimmer stat	: 2 A, 0-230V single phase
Temperature Indicator	: 200ºC, digital type
Thermocouples	: Chromel–Alumel (8 No)

5. Procedure:

1. Check the pressure applied to the plate manually to ensure perfect contact between the plates.
2. Switch ON the main supply and then ON heater supply.
3. Give known steady input to the heater with the help of dimmer stat.
4. Keep initially 100 V for 20 minutes and then adjust it 50/60/70/ 80 V.
5. Record the reading of all temperatures from temperature indicator every 5 minutes in observation table, till steady state condition is reached.
6. Note the steady state temperatures, ammeter and voltmeter reading in observation table
7. Repeat the same procedure for different heat input

6. Observations:

Diameter of all slabs	: 300 mm
Thickness of all slabs	: 12 mm

7. Observation Table:

Observation Time	Voltage in Volts(V)	Current in amp(I)	Temperature readings in ^{o}C							
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8

8. Calculations:

1. Heat in put(supplied)heater Q = VxI   Q=…………..Watts

2. Heat flux $q = \frac{Q/2}{A} = \frac{V.I/2}{\pi r^2}$ = …………..W/m^2

3. Total thickness of composite slab $L = L_A + L_B + L_C$ =………..

4. Mean reading temperatures in ^{o}C
    - $T_A = [T_1+T_2]/2$ T_A = ………..

- $T_B = [T_3+T_4]/2$ T_B = ………..

- $T_C = [T_5+T_6]/2$ T_C =…………

- $T_D = [T_7+T_8]/2$ T_D =…………

5. Thermal resistances

- $R_A = (T_A - T_B)/2$ R_A=………..

- $R_B = (T_B - T_C)/2$ $R_B =$.........

- $R_C = (T_C - T_D)/2$ $R_C =$...........

*Total Thermal resistance of composite slab $R_{comp} = (T_A - T_D) / q$, $R_{comp} =$............

5 Thermal Conductivities

- $K_A = q \times L_A/(T_A - T_B)$ =

- $K_B = q \times L_B/(T_B - T_C)$ =

- $K_C = q \times L_C / (T_C - T_D)$ =

*Thermal conductivity of composite slab $K = K_A + K_B + K_C$, K_{comp}=……….W/mK

9. Result: 1 Total Thermal resistance of composite slab R_{comp}=

2 Thermal conductivity of composite slab K_{comp}=

10. Assignment Questions:

1. What is Fourier's law of heat conduction?
2. What is composite wall?
3. What is conduction?
4. Write note on conduction through plane wall.
5. What is heat transfer? What are different modes of it?

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LABORATORY MANUAL

Experiment No. - 02

1. **Aim: Determination of thermal conductivity of insulating powder.**
2. **Theory and diagram:**

   Reference books: Heat Transfer – K. A. Gavhane
   Heat Transfer – R. K. Rajpt
   Heat Transfer – S. P. Sukhatme

3. Description:

The apparatus consists of two thin walled concentric copper spheres. The inner sphere houses the heating coil. The insulating powder (asbestos) is packed tightly between the inner and outer sphere. The power supply to the heating coil is adjusted by using a dimmer stat and is measured by voltmeter and ammeter. Iron constantan thermocouples are used to measure the temperature. Thermocouples (1 to 4) are located on inner sphere and thermocouples (5 to 10) are located on the outer sphere. Under steady state condition note down the temperature readings T_1 to T_{10} and corresponding voltmeter and ammeter readings. With these readings find out the thermal conductivity of insulating powder packed between the spheres

4. Specifications:

Radius of inner copper sphere r_i	: 50 mm
Radius of outer copper sphere r_o	: 100 mm
Voltmeter	: 0-200V
Ammeter	: 0-2 A
Dimmer stat	: 0-2 A, 0-230V
Heater	: 200W mica type
Temperature indicator	: 0 – 300^{o}C
Thermocouple	: Chromel-Alumel (10 No)
Insulating powder	: Asbestos Magnesia

5. Procedure:

1. Switch on Main supply and then switch on heater switch.
2. Increase slowly the input to heater by dimmer stat and adjust input 40 W by voltmeter and ammeter and this input should not change throughout experiment.

3. Wait till satisfactory steady state condition is reached, this is by done by noting the temperature readings T_1 to T_{10} after time interval of 10 minutes.
4. Take the readings till steady state is reached.

6. Observations:

Radius of inner sphere : 50 mm

Radius of outer sphere : 100 mm

7. Observation Table:

Observation Time	Voltage in Volts(V)	Current in amp(I)	Temperature readings in ^{o}C									
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}

8. Calculations:

Heat in put (supplied) heater Q = V x I Q=…………..Watts

Average temperature of inner sphere surface Ti $=\frac{(T1+T2+T3+T4)}{4}$ = Ti =…………

Average temperature of outer sphere surface T_o $=\frac{(T5+T6+T7+T8+T9+T10)}{6}$ = T_0=………

Thermal conductivity of insulating powder $k = \frac{0.86\ Q(ro - ri)}{4\pi\ ri.ro(Ti - To\ )}$=

9. Result:

10. Assignment Questions:

1. What is thermal conductivity?
2. What are good conductors?
3. What are insulators?
4. What are applications of thermal conductivity?

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LABORATORY MANUAL

Experiment No. - 03

1. **Aim: Determination of heat transfer coefficient by natural convection.**
2. **Theory and diagram:**

   Reference books: Heat Transfer – K. A. Gavhane
   Heat Transfer – R. K. Rajput
   Heat Transfer – S. P. Sukhatme

3. Description:

The apparatus consists of a cartridge heater with brass tube fitted in a rectangular duct in a vertical position. The duct is open at top and bottom, and forms an enclosure and serves the purpose of undisturbed surrounding. One side of the duct is made up of Perspex for visualisation. An electric heating element is kept in the vertical tube, which in turn heats the tube surface. The heat is lost from the tube to the surrounding air by natural convection. The temperature of the vertical tube is measured by eight thermocouples. The heat input to the heater is measured by an ammeter and voltmeter by variable dimmer stat The vertical cylinder with position of thermocouple is shown in figure1, while the possible flow pattern and also variation of local heat transfer coefficient. The tube surface is polished to minimise the radiation losses

4. Specifications:

Diameter of the heater (d)	: 25 mm
Length of the heater (L)	: 750 mm
Duct size	: 250mmx250mmx900mm
Ammeter	: 0-2 A
Voltmeter	: 0-200V
Dimmer stat	: 0-2 A, 0-230V

Heater : 400W Cartridge type

Temperature indicator : 0 – 200^{o}C

Thermocouple : Chromel-Alumel(8 No)

5. Procedure:

1. Switch on main supply and then switch on heater switch.
2. Increase slowly the input to heater by dimmer stat and adjust input 40 W by voltmeter and ammeter and this input should not change throughout experiment.
3. Wait till satisfactory steady state condition is reach, this is by noting the temperature readings T_1 to T_8 after time interval of 10 minutes
4. Take the readings till steady state is reached.(i.e. dT/dt =0)

6. Observations:

Diameter of the heater (d) : 25 mm
Length of the heater (L) : 750 mm
Input to heater : V x I in watt

7. Observation Table:

Observation Time	Voltage in Volts(V)	Current in amp(I)	Temperature readings in ^{o}C							
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8=Ta

8. Calculations: *Experimental heat transfer coefficient

1. Heat in put(supplied)heater Q = V x I, Q=…………..Watts

2. Area of heat transfer surface ,As= π.d.L, As=…………m^2

3. Average temperature of tube surface Ts $= \frac{(T1+T2+T3+T4+T5+T6+T7)}{7} =$ Ts=…….

4. Heat transfer coefficient $h = \frac{Q}{As(Ts-Ta)} =$ h=…………W/m^2K

5. **Experimental heat transfer coefficient by using convection correlations.**

6. Film temperature $T_f = (Ts + Ta)/2 =$ T_f=………..ºC

7. Coefficient of thermal expansion β=1/(Tf+273) = β=……………/K

8. Prandtle No Pr = $\mu C_p/K$ N_{Pr}=……………..

9. Gr (Grashof no) = $\frac{\beta x\ g\ x\ L3(Ts - Ta)}{\nu 2}$ = ……….

10. Nu(Nusselt no) = 0.59(Gr xPr)$^{1/4}$……………for Gr.Pr<10^9

11. Nu = h x L $h = [\frac{Nu\ x\ K}{L}]$ => h=……………W/m^2K

9. Result:

10 Assignment Questions:

1. What is convection?

2. What is natural convection? Explain with example.
3. What is heat transfer coefficient?
4. Give classification of individual heat transfer coefficient.

Experiment No. - 04

1. **Aim: Determination of heat transfer coefficient by Forced convection.**
2. **Theory and diagram:**

   Reference books: Heat Transfer – K. A. Gavhane
   Heat Transfer – R. K. Rajput
   Heat Transfer – S. P. Sukhatme

3. Description:

The apparatus consists of blower unit fitted with test pipe. The test section is surrounded by Nichrome band heater. Four thermocouples are embedded on the test section and two thermocouples are placed in the air stream at the entrance and exit of the test section to measure the air temperature.

Test piece is connected to the delivery side of the blower along with the orifice to measure flow rate of air through the pipe. Input to the heater is given by a dimmer stat and measured by voltmeter and ammeter. A temperature indicator is provided to measure temperature of pipe wall in the test section.

4. Specifications:

Pipe diameter(D) : D_i=28 mm,D_o=33 mm

Length of test section (L) : 570 mm

Orifice diameter(do)	: 14 mm
Blower motor	: single phase
Ammeter	: 0-10 A
Voltmeter	: 0-100V
Dimmer stat	: 0-2 A, 0-230V
Heater	: Nichrome band type
Temperature indicator	: 0 – 200ºC
Thermocouple	: Chromel-Alumel(6 No)

5. Procedure:

1. Switch on main supply and start the blower and adjust the flow rate by means of valve to some desired difference in manometer level
2. Switch ON heater switch. Give desired heat input to heater of test section by dimmer stat with help of voltmeter and ammeter.
3. Without disturbing heater input, take reading of all thermocouples at interval of 10 minute until steady state condition is reached and confirmed.
4. Note the manometer deflection and temperature readings at steady state.
5. The procedure is repeated at different heater input and flow rate values

6. Observations:

Diameter of the test pipe (d)	: Di=28 mm, D_o=33 mm
Length of the test section (L)	: 570 mm
Diameter of orifice do	: 14 mm
Input to heater	: VxI in watt

7. Observation Table:

Voltage in Volts(V)	Current in amp(I)	Temperature readings in ^{o}C						Manometer Reading		
		T_1	T_2	T_3	T_4	T_5	T_6	H_1	H_2	$H_w=H_1-H_2$

8. Calculations: ForExperimental heat transfer coefficient

1. $T_f=(T_1+T_6)/2$ =..................

2. $(\rho_a)_{Ta}=P/RT_f$=...................

3. Discharge (volume flow) rate $V = \frac{\pi}{4} d^2_o \times C_d (2gH_w \times \rho_w/\rho_a)^{1/2}$ V=…………………..m3/sec

4. Mass flow rate of air M_a = density (ρ_{air})x Volume flow rate(V_{air})

5. $M_a = \rho_{air} x V_{air}$ Ma= ………………..Kg/s

6. Average temperature of tube surface $Ts = \frac{(T2+T3+T4+T5)}{4}$ =…………^oC

7. Area of test section As= π x Di x L =…………m^2

8. Heat carried (gained) by air, Qa= $M_a \times C_p \times (T_6-T_1)$ watt   Qa=………………

9. Convection heat transfer rate Q =$h_a.A_s.(T_s-T_f)$ hence

$$h_a=\frac{Qa}{As\,(Ts-Ta)} \quad \text{-------W/m2K}$$

Experimental heat transfer coefficient by using convection emperical correlations.

1. $V_m=V/(\pi/4.D_i)^2$ = ……………

2. $Re=\rho_a x V_m x\, D_i/\mu = V_m D_i/\nu$ = ...

3. $Pr= \mu.C_p / k$ =……..

4. (Nusselt no)Nu = $0.023(Re)^{0.8}Pr)^{0.4}$ = ……

5. N_u = <u>(h_a x Di) </u> / Kair

$$h_a = \frac{N_u x K_{air}}{D_i} = \ldots\ldots\ldots\ldots\ldots\ldots W/m^2K$$

9.Result:

The heat transfer coefficient in forced convection by experiment is……………….

The heat transfer coefficient in forced convection by empirical relation…………`

10 Assignment Questions:

1. What is forced convection?
2. Differentiate between natural and forced convection.

Experiment No. - 05

1. **Aim:** Determination of Stefan Boltzmann's constant of radiation by parameters emissive power and temperature.
2. **Theory and diagram:**

Reference books: Heat Transfer – K. A. Gavhane
Heat Transfer – R. K. Rajput
Heat Transfer – S. P. Sukhatme

3. **Description:**
The apparatus is cantered on a flanged copper hemisphere fixed on non-conducting plate. The outer surface of hemisphere is enclosed in a metal water jacket used to heat hemisphere to some suitable

constant temperature. Four thermocouples are attached to various points on surface of hemisphere to measure its mean temperature. Test plate is mounted in an insulating Bakelite sleeve, is fitted in a hole, drilled in the centre of base plate(non -conducting plate).A thermocouple is used to measure the temperature of Test plate(T_5).The thermocouple is mounted on the disc to study the rise of its temperature. When the disc is inserted at the temperature T_5(T_5>T) i.e the temperature of the enclosure, the response of the temperature change of the disc with time is used to calculate the Stefan Boltzmann constant.

4. Specifications:

Hemispherical enclosure diameter	: 205 mm
Base plate, Bakelite diameter	: 255 mm
Test disc diameter	: 20 mm
Mass of the test disc	: 0.006 Kg
Specific heat of the copper test disc	: 0.41868 KJ/kg ^oC
Thermocouple on hemisphere & test piece	: 4 and 1 (Chrome alumel)
Digital temperature Indicator	: 0-200 ^oC range
Water Heater	: 2 KW (instant with thermostat)
Hot water bath	: 5.75 liters

5. Procedure:

1. Fill water in thetank completely and set thermostat to desired temperature @ 90^oC for water heating
2. Switch on the heater to heat the water and wait till the water is heated to set temperature.
3. Remove the test piece before pouring the hot water into the jacket, then pour hot water in the water jacket.
4. Record the temperature of thermocouple (T1 to T4) of hemispherical enclosure
5. The hemisphere surface will come to some uniform temperature in a short time T.
6. The test piece is now inserted at temperature T5 in the Bakelite plate
7. Note down the temperature readings of test piece at the interval of **5** seconds @ ten

Readings.

8. Plot the temperature time data for the test piece.

6. **Observations:**

Test disc diameter : 20mm
Test disc thickness : 3 mm
Mass of the test disc : 0.006 kg
Stefan Boltzmann Constant :5.669 x10^{-8} W/m^2.k^4

7. Observation Table:

Themocouples	T_1	T_2	T_3	T_4				
Temperature in oC								
Time in sec	5	10	15	20	25	30	35	40
Test Disc Temp(T_5)								

8. Calculations:

PlotdT-dt

- Average temperature of hemispherical sphere Ts= ($T_1+T_2+T_3+T_4$)/4 Ts =……

- Temperature of disc at the instant when inserted T= T_5=…………

- Slope from graph dT-dt ,$(\frac{dT}{dt})t=0=\frac{Y2-Y1}{X2-X1}$=…………..

- Area of disc A= $\frac{\pi}{4}$x d^2 =………..

- Stefan Boltzmann Constantσ = $\frac{mgc_p(dT/dt)}{A(T^4_s - T^4_5)}$=> σ =……………………… $W/m^2.k^4$
-

9. Result:

10. Assignment Questions:

1. Write Stefan Boltzmann Law.
2. Define following:
    - Monochromatic emissive power.
    - Total emissive power
    - Monochromatic emissivity

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LABORATORY MANUAL

Experiment No. - 06

1. **Aim:** To study phase change using virtual lab.
2. **Theory and diagram:**

   Reference books: Heat Transfer – K. A. Gavhane
   Heat Transfer – R. K. Rajput
   Heat Transfer – S. P. Sukhatme
3. **Diagram:**

4. Procedure:

1) Select the material from the drop down box.NEXT
2) Select the mass of the substance and surrounding temperature from the slider.NEXT
3) Click on the 'START EXPERIMENT' button to start.NEXT
4) Check/Uncheck the 'Show Result' button for the result.NEXT
5) Note the Temperature T(t) from the Thermometer and in the graph.CLOSE

5. **Observation table:**

6. **Result:**

7. **Conclusion:**

Experiment No. - 07

1. **Aim:** To study heat transfer by radiation using virtual lab.
2. **Theory and diagram:**

Reference books: Heat Transfer – K. A. Gavhane
Heat Transfer – R. K. Rajput

Heat Transfer – S. P. Sukhatme

3. Diagram:

4. Procedure:

1) Change the diameter, thickness and temperature sliders.NEXT
2) Change the voltage of TP and BPNEXT
3) Dropdown list contains the materials. We can choose any of them from there.NEXT
4) Change the TP and BP switch.NEXT

5) Indicator value changed using the indicator forwaded and backwaded arrow.NEXT
6) Click on Power On button or motor on button.NEXT
7) Show result contains the emissivity of the plate.CLOSE

5. Observation table:

6. Result:

7. Conclusion:

Experiment No. - 08

1. Aim: To study heat transfer by conduction using virtual lab.

2. Theory and diagram:

Reference books: Heat Transfer – K. A. Gavhane
Heat Transfer – R. K. Rajput
Heat Transfer – S. P. Sukhatme

3. Diagram:

4. Procedure:

1. Change the diameter, thickness and temperature sliders.NEXT

2. Change the voltage of TP and BPNEXT
3. Dropdown list contains the materials. We can choose any of them from there.NEXT
4. Change the TP and BP switch.NEXT
5. Indicator value changed using the indicator forwaded and backwaded arrow.NEXT
6. Click on Power On button or motor on button.NEXT
7. Show result contains the emissivity of the plate.CLOSE

5. Observation table:

6. Result:

7. Conclusion:

Experiment No. - 09

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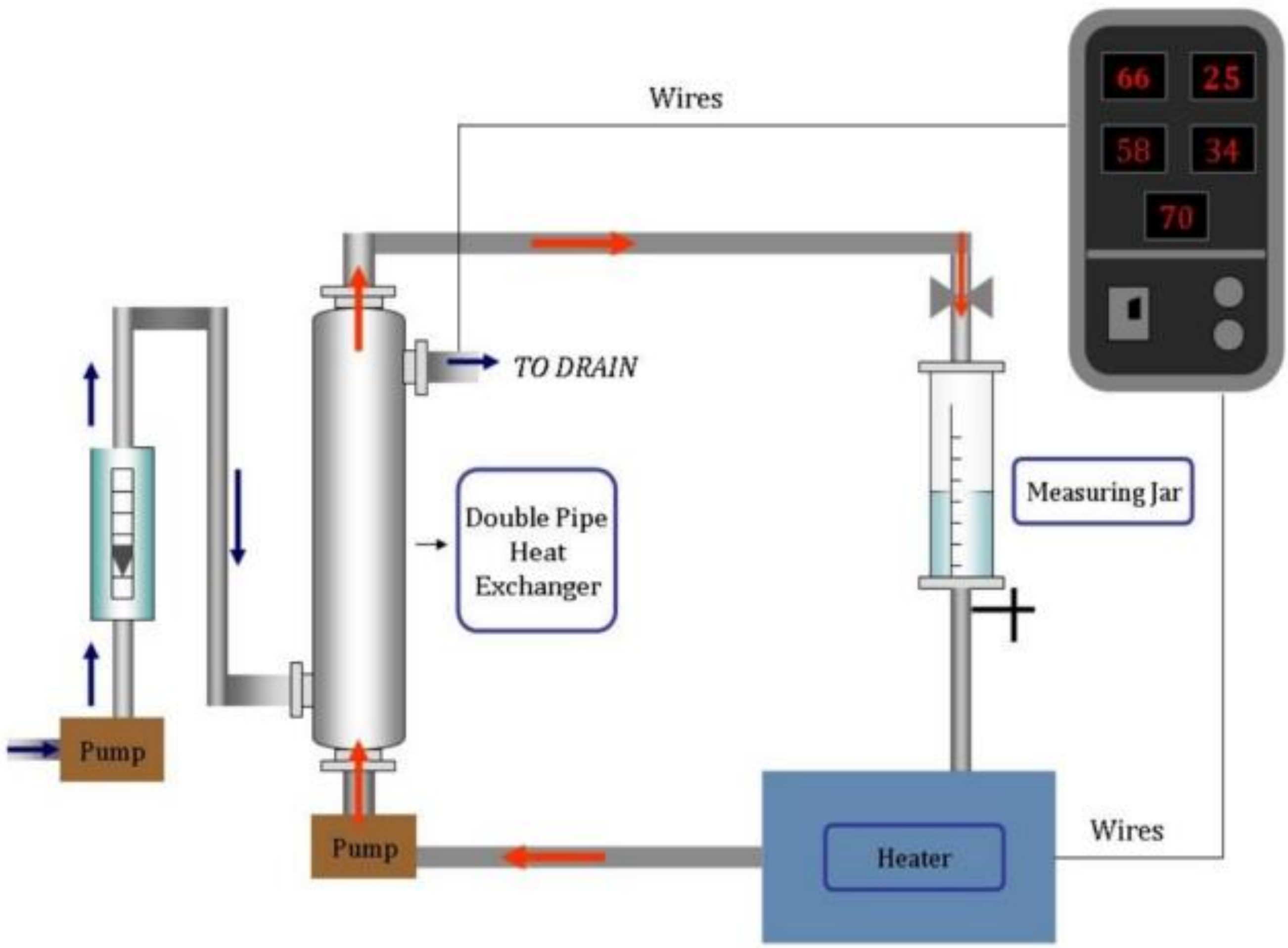
LABORATORY MANUAL

1. **Aim:** a) To determine the overall heat transfer coeffcient making use of logarithmic mean temperature difference. From overall heat transfer coeffcient, determine the individual film heat transfer coefficient and verify the Seider-Tate equation for laminar flow heat transfer.
   b) To determine the overall heat transfer coeffcient making use of logarithmic mean temperature difference. From overall heat transfer coeffcient, determine the individual film heat transfer coeffcients and verify the Dittus-Boelter equation for turbulent flow heat transfer.
2. **Theory and diagram:**

Reference books: Heat Transfer – K. A. Gavhane
Heat Transfer – R. K. Rajput
Heat Transfer – S. P. Sukhatme

3. Diagram:


Wires
66
25
58
34
70
TO DRAIN
Double Pipe Heat Exchanger
Measuring Jar
Pump
Pump
Heater
Wires

4. **Procedure:**

   a) **Laminar Flow**

      1. Note down the Zero Error in digital Thermometers. Set the heater temperature.
      2. Adjust the volumetric flow rate of water to 400 lph.
      3. Adjust the flow rate of hot fluid in laminar region.
      4. Measure the time taken to cross 10 cm mark using stopwatch and close valve.
      5. Note the inlet-outlet hot-cold fluid temperature after steady state
      6. Repeat the above steps to get 8 sets of readings by increasing the flow rate.

   b) **Turbulent Flow**

      1. Switch on the temperature indicator & controller.
      2. Measure the inlet and outlet temperature for both the pipes for zero error.
      3. Check the set point of the controller around 65 °C.
      4. Start the hot fluid circulation pump.
      5. Keep the flow rate of cold fluid constant at around 400 Lph
      6. Adjust the flow rate of hot fluid (between 400 Lph to 900 Lph to maintain Re>10,000)
      7. Once steady state is reached note down the inlet and outlet temperatures of hot and cold fluid.
      8. Repeat the experiment for at least 6 different flow rates of hot fluid.

5. **Observation table:**

6. **Result:**

7. **Conclusion:**