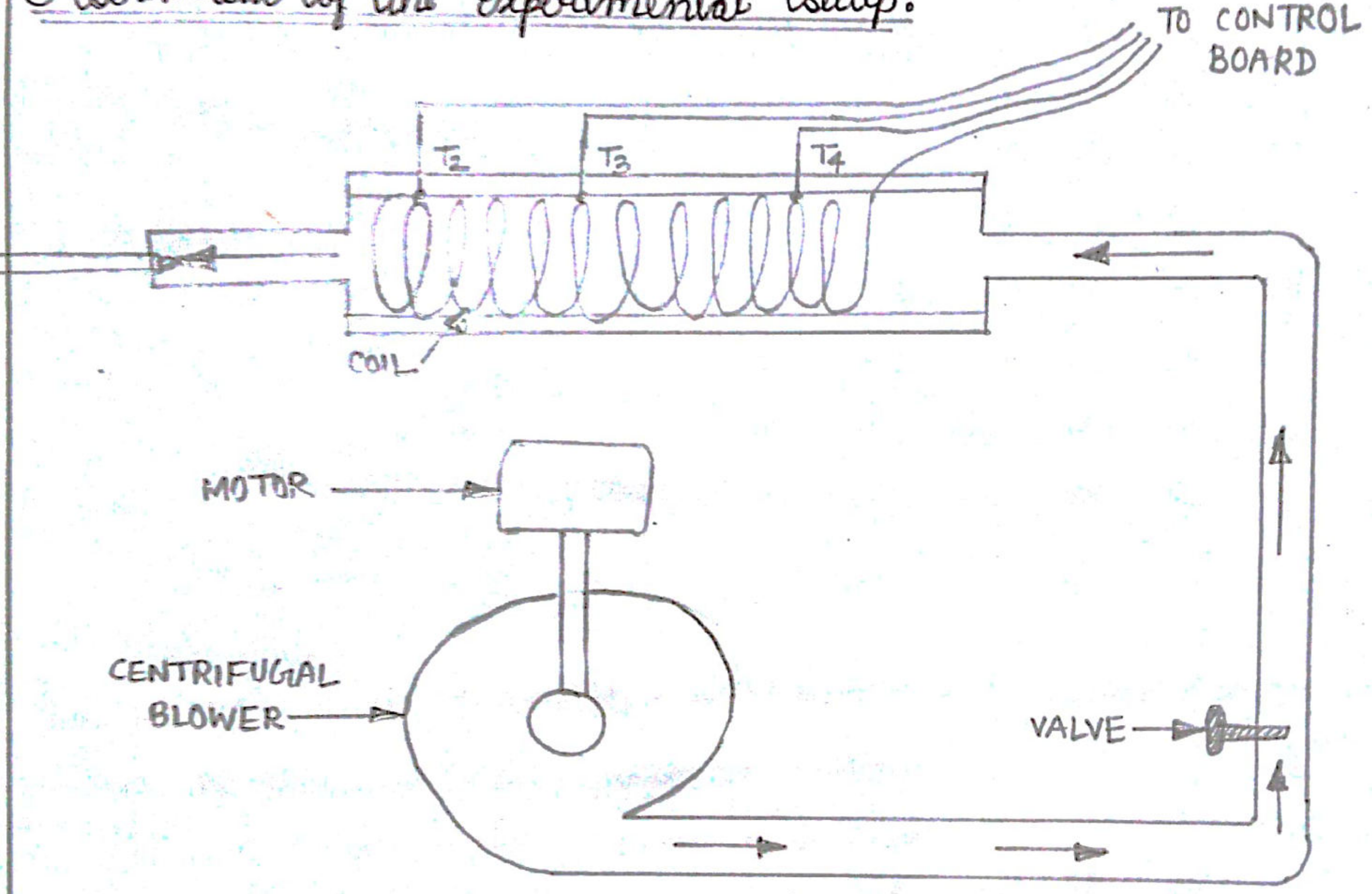
DATE	EXPERIMENT No. : 1	SHEET NO.

FORCED CONVECTION HEAT TRANSFER

- **Objectives:** Determination of average Nusselt number for forced convection in a heated circular pipe at various Reynolds numbers, and correlation for Nussett number

- **Schematic of the Experimental setup:**



Observations

Room Temperature = 30°C

Least count = 1°C for temperature, 0.001A for current, 1V for voltage

Run No. : 1 (Volume flow rate = 4.976×10^{-3} m^3/s, Heater Power = 66.5 W)

SL. No.	TIME (min)	VOLTAGE V (V)	CURRENT I (A)	POWER P (W)	MANOMETER READING LEFT (mm)	RIGHT (mm)	H (mm)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)
1	0	94	0.692	65.05	180	38	142	37	53	63	70	64	48
2	10	92	0.675	62.10	180	38	142	38	61	73	77	76	53
3	20	92	0.672	61.82	180	38	142	40	65	78	89	82	57
4	30	91	0.667	60.70	180	38	142	41	67	80	90.5	84	58
5	35	92	0.674	62.01	180	38	142	41	68	80	85.5	85	59
6	40	92	0.672	61.82	180	38	142	42	68	81	X	85	59

Run No. : 2 (Volume flow rate = 4.351×10^{-3} m^3/s, Heater Power = 62.38 W)

SL. No.	TIME (min)	VOLTAGE V (V)	CURRENT I (A)	POWER P (W)	MANOMETER READING LEFT (mm)	RIGHT (mm)	H (mm)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)
1	0	92	0.678	62.38	163	55	108	41	68	82	89	86.5	60
2	10	91	0.670	60.97	163	55	108	42	68	83	X	88	61
3	15	91	0.665	60.51	163	55	108	41.5	68	82	X	88	61
4	20	89	0.654	58.21	163	55	108	42	68	82	X	88	62

DATE | | SHEET NO.

Run No. :3 (Volume flow Rate = 3.722×10^{-3} m^3/s, Heater Power = 59.22 W)

SL. NO.	TIME (min)	VOLTAGE V (V)	CURRENT I (A)	POWER P (W)	MANOMETER READING LEFT (mm)	RIGHT (mm)	H (mm)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)
1.	0	90	0.658	59.22	149	70	79	41.5	68	82.5	X	88	61
2.	10	90	0.659	59.31	149	70	79	42	69.5	84	X	90	62
3.	20	90	0.660	59.40	149	70	79	42	70.5	86	X	91.5	63
4.	30	88	0.645	56.76	149	70	79	42	70	85	X	91	62.5

Run No:4 (volume flow Rate = Same as Before, Heater Power = 88.22 W)

SL. No.	TIME (min)	VOLTAGE V (V)	CURRENT I (A)	POWER P (W)	MANOMETER READING LEFT (mm)	RIGHT (mm)	H (mm)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)
1	0	110	0.802	88.22	149	70	79	42	71	86.5	X	92	63
2	10	112	0.819	91.73	149	70	79	42	80	100.5	X	107	70
3	20	114	0.832	94.85	149	70	79	42	84.5	106	X	113	73
4	25	112	0.817	91.50	149	70	79	42	86	108	X	115	74.5
5	30	113	0.827	93.45	149	70	79	42	86	108	X	116	75

Sample calculation:

Density of water, $\rho_w = 1000\ kg/m^3$

Gravitational Accⁿ., $g = 9.81\ m/s^2$

Average surface temperature, $T_S = (T_2 + T_3 + T_4 + T_5)/4$
$= 78°C$

Average temperature of air, $T_a = (T_1 + T_6)/2$
$= 50.5°C$

Density of air at Ta and Patm, $\rho_{air} = P_{atm}/(R T_a)$
$= 1.091\ kg/m^3$

Volume flow rate of air through orifice $= C_d \left(\frac{\pi d^2}{4}\right)\sqrt{2gH(\rho_w/\rho_{air} - 1)}$

$\Rightarrow Q_{flow} = 4.976 \times 10^{-3}\ m^3/s$

Mass flow rate of air through pipe,

$m = \rho_{air} Q_{flow}$
$= 5.429 \times 10^{-3}\ kg/s$

Rate of Heat transfer to the air,

$Q_a = m c_p (T_6 - T_1)$
$= 92.71\ W$

Power Input to the heater, $P = VI$
$= 61.82\ W$

Surface area of heated section, $\pi D_i L = 0.04398\ m^2$

Average heat flux

$q_a = Q_a/A = 2108\ W/m^2$

$q_i = P/A = 1405.64\ W/m^2$

Average heat transfer coefficient, $h_a = q_a/(T_S - T_a)$
$= 76.65\ W/m^2K$

Average Nusselt Number, $Nu = h_a D_i/K = 78.36$

Average velocity, $V = Q/(\pi D_i^2/4) = 8.08\ m/s$

Reynolds number, $Re = V D_i/\nu = 12556.76$

Results:

RUN No.	FLOW RATE (m^3/s)	Re_{D_i}	q_a (W)	P (W)	T_s (°C)	T_a (°C)	h (W/m^2K)	Nu
1	4.976×10^{-3}	12557	92.71	61.82	78	50.5	76.65	78.36
2	4.351×10^{-3}	10885	94.85	58.21	79.33	52	78.91	80.34
3	3.722×10^{-3}	9301	83.12	56.76	82	52.25	63.52	64.64
4	3.758×10^{-3}	9084	132.5	93.45	103.33	58.5	67.22	67.28

Determination of correlation for Nusselt Number

We did least square fit analysis to obtain the correlation

Nu	Re	X $\log_{10}(Re)$	Y $\log_{10}(Nu)$	XY	X^2
78.36	12557	4.0988	1.8940	7.7636	16.8008
80.34	10885	4.0368	1.9049	7.6898	16.2959
64.64	9301	3.9685	1.8105	7.1850	15.7492
67.28	9084	3.9582	1.8278	7.2352	15.6679
	Sum =	16.0625	7.4374	29.8738	64.5140

$\bar{X} = 4.0156 \qquad \bar{Y} = 1.8593$

$\therefore$ The eq^n of line is $\bar{Y} = a + b\bar{X}$

$$b = \frac{n\Sigma xy - \Sigma x \Sigma y}{n\Sigma x^2 - (\Sigma x)^2} = 0.61792$$

$\therefore a = -0.62201$

$\therefore$ Obtained correlation is $\log_{10}(Nu) = -0.62201 + 0.61792 \log_{10}(Re)$

$\Rightarrow \log_{10}(Nu) = \log(0.23878) + \log_{10}(Re^{0.61792})$

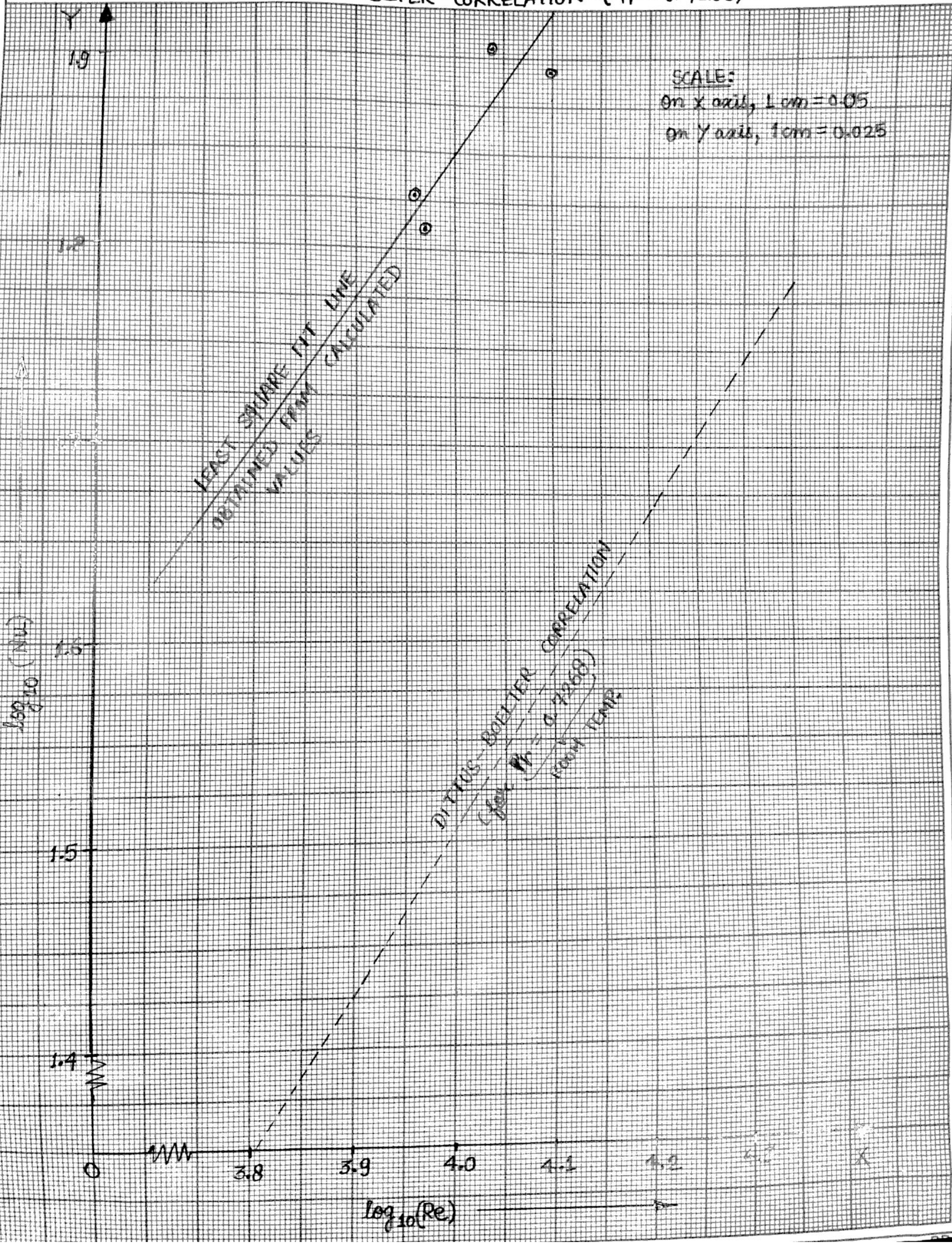
$\Rightarrow Nu = 0.23878\, Re^{0.61792}$

Assuming $Nu \propto Pr^{0.4}$ and $Pr = 0.7268$, $\therefore Nu = 0.27128\, Re^{0.61792}\, Pr^{0.4}$

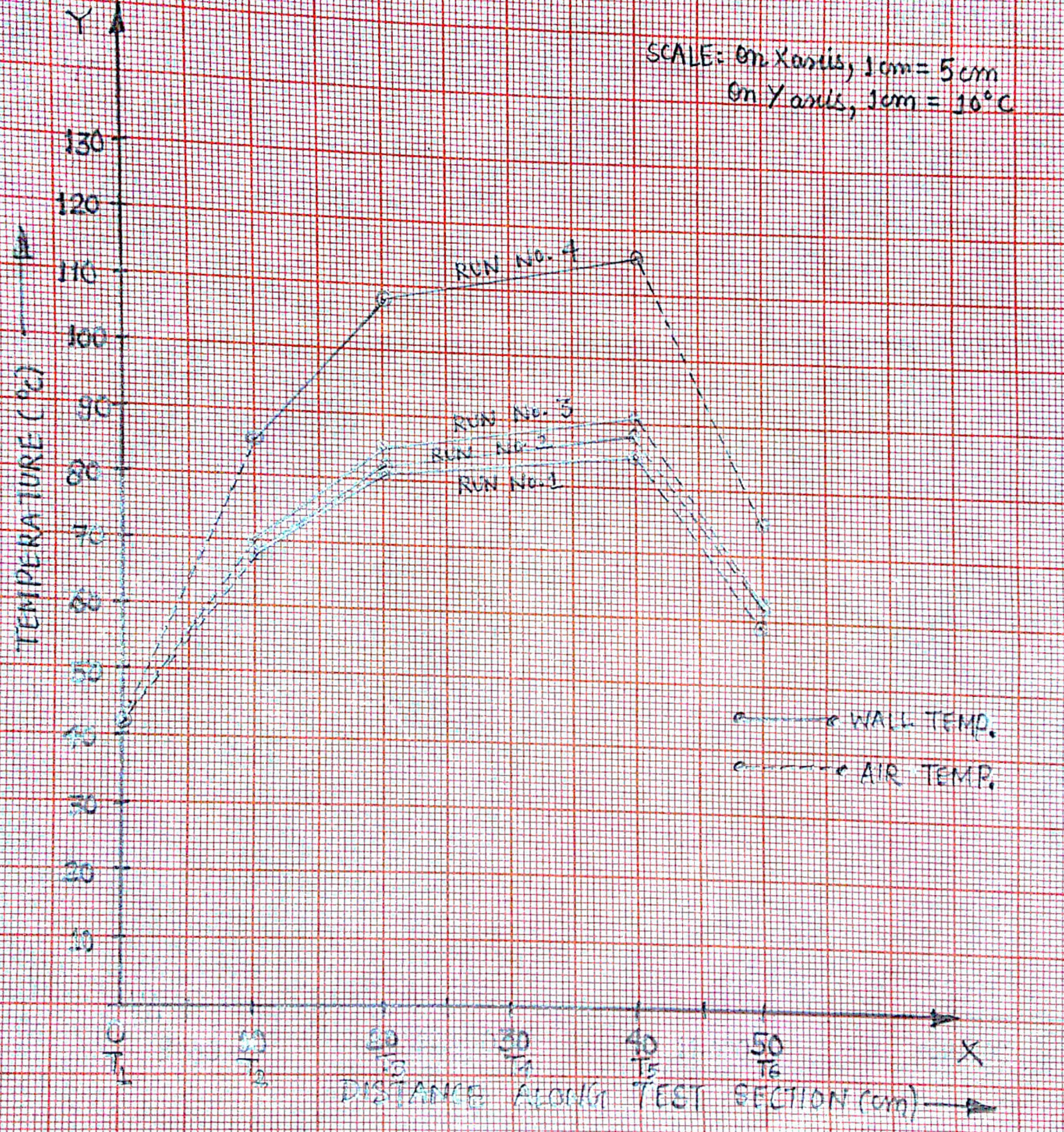
$\Rightarrow Nu = 0.271\, Re^{0.618}\, Pr^{0.4}$

PLOT OF ⊙ $\log_{10}(Nu)$ VS $\log_{10}(Re)$ FROM CALCULATED VALUES

~~⊙ DITTUS – BOELTER CORRELATION ($Pr = 0.7268$)~~



PLOT OF THE WALL TEMPERATURE DISTRIBUTION



INDIAN INSTITUTE OF TECHNOLOGY

DATE

SHEET NO

8) Discussion of Results and Sources of error.

Ans for high Reynolds number value i.e Re = 10393 the nusselt number is high i.e Nu = 26.2 because the flow is turbulent. For a pipe if Re > 2000 then the flow is turbulent.

But for Re = 2698, the flow is in transition zone and hence the value of Nusselt number corresponds close to that of laminar flow.

Also only for high value of Re; Re > 10,000, dittus boelter relation is valid and hence log (Nu) v/s log (NRe) converges for Re > 10,000.

Sources of error:

1) For high Reynolds number, flow is turbulent but the nusselt no. is calculated ~~for~~ assuming laminar flow which results in error.

2) Leakage and losses may also cause error in readings.

3) Error in noting down readings of manometer & measuring temperature.