LAB NUMBER 4

THERMAL CONDUCTIVITY

INSTRUCTIONS FOR EXPERIMENTS

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PLEASE NOTE:

1.
NO ERROR ANALYSIS IS TO BE CARRIED OUT IN THIS LAB 4.

2.

SAMPLE CALCULATIONS NEEDED ARE FOR ONE SET OF K VALUE --- CELL E 30 , IN THE CALCULATION WORKSHEET .

THIS WILL REQUIRE CALCULATIONS IN COLUMN B – B3 TO B25, AND ROW 30

BASICS OF HEAT TRANSFER

The relationship between the heat flux, q (Watt /m^2) , and temperature, T (x) , is given by

$$q = -k\,A\left(\frac{d}{dx}\mathrm{T}(x)\right)$$

or

$$k = -\frac{q}{A\left(\frac{\partial}{\partial x}T\right)} \qquad (1)$$

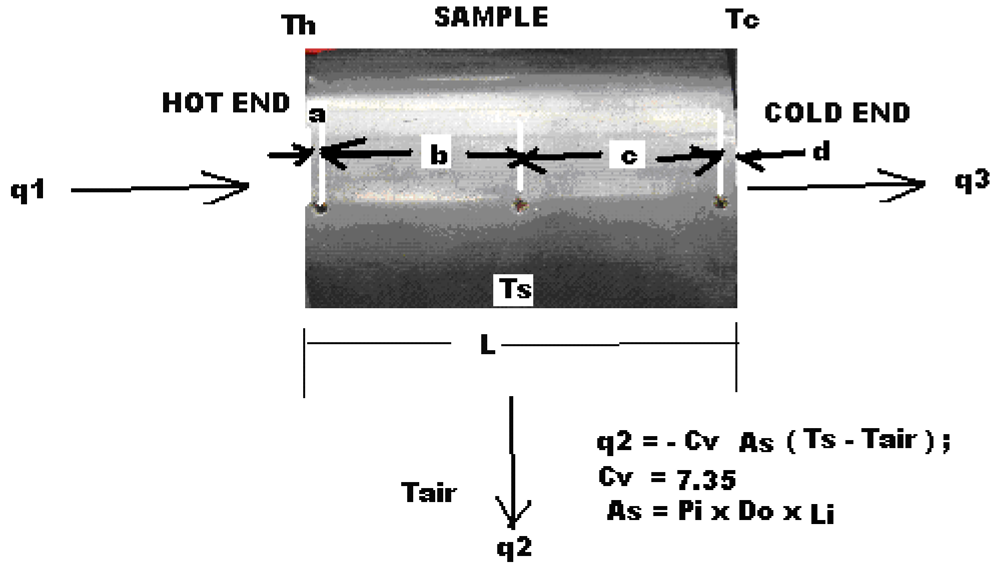
where k is the thermal conductivity of the material, and A is the area perpendicular to the heat flux , q ..
For the sample shown below, on an over all basis, one can write

$$q = -\frac{k\,A\,(Th - Tc)}{L} \qquad (1)$$

where , A is given by

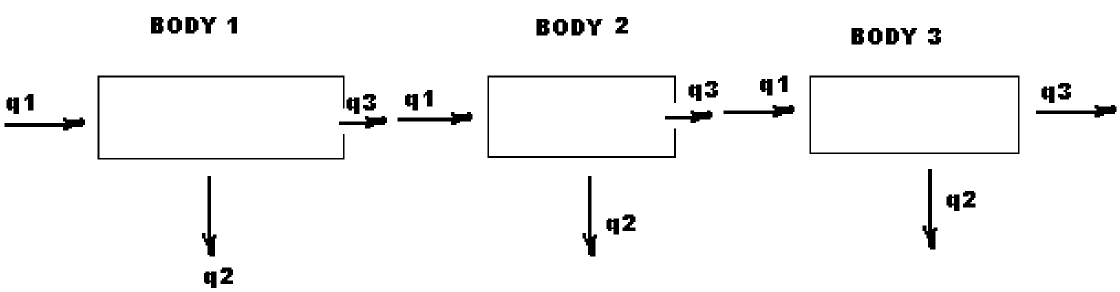
$$A = \frac{\pi\,(Do^2 - Di^2)}{4}$$

FIG 1



HEAT BALANCE

q1 = q2 + q3



CONVENTION FOR HEAT FLOW:

RULE 1

q3 OF BODY 1 = q1 OF BODY 2 ;

q3 OF BODY 2 = q1 OF BODY 3 ;

RULE 2

q2 IS THE HEAT LOSS OF ANY BODY

FIG 1b NOTATION OF q, THE TOTAL THERMAL ENERGY WHERE q/A IS THE HEAT FLUX

FIG. 2

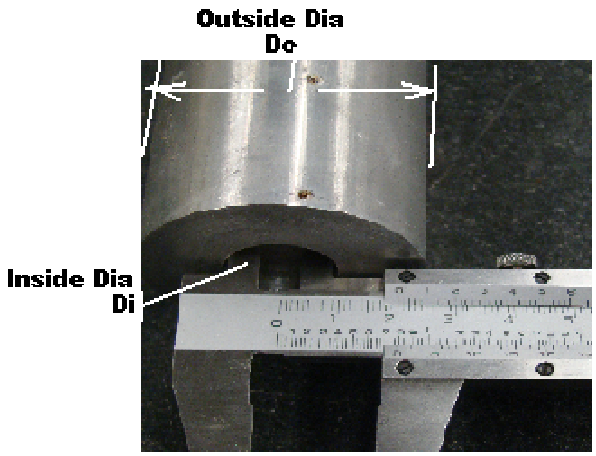
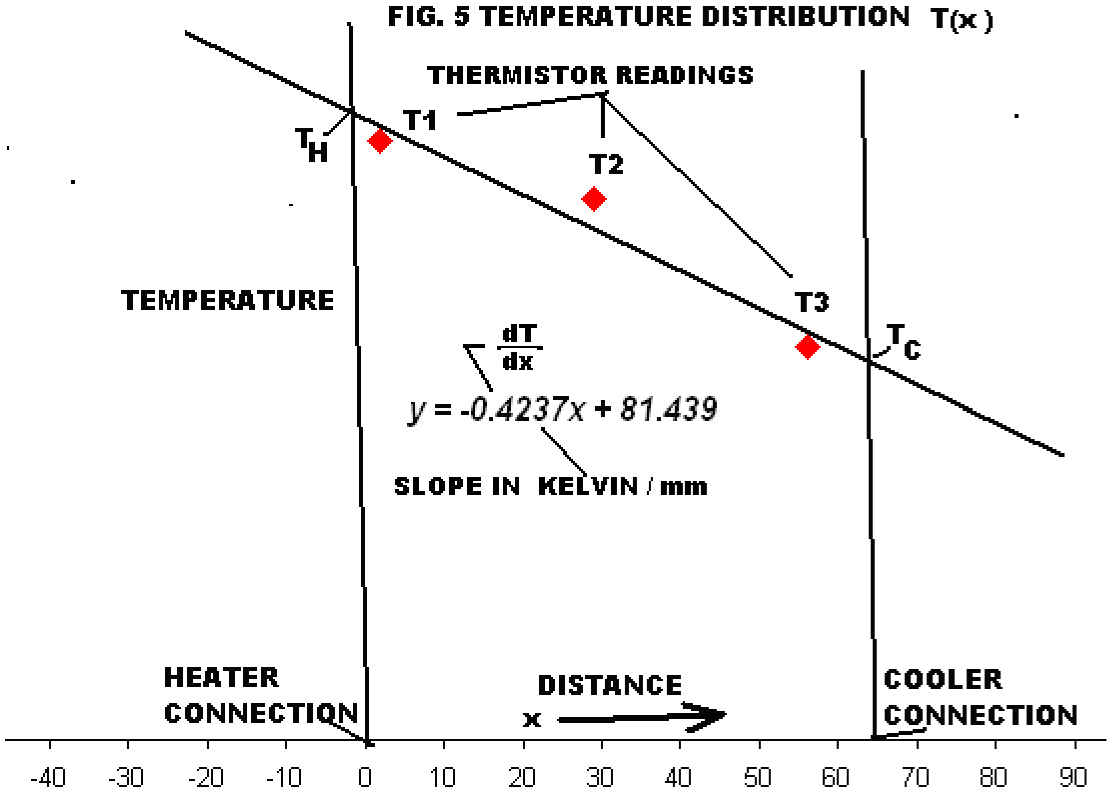


FIG 3



Obtain TH , and TC from the graph above by extrapolation.

EXPERIMENTAL COMPONENTS AND ASSEMBLY

In this experiment, the sample is heated by a Heater Block, cylindrical in shape, using a resistor. The heat flows axially . The sample is cooled by another Cooling Block shown below. The details of each of these units are also shown in the next few figures.

The heating is started by immersing the assembly in an insulating material called vermiculite (see FIG. 6) and when the steady state temperatures are reached then calculations are performed to determine the conductivity of the sample material using Eq. (1)

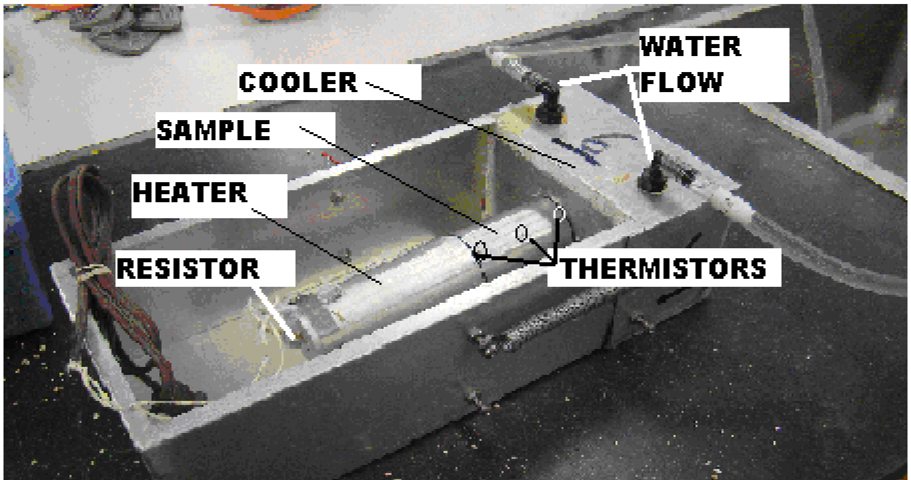


FIG. 2 ASSEMBLY SHOWING POSITION OF HEATING BLOCK, SAMPLE, AND COOLING BLOCK

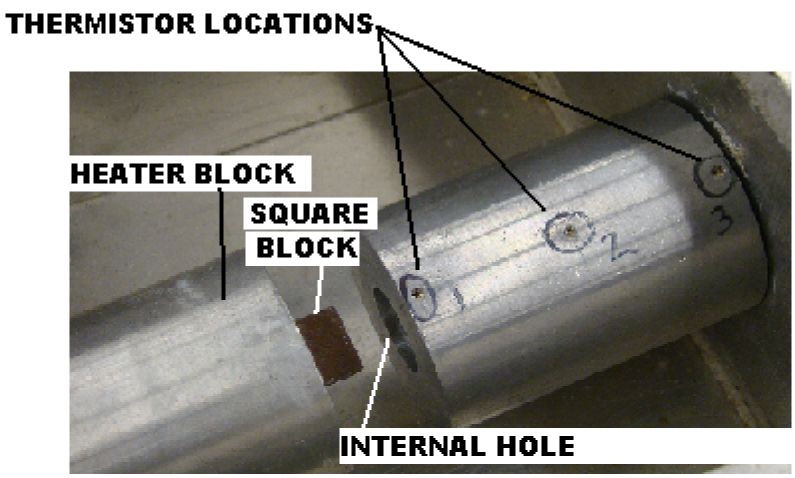


FIG. 3 CONNECTION BETWEEN HEATER AND SAMPLE

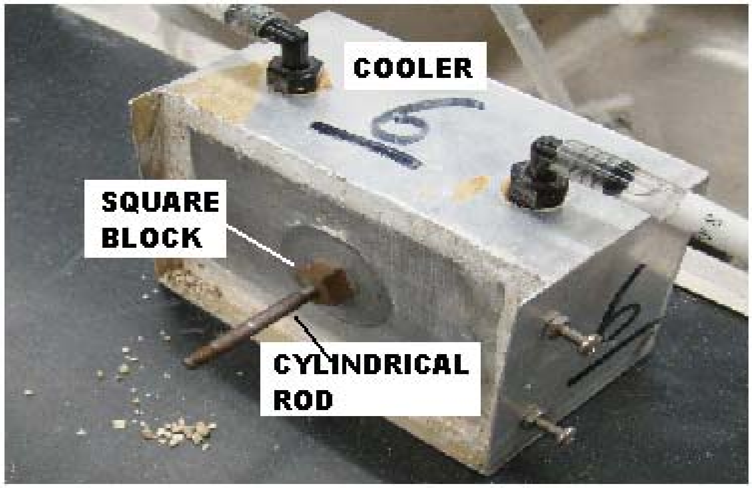
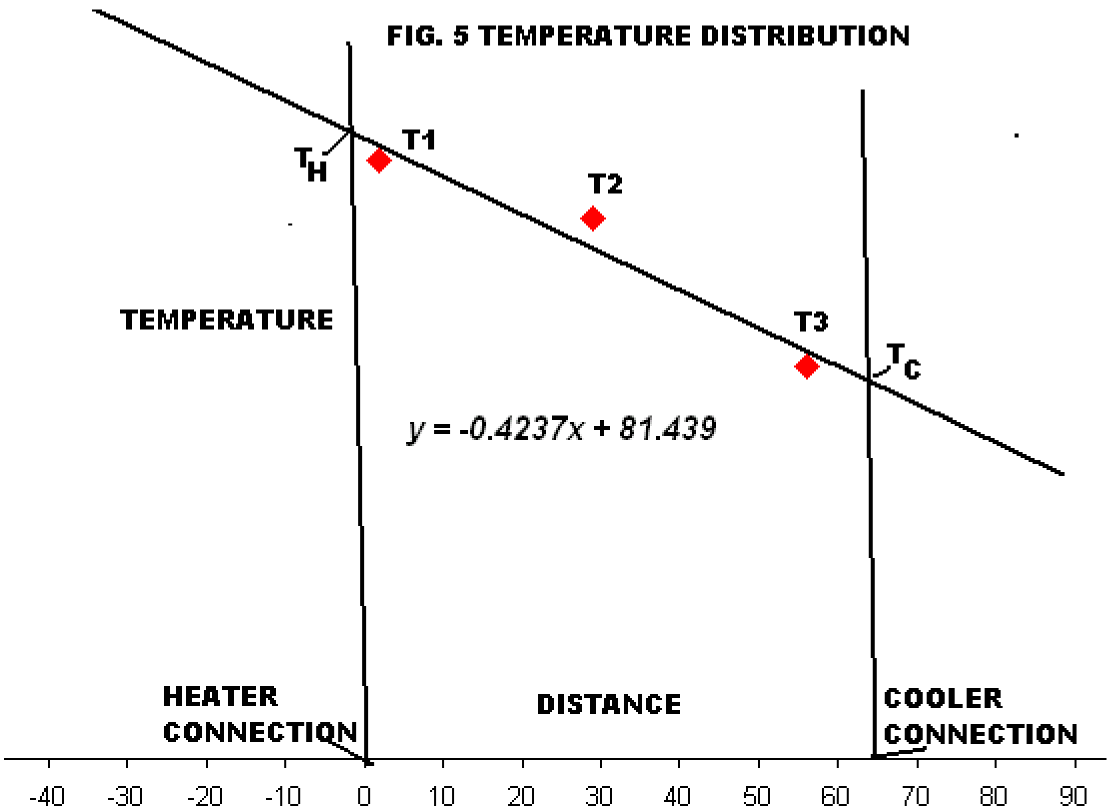


FIG. 4 DETAILS AT THE COOLER END

FIG. 5 TEMPERATURE DISTRIBUTION



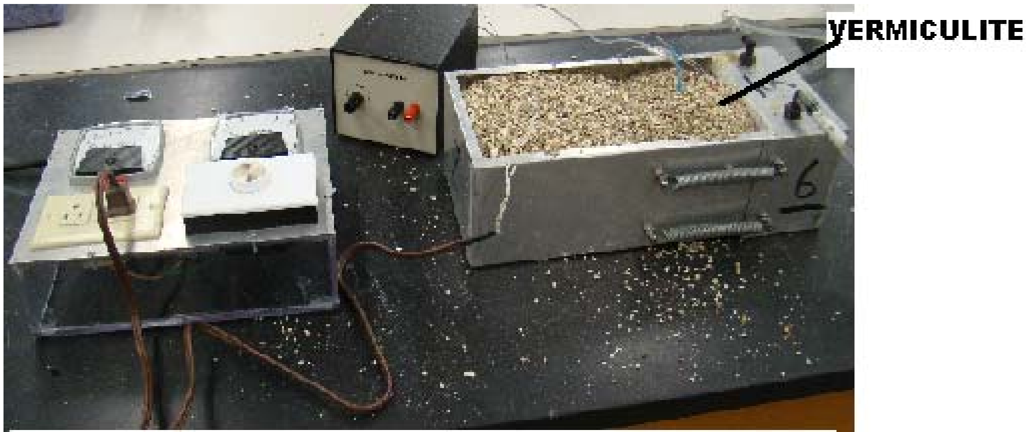


FIG 6 THE ASSEMBLY IMMERSED IN VERMICULITE

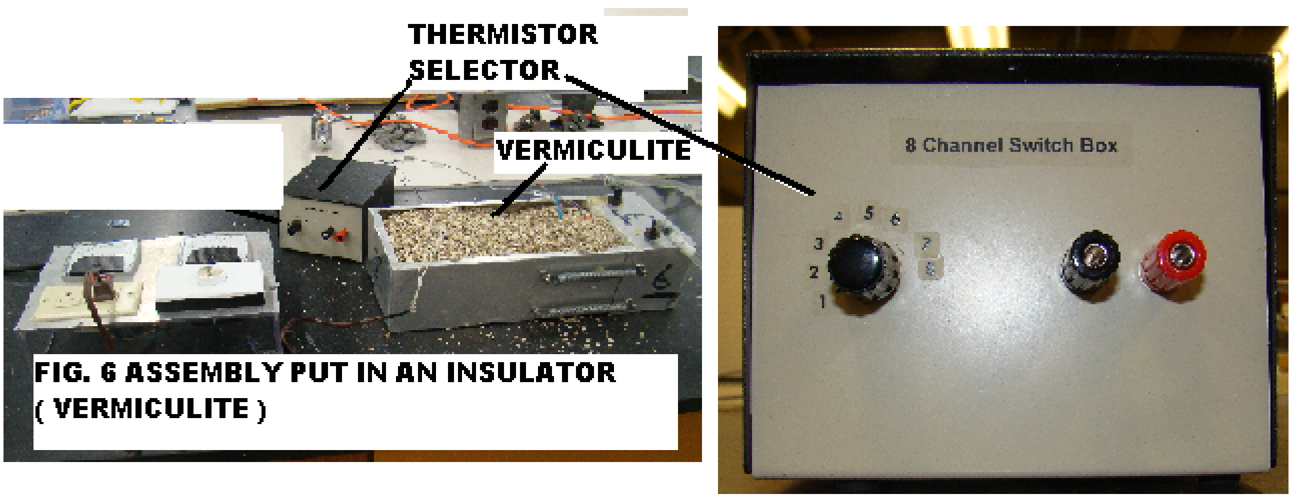


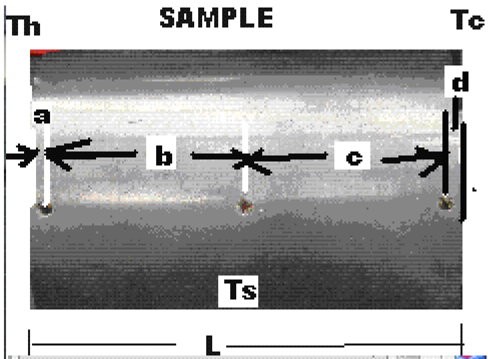
FIG. 6 ASSEMBLY PUT IN AN INSULATOR
(VERMICULITE)

NO 1

DATA SHEET

Measure each of the components, followed by appropriate calculations and then insert in the appropriate cells of the software .

UNIT	COMPONENT	FORMULAS
HEATER BLOCK	**Do =** **L =**	**As** $=(\pi$ **x Do x L)+** π **x Do^2 / 4**
SAMPLE	**Do =** **Di =** **a =** **b =** **c =** **d =**	**A=** π **x (Do^2 – Di^2)/4** **As1 =** π **x Do x a** **As2 =** π **x Do x b** **As3 =** π **x Do x c** **As4 =** π **x Do x d**
ROD	**Radius , Rr =0.00275** **Length , Lr=(a+b+c+d)**	**Ar =**π *** Rr ^2** **Lr=(a+b+c+d)**
HEATER	**VOLTS , V** **CURRENT, I**	**V =** **I =**
TEMPERATURES	**Room Temperature**	**T =**
HEATER , GRAPH	**TH**	**TH =**
COOLING, GRAPH BLOCK	**TC**	**TC =**



C10 fx

	A	B	C
1			
2	**information of aluminum cylinder**		
3	**L** (mm)	62.7	**L**
4	outer diameter (mm)	48	Do
5	hole diameter (mm)	17.1	Di
6			
7	section number	Length of sections (mm)	
8	a	1.8	
9	b	27.2	
10	c	27.2	
11	d	1.8	

SAMPLE DIMENSION DETAILS

SAMPLE

NO 2

THERMISTORS CONSTANTS

SEE THE TABLE BELOW ; T is in degrees Kelvin

$$\ln = C \times 1/T + \ln R_o$$

THERMISTOR	$\ln R_o$ (Ω)	C (K)	THERMISTOR	$\ln R_o$ (Ω)	C (K)
1-1	-2.876	4041	5-1	-3.008	4057
1-2	-2.646	4029	5-2	-2.924	4054
1-3	-2.549	4006	5-3	-2.638	4023
1-4	-2.964	4073	5-4	-2.728	4045
1-5	-2.605	3970	5-5	-2.734	4016
2-1	-2.731	4017	6-1	-2.592	3946
2-2	-2.981	4050	6-2	-2.528	3958
2-3	-2.528	3945	6-3	-2.771	4034
2-4	-2.617	4015	6-4	-2.540	3946
2-5	-2.756	4012	6-5		
3-1	-2.550	3977	7-1	-2.693	4034
3-2	-2.795	4029	7-2	-2.692	4011
3-3	-2.539	3964	7-3	-2.761	4018
3-4	-2.397	3982	7-4	-2.772	4025
3-5	-2.773	4008	7-5		
4-1	-2.661	4018	8-1	-2.769	3996
4-2	-2.551	3962	8-2		
4-3	-2.341	3928	8-3	-2.529	3939
4-4	-2.514	3947	8-4	-2.495	3939
4-5	-2.668	4005	8-5		
A	-2.143	3846	F	-2.272	3903
B	-2.225	3818	G	-2.977	4057
C	-2.365	3865	H	-2.408	3861
D	-2.954	4052	I	-2.800	4000
E	-2.707	3976	J	-2.266	3691

NO 3

C10

	A	B	C	D	E	F
11	d	1.8				
12						
13	**Constants of thermisters**					
14	Channel number	Ln R_0 (ohm)	C			
15	1	-2.8	4000			
16	2	-2.341	3928			
17	3	-2.408	3861			
18						

THERMISTOR READINGS – STEADY STATE :

NOTE MULTIMETER IS SET ON OHMS

PLEASE SEE THE CONNECTION SETTINGS

G20

	A	B	C	D	E	F
19	**Measured data**					
20	Time (min)	Hole #1 (Kohm)	Hole #2 (Kohm)	Hole #3 (Kohm)		
21	0	11.02	16.2	21.05		
22	10	4.13	6.82	10.62		
23	20	3.24	5.51	9.02		
24	30	2.98	5.13	8.52		
25	40	2.89	4.99	8.34	The empty areas	
26	42	2.86	4.95	8.29	are for you to add	
27	44	2.84	4.92	8.24	extra data if it	
28	46	2.82	4.89	8.22	happens in your	
29	48	2.81	4.87	8.19	measurements.	
30	50	2.8	4.86	8.17		
31	52	2.78	4.83	8.12		
32	54	2.76	4.79	8.08		
33	56	2.76	4.78	8.07		
34						
35						
36						

NO 4

37	What is your last three measuremements for each hole in the proceeding form?			
38	Time (min)	Hole #1 (Kohm)	Hole #2 (Kohm)	Hole #3 (Kohm)
39	52	2.78	4.83	8.12
40	54	2.76	4.79	8.08
41	56	2.76	4.78	8.07
42	**Average**	2.767	4.800	8.090

data / Chart1 / Graph / Calculation

NO 5
CALCULATIONS SHEET

The formulas for each of the cells are explained on the worksheet below itself.

E30 | fx =B30/(B20*B25)

	A	B	C	D
1	**HEATER BLOCK**			
2	**When R is stable**			
3	V (v)	70		
4	I (A)	2.5		
5	Q FROM HEATER (Watts)	175	← B3*B4	
6				
7	**Calculation of heat loss in heater block per unit area (L_H, watt/m^2)**			
8	Cv	7.35	**ASSUME**	
9	Room Temperature (K)	300		
10	Extrapolated Temperature (K)	376	**Pick up from the graph , this is the temperature at the e**	
11	L_H HEAT LOSS HEATER BLOCK (watt/m^2)	558.6	**PER UNIT LENGTH**	
12	**Calculation of total Heat loss in heater block (H_L, watt)**		← B8*(B10-B9)	
13	**Dia of the Heater Block (m)**	**0.05025**		
14	length of heater block (m)	0.1158	**L**	

data / Graph / **Calculation**

	A	B	C	D
13	**Dia of the Heater Block (m)**	**0.05025**		
14	length of heater block (m)	0.1158	**L**	
15	surface area (m^2)	0.0203	**As = (Pi Do L) +((Pi/4)*Do^2)**	
16	H_L (watt), **B11*B15** →	11.32	**TOTAL HEAT LOSS , BLOCK**	
17	**Heat Conducted in the rod, Qr**			
18	K (watt/m^2), GIVEN	46	This area here is pi*L*D, which is same as column G10-(	
19	radius of rod (m)	0.00275	RADIUS OF THE ROD	
20	dT/dx,GRADIENT OR SLOPE (K/m)	423.7	This is temperature gradient in term of distance, pick	
21	Qr, (ABS(B18*3.14*B19^2*B20) →	0.463		

	A	B	C	D	E
22	**SAMPLE**				
23	Do (m)	0.050			
24	Di (m)	0.020			
25	Cross Section Area,(Pi/4)*(Do^2-Di^2)	0.001669024			
26					
27					
28	**calculation form of heat loss in each section of aluminum cylinder**				
29	Section number #	Heat enters(watt)	surface area (m^2)	Heat loss (w)	K (w/mK)
30	1	163.218	0.000481244	0.130874374	230.8055335
31	2	163.087	0.003802619	1.053686573	230.6204646
32	3	162.033	0.003802619	1.28287039	229.1304505
33	4	160.750	0.000481244	0.191005843	227.3163485
34					
35	**average K (w/mK)**	**229.4681993**			
36					
37					

B5-B16-B21

Graph!G10

B8*C30*(Graph!H10-

(E30+E31+E32+E33)/4

B3

SECTION 2

Assume the following:

NO 1

Heat Generated by the Resistor = V (voltage) x I (Current) = q1 for the Heater Block.

NO 2

Ts of the Heater Block = **TH (from the graph)**

No 3
Heat Loss from the Heater Block

q2 = { (Pi x Do x L)+ (Pi x Do^2/4) } x {Cv x (TH – TAIR)}

Heat Conducted Away

q3 = V x I - q2 = q1 (SAMPLE)

This will be the Heat Entering Part I

SAMPLE HEAT BALANCE

q1 (SAMPLE) – SECTION I

q3 (SAMPLE) – SECTION I = q1 (SAMPLE) – q2 (SECTION I)

q2 (SECTION I) = As x Cv x (Ts – TAIR)

Ts = Temp of Zone I = T1 From the Graph.

In this way, one can do all the calculations

The equation for K is

$$k = -\frac{q}{A\left(\frac{\partial}{\partial x}T\right)}$$

Where q is q1 for each zone

SOME SELECTED CALCULATION EXAMPLES

SAMPLE CYLINDER

$$L := 0.05400000000$$

$$Do := 0.05025000000$$

$$Di := 0.02000000000$$

$$a := 0.003050000000$$

$$b := 0.02410000000$$

$$c := 0.02410000000$$

$$d := 0.003050000000$$

```
A = 3.1416*( Do^2 - Di^2)/4;
```

$$A := 0.001669020185$$

```
As1  = 3.1416 * Do * a
 As2  = 3.1416 * Do * b
 As3  = 3.1416 * Do * c
 As4  = 3.1416 * Do * d
;
```

$$As1 := 0.0004814883442$$

$$As2 := 0.003804547245$$

$$As3 := 0.003804547245$$

$$As4 := 0.0004814883442$$

ROD

```
Rr =0.00275
 Lr =( a+b+c+d );
 Ar  =3.1416 * Rr ^2;
```

$$Rr := 0.00275$$

$$Lr := 0.05430000000$$

$$Ar := 0.00002375829445$$

FROM THE GRAPH $SLOPE := 423.7$

HEATING BLOCK

```
Do  =50.25/1000;
 L =115.8/1000;
As  =3.1416  * Do * L )+ 3.1416* Do^2 / 4 ;
```

$$Do := 0.05025000000$$

$$L := 0.1158000000$$

$$As := 0.02026395003$$

GRAPH WORKSHEET

CELL F10 CALCULATIONS

THERMISTOR EQUATION FOR TEMPERATURE

ln(R) = C/T +ln(Ro) ;

or

(ln(R)-ln(Ro))= C/T ;

or

T = C/(ln(R)-ln(Ro));

FOR NUMBER 1 HOLE

Ln R0 (ohm) = -2.8

C = 4000

Let

Q1=ln(Ro) =-2.8;

Q2=ln(R) =ln(2.767)

GIVEN

```
C = 4000.;
Q1 =-2.8;
Q2 =ln(2.767*1000);
```

$$C := 4000.$$

$$Q1 := -2.8$$

$$Q2 := 7.925518980$$

```
T (in degrees K )  = C/(Q2-Q1 );
```

$$T := 372.9423264$$

```
T (in Celsius )  =T-273;
```

$$T\_celsius := 99.9423264$$

CALCULATION SHEET

HEATER BLOCK

CALCULATION OF CELL B11

```
 V =70 ;
I1 =2.5;
QH = V*I1;
```

$$V := 70$$

$$I1 := 2.5$$

$$QH := 175.0$$