ENGG*3430: Heat and Mass Transfer

Winter 2019 Lab

Last Name	First Name	Student ID
Ayyache	Bilal	0988616
Signature:		

Date of performing Experiments 1 & 2: Wednesday Feb 26th, 2019

Date of performing Experiments 3 & 4: Wednesday March 11th, 2019

Datasheet for Experiment 1: Modes of Heat Transfer

Material: Al 6061-T6 (Thermal conductivity, k=167 W/mK)

Power setting of Leslie's Cube	= 6.0W	IR thermometer reading (Black wall)	=59.0C
Temperature reading, T_1	= 62.0 C	IR thermometer reading (White wall)	=60.0C
Temperature reading, T_2	=54.7 C	IR thermometer reading (Polished wall)	=26.0C
Temperature difference, ΔT	=7.3 C	IR thermometer reading (Dull wall)	=34.0C
Resistance reading in multimeter	=25.9kΩ	Height of the wall, L	=105.02 mm
Heat flux (panel meter reading)	=545W/m^2	Wall thickness, t	=5.81 mm
Surrounding temperature, T_∞	=22.2C	Wall surface area, A	=11029.2mm^2

Findings:

1. Conduction heat transfer through the wall:

2. Thermal contact resistance:

3. Convection heat transfer rate from the surface to the surrounding:

4. Radiation heat transfer rate from the surface to the surrounding:

Calculations methodology:

1. Conduction heat transfer through the wall:

$$Q_{conduction} = \frac{T_1 - T_2}{R_{conduction} + R_{Contact,total}}$$

Where:

- $\dot{Q}_{conduction} = Conduction\ heat\ transfer\ through\ wall$ (W)
- $T_1 = Temperature\ reading\ 1\ (K)$
- $T_2 = Temperature\ reading\ 2\ (K)$
- $R_{conduction}$ (K/W)
- $R_{contact,total} = Thermal\ contact\ resistance$ (K/W)
- $q_{heat\ fluxsensor} = Heat\ flux\ (panel\ meter\ reading)(\frac{W}{m^2})$
- $A = surface\ area(m^2)$

$$\boldsymbol{Q_{conduction}} = q_{heat\ flux\ sensor} \times A = 545\frac{w}{m^2} \times 0.01103\ m^2 = \mathbf{6.011\ W}$$

2. <u>Thermal contact resistance:</u>

$$R_{conduction} = \frac{t_{wall\ thickness}}{k_{Al}\ A}$$

$$R_{contact,total} = \frac{T_1 - T_2}{Q_{conduction}} - R_{conduction}$$

$$R_{contact,total} = \frac{T_1 - T_2}{q_{heat\ flux\ sensor} \times A} - \frac{t_{wall\ thickness}}{k_{Al} A}$$

$$\boldsymbol{R_{contact,total}} = \frac{62.0\ ℃ - 54.7\ ℃}{545\frac{w}{m^2} \times 0.01103\ m^2} - \frac{0.00581\ m}{167\frac{W}{mK} \times 0.01103\ m^2} = \mathbf{1.211\ \frac{℃}{W}}$$

3. <u>Convection heat transfer rate from the surface to the surroundings (Note: convection for every surface is different, detailed calculations is shown in the table below):</u>

$$\dot{Q}_{convection} = hA(T_2 - T_\infty)$$

Where:

- $\dot{Q}_{convection} = Convection\ heat\ transfer\ to\ surroundings\ (W)$
- $T_\infty = Surrounding\ Temperature\ (K)$
- $T_2 = Temperature\ reading\ 2\ (K)$
- $h = heat\ transfer\ coefficient (W/(m^2K)$
- $A = surface\ area(m^2)$

$$h = \frac{k_{air}}{L}Nu = \frac{k_{air}}{vertical\ height\ of\ the\ wall}Nu$$

Where:

- $k_{air} = Thermal\ conductivity\ of\ air\ (W/(mK)$
- $Nu = Nusselt\ number$
- $h = heat\ transfer\ coefficient (W/(m^2K)$
- $L = vertical\ height\ of\ wall\ (m)$

$$Ra = \frac{\rho^2 g\beta(T_2 - T_\infty)L^3}{\mu^2}Pr$$

- $Ra = Rayleigh\ Number$
- $\rho = density(kg/m^3)$
- $g = gravitational\ acceleration(m/s^2)$
- $\beta = coefficient\ of\ volume\ expansion\ (1/K)$
- $T_2 = Temperature\ reading\ 2\ (K)$

- $T_\infty = Surrounding\ Temperature\ (K)$
- $L = charateristic\ length(m)$
- $Pr = prandtl's\ number$
- $\mu^2 = dynamic\ viscosity(kg/ms)$

$$Nu = \left\{ 0.825 + \frac{0.387 Ra_L^{\frac{1}{6}}}{\left(1 + \left(\frac{0.492}{Pr}\right)^{\frac{9}{16}}\right)^{\frac{8}{27}}} \right\}^2$$

- $Pr = prandtl's\ number$
- $Nu = Nusselt\ Number$
- $Ra = Rayleigh\ Number$

$$h = \frac{k_{air}}{vertical\ height\ of\ the\ wall} Nu$$

Sample Calculations for Black wall:

$$\boldsymbol{\beta} = \frac{1}{\frac{(T_\infty + T_s)}{2}} = \frac{1}{\frac{(22.2\ ℃ + 59.0\ ℃)}{2} + 273.15K} = \frac{1}{40.60\ ℃ + 273.15\ K} = \frac{1}{313.7K}$$
$$= \mathbf{3.19 \times 10^{-3}} \frac{\mathbf{1}}{\boldsymbol{K}}$$

$$\boldsymbol{Ra} = \frac{\rho^2 g \beta (T_2 - T_\infty) L^3}{\mu^2} Pr$$
$$= \frac{\left(1.12 \frac{kg}{m^3}\right)^2 \left(9.81 \frac{m}{s^2}\right) \left(\frac{1}{313.7K}\right) (59.0\ ℃ - 22.2℃) \left(\frac{105.02}{1000}\ m\right)^3}{\left(1.92 \times 10^{-5} \frac{kg}{ms}\right)^2} (0.725)$$
$$= \mathbf{3.32 \times 10^6}$$

$$\boldsymbol{Nu} = \left\{ 0.825 + \frac{0.387 Ra_L^{\frac{1}{6}}}{\left(1 + \left(\frac{0.492}{Pr}\right)^{\frac{9}{16}}\right)^{\frac{8}{27}}} \right\}^2 = \left\{ 0.825 + \frac{0.387\ (3.32 \times 10^6)^{\frac{1}{6}}}{\left(1 + \left(\frac{0.492}{0.725}\right)^{\frac{9}{16}}\right)^{\frac{8}{27}}} \right\}^2 = \mathbf{22.97}$$

$$\boldsymbol{h} = \frac{k_{air}}{L} Nu = \frac{0.0267 \frac{W}{mK}}{\left(\frac{105.02}{1000}\ m\right)} (22.97) = \mathbf{5.83} \frac{\boldsymbol{W}}{\boldsymbol{m^2 K}}$$

$$\dot{\boldsymbol{Q}}_{\boldsymbol{convection}} = hA(T_2 - T_\infty) = 5.83 \frac{W}{m^2 K} \times \frac{11029.2\ mm^2}{1000000\ mm^2} m \times (59.0\ ℃ - 22.2℃)$$
$$= \mathbf{2.37}\ \boldsymbol{W}$$

The calculations repeated for white wall, polished wall and dull wall (results shown below)

4. Radiation heat transfer rate

$Q_{radiation} = \varepsilon\sigma A(T_2^4 - T_\infty^4)$

Where,

ε = 0.95 for black surface

$$\sigma = 5.67 \times 10^{-8} \frac{W}{m^2K^4}$$

$$\boldsymbol{Q_{radiation_{black}}} = (0.95) \times 5.67 \times 10^{-8} \frac{W}{m^2K^4} \times \left(11029.2 \frac{mm^2}{1000000\, mm^2}\, m\right)((59.0℃ + 273.15K)^4 - (22.2℃ + 273.15K)^4) = \mathbf{2.71\ W}$$

Where,

ε =0.92 for white surface

σ = 5.67 ×10−8 $W/m^2 \cdot K^4$

$$\boldsymbol{Q_{radiation_{white}}} = (0.92) \times 5.67 \times 10^{-8} \frac{W}{m^2K^4} \times \left(11029.2 \frac{mm^2}{1000000\, mm^2}\, m\right)((60.0℃ + 273.15K)^4 - (22.2℃ + 273.15K)^4) = \mathbf{2.71\ W}$$

Where,

ε =0.1 for polished surface

σ = 5.67 ×10−8 $W/m^2 \cdot K^4$

$$\boldsymbol{Q_{radiation_{polished}}} = (0.1) \times 5.67 \times 10^{-8} \frac{W}{m^2K^4} \times \left(11029.2 \frac{mm^2}{1000000\, mm^2}\, m\right)((26.0℃ + 273.15K)^4 - (22.2℃ + 273.15K)^4) = \mathbf{0.02\ W}$$

Where,

ε =0.22 for dull surface

σ = 5.67 ×10−8 $W/m^2 \cdot K^4$

$$\boldsymbol{Q_{radiation_{dull}}} = (0.22) \times 5.67 \times 10^{-8} \frac{W}{m^2K^4} \times \left(11029.2 \frac{mm^2}{1000000\ mm^2}\ m\right)((34.0°C + 273.15K)^4 - (22.2°C + 273.15K)^4) = \mathbf{0.57\ W}$$

Black Wall			**Property Interpolations**		
Rcontact,total	1.21	$\frac{°C}{W}$	Temperature	Property	Units
Rconduction	3.15E-03	$\frac{°C}{W}$			
T_f	40.60	°C	40	1.127	$\frac{kg}{m^3}$
Density	1.12	$\frac{kg}{m^3}$	45	1.109	$\frac{kg}{m^3}$
Dynamic Viscosity	1.92E-05	$\frac{kg}{m\ s}$	40	0.00001918	$\frac{kg}{m\ s}$
Prandtl Number Pr	7.25E-01		45	0.00001941	$\frac{kg}{m\ s}$
β	3.19E-03	$\frac{1}{K}$	40	0.7255	
Ra	3.32E+06		45	0.7241	
Nu	22.97		40	0.02662	$\frac{W}{m\ K}$
k	2.67E-02	$\frac{W}{m\ K}$	45	0.02699	$\frac{W}{m\ K}$
h	5.83	$\frac{W}{m^2\ K}$			
Q conduction	**6.01**	W			
Q radiation	**2.71**	W			
Q convection	**2.37**	W			

White Wall			**Property Interpolations**		
$R_{contact}$	0.33	$\frac{°C}{W}$	Temperature	Property	Units
$R_{conduction}$	3.15E-03	$\frac{°C}{W}$			
T_f	41.10	°C	40	1.127	$\frac{kg}{m^3}$
Density	1.12	$\frac{kg}{m^3}$	45	1.109	$\frac{kg}{m^3}$
Dynamic Viscosity	1.92E-05	$\frac{kg}{m\ s}$	40	0.00001918	$\frac{kg}{m\ s}$
Prandtl Number Pr	7.25E-01		45	0.00001941	$\frac{kg}{m\ s}$
β	3.18E-03	$\frac{1}{K}$	40	0.7255	
Ra	3.38E+06		45	0.7241	
Nu	23.09		40	0.02662	$\frac{W}{m\ K}$
k	2.67E-02	$\frac{W}{m\ K}$	45	0.02699	$\frac{W}{m\ K}$
h	5.87	$\frac{W}{m^2\ K}$			
$Q_{conduction}$	**6.01**	W			
$Q_{radiation}$	**2.71**	W			
$Q_{convection}$	**2.45**	W			

Polished Wall			**Property Interpolations**		
$R_{contact}$	5.99	$\frac{°C}{W}$	Temperature	Property	Units
$R_{conduction}$	3.15E-03	$\frac{°C}{W}$			
T_f	24.10	°C	20	1.204	$\frac{kg}{m^3}$
Density	1.19	$\frac{kg}{m^3}$	25	1.184	$\frac{kg}{m^3}$
Dynamic Viscosity	1.84E-05	$\frac{kg}{m\,s}$	20	0.00001825	$\frac{kg}{m\,s}$
Prandtl Number Pr	7.30E-01		25	0.00001849	$\frac{kg}{m\,s}$
β	3.36E-03	$\frac{1}{K}$	20	0.7309	
Ra	4.39E+05		25	0.7296	
Nu	13.39		20	0.02514	$\frac{W}{m\,K}$
k	2.54E-02	$\frac{W}{m\,K}$	25	0.02551	$\frac{W}{m\,K}$
h	3.24	$\frac{W}{m^2\,K}$			
$Q_{conduction}$	**6.01**	W			
$Q_{radiation}$	**0.02**	W			
$Q_{convection}$	**0.14**	W			

Dull Wall			**Property Interpolations**		
$R_{contact}$	4.66	$\frac{°C}{W}$	Temperature	Property	Units
$R_{conduction}$	3.15E-03	$\frac{°C}{W}$			
T_f	28.10	°C	25	1.184	$\frac{kg}{m^3}$
Density	1.17	$\frac{kg}{m^3}$	30	1.164	$\frac{kg}{m^3}$
Dynamic Viscosity	1.86E-05	$\frac{kg}{m\,s}$	25	0.00001849	$\frac{kg}{m\,s}$
Prandtl Number Pr	7.29E-01		30	0.00001872	$\frac{kg}{m\,s}$
β	3.32E-03	$\frac{1}{K}$	25	0.7296	
Ra	1.28E+06		30	0.7282	
Nu	17.75		25	0.02551	$\frac{W}{m\,K}$
k	2.57E-02	$\frac{W}{m\,K}$	30	0.02588	$\frac{W}{m\,K}$
h	4.35	$\frac{W}{m^2\,K}$			
$Q_{conduction}$	**6.01**	W			
$Q_{radiation}$	**0.18**	W			
$Q_{convection}$	**0.57**	W			

Experiment 1 Introduction:

The Leslie Cube model was used in this experiment to demonstrate heat transfer on flat surfaces. The main purpose of the Leslie cube is to demonstrate heat transfer from four different surfaces while being supplied the same source of heat. As seen in the calculations above, different variables were found, recorded and calculated.

Experiment 1 Discussion:

First calculations show the conduction heat transfer through the wall from Leslie Cube's surface to the surroundings. The conductions heat transfer for all the walls was the same for black, white, polished and dull walls which was found to be approximately 6.01 W. The thermal contact resistance in calculation 2 was found to be 1.21 ℃/W for black wall, 0.33 ℃/W for white wall, 5.99 ℃/W for polished wall and 4.66 ℃/W for dull wall. When two solid bodies come in contact of different material, they experience heat flow from the hotter body to the colder body. From experience, the temperature profile along the two bodies varies. It is proven that the contact resistant for polished wall is the greatest while white wall is the weakest. The series of calculations for 3 shows the convection heat transfer rate from the surface to the surroundings (Note: convection for every surface is different, detailed calculations are shown in the table above). It is seen in the table that the convection for heat transfer for black wall is 2.37 W, white wall is 2.45 W, polished wall 0.14 W and Dull wall is 0.57 W. This shows that the highest convection is white and black walls while weakest convection is experienced in polished and dull walls. The series of calculations for 4 shows radiation heat transfer from a surface to surroundings. This was involving different types of surfaces. The black surface had the highest radiation heat transfer rate of 2.71 W followed by the white surface of 2.71 W and then the dull surface of 0.18 W and lastly polished surface of 0.02 W . Realistically black coloured objects tend to radiate more heat than white bodies, but due to experimental errors, the experiment shows that the black body and white body have the same radiation. Polished surfaces tend to be poor absorbers of heat radiation and so have lower radiation heat transfer rates than the other two sides.

Experiment 1 Conclusion:

Based on the IR thermometer readings, the dull wall would have a higher heat transfer rate than the polished wall but lower than the white surface. The calculations showed that the convection heat transfer was highest in the black wall followed by the white wall then the dull wall and finally the polished wall which had the lowest.

All of the calculations were validated using excel spreadsheet and a calculator.

Datasheet for Experiment 2: Inverse Square Law

Filament Resistance at room temperature $R_{filament} = 0.5\ \Omega$

Table: Ambient Radiation level

X (cm)	Ambient Radiation Level (mV)
10	0.2
20	0.2
30	0.2
40	0.2
50	0.2
60	0.2
70	0.2
80	0.2
90	0.2
100	0.3
Avg	**0.2**

Voltage reading, V = 10.3 V
Current reading, I = 2.48 A

Filament Temperature:

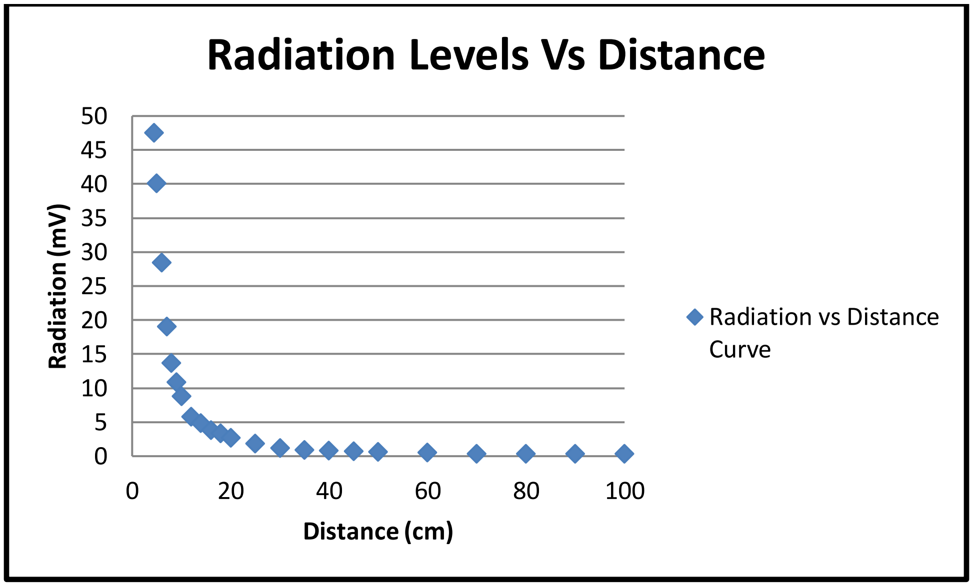
Using Pyrometer = 1207 ℃ = 1480K
Using Equation (page 5)= 1917*K*
Using Table (page 6)= 1703*K*
Using Graph = 1700 *K*

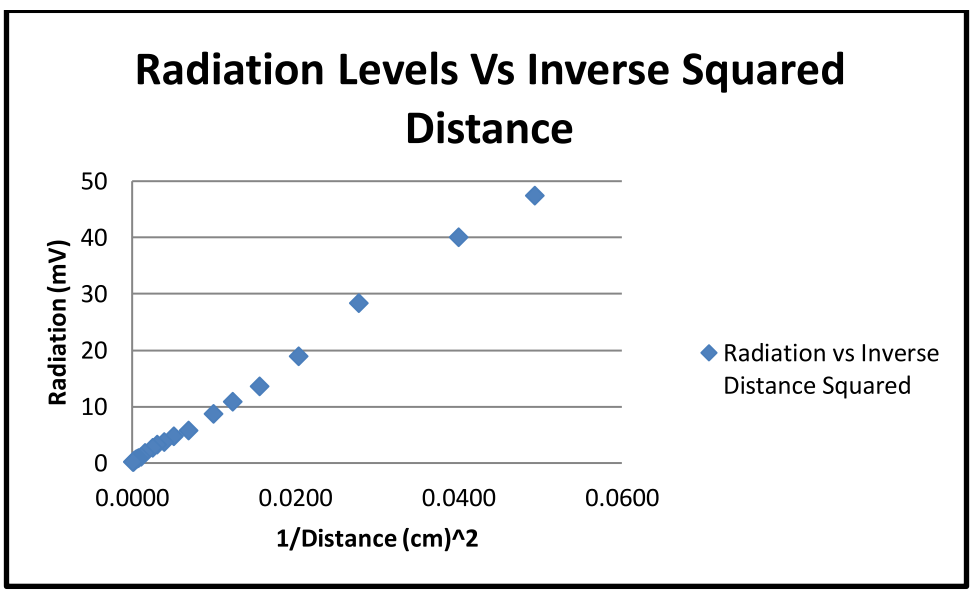
Table: Radiation level vs. distance

X (cm)	Radiation (mV)	$1/X^2$ (cm^{-2})	Rad - Ambient (mV)
2.5	-	0.1600	-
3.0	-	0.1111	-
3.5	--	0.0816	-
4.0	-	0.0625	-
4.5	47.5	0.0494	47.3
5.0	40.1	0.0400	39.9
6.0	28.4	0.0278	28.2
7.0	19.0	0.0204	18.8
8.0	13.7	0.0156	13.5
9.0	10.9	0.0123	10.7
10.0	8.8	0.0100	8.6
12.0	5.8	0.0069	5.6
14.0	4.8	0.0051	4.6
16.0	3.8	0.0039	3.6
18.0	3.3	0.0031	3.1
20.0	2.7	0.0025	2.5
25.0	1.8	0.0016	1.6
30.0	1.2	0.0011	1
35.0	0.9	0.0008	0.7
40.0	0.8	0.0006	0.6
45.0	0.7	0.0005	0.5
50.0	0.6	0.0004	0.4
60.0	0.5	0.0003	0.3
70.0	0.3	0.0002	0.1
80.0	0.3	0.0002	0.1
90.0	0.3	0.0001	0.1
100.0	0.3	0.0001	0.1

Calculations Methodology

1- For each value of X, calculate 1/X2. Enter your results in Table 2.2.
2- Subtract the Average Ambient Radiation Level from each of your Rad measurements in Table 2.2. Enter your results in the table.
3- On a separate sheet of paper, make a graph of Radiation Level versus Distance from Source, using columns one and four from Table 2.2. Let the radiation level be the dependent (y) axis.
4- If your graph from part 3 is not linear, make a graph of Radiation Level versus 1/X2, using columns three and four from table 2.2.





Calculations:

$$R_T = \frac{V}{I} = \frac{10.3V}{2.48A} = \mathbf{4.15\Omega}$$

Where:

- $R_T = Resistance$
- V=Voltage (V)
- I= Current (Amps)

$$Relative\ Resistance = \frac{R_T}{R_{ref}} = \frac{4.15\ \Omega}{0.5\ \Omega} = \mathbf{8.30}$$

Using Table 2: Temperature and Resistivity for Tungsten (Page 6 lab manual)-

$$At\ \frac{R_T}{R_{ref}} = 8.28; T = 1700K$$
$$At\ \frac{R_T}{R_{ref}} = 8.86; T = 1800K$$

Interpolating:

$$y = y_o + (y_1 - y_o)\frac{x - x_o}{x_1 - x_o}$$
$$y = 1700 + (1800 - 1700)\frac{8.30 - 8.28}{8.86 - 8.28}$$
$$y = 1703.45$$
$$\therefore \boldsymbol{T = 1703.45K}$$

Using Temperature versus Resistivity for Tungsten Graph (Page 6 lab manual)-

$$\frac{R_T}{R_{ref}} = \mathbf{8.30} \qquad \boldsymbol{T \cong 1660K}$$

$$T = \frac{R - R_{ref}}{\alpha R_{ref}} + T_{ref}$$

Where:

- T = Temperature (K)
- $R = Resistance\ at\ temperature\ T\ (\Omega)$
- $T_{ref} = Reference\ temperature\ (room\ temp.)$(K)
- $R_{ref} = Resistance\ at\ T_{ref}\ (\Omega)$
- $\alpha = Temperature\ coefficient\ of\ resistivity\ for\ filament$ $(\alpha = 4.5 \times 10^{-3} K^{-1}\ for\ tungsten)$

$$T = \frac{4.15\ \Omega - 0.5\ \Omega}{(4.5 \times 10^{-3}\frac{1}{K})(0.5\ \Omega)} + 295.35K$$

* T_∞ =22.2+ 273.15 (K) = 295.35K from experiment 1 as T_{ref}

$$\boldsymbol{T = 1917.57\ K}$$

Experiment 2 Introduction:

Experiment's 2 main goal is to observe and analyze the validity of the inverse square law. This experiment was conducted using observation and analysis of the radiation emitted from a source of heat at various distances.

Experiment 2 Discussion:

1- Which of the two graphs is more linear? Is it linear over the entire range of measurements?

This correlation can be seen in above figure. It was revealed that a radiation level versus inverse squared distance is more linear. However, was not entirely linear due to the Stefan-Boltzmann Lamp not being a perfect point source and so losing some radiation intensity (spread of light increased so loss of radiation intensity) as the distance from it was increased.

2- The inverse square law states that the radiant energy per unit area emitted by a point source of radiation decreases as the square of the distance from the source to the point of detection. Does your data support this assertion?

The data supports the inverse square law that states that the radiant energy per unit area emitted by a point source of radiation decreases as the square of the distance from the source to the point of detection. This can be seen in radiation levels versus inverse squared distance graph. The radiation level drops increasingly faster as distance increases.

3- Is the Stefan-Boltzmann Lamp truly a point source of radiation? If not, how might this affect your results? Do you see such an effect in the data you have taken?

The Stefan-Boltzmann Lamp cannot be considered a true point source. This is because the graph of radiation level vs $\frac{1}{x^2}$ is not truly linear due to drop of radiation that occurs. If the lamp was a true point source the graph would be perfectly linear.

Error occurred throughout the lab to obtain the parameters needed for this experiment. Those errors showed a major skewness in the results which caused to alter the results and cause miss match of temperatures obtained from tables and calculations. Other possible errors occurred during the measurement of radiation levels with respect to distance from source.

The filament temperature can be determined in other ways, the first method uses a pyrometer, the second using an equation, the third a table and the fourth a graph. The values can be seen in results table of experiment 2.

Experiment 2 Conclusion:

As seen, those results are different from one to another. The pyrometer temperature was 1480K, equation method is 1917K, table method is 1703K and graph method is 1700K. The table, graph and equation methods were very similar to each other however. The pyrometer gave a very low filament temperature while the equation, table and graph temperatures were much higher. This is due a possible error in accuracy of measurement.

Datasheet for Experiment 3: Density Circulation (Temperature)

Both valves closed:

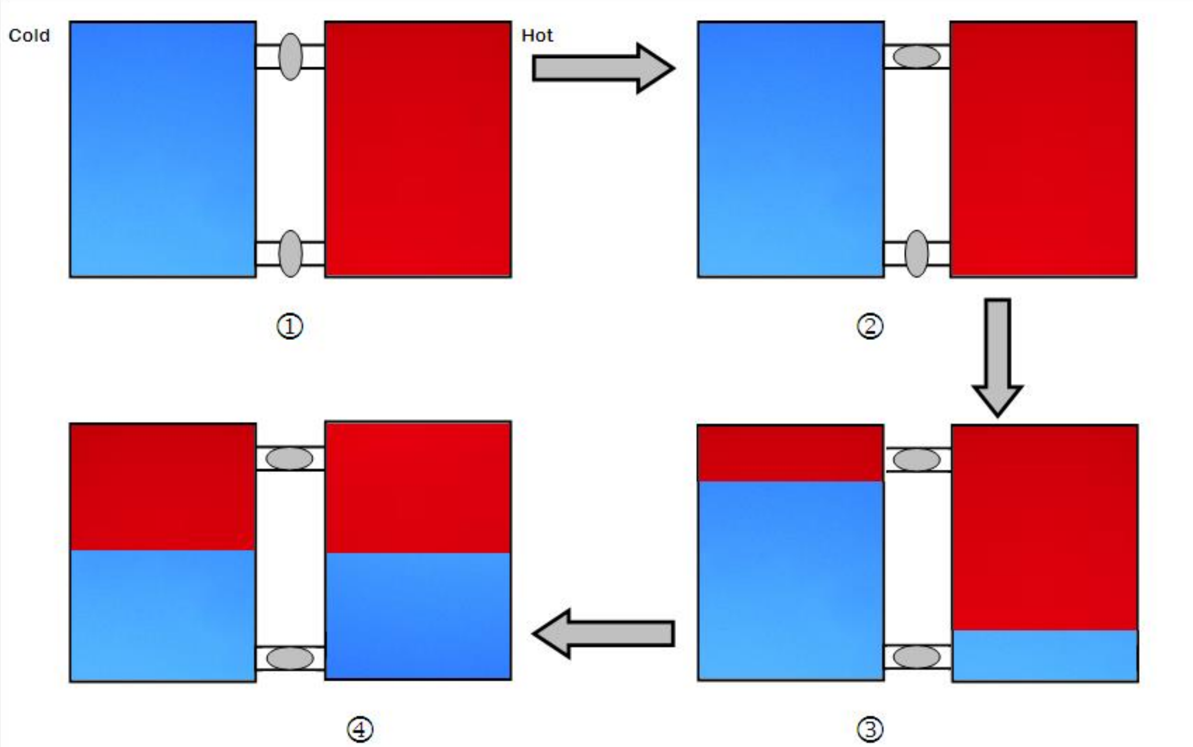
Temperature of the hot water, T_{hot} average at three different heights = **46.1**℃

Temperature of the cold water, T_{cold} average at three different heights = **23.0** ℃

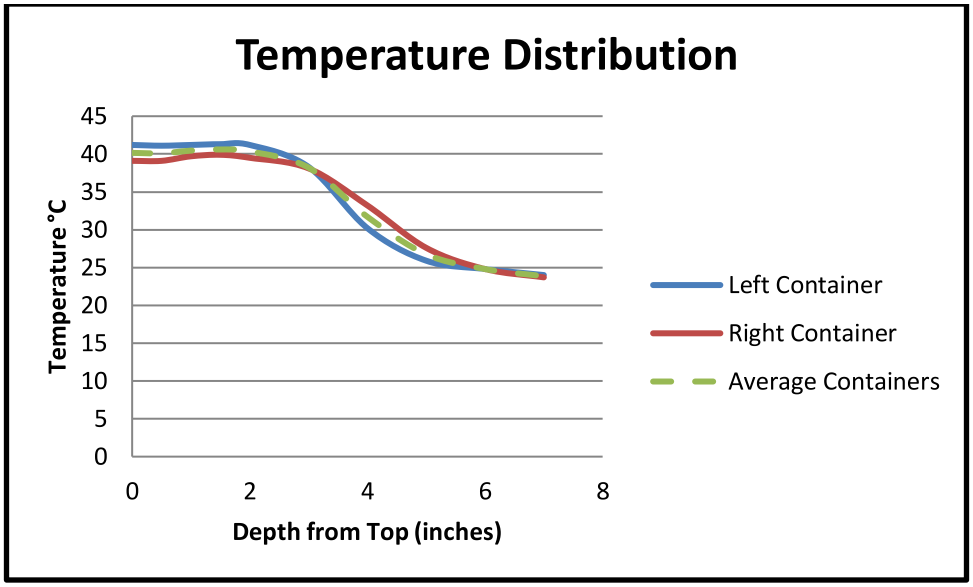
Both valves open:

Depth	Temperature
0	39.1
0.5	39.1
1.0	39.7
1.5	39.9
2.0	39.5
3.0	38.1
4.0	33.2
5.0	27.6
6.0	24.8
7.0	23.7

Depth	Temperature
0	41.2
0.5	41.1
1.0	41.2
1.5	41.3
2.0	41.2
3.0	38.3
4.0	30.2
5.0	25.9
6.0	24.8
7.0	24.0



Draw fluid motion: (1) both valves closed, (2) top valve open - bottom valve closed, (3) both open – transient flow, (4) both open – final steady state (you can also add pictures if you want)



Experiment 3 Introduction:

The main objective of experiment 3 is to analyze circulation caused by the difference in temperature within two different reservoirs.

Experiment 3 Discussion:

In this particular experiment, water with an average initial temperature of 46.1℃ was mixed with water with a cold initial temperature of 23.0℃. The mixing process was observed and is shown above figure.

It was found that when the top valve was opened the hot water flowed towards the cold water tank and a small amount of hot water entered the cold water tank.

When both valves were open hot water flower into the cold water tank through the top opening, while cold water flowed into the hot water tank through the bottom opening. This process continued until the tanks reached a final steady state where the levels of hot and cold water were equal in both tanks.

After the tanks reached steady state temperatures were taken from both tanks at different temperatures. A graph of Temperature vs. Depth for both tanks was created and can be seen above in above figure. In the case of both tanks the lowest temperature occurred at the lowest depth while the highest temperature occurred approximately 7 inches up from the bottom of the tank. The reference point was made that top of the tank is the initial height. As measurement precede downwards, the depth increases. It is seen that the lower the depth, the lower the temperature.

Experiment 3 Conclusion:

From the results displayed above, It can be concluded that the cold water was denser than the hot water as it stayed at the bottom of the tanks during the mixing process and steady state.

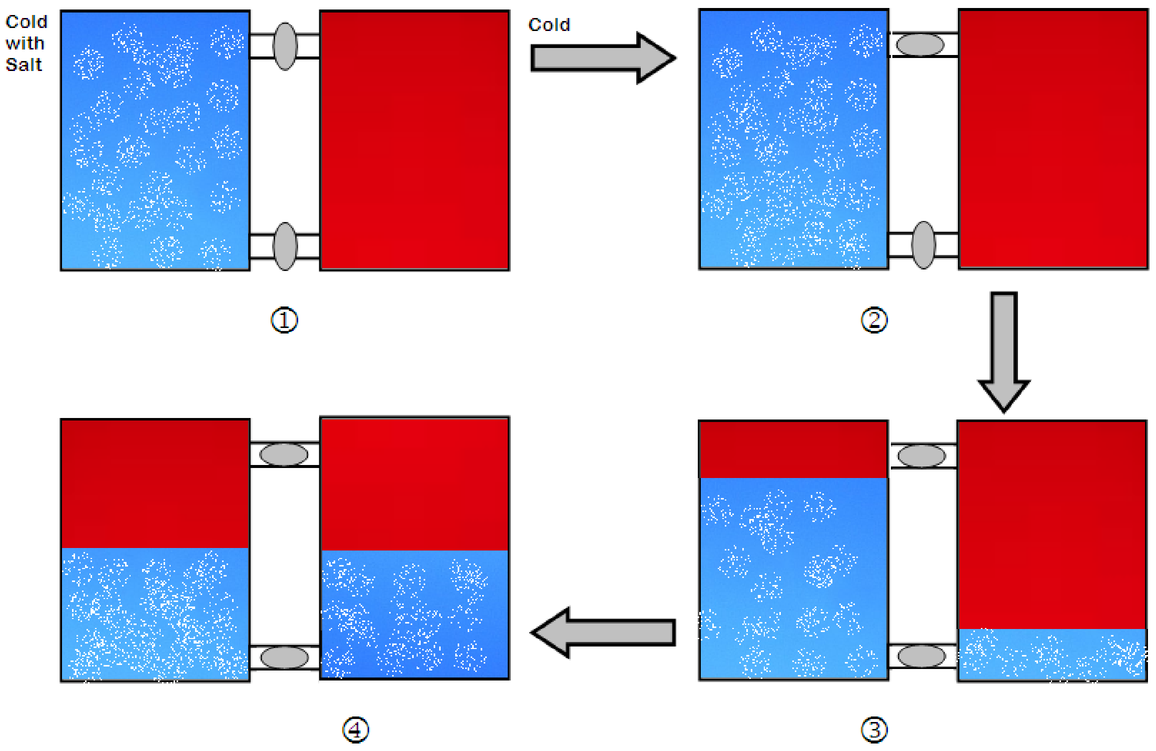
Average of both trials was calculated to provide a more accurate result.

Datasheet for Experiment 4(a): Density Circulation (Salinity)

Both valves closed:

Temperature of the water, T = **21.8**

Salinity of salty water (%) = **5.2**



Draw fluid motion: (1) both valves closed, (2) top valve open - bottom valve closed, (3) both open – transient flow, (4) both open – final steady state (you can also add pictures if you want)

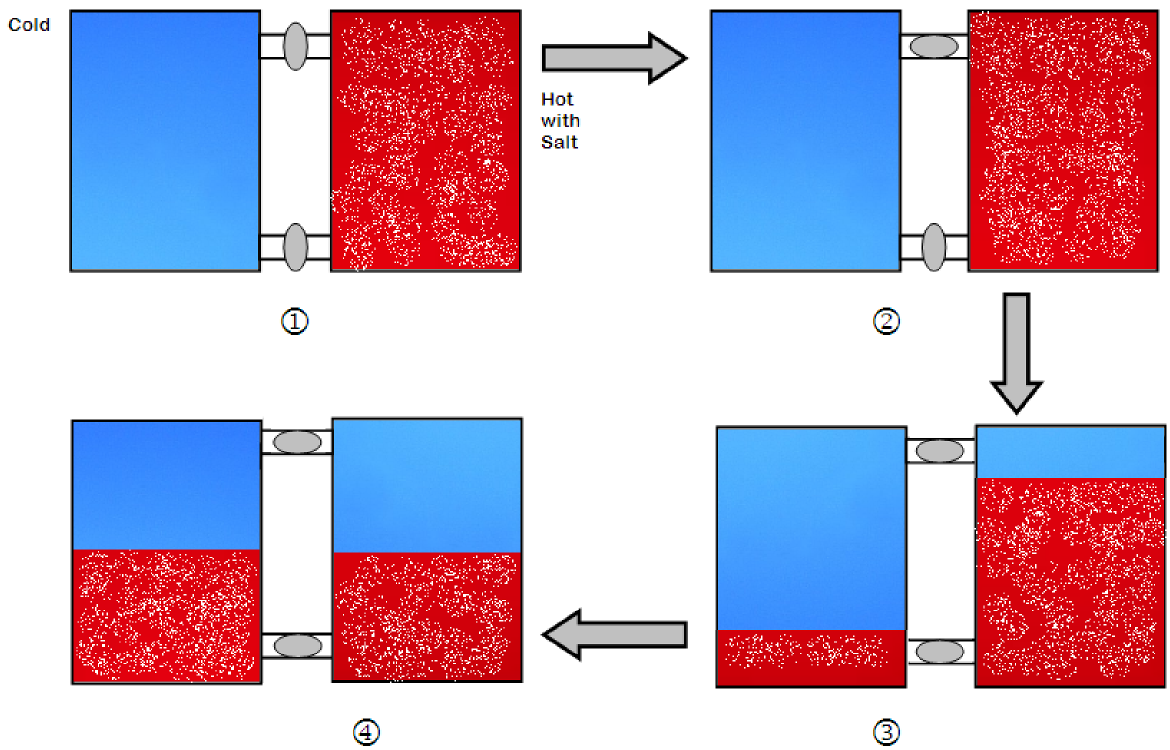
Datasheet for Experiment 4(b): Density Circulation (Salinity & Temperature)

Both valves closed:

Temperature of the hot water, T_{hot} = **44.7**

Temperature of the cold water, T_{cold} = **23.2**

Salinity of hot salty water (%) = **5.1%**



Draw fluid motion: (1) both valves closed, (2) top valve open - bottom valve closed, (3) both open – transient flow, (4) both open – final steady state (you can also add pictures if you want)

Experiment 4 Introduction:

The main objective of experiment 4 is to analyze circulation caused by the difference in salinty within two different reservoirs.

Experiment 4 Discussion:

In part 'a' of experiment, water with a temperature of 21.8℃ and a salinity percentage of 5.2 was mixed with fresh water. Both of containers contained similar water temperature since they were obtained from the same tap. The mixing process was observed and drawn in above figure in experiment 4a. It was found that when the top valve was opened salt water flowed towards the fresh water tank and filled the tube connecting them. It was observed that a small amount of salt water entered the fresh water tank however not enough to change the colour.

The process continued on when both valves were open salt water flower into the fresh water tank through the bottom opening while fresh water flowed into the salt water tank through the tom opening. This process continued until the tanks reached a final steady state where the levels of salt and fresh water were equal in both tanks. From these observations it can be seen that salt water was denser than the fresh water as it stayed at the bottom of the tanks. This also explains to why oceans tend to be more salty as depths goes up.

In part 'b' of experiment, water with a temperature of 44.7℃ and a salinity percentage of 5.1% were mixed with fresh water with a temperature of 23.2℃. The mixing process was observed and is shown in above figure. It was found that when the top valve was opened the hot water flowed towards the fresh water tank in the connecting tube but did not enter the tank.

Experiment 4 Conclusion:

It was found that when both valves were opened, the hot salt water flowed into the cold fresh water tank through the bottom opening and the cold fresh water flowed into the hot salt water tank through the top opening. This process continued until the tanks reached a final steady state where the levels of salt and fresh water were equal in both tanks. From these observations it can be seen that the hot salt water was denser than the fresh water as it stayed at the bottom of the tanks.