AUM
American University Of The Middle East

EXPERIMENT1 - LINEAR HEAT CONDUCTION

A: Steady Sate Heat Conduction
B: Thermal Conductivity of Different Materials



SAFETY INSTRUCTIONS



All practical work areas and laboratories should be covered by local safety regulations, which **must be followed at all times**.

Hot Surfaces and Liquids

The unit incorporates a pumped electric water heater, and is capable of producing temperatures that could cause skin burns.

Before disconnecting any of the pipes or tubing:



- Leave time for the water to cool
- Check that the temperature is at a safe level
- Do not touch any surfaces close to 'Hot Surfaces' warning labels, or any of the interconnecting tubing, whilst the equipment is in use.



General Instructions



- If a spill occurs, turn off the pumps (if possible without injury) and immediately get in touch with the Laboratory Instructor or Technician.
- Ensure that protective clothing (LAB coat) and gloves are worn when handling any of the substances used in the reactor.



- Shorts or skirts should not be worn to the lab.
- Sandals, high heels, or open-toe shoes are not acceptable.



- Safety glasses are a required item to be worn in all areas of the laboratories.



- Electrical - Burn / Shock: Care with electrical connections, particularly with grounding, and not using frayed electrical cords, can reduce hazard.

Contents

Theory 4
Experimental Objectives 4
Safety Precautions 4
Equipment Description 5
Exercise A – A Steady State Heat Conduction 6
Procedure 6
Results 7
Discussion and Conclusion 8
Exercise B – A Steady State Heat Conduction 8
Procedure 8
Results 9
Discussion and Conclusion 9

Theory

Heat transfers in different modes conduction, convection, and radiation. In this experiment, you are going demonstrate heat transfer in conduction. Conduction can take place in gasses, liquids, and solid. In solids, conduction accrues due to vibrations of molecules, and in gasses and liquids due to collisions and diffusion.

In general, the rate of heat conducted depends on medium geometry of the material used, thickness, and temperature difference across the medium. Heat conduction accrues in a diversity of engineering applications and can be calculated using **Fourier's law of heat conduction:**

$$\dot{Q}_{cond} = -k\,A\frac{dT}{dx}$$

Where, $\dot{Q}_{cond}$ is the heat conduction rate (W), (k) is the thermal conductivity of the material (W/m.^{o}C), (A) Heat transfer area (m^2), dT the difference between two temperatures where conduction occurs, dx is the thickness of the material.

When heat transfers over any material it faces resistance depending on the type of this material and its length, therefore, it is important to introduce the term **Overall Heat Transfer Coefficient U**.

$$R = \frac{1}{U},\quad R = \frac{\Delta X}{k}$$

$$\dot{Q}_{cond} = U\,A\,dT$$

Where R is the resistance, U is the overall heat transfer coefficient (W/ms.K), and ΔX is the distance between two surfaces where conduction take place.

Experimental Objectives

In this experiment, you are going to demonstrate **linear heat conduction** according to the following:

A. To measure the temperature distribution for steady-state conduction of energy through a uniform plane wall and demonstrate the effect of a change in heat flow.
B. To determine the thermal conductivity k (the constant of proportionality) of a metal specimen (good conductor).

Safety Precautions

1. Do not touch any surface after operating the experiment.
2. Do not unplug any of the thermocouples. Thermocouples are sensitive devices and can be damaged easily if they are mishandled.
3. Allow time for the equipment after it cool before handling any component.
4. Do not unplug any of water connection as it can cause overheat and serious damage.

Equipment Description

See Figure 1. The linear heat conduction equipment comprises a heating section (1) and cooling section (3) that are clamped together with intermediate section (2). Each intermediate section contains of different specimen of metal conductor. The temperature difference that is created between the hot and cold section creates a heat transfer flow through the intermediate section in a linear mechanism through the wall by conduction. Eight thermocouples (14) are used to measure temperatures along the element, the distance between each thermocouple is 0.015m.

The heating section is made of brass bar with 0.025m diameter, fitted with a cartridge electric heater element at one end. The heating element can be controlled by the heat transfer service unit (**HT10XC**). As shown on figure 2, T1, T2, and T3 are thermocouples placed to measure temperature. The cooling section is also made of brass with mounting thermocouples T6, T7, and T8. The intermediate section is made from brass for this experiment with thermocouples to measure T4 and T5. Note that this section can be replaced with other material.

Cooling water is circulated in the cold section to insure reduction in the temperature and in order for the heat to flow through the bar from the hot surface to the cold. Regulator is connected to control the flow rate of the water. Note that the flow rate will not be calculated during this experiment.

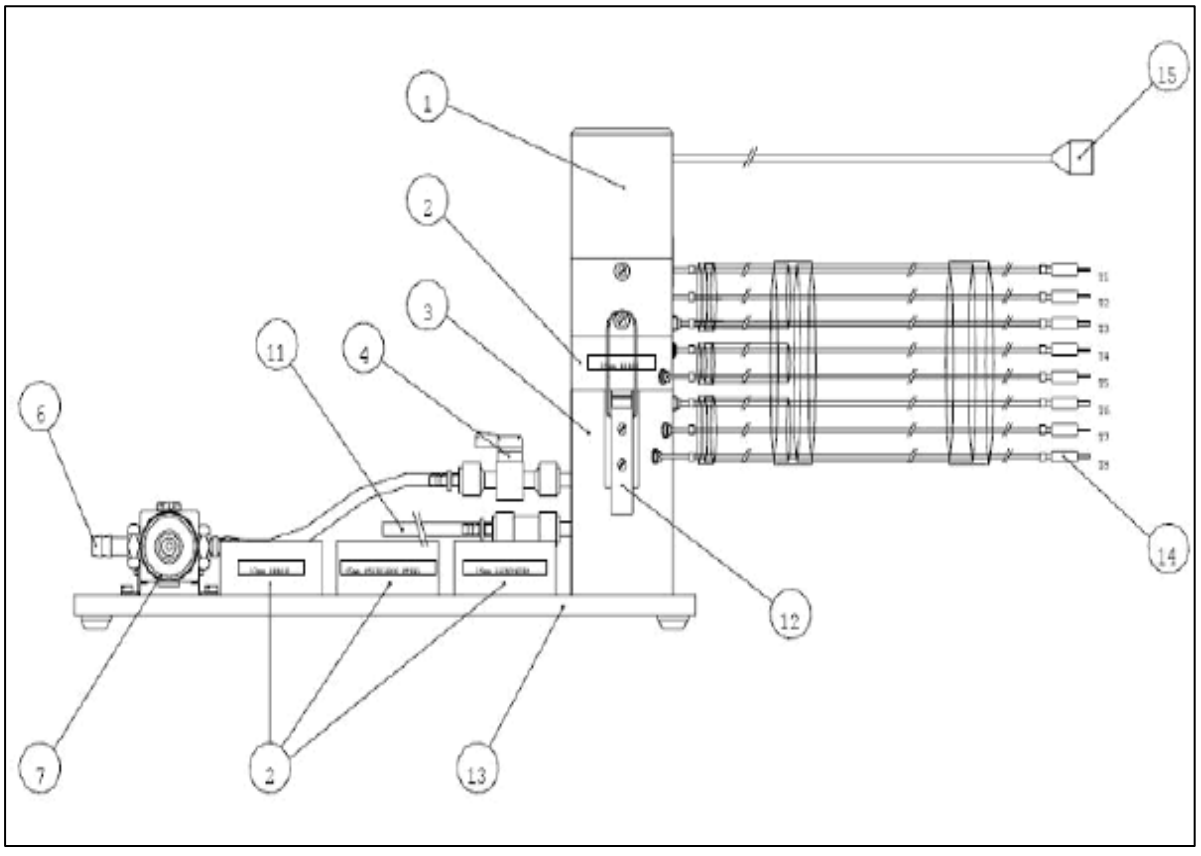


Figure 1: Linear Heat Conduction Device

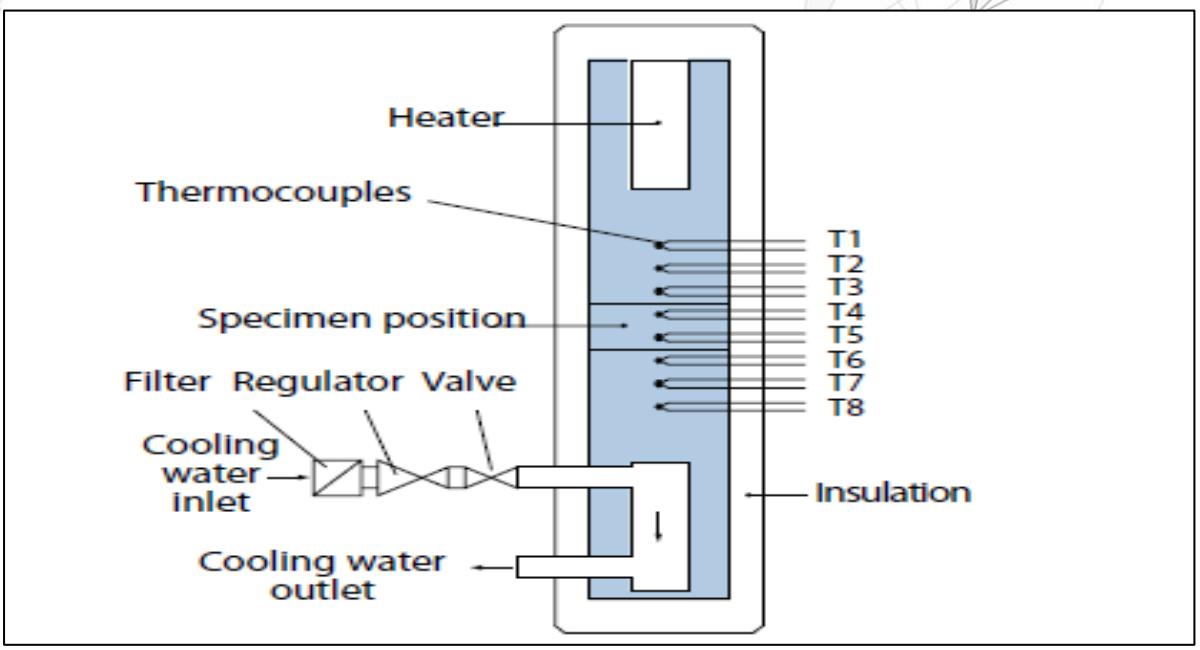
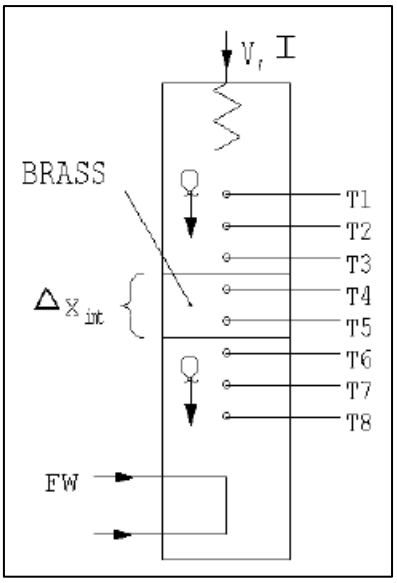


Figure 2: Section View Showing thermocouples

Exercise A – A Steady State Heat Conduction

In this exercise you are going to measure the variation of temperatures resulted from the linear conduction along the bar. At each thermocouple, the temperature will be recorded.



Procedure

1. Start your experiment only after you receive operating and safety practice by your instructor!
2. Insure that water is supplied to the cold section.
3. Insure that the flexible water connection is directed to the drain.
4. Insure that each thermocouple is connected to its socket at part (K) of the service unit.
5. Insure that switch (B) on the service unit is toward the Manual setting.
6. Insure that you select V on the measurement selection switch (E).

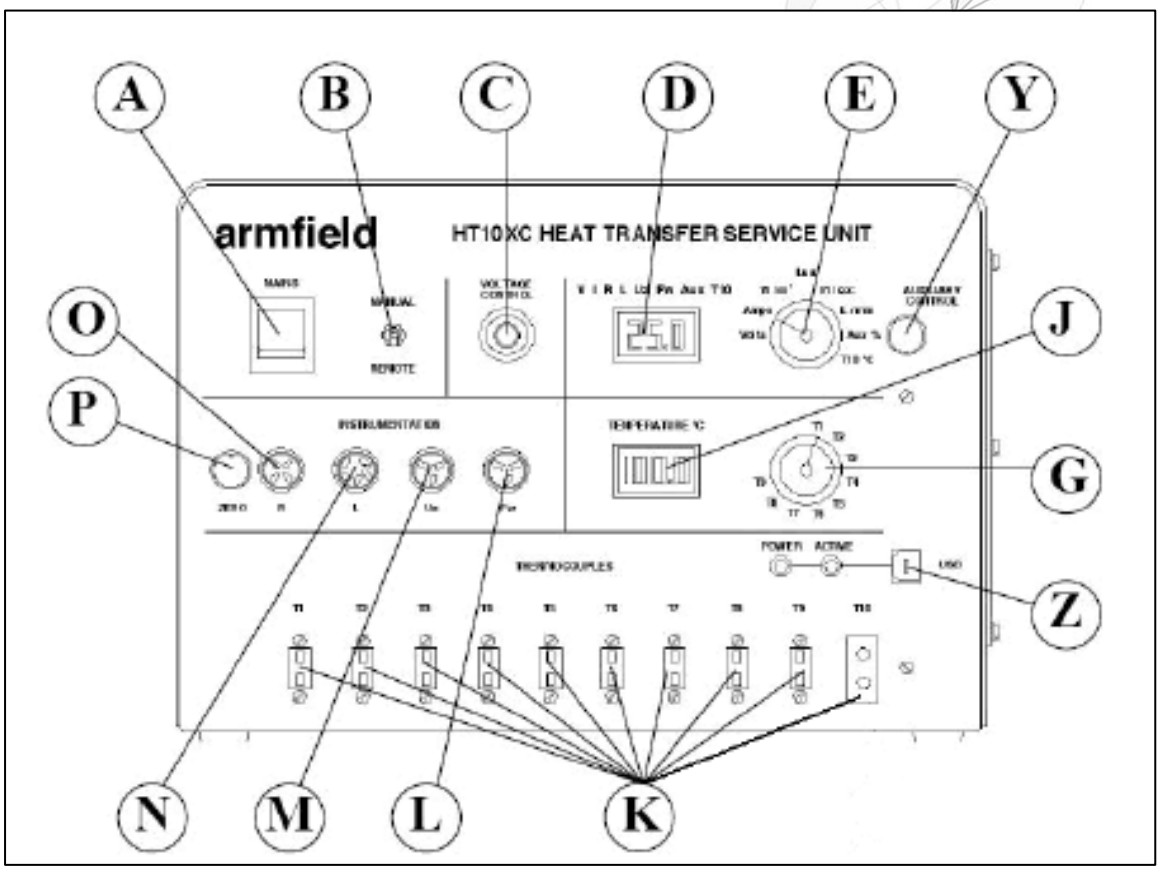


Figure 3: HT10XC Service Unit

7. Turn on the main standby switch (A)
8. Watch the voltage readings on top panel meter (D) (since you selected V on step number 6).
9. Starting from zero voltage increase the volt gradually to 12V
10. Make sure that the temperature switch (G) is located at T1, as a start, you will change it later.
11. The required temperature reading is selected via switch (G), select T1 now.
12. Wait for 10min (for a steady-state condition) and watch the temperature on the adjacent panel meter (J).
13. After reaching a steady state, take the reading of T1 and change the temperature reading switch to display other temperatures.
14. Fill the table below of the readings and don't forget to mention the units!
15. Knowing that the distance between each thermocouple is 0.015m fill in the table the position of each temperature sensor along the brass bar.

Results

Fill the table below according to your experimental results.

Table 1: Temperatures recorded for each thermocouple vs position along the bar

	T1	T2	T3	T4	T5	T6	T7	T8
X	0							
T								

Discussion and Conclusion

In this part, you will discuss and make a conclusion based on your own results in the lab.

Exercise B – A Steady State Heat Conduction

In this exercise, you will use Fourier Rate Equation to determine the thermal conductivity of a brass and stainless steel material by using two different intersection specimen. You will need the results collected from the previous exercise.

$$\dot{Q} = k_{int}\, A_{int} \frac{T_{hot} - T_{cold}}{\Delta X_{int}}$$

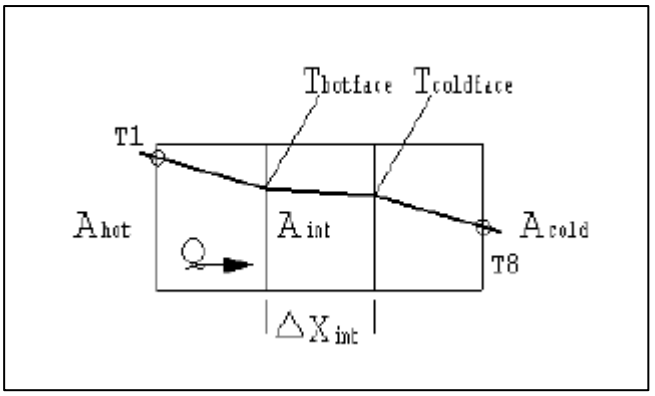


Figure 4: Diagram showing heat transfer through the brass intermediate section.

Procedure

Figure 4 represent the temperature distribution across the cylindrical bar, find the thermal conductivity of the brass specimen by following the following steps:

1. Since we are assuming almost zero heat lost in the heat transfer process. Find the heat transfer rate that is generated as electrical work to the brass bar by using $\dot{Q} = V \times I$
2. The voltage and the current inputs can be read on panel D by adjusting switch E.
3. Measure the lenth of the intermediate section ΔX_{int} by using vernier caliper. Refer to your instructor!
4. Measure the diameter D of the brass in the intermediate section by using vernier caliper.
5. Find the cross sectional area of the brass bar $A_{int} = \pi \frac{D_{int}^2}{4}$. This representing the area of the hot and cold wall surfaces.
6. Find the temperature of the hot and cold wall surfaces using the graph obtained in Excersise A.

$$T_{hot} = T_3 - \frac{T_2 - T_3}{2}$$

$$T_{cold} = T_6 + \frac{T_6 - T_7}{2}$$

7. Finally calculate the value of the thermal conductivity of the intermadiate section k_{int}
8. Repeat the experiment after replacing the other intermediate section made of stainless steel

Results

Fill the table below according to your experimental results.

Table 2: Experimental Results

Quantity	Values	Units
I	1.44	A
V	14.5	V
$\dot{Q}$	20.88	Watt
D_{int}	0.025	m
ΔX_{int}	0.045	m
A_{int}	4.908x10^-4	m^2
T_{hot}	65.85	°C
T_{cold}	44.2	°C
k_{int}	88.41	W/m.k

Discussion and Conclusion

In this part, you will discuss and make a conclusion based on your own results in the lab.

Exercise

According to lab manual of this experiment, complete the following requirements based on the given data. Careful to use the proper units.

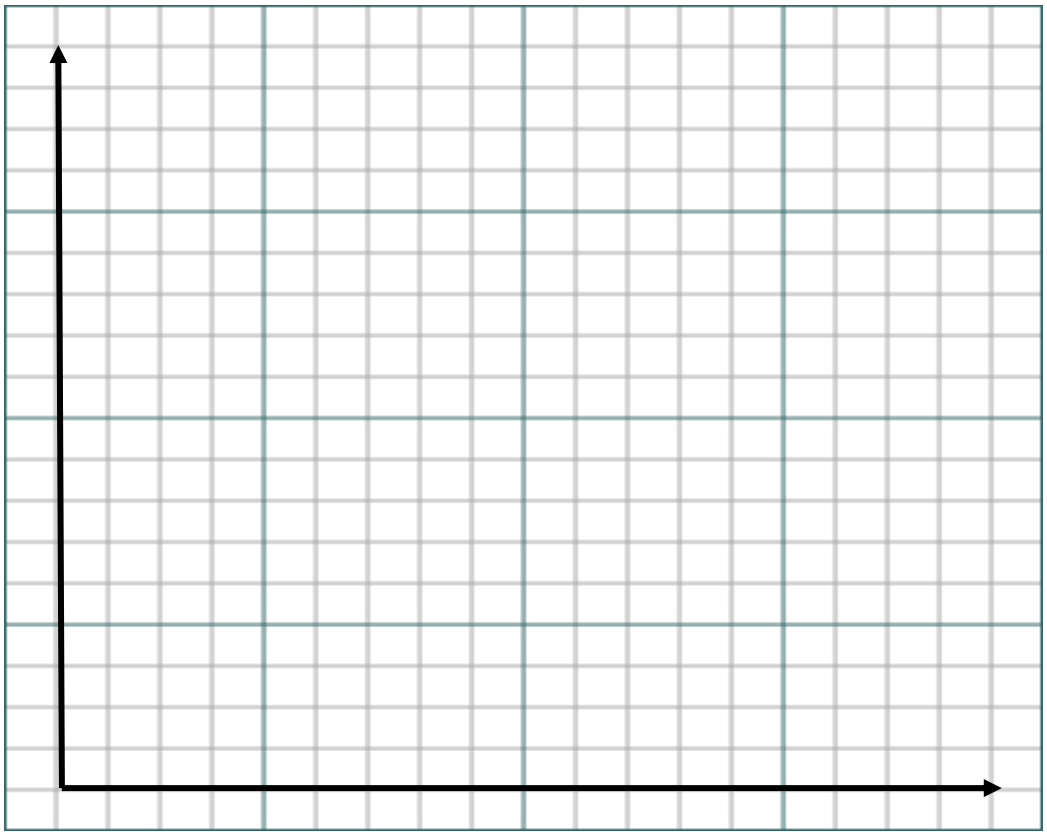
Exercise A:

1. Take measurement for the accurate results and complete the following table.

Table 3: Temperature Vs Location

Electrical Parameters	V= 14.5 V			I = 1.44 A			$\dot{Q}$ = I * V	
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
X (m)	0	0.015	0.03	0.045	0.06	0.075	0.09	0.105
T (°C)	76.9	72	67.9	58.3	55	42.9	40.3	37.1

2. Use the below graph to plot your results.



3. Comment about the graph and try to use equation to verify your results.

+Ve Q*= -K A DT/DX

Exercise B:

4. Fill the below table according to your calculations and readings.

Quantity	Values	Units
I	1.44	A
V	14.5	V
$\dot{Q}$	I * V	Watt
D_{int}	0.025	m
ΔX_{int}	Xc - Xh =0.0529	m
A_{int}	π/4 D^2 4.908x10^-4	m^2
T_{hot}	65.85	°C
T_{cold}	44.2	°C
k_{int}	103.94	w/m ° C

EI = | Kexp - Kth | / Kth * 100

5. The theoretical value of thermal conductivity for a brass is around 109 W/m.°C, compare this value with the experimental value that you already obtained in the previous table and calculate the percentage error.

6. In your opinion and understanding of heat conduction. What are the major factors for these errors in this experiment?