FACULTY OF ENGINEERING AND NATURAL SCIENCES
MECHANICAL ENGINEERING DEPARTMENT
MCE 403 – MACHINERY LABORATORY I
HEAT CONDUCTION EXPERIMENT

Nomenclature Name	**Symbol SI Unit**
Radius of Disk	R [m]
Heat transfer area	A [m^2]
Wall thickness (distance)	L [m]
Constant Value (k/A)	C
Electrical power to heating element	$\dot{Q}$ [W]
Heat transfer rate per unit time (heat flow)	$\dot{Q}$ [W]
Temperature measured	T_a (eg. T_1) [°C]
Temperature at hot interface	$T_{hotface}$ [°C]
Temperature at cold interface	$T_{coldface}$ [°C]
Temperature gradient	Grad (eg. $Grad_{hot}$) [K/m], [°C/m]
Thermal conductivity	k [W/m°C]
Time	t [secs]

1. OBJECT

The purpose of this experiment is to determine the constant of proportionality (the thermal conductivity k) for one-dimensional steady flow of heat.

2. INTRODUCTION

Heat always flows from high temperature objects to low temperature objects. It stops when temperatures equal. This heat is a form of energy and is the total internal energy of a substance. The form of energy can be transferred by(figure 1):

- Conduction
- Convection
- Radiation

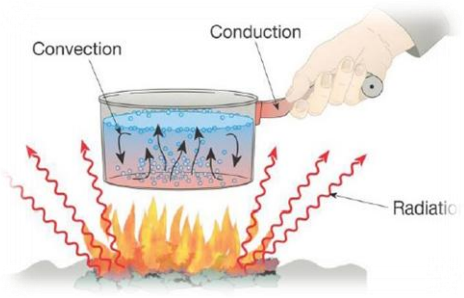


Figure 1

In this experiment, we focus on the conduction way. Conduction is the transfer of heat from an atom (molecule) to an atom (molecule) within a substance.

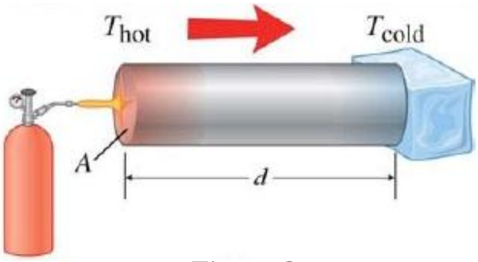


Figure 2

If you put one end of a metal rod over a fire like that in figure 2, that end will absorb the energy from the flame.

Conduction refers to the transport of energy in a medium (solid, liquid or gas) due to a temperature gradient. The physical mechanism is random atomic or molecular activity. It is governed by Fourier's law:

$$q'' = -k\frac{dT}{dx}$$

T is the temperature (°C or K)
x is the length (m)
k is the thermal conductivity of material (W/m°C or W/mK)
q" is the heat flux (W/m^2)

Under steady state conditions, the temperature distribution is linear as shown in figure 3, and the temperature gradient can be expressed as

$$\frac{dT}{dx} = \frac{T_2 - T_1}{L}$$

$$q''_x = k\frac{T_1 - T_2}{L} = k\frac{\Delta T}{L}$$

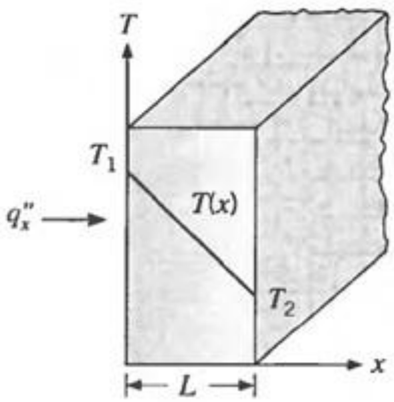


Figure 3

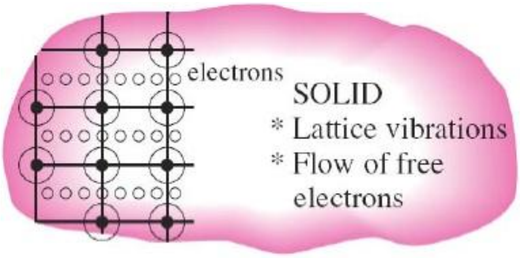


Figure 4

-The measure of how well a substance can conduct heat depends on its molecular structure.

-Pure metals are better heat conductors than alloys.

- ✓ Atoms at this end of the road will gain energy and begin to vibrate faster.
- ✓ Their temperature increases and they begin to bump into the adjacent atoms.

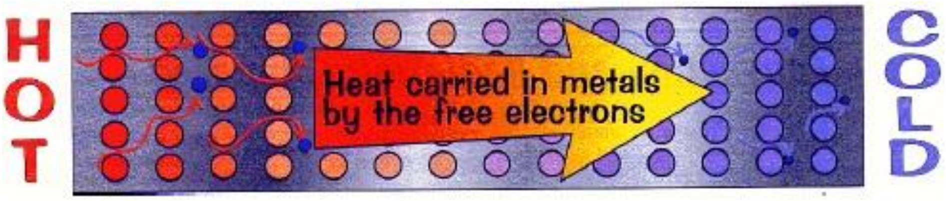


Figure 5

- ✓ Metals have an additional method of conduction.
- ✓ Metals have electrons that can move from one atom to another.
- ✓ These free electrons can pass energy through the metal very quickly. Most of the best conductors are metals.
- ✓ However, diamond, a non-metal, is the best conductor despite only using the molecule to molecule method.

Why does metal feel colder than wood, if they are both at the same temperature ?

Metal is a conductor, wood is an insulator. Metal conducts the heat away from your hands. Wood does not conduct the heat away from your hands as well as the metal, so the wood feels warmer than the metal.

A solid is chosen for the experiment of pure conduction because both liquids and gasses exhibit excessive convective heat transfer. For practical situation, heat conduction occurs in three dimensions, a complexity which often requires extensive computation to analyze. For experiment, a single dimensional approach is required to demonstrate the basic law that relates rate of heat flow to temperature gradient and area.

3. EXPERIMENT TYPES

3.1. LINEAR HEAT CONDUCTION

According to Fourier's law of heat conduction: If a plane wall of thickness (ΔL) supports a temperature difference (ΔT) then the heat transfer rate per unit time and unit area (q") by conduction through the wall is shown in section 2.

If the material of the wall is homogeneous and has a thermal conductivity k (the constant of proportionality) then:

$$Q = -kA\frac{\Delta T}{\Delta L} \quad where \Delta T = (T_a - T_b) \quad \Delta L = (L_b - L_a)$$

It should be noted that heat flow is positive in the direction of temperature fall hence the negative sign in the equation. For convenience the equation can be rearranged to avoid the negative sign as follows:

$$Q = kA\frac{\Delta T}{\Delta L} where \Delta T = (T_b - T_a)$$

Note: In this exercise k and A are constant.

Linear heat conduction experiment setup can be seen in figure 6.

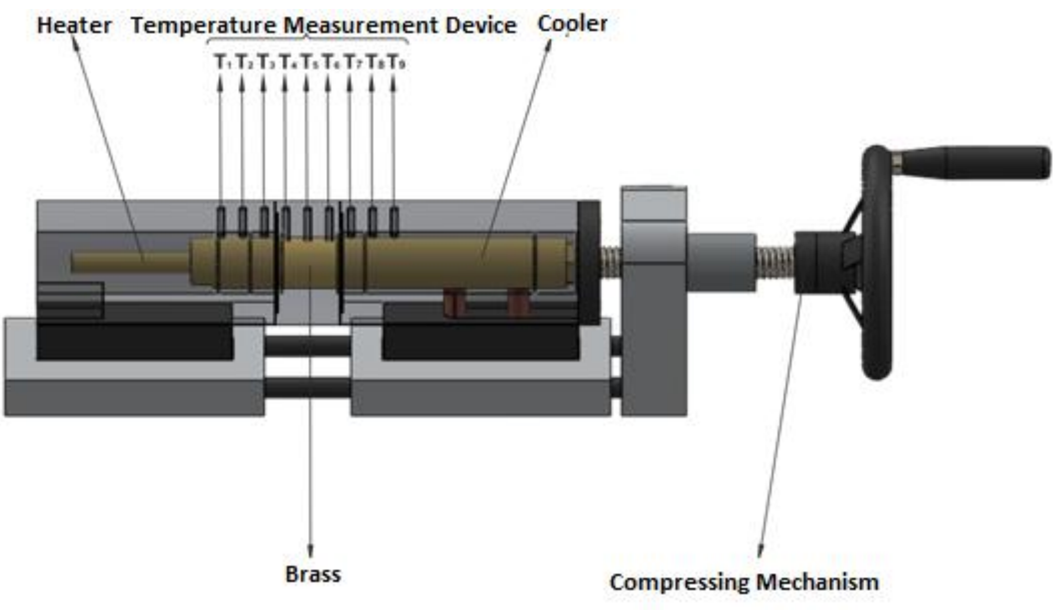


Figure 6

3.2. RADIAL HEAT CONDUCTION

When the inner and outer surfaces of a thick walled cylinder are each at a different uniform temperature, heat flows radially through the cylinder wall. The disk can be considered to be constructed as a series of successive layers. From continuity considerations the radial heat flow through each of the successive layers in the wall must be constant if the flow is steady but since the area of the successive layers increases with radius, the temperature gradient must decrease with radius.

$$k = \frac{W \ln \frac{R_b}{R_a}}{2\pi L(T_b - T_a)}$$

Radial heat conduction experiment setup can be seen in figure 7.

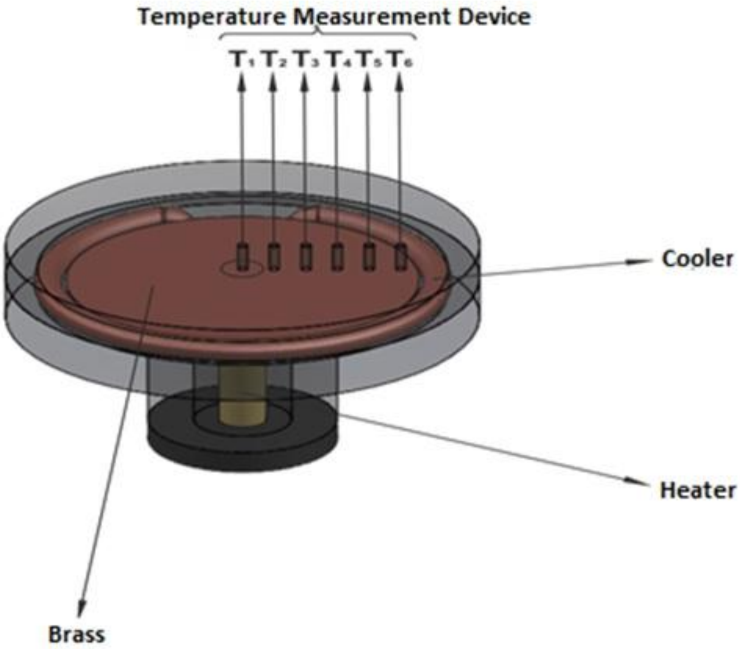


Figure 7

4. EXPERIMENTS TO BE PERFORMED

The test unit will be introduced in the laboratory before the experiment by the relevant assistant.

4.1 Linear Heat Conduction

Aim of the Experiment: To comprehend how to calculate thermal conductivity(k)

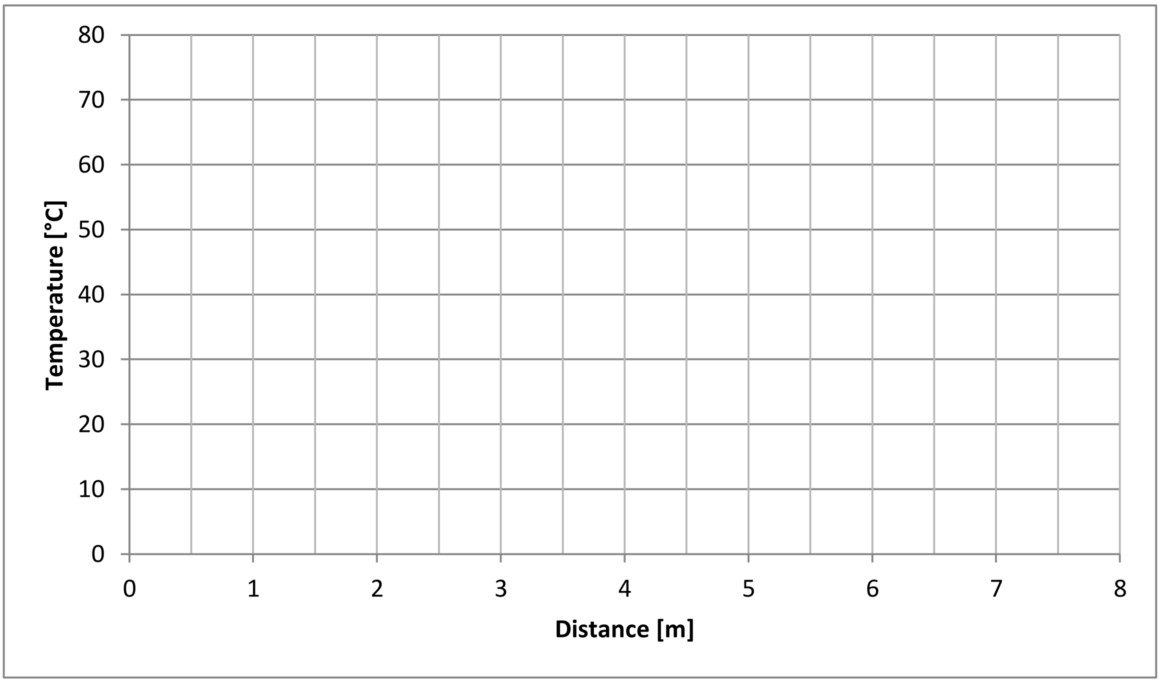
The necessary data for calculations will be recorded to the table given below.

Material:									
Power (W)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Distance from T_1 (m)	0	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08

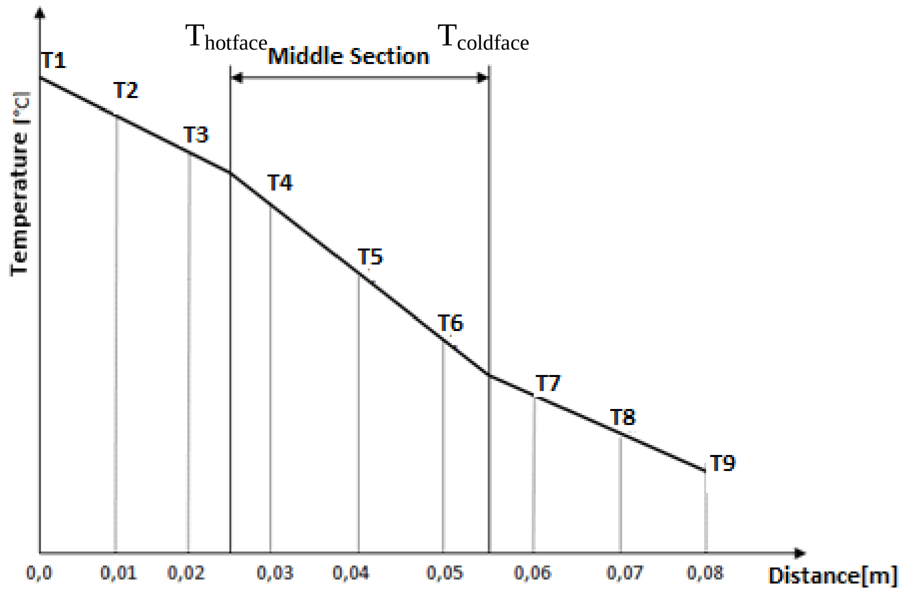
Calculations: Using the equation given below, calculate the thermal conductivity. Thermal conductivity is defined as:

$$k = \frac{Q\Delta L}{A\Delta T} \quad \text{where} \quad A = 7,065x10^{-4} m^2$$

Plot a graph of temperature against position along the bar and draw the best straight line through the points. Comment on the graph.



A sample graph of temperature against position along the bar can be seen.



Compare your result with table 1.

Materials in Normal Conditions (298 K, 24.85 °C)		Thermal Conductivity (k) W/m°C
Metals	Pure Aluminium	205-237
	Aluminium Alloy (6082)	170
	Brass (CZ 121)	123
	Brass (63% Copper)	125
	Brass (70% Copper)	109-121
	Pure Copper	353-386
	Copper (C101)	388
	Light Steel	50
	Stainless Steel	16
Gas	Air	0.0234
	Hydrogen	0.172
Others	Asbestos	0.28
	Glass	0.8
	Water	0.6
	Wood	0.07-0.2

Table 1. Thermal Conductivities for Different Material Types

4.2 Linear Heat Conduction for Different Materials

Aim of the Experiment: To comprehend how to calculate thermal conductivity (k) for different materials.

The necessary data for calculations will be recorded to the table given below.

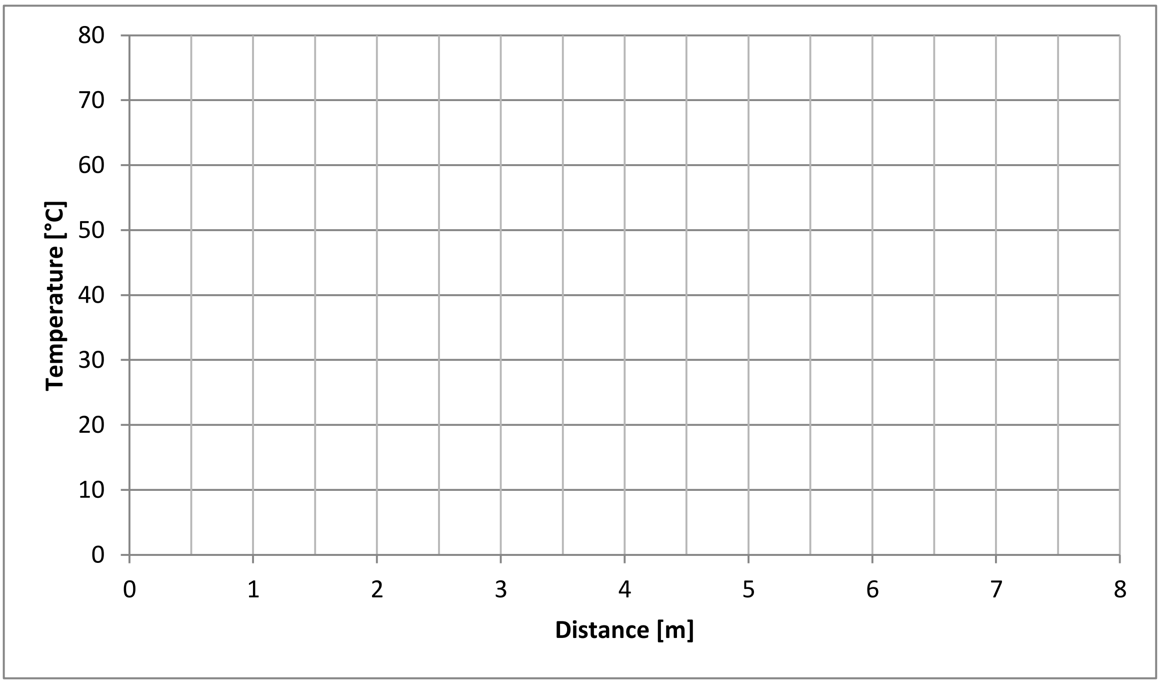
Material:									
Power (W)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Distance from T_1 (m)	0	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08

Calculations: Using the equation given below, calculate the thermal conductivity.

Thermal conductivity is defined as:

$$k = \frac{Q\Delta L}{A\Delta T} \quad \text{where} \quad A = 7,065x10^{-4} m^2$$

Plot a graph of temperature against position along the bar and draw the best straight line through the points. Comment on the graph.



Compare your result with table 1.

4.3 Radial Heat Conduction

Aim of the Experiment: To comprehend how to calculate thermal conductivity (k)

The necessary data for calculations will be recorded to the table given below.

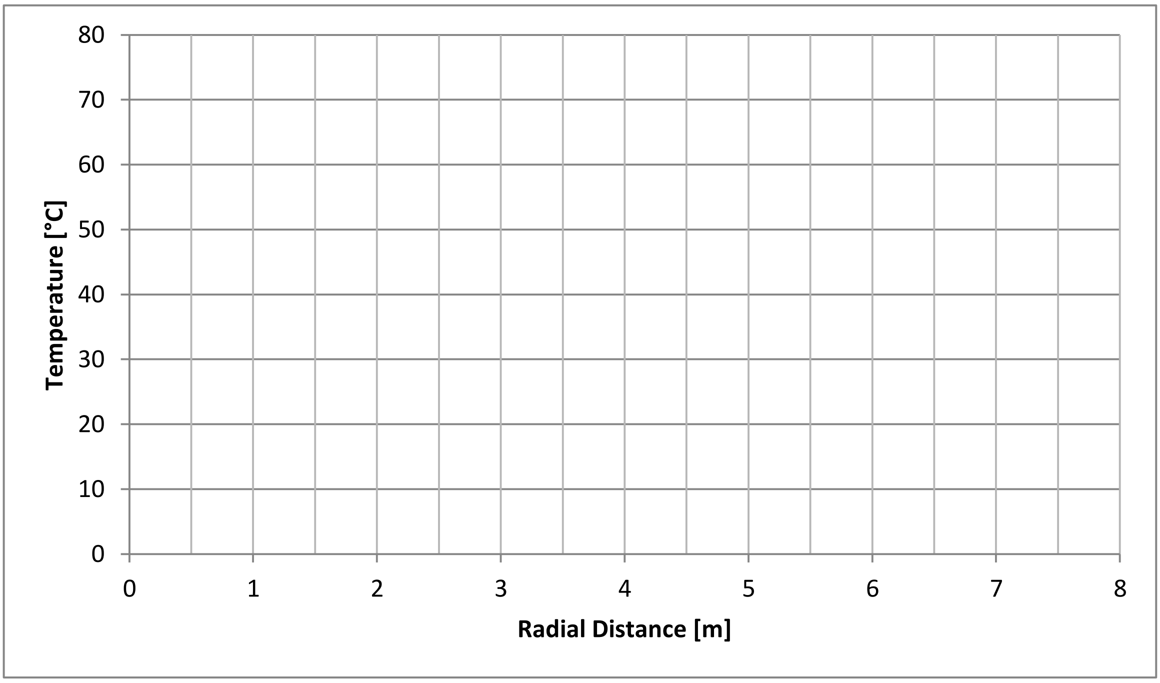
Material:						
Power (W)	T_1	T_2	T_3	T_4	T_5	T_6
Radial Distance from T_1 (m)	0,00	0,01	0,02	0,03	0,04	0,05

Calculations: Using the equation given below, calculate the thermal conductivity.

Thermal conductivity is defined as:

$$k = \frac{W \ln \frac{R_b}{R_a}}{2\pi L(T_b - T_a)} \quad \text{where} \quad L\text{=0,012 m}$$

Plot a graph of temperature against position along the bar and draw the best straight line through the points. Comment on the graph.



5. REPORT

In your laboratory reports must have the followings;

a) Cover

b) A short introduction

c) All the necessary calculations using measured data.

d) Discussion of your results and a conclusion.