THERMAL DIFFUSIVITY OF BRASS

AIM: To study the thermal conduction properties of brass and calculate its diffusivity.

APPARATUS: The thermal diffusivity setup (consisting of a Brass rod with a heater wound on it and two copper-constantan thermocouples glued to it), connecting wires, DC Power Supply, a differential voltage amplifier, DMM and a timer.
(Full description of the apparatus is provided in the setup manual)

THEORY: Thermal diffusivity is defined as κ/ρc, i.e. the ratio of thermal conductivity (κ) and the product of density (ρ) and specific heat (c) of a given material. In steady state measurements only conductivity plays a role. However, if the heat supplied varies with time, then the diffusivity determines how the temperature varies with the space and time in the medium.

In this experiment, you will be expected to calculate two parameters α and β which are related to the amplitude and phase of the temperature oscillations with respect to heating at different points x1 and x2 of the brass rod. The relations are:

$$\frac{Amp(x_2)}{Amp(x_1)} = \exp[-\alpha(x_2 - x_1)]$$

$$\varphi(x_1) - \varphi(x_2) = \beta(x_1 - x_2)$$

α and β can be calculated by measuring the ratio of amplitudes of two points separated by a known distance and by measuring the phase difference of the temperature wave between two points separated by a known distance.

Since, producing a sinusoidal heat wave is difficult, we produce a periodic heat wave by switching the DC Power Supply ON and OFF at regular intervals of time.

Once α and β are known, you can calculate the diffusivity using:

$$\alpha\beta = \sqrt{a^2 + b^2}\cos\left(\frac{\varphi}{2}\right)\sin\left(\frac{\varphi}{2}\right) = \frac{b}{2} = \frac{\omega\rho c}{2\kappa}$$

So that, Diffusivity, $D = \frac{\kappa}{\rho c} = \frac{\omega}{2\alpha}$

PROCEDURE:

1. Connect the heater to the power supply. Set V = 5 V, so that I = 0.5 A.
2. Connect one pair of thermocouples (either (TC1, TC2) OR (TC3, TC4)) to the input terminals I1 and I2 on the DC differential amplifier (mV).
3. Switch on the timer and the power supply together. Toggle the supply ON and OFF EVERY FIVE MINUTES (300 Seconds)
4. No readings are taken for the first two cycles (till 1200s.) Start taking readings from 1215 s. and note down the reading every 30 seconds; for TC1. Fig. 1 shows the schematic on how to take the readings.
5. From 1800 s to 2400 s again, no readings are to be taken; making sure that the heater is turned OFF and ON every 300 s.
6. From 2415 s., Voltages are to be noted for TC2 until 3015 s.
7. Tabulate your observations as shown in Table 1.

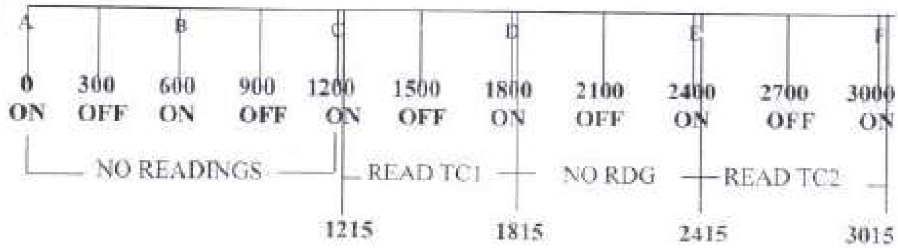

Fig. 1: Schematic showing how readings are to be taken. Numbers denote time in seconds. ON and OFF refer to the heater being turned on and off.

Table 1: A schematic to show how to tabulate data recorded in the experiment

Period (T) = 600 s					Power Voltage = 5 V			
Distance between thermocouple junctions = 3 cm								
Time, t (s)	TC1 (mV)	**TC1cosθ**	**TC1sinθ**		Time, t (s)	TC2 (mV)	**TC2cosθ**	**TC2sinθ**
1215					2415			
1245					2445			
1275					2475			
1755					2955			
1785					2985			
1815					3015			
		SUM	SUM				SUM	SUM
I1cosθ		I1sinθ			I2cosθ		I2sinθ	
	Amp1					Amp2		
	Phase1					Phase2		

CALCULATIONS:

- The first two columns (Time and TC1/TC2) are the observations to be tabulated. The cos and sin values are to be calculated using $\theta = 2\pi t/T$ where t is the value of time in the 1st column.
- SUM = [sum of all readings in column "TC1cosθ" (or TC1sinθ/ TC2cosθ/ TC2sinθ)] – 0.5*[sum of first and last readings]
- I1cosθ = [SUM (for TC1cosθ)]*30/600
  (because 30 s is the interval at which readings are taken)
  Similarly, for I1sinθ, I2cosθ, I2sinθ.
- Amp1 = $[(I1\cos\theta)^2 + (I1\sin\theta)^2]^{1/2}$
  Amp2 = $[(I2\cos\theta)^2 + (I2\sin\theta)^2]^{1/2}$
- Since, both I1cosθ and I1sinθ are negative, the angle is in the third quadrant.
  So, Phase1 = arctan[I1sinθ/ I1cosθ] + π
  And, Phase2 = arctan[I2sinθ/ I2cosθ] + π
- Knowing the amplitudes and phases, α and β can be calculated using relations already mentioned in the theory; which in turn, would yield the required value of thermal diffusivity.

It is suggested for the students to read the setup manual carefully to understand its design principle based on the use of Fourier Analysis. Fourier Analysis occurs whenever a function varies periodically either in space or time or both; and is used in various measurement setups in modern research. Reading the description will help you gain a better understanding of the working of the instrument, and also help you visualize Fourier Analysis used in a practical problem.