PHYSICS LAB 4 - SPECIFIC HEAT CAPACITY

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AIM: THE AIM OF THIS EXPERIMENT IS TO DETERMINE THE SPECIFIC HEAT CAPACITY OF TWO OF THE BLOCKS GIVEN.

BACKGROUND: THE SPECIFIC HEAT (SHC) CAPACITY (C) OF A SUBSTANCE IS THE ENERGY NEEDED TO RAISE THE TEMPERATURE OF A UNIT MASS (1 kg) OF THE SUBSTANCE BY 1°C OR 1K.

- THE EQUATION FOR SPECIFIC HEAT CAPACITY IS:

$$\boxed{\Delta Q = m\,c\,\Delta T}$$

$$\boxed{\Delta T = \underbrace{T_f}_{\text{FINAL T}} - \underbrace{T_i}_{\text{INITIAL T}}}$$

ΔQ = HEAT ENERGY APPLIED (HEATING) OR LOST (COOLING) [J]
m = MASS [kg]
c = SPECIFIC HEAT CAPACITY OF THE SUBSTANCE [$J\,kg^{-1}\,K^{-1}$ OR $J\,kg^{-1}\,°C^{-1}$]
ΔT = TEMPERATURE CHANGE [°C OR K]

- DURING THE EXPERIMENT, A DATA SHEET WITH THE SPECIFIC HEAT CAPACITIES IS PROVIDED (REFER TO THE TABLE AT PAGE 35). THEREFORE, TO ACHIEVE THIS EXPERIMENT'S AIM, THESE SHOULD BE THE EXPECTED RESULTS.
HOWEVER, THE LACK OF INSULATION PLAYS AN IMPORTANT ROLE; THE MORE TEMPERATURE THE BLOCK GETS, THE MORE ENERGY IT RELEASES TO THE SURROUNDINGS.
THEREFORE, IT WILL SIGNIFICANTLY INCREASE THE SPECIFIC HEAT CAPACITY. HENCE, THE FINAL RESULTS WON'T BE THAT ACCURATE ACCORDING TO THE EXPECTED RESULTS. FOR THIS REASON IT IS ASSUMED THAT NO HEAT ENERGY IS LOST TO THE SURROUNDINGS.
- IN ORDER TO GET THE SHC, ANOTHER ASSUMPTION IS MADE: THE ELECTRICAL ENERGY APPLIED IS EQUAL TO THE HEAT ENERGY;
$Q = IVt \rightarrow IVt = mc(\Delta t)$
- REARRANGING IT, AND EXPANDING ΔT, IT IS NOTICEABLE HOW THIS IS SIMILAR TO THE EQUATION OF A STRAIGHT LINE:

$$\Delta T = \frac{IVt}{mc} \rightarrow T_f - T_i = \frac{IVt}{mc} \rightarrow T_f = \frac{IV}{mc}\cdot t + T_i$$

$$y = m\cdot x + c$$

$$m_{(G)} = \frac{\Delta y}{\Delta x} = \frac{\Delta T_f}{\Delta t}$$

$\Rightarrow y = T_f;\ m_{(G)} = \frac{IV}{mc};\ x = t;\ c = T_i$

METAL	SHC ($kJ\,kg^{-1}\,K^{-1}$)	SHC ($J\,kg^{-1}\,K^{-1}$)
ALLUMINIUM	0.91	910
STEEL	0.49	490
COPPER	0.39	390

- SPECIFIC HEAT CAPACITIES DATA SHEET

- A GRAPH WITH T_f (FINAL TEMPERATURE) ON THE y-AXIS AND t (TIME) ON THE x-AXIS IS DRAWN IN ORDER TO FIND THE GRADIENT (m), AND IT IS EXPECTED THAT THE GRAPH SHOWS A STRAIGHT LINE (IN THE MIDDLE OF THE POINTS). AS THERE IS A y-INTERCEPT (T_i), IT IS EXPECTED THAT THE LINE OF BEST FIT TOUCHES THAT POINT.
- AS THE AIM OF THE EXPERIMENT IS TO FIND THE SPECIFIC HEAT CAPACITY, IT POSSIBLE TO REARRANGE THE GRADIENT $(m_{(G)})$:

$$m_{(G)} = \frac{IV}{mc} \longrightarrow c = \frac{IV}{m \cdot m_{(G)}} \longrightarrow$$

THE PRODUCT IV GIVES US THE ~~CAN BE WRITTEN~~ AS POWER(P) ~~AND~~

$m_{(G)}$ CAN BE WRITTEN AS $\frac{\Delta T_f}{\Delta t}$

m(MASS) IS ASSUMED TO BE 1 kg FOR ALL BLOCKS

THEREFORE REARRANGING:

$$\boxed{c = P \cdot \frac{\Delta t}{\Delta T_f}} \qquad \cancel{c = P \cdot m_{(G)}}$$

- DURING THE EXPERIMENT, AN IDEA OF THE TIME TAKEN TO REACH A CERTAIN TEMPERATURE CAN BE MADE REARRANGING THE EQUATION $\longrightarrow IVt = mc\,(T_f - T_i)$

$$t = \frac{mc\,(T_f - T_i)}{IV}$$

m = MASS [kg]
c = SHC [$J kg^{-1} K^{-1}$ or $J kg^{-1} °C^{-1}$] → USING THE ONE GIVEN ON THE DATA SHEET
t = TIME [s]
T_i = INITIAL TEMPERATURE (ROOM T)
T_f = FINAL TEMPERATURE (CHOOSING ANY TEMPERATURE ABOVE T_i)
I = CURRENT
V = VOLTAGE

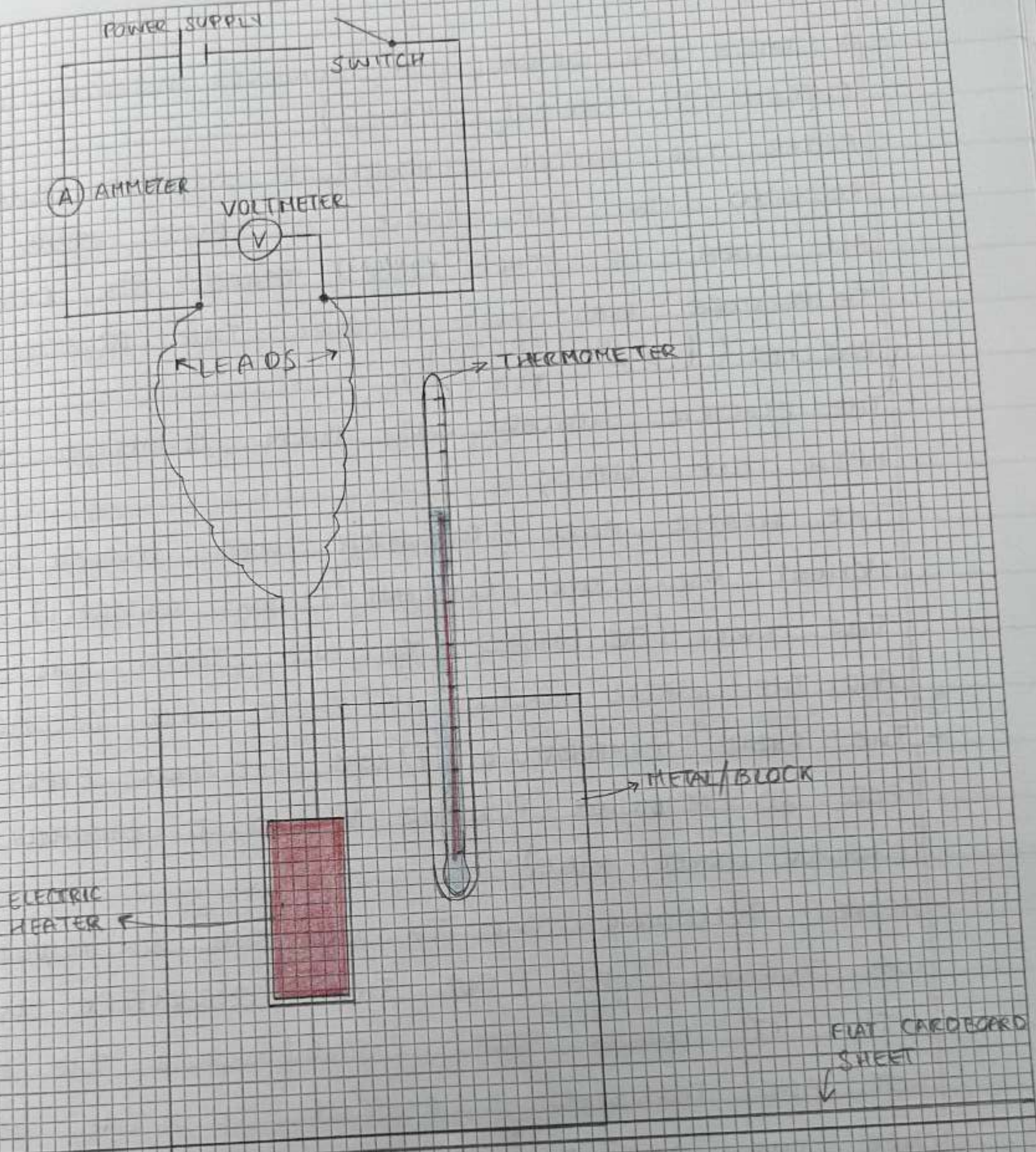
- HOWEVER, AS MENTIONED EARLIER, IT IS EXPECTED THAT THE TIME TAKEN TO REACH A CERTAIN TEMPERATURE WILL BE HIGHER AS THE BLOCK IS NOT INSULATED.

METHOD & EQUIPMENT: EQUIPMENT:

- THREE CALORIMETRY BLOCKS OF 1 kg (COPPER, STEEL, ALLUMINIUM)
- ELECTRIC HEATER
- THERMOMETER (± 1 °C)
- LEADS
- MULTIMETER
- STOP WATCH (± 0.01 s)
- A FLAT SURFACE CARDBOARD SHEET

METHOD (REFER TO THE FIGURE AT PAGE 37):

- THE BLOCK WAS PLACED ON THE FLAT CARDBOARD SHEET;
- THE ELECRIC HEATER AND THERMOMETER WERE PLACED INTO THE SPECIFIC HOLES (MAKE SURE THERE ARE A COUPLE OF DROPS OF WATER IN THE THERMOMETER HOLE TO IMPROVE THERMAL CONTACT, OTHERWISE THERE WILL BE AN AIR GAP BETWEEN THE METAL AND THERMOMETER, NOT GIVING US AN ACCURATE READING);



- RAPPRESENTATION OF THE METHOD & EQUIPMENT

- A TABLE WAS DRAWN (WITH HEADINGS POTENTIAL DIFFERENCE (V), CURRENT (I), TIME (s), Tf (°C));
- AFTER THE INITIAL TEMPERATURE STOPPED CHANGING, IT WAS RECORDED ON THE TABLE AS FIRST READING;
- AN IDEA OF THE TIME TAKEN TO REACH A CERTAIN TEMPERATURE WAS MADE USING THE EQUATION MENTIONED EARLIER ($t = \frac{mc(Tf - Ti)}{IV}$);
- THE ELECTRIC HEATER WAS THEN CONNECTED TO THE MULTIMETER WITH THE LEADS;
- THE HEATER AND STOPWATCH WERE TURNED ON AT THE EXACT MOMENT AND THE CURRENT (I) AND VOLTAGE (V) WERE RECORDED ON THE TABLE (BE AWARE TO NOT TOUCH THE ELECTRIC HEATER AND THE METAL BLOCK AS THESE WILL BECOME HOT DURING THE OPERATION);
- THE FINAL TEMPERATURE (Tf) WAS RECORDED EVERY MINUTE FOR 10 MINUTES (MONITOR V AND I CAREFULLY AS THESE MAY CHANGE OVER TIME);
- AFTER RECORDING THE Tf OF THE 10 MINUTES, THE HEATER WAS TURNED OFF BUT THE TEMPERATURE WAS MONITORED UNTIL IT STOPPED RISING (BECAUSE THE HEATER IS STILL HOT AND TRANSFERRING ENERGY TO THE METAL BLOCK);
- ONCE THE DEFINITIVE Tf WAS RECORDED, THE SAME PROCEDURE WAS USED FOR THE OTHER BLOCK;
- A GRAPH OF Tf − t WAS PLOTTED AND THE RESULTS WERE MARKED;
- ONCE THE LINE OF BEST FIT WAS DRAWN, IT WAS POSSIBLE TO FIND $m_{(Gr)} \left(\frac{\Delta Tf}{\Delta t}\right)$;
- AS MENTIONED IN THE BACKGROUND, IT WAS POSSIBLE TO REARRANGE $m_{(Gr)}$ EQUATION $\left(m_{(Gr)} = \frac{IV}{mc}\right)$ AND GET THE EQUATION TO CALCULATE THE SPECIFIC HEAT CAPACITY $\left(C = P \cdot \frac{\Delta t}{\Delta Tf}\right)$;
- THE CALCULATED SHC AND THE EXPECTED ONE WAS COMPARED, TOGETHER WITH THE ACTUAL TIME AND EXPECTED TIME, TO SEE THE ACCURACY OF THE EXPERIMENT AND TO MAKE SOME CONSIDERATIONS.

- TABLE FOR ALLUMINIUM

TIME (s)	Tf (°C)	I (A)	V (V)
0	16.0	2.70	8.5
60	16.5	2.70	8.5
120	17.0	2.70	8.5
180	18.5	2.70	8.5
240	20.0	2.70	8.5
300	21.0	2.70	8.5
360	22.0	2.70	8.5
420	22.5	2.70	8.5
480	25.0	2.70	8.5
540	26.0	2.70	8.5
600	27.0	2.70	8.5

THE FINAL Tf AFTER TURNING OFF THE HEATER WAS 30 °C.

- TABLE FOR STEEL

TIME (s)	Tf (°C)	I (A)	V (V)
0	16.5	2.65	8.5
60	17.0	2.65	8.5
120	18.0	2.65	8.5
180	19.5	2.65	8.5
240	21.5	2.65	8.5
300	24.0	2.65	8.5
360	26.0	2.65	8.5
420	28.5	2.65	8.5
480	31.0	2.65	8.5
540	33.0	2.65	8.5
600	36.0	2.65	8.5

THE FINAL Tf AFTER TURNING OFF THE HEATER WAS 39 °C.

RESULTS & CALCULATIONS:

EXPECTED TIME TO REACH 25°C BY ALLUMINIUM BLOCK:

$$t = \frac{mc(T_f - T_i)}{IV} = \frac{(1)(910)(25-16)}{(2.70)(8.5)} = 356.9 \text{ sec} \simeq 5 \text{ mim } 57 \text{ sec}$$

$m = 1\ Kg$
$C = 910\ JKg^{-1}K^{-1}$
$T_f = 25°C$; $I = 2.70A$
$T_i = 16°C$; $V = 8.5V$

- ACTUAL TIME t TO REACH $25°C = 480$ sec (REFER TO THE ~~TABLE~~ TABLE AT PAGE 39) $\simeq 8$ mim

- $\% \text{ ERROR} = \frac{|\text{EXPECTED} - \text{CALCULATED}|}{\text{EXPECTED}} \times 100 = \frac{|356.9 - 480|}{356.9} \times 100 = \boxed{34.49\%}$

EXPECTED TIME TO REACH 25°C BY STEEL BLOCK:

$$t = \frac{(1)(490)(25-16.5)}{(2.65)(8.5)} = 184.9 \text{ sec} \simeq 3 \text{ mim } 5 \text{ sec}$$

$m = 1kg$
$C = 490\ JKg^{-1}K^{-1}$
$T_f = 25°C$; $I = 2.65A$
$T_i = 16.5°C$; $V = 8.5V$

- ACTUAL TIME t TO REACH $25°C \simeq 330$ sec (REFER TO THE TABLE AT PAGE 39) $\simeq 5$ min 30 sec

$$\% \text{ ERROR} = \frac{|184.9 - 330|}{184.9} \times 100 = \boxed{78.47\%}$$

- REMIND THAT THERE IS NO NEED TO CONVERT THE TEMPERATURES FROM °C TO K, AS THE DIFFERENCE WILL REMAIN THE SAME.

▸ SPECIFIC HEAT CAPACITY OF ALLUMINIUM:

$$C = P \cdot \frac{\Delta t}{\Delta T_f} = 22.95 \cdot \frac{648}{14} = \boxed{1062.25\ JKg^{-1}K^{-1}}$$

$P = IV = (2.70)(8.5) = 22.95\ W$
$\Delta y = \Delta T_f = 30 - 16 = 14°C$
$\Delta x = \Delta t = 648 - 0 = 648$ sec
(REFER TO THE GRAPH AT PAGE 41)

EXPECTED $C = 910\ JKg^{-1}K^{-1}$

$$\% \text{ ERROR} = \frac{|910 - 1062.25|}{910} \times 100 = \boxed{16.7\%}$$

▸ SPECIFIC HEAT CAPACITY OF STEEL:

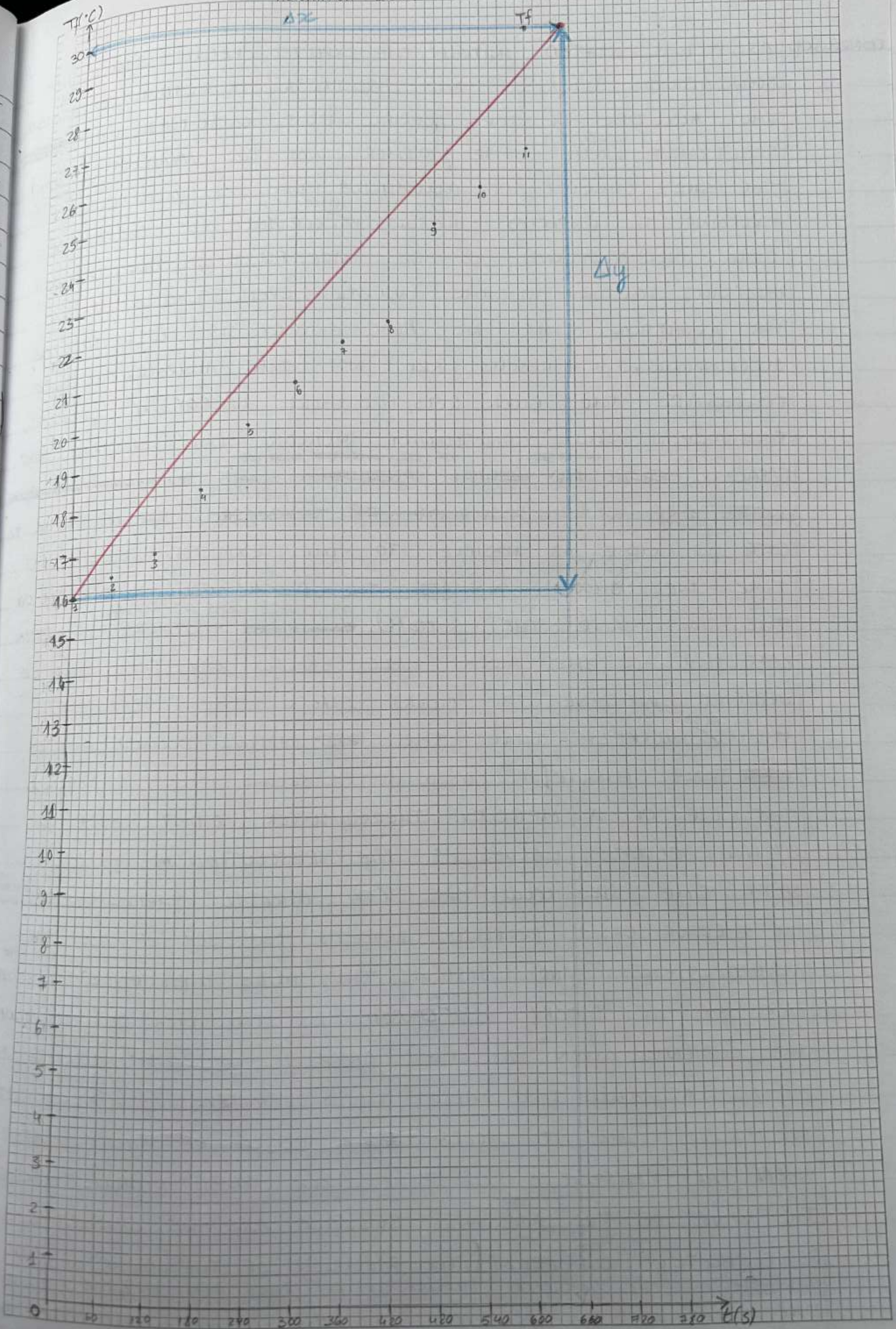
$$C = P \cdot \frac{\Delta t}{\Delta T_f} = 22.525 \cdot \frac{642}{22.5} = \boxed{642.7\ JKg^{-1}K^{-1}}$$

$P = IV = (2.65)(8.5) = 22.525\ W$
$\Delta y = \Delta T_f = 39 - 16.5 = 22.5°C$
$\Delta x = \Delta t = 642 - 0 = 642$ sec
(REFER TO THE GRAPH AT PAGE 43)

EXPECTED $C = 490\ JKg^{-1}K^{-1}$

$$\% \text{ ERROR} = \cancel{\frac{|642.7 - 490|}{6}} = \frac{|490 - 642.7|}{490} \times 100 = \boxed{31.1\%}$$

ALUMINIUM GRAPH



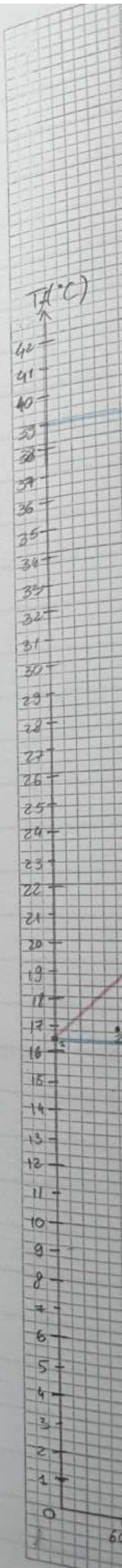
CONCLUSION: AS IT WAS STATED INITIALLY, THE EXPECTED RESULTS SHOULD HAVE BEEN AROUND $910\,JKg^{-1}K^{-1}$ AND $490\,JKg^{-1}K^{-1}$ IN ORDER TO ACHIEVE THE AIM. ONE OF THE SPECIFIC HEAT CAPACITIES WAS ACCEPTABLE (16.7%), WHILE THE OTHER WAS TOO INACCURATE (31.1% ERROR)

THE SHC CAPACITY OF ALLUMINIUM WAS 16.7% IN ERROR ACCORDING TO EXPECTED RESULT. MAYBE ACCEPTABLE, BUT THERE ARE SOME CONSIDERATIONS TO BE MADE. FIRST OF ALL, THE MOST IMPORTANT FACTOR IS THE INSULATION. EVEN THOUGH MAKING THE ASSUMPTION THAT NO HEAT ENERGY IS LOST TO THE SURROUNDINGS, THE RESULTS ARE NOT THAT ACCURATE. THE MORE TEMPERATURE THE BLOCK GETS, THE MORE ENERGY IT RELEASES. THEREFORE, IT WILL SIGNIFICANTLY INCREASE THE SPECIFIC HEAT CAPACITY. ~~ANOTHER ASSUMPTION WAS THAT ALL THE BLOCKS WERE 1kg FOR THE CALCULATIONS~~ ~~THEREFORE~~ HENCE IN ORDER TO GET AS CLOSE AS POSSIBLE TO THE EXPECTED RESULT, NEXT TIME WE SHOULD INSULATE THE BLOCK (USING THE FOAM ON THE SIDES AND THE BOTTOM). AS THERE WAS NO SCALES, ANOTHER ASSUMPTION WAS THAT ALL THE BLOCKS WERE EXACTLY 1kg. THIS COULD BE VERIFIED WEIGHING THE BLOCKS BEFORE THE EXPERIMENT.

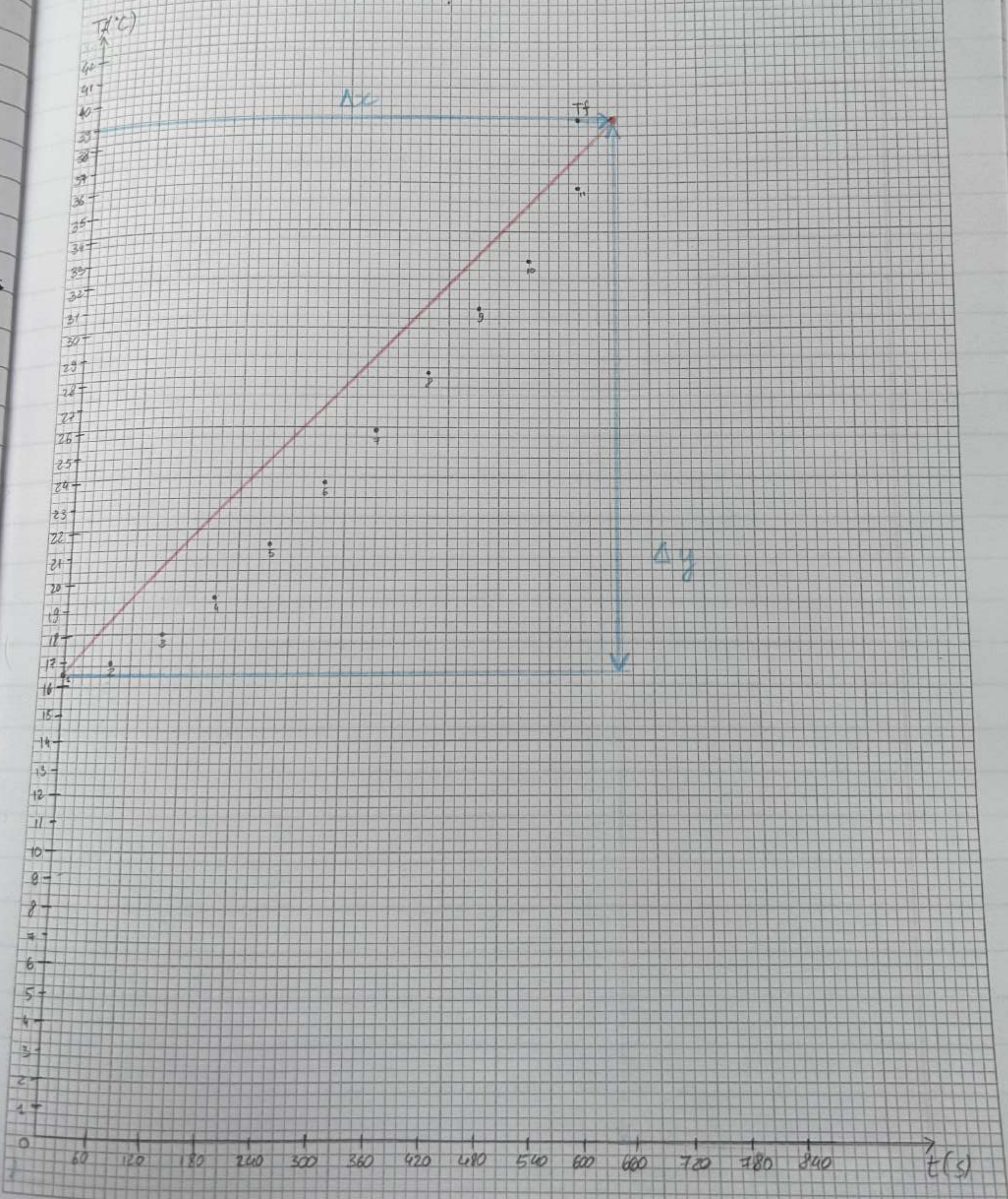
IT IS ALSO UNLIKELY THAT THE READING OCCURED EXACTLY EVERY MINUTE (IT COULD BE 1 SECOND AFTER OR BEFORE).

THE USE OF A MERCURY THERMOMETER DIDN'T HELP US GIVING ACCURATE VALUES, AS THE RESOLUTION WAS ±1°C. NEXT TIME WE COULD OPT FOR DIGITAL THERMOMETER (AS THEY HAVE LOWER RESOLUTION)

THE % ERROR OF t PERFECTLY REFLECTS THE SUM OF ALL THE ASSUMPTIONS, ERRORS AND OVERSIGHTS. THE HUGE DIFFERENCE OF THE TIME TAKEN TO REACH 25°C BY THE BLOCKS IS MAINLY CAUSED BY THE LACK OF INSULATION. THE GRADIENT GIVEN BY THE GRAPH IS NOT THAT ACCURATE, AS WE ARE ASSUMING THAT ALSO THE DEFINITIVE T_f READING OCCURS AT 10 MINUTES (ACTUALLY IT OCCURS A COUPLE OF MINUTES LATER, WHEN THE TEMPARATURE OF THE BLOCK STOPS RISING). THEREFORE, THE VALUES OF SHC ARE NOT RELIABLE AS THE GRADIENT WOULD BE COMPLETELY DIFFERENT (THE PRECISION OF THE GRAPHS IS NOT RELIABLE AS THE GRADIENT DOESN'T REFLECT THE REAL ONE). THE AIM OF THE EXPERIMENT IS ACHIEVED BUT THE RESULTS COULD BE HUGELY IMPROVED BY CONSIDERING THE OBSERVATIONS MADE, ESPECIALLY USING AN INSULATION



STEEL GRAPH


T(°C)
Δx
Tf
Δy
t(s)
60
120
180
240
300
360
420
480
540
600
660
720
780
840