Study of Newton's Law of Cooling to Calculate the Outside temperature of liquids

Pranabh Dwivedi[1], Prathvi Kothari[2], Prof. Parmeshwari Aland[3]
Ajeenkya DY Patil University, Charholi Budruk, Pune , India

Abstract

Newton's law of cooling states that objects with higher temperatures tend to cool down quicker than those with lower ones. It conjointly predicts that temperature distinction between a cooling object associated its surroundings is a function of your time. In this experiment, the scholars ascertained and determined the distinction in temperature between a vessel of cooling sure liquids and also the temperature as a operate of your time. Newton's law of cooling was effectively incontestable during this experiment.

KEYWORDS: Ambient temperature, Asymptotic temperature, Cooling, Heat.

Introduction

Temperature distinction in any scenario results from energy flow into or from a system to surroundings. Energy flow into the system results to heating while energy leaving the system leads to cooling of an object. Newton's Law of Cooling states that the speed of temperature of the body is proportional to the distinction between the temperature of the body which of the encompassing medium. This statement leads to the classic equation of exponential decline over time which can be applied to many phenomena in science and engineering. It is accustomed predict however long it takes for a hot object to chill down at an exact temperature like for work liquid properties. One utilization is to see the time needed for warm water to chill off in pipes utilized in trade. Another application is that it will be utilized in hard the time of death given the probable vital sign at the time of death and current vital sign in criminal investigations.

Newton's Law of Cooling is explicit in terms of the equation explicit below

$$\frac{dT(t)}{dt}=k(T_A-T(t)) \qquad (1)$$

where TA is the ambient temperature, T is the temperature of the object at time t and k is a positive proportionality constant that depends upon the surface properties of the material being cooled. If the initial temperature of the body is given by $T(0) = T_○$, the equation can become

$$T(t)=T_A+(T_O-T_A)e^{-kt} \qquad (2)$$

The constant k is named the decay constant and its inverse is named the time constant denoted by τ.

Subtracting tantalum from either side of the equation,

$$T(t)- T_A=(T_O-T_A)e^{-kt} \qquad (3)$$

It shows that the distinction in temperature between the cooling object and its surroundings is an mathematical function of your time. Thus, plotting t versus $T(t) -T_A$ in a graph, the value of k can be determined.

The objective of this experiment is to prove that the graph of TA is asymptotic and to verify that k is the same for certain materials using the exponential graph of t versus $T(t) -T_A$ and therefore the linear graph of t versus $\ln(T(t) -T_A)$.

Methodology

As preparation for the experiment, the close temperature within the laboratory was measured and recorded by the scholars. Afterwards a 250-mL beaker was filled with water at a temperature higher than the ambient temperature; then its temperature was measured and recorded as well.

After all preparations for the experiment were done, the beaker was heated on a stove while its temperature was taken at 30-second intervals until the temperature reaches 50 to 60 degrees Celsius. When the beaker-water system reached fifty °C, it had been off from heat whereas its temperature was frequently taken till it reaches its most. Lastly, upon reaching its most, the temperature was still frequently taken each thirty seconds because it cooled down for twenty minutes. This procedure was done once more to get 2 trials, and was recurrent, employing a sugar resolution and low resolution rather than water, 2 additional times for every liquid.

Literature Review

For the information related to my topic (newton's law of cooling) referred to Maharashtra state textbook of standard 11& 12 which had detailed information about newton's law of cooling. After finalizing the topic I had to find a day-to-day application related to my topic. Newton's law of cooling can be applied in many fields where heat exchange takes place. Newton gave us a formula to calculate unknown temperature using few known entities. So, we can easily calculate the temperature outside with the help of just a formula.

Results and Discussion

Located below at Table one is that the summarized information gathered from the experiment performed by the scholars within which 3 liquids – particularly water, sugar solution, and coffee solution– had its temperatures taken whereas they were heated and cooled. It was ensured that the measuring device isn't touching the walls of the beaker to allow Associate in Nursing correct activity of the temperature of the liquids. Elaboration on how the summarized data was obtained is shown in Tables 2 and 3.

Table 1. Average temperature reading of liquids

Solution	$T_{ambient}$ (°C)	$T_{\circ}$ (°C)	$T_{maximum}$ (°C)
150 mL water solution	27	28	61.5
150 mL sugar solution	27	28	59
150 mL coffee solution	27	29	58

Table 2. Average temperature reading of liquids throughout the heating method

Time Elapsed (sec.)	Temperature (°C)		
	Water solution	Sugar solution	Coffee solution
0	28	28	31
30	28.75	28.5	33
60	31.5	33	39
90	35	35	43
120	37.5	36.5	47
150	40	42	50
180	42.5	47	52.5
210	51.5	54	57
240	57.5	57	58
270	60	59	-
300	61.5	-	-

Table 3. Average temperature reading of liquids throughout the cooling method

Time Elapsed (sec.)	Temperature (°C)			Time Elapsed (sec.)	Temperature (°C)		
	Water solution	Sugar solution	Coffee solution		Water solution	Sugar solution	Coffee solution
$T_{maximum}$ = 300	61.5	59	57	$T_{maximum}$ + 630	49.5	46	45
$T_{maximum}$ + 30	61.5	58	56.5	$T_{maximum}$ + 660	48.5	46	45

$T_{maximum}$ + 60	61.25	58	56.5	$T_{maximum}$ + 690	48.25	46	45
$T_{maximum}$ + 90	60.75	57	55	$T_{maximum}$ + 720	48	45	44.5
$T_{maximum}$ + 120	60	56	55	$T_{maximum}$ + 750	47.75	45	44
$T_{maximum}$ + 150	59.25	55	54.5	$T_{maximum}$ + 780	47	45	43.5
$T_{maximum}$ + 180	58.75	54	52	$T_{maximum}$ + 810	46.75	44	43.5
$T_{maximum}$ + 210	58	54	52	$T_{maximum}$ + 840	46.5	44	43
$T_{maximum}$ + 240	57.5	53	52	$T_{maximum}$ + 870	45.75	43.5	43
$T_{maximum}$ + 270	56.5	52.5	51	$T_{maximum}$ + 900	45.5	43	42
$T_{maximum}$ + 300	55.5	51	50.5	$T_{maximum}$ + 930	45	42.5	42
$T_{maximum}$ + 330	55	50	49.5	$T_{maximum}$ + 960	44.5	42	42
$T_{maximum}$ + 360	54.75	49.5	49.5	$T_{maximum}$ + 990	44.5	42	42
$T_{maximum}$ + 390	54.25	49.5	49.5	$T_{maximum}$ + 1020	44	41.5	42
$T_{maximum}$ + 420	53.25	49	49	$T_{maximum}$ + 1050	43.75	41.5	41
$T_{maximum}$ + 450	52.75	49	48.5	$T_{maximum}$ + 1080	42.75	41.5	41
$T_{maximum}$ + 480	52.25	48	48	$T_{maximum}$ + 1110	42.75	41	41
$T_{maximum}$ +510	51.5	47	47	$T_{maximum}$ + 1140	42.5	40	40
$T_{maximum}$ +540	50.75	47	47	$T_{maximum}$ + 1170	42	40	40
$T_{maximum}$ + 570	50.25	46.5	46.5	$T_{maximum}$ + 1200	41.5	40	40
$T_{maximum}$ + 600	50	46	46	$T_{maximum}$ + 1230	41	40	40

Using the information above, the graph of the temperature versus time can be found. As observed from Figure 1, the trends of the curves from all liquids are almost similar to each other. Moreover, the 3 solutions are all approaching the ambient temperature Ta of twenty-seven ^{O}C.

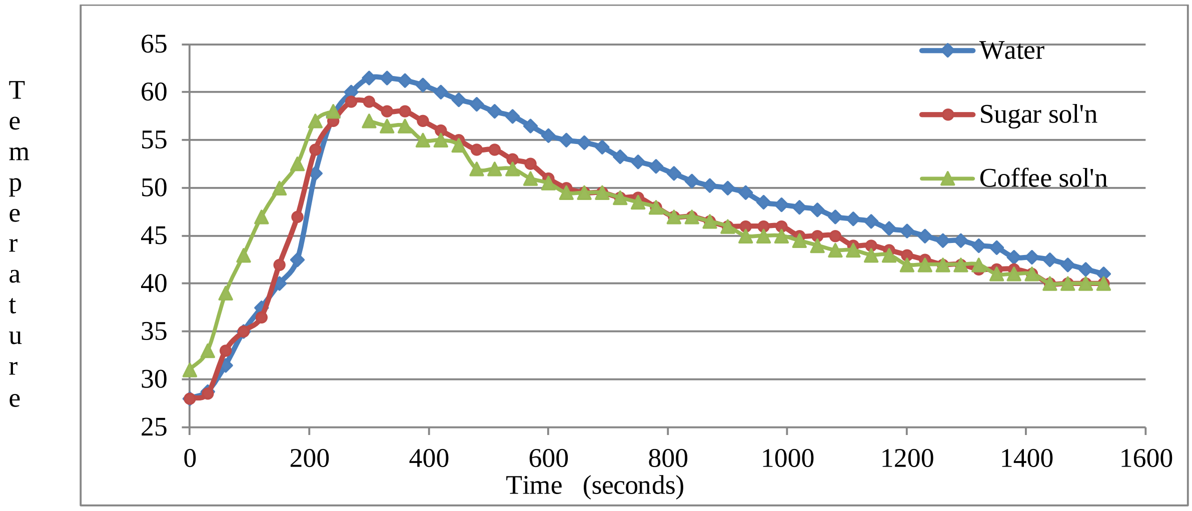

Figure 1. The temperature versus time curve of heating process and cooling process

In order to obtain the exponential graph of time versus T(t) - T_A, the values gathered in Table 3 were subtracted to the value of the ambient temperature (i.e. 27 °C). Afterwards, the values of the differences were plotted and graphed as shown in Figure 2 below and its corresponding exponential equation are also noted.

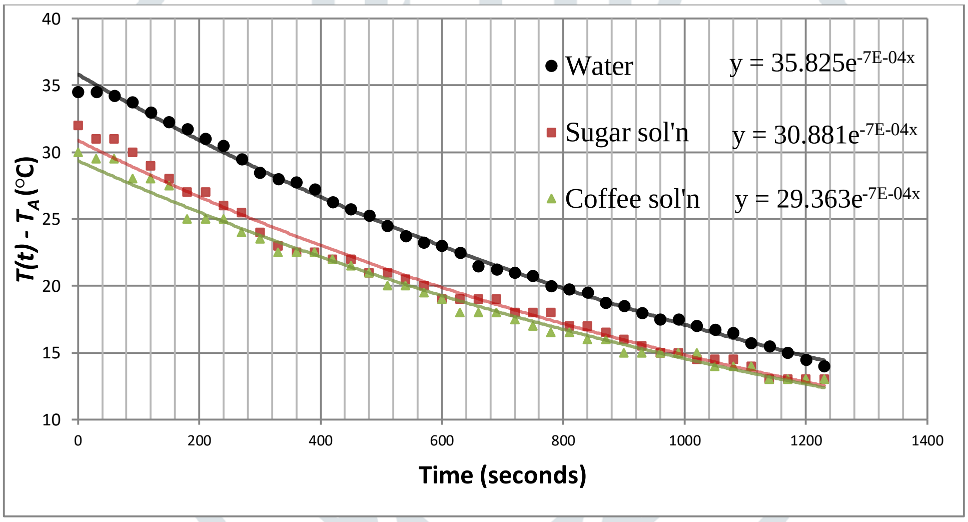

Figure 2. The exponential graph of t vs. T(t) -T_A.

The coefficient of e in the equation is the initial temperature minus ambient temperature (T_o-T_A) and it can be seen in the Figure 2 that T_o-T_A has values of 35.825 for water, 30.881 for sugar and 29.363 for coffee, all near to one another. The exponent of e within the equation is that the decay constant k, that includes a value of 0.0007 for all the 3 solutions.

Finally, in order to obtain the linear graph of time versus ln(T(t) -T_A), the values of the natural logarithms of the y-values from Figure 3 were determined and then plotted and graphed as shown below in Figure 4.

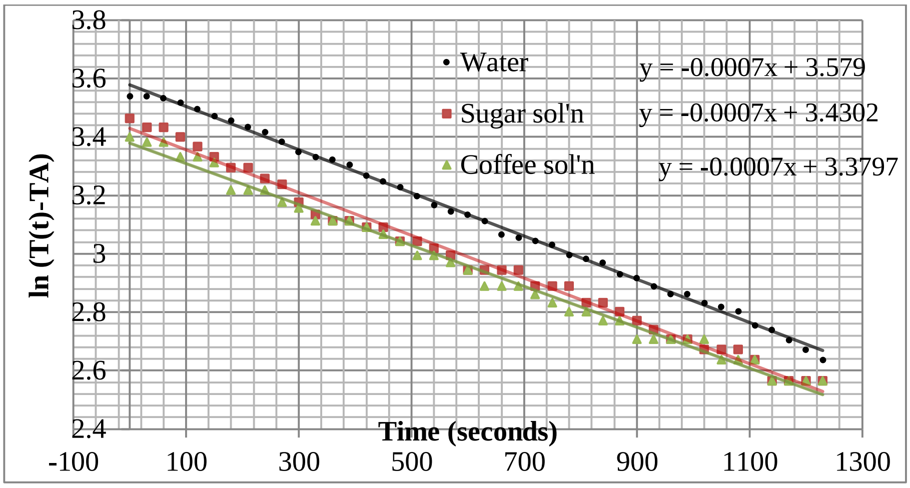

Figure 3. The exponential graph of t vs. ln(T(t) -T_A).

The y-intercept of the equation of the graph is the numerical value of ln(T_o-T_A) and the slope is k. It can be observed that k in Figure 3 is also similar to value of k in Figure 2 for all three solutions.

It is agreeable that decay constant k obtained diagrammatically in Figure two and three are similar since k is constant certainly material that depends on the surface properties of material being cooled such surface properties are nature of substance and solvent, concentration of solution.

In this experiment, sugar and coffee each have water as solvent and also the concentration of the solution is diluted. Since the solutions are solely diluted, the character and also the properties of the solvent appeared dominant, creating the results from the 2 solutions just like that of water. Hence the values of k obtained during this experiment are same for the 3 solutions.

Application- Finding the Temperature Outside

A glass of room-temperature water is carried out onto a balcony from an apartment where the temperature is 22° C. After one minute the water has temperature 26°C and after two minutes it has temperature 28° C. What is the outdoor temperature?

Solution: We are going to assume that the temperature of the measuring device obeys Newton's law of cooling.

Let A be the outdoor temperature and T(t) be the temperature of the water t minutes after it is taken outside.

By Newton's law of cooling,

$$T(t)=A+(T(0) - A)e^{Kt}$$

by Corollary ,

A differentiable function T(t), T(t) obeys the differential equation

$$dT(t)/dt=K[T(t)-A]$$

if and only if

$$T(t)=[T(0) - A]e^{Kt} + A$$

Notice there are 3 unknowns here — A, T(0) and K — so we need three pieces of information to find them all.

We are told T(0) =22, so

$$T(t)=A+(22 - A)e^{Kt}$$

We are also told T(1) =26, which gives

$26=A+(22-A)e^{Kt}$ rearrange things

$e^{K}=26-A / 22-A$

Finally, T(2) =28, so

$28=A+(22-A)e^{2K}$ rearrange

$e^{2K}=28-A / 22-A$ but $e^{K}=26-A/22-A$, so

$(26-A / 22-A)2=28-A / 22-A$ multiply through by $(22-A)2$

$(26-A)2=(28-A) / (22-A)$

We can expand out both sides and collect up terms to get

$(26)^{2}-52A+A^{2} = 28\times22-50A+A^{2}$

$60 = 2A$

$30 = A$

So, the temperature outside is 30° C.

Propose Enhancement

Newton's law of cooling applies to convective heat transfer; it does not apply to thermal radiation. Newton's law of cooling states that the rate of heat exchange between an object and its surroundings is proportional to the difference in temperature between the object and the surroundings.

Conclusion

After the tabulation and graphing of the results, the students found out that the time rate of heating and cooling of a substance or material does not differ that much from each other. Moreover, the graph of ambient temperature is asymptotic and therefore the decay constant k comparably similar for certain kind of materials. additionally to it, the scholars so conclude that the answer of the substance or the character of the matter is freelance of the time rate of heating and cooling.

For any studies, future researchers are counseled to think about if the variation of volume of the liquid to be heated has result on the heating and cooling rate of the topic. Also, the number of matter to act as impurities is additionally an honest varied issue to look at. Future experimenters are advised to use alternative liquids as solvents to ascertain whether there would be variations on the worth of the decay constant k.

Recommendations

Calculating the outside temperature using equation of newtons law of cooling is useful for physics domain and the same equation can be further used for different temperature related problems.

Acknowledgement

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