Time of Death

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Overview

The purpose of this project is to find the time of death of an employee given the following information:

- The body was found at 1:00pm today
- The internal body temperature was 85.2 degrees Fahrenheit.
- Two hours later, the body temperature reduced to 74.1 degrees Fahrenheit.
- The room temperature was 68 degrees Fahrenheit when the investigation team got there.
- The manager usually keeps the office at 74 degrees Fahrenheit.

The questions given for me to answer are as follows:

- What was the approximate time of death?

- If the murdered changed the temperature, how far off is the time of death estimate if the murderer had turned down the thermostat on his way out of the room?

The process that these problems should be solved is by using Newton's Law of cooling which states "The rate at which a body cools is proportional to the difference between the exterior(room) ambient temperature and the interior (body) temperature."

Assumptions

The following were assumed throughout the process of this project:

- The person who died was healthy. Their internal body temperature was 98.6 degrees Fahrenheit initially.
- There are no other factors to consider for the person's death except their body temperature and room temperature.
- Newton's Law of Cooling is an approximation of the time, not exact (answer given in hours).

Problem Set-Up

The first step to solving the questions given was to solve mathematically equation for Newton's Law of Cooling:

$$\frac{\Delta T}{\Delta t} = K * \left(T - Room_{Temp}\right)$$

T = Body Temperature

t = time

K = Constant

$Room_{Temp}$ = Room Temperature

The equation below is what was used to solve for change in T over change in t.

$$\frac{\Delta T}{\Delta t} = \frac{T_2 - T_1}{t_2 - t_1}$$

$$= \frac{85.2 - 74.1}{2}$$

$$\frac{\Delta T}{\Delta t} = -5.55$$

The change in T over the change in t makes sense to be negative because if we are looking at the temperature of someone's corpse, it is likely to decrease as time goes on, hence the negative change. With now knowing $\frac{\Delta T}{\Delta t}$, K could be solved for.

$$\frac{\Delta T}{\Delta t} = K * \left(T - Room_{Temp}\right)$$

$$-5.55 = K * (85.2 - 68)$$

$$-5.55 = 17.2 * K$$

$$K = -0.32267$$

Now that Newton's Law of Cooling equation is solved for, excel can be used to answer the given questions.

Using the above K value, known room temperature (68 degrees Fahrenheit), known body temperature (85.2 degrees Fahrenheit), and the chosen change in t value (-0.1), the following table could be made using excel:

t	T
0	85.2
-0.1	=previous_T_value + K*(previous_T_value – 68) * -0.1
-0.2	=previous_T_value + K*(previous_T_value – 68) * -0.1

t	T
-0.3	=previous_T_value + K*(previous_T_value – 68) * -0.1

This is how the values looked in excel after the equation calculations:

t	T
0	85.2
-0.1	85.755
-0.2	86.3279084
-0.3	86.9193031
-0.4	87.5297807
-0.5	88.1599567
-0.6	88.810467
-0.7	89.4819675
-0.8	90.1751356
-0.9	90.8906705
-1	91.6292939
-1.1	92.3917508
-1.2	93.1788102
-1.3	93.991266
-1.4	94.8299376
-1.5	95.6956711
-1.6	96.5893395
-1.7	97.5118444
-1.8	98.4641161
-1.9	99.4471152
-2	100.461833
-2.1	101.509293
-2.2	102.590553
-2.3	103.706701
-2.4	104.858865
-2.5	106.048207
-2.6	107.275925

Assuming the person murdered was healthy (Body Temperature around 98.6), the highlighted cell shows how many hours ago the person was alive. According to Newton's Law of Cooling, the

person's time of death was -1.8 hours before 1:00pm which would be around 11:12 am, answering the first question "What was the approximate time of death?".

To answer the next question: "If the murderer changed the temperature, how far off is the time of death estimate if the murderer had turned down the thermostat on his way out of the room?", an equation was created to determine the temperature difference in Newton's Law of Cooling equation. The following equation was used to help determine the Room Temperature in Newton's Law of Cooling equation:

$$Room_{temp} = -3 * (Change\_in\_time + 68)$$

The equation was created by applying the change in temperature over the number of hours from when the body was found to the next recorded change in temperature (-9 degrees/ 3 hours). Using this change multiplied by the change in time added to the new room temperature (68), an equation was created to determine the new Room Temperature:

$$= -3 * (Change\_in\_time + 68)$$

With this replacement Room Temperature variable in Newton's Law of Cooling, the equation could now be applied to a new table of data, using the same time step and body temperature.

$$= Previous_{Body_{Temperature}} + K * \left(Previous_{Body_{Temperature}}(-3 * Change_{in_{time}} + 68)\right) * -0.1$$

Applying this new calculation, we get the following data in excel:

t	T
0	85.2
-0.1	85.7453198
-0.2	86.2985554
-0.3	86.8599623
-0.4	87.4298041
-0.5	88.008353
-0.6	88.5958899
-0.7	89.192705
-0.8	89.7990975
-0.9	90.4153765
-1	91.0418611
-1.1	91.6788804
-1.2	92.3267745
-1.3	92.9858943
-1.4	93.6566019
-1.5	94.3392713
-1.6	95.0342885
-1.7	95.7420519
-1.8	96.4629728
-1.9	97.1974757
-2	97.9459989
-2.1	98.7089947
-2.2	99.4869303
-2.3	100.280288
-2.4	101.089564
-2.5	101.915274
-2.6	102.757947

We can see here that the new time of death was approximately -2.1 hours before 1:00pm which would be 10:54am, if the murderer changed the temperature on the thermostat.

The difference between the time of death being at 10:54am and 11:12am does not seem like a large difference. The relative error formula was used to calculate just how significant this time change is.

$$Relative\ Error = \frac{|exact - estimate|}{|exact|}$$

$$= \frac{0.3}{2.1}$$

$$Relative\ Error = 0.1428$$

$$\approx 14.28\%$$

Using the relative error formula, the time of death if the murderer had changed the thermostat would cause a 14.28% error in Newton's Law of Cooling.

Conclusion

The evidence given in this project suggested using Newton's Law of Cooling in order to find the time of death of an individual. After many calculations and using excel, it was found that the approximate time of death was 11:12am. If the murderer changed the thermostat on his way out, the time of death would have been 10:54am; this time difference gives a 14.28% error in Newton's Law of Cooling.