PHYSICS EXTENDED ESSAY

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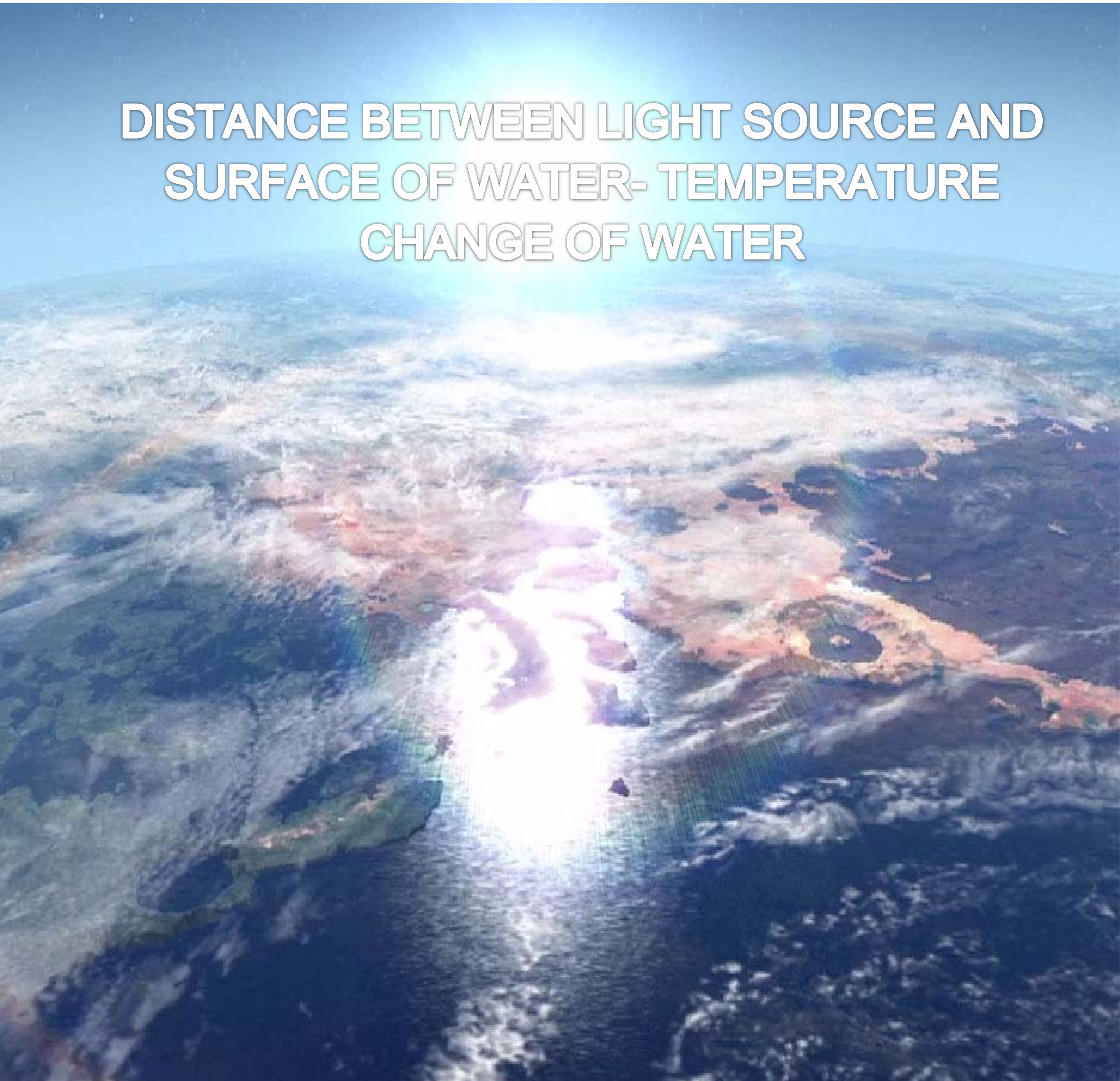
DISTANCE BETWEEN LIGHT SOURCE AND SURFACE OF WATER- TEMPERATURE CHANGE OF WATER



ABSTRACT

Atmosphere is a body, which is composed of gasses. Those atmospheric gases are located around planets because of the gravitation forced applied. Our planet's atmosphere consists of oxygen, nitrogen, carbon dioxide and other atoms and molecules. Although each layer of atmosphere has different qualities, the most important purpose of the atmosphere is to contain gases that are vital for living organisms. If we think about oxygen releasing unconditionally to the space, could we be able to breathe? In the experiment, which I designed, I have made a model of surface waters, sun and the atmosphere of Earth. The aim of the experiment was to observe the impact of the thickness of the layer to the temperature of the earth and surface water. To achieve this aim, I took glass rings with 5 cm diameter and 5 cm height and poured 5 cm water to another glass. After measuring initial temperature of the water, I turned the light on and waited 20 minutes and measured the final temperature of water. When I recorded 3 values for same height, I added one of the glass rings, I mentioned above, to the system and recorded another 3 trial values for initial and final temperatures. When I completed the experiment, I found out that there is an exponential decrease in the change of the temperature. This curved line was caused because after some height, the light bulb was not efficient and there were no difference between initial and final temperatures. When I ignored this systematic error, I assumed that the there was a constant but oppositely proportional relation between distance between light source and surface of water- temperature change of water.

Personal Engagement:

I chose my essay and experiment topic as height/thickness of the Earth's atmosphere which is a large mysterious life giving formation for me and I thought it as a good and an effective topic since it has impacts on all living organisms and also non-living surrounding. In addition it has lots of formation reasons and causes on life, and Global Warming, which has been discussed for decades, plays a role on the experiment's independent variable- atmosphere thickness.

Earth:

Earth is spherical in shape, but not perfectly round. It has a slightly greater diameter at its Equator, the imaginary line running horizontally around the middle of the Earth. In addition to bulging in the middle, Earth's poles are slightly flattened. Another type of motion is known as "revolution". Revolution is when one object completes a circular path around another object. The Earth takes 365.24 days to revolve around the Sun. Earth rotates counter-clockwise, as seen from above Earth's north pole, the same direction it revolves around the Sun. But two planets (used to be 3, when Pluto was a planet) rotate clockwise – Venus and Uranus. When the North Pole tilts most toward the sun, the Northern Hemisphere experiences summer. This occurs when the Earth is farthest away from the sun, and begins around June 21-22. Astronomers refer to the arrival of this event as the Summer Solstice in the Northern Hemisphere.

Axis Tilt

During earth's spin it also tilts at an angle 23.27 degrees. Although the tilt angle is very slight it has very large impacts, the reason behind formation of season, there is world's tilt.

Atmosphere and Atmosphere of Earth

An **atmosphere** (consists of words vapour and sphere in Latin) is an abiotic factor, comprised of several gases around a planet or a body. An atmosphere is kept in its location by an attraction force applied by the plane or the body called gravitation. Powerful gravity helps the atmosphere to retain.

As a planet, Earth has its own gas layer which consists of nitrogen, oxygen and carbon dioxide atoms and molecules. Oxygen, nitrogen and carbon dioxide have cycles occurring inside atmosphere and on Earth whereas it can be said that these elements are necessary for vital actions like breathing and photosynthesis. Another function of the atmosphere is protecting organisms from solar radiation damages by absorbing ultraviolet solar radiation. Also atmosphere warms the surface of the Earth, water and ground. Billion years helped paleo atmosphere to modify itself with biochemical products.

Atmosphere is modelled with layers, taking into consideration of temperature, elements and molecules present, solar radiation and gravity.

Atmospheric Pressure

Since every object with a mass, present inside Earth's boundaries, applies pressure; the atmosphere also has a pressure which is called Atmospheric Pressure. The average atmospheric pressure at sea level is defined by the International Standard Atmosphere as 101325 pascals 760.00 mmHg.

Structure of the Atmosphere:

The Earth's atmosphere consists, from the ground up, of

the troposphere stratosphere (the ozone layer is located in this

layer), mesosphere, thermosphere (contains the ionosphere), exosphere and also the magnetosphere. Each of the layers has a different lapse rate, defining the rate of change in temperature with height.

Exosphere: 700 to 10,000 km (440 to 6,200 miles)

Thermosphere: 80 to 700 km (50 to 440 miles)

Mesosphere: 50 to 80 km (31 to 50 miles)

Stratosphere: 12 to 50 km (7 to 31 miles)

Troposphere: 0 to 12 km (0 to 7 miles)

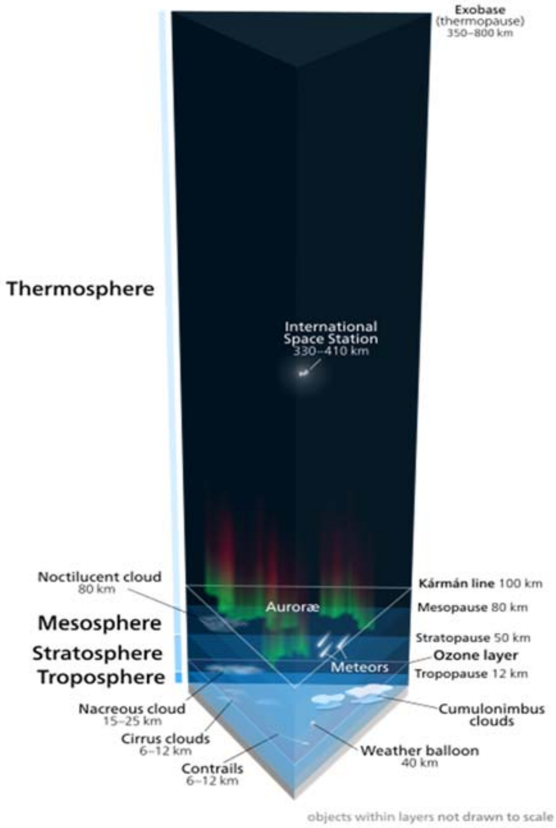


Figure1: Earth's atmosphere Lower 4 layers of the atmosphere in 3 dimensions as seen diagonally from above the exobase.

1) Exosphere

This is a layer surrounding a planetary body which keeps molecules attracted to itself with gravity. Since its low density nature, collision frequency is quite low compared to gas behaviour. Thus, the exosphere no longer behaves like a gas, and the particles constantly escape into space.

To talk about Earth's exosphere, it is the outermost layer which gets thinner upwards and unites with outer space. In some source exosphere is taken as a part of space because it has no clear border in between.

Lightest gases like hydrogen, helium, carbon dioxide and oxygen exist in the Earths' exosphere. Exopause or exobase is the lower part of the exosphere where temperature is nearly constant. "Critical Altitude" was used because of the functionless barometric conditions. In other words, no meteorological phenomena is possible in this altitude. Height range differs from about 500 to 1,000 kilometres depending on solar activity and exosphere contains most of the satellites orbiting Earth.

2) Thermosphere

Thermosphere layer is located above mesosphere. The ultraviolet rays ionize the molecules and this is called photoionization. The term "heat" coming from Greek "thermos" starts at the altitude at 85 km above Earth.

This atmospheric layer undergoes a gradual increase in temperature with height. The temperature of this layer can rise as high as 1500 °C (2700 °F), though the gas molecules are so far apart that its temperature in the usual sense is not very meaningful. A person would not feel warm because of the thermosphere's extremely low pressure.

3) Mesosphere

The **mesosphere layer of atm**osphere, taking its name from Greek meaning "middle"; is the middle layer between stratopause and mesopause. In the mesosphere temperature decreases as the altitude increases. The upper boundary of the mesosphere is the mesopause, which can be the coldest naturally occurring place on Earth with temperatures below 130 K (−226 °F; −143 °C).

4) Stratosphere

The stratosphere is the second-lowest layer of Earth's atmosphere. It lies above the troposphere and is separated from it by the tropopause.

The atmospheric pressure at stratosphere is so low that the pressure hardly reaches to 1/1000 pressure at sea level. Stratosphere contains the ozone layer in itself, which is the part of Earth's atmosphere that contains relatively high concentrations of that gas.

5) Troposphere

The troposphere is the lowest layer of Earth's atmosphere. Its thickness varies season to season due to expansion of gases related to temperature. The thickness of the troposphere is 8 km more at equator than compared to poles of the Earth. When altitude increases, the temperatures usually decrease in the troposphere.

Troposphere is composed from oxygen (21%), nitrogen (78%) and other small concentrations of hydrogen, helium and other elements or compounds.

Moisture in the troposphere is the result of water vapour present and therefore troposphere is the place where weather and climate systems occur.

Ozone Layer

Ozone layer is a layer formed of O3 molecules. This layer is formed and destroyed constantly and in normal conditions the formation is in equilibrium. The purpose of the ozone layer is to behave like a lens and diffract the most of the UV lights coming from sun. Otherwise, the UV radiation would give harm to living organisms.

Nowadays there are very concerning discussions about whether the ozone layer is getting thinner or not. Chloro-floro-carbons aka CFCs mostly present inside refrigerators and aerosol sprays, when released to air, react with sunlight and become catalyst for the breakdown reaction of ozone layer. One atom of chlorine can destroy more than a hundred thousand ozone molecules, according to the U.S. Environmental Protection Agency.

- Chlorofluorocarbons (CFCs)
- The most widely used ODS, accounting for over 80% of total stratospheric ozone depletion.
- Halons
- Used in some fire extinguishers, in cases where materials and equipment would be destroyed by water or other fire extinguisher chemicals. In B.C., halons cause greater damage to the ozone layer than do CFCs from automobile air conditioners.
- Methyl Chloroform
- Used mainly in industry — for vapour degreasing, some aerosols, cold cleaning, adhesives and chemical processing.
- Carbon Tetrachloride

Used in solvents and some fire extinguishers.

Greenhouse Effect:

The greenhouse effect refers to circumstances where the short wavelengths of visible light from the sun pass through a transparent medium and are absorbed, but the longer wavelengths of the infrared re-radiation from the heated objects are unable to pass through that medium. The trapping of the long wavelength radiation leads to more heating and a higher resultant temperature. Besides the heating of an automobile by sunlight through the windshield and the namesake example of heating the greenhouse by sunlight passing through sealed, transparent windows, the greenhouse effect has been widely used to describe the trapping of excess heat by the rising concentration of carbon dioxide in the atmosphere. The carbon dioxide strongly absorbs infrared and does not allow as much of it to escape into space.

Albedo

Albedo is the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of the earth's surface. Ice, especially with snow on top of it, has a high albedo: most sunlight hitting the surface bounces back towards space. Water is much more absorbent and less reflective. So, if there is a lot of water, more solar radiation is absorbed by the ocean than when ice dominate.

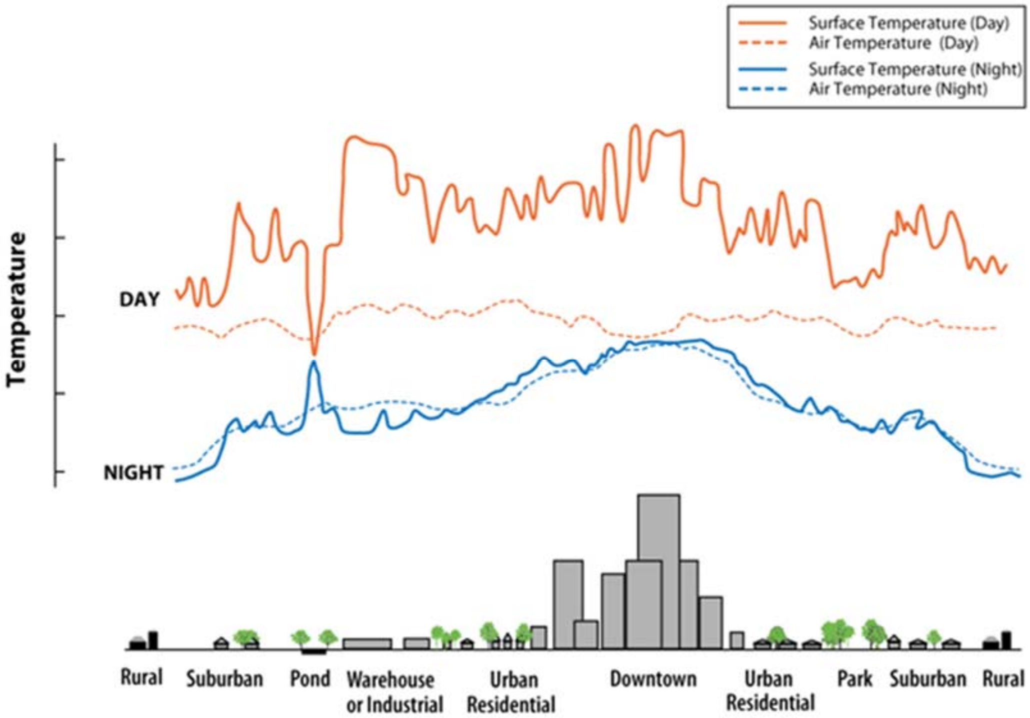


Figure 2: Various land uses have different impacts on daily temperature.

DESIGN:

Aim: to find how total height of system affects the temperature change of tap water at the base of the cylinder at 23°C after 20 minutes.

Research Question: How does distance between light source (also heat source) and water surface affects the temperature change of 0.000098 m^3 tap water in 1/3 hour duration?

Hypothesis: Increased height of gas region decreases the change in temperature constantly in each trial.

Variables:

In this experiment, to find the relation between height of gas region-change in temperature, distance between light source and water surface is taken as independent variable. This variable is changed by adding glass rings to system in each time. To relate with this fact, heights of glass rings are one of the controlled variables with 5cm height and 5cm diameter. The data collected will be about the change in the temperature so temperature change is the controlled variable denoted by ΔT. To have a reliable final temperature value of water, initial temperature and temperature of surroundings are stabilised at 23ºC. Also time duration (20 minutes), power of light source (100 watt), volume of water inside system (0.0019 m^3) are kept constant as controlled variables.

How To Control Controlled Variables:

- Temperature of room (23°C); measure the temperature of room periodically turn on air-conditioner or heater if needed
- Type of water; use tap water when refilling
- Initial temperature of tap water (23°C); measure the temperature of water heat or cool if Needed also refresh the water after each trial from tap
- Volume of water (0.000098 m^3); fill and refill the water to 10 cm in graduated cylinder
- Time duration (20 minutes); use timer to remind when the experiment finishes
- Power of light bulb(100 watt); use the same light bulb every time
- Volume of each cylindrical piece (0.000098 m^3); add identical pieces in each step (see material list for details.)
- Number of added piece to system; add only 1 glass ring to system in each step

Material List:

- 2 thermometers with uncertainty 0.05ºC
- 10 piece of ring shaped cylindrical glass (5 cm diameter, 5 cm height)
- 1 piece of cylindrical glass with base and extension for thermometer (5 cm diameter, 10 cm height)
- 0.057 m³ tap water
- Tape or a glue gun with strips
- A timer
- 100 watt light bulb
- Tin can with diameter 5 cm
- Scissor
- A piece of polymer dough

Thermometer to read temperature of water

Glass base with 5 cm diameter and 10 cm height. (note: fill this piece with water up to 5 cm)

Glass rings with 5 cm diameter and 5 cm height

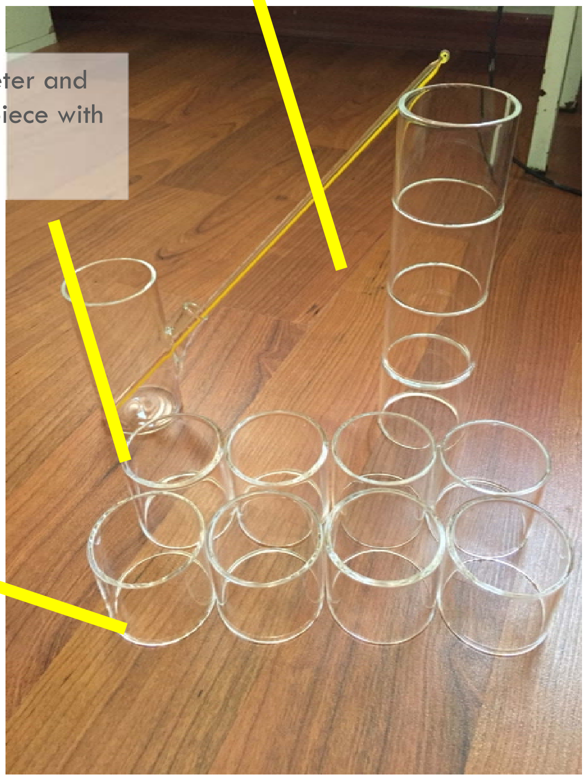


Figure3: Photograph of glass materials with each ring 5 cm height, 10 cm base and thermometer.

Procedure:

1. Create a hole in the tin can
2. Place the light bulb inside tin can and transfer the cord of bulb from the hole.
3. Measure the temperature of surrounding and make sure it is 23°C.
4. Add tap water to cylinder with extension to 5 cm scale (0.000098 m^3).
5. Place the thermometer to extension and cover the rest of the hole with polymer dough.
6. Measure the temperature of water and record also make sure it is 23°C.
7. Place the bulb and tin can to the top of the cylinder.
8. Turn on the lights and start the timer to 20 minutes.
9. Read the value at thermometer after 20 minutes and record.
10. Remove the water.
11. Repeat steps 3 to 10 for 3 trials.
12. After 3^{rd} trial add 1 piece of glass rings to the present cylinder.
13. Consolidate with tape or use glue gun to stick pieces together.
14. Make sure no air can move in or out.
15. Repeat steps 3 to 10 for 3 times and add 1 piece to the system after all trials are done by doing steps 12 to 14.

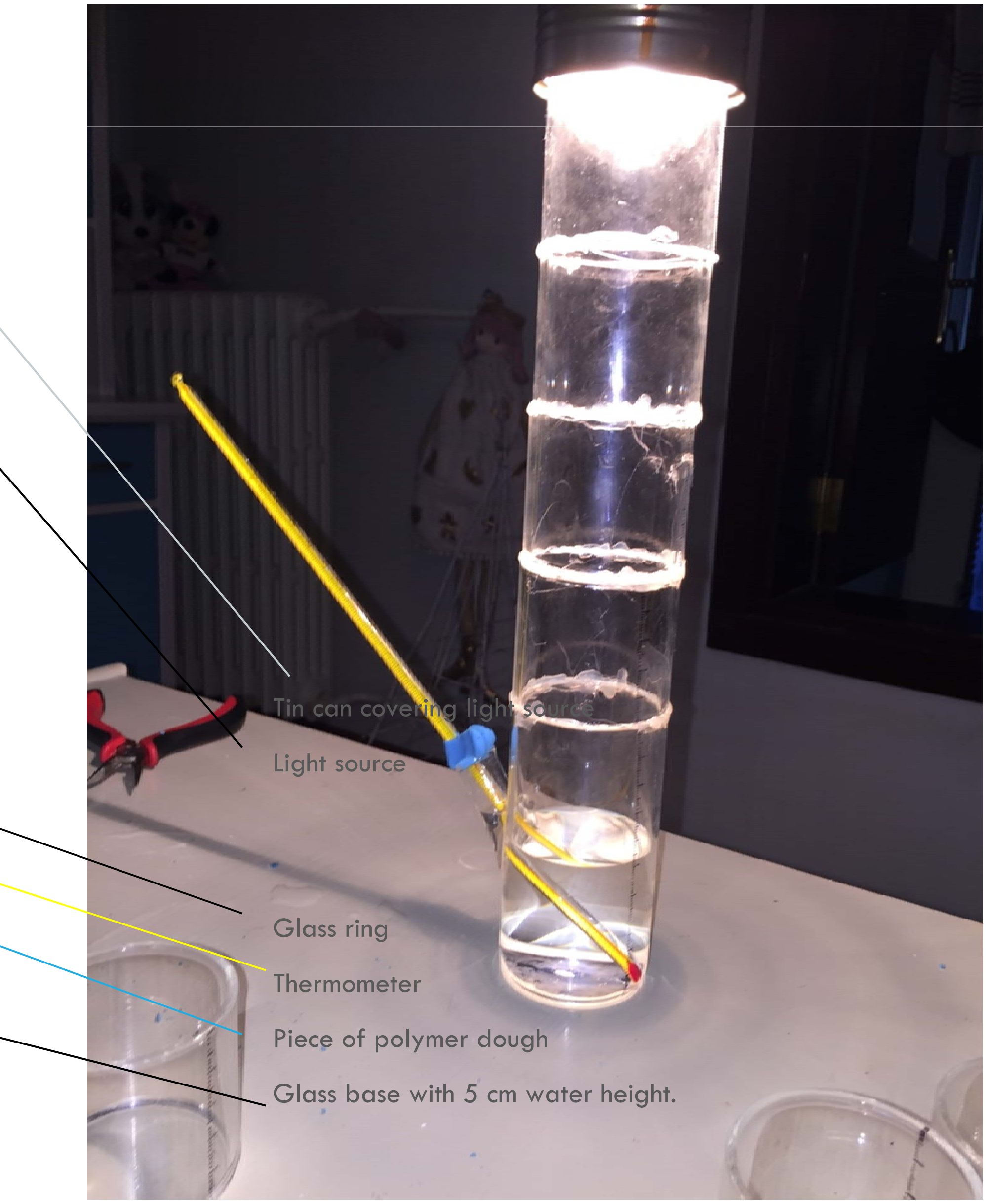


FIGURE 4: Photograph and labels of materials to guide when building the system.

DATA COLLECTING:

COLLECTED DATA TABLE

number of piece in system		height of the system (±0.05)	trials	initial temperature of water (±0.05℃)	final temperature of water (±0.05℃)	temperature of surrounding (±0.05℃)	height of water (±0.05mm)	time duration for each trial (min)
	1		10.00	1	23.00	34.20	23.00	5.00	20.00
				2	23.00	34.10	23.00	5.00	20.00
				3	23.00	34.30	23.00	5.00	20.00
	2		15.00	1	23.00	32.40	23.00	5.00	20.00
				2	23.00	32.80	23.00	5.00	20.00
				3	23.00	32.30	23.00	5.00	20.00
	3		20.00	1	23.00	29.90	23.00	5.00	20.00
				2	23.00	30.10	23.00	5.00	20.00
				3	23.00	29.70	23.00	5.00	20.00
	4		25.00	1	23.00	27.70	23.00	5.00	20.00
				2	23.00	27.40	23.00	5.00	20.00
				3	23.00	27.60	23.00	5.00	20.00
	5		30.00	1	23.00	26.10	23.00	5.00	20.00
				2	23.00	26.30	23.00	5.00	20.00
				3	23.00	26.10	23.00	5.00	20.00
	6		35.00	1	23.00	24.50	23.00	5.00	20.00
				2	23.00	24.20	23.00	5.00	20.00
				3	23.00	24.40	23.00	5.00	20.00
	7		40.00	1	23.00	23.40	23.00	5.00	20.00
				2	23.00	23.30	23.00	5.00	20.00
				3	23.00	23.20	23.00	5.00	20.00
	8		45.00	1	23.00	23.00	23.00	5.00	20.00
				2	23.00	23.00	23.00	5.00	20.00
				3	23.00	23.00	23.00	5.00	20.00
	9		50.00	1	23.00	23.00	23.00	5.00	20.00
				2	23.00	23.00	23.00	5.00	20.00
				3	23.00	23.00	23.00	5.00	20.00
	10		55.00	1	23.00	23.00	23.00	5.00	20.00
				2	23.00	23.00	23.00	5.00	20.00
				3	23.00	23.00	23.00	5.00	20.00

Table 1: Raw data table of recorded values of initial and final temperatures of water after 20 minutes duration and temperature of surrounding, temperature of water, number of cylindrical piece added, and height of water. Controlled variables are shown with green headlines.

Notes about Table 1: Ring shaped glass pieces' heights are 5 centimetres as stated in material list. Table shows the number of glass piece added generally but the base glass is 10 centimetres with 5 centimetres water and other 5 centimetres air and experiment starts with that base so the base glass is assumed as the first glass piece added.

Data Processing:

PROCESSED DATA TABLE

		trials	ΔT (±0.05°C)	mean of ΔT	standard deviation of ΔT
DISTANCE BETWEEN LIGHT SOURCE AND SURFACE OF WATER (±5X10^-5 m)	0.10	1	11.20	11.20 ± 0.10	0.10
		2	11.10		
		3	11.30		
	0.15	1	9.40	9.50±0.10	0.26
		2	9.80		
		3	9.30		
	0.20	1	7.90	7.56±0.40	0.41
		2	7.10		
		3	7.70		
	0.25	1	4.70	4.56±0.15	0.15
		2	4.40		
		3	4.60		
	0.30	1	3.10	3.16±0.10	0.11
		2	3.30		
		3	3.10		
	0.35	1	1.50	1.36±0.15	0.15
		2	1.20		
		3	1.40		
	0.40	1	0.40	0.30±0.10	0.10
		2	0.30		
		3	0.20		
	0.45	1	0.0	0.00	0.00
		2	0.0		
		3	0.0		
	0.50	1	0.0	0.00	0.00
		2	0.0		
		3	0.0		
	0.55	1	0.0	0.00	0.00
		2	0.0		
		3	0.0		

Table 2: Processed Data Table with ΔT calculations of each trial and data set, mean calculations and standard deviation calculations of ΔTs. Uncertainty of mean of ΔT is calculated by (highest data-lowest data)/2 for each data set of height of the system.

SAMPLE CALCULATIONS OF ΔT, MEAN AND STANDARD DEVATION OF FIRST 3 TRIALS OF 1ST DATA SET.

HEIGHT OF SYSTEM, TRIALS AND INITIAL AND FINAL TEMPERATURE OF WATER TABLE FOR 1ST DATA SET

HEIGHT OF SYSTEM	trials	initial temperature of water (±0.05°C)	final temperature of water (±0.05°C)
	1	23.00	34.20
	2	23.00	34.10
10.00	3	23.00	34.30

Table 3: Height of system at 10.00 cm and three trials initial temperature and final temperature values table.

ΔT CALCULATION FOR 1ST DATA SET:

ΔT =TFINAL-TINITIAL

1ST TRIAL: 34.2-23.00=11.20°C

2ND TRIAL: 34.10-23.00=11.10°C

3RD TRIAL: 34.30-23.10=11.30°C

MEAN CALCULATION FOR 1ST DATA GROUP TRIALS' ΔT

11.20 +11.10+11.30=33.60

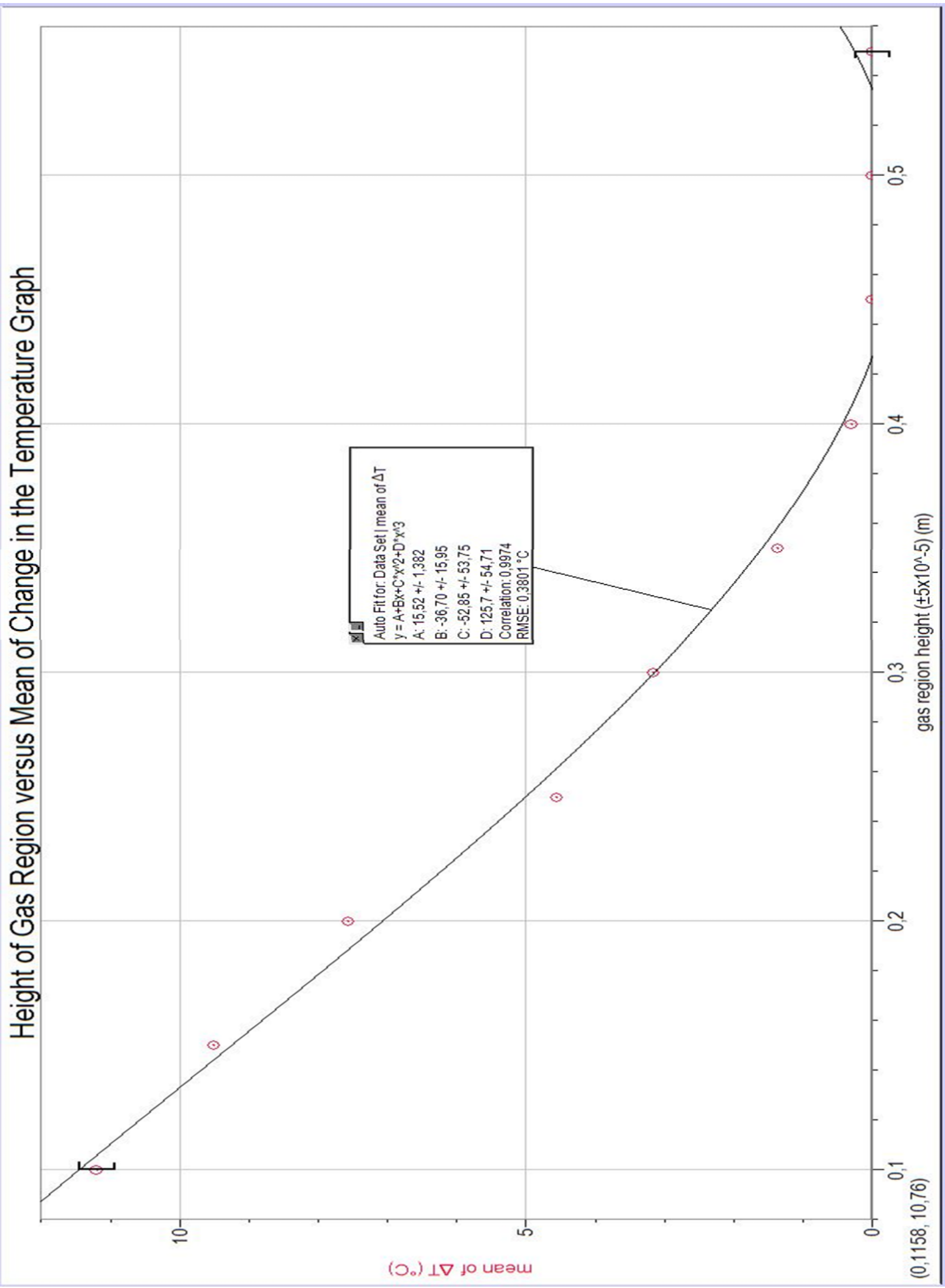
33.60/3=11.20 °C

STANDARD DEVIATION CALCULATION FOR 1ST DATA GROUP:

TRIAL	MEAN OF ΔT	DATA-MEAN ΔT	(DATA-MEAN ΔT)²
1	11.20	11.20-11.20=0	0
2	11.10	11.10-11.20=-0.10	0.01
3	11.30	11.30-11.20=0.10	0.01

0.00+0.01+0.01=0.02

$\frac{\sqrt{0.02}}{\sqrt{3-1}}$=0.1



Graph1: Curved fit line for height of gas region and Mean of Change in the Temperature.

As shown in the Table 2 and Graph 1, as the height of system increases, ΔT decreases. It can be said that change in the temperature is inversely proportional to height of the system. Best-fit quadratic line was drawn as shown in the Graph 1, uncertainty of the data set at ΔT is 0.38 ºC. With a small error for this graph, it is appropriate to say that the correlation of the mean data of ΔT is tending to fit a curved line. The reason of this difference is the last 3 data set with ΔT value 0.0 °C in Table1 and Table2. Although there is no change in the temperature when system had height between 0.45-0.55 metres, the measured values of ΔT are assumed as new data and best fit lines are shaped according to them. The exponential decrease of the change in the temperature, brings the equation calculated as in the type $ax^2+bx+c=0$

DISCUSSION, EVALUATION AND CONCLUSION

Discussion:

Before starting the experiment, the aim was to find how distance from the light source affects the temperature change of tap water at the base of the cylinder at 23°C after 20 minutes. To achieve this aim, some quantities had to be kept constant. Pressure of air and density of air inside system were the quantities that are kept constant. Also while calculating and measuring the thermal conductivity of glass was ignored because it has a value of 0.9 W/(m.K) at 23ºC.

The distance from light source to surface of water is the independent variable in the experiment and increased constantly by adding glass rings with 5 cm height. After collecting three trial values, one glass ring is added. After all glass rings were added total height of the system should be 55 centimetres. 3 recorded trials were in time duration within 20 minutes each and after collecting; temperature change is calculated. Final temperature - initial temperature = change in the temperature. means of ΔT values are calculated it is observed that there is an exponential decrease in the Graph 1; when distance between water surface and light bulb was 5 centimetres, temperature change was 11.20 °C but when distance increased to 10 centimetres mean of ΔT was 9.50 °C. when another glass piece was added the temperature change became 7.56 °C and so on decreased to 0.30 °C and for last three heights, there were not any temperature change. Because the power of the light bulb was not sufficient to release enough energy to heat the water. In other words, when distance between water surface and light bulb increased, temperature change decreases. Due to the last three unchanged temperature distance values, the exponential graph was drawn if the last three data group had ΔT values different from 0.00 °C, the graph would possibly be a linear line and the “constant decrease in the temperature change” hypothesis would be confirmed. But according to the collected and calculated data, the hypothesis was collapsed because the decrease was not constant.

When the experiment is customised to the Earth, the light bulb refers to the Sun and water refers to the surface waters. The actual distance between Sun and Earth’s surface is the atmosphere of Earth. The aim of the experiment was to find how distance from the light source affects the temperature change of tap water at the base of the cylinder. When this aim is put into real life scenario, the aim becomes to find how thickness of atmosphere affects change in the temperature of surface waters. As we know from the background information given, the troposphere of the Earth changes its thickness due to seasons but the literary value for this is; one layer of atmosphere, troposphere, is 8 kilometres thinner at poles but thicker in equator. According to experiment results, the thicker atmosphere gets, the smaller temperature change. I we look at the image below we can clearly see the shape and how 8km difference in atmosphere is located:

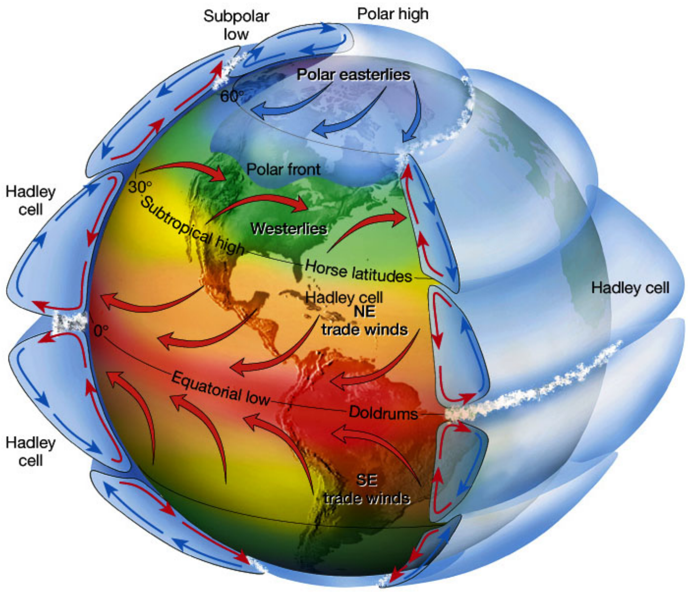


Figure 5: Illustration of earth with air flows and names.

due to this thickness difference, the Earth manages to save itself from desertification at equator. Although the equator climate reaches high temperatures, this thick layer prevents this biome to perish from the Earth. The actual reason of equator to be very hot is the angle it gets sunlight is very close to right angle so these rays are less diffracted from other rays going other locations on Earth:

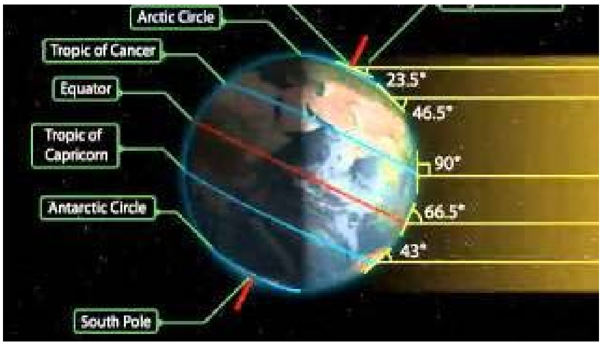
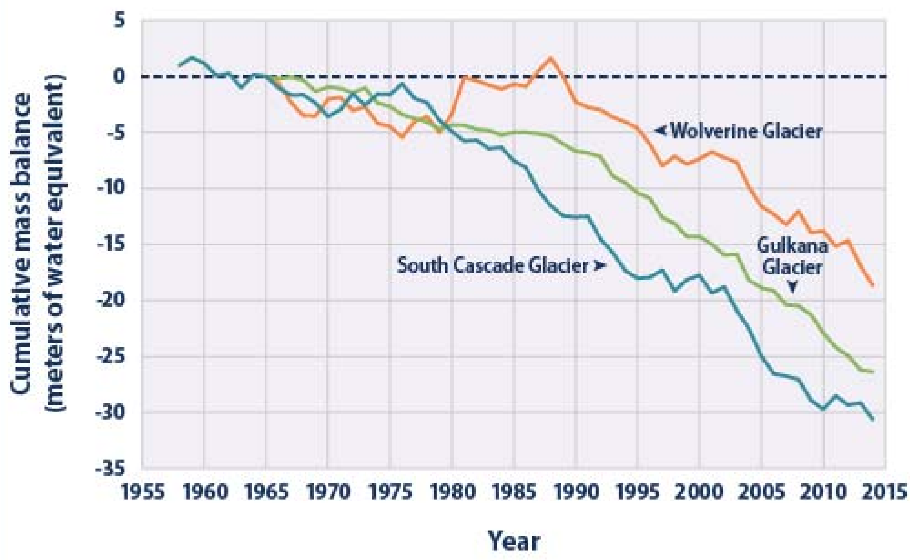


Figure 6: Illustration of earth's sunlight receiving angles.

To talk about North and South poles of the Earth, the atmosphere here is 8 km thinner. When this is review from experiment, we estimate that due to short distance between sun and surface, the temperature change would be very easy and fast. Despite this thin atmosphere, poles do not get sunlight perpendicular to Arctic Circle, so that the poles do not get very hot in summers. The 23°27" tilt of the Earth is the reason to form seasons and the shape itself of the Earth together protects the ice glaciers to melt. But the environmental pollution, greenhouse gases and global warming accelerates the melting rate of ice caps.

Figure 7: Cumulative Mass Balance of Three U.S. Glaciers, 1958-2014.



As seen in the above figure, total mass of three glaciers located in the USA highly decreased from 1958 to 2014.

Evaluation:

The last three ΔT values in the experiment did not changed, stayed at 0.00. The reason lying behind this error was the inefficient light bulb. Although it was 100 watt, it was not enough to heat water from distances; 40.0, 45.0,50.0 cm. To overcome this systematic error, a direct heat source could be used or the time duration might be longer than 20 minutes. When looked to table 2, it can be seen that the standard deviation of these data groups are not same with each other. The reason behind this random error is the possible misreading from thermometer. To overcome this issue, electronic thermometer ought to be used. Another reason for this standard deviation values is the temperature of the surrounding. Although air conditioners were used to keep room's temperature at 23.00°C, it was summer time and the weather was way higher than 23.0 °C. Final issue I came across is about the equipment used in the experiment. Glass rings with same height and a base glass were very hard to find, the system was hard to obtain so I went to glassworkers and ordered the equipments I designed for the experiment. I can say that this was the most time consuming and costly part.

Conclusion:

According to the research question: "How does distance between light source (also heat source) and water surface affects the temperature change of 0.000098 m^3 tap water in 1/3 hour duration?" I planned and designed to answer this question. Collected data and reviewed my hypothesis in which conditions it was confirmed, which conditions it was not acceptable. I related my research topic and findings to real life, to atmosphere of earth. In addition I referred to recent issues discussed like greenhouse effect and global warming and the exceptions that protects earth were discussed like tilt angle and shape of the Earth.

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