Keeping Warm

Aim

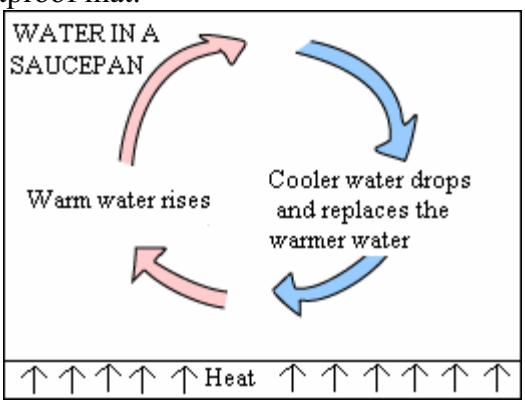
My aim of this investigation is to discover which insulating material is the most efficient for keeping warm.

Background information

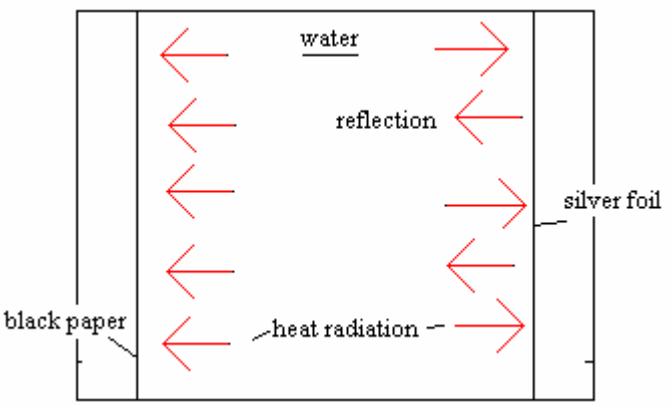
An insulator is a material which helps prevent heat loss therefore keeping an object warm. Insulators protect against three types of heat loss:

1. Convection
2. Conduction
3. Infra red radiation.

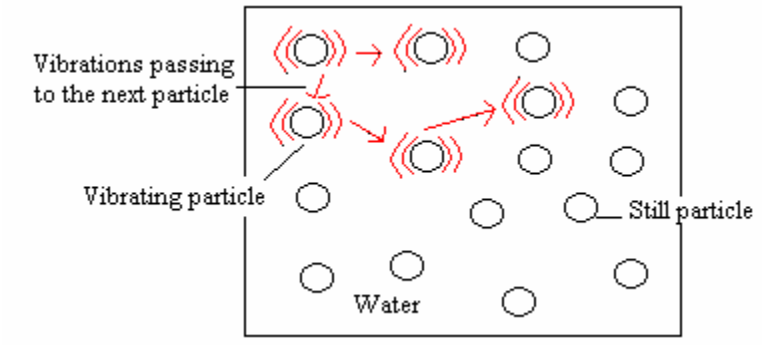
Convection best occurs in liquids and gasses. Hot air and water rises, e.g. when a pot of water is placed on a stove, the water at the bottom gets heated and becomes less dense, so moves upwards and is replaced by the colder water. To prevent this happening in my experiment I will cover the top of the beaker with a lid. This will stop most of the heat escaping from the top but not all of it, and therefore affecting the result of my experiment on insulation. To prevent minor heat loss from the bottom, I will place the beaker on top of a heatproof mat.



Infrared radiation is where the water particles at the top of the beaker will radiate heat into the surrounding air. For radiation to occur it does not need to be in contact with matter. Radiation can pass from one object to another through a complete vacuum and this is how the sun warms up the earth. The effect of infrared radiation in my experiment depends on the colour of the insulator. The worst of my insulators for infrared radiation will be the black paper. This is because the black is a better emitter of heat but not a good reflector. The best insulator of radiation will be the aluminum foil. This is because the foil will reflect the infrared radiation energy back into the water so it stays warm.



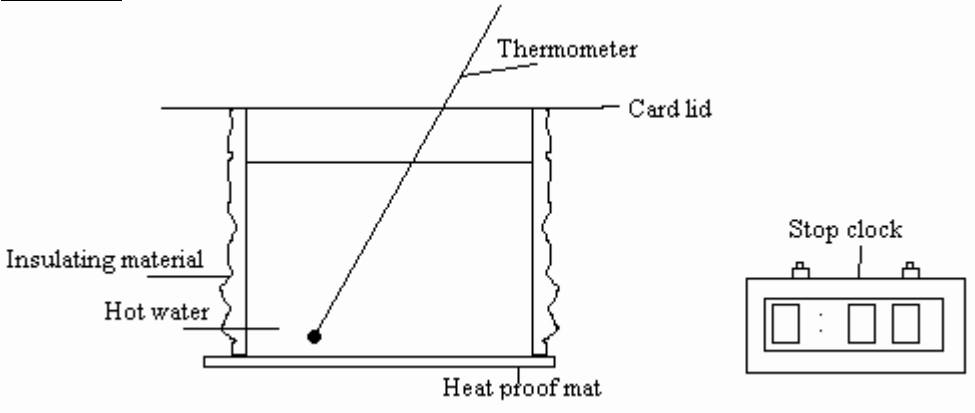
Heat transfer usually takes place from a high temperature object to a lower temperature object. Conduction of heat best occurs in solid materials. This is because it is created by particles vibrating and passing on their vibration to the neighboring particles. This process is known as gradient transport. Materials that are good electrical conductors also tend to be good thermal conductors. Certain metals such as gold, copper etc, are better conductors of heat because of 'free electrons' which makes conduction happen faster. In my experiment, the insulators will be placed around the sides of the beaker. This is because that is where the main heat loss will occur. To ensure this I have placed lids onto my experiments to prevent convection. Therefore my experiment will mainly be around conduction.



Equipment

- Insulators – rockwool, jay cloth, bubble wrap, black paper, foil
- Cardboard lid x6
- Thermometer
- Stop clock
- Heat proof mat
- Beakers x6
- 200ml of water

Diagram



PRELMINARY INVESTIGATION

Prediction

I predict that out of my 5 chosen insulators, the most efficient will be the bubble wrap. I believe this because it is thick and has lots of pockets, which contain still air. It is a good insulator because convection currents cannot form because the air is not moving. I believe that the second best insulator will be the rockwool, which is a fiberglass substitute. This is because it is a thick layer and again has trapped still air in it, though not as much as the bubble wrap. The third best of my insulating materials will be the sliver foil. The silver foil will reflect the infrared radiation. This means that it will be good for keeping the heat inside the beaker. However, the foil is also a good conductor due to its metallic molecular structure. This means that although it will keep infrared heat inside, it will lose heat due to conduction. The fourth best insulator will be a jay cloth. Altogether it is not that good because it is very thin. However it is a very poor conductor so not much heat will escape through it and it does contain very small pockets of still air. However, if the jay cloth becomes wet at anytime during the experiment, its insulating ability will go completely down. This is because the water is a good conductor, which means that a lot more heat can be lost. When wet the pockets of still air will also be lost which means that another insulating quality of the jay cloth will be gone. I believe that out of all of my insulating materials the worst one will be the black paper. Firstly because it will absorb, not reflect, the infrared radiation energy. This means that a great amount of heat will be lost because the heat is not reflected back into the water. It is also a very thin layer and contains no still air. Even though it is a very poor conductor, it is still not a very good insulator either due to the above reasons.

Range and fair test

To make my experiment fair, I will keep the following factors of my experiment the same: -

1. The amount of water used inside the beakers. This is because, if there is more water, heat convection will take longer to even out, therefore staying warmer than if there was only 50ml of water.

2. The beginning temperature of the water (55ºC). This is because if the water started off at different temperatures for each experiment, my results will be inaccurate, unfair and unreliable.
3. The amount of time the experiment lasts (20mins). If one experiment was taken for longer times then my range and averages will be all different and inaccurate.
4. The time intervals that the temperature is taken (5mins). If the results were taken at different time intervals then the averages would be wrong. The range would also be different so that when I come to calculate the reliability, my results would be inaccurate.
5. They will all have lids. If some of the experiments were taken without lids then their results will be less accurate and different to the others because it will have lost more heat due to convection.

To only part of my experiment that will be changed is the insulating material. The range of my insulators will be rockwool (fiberglass substitute), jay cloth, bubble wrap, black paper, foil and a control experiment. For my results, I will be measuring what temperature the water is for each of the insulators every 5minues for 20 minutes in total. Because this experiment is only a preliminary experiment, I will not be repeating any of the insulating materials because it is unnecessary.

Method

- Firstly I will cover 5 of the beakers around the sides with my chosen insulating materials. One of my beakers will remain with no insulating. This will be my control experiment. Place one of them on a heatproof mat. This is because I am only doing one at a time to make my results more accurate.
- Secondly boil some water in a kettle and pour 200ml of it into the beaker. Insert the thermometer and wait until it is at 55ºC.
- Place a cardboard lid to help reduce convection, onto the beaker and start the stop clock.
- Every 5 minutes take the temperature and record it in a table of results. Before I take the temperature, I will stir the water around to prevent convection in the water, which will affect my results. I will continue this for 20mins. This will provide my results for my preliminary and help give me an idea about my full investigation.
- Repeat the experiment for the other insulating materials and the control experiment.

Results

	Temp of water ºC				
Insulator	**Time in minutes**				
	0	**5**	**10**	**15**	**20**
Control	55	50	41	37	32
Jay cloth	55	51	43	40	35
Black Paper	55	47	40	36	33

Rockwool	55	53	50	46	43
Bubble wrap	55	54	49	44	42
Foil	55	50	43	40	38

My preliminary results show that the most affective insulator (excluding the control experiment) was the rockwool, followed very closely by the bubble wrap, then the silver foil, then the jay cloth and finally the black paper. These results show that my prediction that I made for my prelim was fairly accurate. The only part that did not relate to my results was that the rockwool was slightly more efficient then the bubble wrap. My preliminary results will help my prediction for my main investigation and help improve my range.

MAIN INVESTIGAITON

Range and fair test

To make my experiment fair, I will keep the following factors of my experiment the same: -

1. The amount of water used inside the beakers.
2. The beginning temperature of the water (55ºC).
3. The amount of time the experiment lasts (30mins).
4. The time intervals that the temperature is taken (2mins).
5. They will all have lids.

To only part of my experiment that will be changed is the insulating material. The range of my insulators will remain the same as for my preliminary investigation. For my results, I will be measuring what temperature the water is for each of the insulators every 2 minutes for 30 minutes in total. Recording the temperature every 2 minutes instead of 5 will make my results more accurate and reliable. I will do this for 30 minutes instead of 20 so that I get a better line of best fit on my graph and get more reliable results. Also making the experiment longer will help my conclusion. To make my results more reliable, I will repeat each insulating material three times then work out an average.

Prediction

This time, because of the results from my preliminary experiment, I predict that out of my 5 chosen insulators, the most efficient will be the rockwool. I believe this because it is very thick and contains still air. It is a good insulator because convection currents cannot form because the air is not moving. I believe that the second best insulator will be the bubble wrap, and then the third best of my insulating materials will be the sliver foil, the fourth best insulator will be a jay cloth and again I believe that out of all of my insulating materials the worst one will be the black paper.

Method

- Firstly I will cover 5 of the beakers around the sides with my chosen insulating materials. One of my beakers will remain with no insulating. This will be my control experiment. Place one of them on a heatproof mat. This is because I am only doing one at a time to make my results more accurate.
- Secondly boil some water in a kettle and pour 200ml of it into the beaker. Insert the thermometer and wait until it is at 55ºC.

- Place a cardboard lid to help reduce convection, onto the beaker and start the stop clock.
- Every 2 minutes take the temperature and record it in a table of results. Before I take the temperature, I will stir the water around to prevent convection in the water, which will affect my results. I will continue this for 30mins.
- Repeat the experiment three times with each of the insulating materials
- Repeat the experiment for the other insulating materials and the control experiment.

Results

		Temperature of water ºC															
		Time in minutes															
		0	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
	Insulator																
Test 1	**Control**	55	52	50	48	47	45	44	43	43	43	41	40	39	38	37	37
Test 2		55	51	50	48	47	46	45	44	43	42	41	40	40	39	38	37
Test 3		55	48	47	46	45	44	42	41	40	39	38	38	37	36	35	34
Average		55	50	49	47	46	45	43	42	42	41	40	39	38	37	36	36
Test 1	**Black paper**	55	46	45	43	42	42	39	38	37	36	36	36	35	35	35	35
Test 2		55	51	49	47	46	43	44	43	40	40	38	38	37	37	36	36
Test 3		55	51	48	46	45	43	43	40	40	39	38	37	37	35	34	34
Average		55	49	47	45	44	42	42	40	39	38	37	37	36	35	35	35
Test 1	**Jay cloth**	55	51	51	49	48	46	46	45	45	44	43	42	42	40	40	39
Test 2		55	50	48	47	46	45	43	43	42	41	41	40	39	39	38	38
Test 3		55	49	48	46	46	44	43	43	43	41	40	39	37	36	36	35
Average		55	50	49	47	46	45	44	43	43	42	41	40	39	38	38	37
Test 1	**Rockwool**	55	55	50	50	48	46	46	45	45	44	43	42	42	40	40	40
Test 2		55	52	50	49	48	47	46	45	44	44	43	42	41	41	40	39
Test 3		55	51	49	48	46	46	44	43	43	43	41	40	39	37	36	36
Average		55	52	49	49	47	46	45	44	44	43	42	41	40	39	38	38
Test 1	**Bubble wrap**	55	48	46	44	41	42	39	38	37	36	36	36	37	34	35	35
Test 2		55	47	47	45	44	42	42	42	41	40	38	37	37	37	36	38
Test 3		55	46	46	44	42	41	39	40	39	38	37	36	35	34	33	33
Average		55	47	46	44	42	41	40	40	39	38	37	36	36	35	34	35
Test 1	**Foil**	55	48	46	44	43	44	42	40	39	39	38	38	38	37	37	36
Test 2		55	52	50	48	47	44	44	43	42	41	40	38	38	37	36	36
Test 3		55	52	48	48	46	47	44	44	43	42	41	40	38	38	37	36
Average		55	50	48	46	45	45	43	42	41	40	39	38	38	37	37	36

= odd results

My results and my graph show that the best insulator was the rockwool. This is because the rockwool is a very thick layer of insulation. It also contains pockets of still air. Still air is a good insulator because conduction currents are unable to form because the air molecules are unable to move. The fact that rockwool was the best insulator supports my

prediction. The worst insulator was the black paper and the bubble wrap. This does not support my conclusion and was even stranger with the fact that they lost more heat than the control experiment. However I did predict that the black paper would be one of the worst insulators. This is because the black paper absorbs the infrared radiation so it is a better emitter than a reflector. However the black paper is a very poor conductor because the particle structure is very dense and thick so the conduction currents are unable to move around as freely. The reason that bubble wrap was a poor insulator was very strange. It may be due to odd results that were recorded. The reason that bubble wrap should have been a good insulator is because it contains large pockets of still air. Plastic is also a good insulator because it is made up of many layers, which has still air in between each layer. After rockwool the next best insulator was the jay cloth. This is very surprising as it is not very thick and is a very bad insulator when wet. However, the jay cloth is a net design, which traps air and is made of several layers, which also contains air. It is also a very bad conductor because it is a dense particle structure. Then the middle insulator was the silver foil as I predicted. This is very good at insulating against infrared radiation because the shiny surface reflects the energy. The poor point to this insulator is that it is a good conductor because of free particles that allows conduction currents to move faster and easier.

According to my graph, the steeper the line of best fit is, then the faster the temperature dropped, therefore the less reliable the insulator was. My graph shows that most of the insulators had a steady drop in temperature and that the range between the results is very small.

Evaluation

I believe that my results are fairly good. But to prove this I will calculate the reliability of my second result, middle result and end result for each insulator. The reason that I will not be doing my beginning result is because they are all the same and will all therefore, be 100% reliable. The formula for this is:

$$\text{Reliability} = \frac{\text{Range}}{\text{Average}} \times 100$$

The higher the percentage, the less reliable the results are. For example, 100% will be very unreliable but 0% will be very reliable. As a guideline, if my results are above 10% I will say they are unreliable. If they fall below 10% but above 5% they are fairly reliable and below 5% they are reliable.

Insulator	Start temp	Reliable?	Middle temp	Reliable?	End temp	Reliable?
Control	8%	Fairly	7%	Fairly	8%	Fairly
Black paper	10%	Fairly	7%	Fairly	5%	Yes
Foil	8%	Fairly	9%	Fairly	0%	Yes
Rockwool	7%	Fairly	4%	Yes	10%	Fairly
Bubblewrap	4%	Yes	10%	Fairly	14%	No
Jay cloth	4%	Yes	6%	Fairly	13%	No

As you can see my results are mostly reliable. The reason that some may not be reliable is because the material may have got wet which would affect the conduction prevention. Water is a very good conductor because the convection currents pass easily from particle to particle.

What was good about my chosen method was that it was easy to set up and produces fairly accurate results. It was very simple but got me what I wanted. Also it was the best possible method as I had a very limited time restraint. It covered the fact that heat could be lost by convection and I found ways to prevent that by placing a lid on the beaker. I feel that the method did not really have any bad points. However to make my results more accurate I could use a digital thermometer that counts the temperature to two decimal places. I could also use plastic or glass lids instead of cardboard ones. These will be more reliable at keeping in heat.

For additional experiments that involve investigating insulation I could experiment on these factors: -

1. Different containers. Instead of glass beakers, which are very good insulators, I could experiment on using other containers. Like copper cans or instead of a beaker I could use a conical flask, which has a slender neck and a smaller lid.
2. How the colour of the material affects the infrared radiation.
3. How convection affects the loss of heat.