INTRODUCTION

For this piece of coursework, I am investigating the rate at which heat energy is lost and heat transfer happens when a beaker of boiling water is wrapped in different materials. These experiments involved the temperature of hot water being recorded at different times in a glass beaker. Heat is generally transferred by conduction, convection and radiation.
Energy transfer in solids is by means of CONDUCTION.

CONDUCTION

Materials that allow thermal energy to transfer through them quickly are called CONDUCTORS. Those that do not are called INSULATORS. If one end of a conductor is heated the atoms that make up its structure start to vibrate more vigorously. As the atoms in a solid are linked together by chemical bonds the increased vibration can be passed on to other atoms. The energy of movement (kinetic energy) passes through the whole material.

Metals are particularly good conductors because their structure contains freely moving electrons, which transfer energy very rapidly. Air is a good insulator and reduces thermal transfer by conduction. As air is a gas there are no bonds between the particles and so energy can only be transferred by the particles colliding with each other. To obtain the best results the air needs to be trapped so that energy cannot be transferred by convection. Conduction cannot occur when there are no particles present, so a vacuum is a perfect insulator.

Examples of good conductors are metals such as gold, silver and copper - they will conduct heat readily. Materials that are good thermal conductors tend to be good electrical conductors also. Materials such as glass have much smaller heat transfer values and are poor heat conductors.

CONVECTION

Convection occurs in liquids and gases because these materials flow (which is why they are described as 'fluids'). Convection occurs when hot fluids rise and cold fluids sink. The circulation of fluids that this causes is called a CONVECTION CURRENT. The particles in a fluid move all the time. When a fluid is heated, energy transferred to the particles causing them to move faster and further apart. This makes the heated fluid less dense than the unheated fluid. Consequently, the less dense warm fluid will rise above the denser, colder fluid. This is how the thermal energy id transferred.

If a fluid's movement is restricted, then energy cannot be transferred. That is why many insulators, such as ceiling tiles, have trapped air pockets. Wall cavities in houses are filled with fibre to prevent air from circulating and transferring thermal energy by convection.

RADIATION

Radiation, unlike conduction and convection, does not need particles at all. Radiation can travel through a vacuum. All objects take in and give out infrared radiation all the time. Hot objects radiate more infrared than cold objects. The amount of radiation given out by an object depends on its temperature and on the object's surface. The surface of an object also determines how good it is at absorbing infrared radiation.

Type of surface	As an emitter of radiation	As an absorber of radiation	Examples
Dull black	good	good	Cooling fans on the back of a refrigerator are dull black to radiate away more energy
Bright shiny	poor	poor	Marathon runners wrap themselves in shiny blankets to prevent thermal transfer by radiation. Fuel storage tanks are sprayed with shiny silver paint to reflect radiation from the sun

Investigation Intentions

In order to carry out this Physics coursework, I intend to focus on how extra layers of a material affect the rate at which heat is lost from a beaker containing water. I will repeat the experiment several times by adding an additional layer of the material to my beaker each time.

During the investigation, I will be recording the results from my experiments in order to analyse them on completion of the practical work. I will be able to take a close look at my results and see whether or not they confirm my thoughts stated in my hypothesis. I will then be able to evaluate my performance and results and try to understand where I went wrong, if necessary.

Before carrying out the experiment, certain factors need to be taken into consideration as they can make a significant difference to the experiment.

The factors that need to be considered are:

- The volume of water in the beaker.

When the volume of water in the beaker is higher, it will stay warmer for longer than if there was a low volume of water. This is because when there is a high volume of water, although the outside of the water will cool down, the inside will stay warm.

- Whether or not a lid is used.

There will be a great difference in the speed of heat loss if I use a lid. This is because a large amount of heat will escape form the top of the container by convection and evaporation if a lid is not used. Therefore, if I did use a lid it will slow down these processes.

Also what the lid is made of will make a difference. If a lid is made of paper or card then its insulation properties will not be as affective as if I were to use polystyrene or bubble wrap as these materials will decrease the rate of reaction.

- Insulation

If the inside of the beaker is painted it will make a difference to the heat loss. If it is painted silver then it will reflect some heat back to the water, whereas if it is painted

black it will absorb the heat and pass it out the other side. This is due to thermal radiation.

If the container is covered in bubble wrap or cotton wool it will have an affect on how fast the water cools as these are good insulators and will stop the container from losing heat as quickly by conduction, whereas materials such as paper do not have as good insulation properties.

For this investigation, I have chosen one material and I am going to experiment into the heat loss when different numbers of layers are used to insulate the beaker. I am not going to use a lid to slow the process of convection and evaporation. The material I have chosen is bubble wrap.

In order to carry out my experiments, I will need to use certain equipment. This equipment will consist of:

- A beaker
- A thermometer
- Hot water
- Bubble wrap
- Cello tape
- Scissors
- A kettle
- A stopwatch

However, when carrying out this practical work, I will have to ensure that each experiment is fair. I shall do this by keeping certain variables the same throughout and by implying the same strategy for each test. I will also have to ensure that it is safe.

Safety precautions are needed because I am dealing with hot water, which can scald. To ensure that safety is maintained whilst performing this experiment, safety

measures have to be emplaced to reduce the risk of harm and dangers when carrying it out.

The following things need to be acknowledged to, in order to keep this experiment safe:

- Be careful not to knock over the beaker, which will be filled with hot water.
- Be careful not to knock over anybody else's beaker.
- Care is needed when pouring hot water.
- Do not run with the beaker of hot water.
- Make sure not to smash the thermometer as it has mercury in it.

To ensure that the experiment is made fair, I shall:

- Start the experiment at the same temperature each time.
- Use the same volume of water. This is because a greater volume of water means more energy, which would be unfair.
- Make sure that the amount of beaker covered by material is kept the same.
- Use the same bubble wrap so that the thickness and size of bubbles are kept the same.
- Use the same colour bubble wrap.
- Carry out the experiment twice and take the average – this will make the results more accurate.

EVALUATION

On completion of my experiment it can be seen that I could have improved the experiment, however, I was pleased with what I had done.

I felt that I was quite precise when measuring volumes of water and the temperature. I slowly and carefully, poured in the boiling water, however it was difficult to see measured amounts on the beaker when it steamed up and when I added more layers of bubble wrap. I think that I could have eliminated this problem by firstly pouring the water into a measuring cylinder and then putting it into the beaker.

Also when using the thermometer to measure the temperature, I took great care when obtaining my readings and ensured that I measured the starting temperature accurately. However, sometimes I would be slightly late when taking a reading because I wasn't looking. I think that if I had used a timer with an alarm that sounded every two minutes then this problem wouldn't have occurred.

During the experiment, I took a reading every two minutes for ten minutes, which gave me five readings. At the time I felt that these five readings were enough. I repeated the experiment twice and took the average, I felt that this made the readings much more accurate yet not as time consuming as it would have been had I done the experiment three times.

When looking at my graphs, it is apparent that there are several anomalous points. There are many explanations that could suggest why these points have been obtained. There could be anomalous points because of the bubble wrap. The material could have been overlapping, allowing an extra piece to be added when each layer is applied. Because I used cello tape, it could have helped to insulate or reflect the heat back as it was shiny cello tape that was being applied. When looking at the graphs, one could also suggest that there are anomalous points because the results are starting to form a curve, which could only be seen if the experiment had been carried out for a longer period of time. Another reason why these results may have been in error is because I may have recorded the temperature at slightly different times, but also, these points maybe due to the movement of the thermometer, from the middle of the beaker to the edges.

I feel that although I was happy with what I had done, I could have made the experiment a lot better if I had done certain things differently. One factor that I feel probably would have made a significant difference to my experiment and readings would be a lid. If a lid were used there would probably be a great difference in the rate of heat loss. This is because a large amount of heat would have escaped from the top of the beaker by convection and evaporation. Hence, a lid would slow down these processes. Also what the lid is made of will make a difference. If a lid is made of paper or card then its insulation properties will be at a minimum, however if the

material used for a lid is polystyrene or bubble wrap then the heat loss through the top of the beaker will slow down.

As an improvement to my experiment I could have used a clamp and stand to place the thermometer accurately, especially when there isn't a lid to support it to stop any inaccuracies caused by this. I also think a note of the room temperature should be made just to be aware of an outside factor that may effect the results.

I think it would have been beneficial if I had enough time to repeat the experiment a third time and also if I had enough time to allow each experiment to continue for a longer period of time. I think that if I had done this, there would have been more of a difference in results and also in the appearances of my graphs.

I feel that if I were to carry on taking more readings for a longer time, I may have got greater temperature falls for the different number of layers of bubble wrap. This would have made it much clearer whether or not the number of layers affected the heat loss.

To improve my experiment, I could also have cut the bubble wrap layers to size, so that it wouldn't be overlapping. Also a certain amount of cello tape could be decided upon, so that the results are more accurate.

In order to provide additional evidence about the theories of heat loss I could experiment with other materials to see which was the better insulator. I could maybe experiment with cotton wool and see how it differs from bubble wrap.

In addition, I could also repeat my experiments but use a lid. This would help to decide whether the different number of layers made a difference as a lot of heat was lost from the beaker due to convection and evaporation.

HYPOTHESIS

For my investigation I have chosen to focus on one material and see how it affects heat loss. I will use this material to surround a beaker and add extra layers in order to see what results I get when increasing the quantity of the material. The material I have chosen to use is bubble wrap.

Because bubble wrap is made up of many bubbles of trapped air I am predicting that it will be a good material for reducing the rate at which heat is lost. I am saying this because air is a very good insulator in small pockets.

I think that the more bubble wrap surrounding the beaker, the less heat will escape.

My prediction is that each time I add an extra layer of bubble wrap; the results will show a higher temperature at the end of the ten minutes, as there will be less heat being lost.

I am making this prediction on the basis that conduction can only transfer heat through solids because of the particle formation and so cannot transfer heat through a vacuum, as the particles are too far apart. Particles in a solid are tightly packed so when the water is warmed up they use the heat energy to move but as they are tightly packed, they can only vibrate vigorously not freely move. The vibrating causes them to bump into neighbouring atoms, transferring the heat through the walls of the can and out to the surroundings. This theory therefore suggests that conduction can occur easily in a solid if there is no barrier between the walls and the outside surroundings. However, as I am placing bubble wrap around the beaker, I am expecting the heat loss to be lower.

I think that the more bubble wrap around the beaker of boiling water, the better the insulator, therefore, less heat being lost.

CONCLUSION

After completing my experiment, it can be seen that my prediction of what would happen to the rate of heat loss was incorrect. My results show that adding layers of bubble wrap to my beaker made almost no difference at all.

The results show that when the first couple of layers were added to my beaker, there was a very slight difference in the results however as we see the rest of the results, the bubble wrap seems to have had next to no effect on the heat loss.

Although my prediction was wrong and there is not really a difference between the results, I feel that if the experiment was longer, then there would have been more significant differences in the results and therefore in the graphs also.

Even though adding extra layers of bubble wrap hasn't made much of an effect on my overall results, if we look at the preliminary tests, which helped decide on the volume of water being used, it can be seen that more heat was lost. I can make this observation because I did not use an insulation layer when carrying out these experiments. The table below shows one of my preliminary experiments. The volume of water was the same as what I used in my real experiments. It can be seen that the drop in temperature over the period of ten minutes is 32°C.

	Time (mins)					
Volume of water	0	2	4	6	8	10
100ml	89°C	78°C	70°C	65°C	60°C	57°C

However, if you look at the results (below) when a layer of bubble wrap is used, it can be seen that the temperature drop is only 23°C.

1 layer of bubble wrap	Time (mins)					
Volume of water	0	2	4	6	8	10
100ml	80°C	73°C	69°C	64°C	60°C	57°C

I conclude that the bubble wrap does affect the heat loss, although the amount of bubble wrap used to insulate the beaker does not have a definite effect on the results.

I predicted that the more layers of bubble wrap used would mean there would be less heat loss. One could argue that if the experiment was carried on for a longer period of time, then this prediction could have been proven.

I think the results could also be related to convection as I did not use a lid on my beaker and so a lot of heat was lost through the top of the beaker.

Method

Due to the fact that I am investigating how different numbers of layers of bubble wrap will affect heat loss, I have to imply a certain strategy for my experiments in order to make them fair and to obtain accurate results. The volume of water, the colour of bubble wrap and the starting temperature, are all key factors that can have an effect on the heat loss results that I record. Therefore, I must ensure that the only variable I change is the number of bubble wrap layers and I must make sure that all the others remain the same throughout the investigation.

Before I began my actual experiments, I ran a series of preliminary tests so that I could decide upon what volume of water to use in my real experiments. I needed to ensure that the bulb of the thermometer was covered but the amount of water couldn't be too much, as it would take a long time to cool.

I then decided upon my hypothesis and was ready to start my investigation next time. I gathered the necessary equipment so that my tests could run smoothly. The equipment consisted of a: A beaker, a thermometer, bubble wrap, cello tape, a scissors, a kettle and a stopwatch.

In point form; this is how I carried out my experiment:

- Collected equipment
- Cut a piece of bubble wrap that was sufficient to form one layer around the beaker.
- Stuck the bubble wrap to the beaker using cello tape.
- Boiled a kettle full of water.
- Carefully poured 100ml of water into the beaker. (This amount will cover the bulb of the thermometer yet not take an extensive amount of time to complete my experiments)
- Placed the thermometer into beaker and watched it rise.
- Waited until the temperature dropped to 80°C. (Chose this starting temperature as it allowed me time to get back to my table and be prepared to begin the experiment. It also made the experiment fair because I had a set temperature to start rather than beginning as soon as the water was in.)
- Started the stopwatch and timed ten minutes. Every two minutes I noted down the temperature of the water in my results tables.
- When I had finished the ten-minute experiment, I repeated the whole process for accuracy and then took the averages for the temperatures at the different stages of the experiment. (It would have been more accurate to do it three times and then take the average, but it would take to long, therefore, I was relying upon my two sets of results
- After doing this experiment twice, I added another layer of bubble wrap and started again (making sure to record my results). I continued to do this until I had the results for the beaker with one layer of bubble wrap up unto five layers of bubble wrap.