# Physics and Cooking

*Contents:* Information, recipes and questions relating to some of the physical principles involved in cooking.

*Time:* If recipes are used: 3 homework sessions and one classroom period for follow-up. If recipes are not used, the unit could be done in class in about 2 periods.

*Intended use:* GCSE Physics and Integrated Science. Links with work on heat transfer, insulation and microwave radiation.

*Aims:*

- To complement and revise prior work on heat transfer
- To show that scientific principles are applicable outside the laboratory in such everyday activities as cooking
- To develop willingness to look for scientific patterns and principles in everyday situations
- To provide opportunities to practise skills in reading, comprehension and cooking.

*Requirements:* Student's worksheets No. 303. The requirements for the recipes are given in the worksheets.

If possible, students should try out the recipes for themselves, if they are not already familiar with them. The unit lends itself particularly well to homework. Naturally there are good opportunities for links with the home economics department.

## Notes on some of the questions

Within each part of the unit, the questions are in approximate order of difficulty, with the easiest first.

*Q.6* The table below shows how the boiling point of water changes due to the lower pressure at high altitudes.

| *Height above sea level/m* | *Boiling point of water/°C* |
|---|---|
| 0 | 100.0 |
| 250 | 99.2 |
| 500 | 98.3 |
| 750 | 97.5 |
| 1000 | 96.7 |

As an optional extra, students might be asked to plot a graph of these figures, and perhaps use it to work out the boiling point of water at the altitude of their school/home (found from a local map).

In high altitude countries such as Tibet, where the boiling point of water may be as low as 90°C, cooking by boiling is noticeably slow, unless pressure cookers are used.

*Q.9* The poor thermal conductivity of sponge cakes and other air-filled foods is of considerable importance in cooking. Students should be able to relate this to the insulating properties of expanded polystyrene, birds' feathers, clothing, etc.

*Q.10* It is fairly simple to relate the rising of a cake to the expansion of gas bubbles in the mixture, but students may find it harder to see that the bubbles will collapse if the cake is taken out of the oven before the sponge mixture has become hot enough to set and support the bubbles. The setting of sponge mixture is due to the gelatinization of starch (in the flour) and denaturation of protein (in the eggs).

*Q.12* Most microwave cookers have a microwave source at the top, together with a 'paddle' which reflects the rays so they come from varying directions.

Cakes do not cook particularly well in microwave ovens because of their low water content. The cake often has a hard, dry texture and rises poorly by comparison with conventionally cooked cakes. Adding extra water to the mixture helps.

*Qs 13 to 16* The trick with Baked Alaska is to ensure sufficient thickness of insulating meringue and sponge to prevent significant heat transfer to the ice cream. A high baking temperature ensures quick browning of the meringue.

## Further questions

Interested classes might like to tackle further questions, for example:

1 Why do kebabs cook faster on metal skewers than on wooden ones?

2 Why is the top of an oven the hottest part?

3 Why, when you eat apple crumble, does the apple seem hotter than the crumble?
This can be related to (a) the lower thermal conductivity of crumble, and (b) the higher specific heat capacity of apple. The higher specific heat capacity of apple is due to its higher water content. The values below are in J $kg^{-1}$ $K^{-1}$:

| | |
|---|---|
| water | 4200 |
| apple | about 3700 |
| crumble | about 2900 |

4 Roasting instructions for two joints of beef:

| *Mass / kg* | *Oven temperature / °C* | *Cooking time / min* |
|---|---|---|
| 1.5 | 180 | 60 |
| 3.0 | 160 | 140 |

Why is the larger joint
(a) roasted at a lower temperature,
(b) roasted for longer?
(Both thermal conductivity and heat capacity are important here.)

5 How does a meat thermometer work?

6 Why does food burn (or 'catch') more easily when heated in a cheap, thin saucepan than a heavy, thick-based pan?

## Other resources

The Nuffield Home Economics course (published by Hutchinson) is an excellent source of information and activities relating to the scientific principles of cooking.

Practically any recipe from a cookery book is a source of ideas to illustrate scientific principles.

# PHYSICS AND COOKING

Boiled eggs, sponge cake, Baked Alaska — you may have enjoyed all these at different times. But like all cooked food, they depend on the skill of the cook.

Cooks perform fantastic feats of physics. They make instant estimates of thermal conductivity and heat capacity. They are geniuses at controlling the transfer of heat for the complex chemical changes involved in the cooking of food.

In this unit, we will apply some basic principles of physics to three simple recipes. If possible, you should try out the recipes for yourself.

You will probably have covered the basic principles in your science or physics lessons. Here is a simple summary.

## Part 1 — Some important principles

### 1 Heat transfer

Heat is transferred from one place to another in three ways:

(a) *Conduction* The flow of heat through a substance from places of higher temperature to places of lower temperature, without the substance itself moving. Conduction allows heat to travel to the centre of a potato when it is cooked (Figure 1).

Some substances conduct heat better than others. Metals are good conductors. Air is a poor conductor (a good insulator).

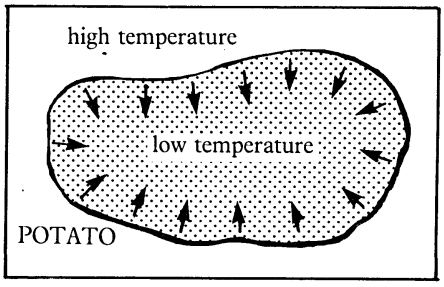


*Figure 1 Conduction of heat to the centre of a potato*

(b) *Convection* The transfer of heat by the *movement* of a liquid or a gas because of temperature differences in it.

Hot liquids or gases are less dense than cool ones. They therefore rise, which makes the hot mix with the cold. Convection allows heat to travel through water when it is heated in an electric kettle (Figure 2).

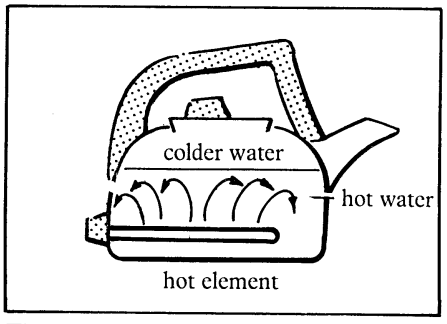


*Figure 2 Convection in an electric kettle*

(c) *Radiation* The transfer of heat as rays. These rays are infra-red rays, a form of electromagnetic radiation. They can pass through empty space.

Radiation allows heat to pass from a hot grill to a piece of toasting bread (Figure 3).

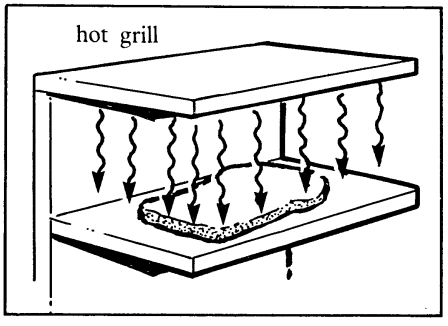


*Figure 3 Heating toast by radiation*

## 2 Surface area

Objects gain or lose heat through their surfaces. The larger the surface area, the faster heat can be gained or lost. For any object, the surface area can be increased by cutting it up into smaller pieces. This is why potatoes cook faster when cut into pieces (Figure 4).

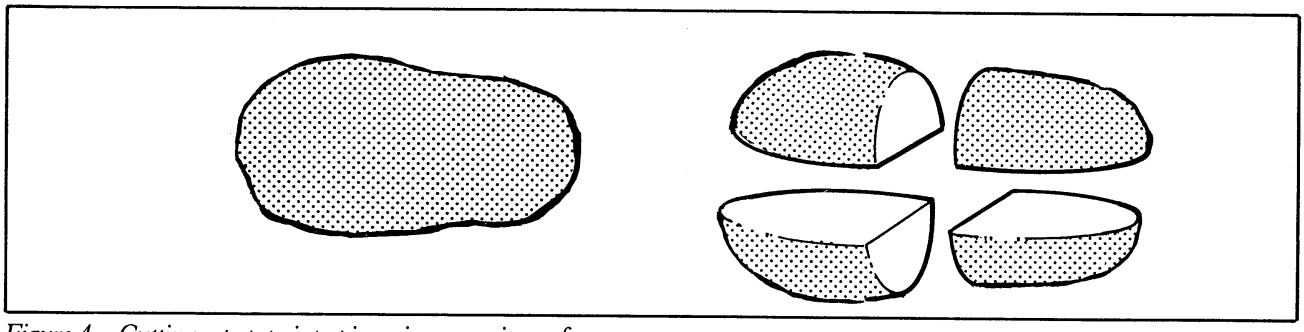

*Figure 4 Cutting a potato into pieces increases its surface area*

## 3 Expansion

All substances expand when they are heated. Gases expand much more than solids or liquids, for a given rise in temperature.

# Part 2 — Boiling eggs

### Recipe for soft-boiled eggs

Carefully lower the eggs into gently boiling water and cook them for four minutes (Figure 5).

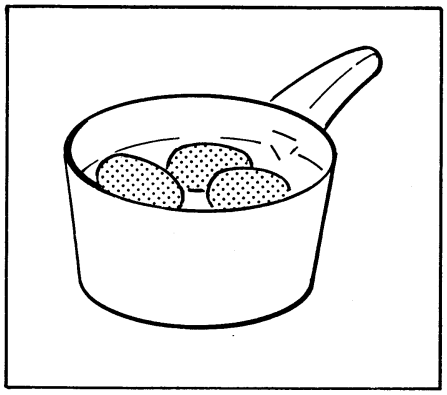

*Figure 5 Boiling eggs*

*Questions*

1 *Describe*
   *(a) how you like your 'perfect' boiled egg*
   *(b) what a four-minute boiled egg is like*

2 *By which process, conduction, convection or radiation, does heat*
   *(a) pass through the base of the saucepan*
   *(b) spread through the water*
   *(c) pass into the eggs?*

3 *Why does heat flow into, not out of, the eggs?*

4 *Does heat reach the middle of an egg immediately cooking begins? Give a reason for your answer.*

*This recipe does not mention the size of the eggs. It also assumes that the eggs have been stored at room temperature.*

5 *Describe, giving reasons, what you would have to do to cope with*
   *(a) different sizes of eggs*
   *(b) eggs which had been stored in a refrigerator.*

6 *It takes longer to boil an egg at the top of a mountain than at sea level. Try to explain why.*

## Part 3 — Sponge cakes

Good food has a variety of colours, flavours and textures. Think how the texture of crusty bread or of crisp Yorkshire pudding contrasts with the soft inside.

Even a boiled egg has two contrasting textures: a firm 'white' but a soft, runny yolk.

Cooking a boiled egg is simple because

1 All eggs are of roughly the same shape and mass

2 The cooking temperature is fixed at the boiling point of water.

Usually there are more variables to control. Take sponge cakes as an example. This recipe can be used either for a sponge sandwich or for small cakes. Try it for yourself.

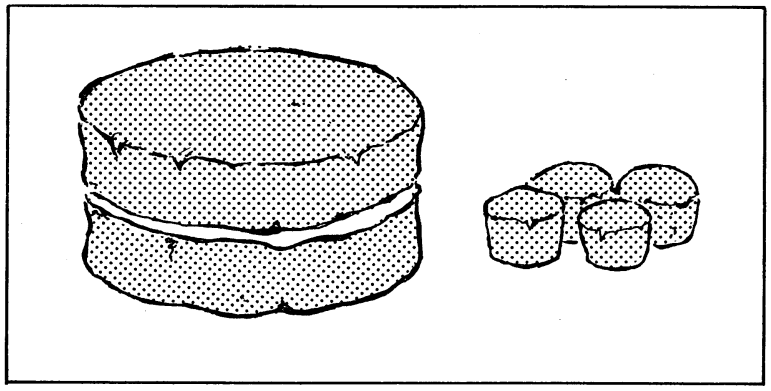

*Figure 6 Sponge cakes*

### Recipe for sponge sandwich cake or small cakes

0.1 kg margarine
0.1 kg caster sugar
0.1 kg self-raising flour
(0.1 kg is about 4 ounces)
2 eggs

1 Beat the margarine and sugar together with an electric mixer or a wooden spoon until the mixture is light and fluffy.
2 Gently beat the eggs together in a basin.
3 Add the eggs a little at a time to the margarine/sugar mixture.
4 Gently stir in the flour. Mix thoroughly.
5 Bake in greased tins according to Table 1.

*Table 1 Baking temperatures and times for sponge cakes*

| *Cake* | *Baked in* | *Temperature/ °C* | *Time/min* |
|---|---|---|---|
| sandwich cake | 2 sandwich tins (about 180mm diameter) | 180 (350°F, gas mark 4) | 20 |
| small cakes | 10 small tins or paper cases | 190 (375°F, gas mark 5) | 15 |

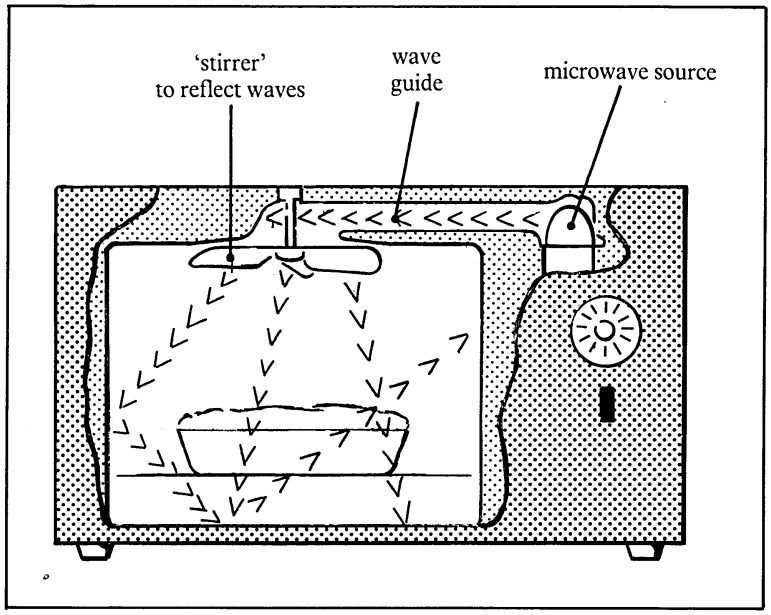


*Figure 7 A microwave oven*

Sponge cakes, and many other foods, can be cooked very quickly in a microwave oven (Figure 7). These ovens heat food using microwave radiation. Here are some properties of microwaves.

- They are a form of electromagnetic radiation. They travel at the speed of light and have a wavelength of 122 mm.
- They are absorbed by water. Water gets hot when it absorbs microwaves, because the microwaves make the water molecules vibrate. This makes microwaves useful for heating food, because all food contains water.
- They pass through air, glass and plastic without causing any heating. They are reflected by metal.
- They can penetrate food to a depth of about 50 mm.

*Questions*

7 *How does heat travel from*
*(a) the oven heater to the cake*
*(b) the outside of the cake to the inside?*

8 *In which size of cake (sandwich or small) will heat reach the centre more quickly?*

9 *Explain why the spongy texture makes this type of cake a very poor conductor of heat.*

10 *Why do sponge cakes*
*(a) rise in the oven?*
*(b) flop if they are taken out too soon?*

11 *The larger sponge cake is baked in a cooler oven than the smaller cakes. This is because when a large cake is baked in a hot oven, it gets burnt on the outside before it is completely cooked in the middle. Why does this happen?*

*Question*

12 *Explain the following about microwave cookery:*

*(a) Microwave ovens cook food much more quickly than ordinary ovens*

*(b) Food baked in microwave ovens is not brown on the outside*

*(c) Food to be baked in microwave ovens must not be put in metal tins*

*(d) Plastic containers can be used in microwave ovens, but not in ordinary ovens*

*(e) To bake a good sponge cake in a microwave oven, you need to add a little water to the cake mixture.*

## Part 4 — Baked Alaska

Baked Alaska is a hot ice cream dessert. It is made of ice cream, sponge cake and soft meringue (Figure 8).It is baked in a hot oven until the peaks of the meringue are golden.

But why doesn't the ice cream melt?

Try it yourself and find out. The recipe given below is very easy.

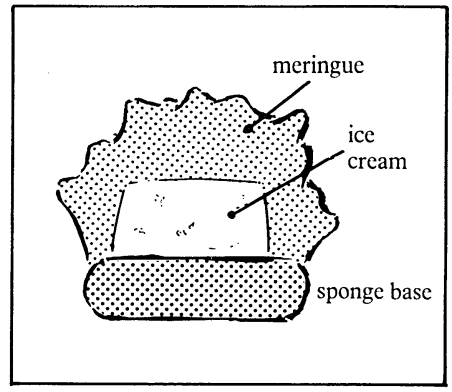


*Figure 8 Cross-section through a Baked Alaska*

### Recipe for Baked Alaska

sponge cake, 180 mm diameter approximately (buy one or use the recipe in Part 3 to make your own)
family size block of vanilla ice cream
raspberry sauce or jam
3-4 egg whites
0.1 kg caster sugar (about 4 ounces)

1 Preheat the oven to 230°C (450°F, gas mark 8).

2 Place the sponge cake on a flat heatproof dish.

3 Spread the raspberry sauce or jam on the top of the sponge.

4 Make the meringue by whisking the egg whites until they are stiff (use an electric mixer if you have one). Add the sugar and whisk again.

5 Place the ice cream on the sponge cake, and spread the meringue mixture carefully all over it. Make sure that there are no gaps.

6 Bake in the hot oven for three minutes until the outside of the meringue just begins to turn golden brown.

7 Serve immediately.

*Questions*

*13 Both meringue and sponge cake are good insulators. Explain why.*

*14 Explain why the ice cream does not melt.*

*15 The secret of success is to cook this dish in a very hot oven. Explain why.*

*16 Why is it not possible to prepare this dish in small individual portions?*