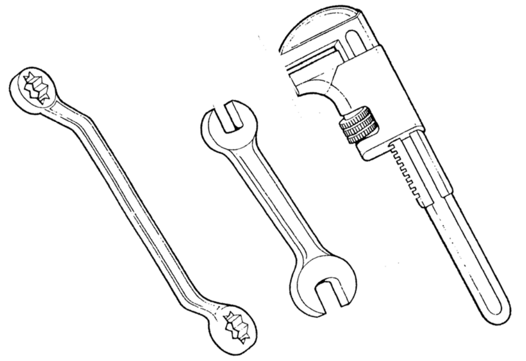
# Trade of Plumbing

## Module 1: Thermal Process and Mild Steel Pipework

## Unit 11: Heat Bending Mild Steel

## Phase 2



# Table of Contents

# List of Figures

# List of Tables

# Document Release History

| Date | Version | Comments |
|---|---|---|
| June 2006 | V.1.0 | |
| 18/02/14 | 2.0 | SOLAS transfer |
| | | |
| | | |

# Module 1 –Thermal Process and Mild Steel Pipework

## Unit 11 – Heat Bending Mild Steel Pipe

**Duration – 30 Hours**

**Learning Outcome:**

By the end of this unit each apprentice will be able to:

- Form square bends and offsets using oxy-acetylene plant.

**Key Learning Points:**

| | |
|---|---|
| M | **The circle - radius and circumference.** |
| M Sk | **Calculation of length of heat bend.** |
| Sc | **Heat transfer – conduction, convection, radiation.** |
| Sc | **Heat treatment – annealing and tempering.** |
| Sc | **Temperature scales and conversion.** |
| M Sk | **Angles and use of set squares.** |
| Sk | **Manufacture and use of templates.** |
| M Sk | **Use of oxy-acetylene plant.** |
| Sk | **Heat bending - radius bends, offsets, crossovers.** |
| Sk | **Pipe alignment.** |
| Sk | **Interpretation of drawings.** |
| Rk | **Materials list.** |
| P | **Planning, communication.** |
| Sk | **Bracketing and levelling pipework.** |
| Sk | **Cooling procedures for hot metals.** |
| H | **Hot metal, thread swarf.** |
| P | **Good working practice.** |
| Sk | **Testing pipework.** |

**Training Resources:**

Classroom facilities, information sheets, workshop facilities, sample bends.

**Exercise:**

Apprentice to answer sample questions:

Heat bending pipe exercises as per Exercises Nos. 2.1.11a and 2.1.11b, shown in the curriculum document.

**Key Learning Points Code:**

$\boxed{\text{M}}$ = Maths $\boxed{\text{D}}$= Drawing $\boxed{\text{RK}}$ = Related Knowledge $\boxed{\text{Sc}}$ = Science

$\boxed{\text{P}}$ = Personal Skills $\boxed{\text{Sk}}$ = Skill $\boxed{\text{H}}$ = Hazards

# Heat Bending

Another method of bending mild steel pipe is by the application of heat. The high temperatures required can only be achieved by the use of oxy/acetylene welding equipment. One advantage of heat bending is that pipes can be bent to different radii. In order to achieve an accurate band radius the pipe should first be loaded with sand. The sand should be fine and dry and compressed as much as possible into the pipe. The purpose of the sand is to prevent the pipe from collapsing, wrinkling and flattening during the bending process by supporting the internal walls of the tube.

## The Formula for Determining the Radius of a 90° Heat Bend

When bending a pipe to any radius it should be remembered that you are constructing part of a circle.

The parts of a circle relevant to a plumber are:

- THE CIRCUMFERENCE - the outer rim of the circle.
- THE RADIUS - a straight line from the centre of the circle to the circumference.
- THE DIAMETER - a straight line going from one side of the circumference to the other passing through the centre. The diameter is twice the length of the radius.

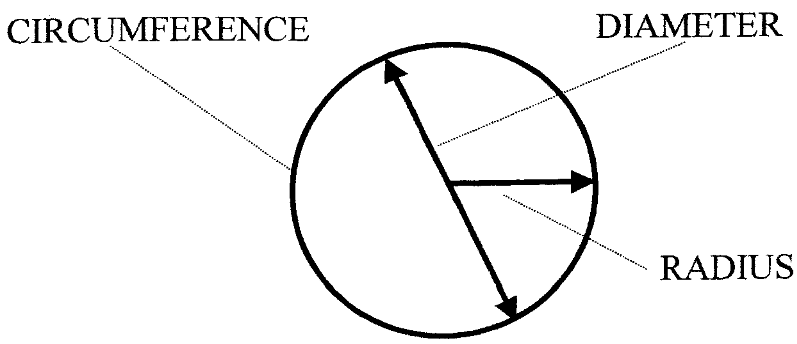



*Figure 1. Parts of a Circle*

Every circle has 360°, as shown below.

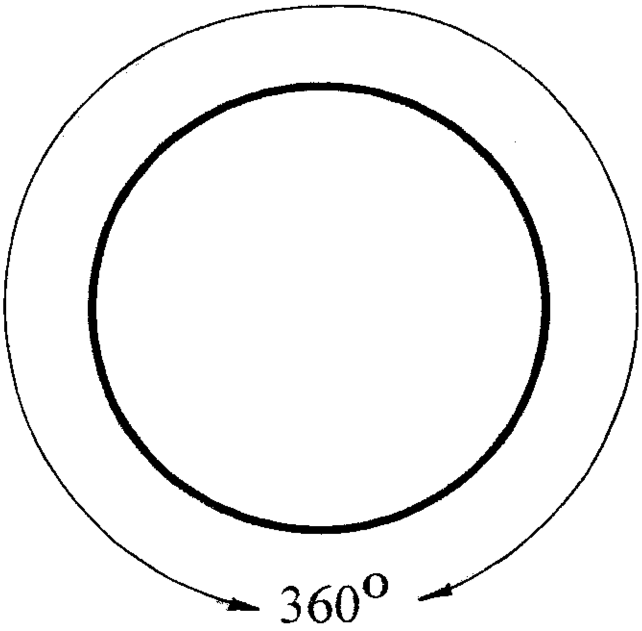



*Figure 2. 360°in a Circle*

Therefore, there are four 90° segments in every circle.

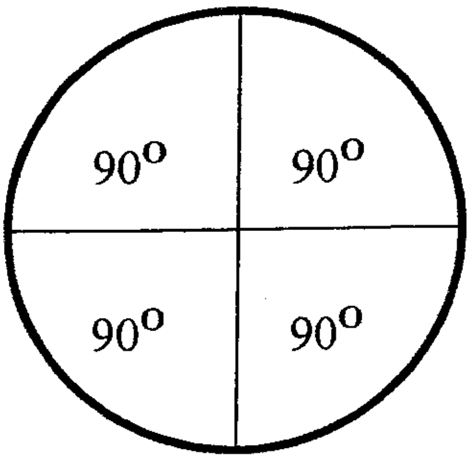



*Figure 3. Four 90° Segments in a Circle*

A 90 bend involves bending a pipe through ¼ of a circle.

In the following examples the following abbreviations will be used:

C = CIRCUMFERENCE

R = RADIUS

D = DIAMETER

**Example 1:**

Calculate the total length of heat required to bend a pipe through 90° to a radius of 75mm.

To carry out this calculation we must find the length of the circumference and divide it by 4:

If **R** = 75mm Then **D** = 150mm

**C** = π **D** Where π = 3.142

Therefore: **C** = 3.142 X 150mm

**C** = 471mm

LENGTH OF HEAT = 471 ÷ 4 = 117.75

Which can be written as 118mm.

**Example 2:**

A pipe is to be bent to a radius of 125mm and to an angle of 90°. Calculate the total length of heat required for this operation.

If **R** = 125mm Then **D** = 250mm

**C** = π **D** Where π = 3.142

Therefore: **C** = 3.142 X 250mm

**C** = 786mm

LENGTH OF HEAT = 786 ÷ 4 = 196.5mm

Which can be written as 197mm.

**Example 3:**

Calculate the length of heat required to bend a pipe through 90° to radius of 100mm.

If **R** = 100mm Then **D** = 200mm

**C** = π **D** Where π = 3.142

Therefore: **C** = 3.142 X 200mm

**C** = 628mm

LENGTH OF HEAT = 628 ÷ 4 = 157mm.

# Heat Transfer

Some knowledge of the ways in which heat is transferred is necessary to understand fully the working principles of central heating and hot water systems. There are three methods of heat transfer – conduction, convection and radiation. Each of these will be discussed separately.

## Conduction

Conduction is the transfer of heat through or along a solid. If you hold a metal rod and heat up one end with a blowtorch the other end would soon become warm. This is because the heat is being transferred through the metal. Heat travels through all materials but the speed at which it travels varies. The faster the heat travels the better the material is at conduction.

## Convection

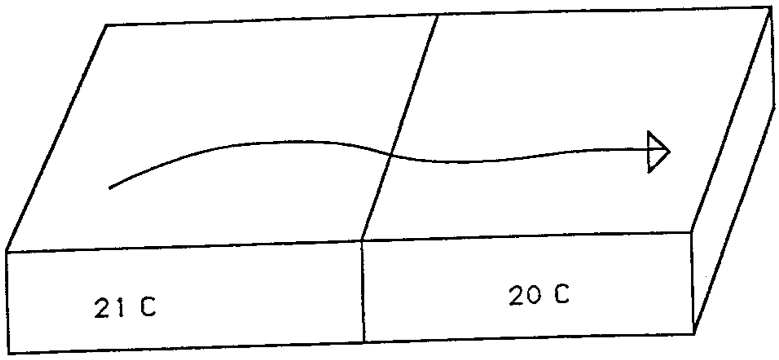
Convection is a form of heat transmission peculiar to liquids and gases. Water and air are typical materials in which it occurs. Very briefly, it may be described as the transmission of heat by the actual movement of particles of liquid or gas. This movement is caused by the change in the particles' weight brought about by a variation in their temperature.

This form of heat transfer explains the movement of heated gases up a fuel pipe or chimney; the movement of water through the circulatory pipework of a hot-water system; and the movement of heated water around the pipework and radiators of a central heating system. It also explains the movement of warmed air around a room.

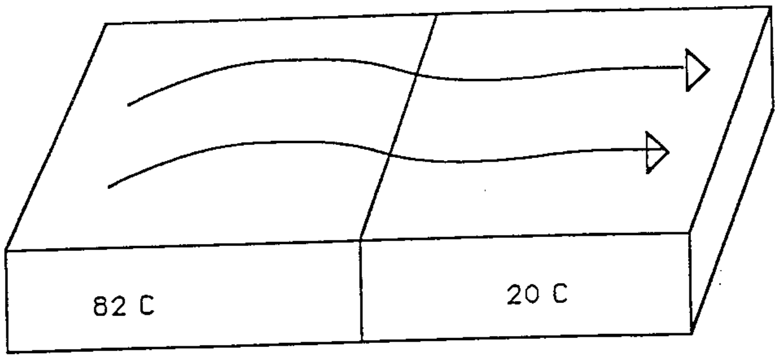
## Radiation

Radiation is the transfer of heat energy in the form of straight lines. Radiant heat will pass through the air without appreciably warming it. The heat from the sun is a good example of radiant heat as it travels through millions of miles of space to reach the earth. This heat will also pass through the air without appreciably warming it, but any solid object obstructing the rays will become warmed by them.

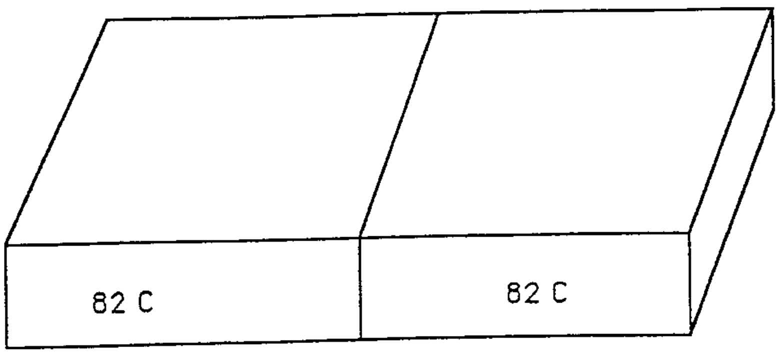
The rate at which a surface absorbs heat depends upon its colour. A blackened surface is an excellent absorber of heat as well as an excellent emitter. Objects that are good absorbers of heat are also good emitters. A surface that is painted silver will not absorb or emit heat readily.




Small temperature difference -*low rate* of heat flow




greater temperature difference -*Higher rate* of heat flow




No temperature difference - *NO* heat flow

*Figure 4. Rates of Heat Flow*

## Conduction

The transference of heat through or along a solid

## Thermal Conductivity of Materials

| | |
|---|---|
| Copper | **GOOD CONDUCTORS** |
| Aluminium | |
| Iron | |
| Glass | |
| Brick | |
| Water | |
| Wood | |
| Still Air | **BAD CONDUCTORS** |

**Convection**

The transference of heat through a Liquid or a Gas.

**Example**

Liquid: The water in a hot water cylinder is heated from the boiler below by convection currents.

Gas: Smoke from a fire is carried up the chimney by convection currents.

**Radiation**

The transference of heat from its source to another solid object through Air or Space.

**Some Examples**

From the Sun to You.

From a Fire to You.

# Methods of Heat Transfer

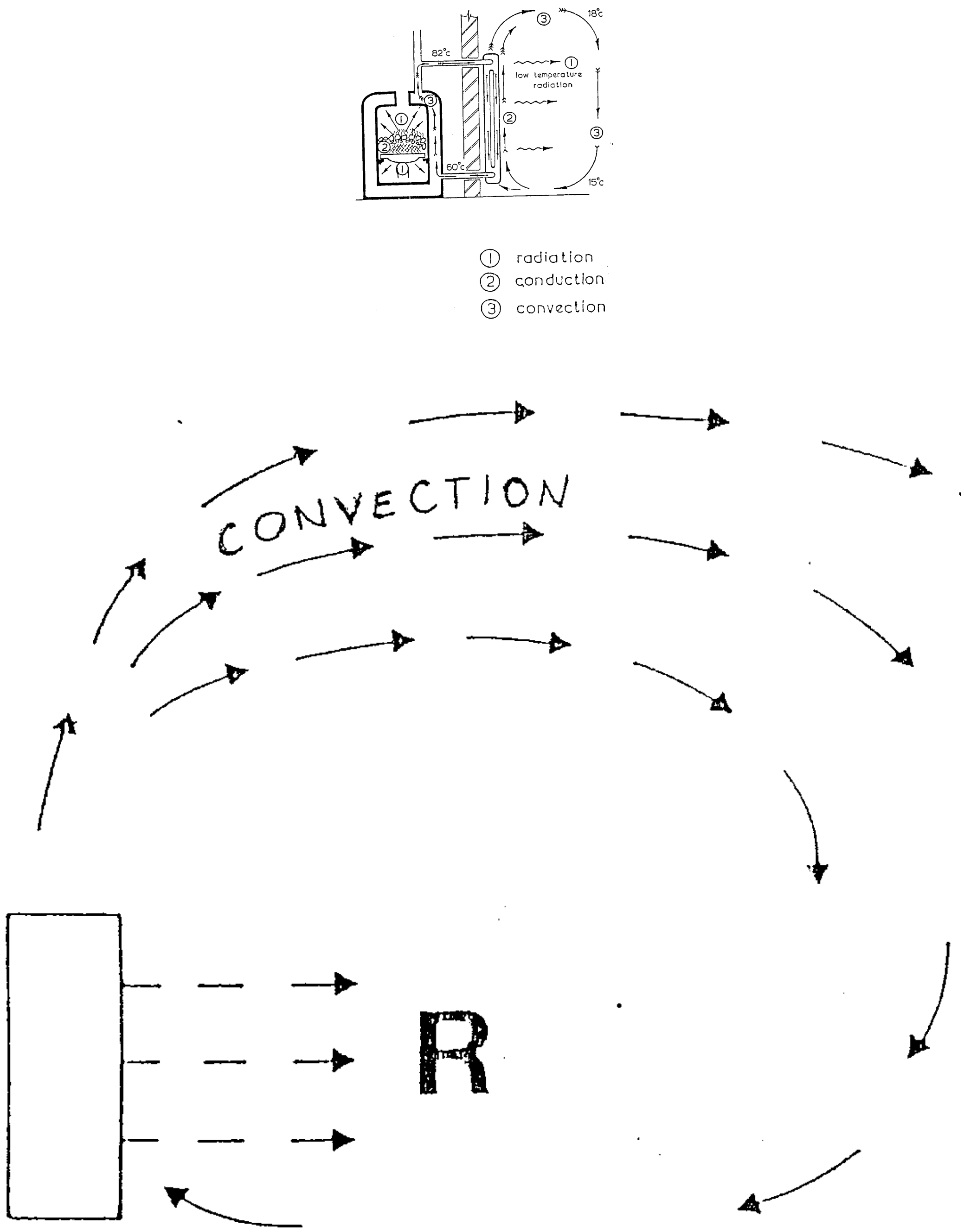



*Figure 5. Methods of Heat Transfer*

# Temperature

Temperature is a description of heat or coldness measured on any one of several scales. The temperature of a substance determines whether heat shall flow into it or out from it, normally heat flows from the hotter to the cooler substance. If two materials at different temperatures are placed in contact with one another, heat will flow from the hotter to the cooler material, and will continue to do so until the difference in temperature disappears. Furthermore, the greater the difference in temperature, the faster will be the rate of flow of the heat. Thus heat will flow from a hot radiator to warm up the air around it, but on the other hand it will also flow through the walls of a warm building to be wasted in the cooler air around it.

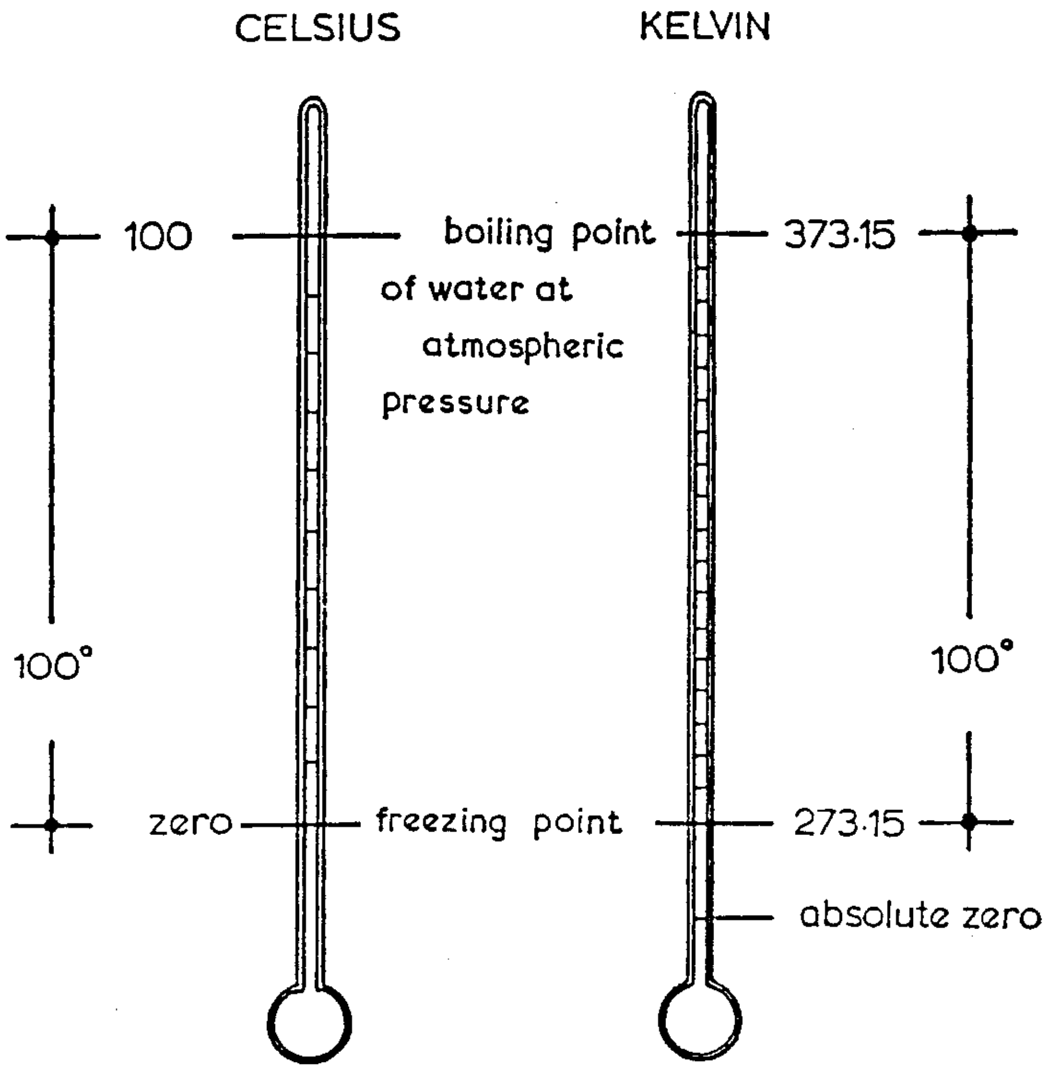
There are three temperature scales in general use, the Fahrenheit, the Celsius and the Kelvin scales.

The Kelvin scale is used in scientific work and 0º Kelvin, which is 273 degrees below 0º Celsius, is referred to as absolute zero – the lowest temperature theoretically obtainable.

$1\,^\circ K$ covers the same interval of temperature as $1\,^\circ C$

For Example, $10\,^\circ K$ equals - $263\,^\circ C$

Likewise, $100\,^\circ C$ equals $373\,^\circ K$




Thermometers

Graduations & Comparisons

°C = °K − 273·15 and °K = °C + 273·15

*Figure 6. Thermometers*

# Annealing and Tempering

**Annealing** is the treatment of a metal or alloy to reduce its brittleness and improve its ductility. Annealing is often referred to as the softening of a metal. If a metal becomes work hardened it may require softening before work is continued, otherwise it might fracture. Annealing is achieved by the application of heat.

Copper pipes are annealed before spring bending. The pipe is heated to a dull red colour and then allowed to cool or quenched in cold water.

**Tempering** or hardening, is a process of improving the characteristics of a metal, especially steel. Tempering is carried out by heating the metal to a high temperature and then cooling it, usually by quenching it in oil or water.

Cold chisels, screwdrivers, bending springs and the jaws of stilsons are examples of tools which are tempered.

# Anders Celsius

Anders Celsius was born in Sweden in 1701. He was professor of astronomy at the University of Uppsala from 1730 until 1744.

In the year 1736 he took part in an expedition to Lapland which verified Newton's theory that the earth is somewhat flat at the Poles.

In 1740 he built an observatory at Uppsala and two years later devised a temperature scale in which one degree was taken as one hundredth part of the interval between the freezing point and boiling point of water. In the original scale Celsius had water freezing at 100° and boiling at 0°. The scale was reversed three years later after his death and has remained in use ever since.

For many years this scale was referred to as the Centigrade scale but it was officially renamed Celsius in 1948.

Before his death in 1744, Anders Celsius published several papers on astronomy, the most important of which was a method of determining the distance of the Earth from the Sun.

# William Thomson (Lord Kelvin)

Any of several great scientists could be called the farther of British physics, but William Thomson (Lord Kelvin) heads the list. Thomson uncovered principles in geology, mechanics, hydrodynamic, thermodynamics, and electricity. Perhaps his greatest gift was a powerful ability to turn experimental questions into mathematical problems, and then to translate the results back to practical applications. In fact, he was distinguished both as an electrical engineer and as theoretical physicist. He breathed new life into British physics, and earned the respect of his colleagues and countrymen.

William Thomson's approach to life was always one of active curiosity. As a young boy, he and his older brother played with spinning tops and soap bubbles in an effort to understand why they behaved the way they did. Many years later, Thompson could still occasionally be found in the study blowing soap bubbles. Since his father was a professor of mathematics at the University of Glasgow, Williams's curiosity was fostered and encouraged at home. Both he and his brother, James, often attended their father's lectures and blurted out answers before the other students. Although Williams never had any children of his own, his household was always buzzing with nieces and nephews who shared in their uncle's curiosity and tried to help as well as they could.

Thomson's initiation into theoretical physics came when he was sixteen. In the summer before he entered Cambridge, he avidly read Fourier's *Theorie Analytique de la Chaleur* and Laplace's *Mecaniique Celeste.* It quickly became clear that the young boy's mathematical abilities were astonishing. Before graduating from Cambridge in 1845, he placed second in the famed Mathematical Tripos examination and later won the Smith prizes. His professors agreed that he was the most creative of all their students. Thomson quickly focused his powers on electrical theory. He worked to reconcile the various approaches of Faraday, Poisson and Coulomb. He set the stage for Maxwell's theory, but never quite accepted it as the last word. As his investigations increased in number, they also increased in breadth. He jumped into the theory of thermodynamics where he made several contributions including the definition of the Kelvin scale of absolute heat content.

Despite hundreds of honors, Thomson forever maintained that his best efforts resulted in failure. He was a modest man with patience that ultimately yielded progress. Socially, Thomson had a good sense of humor, an infectious laugh, and a friendly disposition. He loved playing game, and became absorbed in whist although the other players had to periodically remind him what a trump was. At one gala picnic, he was introduced to a young woman and he offered to fetch her an ice cream cone. She wondered out loud how anyone could make ice cream when it was so warm outside. To her subsequent delight, Thomson carefully explained the process. He had a talent for making the complex understandable to the layman. His kindness carried over to animals and, in particular, to his pets. His parrot, Dr. Redtail, was a favourite companion, and together they spent many hours whistling melodies. In what spare time he could find, Thomson loved to sail his yacht, the Lall! Rookh. It was on one of his cruises that he met his second wife.

After being knighted earlier, William Thomson became Lord Kelvin in 1892. This was only one of the many honors he received. His final honor came in 1907 when he was buried next to Sir Isaac Newton in Westminister Abbey.

# Self Assessment

**Questions:**

1. Calculate the amount of pipe to be heated to form a 900 bend with a radius of 150mm.
2. State why it may be necessary to anneal a pipe before bending.
3. State the three forms of heat transfer and where they may occur in the plumbing trade.
4. Give three examples of good conductors.
5. Calculate the total radius of heat required to bend a pipe through 90° to a radius of 175mm.
6. A pipe is to be bent to a radius of 150mm and to an angle of 90°. Calculate the total length of heat required fro this operation.
7. Calculate the length of heat required to bend a pipe through 90° to a radius of 200mm.

Answers to 5, 6 and 7 are on the next page.

## Answers

| | | |
|---|---|---|
| Question 5 | = | 87.5mm |
| Question 6 | = | 75 mm |
| Question 7 | = | 100mm |

# Index