DESIGNING AND MAKING A DESK TOP CHRONOMETER

WHAT YOU WILL LEARN

After completing this project, you should understand:

- The process of vacuum forming.
- The principles behind effective mould design.
- The working properties of thermoplastics.

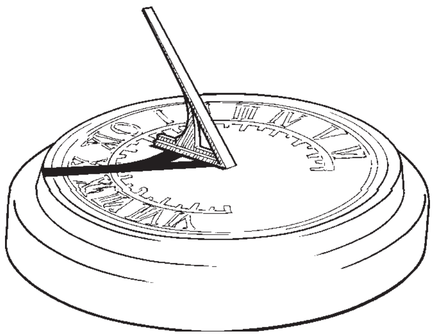
After completing this project, you should be able to:

- Work to a design brief and write a specification.
- Shape and smooth wood to produce a quality mould.
- Use a vacuum former.

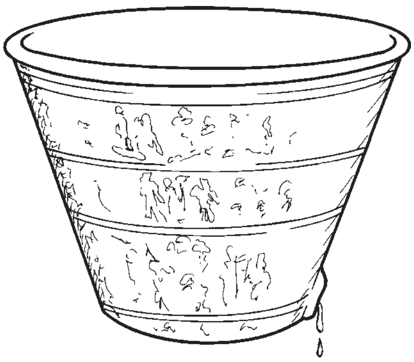
MEASURING TIME

One of the earliest means of measuring time was the sundial. Obviously a sun dial could only be used for daylight hours and so the Egyptians devised simple water clocks in the form of a bowl with a hole near the bottom. It would have been filled with water at dusk and the hours indicated by the falling water level against marks on the inside.

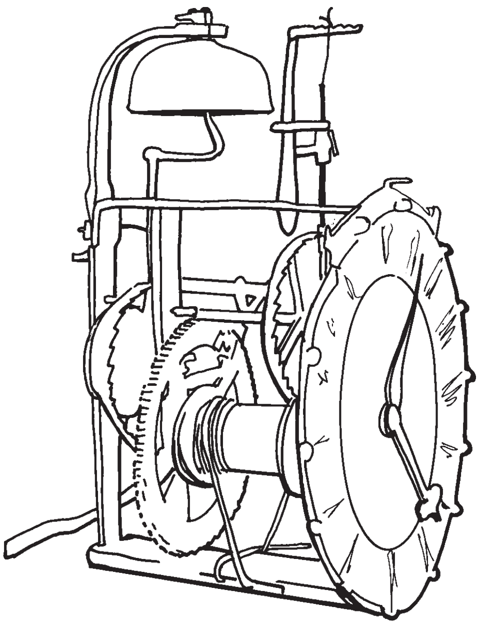
The first mechanical clock in about 1370 marked a breakthrough in timekeeping but was only accurate to within ±15 minutes per day.



Sun dial



Egyptian water clock

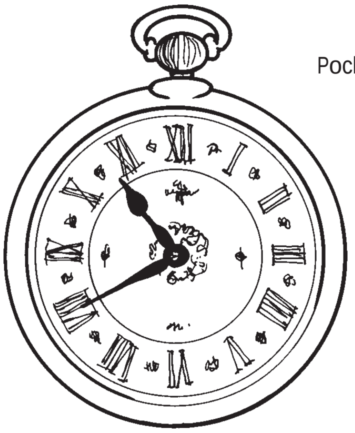


Mechanical clock

As technology and manufacturing processes improved, it became possible to make clocks smaller and more accurate. Pocket watches became available from the 17th century and the first wrist watch made its appearance in about 1800. In the 18th Century John Harrison spent 40 years building three clocks and a watch which were sufficiently accurate for use in determining longitude at sea.

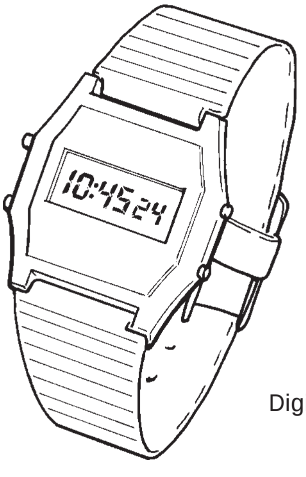
In 1957 an American designed electronic wrist watch was put into production and for the first time the accuracy of a watch could be guaranteed to a minute a month. The makers of electronic clocks and watches then made amazing progress. Some designs now incorporate solar cells on the case, that recharge the power cell when exposed to light. Others combine with wrist calculators, operated by the tip of a ball point pen. But their accuracy is their most remarkable feature. Indeed **almost any electronic quartz watch that can be bought from a shop today for just a few pounds is more accurate than the finest precision clocks of 80 years ago.**

➤ MATHS OPPORTUNITY



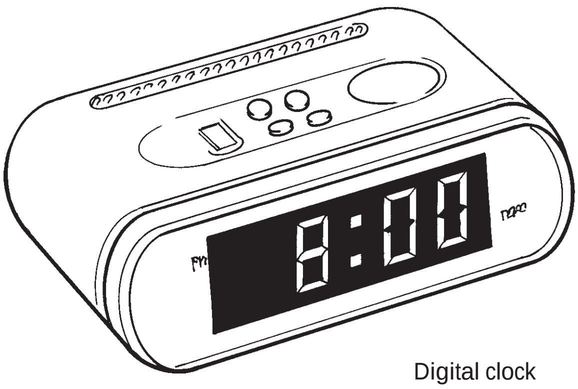
Pocket watch

Analogue watch



Digital watch

With the development of Liquid Crystal Displays (LCDs) during the 1970s and 1980s, most clocks and watches were designed with digital displays. However, the digital display did not entirely replace the traditional clock face and hands (analogue display) which many people find easier to read.



Digital clock

In a modern quartz clock movement, the hands are driven by a special electric motor which moves in small steps. The motor is driven by a circuit whose speed and accuracy is controlled by a tiny piece of quartz crystal vibrating 48 million times every second! **It is accurate to one tenth of a second per day.** Very accurate clocks used in precise measurement of time are called chronometers. An example is the type of clock used in boats for navigation.

DESIGN BRIEF

YOUR TASK

Design and make a desktop chronometer that uses a quartz clock movement. It is to be used by someone who needs a very accurate timekeeper. It should be freestanding on the surface of the desk and suitable for volume production.

DESIGN SPECIFICATION

DESCRIBING YOUR TASK

First of all you need to draw up a specification for your chronometer. A specification is a more detailed description of what a product will be like, what it will do and who will use it.

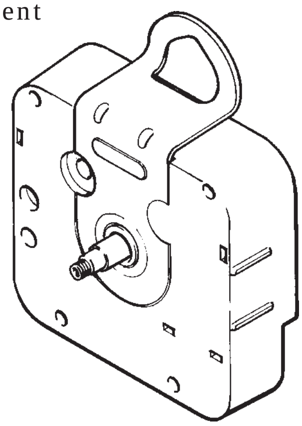
Here are some questions which will help you produce your product specification:

- Who will use the chronometer?
- What size should it be? (Remember it must be large enough to house the chronometer body!)
- Should the hands point to numbers, numerals or other indicators?
- What material will you use to house the chronometer?
- What angle should it be clearly visible from?
- How will you ensure that each one produced will be identical?

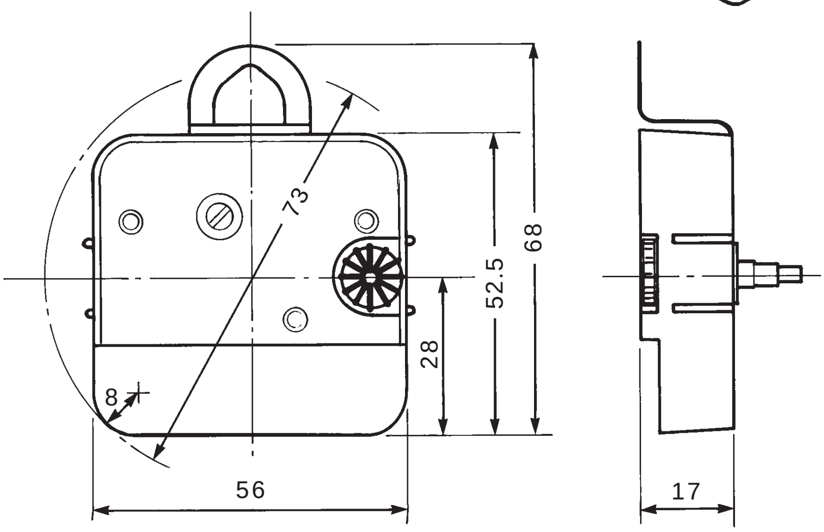
DESIGN CONSTRAINTS

MATERIALS AND COMPONENTS PROVIDED

Before you get on with your design work, you need to know what materials and equipment are available. You also need to know something about the properties of these materials and the processes involved.



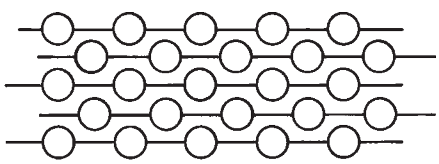
The most important component that you will need is the clock movement. A single AA size 1.5 V cell will give a running time of approximately two years. A popular type is shown with overall dimensions of - 56 mm wide, 52.5 mm high and 17 mm deep.



The chronometer case might be made from polystyrene sheet. This is available in bright colours and provides a good quality surface finish. It can easily be moulded using a process called **vacuum forming** to provide a rigid structure.

SCIENCE OPPORTUNITY

Polystyrene is a thermoplastic which allows it to be softened when heated and formed into different shapes. Once cooled, it becomes stiff and retains its new shape. The shape can be changed repeatedly with the application of heat.


Thermoplastic molecular structure

WORKING OUT YOUR DESIGN

Having considered what is available, you need to think about some ideas for the chronometer.

- *Set your ideas down on paper.*
- *Play around with your ideas.*
- *Check your ideas against your specification.*
- *Decide which is the best design.*
- *Do a detailed drawing of it.*
- *You will need to end up with a working drawing from which you or someone else can work to mark out, make and assemble the parts.*

NOTE

See Technology Study File 2.

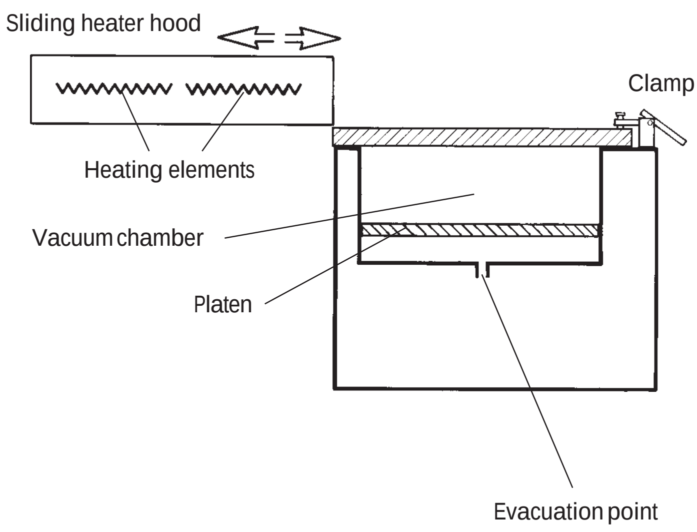
CONSIDERING APPEARANCE

Most things are designed to fit within a certain environment. An antique desk may be made of highly polished oak and adorned with blotter pad and inkwells. A modern desk may be steel framed with a brightly coloured surface and adorned with filing trays and a computer. Whatever the environment the chronometer must be designed to fit in. Size, shape and colour are obvious considerations but surface detail and the choice of hands will also be important. Consider your environment carefully and plan your design with these considerations as a priority.

HOW WILL THE CHRONOMETER BE CONSTRUCTED?

Vacuum forming is used widely in industry to produce a range of products from egg boxes to fridge liners. A sectional view of a vacuum forming machine shows three main parts.

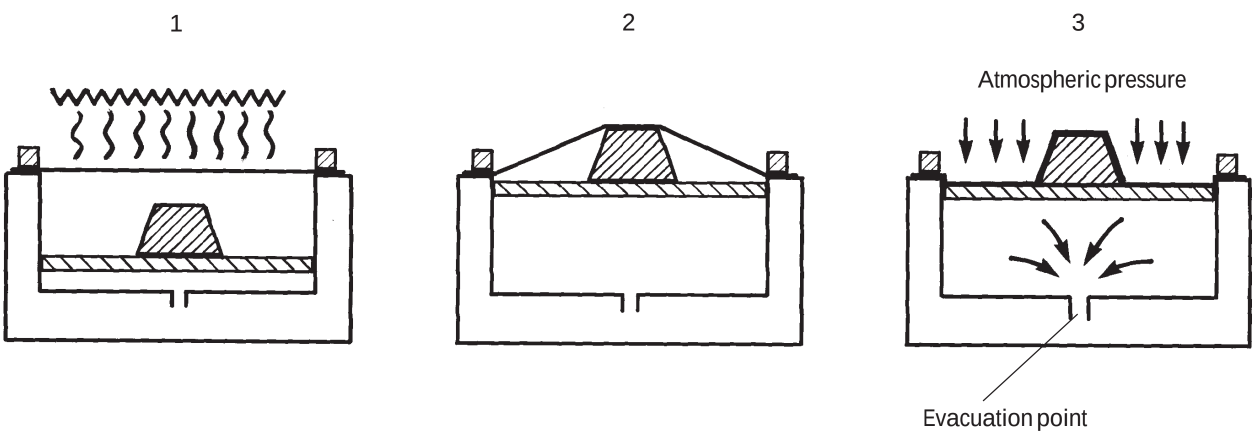
- The first is the heating element which provides heat to soften the thermoplastic and can be slid back to allow access to the clamp.
- The second main part is the clamp which secures the thermoplastic. When secured it forms an air tight seal over the chamber below and holds the thermoplastic in place during the process.
- The third part is the vacuum chamber which contains an adjustable platen or table over which the mould is placed and an evacuation point from which the air is sucked out to create a vacuum by means of a pump.



Vacuum forming uses the following sequence:

- The mould around which the thermoplastic is to be formed is placed centrally on the platen and the platen lowered to the bottom of the chamber.
- The thermoplastic sheet is clamped into place ensuring that it forms a seal all around the chamber.
- The heating elements are pulled into position and the plastic heated.
- When the thermoplastic is soft and flexible (a simple tap with your finger will allow you to judge its condition) the heating element is removed.
- The platen needs to be raised pushing the mould into the thermoplastic sheet and the vacuum pump switched on to draw the air out of the chamber.
- Atmospheric pressure will force the thermoplastic into the chamber and down onto the mould producing a reproduction in the form of a plastic shell.
- After a few seconds the vacuum pump is turned off. When cool, the thermoplastic sheet is unclamped and lifted away from the mould.
- If the pump is turned off too soon the hot thermoplastic will attempt to return to a flat sheet. 30 seconds operation of the pump should be sufficient to prevent this happening.

Warning! The hood which houses the heating element will become hot with prolonged use. Take care to slide it back and forth using the handles provided.

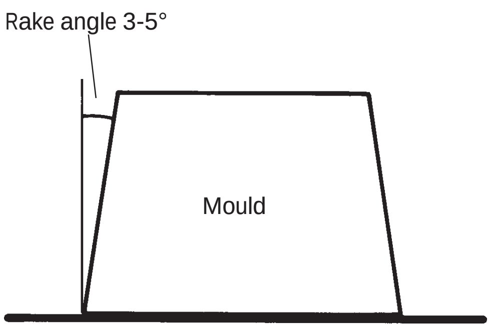


DESIGNING A MOULD

Most vacuum forming moulds are made from wood. (If a mould is to be used many times it may, once tested and found to be satisfactory, be cast in resin.) The mould can be constructed from almost any heat resistant material but MDF (medium density fibreboard) is widely used.

During the vacuum forming process the thermoplastic is stretched over the surface of the mould causing the thermoplastic to get thinner in places. The stretching is rarely even and results in over-thinning of the material at one or more places making it weak. The height of a mould affects the amount of stretching and therefore moulds should be kept shallow if possible.

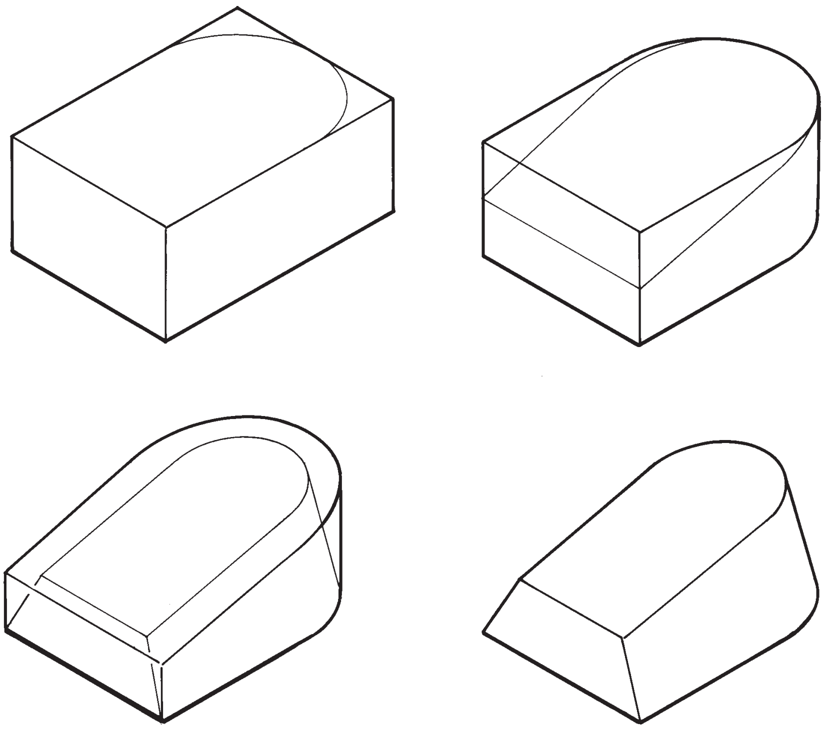
The best made moulds will fall easily from the thermoplastic when formed. In industry it is imperative that a mould can be removed and replaced as quickly as possible and so they are manufactured to give the best moulding effect with good releasing properties. If the mould is to be removed successfully, the base of the mould must be larger than the top of the mould.



A wooden mould needs to have all vertical sides finished to an angle of between 3 and 5 degrees. This is called the rake angle and results in the top of the mould being smaller than the bottom. Whereever possible the corners are rounded rather than left sharp as sharp corners give more resistance to the thermoplastic and are likely to puncture the surface or cause webbing when forming occurs.

MAKING A MOULD

Once the mould has been designed, the process of shaping can begin. Select an appropriately sized piece of MDF or other material and mark out your design on the top surface in accordance with the plan view from your detailed drawing. You may need to glue two or three pieces of material together to achieve the required thickness. Carefully cut the outline shape a little larger than required. With the plan view cut, carefully mark the side view and again cut roughly to size. Your mould should now start to resemble the shape of your design.



Shaping the mould

The next stage is to use a belt or disc sander to refine the shape, making sure that the mould is held firmly against the bed of the sander. The rake angle can be added at this point. Ask your teacher to adjust the sander bed to an angle of between 3 and 5 degrees and with the base of your mould sitting firmly on the bed create the angle all around your mould. Final shaping can be achieved using a rasp, general purpose files and glass paper.

SURFACE FINISH

Vacuum forming can give excellent reproduction of detail particularly with thin polystyrene sheet. This means that any unwanted indentations, roughness, or saw cut marks will show up on the surface of the polystyrene. A professional mould maker will often spend hours on a mould using progressively finer grades of glasspaper until the surface finish is without blemish.

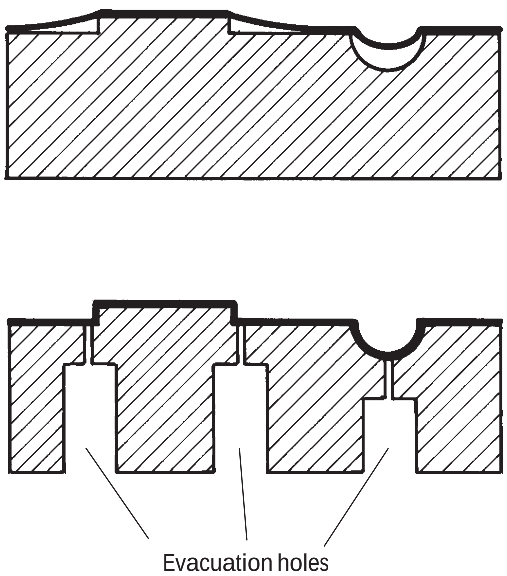
SURFACE DETAIL

Sometimes surface detail is added to a mould. For example, if a moulding needs to be drilled after forming, a small indentation in the appropriate place on the mould will produce a small indentation on every moulding taken from it, showing the drilling position.

Detail can be added to the mould in the form of relief lettering or numbers. These might be cut from a sheet of 3 mm hardboard and attached to the top surface of the mould with double sided tape. Care must be taken not to place letters or numbers too close together, otherwise the thermoplastic will bridge the gap between them rather than pulling right down to the surface of the mould.

When forming takes place, pockets of air can become trapped around points of surface detail preventing the plastic taking up shape.

To prevent this, evacuation holes must be provided. These holes go right through the mould. They are usually small diameter on the surface so as not to leave an impression on the thermoplastic, but larger underneath to facilitate good airflow. Evacuation holes need to be drilled at a number of points around any detail.

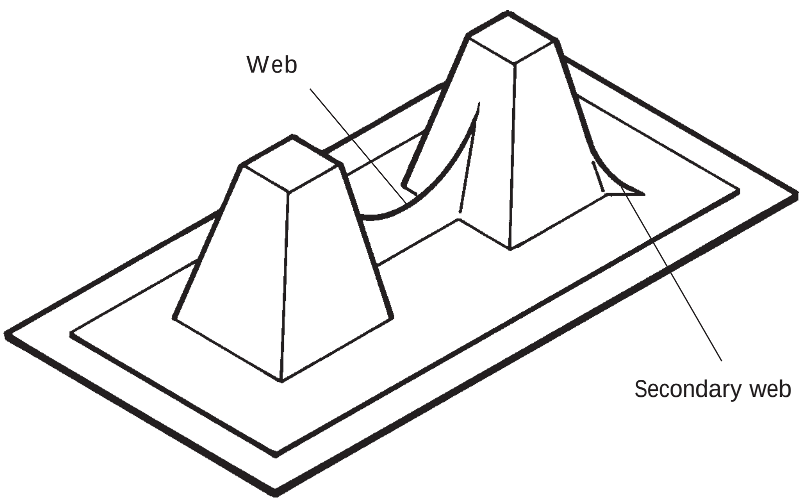


WEBBING

Webbing is a common fault in vacuum forming. It usually occurs between two high points of a mould or at a corner. The commercial answer to webbing is to mount a frame roughly matching the mould on an overhead ram which pushes the material down whilst the vacuum stage takes place. Probably the simplest method of overcoming this problem in school is to use a stiff piece of card and assist the machine at the appropriate point by gently applying pressure just before and during the vacuum stage.

Warning! The polystyrene sheet will be very hot during the forming stage. If you do need to push the plastic down during forming make sure your fingers are protected.

If this fails to cure the problem then a redesign of the mould must be considered.



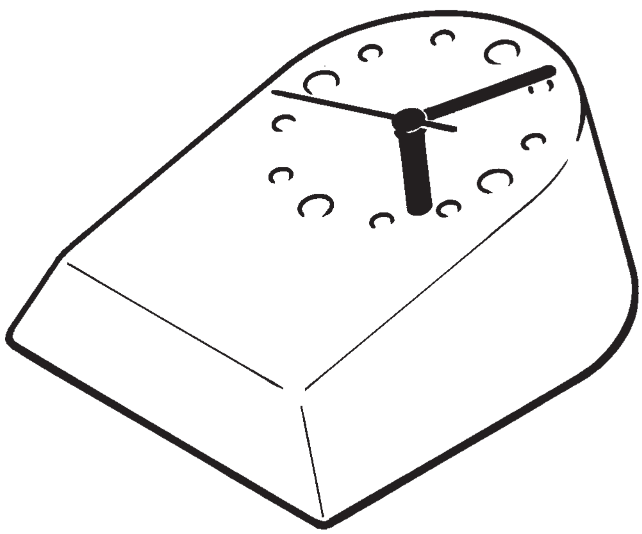
TRIMMING THE MOULDING

Your completed moulding will have waste around its edge which needs removing. This is done in industry using a variety of machine methods. In school polystyrene can be roughly trimmed to shape with a coping saw or strong scissors. Final finishing around the edges can be achieved using glass paper or wet and dry paper glued to a flat board. The bottom of the moulding is rubbed over this board in circular movements.

PUTTING IT ALL TOGETHER

Your moulding will need to be drilled to attach the clock movement. Drilling is best done using a hand drill with the mould inside the forming for support. The movement should be inserted from below so that the locking thread protrudes through the hole to be secured by means of the nut provided. Once in place, the hands can be push fitted onto the spindles.

You may wish to add further surface detail to your chronometer after moulding. Make sure that any further surface detail added allows sufficient clearance between the moulding and leaves the clock hands free to rotate.



EVALUATION OF THE PRODUCT

There are a number of things to consider when evaluating the success of your desktop chronometer.

- Does your chronometer meet your specification? Consider all of the points you originally listed.
- Was the mould successful and did it enable you to make what you intended?
- Does the chronometer display the time clearly?
- Costs. What do you estimate your chronometer cost to make (including the mould and your time to make it)? How much would 10 cost to make as opposed to just 1?
- How does its appearance compare with other clocks you can buy?