British Horological Institute

Practical Clock and Watch Servicing

Distance Learning Course

Technician Grade

Introduction

Version 2

BRITISH HOROLOGICAL INSTITUTE
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Founded in 1858, the British Horological Institute is the professional body for clock and watch makers and repairers in the UK. It provides information, education, professional standards and support to its members around the world.

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Contents

Welcome!

Welcome to the Practical Clock and Watch Servicing – Technician Grade of the Distance Learning Course (DLC) produced by the British Horological Institute, the professional body for horologists in the United Kingdom. We also have many overseas members who join the Institute and use the Distance Learning Course. This course, combined with experience gained through practice, will give you the skills, understanding and knowledge you need to become a competent technician.

Figure 1 – learning can be great fun too!

Horology is both a science and a craft. Most of our effort in this course will concentrate on the craft. You will learn how to repair and service basic clocks and watches. Further grades of study will enable you to undertake more complex repairs.

It is, however, important to understand the theory, because it helps you understand **why** something happens, and why a clock or watch is designed in a particular way. Without understanding the theory you will find the actual servicing of clocks and watches much more difficult.

Clocks were first made long before "engineering" in the modern sense existed, and many clocks still retain features that do not align with modern engineering practices. Having an engineering background is a good start, but you may need to put aside some of your preconceptions. Regardless of your background, this course is designed to lead you on your way to becoming an expert.

Why it is a good thing to learn

Nowadays many people use low cost quartz clocks and watches to tell the time; they do the job exceptionally well. However, people still enjoy owning and using mechanical watches and clocks because of the enduring fascination that electronic devices cannot offer. Also, many timekeepers have a strong sentimental value to the owner and some have historical significance. In recent years, Swiss mechanical watch sales have exceeded quartz watch sales by value. **All mechanical timekeepers require maintenance and repair – cleaning, lubrication and the replacement of worn parts** and, in fact, the demand for clock and watch repairs is as high as it has ever been.

If you are considering horology as a career, you will be successful providing you do an excellent job. You will be able to work with a wide variety of timekeepers and gain tremendous satisfaction from maintaining and adding value to everything that passes through your hands.

Even if you do not wish to become professional, you should learn to do the work well and will be able to take great pride in your achievements. Working on your own collection is an excellent pastime, and you will be able to sell it or pass it on knowing you have left it in better condition than you found it.

Another benefit of following the Distance Learning Course is that it will require you to tackle types of watch and clock that you felt might be beyond your capability. Many former students have greatly benefitted from being "forced" to study and repair a wide variety of clocks, and this has resulted in them acquiring a far greater level of confidence and skill than would otherwise have been the case.

Will I be able to learn this?

This course is designed to help people with a wide range of abilities; you will need a certain amount of mechanical aptitude but usually this can be achieved with practice. Unless you are designing you own clock from scratch, there is very little mathematics required in horology; it is mainly just basic arithmetic.

How this course is structured

The Technician Grade Distance Learning Course (DLC) is the first of the new courses which follow the syllabus for the BHI / EAL 'Diploma' examinations. The Institute works with the Awarding Body EAL (Excellence, Achievement and Learning Ltd.) to provide nationally accredited examinations for clock and watchmaking. This means that the awards meet the same standards for quality assurance as other accredited qualifications and have been designed to meet the needs of the horological industry.

- The Technician Grade (or 'first year' course) prepares students for the first examination, the *Diploma in Clock and Watch Servicing*.
- Currently, the Intermediate Grade (or 'second year' course) prepares students for the first year of the *Diploma in the Servicing and Repair of Clocks / Watches* or the *Diploma in the Repair, Restoration and Conservation of Clocks / Watches*.
- Currently, the Final Grade (or 'third year' course) prepares students for the second year of the *Diploma in the Servicing and Repair of Clocks / Watches* and the second year of the *Diploma in the Repair, Restoration and Conservation of Clocks / Watches*.
- New Distance Learning Courses are being developed to replace the Intermediate and Final Grades. The new courses will be called the 'Professional Grade'; there will be a 'clock' course and a 'watch' course. For the interim period, the syllabus for the theory examination units has been referenced to the existing Intermediate and Final Grades. The syllabus for each qualification, together with specimen examination papers are available on the BHI website.

This book is yours to keep. Feel free to write notes in the left margin, which is made wide for this purpose.

Make sure you read these boxes as they contain supplementary information which adds detail to the main text.

This is the first year of the course – the Technician Grade – and it consists of:

- Introduction (this book)
- Lessons 1 to 12

__Written exercises__ We strongly recommend that once you have written your answer you re-read the question to check that:

a) you have answered the question set

b) you have answered all parts.

Practical exercises:
For students who have purchased the Tutor Feedback option, guidance on completing, packaging and sending your practical exercises is given in Section 9 of Lesson 1.

Lessons

Each year of the course consists of twelve Lessons. Each Lesson has some theory and some practical content, and at the end of each Lesson are exercises, both written and practical.

Although you can progress at any speed, the Lessons are nominally intended to be undertaken one per month, so each part of the course would last a year, and the whole course would last three years. That is why most people refer to each part of the course as a "year", and this is informally known as the "first year course".

Assessment of your exercises

In any endeavour, critical assessment whether it be self-assessment or assessment by another person is very valuable. The BHI is able to offer a Tutor Feedback correspondence service for students purchasing this course for both the written and practical exercises at the end of each Lesson.

If you have paid for Tutor Feedback, you can send your answers to the written exercises and your practical exercise work to a BHI tutor and gain feedback on your progress, along with corrections and comments on your answers.

Students may submit their written exercise answers for assessment by E-mail. If you do, make sure any image files you attach are saved in a universally readable format (e.g. JPEG).

Marks are awarded as a guide only; in an examination there will be no access to Lessons, notes, etc., so your mark may not reflect your achievement in an examination.

Details of the Tutor Feedback option are given on the BHI website.

Examinations

You may wonder how examinations can help you in your studies to become a clock or watchmaker.

Examinations provide a target for learning and enable you to check your progress against recognised standards. The qualifications are nationally accredited; students in the United Kingdom and abroad enter the examinations annually.

The challenge of gaining individual units which lead to a recognised qualification will contribute to your determination to progress. The content of this Technician Grade course is based on the syllabus for the qualification, the *Diploma in Clock and Watch Servicing*.

Syllabus Units for the Diploma in Clock and Watch Servicing

The examinations are held in May / June each year. If you wish to gain the Diploma in Clock and Watch Servicing you must enter the following units:

D1 : Theory of Clock and Watch Servicing

D2 : Constructing Clock Components

and either…

D3 : Servicing and Correcting Faults in a Single Train Clock Movement

or…

D4 : Servicing and Correcting Faults in a Quartz Watch

The Technician Grade covers the syllabus for all of these Units.

Figure 2 – the examination centre at Upton Hall

Study Streams

Each Lesson in this Technician Grade course is split into five "streams":

1) ***Knowledge and Understanding:*** all of the material in this stream is within the syllabus for Unit D1 : *Theory of Clock and Watch Servicing*.

2) ***Workshop Skills:*** The entire syllabus for Unit D2 : *Constructing* Clock *Components* is covered in this stream. Some of the aspects are also included in the syllabus for Unit D1 : *Theory of Clock and Watch Servicing*.

3) ***Clock Servicing Skills:*** this covers all the clock-related practical work for Unit D3 : *Servicing and Correcting Faults in a Single Train Clock Movement*. Some of the aspects are also included in the syllabus for Unit D1 : *Theory of Clock and Watch Servicing*.

4) ***Watch Servicing Skills:*** this covers all the watch-related practical work for the Unit D4 : *Servicing and Correcting Faults in a Quartz Watch.* Some of the aspects are also included in the syllabus for Unit D1 : *Theory of Clock and Watch Servicing*.

5) ***The Practical Exercise:*** there is a practical exercise in each Lesson to enable you to learn the use of hand and machine tools to make small components. Making these exercises will cover the skills required for Unit D2 : *Constructing Clock Components*

A word about technical drawing

Technical Drawing was an optional Unit in the previously accredited qualification but is not required for the *Diploma in Clock and Watch Servicing*. It is therefore not included as part of the Technician Grade Distance Learning Course.

An understanding of Technical Drawing is useful to help the student develop the ability to make and understand drawings and sketches of clock and watch parts. The Professional Grade course includes details of the geometrical drawing constructions for escapement design and Technical Drawing skills.

Setting up your workshop

You can repair clocks and watches with little more than a table and a clamp-on vice. However, it is far more effective to have a space dedicated to the task, so you can leave your work-in-progress on the bench and have somewhere convenient to store your tools and parts.

If you have a choice (which is most unusual), select a room which avoids working in direct sunlight.

Look to your kitchen for an example of what a good workshop looks like. The surfaces are smooth and durable and the room is well lit. There are cupboards and a sink. Indeed, the kitchen is a workshop in its own right. However, we do not advocate using your kitchen as a workshop for clocks and watches, but as an example of what you should aim for, an ideal workshop has plenty of storage, plenty of smooth flat surfaces, good lighting, a generous supply of electrical sockets, a smooth, easily cleaned floor, and a sink.

Figure 3 – a watchmaker's bench. Note the adjustable lamp and height of the bench, both of which facilitate comfortable working

Bench

You will require some sort of work surface. Purpose made commercial benches are quite expensive – Figure 3 – but it is often possible to make your own bench.

It is important that you adopt a good posture when working at the bench. Your back should be straight, and you should not be hunched over the work. For horological work you want the bench quite high. For clock pathway students a height of 900 mm is a good start (which is the UK standard height for a kitchen worktop). For a watch workshop 1100 mm height is probably a more appropriate starting point. A normal table or desk is somewhat lower at about 700 to 750 mm in height.

Figure 4 – for larger clockmaker's work a normal desk or table height in a well-lit workshop is fine

Stool or Chair

Watch pathway students will ideally need a chair which runs smoothly on castors, turns about its axis and is adjustable in height. Clock pathway students may find a stool more convenient. The stool or chair should be matched to the bench for height; the most important consideration is that you do not suffer from back strain from hours sitting in a poor posture.

Where there is a danger of electrocution should a bulb be broken (e.g. if used in conjunction with a lathe or "wet" cleaning station), consideration should be given to selecting lamps designed to take low-voltage (less than 50 volts) halogen or LED bulbs.

Lighting

If you can afford it and are allowed to do it, plenty of fluorescent battens are the best for providing general illumination. Fluorescent battens with or without a diffuser taking single or twin 1200 mm, 1500 mm or 1800 mm long T8 tubes reduce shadows, which is an enormous advantage. The ones that hang from the ceiling on chains are best, because they concentrate the light closer to your work. Ideally they should be over the benches rather than in the middle of the room. This usually means mounting them parallel with the walls, and about 400mm away from the wall.

If you are selecting new fluorescent battens, the modern high-frequency battens ("the holder") offer advantages compared with the more common d-i-y store "switch-start" type; light output is slightly greater, they offer less flicker and they all but eliminate any possible stroboscopic effects with rotating machinery. The same tubes ("bulbs") can be used in either type.

For close-up work you will need one or two adjustable bench lamps.

Today there is a wide choice as to bulb types and light "whiteness". Approximate wattage equivalents for the same light output are given in Table 1, together with the available options for "whiteness"; the higher the "temperature" (measured in degrees Kelvin (K)) the whiter the light will be.

Tungsten filament *	Halogen	Fluorescent (compact or tubular)	LED
60 watt	40 watt	12 watt	5 watt
warm white	warm white	warm white, cool white, daylight	warm white, cool white, daylight
"Temperature": warm white ≈ 2 700K, cool white ≈ 3 500K, daylight ≈ 6 400K			
* Traditional tungsten filament bulbs are now banned from retail sale in some countries			

Table 1 – bulb types and power rating for equivalent light output

Figure 5 – the tutor shows how to use a fretsaw in the clock workshop

Figure 6 – buying a jewelling tool from a BHI auction

Tools

It is commonly said that you should only buy the best quality tools. However, this can be very expensive, and may not be the best use of money if you use a tool only rarely. In many cases you need to make a judgement between cost and quality. One good way to get good quality tools is to buy them second hand. Clock fairs often have stalls with used tools, and it is always worth looking to see if there is something that you will require – Figure 6.

Tools require to be kept in good condition, and you will quickly have to learn how to sharpen them, which will mean investing in one or more sharpening stones (ideally coarse, medium and fine). For the finest work Arkansas stones provide the best finish. A blunt tool is not capable of good work and is often more dangerous due to the additional cutting force needed.

Finally, you will make some tools yourself. This can be very satisfying, and you can ensure that they are of good quality.

The list given below gives many of the items which you will find necessary during this first year of study. They are not all required at the outset but can be added according to progress through the course.

- bench vice
- steel ruler 12"/300mm
- scriber
- engineer's square
- centre punch
- dividers
- files – various sizes and cuts; including a set of needle files
- hacksaw – large and small
- piercing saw
- hammers – various sizes

- micrometer, digital calliper or vernier calliper
- eye glass
- screwdrivers – various sizes; including a set of watchmaker's screwdrivers
- tweezers – various sizes and types
- movement holder
- blower
- pliers
- tool sharpening stones (coarse, medium, fine)
- Arkansas stone slip and sharpening stones
- drills – imperial and metric
- BA taps and dies – purchase according to the sizes which are required
- pin vice
- mainspring winder
- oilers
- gas blowtorch with small and larger burners
- drilling machine – A pillar drill is a very useful machine. Guidance on types of drilling machine is given in Lesson 5
- lathe – see next section.

Figure 7 – without some basic training, selecting the right lathe is very difficult

In addition, you will need consumables such as:

- several grades of wet or dry paper
- materials for polishing such as Brasso and Autosol
- pegwood and pith
- Rodico
- oils and greases
- cleaning fluids
- latex or vinyl gloves or finger cots

As you advance through your course, other equipment will be useful, though how useful each one is will depend on your primary interest (clocks or watches). These include:

- bench grinder for sharpening tools
- timing instrument suited to your main study pathway (clock or watch)
- digital multimeter (DMM) or battery tester (quartz watches)
- staking tool
- jewelling tool

For the practical examinations you may need some additional, expensive equipment. For example, watch pathway students will need to undertake water resistance tests using a testing machine, while all students may be required to service jewelled pivots. Examination centres will provide such equipment, and you should gain experience of its use before taking your examination. The BHI runs suitable courses.

Lathe

Advice on lathes is given in Lesson 6 and there are some additional comments relating to the safe use of a lathe for horology-specific operations. You should read this Lesson in some detail before investing in a lathe.

As a very simple generalisation, while a centre lathe will be of more use to a clock pathway student, a watchmaker's lathe will be more suitable for a watch pathway student. In practice, most established horologists require both types.

- ***Centre Lathe*** – To complete the later practical exercises (Lesson 6 onwards) you will ideally need a centre lathe with a through-the-headstock spindle bore of at least 4 mm or $^5/_{32}$ in. A centre height of about 45 mm is a good size to aim for.

  If the lathe does not have collets and a 'T' rest for using a graver, it may not be possible to complete all parts of the practical exercises following the recommended procedures without access to a watchmaker's lathe.

- ***Watchmaker's Lathe*** – an 8 mm lathe with a good range of collets is the best for the purpose.

  A 6 mm lathe is also good and it will be cheaper to purchase second hand. However, it will not be possible to make the Lesson 6 practical exercise without a larger lathe.

  New replacement collets can be purchased for 8 mm watchmaker's lathes but are not available for 6 mm lathes.

Figure 8 – student and tutor checking a jewel using a microscope. There is plenty of storage space in the cupboards

Storage

You need your tools to be easily accessible, but not in the way. Some self-discipline is required here; the temptation to leave tools lying around on your bench should be avoided. It slows you down as you search for them.

Low cost mechanics' tool boxes are not suitable as the tools lie in a heap and are hard to find. Toolboxes with trays and cut-outs work well, but are very expensive.

Strips of wood on the wall with holes in them, or clips screwed to them, can make good tool storage for supporting the more regularly used larger tools. Open shelves can also be useful; however, in general it is better to avoid storing tools in the open as they get very dusty. Cupboards, including kitchen-type wall cupboards proved better protection and security.

You also need to store various parts, bits and pieces. Low cost plastic storage boxes, with or without internal partitions, are available in all hardware stores, kitchen supplies, as well as supermarkets. You can also use jam jars and tins when their contents have been used. Transparent containers have obvious advantages.

Finally and most importantly you have a duty of care to your clients to keep their clocks and watches safe. You will need secure storage for them in both their assembled and disassembled state.

Materials

To make the practical exercises in the Lessons you will need materials such as brass and steel. Of course you can purchase your own materials and indeed you may already have the correct materials in stock.

Sourcing materials in small quantities is not always that easy, and many horological suppliers do not stock a wide range of material. Probably the most useful source of small quantities is companies supplying materials to model engineers.

The BHI has made arrangements with a supplier for a bespoke kit of materials that will enable you to complete your practical exercises in the Technician Grade. Students wishing to take advantage of this arrangement can find details on the BHI website.

A list of the materials required is provided on the next page.

Materials needed for practical exercises

Dimensions: This list uses mixed Imperial and metric dimensions. We are sorry about this, but it is based on the dimensions most commonly offered by UK material suppliers able to supply small quantities at the date of publication. Acceptable alternatives are suggested. ***Always check the dimensions of your material before starting your practical exercise.***

Lesson 1 – Hand removing levers			
1/1	Silver steel – 5 mm dia.	165 mm (6.1/2”) long	Half a standard 330mm (13”) length. Alternative: 3/16” dia.
1/2	Brass – 10mm dia.	25 mm (1”) long	For use as a bending former. Alternative: 3/8” dia.
Lesson 2 – Toolmaker’s square			
2/1	Gauge plate – 1/8” thick	2” wide x 2.7/16” long	Alloy steel. Cut from 50mm (2”) wide gauge plate. Alternatives: 3 mm gauge plate; 50 mm x 65 mm long
Lesson 3 – Scraper			
3/1	Gauge plate – 1/8” thick	1/2” wide x 5.1/2” long	Must be heat-treatable steel. Alternatives: 3 mm gauge plate; 12 mm x 140 mm long.
Lesson 4 – Balance stake part 1			
4/1	Brass sheet – 1/16” thick	35 mm x 30 mm	CZ108 or CZ120. Alternatives: 16 gauge; 1.5 mm
Lesson 5 – Balance stake part 2			
5/1	Gauge plate – 1 mm thick	50 mm x 35 mm	Must be heat-treatable steel. Alternatives: not less than 35 mm x 30 mm
5/2	Brass wire – 2 mm dia.	150 mm (6”) long	To make taper pins. Alternatives: 3/32 in; 13 gauge
Lesson 6 – Oilsink and countersink tools			
6/1	Silver steel – 6 mm dia.	165 mm (6.1/2”) long	Half a standard 330mm (13”) length. Alternative: 1/4” dia.
6/2	Silver steel – 4 mm dia.	165 mm (6.1/2”) long	Half a standard 330mm (13”) length. Alternative: 5/32” dia.
6/3	Brass sheet – 1/8” thick	25 mm x 25 mm	To drill test holes. CZ108 or CZ120. Alternatives: 10 gauge; 3 mm; Slice from 1/8” x 1” brass section.
	Note to student: Use a sheet/plate offcut from an earlier Lesson to make the oilsink radius gauge.		
Lesson 7 – Watchmaker’s hammer			
7/1	Brass section	1/2” x 3/8” x 2.1/2” long	CZ121 preferred.
	Note to student: If you prefer to make a steel hammer head please refer to the side box in the Lesson.		
Lesson 8 – Balance stake part 3			
8/1	Brass – 1/8” dia.	150 mm (6”) long	Alternatives: 10 gauge; 3 mm dia.
Lesson 9 – Balance stake part 4			
9/1	Silver steel – 3 mm dia.	165 mm (6.1/2”) long	Half a standard 330mm (13”) length. Alternative: 1/8 in.
Lesson 10 – Bolt tool part 1			
10/1	Brass sheet – 3 mm thick	50 mm x 25 mm	Alternatives: 10 gauge; 1/8 in.
10/2	10 BA steel screws	2 off x 3/8” long	Cheese head preferable; round or countersunk head acceptable
Lesson 11 – Bolt tool part 2			
11/1	Brass – 6 mm dia.	50 mm long	Alternative: 1/4” dia.
11/2	Brass hexagon 5/16” a/f.	50 mm long	Alternative: 8 mm a/f.
11/3	8 BA steel screws	3 off 1/2" long	Cheese head preferable; round or countersunk head acceptable
Lesson 12 – Bolt tool part 3			
12/1	Silver steel – 6 mm dia.	165 mm (6.1/2”) long	Half a standard 330mm (13”) length. Alternative: 1/4” dia.
12/2	Silver steel – 3 mm dia.	165 mm (6.1/2”) long	Half a standard 330mm (13”) length. Alternative: 1/8” dia.

Health and safety

Before going any further it is important that we mention Health and Safety issues.

First and foremost it should be remembered that you have a significant contribution to make to the health and safety of yourself as well as others. A course like this can go a considerable way towards explaining good practice, but inevitably when describing practical approaches to doing things (notably in the Practical Exercises) there is a limit to the extent of the teaching that can be included. For example, the electrical safety of the machines you use is beyond the scope of this course, while it must always be remembered that sharp edged tools and rotating machinery always represent a hazard if incorrectly or inexpertly used.

Duty of care in the workshop

Key questions you should always ask before embarking on any activity are:

1) what are the hazards that I (or others) face when undertaking this process?
2) what are the hazards if I slip or things start to go wrong?
3) how do I mitigate (reduce or eliminate) these hazards?

Of course you will recognise some hazards quite easily (like do not wear loose clothing when near a rotating machine, or do not heat components or fluids where they may get knocked over), but others you will not be able to recognise until you have some experience (e.g. sharp tools are generally safer than blunt tools, or that removing a bracket clock mainspring from a barrel can easily result in lacerated fingers if approached incorrectly).

This course draws attention to many of the hazards, but without knowing the circumstances in which a tool or process is being used or undertaken the advice cannot anticipate all situations. Consequently, at the start of your course or whenever using machinery or a process that is new to you, we strongly suggest you seek supervised training on the use of such tools and processes.

In the introduction to the practical exercise in Lesson 6 we make some comments about lathe techniques unique to horology aimed specifically at those who have limited experience in the use of a lathe.

Duty of care to the owner and others

Health and safety does not stop at the workshop door; you also have a duty of care to the owner of the clock or watch and others. The questions you should ask are similar to those applicable to the workshop.

Few clocks and watches represent a major hazard to the owner or public, but there are exceptions. Turret clocks involve considerable weights and torques and can cause extensive damage and injury if something should fail. If a longcase clock is not secured to a wall, it can easily be toppled over by a child or when removing the hood (e.g. for date setting).

Some clock mainsprings are very powerful and can cause injury to the owner's hand or wrist if they, or their associated ratchet and click, fail; it is important that you treat these components with respect and ensure that they are delivered back to the owner in the best possible condition. A few older clocks and watches may contain harmful substances such as radium on luminous dials or mercury in a glass jar pendulum, and appropriate measures must be taken to maintain them in a safe condition.

Figure 9 – Upton Hall, headquarters of the BHI

These hazards are highlighted in the course, and you should always be prepared should the unexpected happen (e.g. how would you clean up the mercury from a broken pendulum jar?).

Finally do not forget transport issues; much damage can be caused by poorly secured or packed clocks, the consequence of which may even be injury if, for example, one is distracted by a shifting package while driving the clock or watch back to its owner.

How the British Horological Institute can help

Purchasing the Distance Learning Course is the first step to becoming a skilled horologist. The course provides all the knowledge to enable you to make a start on servicing and repairing clocks and watches but to master these skills requires more than reading. It is only as a result of determination and practice that you will be able to gain the ability to confidently handle small watch components, turn and file metal accurately and finish brass and steel components to a suitable standard.

Figure 10 – silvering a chapter ring in the BHI clock workshop

Even though there are detailed step by step explanations describing, for example, how to dismantle and re-assemble a watch movement, you will only become confident and proficient by completing the exercise a number of times.

Learning these skills by distance learning is a greater challenge than actually being present at a college and receiving advice and instruction from a tutor.

Courses

The British Horological Institute arranges many short courses in the clock and watch workshops at Upton Hall. The courses are usually of two days or five days duration and accommodation is available at Upton Hall. Courses provide a learning experience beyond just the formal workshop sessions during the day; there is a chance to discuss the problems you have experienced with theory and practical work with other students and the course tutor. You will also meet and get to know colleagues and so may be able to assist one another in the future when faced with a horological problem you have not encountered before.

The workshops provide a range of equipment for students to use and skilled tutors to teach you how to undertake many of the exercises in the Distance Learning Course. In some instances there is a series of short courses to gradually extend your skills.

A list of courses is published in the *Horological Journal* each month and can be viewed on the BHI website; there is an annual programme with popular courses being offered more than once. Whether you wish to learn the basic skills required to service a quartz watch or master the repair of platform escapements there is likely to be a course to guide your learning.

Branch Meetings

Figure 11 – practical demonstrations at BHI Branch Meetings are always well-attended

Although the opportunities for overseas students are limited, there are over twenty branches of the Institute in the United Kingdom. Branches are not directed by the Council or staff of the Institute but rely on the enthusiasm of committed members to arrange a programme of evening lectures, demonstrations, visits and displays. Branch programmes are published in the *Horological Journal* and on the BHI web site, and there is the added benefit that you can make contacts and learn from others in a friendly atmosphere.

The Horological Journal

Published monthly, the *Horological Journal* includes a wide range of articles and caters for the interests of the majority of members. This Distance Learning Course provides the backbone for study but a broad knowledge of horology is desirable. Whether your enthusiasm is for classic watches or longcase clocks there are high quality articles written by authors with specialist knowledge.

Once you have completed the course, the *Horological Journal* makes a valuable contribution to your Continuing Professional Development (CPD).

Figure 12 – something for all the family at the BHI Annual Show

The Institute website

You may originally have "discovered" the Institute via the website but few have fully explored the breadth of information available. If you require guidance on planning your workshop or detailed information about ETA calibres you need look no further than the BHI website.

You can access the Members' Area by using your membership number as the username and your membership number plus the first three letters of your surname (in lowercase) as your password. There is a Discussion Forum with a separate section for Education. Perhaps your difficulty in understanding a particular topic is shared by others who can help to provide the answer?

Open days at the BHI Headquarters

There are three regular opportunities to visit the BHI Headquarters at Upton Hall: the "Spring Open Day" and "Autumn Open Day" events take place when the clocks are changed; and the annual "Summer Show" which includes trade stalls. Whenever Upton Hall is open to the public, the workshops are usually on show with demonstrations provided by members – Figure 12.

You may want to look at lathes to help you decide your most appropriate purchase, study the action of the lever escapement or seek guidance about a particular aspect of watch construction. It is likely that someone will be there who can help. There are often valuations for clocks and watches and an auction of horological items, tools and spare components. Not just a good day out but an opportunity to increase your knowledge from experts and purchase items for your workshop.

Figure 13 – a small fraction of the literature available for research in the BHI library

The Library and the Collection

In additional to the open days, members are able to use the library and the collection by arrangement for information and research. The Librarian and Curator is always willing to assist by directing students to appropriate textbooks, and every copy of the *Horological Journal* is available in bound editions.

Enquiries by letter and E-mail can often provide the answer to that important query about the historical background of a maker.

Figure 14 – clocks old and new in the entrance hall at the BHI

External training

Although outside the responsibility of the BHI, there are several organisations that can provide both theoretical and practical horological training. Some specifically prepare students for the EAL / BHI Examinations in horology. The BHI website has links to these organisations.

And finally…

All that now remains is for you to start on Lesson 1. Put in the effort and there will always be someone to help you whether it is your colleagues, through your local Branch or perhaps the web-site discussion forum. But above all enjoy your learning.

Glossary of horological terms

Addendum	The portion of a gear tooth above the pitch circle diameter.
American chuck	See Collet.
Anchor escapement	A type of clock escapement in which the pallets can resemble an anchor. Also known as a recoil escapement.
Annealing	Reducing a metal to a softer state by heat treatment.
Annular balance	A plain uncut circular balance made of a single metal or alloy.
Apparent solar time	See Solar time.
Arbor	A spindle which carries a wheel and /or pinion or other component. e.g. centre arbor.
Arc of vibration	The length of the arc described by a pendulum or balance in making a swing from one extreme to the other. Called the semi-arc of vibration if measured from the centre of swing to one extreme.
Arkansas stone	A very fine grey/white coloured natural oilstone used for polishing hard metals. (Pronounced "Ar-can-sore".)
Automatic watch	A watch wound by the normal movements of the wearer, either in the pocket or on the wrist.
Backlash	Non-productive free movement between a screw and its nut (e.g. a feedscrew) or meshing gears. See also Shake.
Balance spring	The spring controlling the balance bringing it to its neutral position. Also called the hairspring. Generally a flat spiral in shape but may occasionally be a helical (cylindrical) shape.
Balance	The oscillating wheel which determines the time interval of each vibration of a watch or platform escapement. Also called the balance wheel. There are two generic types: 1) an uncut balance which is usually mono-metallic, 2) a cut balance which is usually bi-metallic and used where significant temperature compensation is needed.
Banking	A stop pin or stop block. In the lever escapement, the part against which the lever rests while the escapement is not actually in operation. It limits the travel of the lever. In a cylinder escapement a pin – the banking pin – in the balance rim which hits a banking pin beneath the cock.

Bevel gear	Gears which connect arbors that are not parallel. Connecting arbors whose axes intersect, they are usually used to connect arbors at right angles to one another.
Bezel	That part of a watch or clock which holds the glass (or crystal) protecting the dial and hands.
Bi-metallic	Made from two different metals. A bi-metallic balance rim is made of two different metals (brass and steel) fused together to provide compensation for changes in temperature.
Birdcage movement	A clock movement with a frame constructed from bar material in the shape of a birdcage as distinct from a movement where the frame consists of plates connected by pillars. Also called a posted movement.
Blue pivot steel	Carbon steel supplied in a hardened and tempered condition which is blue in colour from its heat treatment (tempering). Used mainly where strength is required e.g. making balance staffs. Carbon content, 0.7% – 0.8% carbon.
Bluing	Colouring steel by heat treatment.
Bob	The weight attached to the end of a pendulum rod.
Boot	See Curb pins.
Boss	A cylindrical projection giving extra strength or length to a bearing hole or gear wheel.
Bouchon	A bush. Also available as lengths of hollow wire (bouchon wire).
Bow	1) A tool rather like an archer's bow, used for driving work in the turns. 2) That part of a watch case which is used for attaching a pocket watch chain.
Brace	A barrel hooking consisting of an extra piece attached to a mainspring to secure the spring to the barrel.
Bracket clock	A spring driven clock designed to stand in a semi-permanent position, e.g. on a bracket, shelf, mantelpiece or table. Also known as a spring-driven table clock or mantel clock.
Brass	An alloy of copper and zinc.
Brazing	A form of hard soldering. A method of joining metal by melting brass which fuses onto the parts to be joined.
Breguet balance spring	See Overcoil.

Bridge	A detachable supporting bracket in the form of a bridge (i.e. has two feet). Used to provide a bearing for the pivot of an arbor, or pivots of arbors which are external to the clock/watch plate.
Broach	Cutting broach: A five sided tapered cutting tool used to enlarge a round hole. Smoothing Broach: A tapered tool used to smooth or burnish the inside of a pivot hole.
Brocot escapement	An escapement consisting of pallets in the form of semi-circular pins. Invented by Achille Brocot (C19th).
Brocot suspension	A suspension block permitting adjustment of the effective length of a pendulum. Invented by Achille Brocot (C19th).
Burnishing	A method of improving the finish on a piece of metal by rubbing the surface with a hardened steel tool, the surface of which has a fine grain at right angles to the direction of movement. Mainly used to obtain a high standard of finish to pivots or pivot holes.
Burr	The rough edge or burr left on metal after filing or machining operations.
Bush	1) A hollow cylinder or shouldered hollow cylinder used to correct wear in a pivot hole. 2) A bearing in clock or watch plates.
Bushing wire	A cylindrical piece of brass with a central hole from which bushes can be easily made. Usually made of hard brass.
Button	The external component of a watch used to wind the watch and set the hands to time. Also called the crown.
Calendar work	The mechanism which allows the day/date to be automatically displayed on a clock or watch.
Calibre	The size (in lignes) or layout of a watch movement.
Callipers	A measuring instrument used to determine the internal or external diameter of a component.
Cam	A (usually) rotating disc which has the outer edge shaped to lift levers, etc.
Calotte	A watch case that fits into a folding case made from metal or leather.
Cannon pinion	The pinion turning with the centre arbor which carries the minute hand and drives the motion work.
Carriage clock	A portable clock usually in a brass frame with glass panels on all four sides fitted with a platform escapement.

Carrier	A driving clamp fitted to work to be turned between lathe centres.
Catching	1) Catching a centre – forming a centre using a graver. 2) The butting of the tips of wheel teeth against pinion leaves or escapement pallets against the escape wheel.
Centrifugal fly	See Fly.
Chatelaine	An ornamental strap or chain by which a pocket watch may be hung from a belt or a dress.
Chatter	Unwanted vibration. Used to describe a bell hammer bouncing on a bell or an excessive depth of cut being taken with a lathe tool.
Chiming clock	A clock which chimes at the quarters and at the hour in addition to striking the number of hours.
Chops	1) False jaws to protect a component being held in a vice. Usually made of a soft material e.g. aluminium, copper, wood. Also called clams. 2) The pieces of metal which support the suspension spring of a pendulum.
Chronograph	A watch with an independent centre seconds hand (usually driven from the fourth wheel), which may be started, stopped and made to fly back to zero. Also functions as an ordinary timepiece.
Chronometer	1) An instrument having a detent escapement for measuring time accurately. 2) A marine chronometer: used by navigating officers when determining a ship's longitude. 3) A high quality wrist watch.
Circular error	The error in timekeeping which is caused because the pendulum follows a circular path instead of a cycloidal path. If the semi-arc is less than 2 degrees (4 degrees total swing), the error is small.
Clams	See Chops.
Click	A device, sometimes called a pawl, which acting on the teeth of a ratchet or gear wheel allows it to turn in one direction only. It is usually held against the wheel teeth by a click spring.
Cock	A detachable bracket in a clock or watch movement used to provide a bearing for the pivot of an arbor which is external to the clock/watch plate. It has one foot, as distinct from a bridge which has two feet.

Collet	1) A split collar sprung in position on a staff or arbor; e.g. a balance spring collet. 2) A split chucking device which can be used to hold an object by tightening the jaws. Usually used with a lathe. Sometimes called an American chuck. 3) A collar used to attach a wheel to an arbor.
Compensation	A term usually used in connection with a balance or pendulum which has provision for automatic correction for changes in rate due to rising or falling temperature.
Concentricity	When the periphery of a wheel or similar is equidistant from the centre (i.e. the wheel runs true).
Contrate wheel	A gear wheel with teeth set at right angles to its periphery. Generally used in carriage clocks and verge clocks and watches.
Count	Referring to a clock / watch train, the vibrations of the pendulum or balance in order to enable the clock / watch to keep time.
Count wheel	The notched wheel which determines the number of blows sounded on older striking clocks. Sometimes called the Locking plate. Superseded by rack striking.
Crown	See Button.
Crutch	The part of a clock which links the pendulum to the escapement.
Curb Pins	The pins fitted to the index of a watch or platform escapement which control the active length of the balance spring. On modern watches, there is usually just one curb pin together with a boot.
Cut balance	See Balance.
Cycloid	A line traced by a point on the circumference of a circle rolling without slip on a straight line.
Cycloidal tooth	A gear tooth form commonly found in clock and watch gear trains. See Epicycloid and Hypocycloid.
Cylinder escapement	A type of escapement invented Ca.1700 characterised by a cylinder to transmit impulses to and from the balance.
Dart	Another name for the guard pin in a lever escapement.
Dead-beat escapement	A type of clock escapement in which there is no recoil during the supplementary arc. Usually ascribed to George Graham C18th.
Dedendum	The portion of a gear tooth below the pitch circle.

Demagnetiser	A device for removing residual magnetism from watch movements, steel work or tools such as tweezers.
Depthing	The operation of correctly positioning and/or adjusting the gear wheels and pinions centres so that the pair will run with the depth of engagement to give least possible frictional loss. The distance is often determined by the use of a depthing tool. Also known as pitching.
Detent	1. A form of click or pawl or stop. 2. A name given to the chronometer escapement.
Detached escapement	An escapement where the pendulum, or balance, is free or almost free from influence by the motive force (e.g. lever escapement, detent escapement).
Dial clock	A circular type of clock and case sometimes referred to as school clock, office or kitchen dial. English dial usually refers to the familiar fusee movement fitted into a rectangular case bearing a large circular dial.
Dial washer	A thin curved springy washer placed between the hour wheel and dial on a watch to prevent the hour wheel from riding up and disengaging from the minute pinion.
Diamantine	Fine white powder mixed with oil used for polishing steel.
Die	A tool used for cutting external screw threads on rods, etc.
Discharge pallet	See Exit pallet.
Disengaging friction	The type of resistance present when a wheel tooth acts on a pinion leaf after the line between the centres.
Dog screw	1. A screw with a portion of the head cut away used to secure watch movements to the watch case / watch dials to the movement. 2. A screw with a cylindrical point (dog-point) used to engage with a circular groove in a shaft or arbor.
Douzième	An old French unit of measurement. 12 douzièmes = 1 ligne; 12 lignes = 1 pouce. 1 douzième = 0.0074 inches = 0.188 mm 1 ligne = 0.089 inches = 2.256 mm 1 pouce = 1.0657 inches = 27.069 mm
Draw	1) The angle on the pallet stone in the lever escapement. It ensures that the lever is drawn back to the banking pin if it moves away slightly. 2) Sometimes used for the process which occurs when the lever moves to the banking after locking.

Driven wheel	The pinion (or wheel) of two intermeshed gears which is driven by the other. Also termed as “the follower”.
Driver	The wheel (or pinion) of two intermeshed gears which transmits the drive to the other.
Drop	The free movement of the escape wheel which takes place after impulse is complete and before locking.
Drop dial	A type of dial clock where the case projects below the dial. See also Dial clock.
Dynamic friction	See Friction.
Ébauche	An unfinished movement; sometimes a movement not yet fitted into a case.
Eccentricity	When the periphery of a wheel or similar unit is not evenly disposed about its pivot centre it is in a state of eccentricity. It may be out of true or out of round (or both). See also Concentricity.
Elevation	That portion of a drawing showing a side view of a component or assembly
Elinvar	An alloy used for balance springs for an uncut balance. Its elasticity is little affected by changes in temperature; it does not rust and is non-magnetic.
End shake	See Shake.
End stone	See Stone.
Engaging friction	The type of resistance present when a wheel tooth acts on a pinion leaf before line between the centres.
Entry pallet	The first pallet to be engaged by each escape wheel tooth.
Epicyclic gear	Gearing in which one gear is fixed (the sun gear) and other gears revolve around (the planetary gears). Found in some turret clocks and tourbillon watches.
Epicycloid	A line traced by a point on the circumference of a circle rolling without slip on the exterior of another.
Equation of time	The difference between apparent solar time and mean solar time. See Solar time. Usually published not as an equation but as a graph of time difference against days of the year.
Escapement	The mechanism in a mechanical clock or watch which both regulates the speed of the train driving the hands and provides an impulse to maintain the oscillations of the pendulum or balance.

Escapement error	Errors in isochronism inherent in the particular escapement.
Exit pallet	The last pallet to be engaged by each escape wheel tooth. Also called the discharge pallet.
Face	See Flank
Feather edge	See Burr.
First angle projection	See Orthographic projection
Flank	The part of a wheel tooth or pinion leaf which contacts the mating gear teeth below the pitch circle. The part above the pitch circle is called the face.
Flat balance spring	A balance spring without an overcoil.
Fly	A rotating vane which acts as a governor to control the speed of a striking train by using air resistance. A centrifugal fly has spring-loaded vanes which extend as the speed increases.
Foliot	An early form of balance in the form of a pivoted bar with adjustable weights; used in early verge escapements.
Follower	1) The second of two intermeshed wheels, driven by the other. The driven wheel or pinion. 2) The part of a lever which follows the contour of a cam.
Fork	That part of the lever of the lever escapement into which the ruby pin or impulse pin engages. Also called the notch.
Frame	The assembly usually formed by plates connected by pillars designed to provide bearings for the wheels and pinions of a clock or watch movement.
Free escapement	An escapement in which the balance or pendulum has contact with the other parts for an insignificant portion of its motion.
Free sprung	A watch or chronometer movement with a balance and spring but no index. It is adjusted for rate by the movement of screws on the balance rim.
French silvering	See Silvering.
Frequency divider	The electronic circuitry in a quartz watch or clock which reduces the impulses from a quartz crystal oscillator to drive the stepper motor.

Friction	A force resisting motion. Static friction: the highest frictional force experienced when trying to move a stationary component. Dynamic friction. A lower frictional force experienced when the component is moving. Rolling friction: The lowest frictional force of all experienced when the moving component rolls rather than slides.
Frictional rest escapement	An escapement in which the escape wheel teeth rest on the pallets (e.g. Graham dead-beat escapement) or cylinder (e.g. Cylinder escapement) during the supplementary arc.
Fusee	A mechanism for overcoming the variation in power provided from a mainspring as it unwinds. The mechanism is in the form of a “cone” with a spiral groove for a chain or line which transmits the power from the spring barrel to the fusee. At full winding the chain pulls on the smallest diameter of the cone and as the spring unwinds gradually pulls on the larger diameter thus transmitting an equal force to the pendulum or balance throughout the period of unwinding of the mainspring.
Gearing	Refers to the engagement of a toothed wheel with another or with a pinion. A train of gear wheels.
Gear wheel	See Wheel.
Geneva mechanism	See Maltese cross.
Going barrel	A mainspring barrel fitted with a geared rim driving the train directly (i.e. not via a fusee).
Grain	The fine lines left by filing or polishing in one direction.
Guard pin	The pin fixed at the end of the lever of the lever escapement which, when the watch is jolted, bears against the safety roller to keep the lever in its correct position. It prevents overbanking which causes the watch to stop. Sometimes known as the dart or safety finger.
Gut line	A line used for supporting clock weights or connecting a mainspring barrel to a fusee. Traditionally made from the intestines of sheep or goats but synthetic alternatives are available.
Heat treatment	Alteration of the properties of a metal by heating it. Sometimes followed by rapid cooling. Can be used to change the colour of steel (see Bluing).

Helical gear	A gear wheel in which the teeth are cut at an angle to the axis to form part of a helix.
Heel	The part of the tooth of a Swiss lever escapement which first acts on the pallet. See also Toe.
Hob	A type of gear cutter generally used for the mass-production of gear wheels and pinions.
Horns	The part of the lever in the lever escapement each side of the notch.
Horology	The science and practice of measuring time.
Hunter	A pocket watch with a hinged flip-up lid to cover the face.
Hypocycloid	A line traced by a point on the circumference of a circle rolling without slip on the interior of another. This locus is used in the design of gears for clocks and watches.
Idle wheel	A gear in a train of wheel and pinions which does not affect its ratio or speed. Its function is either to reverse the direction or make up the distance between other gears. Also called an idler.
Idler	See Idle wheel.
Impulse	The force transmitted to a balance or pendulum by the impulse face of the pallet.
Impulse clock	A clock driven by electrical impulses from a master clock. Sometimes called a slave clock.
In beat	A term used to signify that an escapement action is even, i.e. the balance or pendulum vibration is displaced equally in both directions of swing to release an escape wheel tooth.
Index	A lever on a lever escapement for adjusting the length of the balance spring and so bring to time.
Invar	A nickel iron alloy from which pendulum rods may be made. It has the advantage that it shows very little alteration in length due to temperature changes.
Involute	The curve formed by a point in a cord as it is unwound from a fixed cylinder. Gear teeth designed on this principle have a number of advantages for the vast majority of engineering applications, but suffer from being less suited to gear ratios where the wheel is the driver and the pinion has a low number of teeth.
Isochronism	Constant time. The clock or watch keeps the same time whatever the arc of the pendulum or balance.

Jacot tool	A specialised form of turns used in watchmaking and driven by a bow.
Jewel	A hard semi-precious stone used for pallets, pivot holes and end stones mainly in watches and platform escapements.
Keyless work	The winding mechanism on usually a watch but sometimes a clock which is wound by turning a button or crown rather than inserting a winding key.
Knocking the bankings	Excessive rotation of the balance so that the impulse pin strikes the outside of the lever horns while the lever is resting against the banking.
Lantern pinion	A pinion in which the teeth are made of pin wire (trundles) held at the ends by metal discs.
Lantern runner	A jacot tool accessory, used when finishing the ends of a pivot.
Leaf	A pinion tooth.
Letting down	Releasing mainspring power prior to examination / repair.
Lever	1) A pivoted bar or similar which, if force is applied at one point, will transmit the force to another point. 2) The part of a lever escapement which carries the pallets.
Lever escapement	A type of escapement invented by Thomas Mudge in 1759 characterised by a lever to transmit impulses to and from the balance.
Lift angle	The impulse angle.
Lifting piece	The part of a striking / chiming mechanism used to release the train causing the clock to strike / chime.
Ligne	See Douzième.
Line of centres	An imaginary straight line drawn through the centre of the pivot holes of intersecting gears or interacting components (e.g. pallet arbor and escape wheel arbor).
Locking	The stage in the action of an escapement when the escape wheel is arrested.
Locking plate	See Count wheel.
Long case clock	A grandfather clock, i.e. a clock which has a long case to accommodate weights and pendulum.
Lossier curve	The theoretical inner and outer terminal curves of a Breguet balance spring as designed by L. Lossier.

Lugs	1) Rounded extension pieces on cocks or similar fitments for accommodating pivot or screw holes. 2) Projections on wrist watch cases supporting the strap or bracelet.
Lunation	A lunar month; approximately 29 days, 12 hours, 44 minutes. (29.530589 days)
Lunar	Pertaining to the Moon.
Maltese cross	A type of stop work for limiting the winding of a mainspring. Also called a Geneva mechanism.
Maintaining power	A device designed to keep a clock or watch going while it is being wound. The device is referred to as *maintaining gear*.
Mandrel	A face plate of a watchmakers' lathe provided with adjustable dogs and usually a spindle or running centre. The centre centres the work and the dogs clamp it into position.
Mantel clock	See Bracket clock.
Master clock	A clock which can transmit electrical impulses to drive slave clocks.
Mean solar time	See Solar time.
Metelinvar	An alloy used for balance springs with similar characteristics to Invar and Elinvar.
Mono-metallic	Made from a single metal, e.g. a balance rim made of a special alloy. Used in conjunction with a balance spring that needs no significant compensation for changes in temperature.
Moon work	Mechanism added to or incorporated in a movement for indicating the phases of the moon on a moon disc in the dial.
Motion work	The train of wheels in a clock or watch connecting the minute hand to the hour hand. 12 : 1 ratio.
Motor	An American term for the barrel and mainspring.
Movement	The mechanism for a clock or watch.
Nivarox	An alloy used for balance springs with similar characteristics to Invar, Elinvar, and Metelinvar. Has the special qualities of extreme hardness and almost complete lack of reaction to magnetism.

Nominal
A way of specifying a dimension, size or capacity that is sufficient for many purposes. Where greater precision or information is needed on the amount by which the dimension, size or capacity varies from the nominal size, a tolerance will be specified.

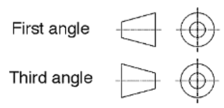
Notch
See Fork.

Ogive
A term for the tip of a gear tooth (usually a modified form of cycloidal tooth). See Rounding.

One second pendulum
A pendulum which takes one second to swing from its mid-point to one side and back to the mid-point again. (Often called a seconds pendulum)

Orthogonal
At right angles. Two planes that are orthogonal are at right angles (90 degrees) to one another.

Orthographic projection
A method of drawing a three-dimensional object in two dimensions. Orthographic projection follows one of two standardised conventions: First angle projection or Third angle projection. Which convention has been used is indicated on a drawing by a symbol in the form of a side and end view of a truncated cone.



Oscillation
1) A repetitive variation over time between two different states.
2) One complete cycle of an oscillator. In a mechanical clock or watch, one oscillation is one full cycle of the action of a balance and spring or pendulum from its starting position to one side, back through its starting position to the other side, and back to its starting position again. Other types of oscillation are possible such as the electrical oscillations found in a quartz crystal clock or watch.

Overbanking
1) The condition in a cylinder escapement when "over-vibration" of the balance occurs and the toe of an escape wheel tooth becomes wedged behind the cylinder shell engaging lip, thus stopping the watch. The over-vibration is usually due to a missing or short banking pin.
2) The condition when the ruby pin obtaining in a lever escapement when the ruby pin gets on to the wrong side of the "lever" due to a short guard pin, a short ruby pin or excessive end shake of the lever or balance staff.

Overcoil
A flat balance spring with its outer coil raised above the level of the remaining coils. Often referred to as a Breguet overcoil. Invented by A.L. Breguet (C19th).

Oyster watch	A waterproof watch made by the Rolex Company, hermetically sealed by mechanical means.
Pair case	A watch with an inner and outer case.
Pallet	That part of an escapement through which the impulse from the escape wheel is transmitted to the pendulum or balance. Also regulates the speed at which the escape wheel is allowed to rotate.
Pallet stone	See Pallet; also see Stone.
Parting	The operation of cutting off a length from a piece of work while it is revolving in a lathe or turns. Also known as parting off.
Pawl	See Click.
Peening	The operation of stretching the surface and edges of metal parts by hammering.
Pendant	1) The part of the case to which the bow or ring is fitted and by which the pocket watch may be hung. Generally contains the winding and hand setting button in keyless work. 2) Used to define the orientation of a watch when timing in differing positions, e.g. "pendant up" (PU) which means the watch is held vertically with the pendant uppermost. See also Positional error.
Pendulum	The swinging bob and its associated rod which determines the time interval of each vibration of a pendulum clock.
Periphery	The outer edge of (usually) a flat object or area. The circumference of a disc.
Perpetual watch	See Automatic watch.
Pillars	The distance pieces which hold together the front and back plates to form the frame of a clock movement.
Pinion	A small gear wheel (typically with less than 20 teeth) which meshes with a larger gear wheel.
Pin pallet escapement	A form of lever escapement in which the pallets are made of circular pins. Also called the Roskopf escapement.
Pin wheel escapement	A form of escapement in which the escape wheel teeth are made of semi-circular pins.
Pipe	A tubular projection from a component, e.g. that part of a cannon pinion which fits over the extended centre arbor.

Pitch circle	1) A circle defining the centres of two or more holes, etc. set at a constant radius from a central hole or axis. The hammer pins on a hammer wheel are on a pitch circle, which is defined by the pitch circle diameter (PCD). 2) The effective diameter of a wheel or pinion, i.e. the circle above and below which the tooth addendum and dedendum are measured. If two plain wheels, one driving the other by frictional contact only, were designed to replace two gear wheels and give the same ratio, their contacting diameters would be equivalent to the respective pitch circles of the replaced gear wheels.
Pitching	See Depthing.
Pivot	1) The reduced end of an arbor, staff etc, which runs in a hole, bearing, bush or jewel hole. 2) The action of a lever, etc. pivoting or rotating about a post, etc.
Plan view	That portion of a drawing showing a top view of a component or assembly.
Planishing	Bringing sheet metal to a fine, smooth finish by hammering or rubbing, typically with a planishing hammer or planishing tool. It is a form of burnishing.
Plates	Plates linked together by pillars to form the movement frame.
Plated movement	A clock movement with a frame constructed from plates connected by pillars.
Platform escapement	A lever or cylinder escapement mounted on a platform. Found primarily in carriage clocks.
Play	See Shake.
Poising	The operation of balancing any part which runs on pivots, i.e. adding or reducing weight at various points in the rim until it is of equal distribution all around the centre. Mainly applied to the balance of a watch or platform escapement.
Polishing	Producing a bright polished surface.
Positional error	Errors in isochronism caused by differing positions of a watch (dial down, pendant up, etc.).
Posted movement	See Birdcage movement.
Potence	A cock supporting a vertical arbor such as the escape wheel of a verge clock. Also spelt Pottance.

Power curve	A curve indicating graphically the decline in power of a mainspring from fully wound and completion of uncoiling.
Pouce	See Douzième.
Primitive circle	Another name for pitch circle.
Pusher	See Push piece.
Push piece	A button or knob in a watch case which operates an auxiliary function (e.g. starting/stopping a chronograph, setting the date, etc.).
Quarter screw	A long screw, usually four, sometimes fitted in a balance rim and used for mean time adjustments. Unscrewing the quarter screws (moving the screws outwards) results in an increase in the radius of gyration and a consequent increase in the inertia of the balance leading to a decrease in rate. See also Timing screw.
Quartz	A crystalline material used in highly stable electrical oscillators in quartz clocks and watches.
Quill	A quill is a sliding feeding device, usually in the form of a hollow spindle that slides in an out of the lathe tailstock or over the arbor supporting the drilling attachment. It also can refer to the vertical sliding body that supports the rotating drilling spindle in a drilling machine.
Rack	The toothed quadrant which acts as a controlling unit in a type of striking or chiming mechanism.
Radius of gyration	The distance at which the effective mass of a balance is concentrated from the centre of rotation. For a balance of fixed mass, it is effectively a measure of the inertia of the balance, and to a rough approximation can be taken as the outer radius of the rim.
Ratchet	A saw-toothed wheel, which in conjunction with a click will turn in one direction only.
Rate	The amount by which a clock or watch gains or loses over a specified interval (usually one day).
Rating	The operation of adjusting a timepiece to record accurate time.
Recoil	1) A slight backwards movement of the normal run of the train caused by certain types of escapement and designed to give an increase of impulse to the pendulum. 2) The very slight backwards movement of an escape wheel during unlocking. 3) Recoil escapement: An Anchor escapement.

Recoiling click	A click mechanism which allows the engaged wheel to recoil thus allowing some of the tension generated to be released. Mainly used to allow a watch mainspring to release partly from the fully wound state to prevent "knocking the bankings" and help prevent a spring from becoming locked by friction between its tightly wound coils.
Remontoire	A device which periodically rewinds an auxiliary spring or lifts an auxiliary weight to provide impulse to the escapement, thereby producing a more constant force and improved isochronism.
Repeater	1) A striking watch or clock, which repeats the last hour at the press of a button or pull of a cord. Some watches also repeat the last quarter or even last minute. Designed for use in the dark. 2) An alarm clock which repeats its alarm at intervals until silenced manually.
Regulator	A timepiece used for keeping accurate mean time for regulating purposes in watchmakers' workshops or in observatories. They are fitted with compensating pendulums and their movements are of the simplest and most accurate form possible, i.e. everything is subordinated to good time-keeping.
Root circle	A circle drawn round the bottom of the tooth spaces of a gear wheel or pinion.
Roller	1) That part of a lever "escapement" which is attached to the balance and through its ruby pin contacts the lever fork or horns. 2) Cylindrical parts fitted to the balance staff of a marine chronometer which provide unlocking (small roller) and impulse (large roller).
Rolling friction	See Friction.
Roskopf escapement	See Pin pallet escapement.
Roughing	The first stage of making a new part, preceding finishing operations.
Rounding	1) The tip of a pinion tooth. See also Ogive. 2) Making a sharp edge rounded either deliberately (e.g. with a file) or unintentionally (e.g. when using abrasive paper).
Rubbing over	A form of riveting done in the lathe to secure a wheel to its collet.
Run	A term sometimes used instead of warn or warning.

Run to banking	In the lever escapement it refers to the movement of the lever after locking and until it is arrested by a banking pin. Sometimes "run to the banking".
Runner	An accessory used on the turns or Jacot tool in which a pivot runs during a turning operation.
Safety finger	See Guard pin.
Scraping	A hand-finishing process which, with skill, is used to bring a machined surface dead flat. Also used to impart a decorative finish. Done with a scraper.
Seat or Seating	1) A surface specially prepared to take another permanently attached component (e.g. a bridge or cock secured by screws and located by pins) or by an interference fit (e.g. an arbor collet secured by a push or press fit). 2) A surface on which a component periodically comes to rest.
Second pendulum	See One second pendulum.
Section	Material supplied per unit length generally in square, rectangular or hexagonal form. For example, 100 mm of 10 mm x 15 mm steel section will be cut to 100 mm length from a bar with a cross section of 10 mm x 15 mm.
Sector	1) An instrument for gauging the comparative sizes of wheels and engaging pinions. 2) Part of a circle enclosed by two straight lines drawn from the centre to points on the circumference.
Self-winding	See Automatic watch.
Set-hands mechanism	A device for periodically correcting the time shown on a clock or watch. Usually operates on the minute hand.
Shaft	An arbor.
Shake	1) Non-productive free movement of a pivot or interrelated parts of a mechanism. Also known as play. a) End shake: Endwise (axial) freedom or movement in an arbor between the pivot shoulders or endstones. b) Side shake: Sideways (radial) freedom or movement in an arbor between a pivot and its bush or jewel hole.
Sidereal time	Time based on the time taken for the earth to revolve once about its own axis as measured with respect to a fixed star. The sidereal day is approximately one three hundred and sixty sixth part of a year, and three minutes

	fifty six seconds short of a mean solar day. Used by astronomers.
Side shake	See Shake.
Silvering	A method of creating a silver finish to brass dials, etc. A compound primarily of silver chloride is rubbed on as a paste, followed by cream of tartar, rinsing in water and drying. On completion a coat of lacquer is generally applied for protection.
Silver soldering	A form of hard soldering. A method of joining metal by melting an alloy of silver and copper which fuses onto the parts to be joined. Sometimes called silver brazing.
Skeleton clock	A pendulum clock with its plates pierced out, usually not fitted into a case but displayed under a glass dome.
Skew gears	Helical gears on non-intersecting, non-parallel arbors commonly meshing at right angles.
Slave clock	A clock dial driven by a master clock.
Slip	1) A slip stone, an abrasive stone used for finishing metal parts such as steel pallets. 2) The unintentional or deliberate condition that results from a friction drive failing to drive the unit mounted on it due to limited grip.
Snail	That part of a striking mechanism (shaped roughly like a snail shell) which, operating with the rack, regulates the number of blows being struck.
Solar time	1) Time determined by the position of the sun at noon at the local meridian (longitude). Also known as apparent solar time. 2) Mean solar time. Solar time averaged out over the whole year (See Equation of time).
Spinning	The process of raising a flat disc to a domed shape in a lathe. The disc is spun in the lathe and generally rubbed over a former of the required shape. Can be used to make pocket watch cases.
Spur gear	A gear wheel meshing with another wheel or pinion on parallel shafts.
Staff	The spindle on which the balance or pallet seats. An oscillating arbor.
Stake	1) A tool used, in conjunction with a punch in staking operations. 2) An old generic term for spindles, staffs, arbors, etc.

Staking	The operation of driving the "stake" into the part in which it fits but used to describe many similar operations.
Static friction	See Friction.
Steel	An alloy of iron and carbon (typically less than 1%) Can be heat treated.
Stem	See Shaft.
Stepper motor	A small electric motor which "steps" through a defined angle of rotation at each electrical impulse. Found in quartz clocks and watches.
Stone	A jewel used for pallets (pallet stone) or to provide end location for an arbor (end stone).
Stop watch	An interval timer which, unlike a Chronograph, does not tell the time.
Stopwork	1) The mechanism which allows only the middle turns of a mainspring to be used. This results in a more constant drive torque. 2) Sometimes used to describe the silencing mechanism on an alarm clock.
Stretching	The operation of increasing the surface area of sheet metal by hammering or compressing between rollers. Used principally for increasing the diameter of wheels.
Striking clock	A clock which strikes the hour or hours and half hours but does not chime.
Stud	1) A type of post usually screwed at one or both ends and with a plain portion exposed above the screwed hole in which it is fitted. 2) A pin or small block used to secure a balance spring.
Supplementary arc	The arc of vibration at the extremities of the swing of a pendulum or balance when no longer being impulsed by the escape wheel.
Suspension	The springy steel strip supporting the top of a pendulum.
Swing	The motion of a pendulum or balance; its vibration.
Synchronome	A type of periodically impulsed electrical clock capable of operating slave dials. Previously used in offices and schools.
Synchronous clock	A clock whose timekeeping is synchronised to, and totally dependent upon a source of alternating current (usually the mains).
Tandem drive	The use of a single source of power for driving both time

	and striking trains.
Tap	A tool used for cutting internal screw threads in holes.
Tempering	Reducing the hardness of steel by heat treatment.
Terminal curve	See Overcoil and Lossier curve.
Third angle projection	See Orthographic projection
Tic-tac	A type of anchor escapement which embraces just two teeth of the escape wheel. Also a tic-tac clock.
Timepiece	A clock which tells the time only (it has no strike or calendar work).
Timing machine	An accurate instrument for counting the number of beats per hour. Used for checking the timekeeping of a clock or watch.
Timing screw	A screw, sometimes as many as twelve, used to adjust the radius of gyration of a balance and hence its period of oscillation. See also Quarter screws.
Ting tang clock	A clock which strikes on two bells or gongs at the first second and third quarters and on the lowest toned bell or gong only at the hour.
Tip circle	A circle drawn round the tips of the teeth of a wheel or pinion, i.e. outside the pitch circle.
Toe	A term used in describing the appropriate part of a mechanism which has the rough shape of a human foot, e.g. a club foot escape wheel tooth.
Tolerance	A measure of the amount by which a stated dimension, size or capacity may vary from its nominal size.
Topping	The operation of cutting or re-cutting the tips of wheel teeth usually after stretching.
Torque	Twisting force.
Tourbillon	A watch in which the escapement is fitted into a revolving carriage in order to average out positional errors.
Train	A system of intermeshed gear wheels and pinions used for transmitting power and (usually) reducing or increasing the speed.
Train count	Counting the number of teeth in a gear train in order to ascertain the overall gear ratio.
Trundle	See Lantern pinion.

Turns	A hand driven lathe.
Turret clock	A clock designed for mounting in a turret or tower, e.g. a church clock.
Uncut balance	See Balance.
Undercut	A recess cut at a shoulder which has the effect of eliminating any possible root radius or uncut screw thread left by a previous machining operation. Undercut permits accurate seating of the shoulder.
Underslung clock	A type of chiming clock in which the chiming hammer and their barrel are located below the main movement enabling the case to be made less deep.
Uprighting	The operation of aligning holes to ensure that the pivots running in them are vertical. May require rebushing if the holes are worn.
Vibration	The swing of the pendulum or balance in one direction only. See Arc of vibration.
Vienna Regulator	A wall timepiece, some of very high accuracy. Usually fitted with a long wood pendulum and a dead-beat escapement.
Warn	Refers to the movement of the warning wheel of a striking mechanism before the striking train is released.
Wheel	A larger gear wheel (typically greater than 20 teeth). Usually meshes with a pinion.
Winding shaft	A screwed spindle or stem through which the winding mechanism is operated.
Worm	A small gear wheel like a screw which meshes at right angles with a worm wheel. Great reductions in speed are possible without recourse to a train, but generally must act as the driver (cannot be driven).
Worm wheel	A wheel with spirally cut teeth made to mesh with a Worm. Generally must be the driven wheel.
Year clock	A clock which will run for a period of one year with one winding.
Young's modulus	The modulus of elasticity, sometimes called the coefficient of elasticity.
Zaandam clock	A style of Dutch clock.

END

Practical Clock and Watch Servicing

Distance Learning Course

Technician Grade

Lesson 1

Version 2

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Founded in 1858, the British Horological Institute is the professional body for clock and watch makers and repairers in the UK. It provides information, education, professional standards and support to its members around the world.

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Contents

Knowledge and Understanding

1 A brief history of timekeeping

The word "clock" comes from the Medieval Latin word clocca, which means "bell".

It is likely that Man first needed to keep time around 9000 years ago, with the invention of agriculture. Of course, predicting the right time to plant crops is much less demanding than arriving at a train station on time, and early Man almost certainly did not require timekeeping instruments, relying instead on observing the cycles of the sun and moon.

As civilisation became more sophisticated, timekeeping became more important, and the first timekeeping instruments were developed. These were used in secular life, as well as in religious institutions to manage regular periods of worship. By modern standards their timekeepers were still very crude and inexact; they included candles and incense sticks which burned at a known rate. Sundials, which allow the passage of the sun to be accurately indicated, date back to around 3,500BC. The clepsydra, which works by the flow of water through a small hole, dates to around the 16th Century BC.

By the 14th Century AD mechanical clocks were being made in a form which would be familiar to us today. The first such clocks did not display the time, but simply rang bells to call people to worship. Over the following centuries, the developing sciences (such as astronomy) drove the need for ever more accurate clocks. The invention of the pendulum clock by Christian Huygens in 1656 led to a massive improvement in timekeeping accuracy.

Figure 1 – marine chronometer

Accurate timekeeping is essential for the navigation of ships, but a pendulum is quite unsuitable for use at sea due to the movement of the ship. It was not until 1773, a century after the pendulum clock had been invented, that John Harrison was recognised for producing a watch incorporating a balance that would keep time accurately enough for navigation at sea. Figure 1 shows a 20th century marine chronometer mounted in gimbals in a protective box.

The Industrial Revolution drove the need for public timekeeping. Factory workers had their daily schedules dictated by the unvarying beats of the machinery they tended. Few ordinary people could afford their own clock, so most factories and public buildings had large clocks on display, and factories would sound sirens to call the workers for the next shift.

Figure 2 – American railroad watch

The development of the railway network in the 18th and 19th Centuries required a sophisticated system of management based upon complex timetables. Accurate timekeepers (Figure 2) were essential for the railway operators, and a major asset for the travelling public.

The need for accurate timekeeping has invaded almost every aspect of modern life, and especially the sciences. Massive leaps in timekeeping accuracy were made in the 20th Century. The 1920s saw the invention of the quartz oscillator, which is still the most ubiquitous timekeeper in use today, and, arguably, marks the point at which the science of timekeeping was taken from horologists by physicists.

The most accurate timekeepers currently in use are known as "atomic clocks". At their heart is a caesium resonator, accurate to better than one billionth of a second per day.

John Harrison would be impressed were he alive today. The caesium timekeepers used by the present-day Global Positioning System (GPS) allow anyone to pinpoint their position to within 20m or so, anywhere on the globe, using low cost shop-bought navigation aids. Sophisticated enhancements and error correction techniques provide positioning to within a few centimetres.

2 Types of clocks and watches

Bearing in mind how many centuries we have been making clocks, it is no surprise that there are countless different types. In this section we will look at some of the more common types you may come across.

Note: we have deliberately not used photographs of pristine clocks; many of the clocks you work on will be in average or poor condition.

2.1 Lantern clock

The lantern clock was introduced into Britain and Europe around 1620, and fell from popularity in the first half of the 18th century. The properties of the pendulum were discovered by Galileo in 1581 and early lantern clocks, which had only one hand, were made before the invention of the pendulum clock in 1656: they used balance wheels and kept fairly poor time.

The pendulum offered much better timekeeping, so clockmakers quickly adopted it, and many of the original lantern clocks were converted to use a pendulum.

Despite their improved accuracy, they were still made with just an hour hand, presumably for reasons of style and tradition.

Original lantern clocks from the era mentioned were all weight driven. Occasionally a spring-driven lantern clock may be found, but it will be either a modified weight-driven clock or a more modern reproduction.

Figure 3 – lantern clock

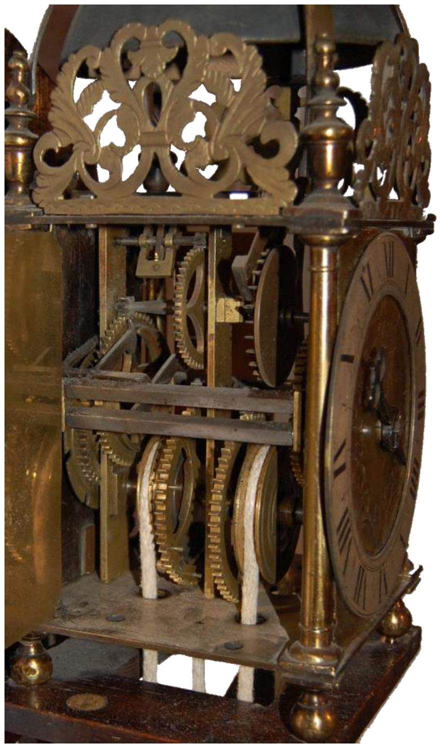

Figure 4 – lantern clock mechanism (modified to pin wheel escapement)

The style of the lantern clock is very popular, and it enjoyed a resurgence of interest in the Victorian era. For this reason many clocks have been made in the style of the lantern clock, including modern quartz clocks.

Due to their great age, and the fact that many were modified to improve their performance, it is very rare to find a fully original lantern clock. Lantern clocks are historically important and valuable, so you should to take advice from an experienced professional before working on one.

The origin of the name "lantern clock" is uncertain. One theory is that the shape resembles a lantern of that historical period. Another theory is that it is a corruption of *latten*, which is a term used around that time for brass, i.e. a *brass clock*.

2.2 Bracket clock (sometimes known as a "spring clock")

Figure 5 shows a typical 18th century bracket clock (this one was made around 1730). The two key holes in the dial indicate that it has two trains: a timekeeping train (known as the "going" train) and the striking train (clocks which chime use a third train). The movement is of good quality and beautifully engraved. The bell at the top of the movement is used to sound the hours, and you can see the hammer to the right of it. The pendulum is shown in its hold-fast, which is used when the clock is carried from room to room. The cord visible in the left photograph operates the repeat mechanism, which makes the clock strike the most recent hour again. This clock was made before electric or gas lighting so night-times were often pitch dark, making it impossible to read the time. The repeat cord lets the user know the time to within an hour.

Figure 5 – bracket clock

Figure 6 – bracket clock, showing beautiful engraving on back plate

The term *bracket clock* was first used for weight-driven clocks, which had to be mounted on a wall bracket to provide room for their weights to drop. Spring driven clocks like the one shown here continued to be made in the same style, and are often still referred to as bracket clocks, even though they are normally placed on a table. They are also sometimes called “spring clocks”.

2.3 Longcase clock

Longcase clocks are tall, weight driven pendulum clocks. They evolved from the lantern clock, the first ones essentially being lantern clocks with a case built around them.

There are two basic types of longcase: the 30 hour clock, which is wound by pulling on a rope to lift the weight, and the 8 day clock, which is key-wound through a hole in the dial. The 30 hour clock was aimed at the lower cost end of the market.

Figure 7 – a typical 8-day longcase clock

Most longcase clocks were made between the late 17th century and the second half of the 19th century, although clocks outside those dates can sometimes be found and they are still being made in small quantities to this day. Most struck the hours on a bell, and some had additional features such as a date or moon phase display.

Due to their historical interest and impressive appearance they are highly collectable. Interestingly, few of them have any great horological merit; they were conservative in their technology and did not generally employ the latest technical advances available at the time of manufacture. Robustness and reliability were more important. Nevertheless, due to their high value and historical importance there should be a careful consideration of the servicing approach.

The longcase is not to be confused with the “regulator” clock. There is sometimes a superficial resemblance, but regulator clocks used the most advanced techniques available at the time to achieve the highest possible timekeeping accuracy. Such techniques include the use of sophisticated escapements and pendulums compensated for changes in temperature and barometric pressure. Regulators are exceptionally valuable and you should not work on one until you are fully competent.

Most, but not all, longcase movements were made in a few cities around Great Britain. They were shipped around the country to the provincial makers for final finishing and installation in the clock case.

Figure 8 – a 30-hour longcase (note the absence of winding holes in the dial)

2.4 English dial clock

The English dial clock is very popular with collectors. They usually have a simple and robust movement, many of them using a "fusee". A fusee evens out the torque from the mainspring as it unwinds, which helps improve timekeeping. We will look at the fusee in some detail later in the course.

Where the case descends below the dial, to accommodate a longer pendulum, it is known as a "drop dial" clock.

Figure 9 – English dial clock

Figure 10 – English drop dial

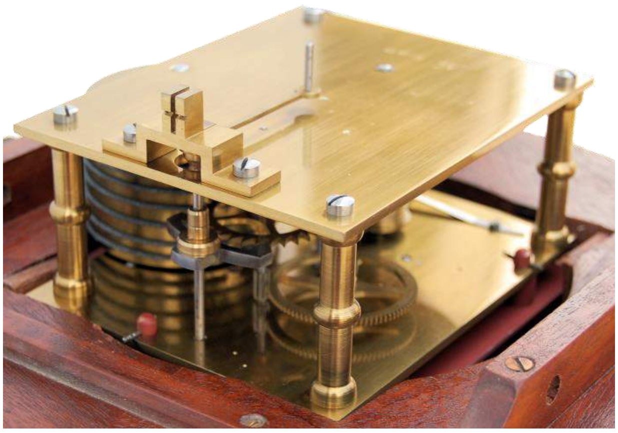

Figure 11 – drop dial movement (the fusee chain is visible, wrapped around the barrel)

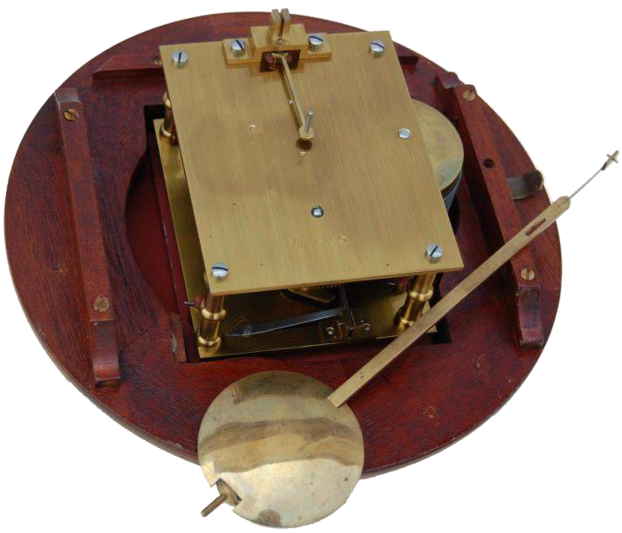

Figure 12 – drop dial movement showing typical pendulum

2.5 American wall clock

America mass-produced large numbers of clocks in the 19th and early 20th centuries. Thousands were imported into Britain, and they are still commonly found. The cases tend to be more ornate than the English dial clock.

Figure 13 – American wall clock by Ansonia

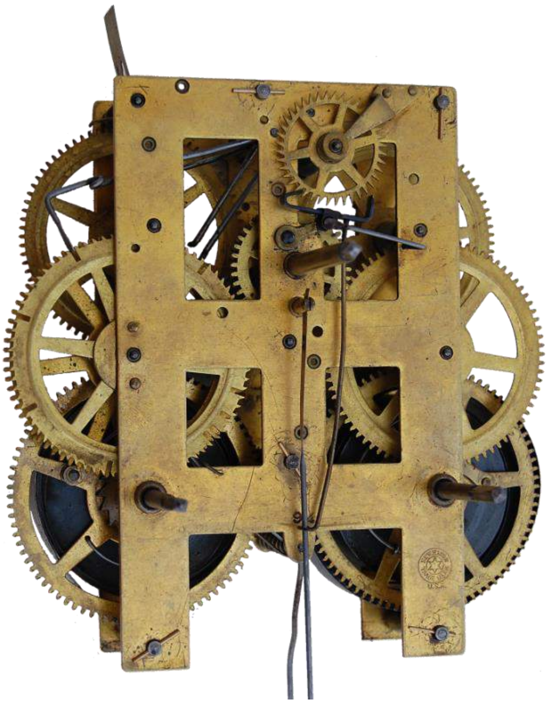

Figure 14 – Ansonia movement, front view

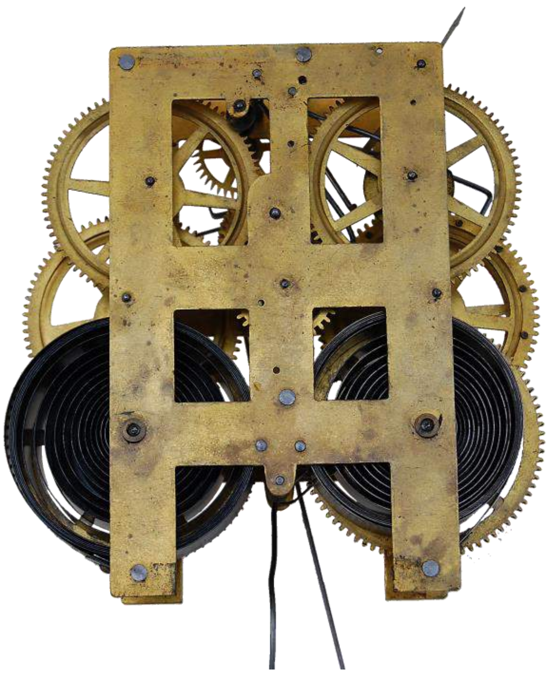

Figure 15 – Ansonia movement, rear view

2.6 Carriage clock

The carriage clock combines portability with compactness and an attractive appearance. It is no surprise that they are still popular to this day. Most of the ones you come across will be 19th century French. The movements are of good quality, with very hard steel parts which resist wear well. The platform escapement is visible through a window in the top. Some carriage clocks have a protective leather case.

The terms "balance" and "balance wheel" are used interchangeably in horology, and you will hear both in use. However, the former is regarded by experts as the more correct.

You will learn a lot more about the balance as the course progresses.

We will look in detail at the platform escapement later in the course, but for now note that the use of a balance means that the clock can be transported without having to stop it, so it will keep time on a journey. Pendulum clocks do not work when subjected to movement; moreover extreme movements of the pendulum may damage the clock. Consequently, pendulum clocks must be stopped and the pendulum safely stowed before they are moved.

Figure 16 – carriage clock

Figure 17 – carriage clock rear, showing attractive finish

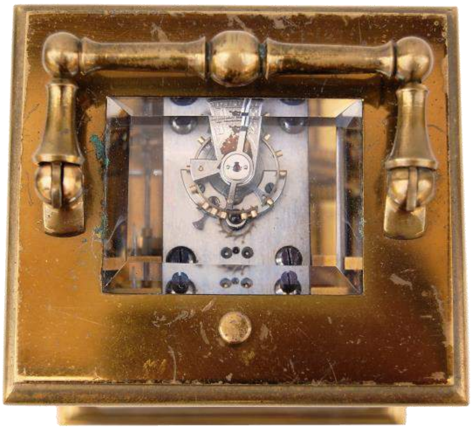

Figure 18 – visible platform escapement

2.7 French clock with a drum movement

French clocks with a drum movement were made in vast quantities, and in all sorts of styles. As with carriage clocks, most of the ones you come across will be 19th century. They are characterised by a round – drum-shaped – movement, usually protected by a metal sleeve, and fitted into a close-fitting round hole in the case. As a general rule the quality and finish of the movements is high. Drum movements were made with either a pendulum or a balance – both types are quite common. Usually the balance is on the back instead of, as in this example, on the top,

Clock movements with a balance frequently make use of a platform escapement of the type illustrated in Figure 18.

The movement shown in Figure 20 is fitted with one at the top.

Figure 19 – typical example of a French clock with a drum movement

Figure 20 – drum movement showing platform escapement

Figure 21 – another view, showing typical proportions of a drum movement

2.8 Vienna regulator

Vienna regulators are wall-mounted clocks. They were made between about 1790 and 1910 (although modern reproductions are still being made to this day, mostly with German-made Hermle movements). The first ones were made in Vienna, although manufacture spread throughout the German-speaking countries. Although there are numerous variations, they generally have an ornate wood case with glass in the sides and front. They are key wound and have visible weights which descend below the movement. They normally use a Graham dead-beat escapement (we will look at these later in the course) and a wooden pendulum rod with a large, disc-like bob in polished brass.

They use a shorter pendulum than a longcase clock, and have a pleasing appearance even to modern eyes.

The wood pendulum rod (which is relatively insensitive to temperature variations) combined with the dead-beat escapement allows the Vienna regulator to keep good time, although – despite their name – they should not be confused with the true regulator clocks mentioned in Section 2.3.

You should also note that some clocks in the Vienna Regulator style are spring-driven.

Figure 22 – typical Vienna regulator

2.9 20th century mantel clock

Clocks to be placed on mantelpieces were mass-produced in many countries throughout the early- and mid-20th century (and, with quartz movements, continue to this day). Case styles vary considerably, although the "Napoleon hat" style was popular and will be familiar to most people. The quality of the movements varies considerably. Single-train, two-train (time and strike) and three-train (time, chime and strike) variants were made. Some are easy to work on, others can be extremely tedious to set up, which means some clock repairers turn them away. It frequently costs more to service one than it is worth in monetary terms. However, many such clocks have a high sentimental value, which means customers will often pay the relatively high cost of servicing.

The clock shown in Figure 23 and Figure 24 is a fairly low-cost clock, although the Bakelite case makes it slightly unusual and more collectable. In the rear view you can clearly see the hammer and wire gong used for striking the hours, and behind it is the pendulum.

Figure 23 – 20th century striking mantel clock with Bakelite case

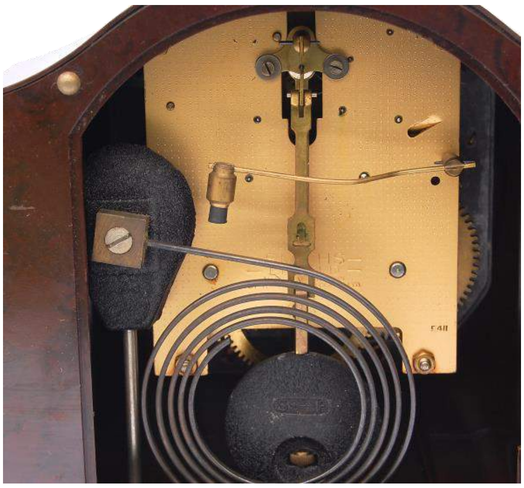

Figure 24 – rear view showing strike hammer and gong

The clock shown in Figure 25 and Figure 26 is a typical striking and chiming clock. It has a three-train movement and you can see the chime rods below the movement (which are also used for striking). There were many thousands of clocks of this type produced in varying qualities.

Figure 25 – 20th century chiming mantel clock

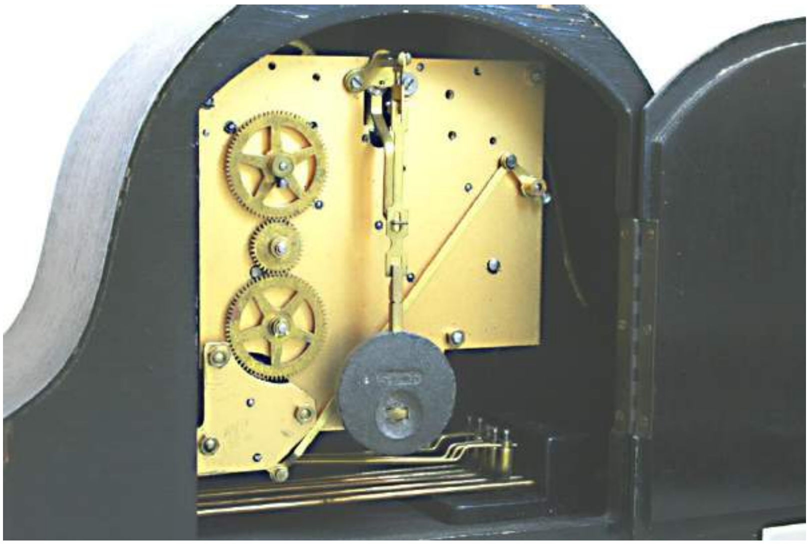

Figure 26 – rear view of chiming mantel clock showing gongs and hammers

We should also point out the "floating balance" clock. This one was made by Smiths in the 1950s. You can see that the balance is horizontal and suspended on a helical spring. The balance runs on a fine wire down its centre, but literally floats vertically. This clever arrangement results in a very low level of friction on the balance, and allowed Smiths to make an 8-day clock more cheaply – and in a more compact form – than the pendulum clocks you have seen above. Also, pendulum clocks can be damaged when moved around unless the pendulum is removed or constrained – something many owners do not understand. The floating balance clock is fully portable without harm.

Figure 27 – 1950's Smiths mantel clock

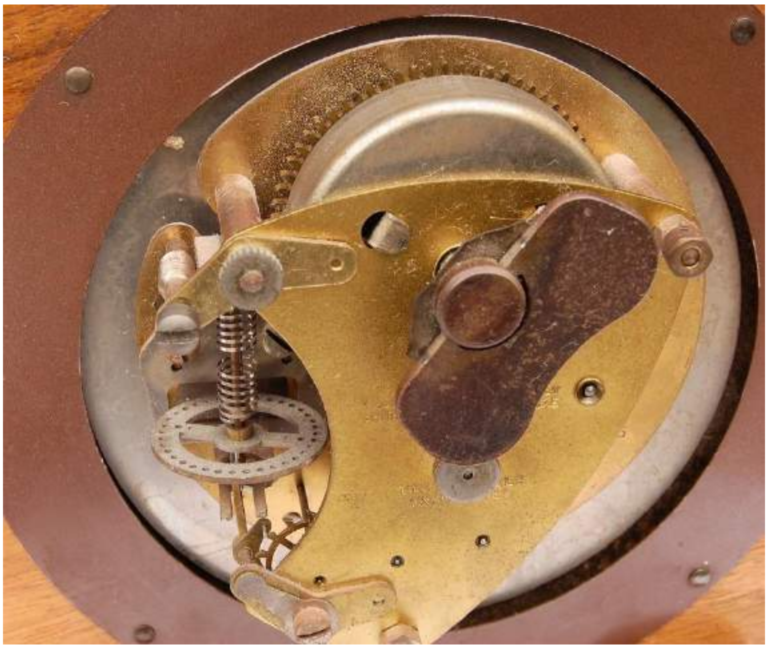

Figure 28 – floating balance

2.10 Appearances can be deceptive

Here is a fairly unassuming 20th century clock, made in the traditional style of a bracket clock. However, when you look in the back you see a superb quality movement with a platform escapement. At this stage in your horological learning, if you come across a clock like this that needs servicing you would be well advised to take it to an experienced and qualified professional – a Member or Fellow of the British Horological Institute.

Figure 29 – 20th century chiming clock in traditional style

Figure 30 – rear view of a high quality chiming clock

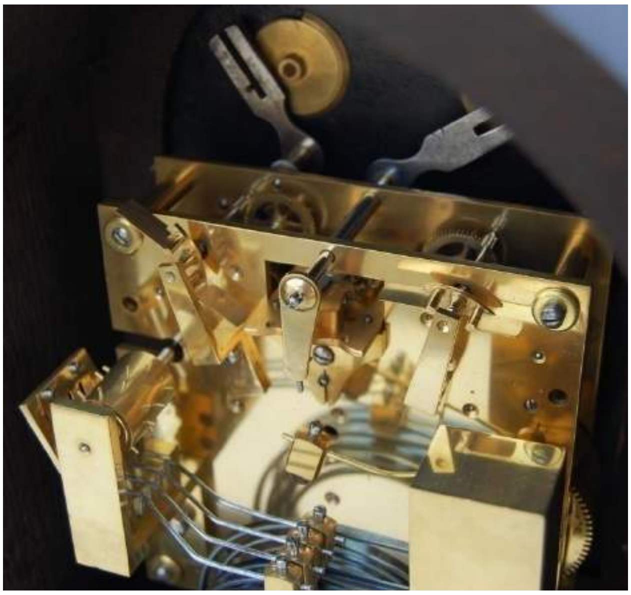

Figure 31 – another view (note the platform escapement mounted between the plates)

2.11 400 day (anniversary) clock

Figure 32 – 400 day (anniversary) clock

Anniversary clocks were made throughout most of the 20th century, the majority being made in Germany. By using a special "torsion" pendulum which rotates back and forth extremely slowly, it is possible to make a clock which runs a whole year on one winding. This made anniversary clocks popular for commemorative gifts. Also, the slowly rotating pendulum has a distinct visual appeal which makes them desirable to some people.

Their timekeeping is usually quite poor, and some clock repairers find them difficult to set up. However, provided the correct techniques are used, they pose no real problems.

2.12 20th century alarm clock

Figure 33 – 20th century Smith alarm clock

The Smith Alarm is probably the archetypal 20th century alarm clock. Mass produced in vast numbers, they found their way into virtually every British home. Despite their popularity they were rather unreliable and not very durable. The Westclox Big Ben (not shown) was a more recent competitor and proved more reliable, as well as having a quieter tick (important in a bedroom).

Figure 34 – movement of Smith alarm clock

Figure 35 – late 20th century Japanese alarm clock

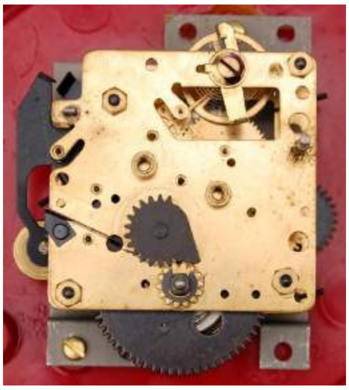

Figure 36 – movement of Japanese alarm clock

In the 1970s the Japanese made inroads into the alarm clock market using the Rhythm brand, amongst others. At first glance the movement seems similar in technology to the Smith Alarm, but in fact they were far more reliable and durable due to improved manufacturing techniques and needed little or no servicing for years at a time.

Figure 37 – late 20th century Chinese alarm clock

Figure 38 – late 20th century Chinese alarm clock, showing plastic movement parts

In the late 20th century the Chinese had entered the market. By now quartz alarm clocks were in widespread use, but mechanical clocks still had an attraction if they were distinctive enough. This one uses plastics for almost every part, to remarkable visual effect.

2.13 Quartz clock

Figure 39 – standard quartz clock movement

Figure 40 – view from the dial of a standard quartz centre nut which secures the movement

Everyone is familiar with the quartz clock and they are to be found everywhere. They are small, (approximately 52 mm wide x 45 mm high) cheap, accurate, reliable and durable. Virtually all quartz movements are fixed with a slotted nut which screws onto the movement from the front of the dial – Figure 40. Sometimes it is hidden, but if you see something like this is the middle of the dial you can be pretty sure there is a quartz movement behind it.

The low cost and compact size of the quartz movement makes it very popular for novelty clocks, such as the one shown here.

Figure 41 – quartz novelty clock

2.14 Radio-controlled clock

Figure 42 – radio controlled quartz movement

Radio-controlled clocks are based on quartz clock technology, but they also have a radio receiver which receives the time signals broadcast in most countries. An electronic circuit corrects the quartz clock to the broadcast time, usually twice a day. This means that the clock never needs to be put right; it will even correct itself automatically after a battery change.

They cannot normally be serviced, but replacement movements are easily obtained. They generally use the same method of fitting as a standard quartz movement.

2.15 English lever pocket watch

Figure 43 – English lever watches, front and rear views

Here are two typical English lever pocket watches ("lever" referring to the type of escapement – we will look at them later in the course). They were made using special machinery, but not mass-produced in the modern sense. You will see that the dials, and the movements, have different signatures, but in fact the movements are clearly identical. This is very normal with English lever watches – they were made in various degrees of completeness, and then "finished" prior to sale. Note that despite the obvious similarity of the movements, the parts may not be interchangeable between them. This is due to relatively poor control of manufacturing tolerances – many parts being hand finished to fit.

2.16 American railroad pocket watch

Figure 44 – American railroad watches, front and rear

In the late 19th century many of America's railroads were still single track. This required sophisticated time management of the trains so they were not at risk of collision. It was not always successful – in Ohio in 1891 an engineer's watch stopped for four minutes and then restarted. The end result was a serious crash with fatalities and property damage. In response, the railroad industry designed a specification for the watches its staff must use. The specification covered the construction as well as the performance requirements (for instance, they must keep time to within four seconds a day in any of five positions, as well as over a wide temperature range). The time may only be set by removing the bezel and pulling out the setting lever (see the top left photo), which made it impossible to accidentally disturb the time setting when winding the watch.

The American watch industry met the challenge with enthusiasm and success. Unlike the watch industry in Britain at that time, the Americans used modern mass-production techniques. Shown above are two Hamilton railroad watches. The one on the left is relatively early – 1904, and the one on the right was made in the 1930s. Many people believe that the American railroad watch is the pinnacle of mass-produced mechanical watches. Even modern day Swiss mechanical watches are remarkably similar in design and construction – and performance – to the railroad watches.

You will also see that the manufacturers applied a superb finish to parts of the movement, including machined damaskeening (normally spelt "damascening in Europe, with a silent 'c') and beautiful engraving embedded with gold leaf. They wanted to signal to potential purchasers the high quality of their product. As the 20th century progressed the watches continued to improve in quality and performance, but there was much less emphasis on the relatively high-cost decorative finishes, so more recent ones are sometimes regarded as less desirable, despite their superb quality and performance.

2.17 Mechanical wristwatch

As soon as your friends find out you are studying horology you are certain to be asked to repair countless old watches dragged out from the backs of drawers.

The number and variety of 20th century mechanical watches is vast. Two watches are pictured in Figure 45; they illustrate the different tastes of two cultures: the one

Figure 45 – late 20th century Japanese (left) and Russian wristwatches

on the left is made in Japan for the European market; the one on the right is made in Russia for the home market.

Figure 46 – examples of the more "characterful" watches you may come across

You will also come across some superbly characterful watches. The one on the left in Figure 46 was bought in China – Chairman Mao waves his arm when the watch runs. On the right is a magnificent example of a watch that has clearly earned its keep. Every surface is deeply scored; it has been knocked so many times the outline of the movement has imprinted itself on the dial; and the back of the watch has been corroded right through by sweat. It has obviously faithfully served its owner – perhaps a labourer or workman – for many years, if not decades, and it is still in perfect working order. Its history is deeply etched into the watch, and this may have great appeal to the owner. On the other hand, even a watch in this state can be restored to pristine condition.

Figure 47 – 20th century ETA and Bulova movements

On the left in Figure 47 is an example of the popular ETA 2824-2 movement. It is a fast train movement (these terms will be explained later in the course) of good quality and is found in numerous mid-range Swiss watches. The semi-circular rotor covering half the movement is the automatic winding weight.

To the right is a beautiful movement by Bulova. This uses a so-called micro-rotor for the automatic winding – visible at the 9 o'clock position – which sits *within* the movement, rather than on top of it. This makes the movement slimmer and allows the use of a more elegant, low-profile case.

2.18 Quartz analogue wristwatch

Perhaps surprisingly, quartz analogue watches are eminently repairable. Again, though, the only reason to do so would be when the watch has some sentimental value. In most cases it is cheaper to buy a new watch.

Figure 48 – two quartz analogue watches

Good quality quartz analogue movements can be dismantled and serviced much like a mechanical watch. Some low cost quartz movements cannot, but they can usually be replaced in their entirety for a very reasonable cost – again making repairs viable.

The Tissot shown in Figure 48 is one of the earliest quartz analogue watches, made to a very high standard, before market pressures forced cost reductions. The Citizen to the right is interesting in that it is powered solely by heat from the wearer's body.

2.19 Quartz digital watch

Figure 49 – Quartz LED digital watch

Most quartz digital watches use either a light emitting diode (LED) display, or a liquid crystal display (LCD). LED displays were used on early quartz digital watches from the 1970s, but they had two major disadvantages. Firstly, they use a lot of electrical current, so the watch battery would often last just a few months. Secondly, in order not to discharge the battery in mere minutes, the display was switched off until a button was pressed. Thus, both hands were required to tell the time. Figure 49 shows a typical example of such a watch. The time display button is visible at the upper right of the case. The dark red – almost black – appearance of the dial is typical of these watches.

LCD watches replaced them. An LCD display uses an extremely small amount of power, so the time can be permanently displayed. However, unlike an LED watch which lights up in the dark, or an analogue watch which can have luminous hands, an LCD watch requires a backlight for night time viewing. The watch in Figure 50 is extremely rare, but is shown to illustrate the first type of liquid crystal display used in watches. Watches like that in Figure 51 have been made from the late 1970s onwards.

Quartz digital watches are not serviceable in the normal sense, but the movements can be replaced. However, replacements are not as easy to find as quartz analogue movements.

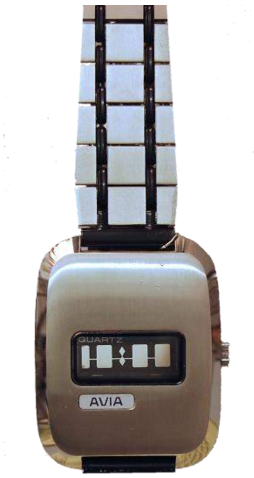

Figure 50 – very early LCD watch with "random dispersal" display

Figure 51 – a good quality LCD watch (this cost the owner a week's wages in 1977)

3 Is time smooth?

The true nature of time is still being debated by physicists and philosophers, and such discussions are sadly beyond the scope of this course. However, most people would agree that time seems to move smoothly and continuously. Therefore it is natural that the first timekeepers also used a smooth, continuous process to represent the passage of time.

Candles with regular marks along their length are an obvious example. Water clocks (clepsydras) of varying levels of sophistication were developed, although all of them relied on the steady flow of water through a small hole or constriction.

In the collection of the British Horological Institute is an incense clock (Figure 52). Several pairs of weights are suspended over a tray, each pair being held by a piece of string. The strings are evenly spaced apart and stretched horizontally across a frame. A burning stick of incense is placed across the strings. The incense burns along its length at a constant rate, and each time the smouldering end reaches a string, the string burns through allowing the weights to drop onto the tray. The audible clangs of the falling weights indicate the passage of time.

The hourglass is another example of a smooth, continuous process being used to measure the passage of time. The sand trickling through a small constriction means they operate in much the same way as a clepsydra. Interestingly, though, the earliest solid evidence for the hourglass goes back only to the 14th Century.

You can see that people have been quite inventive in this field, and we might expect timekeepers using a smooth, continuous motion would measure the smooth passage of time with great accuracy.

Even though this seems like common sense, by a strange quirk of physics it turns out not to be the case. In fact the most accurate timekeepers use a totally different principle; they rely on something moving regularly between two states: an oscillator. There are many types of oscillator, but all modern timekeepers (apart from a sand-filled egg timer) rely on an oscillator of some sort.

Figure 52 – incense clock

4 The oscillator as a timekeeper

Anything that goes back and forth between two positions with reasonable regularity is said to oscillate. Oscillations are found everywhere, from the swaying of a tree branch to the vibrations of a violin string. The complete motion from one extreme position to the other and back again is called an oscillation, or a cycle. The number of cycles in a given period is called the frequency. *For more information read the box to the left*.

For timekeeping purposes, mechanical oscillators are more stable, and easier to implement, than the continuous motion devices mentioned previously. An example of an early mechanical oscillator is the verge and foliot, used throughout Europe in the 15th and 16th Centuries. The verge and foliot is described in Lesson 12.

In the year 1581 Galileo discovered the properties of the pendulum, which is the first known **resonant oscillator**. Resonant oscillators have a natural frequency of vibration, in contrast to the verge and foliot, for example, which has no natural frequency and is thus non-resonant.

The discovery of the resonant oscillator was the greatest breakthrough in the history of horology, and gave the potential for massive improvements in timekeeping accuracy. There are two common forms of the resonant mechanical oscillator: a weight acting against gravity (i.e. a **pendulum –** Figure 53); and a weight acting against a spring (i.e. a **balance –** Figure 54). All modern mechanical timekeepers use one of these forms. We will look in detail at both of these during the course.

Figure 53 – a mantel clock pendulum

Figure 54 – a balance

For reasons outside the scope of this course, it turns out that – all things being equal – high frequency oscillators keep better time than low frequency ones. Harrison realised this when he abandoned his third attempt at a marine chronometer and used a watch for his fourth, successful, attempt. There are limits to how rapidly a mechanical device can oscillate, but the world of electronics is not constrained in the same way. The balances in modern mechanical watches typically run in the range 2.5 to 4 cycles per second, but the quartz crystal in a modern watch typically oscillates at over 32,000 cycles per second. That is one reason why they keep much better time than a mechanical watch. The most accurate timekeepers of all, atomic clocks, oscillate several billion times per second.

*The standard way of measuring frequency is in cycles per second. The unit of frequency is the **Hertz**, abbreviated to Hz and pronounced "hurts". One cycle per second is 1Hz. For historical reasons we usually use **beats per hour** (bph) in horology. There are normally two beats (or ticks) to each oscillation, so that a timekeeper ticking six times per second oscillates at 3Hz, and beats at:*
6 x 60 x 60 = 21,600bph.

A 2Hz oscillator completes two cycles in a second – the time for one cycle is thus half a second. It is simple to convert between frequency and the time for one cycle:

frequency (in Hz) =
1 / time for one cycle (in seconds)

time for one cycle (in seconds) =
1 / frequency (in Hz)

5 Basic divisions of a mechanical movement

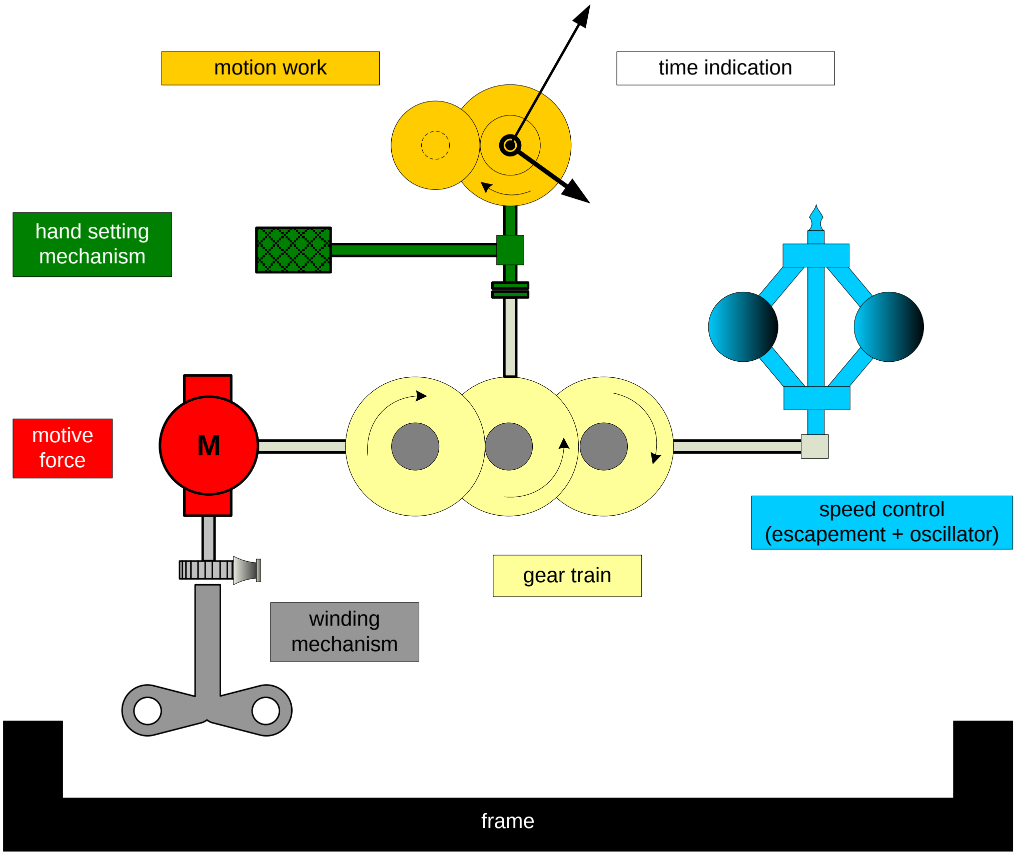

Figure 55 – the divisions of a mechanical movement

All mechanical watches and clocks work on the principle shown here:

- a **motive force** drives a **gear train**,
- the gear train operates some form of **time indication** (which usually employs **motion work**),
- a **speed controller** controls the speed of the gear train, such that the time indicator accurately shows the passage of time (the speed controller consists of an **escapement** and an **oscillator**).

In horology, the term "gear train" is usually abbreviated to "train", and this is regarded as the preferred usage.

You will hear both terms used.

In addition we have:

- the **frame**, which acts as the chassis for the rest of the mechanism; for clocks, it is usually two plates held apart by pillars. There are separate bridges and cocks where necessary. A modern watch consists of one plate with bridges and cocks,
- a **winding mechanism**, which allows us to replenish the energy in the weight or the spring,
- a mechanism for **hand setting**, so we can set the clock or watch to the right time.

You can see straight away that the speed controller is crucial in making the clock or watch indicate time accurately. A good speed controller will ensure the train runs at exactly the same speed even if the motive force varies, or if the train suffers from varying friction. We will come back to this in much more detail later.

5.1 The motive force

We do not want a timekeeper which requires a continuous supply of external energy, as this would be very inconvenient. Therefore we need a device which stores energy, such that we can replenish it at convenient intervals. There are two energy storage systems used in mechanical timekeepers: weights and springs.

A weight stores energy when it is lifted from the ground, and releases the energy as it descends. By lifting the weight at regular intervals, we provide it with enough energy to operate the clock for the intervening period.

A spring stores energy when it is tightly wound, and releases it as it unwinds. We store energy in the spring by "winding it up".

In both cases the stored energy acts on the train as **torque** (turning force). The spring or weight is coupled to the first wheel in the train, which is commonly called the "great wheel". As the torque is allowed to turn the train, the stored energy is gradually dissipated.

For a clock, the torque from a descending weight is always constant until the weight can descend no longer. This makes the design of the rest of the clock simpler and gives the potential for very stable timekeeping. On the other hand, a weight-driven clock requires room for the weights to fall, which is a disadvantage. Also, weight-driven clocks cannot be carried around. A spring drive shows a diminishing torque as the energy is dissipated, but timekeepers using a spring can be made compact and portable. The ultimate example of this is, of course, the wristwatch.

In theory, the stored energy from either system could appear as a very small torque at the first wheel, but which can be maintained over a large number of turns; or a large torque which can be maintained over just a few turns.

It happens that both weights and coil springs work best in the latter arrangement; that is, generating a lot of torque but only over a few turns.

5.2 The winding mechanism

Most mechanical clocks are wound by turning an arbor which lifts the weight, or winds the spring; a watch is wound by turning the winding crown. The arbor is prevented from turning backwards (thus unwinding the clock or watch) by a simple **ratchet** mechanism comprising a ratchet wheel, click and click spring.

5.3 The train

It also happens that all the commonly used speed controllers require a very small torque (compared with the motive force) over lots of turns, so we use a train to reduce the torque from the first wheel and increase the available turns. Each stage in the train divides the torque and multiplies the number of turns. In other words, the train converts *high-torque, few-turns* into *low-torque, many-turns*.

The train also provides a suitable place to derive the time indication. We will discuss this shortly.

5.4 The speed controller (escapement and oscillator)

You will recall our discussion in Section 3 above about time flowing smoothly. We pointed out that maintaining a smooth, continuous motion at a constant rate is very difficult to do accurately, whereas we can make devices which move back and forth – oscillators – with great accuracy. Therefore we want an **oscillator** at the heart of our speed controller.

There is no easy way of converting the smooth, continuous motion we want in our train into a back and forth motion for our oscillator. Luckily, it does not matter – we can compromise. We can allow our train to move in steps, provided they occur closely enough together. For instance, the time indication on your quartz analogue watch with a seconds hand moves in one second steps, which is perfectly acceptable for normal purposes.

Allowing the train to move in small steps turns out to be essential to overcoming the problem of using an oscillator as the time reference.

A device called the **escapement** sits between the train and the oscillator. It has two jobs: firstly, it provides energy to the oscillator to keep it going; secondly, it releases the train in small steps, *under the control of the oscillator*, so the train runs at the required speed. The escapement plays a key role in all mechanical clocks and watches. There are numerous designs of escapement, and in due course we will be studying several of them closely.

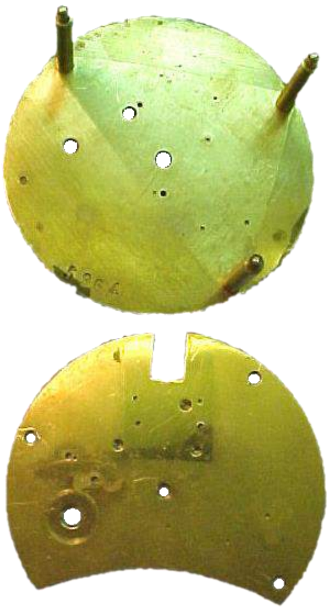

Figure 56 – example clock plates with pillars

5.5 The time indication

We now have our train running at the desired speed. The timing indication is traditionally one or more hands moving around a dial, although timekeepers with a digital readout have been made.

5.6 The motion work

Most clocks and watches have the minute and hour hands mounted concentrically. The minute hand turns twelve times for one turn of the hour hand. The gearwheels which do the job of driving the concentric clock hands at the appropriate 12:1 ratio are called the **motion work**. The motion work is driven from a convenient point on the train.

5.7 The time setting mechanism

The hands must be settable to the correct time even though the escapement and oscillator limits the speed of the train. This is achieved by a friction drive between the train and the motion work. As the movement runs, the friction drive turns the hands but the user can overcome the friction in order to adjust the hands to the correct time. Some clocks are set simply by moving the minute hand round; others have a knurled knob geared to the motion work. For the watch, the winding crown is pulled outwards so that, when turned, the position of the hands is adjusted.

5.8 The frame

On most clocks the frame consists of a front plate and a back plate, with three to five pillars between them. Bridges and cocks are used to provide support for arbors extending beyond the plates. Figure 56 shows some plates from a French drum clock. Early watches were made using a similar construction but modern watches use a main plate with bridges and cocks – Figure 57.

Figure 57 – example watch plate, bridges and cocks

5.9 Summary

The basic divisions of a mechanical movement are:

- frame,
- motive force,
- winding mechanism,
- train,
- time indication, including motion work,
- hand setting mechanism,
- escapement,
- oscillator.

6 A hands-on look at a simple clock

If you are thinking about dismantling a clock to look at the component parts, ***it is essential that the mainspring is let down*** *before you start. Look in the Clock Servicing section of Lesson 4.*

In this section we will dismantle a mass produced eight-day movement to learn about the component parts. This one is spring driven, with the spring in a going barrel, and uses an anchor (or recoil) escapement – the commonest of all clock escapements. These terms will be explained more fully as we proceed, and in later Lessons.

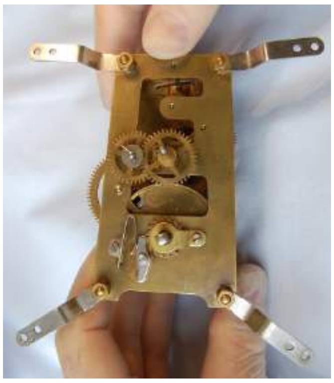

Figure 58 – front view of movement

Figure 59 – rear view of movement

6.1 Overview

Our clock is a mid-20th century Bentima mantel clock movement, shown in Figure 58 and Figure 59. In these two photos you can see the brackets for mounting the movement to the clock frame. We have removed these for all the subsequent photographs.

6.2 Motion work

Figure 60 – motion work on the front of the clock

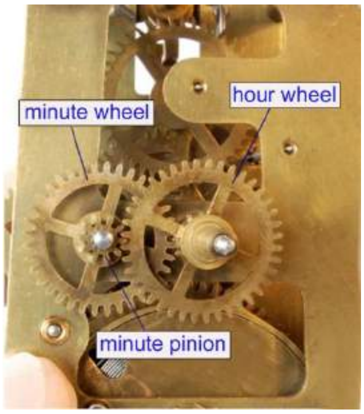

Figure 61 – minute wheel and hour wheel

The **motion work** allows the minute and hour hands to be mounted concentrically, and provides the required 12:1 ratio between them (i.e. twelve turns of the minute hand results in one turn of the hour hand). Lesson 2 explains this much more fully.

In Figure 61, we have removed the tapered pin and washer which retain the **minute wheel**. You can now see that the **minute wheel pinion** (the smaller gear, sometimes called the **minute pinion**) engages with the **hour wheel**. The hour wheel is so called because it carries the hour hand. The name of the minute wheel could be confusing because it does not carry the minute hand, nor does it turn once a minute. It merely acts as the intermediary between the cannon pinion and the hour wheel.

In Figure 62, the hour wheel is lifted clear, revealing the cannon pinion, which is pressed onto the **centre arbor** (an arbor is the horological term for an axle or shaft).

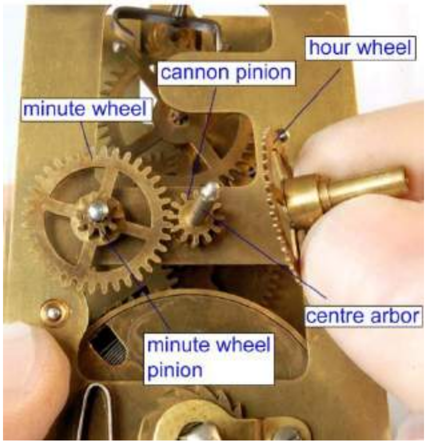

Figure 62 – the hour wheel lifted clear

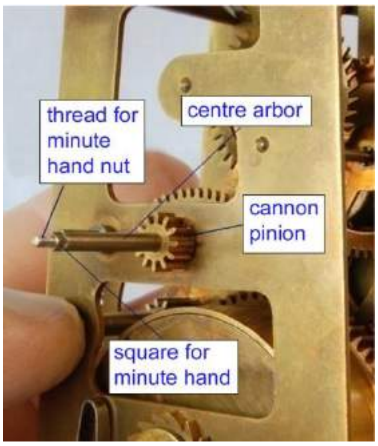

Figure 63 – centre arbor and cannon pinion

It should now be clear that the drive from the centre arbor (which carries the minute hand) goes via the cannon pinion to the minute wheel; the pinion attached to minute wheel then drives the hour wheel.

The centre arbor is more easily visible in Figure 63, where you can see the square upon which the minute hand sits, and the threaded portion for the nut which retains the minute hand.

6.3 Pendulum and crutch

Mounted at the top of the **back plate** is the **back cock**. The upper part of the **suspension spring** is held in the slot in the back cock by a taper pin. The top part of the **pendulum rod** hooks onto another pin through the lower part of the suspension spring. In Figure 65, you can also see the **crutch**, which engages with a vertical slot in the upper pendulum rod. The crutch moves from side to side with the pendulum, and transmits the small force necessary to keep it swinging.

A close-up of the suspension spring is shown in Figure 66. The suspension spring carries the weight of the **pendulum** and allows it to swing from side to side. In this instance the suspension spring is two narrow springs side by side.

*Raising and lowering the bob alters the **rate** of the clock, so we can adjust it to keep good time.*

Figure 64 shows the complete pendulum, consisting of the upper and lower rod, with the **bob** at the bottom. The bob can be raised or lowered using the knurled **rating nut** in the middle, which engages with a threaded portion of the lower pendulum rod.

Figure 64 – complete pendulum

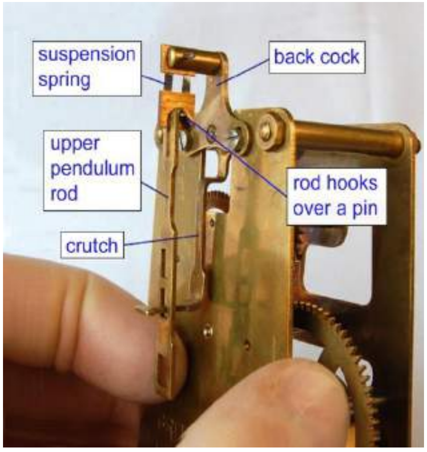

Figure 65 – mounting the pendulum

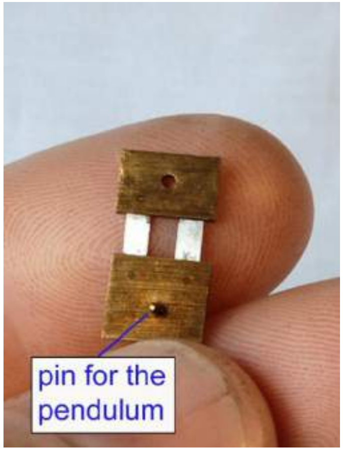

Figure 66 – suspension spring

This pendulum bob is made from cast metal, but often it is a brass case filled with lead.

Some clocks have a different type of crutch and pendulum rod. More details are given in Lesson 3.

6.4 Cocks and bridges

Bridges and cocks are part of the frame of the clock; they are fitted where an arbor extends beyond the plate and requires a pivot outside the plate. Occasionally cocks are also found between the plates.

Technically, a bridge "bridges" over the pivot and has two feet by which it is fastened to the plate. A cock has just one foot and is generally fastened to the plate by just one screw. Some more information and examples are given in Section 6.12.

There is one exception where the naming rule is broken: the "back cock" which we will discuss next.

6.5 Back cock and pallets

Back to our clock, and another example of strange horological terminology.

Figure 67 – back cock in situ

Figure 68 – close-up of back cock

Figure 67 and Figure 68 show the **back cock**, which is clearly a bridge because it has two screws to fasten it to the clock plate. Even so, it is always called the back cock. The slot for the upper part of the suspension spring is clearly visible.

In this instance the screw holes are slotted to allow the position of the back cock to be adjusted to alter the depthing of the pallets with the escape wheel. In some clocks there is no adjustment; the back cock is located precisely with steady pins. Another approach, often found on French drum movements, is a “turntable” – a separate circular piece of brass lightly rivetted in the front plate. The pivot hole is off centre so that turning the “turntable” will adjust the position of the pivot hole and therefore the depthing of the pallets. The brass turntable usually has a slot for adjusting with a screwdriver. It is very tight and usually no alteration to the depthing is required.

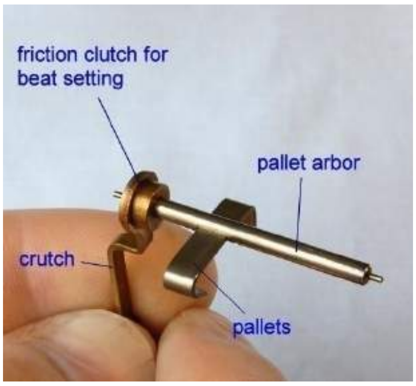

Figure 69 – pallet assembly

Figure 70 – close-up of pallets

The **pallet assembly** – Figure 69 – has been taken out of the clock.

Pallets are made in two ways: bent strip pallets, as found in this clock, or using a steel forging or steel plate. Bent strip pallets are cheaper in production and found in less expensive mass produced clocks. The acting faces, the pads, are hardened and highly polished.

The **pallets** are mounted on the **pallet arbor**. In this instance the pallet arbor has a friction device connecting it to the crutch. This lets us adjust the relative position of the crutch and the pallets, which is used to set the clock in beat (to give it an evenly spaced tick-tock-tick-tock). We will look at the pallets (part of the escapement) in much more detail in Lesson 3. The pallet assembly is part of the escapement. As the pendulum swings from side to side, the pallet assembly, being linked to the pendulum by the crutch, rotates about the axis of the pallet arbor. This movement of the pallets allows an escape wheel tooth to be released, which, at the same time, impulses the pendulum to keep it swinging.

6.6 Winding mechanism

Deficiencies in any part of the winding mechanism can cause serious hazards to the person winding the clock, and the clock itself. We will discuss this in more detail in Lesson 2.

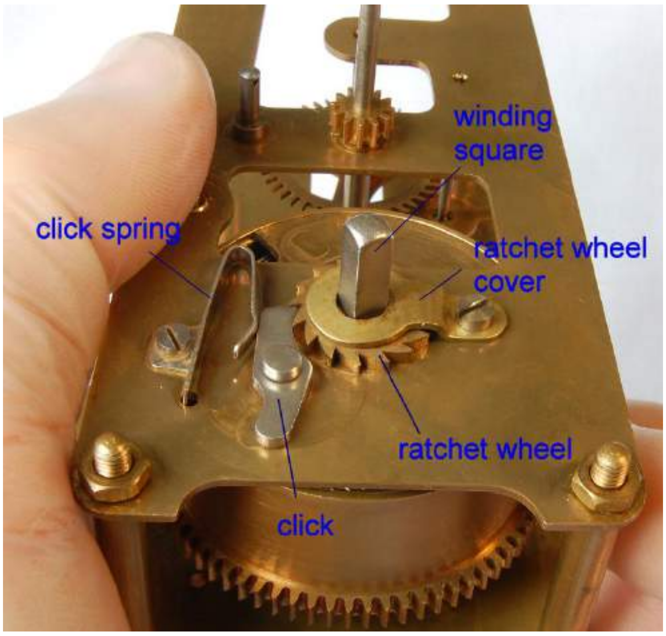

Figure 71 – the winding mechanism

Figure 71 shows the complete **winding mechanism**. The **winding square** is formed on the end of the **barrel arbor** (Section 6.9). The key (not shown) fits the winding square and is used to turn the barrel arbor, winding the spring inside the barrel.

Figure 72 – ratchet wheel cover

Figure 73 – ratchet wheel

The ratchet wheel fits over the winding square and turns with the barrel arbor. The **click** is held on the front plate by a shoulder rivet, and is therefore free to rotate; it is held in engagement with the **teeth** of the **ratchet wheel** by the **click spring**. As winding takes place, the click snaps in and out of the ratchet wheel teeth, giving the characteristic "clicking" sound. When the key is released the click engages the ratchet wheel, preventing it from turning anticlockwise again when the key is released.

The **ratchet wheel cover** holds the ratchet in place, and is shown in Figure 72. Figure 73 shows the ratchet wheel. The square hole fits the winding square on the barrel arbor so the two rotate together.

Figure 74 gives a close-up view of the click spring, and in Figure 75 you can see the foot which fits in a hole in the clock plate and keeps the spring properly located.

On some clocks the click is secured by a shoulder screw instead of a rivet.

Figure 74 – click spring in situ

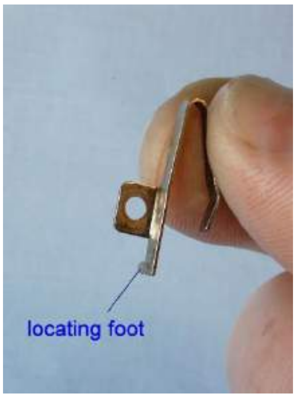

Figure 75 – detail of click spring

6.7 Overview of the train

Figure 76 and Figure 77 show two views of the **train**, and how it fits between the front and back plates. We will now look at the individual wheels and pinions.

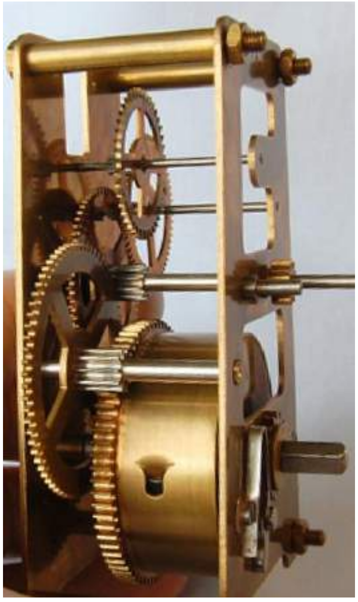

Figure 76 – the train in position

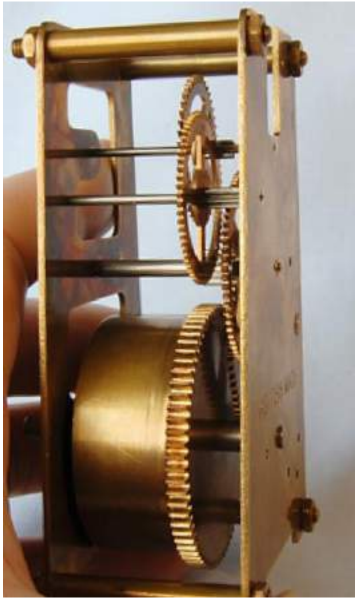

Figure 77 – another view of the train

6.8 A typical clock wheel and pinion

The train is made up of wheels and pinions on arbors. There are specific terms for each part which you need to know, as shown in Figure 78.

The wheels on our Bentima are mounted in a different way. Instead of using the traditional collet – Figure 78 – they are fastened directly to the pinion. A portion of the pinion has been turned down to locate the wheel, which is then rivetted to it.

This method is more commonly found in low cost, mass-produced clocks.

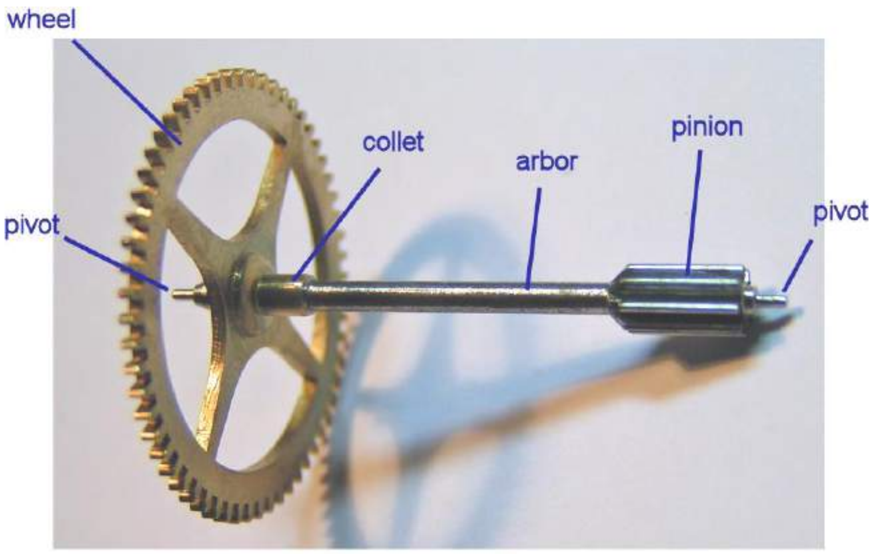

Figure 78 – a wheel on its arbor

This is a typical example of a wheel and pinion. The wheel has teeth all round it. The wheel is normally made from brass, and is rivetted to the brass collet, which in turn is soft-soldered to the steel arbor. At each end of the arbor is a pivot, machined from the arbor. Each pivot runs in a hole in the front or back plate of the movement. The pinion is like a small gear wheel, but it also is machined from the same piece of stock as the arbor. The teeth on a pinion are properly called leaves.

In horology, a wheel generally has twenty or more teeth. An exception is the escape wheel, which may have fewer. Pinions have less than twenty leaves.

The pinion is hardened and tempered, and the leaves polished to reduce wear. The pivots are also hardened, tempered and polished before being burnished to a shiny finish. Burnishing smoothes the metal by "flowing" it, rather than abrading it. This work hardens the surface and makes the pivot less prone to wear.

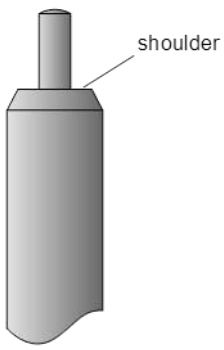

Figure 79 – the form of a typical pivot

The shoulders of the pivots (Figure 79) are slightly chamfered at their outer edge to eliminate sharp edges and reduce the diameter of the metal actually rubbing against the plate. This reduces the running friction of the train. The diameter of the pivot is typically about one third of the diameter of the arbor.

The wheel is **crossed out** to give four "spokes" of a traditional shape. Some wheels have more crossings. This reduces the mass of the wheel, improves its appearance, and saves on brass (which was, at one time, a scarce and expensive material).

When assembled into a train, the wheel on one arbor engages with the pinion on the next, thus providing a "gearing up" or multiplying effect. One turn of the wheel forces the driven pinion to make many turns. We will look at how to calculate the multiplying effect later in the course.

Figure 80 shows the train in position, but with the back plate removed. In Figure 81, the direction of power flow through the train is shown by the thick black arrows, and the thin blue arrows show which way the wheels rotate.

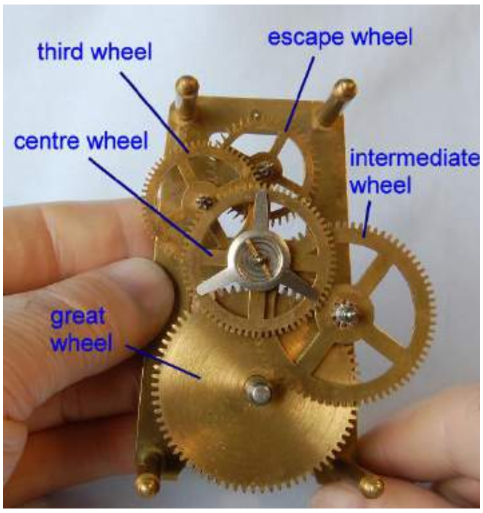

Figure 80 – the train wheels named

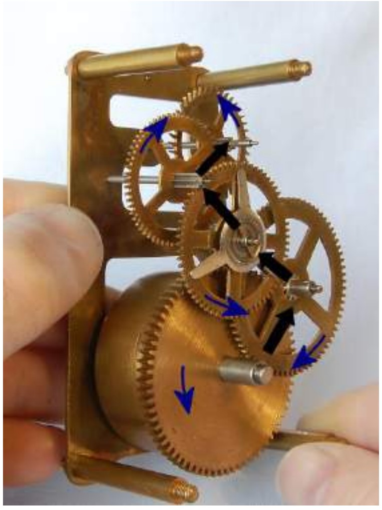

Figure 81 – power transmission through the train

6.9 Barrel and great wheel

Figure 82 – the barrel

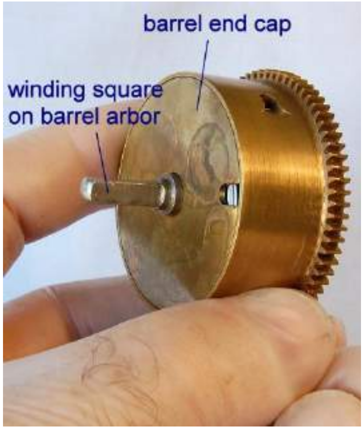

Figure 83 – another view of the barrel

*This type of barrel is called a **going barrel**.*

The **barrel** contains the **mainspring**, which stores the energy to run the clock. The spring is hooked to the **barrel wall** and – when wound – tries to turn the barrel. The inner end is hooked to the arbor. Integral with the barrel is the **great wheel**. This is the first wheel in the train. In Figure 84, the **end cap** has been removed so you can see the spring inside. Turning the barrel arbor clockwise winds the spring, and as the barrel slowly rotates clockwise the spring unwinds again.

Figure 84 – barrel with end cap removed

6.10 Intermediate, third and escape wheels and pinions

Figure 85 – intermediate wheel and pinion

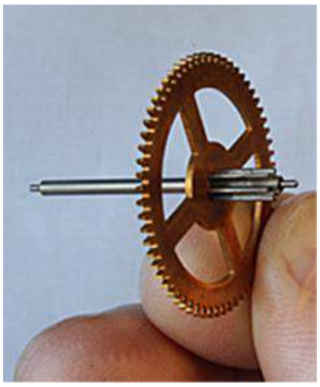

Figure 86 – third wheel and pinion

The **intermediate wheel and pinion** – Figure 85 – goes between the great wheel and the **centre wheel and pinion**. It is only used on clocks designed to run for a week or longer. In 30 hour clocks, the great wheel drives the centre pinion directly.

Note the sturdy pivots on the arbor of intermediate wheel – it must withstand a large amount of torque.

Figure 86 shows the **third wheel and pinion**. It is actually the fourth wheel in this train (after the great wheel, intermediate wheel and centre wheel). In a 30-hour clock there is no intermediate wheel, so it would be the third wheel. The nomenclature is retained whether it is a 30-hour or 8-day clock: the third wheel is always the wheel after the centre wheel. You can see that the pivots are finer as it operates under much less torque.

We talked about how the torque varies through the train in Section 5.3.

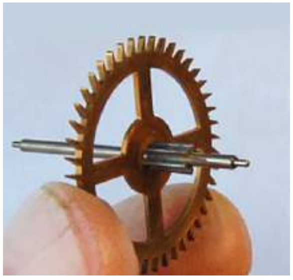

Figure 87 – escape wheel and pinion

Figure 88 – tooth form of escape wheel

The **escape wheel and pinion** is shown in Figure 87. It is made in much the same way as the rest of the wheels, except that the shape of the escape wheel teeth – Figure 88 – is completely different because the teeth engage with the pallets, rather than driving another pinion. We will look in detail at the recoil escapement in Lesson 3.

6.11 Centre wheel and hand setting

We have left the **centre wheel and pinion** until last because it is the most complicated. If you remember back to Section 5.7 you will recall that the hand setting mechanism requires a friction drive between the train and the motion work. The centre arbor assembly incorporates this clutch. The wheel and pinion form part of the train and thus *cannot* be turned by hand, but the centre arbor – which carries the minute hand – *can* rotate with respect to the minute wheel and pinion, thus letting us turn the hands to the correct time.

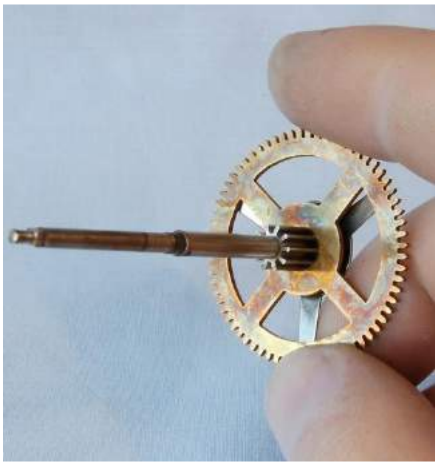

Figure 89 – centre arbor assembly

Figure 90 – the components of the friction drive

We call it the "centre arbor assembly" because it is made of several parts. In Figure 89, it looks much like any other wheel in the train, although the extended arbor to carry the minute hand is obvious. However, there is one major difference: the wheel and pinion are not solidly connected to the arbor, as with all the other wheels. In fact, without the friction drive assembly – Figure 90 – they would spin freely on the arbor.

All will become clear when we dismantle it. In Figure 91, we have removed the brass pin and released the three-legged friction spring.

Figure 91 – three-legged friction spring

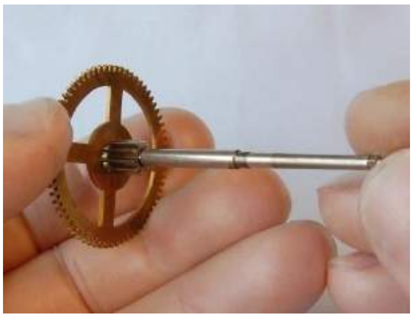

Figure 92 – centre arbor in the centre pinion

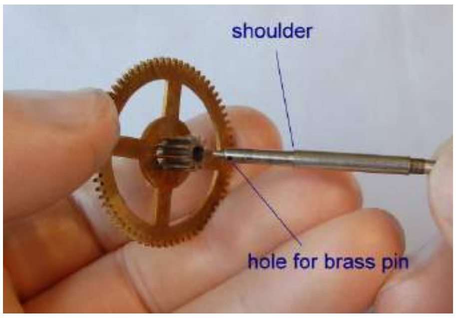

Figure 93 – centre arbor withdrawn from centre pinion

As you can see from Figure 92 and Figure 93, the centre wheel/pinion assembly is free to rotate on the centre arbor, but is “pinched” between the shoulder and the brass pin by the friction spring. Under normal running there is enough friction at the shoulder and the pin to turn the arbor along with the wheel/pinion assembly. However, when the arbor is forcibly rotated by setting the minute hand, slippage occurs at the shoulder and between the brass pin and the friction spring. The strength of the friction spring determines how much force is required to set the minute hand.

There are other friction drive arrangements used on older clocks – we will look at some of these in Lesson 2.

6.12 The frame – plates and pillars, bridges and cocks

Figure 94 – front plate with pillars

Figure 95 – back plate

Virtually all clocks use brass plates and pillars. The pillars separate the two plates, and provide some rigidity between them. It is common to find large voids in one or both plates – it helps save brass and thus reduces manufacturing costs.

Figure 97 – oil sink

Most of the pivot holes have an oil sink – Figure 97. This acts as a reservoir for the lubricating oil. It is made with a circular chamfering tool called a **roller sinker** – Figure 96. If the oil sink is too shallow it will not hold sufficient oil. If it is too deep it reduces the thickness of the plate too much, allowing the pivot to wear the hole to an oval shape.

Cheap clocks with excessively thin plates do not have enough thickness for proper oil sinks. The lack of plate thickness, and the shortage of oil, leads to more rapid wear.

Figure 96 – roller sinker

Oil sinks should have sharp shoulders at their outer edge. This helps prevent the oil spreading down the plate, away from where it is needed.

Figure 98 – pillars fastened to plates with nuts

The clock we are working on uses nuts to hold the pillars to both front and rear plates, as shown in Figure 98. Sometimes the pillar has a threaded hole and a screw passes through the plate into the pillar. The hole in the plate may be countersunk so that the screw head is flush with the plate.

Earlier clocks avoided using screw fasteners in this role. Figure 99 and Figure 100 show the arrangement from a 19th century wall clock. The pillars are rivetted to the back plate. The job is so neat, only the slight difference in colour of the brass makes the rivetting apparent.

Figure 99 – pillar rivetted to back plate

Figure 100 – front plate retained to pillar by tapered pin

The other end of the pillar has a hole drilled through, and the plate is firmly clamped to the pillar when a tapered pin is forced through the hole.

It has already been explained that there are often bridges and cocks which form part of the frame of a clock. The example of a bridge, although it is called a back cock, has already been mentioned during the dismantling of the Bentima clock. Another example of a bridge, the hour wheel bridge, will be provided together with an example of a cock.

The hour wheel bridge is generally found on longcase, dial and bracket clocks; it carries the pipe that provides a bearing for the hour wheel – Figure 101.

Figure 101 – long case hour wheel

When the hour wheel is removed the hour wheel bridge can be seen more clearly, Figure 102.

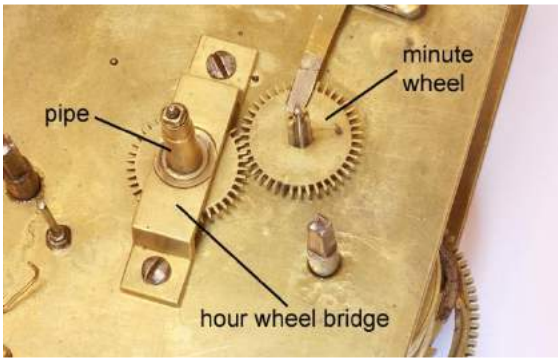

Figure 102 – longcase hour wheel bridge

The pipe forms the bearing for the hour wheel. The hour wheel bridge straddles the cannon wheel. The cannon wheel pipe and the centre arbor protrude through the pipe on the hour wheel bridge. The hour wheel bridge is secured by two screws and located with two steady pins which fit into holes in the front plate, Figure 103.

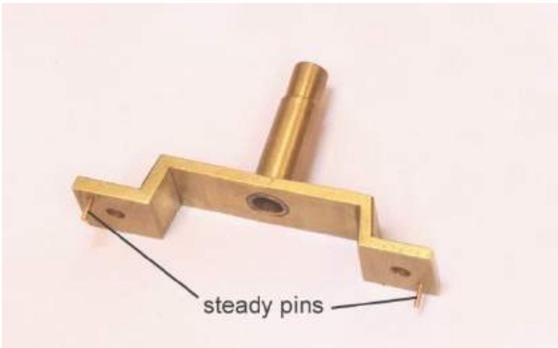

Figure 103 – steady pins to locate the hour wheel bridge

Figure 102 shows the minute wheel with its pinion; they rotate together on a post or stud projecting from the front plate. On many clocks a cock is used; the minute wheel and pinion turn with one pivot in the front plate and the other in a minute wheel cock, Figure 104.

Figure 104 – minute wheel cock

6.13 Summary

We have covered an enormous amount of ground in this section. Do not try to learn all the parts at this stage. Instead, refer back to it as we proceed through the course, and when you are revising for the examination. We will come across all these terms many more times as the course progresses.

Workshop Skills

7 Health and Safety

There is a great deal of legislation relating to health and safety. In particular, if you are an employer, you should seek advice on your legal obligations to employees and customers. The BHI – the publisher of this course – is not allowed to give any legal advice.

However, for readers with a workshop just for their own use, we can point out some basic safety measures which you should consider.

Flammable or inflammable?

Both these words mean "combustible", "liable to burn" and you will see both used.

Unfortunately "inflammable" is often incorrectly thought to mean non-flammable, so current recommended practice is to use the word "flammable".

Always use the word "flammable" in any dealings with the public.

7.1 Fire

Generally the risk of fire is small. However, some of the solvents you will be using are flammable. You should do two things straight away:

1) buy a *fire extinguisher* and install it in your workshop
2) put a *smoke detector* just outside the entrance to the workshop (it might prove too sensitive if it is actually in the room)

7.2 Electrical

Normal domestic wiring standards are sufficient for a small clock and watch workshop. The biggest safety risk comes from old electrical equipment bought at clock fairs. Consider having it checked, and if necessary rewired, by a competent electrician. Basic domestic electrical safety practices should be observed.

7.3 Chemicals

You will be using:

- cleaning fluids
- solvents
- lubricants

Most of these are fairly benign, although solvents can be flammable. Avoid storing large quantities of these in the workshop – consider keeping them outside in a shed or garage, and decanting small quantities into containers for use in the workshop. Cleaning fluids can give off harmful fumes, so use them in a well-ventilated place. Read and observe the warnings given on the container.

7.4 Eye protection

Buy some eye shields or safety goggles, and use them whenever you are using rotating machinery such as a grinder, drill or lathe. Also use eye shields when using a chisel, and using fluids that may splash (e.g. cleaning chemicals) or when heating substances that may spit (e.g. bluing salts, soldering operations, etc.)

7.5 Hand protection

If your skin is sensitive, use vinyl gloves. These will protect the skin against the chemicals you will be using in your workshop. We will be using these gloves anyway to protect clock parts from fingerprints after they have been cleaned, so put them on your shopping list now. Latex gloves are not recommended for two reasons: firstly, some people are allergic to latex; secondly, latex goes sticky when in contact with some of the chemicals we will be using, which can result in fingerprints being left on the parts.

The only other significant hazard to your hands comes from using a mainspring winding tool (we will be looking at these later in the course). A pair of tough leather gardening gloves is ideal protection.

7.6 Visitors

An injured visitor may have the right to sue you. If you are going to let visitors into your workshop, you should consider getting insurance to cover third party damages. This may be expensive. Alternatively, do not allow them into your workshop. “Enter at your own risk” signs may not carry much weight in law.

7.7 Common sense

The most important safety asset is common sense. Take a good look around your workshop. If something looks like it could be hazardous – sharp corners, objects teetering on high shelves – it probably will be. Put aside an hour to make your workshop as safe as possible.

8 Some common workshop tools

8.1 Screwdrivers

With the exception of a few 20th century mass-produced clocks, only slotted screws are used in horology.

Clock screwdrivers

Buy some good quality “flat” or “straight” tipped screwdrivers in a range of sizes. Worn tips are prone to riding out of screw heads and skidding across the surrounding surfaces, damaging the screw head itself and other parts of the clock. That is why you need good quality screwdrivers with hard, correctly formed tips. As the tips wear, reshape them with a file (the heat from grinding tends to soften the metal).

Small cross-headed screwdrivers can be purchased for any cross-head screws you might find.

Watchmaker’s screwdrivers

Bruised screw heads indicate poor workmanship and will lose marks when you take your examinations. Manufacturers of high value movements expect that after a complete service the movement should be as new and not show any signs of work. The damage shown in Figure 105 is totally avoidable.

Figure 105 – damaged and undamaged screws

To minimize bruising of the screw slot and damage to components from the screwdriver slipping, the blade should fit the slot perfectly – Figure 106.

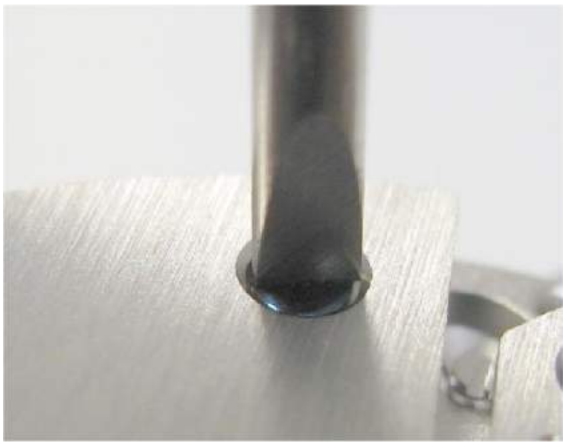

Figure 106 – the blade should fit the slot perfectly

If the blade is too wide it will scrape the plate causing unsightly damage; if it is too narrow the slot in the screw will be marked because pressure is concentrated on just a small area. In addition to the blade fitting the length of the slot it should also fill the width of the slot.

Figure 107 shows the situations that can occur. In diagram A, the angle of the blade is too steep and too much downward pressure is needed to ensure the blade will not slip out of the slot and damage the plate; the blade will also bruise the edges of the screw slot.

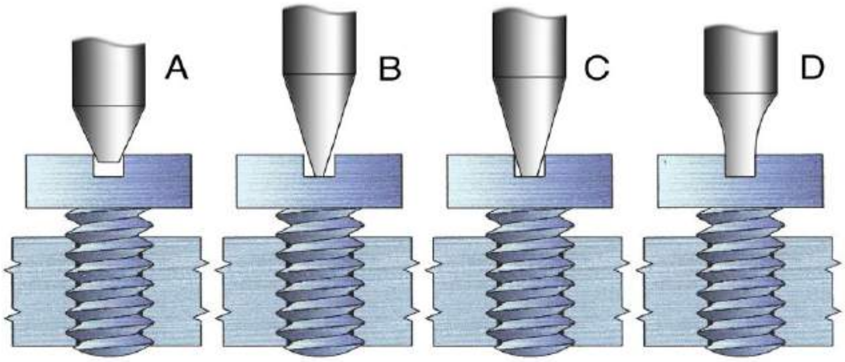

Figure 107 – the screwdriver blade must be the correct angle and width for the slot

Diagram B shows the correct angle but the point is too sharp and not strong enough. This also could damage the slot, or the corners of the blade could break off or twist, again causing damage.

Diagram C is sharpened at a suitable angle and fits the screw slot well; it should nearly touch the bottom of the slot to cause minimum bruising to the screw head.

Diagram D is hollow ground and fits perfectly and should need very little downward pressure to turn the tightest of screws. There are tools available to hollow grind the blade so the fit in the screw slot is exact, thus avoiding bruising the edge of the screw slot. The sharpening stone is curved to form the hollow ground shape. (Bergeon ref. 6924; Horotec ref. MSA 01.502 – see Figure 108).

Figure 108 – Horotec screwdriver sharpener

Many watchmakers will have more than one set of screwdrivers available for different widths of screw slots. Some will have a set with beryllium bronze blades to reduce the risk of damage even further (beryllium bronze blades are available from some material dealers). These are especially useful when the same screw must be removed and refitted repeatedly, as was the case in Figure 105.

Very often watchmakers will put off sharpening their screwdrivers because this takes time, and time is money when you are self-employed, on a bonus or a piece-work contract. Most sharpen their screwdrivers in the traditional way, on an India stone, sometimes with the aid of a wheeled clamp to achieve symmetry and the desired angle – Figure 109. This approach is excellent but time consuming.

Figure 109 – using a screwdriver sharpening device

This process can be speeded up by using a 6inch, No. 4 cut, good quality pillar file. With practice, a well sharpened screwdriver blade can be achieved in seconds – Figure 110 and Figure 111. A fine oilstone will remove the file marks if required.

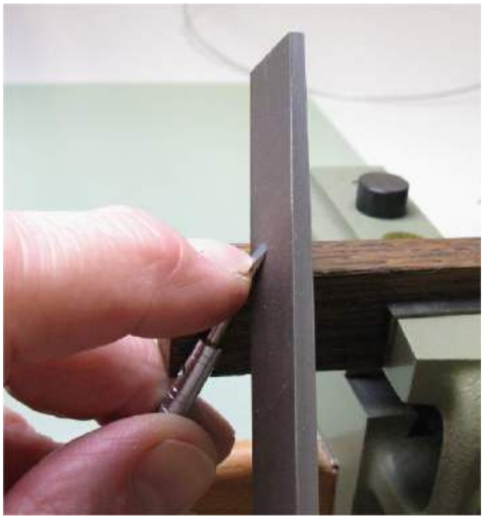

Figure 110 – sharpening the screwdriver on a file

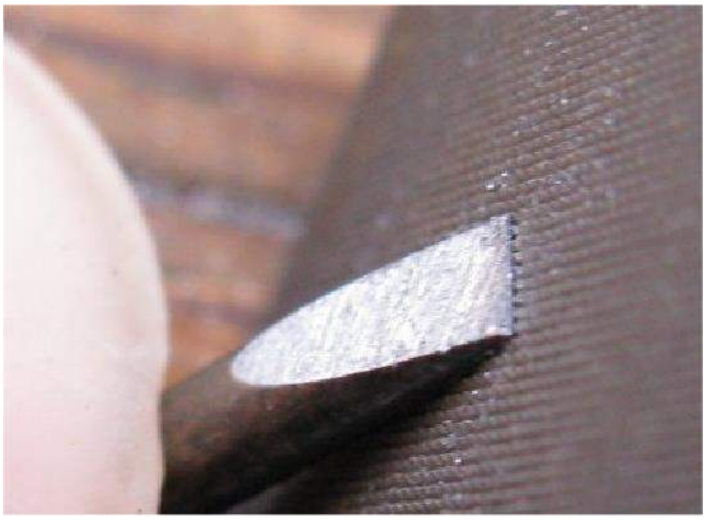

Figure 111 – the blade can be sharpened in seconds

8.2 Tweezers

Tweezers are used for handling very small parts – especially watch parts.

As well as enabling tiny parts to be handled and manipulated, they also avoid finger marks getting onto the parts.

Tweezers come in a variety of sizes, shapes and materials.

Sizes

The size refers to the fineness of the tips. Very fine tips are needed for manipulating the smallest parts (such as watch screws). However, fine tips are delicate, being easily bent or distorted out of shape, so for larger parts you should use tweezers with broader tips. That is why you need a selection of sizes.

Unfortunately the manufacturers tend to use different numbering and lettering schemes for their tweezers. However, most watch tool suppliers give you an English description for each size, typically:

- broad
- medium
- fine
- very fine
- super fine

It is worth getting one of each, except for the broad tip, which does not have much use for watch work, although some people like them for handling clock parts.

Shapes

The tweezers used most of all in horology are straight with plain tips (you can get specialist tips for holding jewels, etc, but you will not need them for our purposes). The other shape you may need are curved tweezers, specifically made for manipulating balance springs.

Finally, you can get plastic tweezers with special spade tips, specifically for handling batteries.

Materials

Tweezers are available in steel, brass and plastic. You can also get metal tweezers (typically aluminium) with plastic or carbon fibre tips.

Steel tweezers are good for most purposes, but make sure you buy anti-magnetic ones. The big problem with steel tweezers is that they will mark delicate surfaces. Steel tweezers are electrically conductive so they must not be used for handling watch batteries because they will form a short circuit between the positive and negative poles.

Brass tweezers should be used for handling soft or delicate metal parts, such as watch plates. Not as hard as steel, they still make excellent all-round tweezers. As with steel, they conduct electricity so cannot be used to handle watch batteries.

Plastic tweezers are suitable for handling even the most delicate of parts, and are ideal for manipulating watch batteries. They lack rigidity, so the tips are prone to "crossing over". They also lack strength at the tips, so they can easily be distorted or damaged.

Metal-bodied tweezers with plastic or carbon fibre tips have the rigidity of the steel or brass tweezers, but with non-marking, non-conductive tips.

Figure 112 shows a selection of tweezers.

Figure 112 – from top to bottom: medium steel, fine steel, spade-tipped plastic, medium brass, balance spring tweezers

We would advise buying the following to start with:

- Steel: medium, fine, very fine, super fine,
- Brass: medium, fine,
- Plastic: one pair with 3mm spade tips for handling batteries.

Carbon fibre- or plastic-tipped tweezers can wait until you know you need them. You will need one or two pairs of balance spring tweezers, but not until Lesson 8, when we service a platform escapement.

Using and maintaining tweezers

The tips of tweezers will wear after a lot of use, or distort or bend if they are abused. Therefore it is often necessary to "dress" the tips to make them perfect.

You want the tips to be of equal width and thickness, with the correct degree of sharpness, and you want the inner surfaces to meet for a short distance behind the tip when the tweezers are closed with moderate pressure.

In particular, you do not want the tips to curl outwards when a part is held, as this can cause the held part to be ejected – Figure 113.

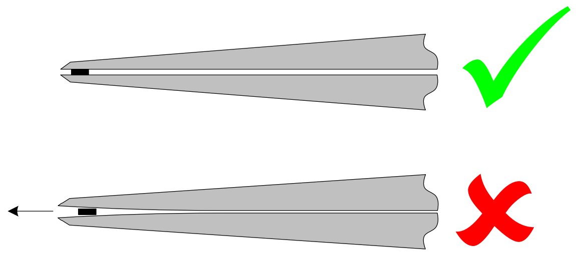

Figure 113 – the tips must be parallel when holding a part under moderate pressure

Before dressing, see if the tips need bending into position. Brass tweezers, in particular, are rather prone to getting bent tips.

Once any bending is done, use an Arkansas slip to dress the tips to perfection. Do not try to polish the inner, gripping surface: the finish from the Arkansas slip is just right to help the tweezers grip the part.

8.3 Vice

A vice is used to hold a part firmly while you work on it with other tools. For this course you need a vice with jaws 75mm wide, or wider (Figure 114). Bolt it rigidly to your bench, using large washers – or even a metal plate – to spread the load across the underside of the bench surface.

Most vices have serrated jaws to grip the work. Sometimes you will need to protect your work from the serrations using **clams**. Go to a large DIY store, model shop or metal supplier and buy a length of right-angled metal. Brass or steel is best, but aluminium will do. If possible get the type where the outer corner of the angle is sharp (i.e. the material has been extruded in this form) rather than blunt, which happens when the metal has been folded into a right angle.

Figure 114 – bench vice with clams

Clamp the length in the vice, protecting the outer surface with a piece of cardboard, and saw it off to the width of the jaws. The cardboard stops the serrations on the opposite jaw marking the working surface of the clam. Repeat to make the other clam. When you need to hold work without marking it, simply place the clams over the jaws and grip the work in the normal way.

We also recommend you buy a small, clamp-on table vice. These are excellent for holding small parts. The one shown in Figure 115 is adjustable to any angle and comes with removable plastic clams.

Figure 115 – clamp-on vice

8.4 Hacksaw

Hacksaws are designed to cut metal. A junior hacksaw (6” or 150mm blade) is always handy for small work, although most of the time we will be using a standard hacksaw with a 300mm blade. Figure 116 shows some examples. Buy one of each.

Figure 116 – 300mm hacksaw, and two junior hacksaws

Hacksaw blades wear out, which is why the blades are replaceable. Poor quality blades are all too common in DIY shops, so make sure you buy ones from a well known brand. It is always worth spending the extra to get good blades.

They come in different cuts from coarse to fine. A medium cut (around 20 teeth per inch) is best for our purposes. In general, a finer cut is better for cutting thin material, and a coarser cut for thick or soft material.

The hacksaw cuts on the forward stroke; blades should be fitted so that the teeth point forward. Blades can often be fitted into the hacksaw (but not the junior hacksaw) at right angles.

Figure 117 – from left to right: ball pein hammer; clock hammer; watch hammer; soft nosed hammer

8.5 Hammer

Depending on the type of work which you will be undertaking, you may need four hammers. Firstly, a **watch hammer** which has a steel head with a round, flat face at one end. The opposite end tapers to a flat, blunt, chisel-like shape, known as the **pein**. The weight of the head should be around 1 to 2oz (30 to 60gm).

Next you need a **clock hammer**. This is the same shape as the watch hammer, but heavier.

Thirdly you need a **rivetting hammer**, more commonly called a **ball pein hammer**. These have a smoothly domed face, instead of flat. For our purposes a fairly light one will be suitable – typically 4 to 8oz (100 to 200gm).

Finally, you should get a **soft-nosed hammer**. The type with a white nylon faces work well and will meet our requirements. Buy a light one: 8oz (200gm) is about right.

8.6 Files

There are two types of files you need to know about: *engineering files* and *precision files*. Engineering files are the type you see in every household toolbox, and can be bought cheaply from any tool shop or DIY store.

Precision files are sometimes called *Swiss files,* although that does not necessarily mean they are made in Switzerland. Precision files are made to a higher standard than engineering files. They also come in a wide range of shapes and sizes, some very specialised.

The coarseness of the cut is important. In general, coarser files (with a larger distance between the teeth) remove more material and leave a rougher finish. Also, coarser files are better on softer metals such as brass and aluminium, because smooth files will tend to clog. The table below compares the cuts of engineering files with precision files.

Precision file cut	Engineering file cut	Teeth per centimetre
00	Bastard	up to 17
0	Bastard/Second	
1	Second	18–22
2	Smooth	22–28
3	(no equivalent)	
4	(no equivalent)	
5	(no equivalent)	

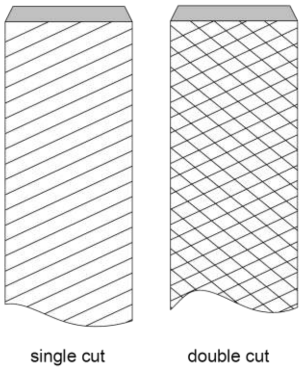

Figure 118 – single and double cut files

There are *single cut* and *double cut* files. Single cut files just have one row of teeth along the length. Double cut files have two rows of teeth set at an angle to each other – Figure 118. We will now look at the most common types of precision file.

Hand file and pillar file:

The hand file is flat on both sides, not tapered, and has one 'safe' (smooth) edge. It is the most commonly used, general purpose file in horological work. The pillar file is similar, but narrower so it can be used on more intricate pieces.

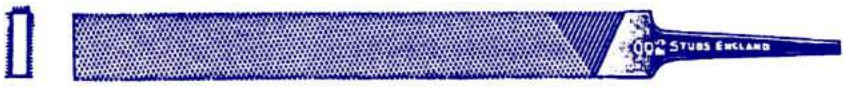

Figure 119 – hand file

Figure 120 – pillar file

Figure 121 – narrow pillar file

Taper flat (or warding):

This is similar to the hand file, but the blade is tapered so it can be used on small and restricted surfaces.

Figure 122 – taper flat (or warding) file

Three square:

This type has a triangular cross section and is tapered. It is useful for filing into tight corners.

Figure 123 – three square file

Half round:

The half round file is flat on one side, and rounded on the other (but not semi-circular). Both sides have teeth. The blade is tapered to improve access to small spaces. It is used for filing concave surfaces, and is good for filing into corners.

Figure 124 – half round file

Knife:

This is rather like a three square file, but the triangular cross-section is greatly elongated and narrowed into a knife blade shape. It is used for filing slots.

Figure 125 – knife file

Ridgeback or barrette (not shown)

This has a very flat triangular cross section, just the opposite of the knife. Teeth are provided on the base only – both top surfaces are safe (smooth).

Round or rat tail:

This type is used for enlarging holes, or “drawing” them (making them oval). The rat tail tapers to a fine point so it can enter a very small hole. It can also be used for rounding of corners.

Figure 126 – round or rat tail file

Square taper

This has a square section with all four sides cut. Like the round file, it is tapered to a fine point. It is useful for making square holes, sharpening up slots, etc.

Crossing file:

The crossing file has a tapered, oval cross section, and is used for crossing out wheels and similar jobs.

Double ended pivot file and burnisher:

As the name implies, this is two files in one, with the handle in the centre. There is a pivot file at one end, the teeth of which are extremely fine. At the other end is a smooth strip of steel, which is prepared by rubbing it on an abrasive before using it to burnish a pivot.

Slotting file:

This is used for cutting slots in screw heads. It is rather like a fine saw with teeth on both edges.

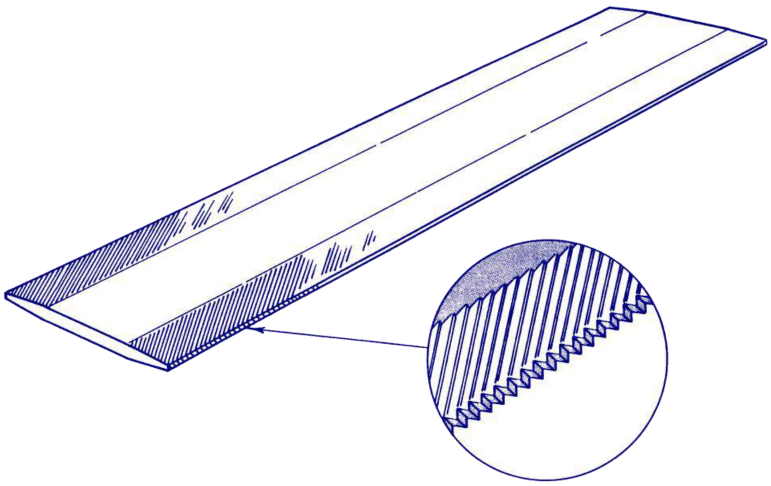

Figure 127 – slotting file

Needle files:

Needle files are smaller than engineering or precision files. Instead of a tang, the handle is formed as one piece with the blade. Sometimes the handle is round so it will fit into a pin vice or collet.

Needle files come in all sorts of shapes, including those listed above.

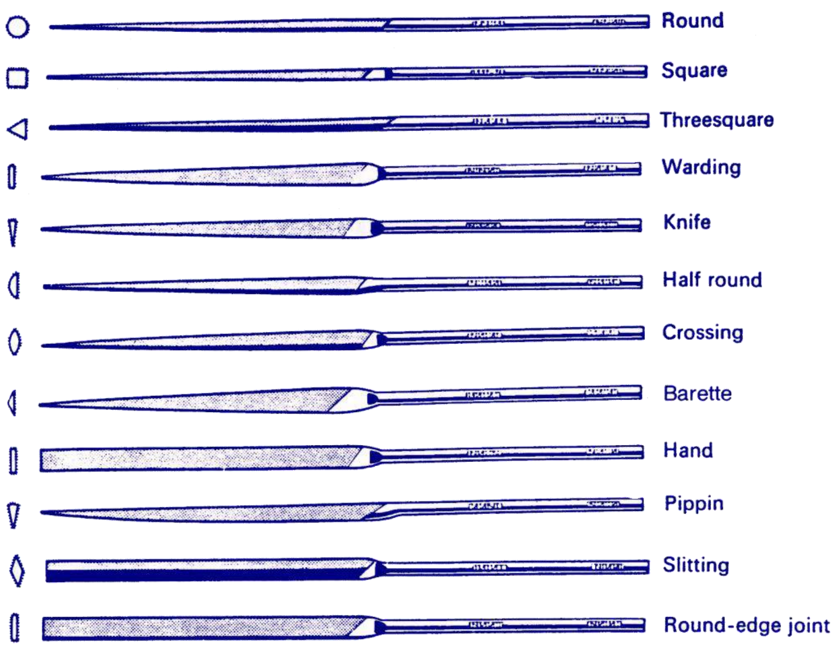

Figure 128 – needle files

Escapement files:

Escapement files are like needle files, only smaller still and they normally have square handles. They are used for filing the tiny parts of an escapement, and come in a great variety of shapes.

8.7 Care of files

Files are made from very hard steel, and the teeth will chip with careless handling. Do not throw them into a drawer with other tools.

Filing brass requires very sharp teeth for the best result. A file which has been dulled by filing steel will never cut brass quite as well. If you are concerned about this, consider putting aside brand new files solely for use on brass. When they eventually become worn, they can then be "demoted" for use on steel.

Files tend to clog with dirt and grease – clean them with white spirit or petrol.

Files can also become clogged with bits of metal – especially after filing something soft such as brass. Do not attempt to use the type of steel brush generally recommended for cleaning files it can easily damage a file, especially a fine file.

A brass wire brush is more acceptable but does not work as well. Better, take a piece of brass plate, file one edge sharp, and feed it between the teeth to push the swarf out. You can also buy special tools for cleaning files, although they are essentially a special type of steel wire brush, so should never be used on a good quality file.

To help prevent swarf clogging the file, rub a piece of soft chalk over it, making sure it goes to the root of the teeth. Be aware that this will make your workshop dusty.

8.8 File handles

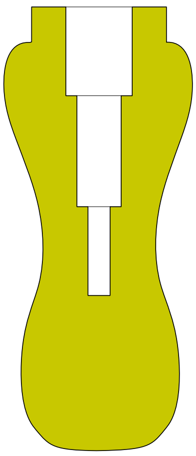

Figure 129 – drilling a file handle for a tang

Files with tangs are meant to have a handle fitted. Never use such a file without a handle, because if it catches on the work you can drive the tang into the palm of your hand.

You can buy file handles from hardware shops. Make a roughly tapered hole in the handle by using three drills of different sizes; Figure 129 gives you the idea, exaggerated for effect.

Make sure the hole is deep enough to fit the whole tang. Ensure the ferrule is fitted around the open end of the handle. Push the tang firmly into the hole, and then hit the base of the handle smartly onto a hard surface, embedding the file tang firmly into the handle. You might need to experiment a couple of times with the hole sizes.

To remove the handle, grip the edge of the file in a vice, making sure the jaws grip an uncut area, and then give the ferrule a sharp tap with a hammer.

8.9 What files to buy

By now you are probably feeling rather overwhelmed at the number of files you might need, and the costs involved, but there is no need to worry.

For now, you should buy four good quality engineering files. They may be available from a DIY shop or otherwise you will need to approach a horological tool dealer or engineering supplier. Two “cuts” will be required: a coarse file to remove metal quickly; and a finer file for finishing. If you can afford it, “precision” files are a better alternative to the finer engineering files. The table below gives the details.

Shape of file	Coarse	Fine, either Engineer’s or Precision Files	
	Engineer’s File 150mm (6in) long	Engineer’s File 100mm (4in) long	Precision File 100mm (4in) long
Hand	Second Cut	Smooth	Cut 4
Half Round	Second Cut	Smooth	Cut 4

The hand file is probably the single most important general purpose engineering file, because it has one safe edge, and the parallel cross-section makes it easy to use. The next most important is the half-round file. If you are purchasing precision files then Vallorbe is a well respected maker.

Another very useful file for internal curves is the “crossing” file; it will only be available as a precision file. A fine crossing file (cut 4) approximately 100mm (4ins) long will be useful for finishing the crossings on wheels. That takes care of the full sized files.

Finally, needle files are necessary to complete your collection. There are packs of needle files that can be bought very cheaply from tool shops, modelling shops or DIY stores; these will contain almost all the special shapes we have described earlier.

The files in these packs usually have quite a coarse cut and it will be useful to buy three good quality needle files (such as Vallorbe). For these individual files, the best shapes to buy are barrette, square and crossing, and they should be cut 4. Keep these files for use on brass until they lose their sharpness and then they can be relegated for steel and new files purchased for brass. The needle files should be ground, as shown in Figure 130, to help you file sharp internal corners. When grinding the needle files, take great care to ensure that the file does not overheat; careless grinding will draw the temper of the file making it soft and of little use.

Diamond coated needle files are readily available from Clock Fairs and material dealers. They are suitable for filing hardened steel but many are of a coarse cut which requires careful finishing. Fine diamond needle files can be very useful for making adjustments to clock escapements.

As your work proceeds you will find that more files will be required but this selection will enable you to commence on the practical exercises in the course as well as making some clock components.

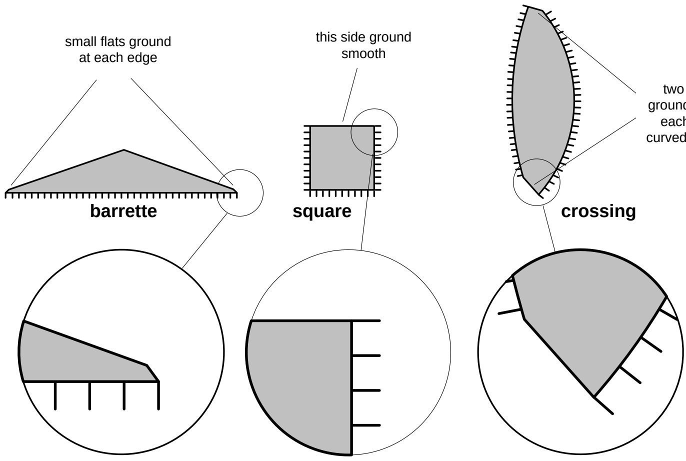

Figure 130 – grinding as shown provides a "safe" edge and ensures the teeth go right to the edge

8.10 Broaches

There are two types of broach: the cutting broach; and the smoothing broach. Both are superficially similar in appearance – a long, thin, spike-like blade, either with a tang for gripping in a pin chuck or mounted in a handle.

Cutting broach

The cutting broach is used to enlarge an existing hole. It cannot make a hole itself. It is used to open a hole to a precise diameter.

It has a pentagonal (five-sided) cross section, and is gently tapered along its length. The blade is hardened and tempered steel. The corners of the pentagon form the cutting edges. The broach is introduced into the hole until the cutting edges contact the walls of the hole. The broach is then turned between the finger and thumb with gentle pressure towards the hole. The cutting edges remove brass from the hole, increasing its diameter. As the diameter increases, the broach naturally enters the hole further.

A cutting broach is not normally used with oil.

There are three points to emphasise:

1) the broach must be held at right angles to the plate, in both vertical and horizontal planes, and this requires some skill

2) due to the gentle taper, the resultant hole is tapered; this can be mitigated to some extent by using the broach from both sides of the plate

3) cutting broaches are designed to work in brass and should not be used in steel. If used in steel the edges will quickly become blunt and the broach will be of no further use.

Figure 131 – smoothing broach (left), and cutting broach

Smoothing broach

The smoothing broach resembles the cutting broach except that it has a round section (it is still tapered along its length). Like the cutting broach it is designed for use on brass, and its function is to smooth and work harden the inner surface of the hole. The surface of the broach has a fine longitudinal grain so that it displaces (or burnishes) the brass. A coarse grain would cut rather than displace the brass and so not achieve the desired work-hardened surface.

Smoothing broaches are <u>never</u> used with abrasive, if they were this would merely embed grains of abrasive in the hole which would lead to rapid pivot wear.

The smoothing broach is used after a cutting broach. The smoothing broach is first thoroughly cleaned to remove any dirt or particles of abrasive or polish, after which it is given a very light wipe of oil to prevent any tearing of the brass. The broach is gently pushed into the hole and turned between finger and thumb to finish the hole.

Because the smoothing broach displaces the brass, a small burr around the edges at both ends of the hole is quite normal and should be removed.

We will learn more about using broaches in Lesson 5.

8.11 Thread cutting

We will look at three ways of cutting threads: tap; die, and screw plate. The screw plate is really just a die in another form.

Figure 132 – tap wrench and tap

Tap

A tap is used to cut an internal thread, like the thread in a nut. It is made from hard steel, and has a sharp thread around the outside which cuts the thread in the receiving hole. Three flutes run down the length of the tap to provide the cutting edges and remove the swarf.

Taps are normally held in a *tap wrench* which allows the tap to be turned by hand.

Taper taps are tapered towards the end, so that the first few threads they cut are shallow, making it easy for the tap to enter the hole and start cutting. If the hole is open at the other end, a taper tap can be screwed right through, making the thread in one operation. If the hole is closed at the far end ("blind"), then the taper tap must be followed by a *second tap* (slightly less tapered) and finally a *plug* or *bottoming tap*. The plug tap has no taper and will form a full depth thread right to the bottom of a blind hole.

When using a tap, it must be held exactly perpendicular to the surface, so that the threaded hole is true. The tap is turned forwards and backwards, cutting the thread a little at a time. The backward rotation – of about half a turn – breaks the newly cut swarf so it does not built up and jam the tap, leading to breakage.

Tapping requires some practice, as taps snap quite easily and the correct back-and-forth action is required to prevent the thread becoming torn.

It is important that the hole is exactly the right size for the required thread. Tables are available giving the correct size pilot hole (tapping size) to drill for any given thread. It is not really practicable to tap hardened steel, because the tap will almost certainly break. Steel should be brought to its final hardness after it has been tapped.

Special thread-cutting lubricant is available which prevents the tendency for swarf to adhere to the tap (galling / friction-welding) and improves the finish when threading steel.

Figure 133 – die stock and two dies

Die

A die is used to cut an external thread onto a rod, like the thread on a bolt. It is a round steel block with an internal hole threaded to the required size and pitch. Three or four flutes are cut into the internal wall to provide the cutting edges and allow the swarf to fall free.

Dies are normally held in a die stock, which allows it to be handled and turned easily.

On one side of the die, the hole is slightly chamfered. This makes the first few threads shallow and allows the die to get started properly. When the required length has been cut, the die is turned over so the side without the chamfer leads, cutting a full depth thread for the entire length. Some dies are chamfered on both sides, so cannot be used in this way.

As with a tap, the die must be held perpendicular to the rod being cut. Unlike a tap, the die is quite robust. However, it should not be used to cut hardened steel (the steel should be annealed first), nor should it be forced to cut a rod of the wrong starting diameter, as it will spoil the finish and form of the thread. A chamfer should be formed on the end of the material to help start the thread.

The exact diameter of the rod is important. Tables are available which give the required diameter of rod for a given thread.

Screw plate

The screw plate is really just a number of dies all formed in one plate. They are normally used to make very small screws, such as those used in watches. Some have holes with a sharp internal thread, and a slot leading from the holes to clear the swarf. Others work by "burring" or "flowing" the metal into a thread, and do not have swarf clearance holes. As with taps and dies, the material to be threaded must be considerably softer than the screw plate.

Figure 134 – screw plate and three watch-sized taps, with a pound coin for scale

Figure 134 shows a typical screw plate with both "burring" and "cutting" holes, along with three watch-sized taps. A British pound coin is shown for scale, emphasising the tiny size of the taps.

Just the beginning...

Whole books have been written on the subject of taps, dies and thread cutting. The above is merely an overview to make you aware of how it is done.

8.12 Abrasives

Abrasives are used for imparting a finish to a piece of metal. We will be using abrasives in two different roles:

1) sharpening tools
2) achieving a suitable finish on clock and watch parts

The finish we apply to parts of clocks and watches has two purposes: first, to make the parts look nice; second, to allow parts to operate against another without too much friction.

India stone:

This is the common name for a tool sharpening stone made from aluminium oxide. Sometimes they are double sided, with one side coarser than the other (the orange side being the smoother of the two). It is suitable for sharpening all grades of steel tool, but not tungsten carbide. Brass clogs the stone. It imparts a good, smooth finish to steel edges and surfaces. Oil should be used to prevent clogging.

Figure 135 – India (aluminium oxide) stone

Arkansas stone:

This is a natural stone which is cut into slabs and rods with rectangular, triangular, knife or circular cross section. It will sharpen all grades of steel, but not tungsten carbide. Brass clogs the stone. It imparts a finer finish than an India stone. Arkansas stones can also be used in the preparation of pivots and other steel clock and watch parts (we will cover this later in the course). The stone should be wetted with oil.

Water of Ayr stone:

This is a soft, abrasive stone which must be used thoroughly wetted with water. It is excellent for removing marks from brass clock plates. It cannot be used on steel or tungsten carbide.

Figure 136 – assorted Arkansas stones, and a Water of Ayr stone

Diamond slips:

Diamond slips come in a variety of shapes and grades (coarseness). They sharpen steel tools very quickly, but the finish is not as good as an India stone unless a very fine grade is used. A good approach is to bring the tool edge to shape on a diamond slip, and then do the final smoothing with an India stone. Diamond slips should be thoroughly wetted with water (*not* oil). They are the only type of abrasive to sharpen tungsten carbide tools. Brass clogs a diamond slip.

Figure 137 – an assortment of diamond slips

Abrasive paper:

"Wet and dry" abrasive paper sheets are widely used in horology. They are available in a range of grades. The coarsest grade usually used in horology is 320 grade, and the finest generally available is 1000 or 1200 grade.

Also available is a range of 'micron paper' from 3M – micro finishing film and micron abrasive lapping film. There are a number of grit sizes down to a few microns; micro finishing film is available with a self adhesive backing.

Abrasive papers can be used on brass or steel, but do not work on tungsten carbide. The wide range of grades means they can impart a range of finishes, and they are extremely versatile. Every horologist should have a range in stock. A good start is to stock 400, 600 and 1200 grade sheets.

Approximate micron (µm) equivalents to European grit papers:

400 grade (P400) = 35 µm

600 grade (P600) = 25 µm

1200 grade (P1200) = 15 µm

Although “wet and dry” sheets can be used dry, it is almost always better to use them wet, or even under water. This greatly reduces clogging (which can cause scratches) and improves the quality of the finish. Detergent can be added to the water to improve its wetting action and reduce clogging further.

You can also buy emery cloth and emery paper; these are not waterproof. Emery cloth has a cloth backing with an abrasive grit stuck to it. It is not so suitable for horological work as wet and dry paper, because it is much more prone to shedding the abrasive which causes scratches on the work.

Figure 138 – "wet and dry" abrasive paper

Buff sticks:

These are flat sticks of wood with abrasive paper glued to them. You can buy them, but it is better to make them yourself. In many respects they are like a file, except the surface abrades rather than cuts, and you can choose a much wider range of grades.

For finer work, abrasive paper can be stuck to pieces of metal with double sided Sellotape (a piece of metal shaped like a barrette needle file is ideal).

They are very useful for final finishing of parts, as the wood/metal ensures the abrasive surface is dead flat and rigid.

Steel wool:

Steel wool, sometimes called wire wool, is commonly available in a variety of grades. It is excellent for removing rust from steel parts.

Clock Servicing Skills

Content begins in Lesson 3

Watch Servicing Skills

Content begins in Lesson 3

Practical Exercise

9 Introduction to the Practical Exercises

Tools

Frequently we are asked "what tools do I need?". This is a very difficult question to answer, and in reality one's stock of tools continues to build up over a lifetime.

In addition, tools with sharp edges need to be regularly cleaned and sharpened to keep them in good condition.

An indication of what you need is provided in the Introduction booklet to this course.

The lathe

You will not need a lathe until you get to Lesson 6. To complete the later practical exercises you will need a centre lathe with a through-the-headstock spindle bore of at least 6 mm or $^1/_4$ in.

Section 1 of Lesson 6 describes one type of centre lathe that would be suitable. A watchmaker's lathe of the type described in Section 2 of Lesson 6 is unlikely to be suitable.

The Lessons in the practical sections of this course have been designed first of all to teach the correct way in which to carry out the fundamental operations which are the foundation of all practical horological work and then to apply the instructions given. We realise that it is a very difficult task to teach by correspondence all that is necessary for the acquisition of practical ability, but with an enthusiastic "can-do" attitude and your co-operation we know that success will result as demonstrated by the many students who have successfully completed the course by distance learning.

Each Lesson progressively introduces new skills and the Practical Exercises are broken down into sections covering definitive steps. You are encouraged to follow the instructions. Inevitably there are different approaches to achieving the same result; sometimes these are dictated by the tools and workshop equipment available and it would be foolish to pretend otherwise. However, be aware that if you deviate from the processes described by, for example, machining a component instead of filing it to the correct shape, then you may not learn the skill being taught.

Moreover, bad habits are easily formed and are hard to break. The instructions given are based on the experience of many skilled horologists and there is considerable consensus that they are the most satisfactory way of completing an operation. If you start by learning to saw or file in an unorthodox way, you may find that it is very difficult to produce a straight cut or a flat surface. Worse still, you may find it very difficult to correct your method of working.

Students embarking on this course will have varying degrees of knowledge and experience. If a process being described is unfamiliar to you, it may be worth reading forward a few Lessons to see if it is covered there.

Do not be concerned if an exercise is taking longer than you expected or you have to start again. This is not uncommon, and even the most experienced horologists can make mistakes and have to cut their losses by starting again. We want you to learn from your mistakes; by doing it again you will learn far more than if you just submit a sub-standard exercise for assessment. Practice, and lots of it, is the essence of all practical work, and when it goes wrong it is best to pause and read the directions again before starting afresh.

9.1 Some fundamentals

Before you start any work it is always important to plan and analyse it right down to the last detail. If you do not, you will find that an aspect that could be easily accomplished at an early stage becomes very difficult. As a guide think in the following steps:

- Do I understand the purpose of the component and how it will be eventually used?
- Do I understand the drawings or sketches and how each component fits with other components?
- Can I see a way of completing each step in a logical sequence?

- Have I got the necessary tools and materials to hand?

The processes that will be required to complete the Practical Exercises can be broken down into five fundamental operations. Not all operations are required for every exercise, but by the end of the course you should be proficient at:

- sawing and filing,
- drilling,
- turning,
- rivetting,
- heat treatment (hardening and tempering of steel),
- finishing.

Materials

The BHI has made arrangements with suppliers for a "kit of materials" from which you can make all of the Technician Grade practical exercises. For details of current suppliers check the BHI web-site.

Before starting work on any exercise, always check the size of your material. The small quantities involved mean that if metric sizes are not in stock most suppliers will reserve the right to supply to the nearest Imperial size.

9.2 Assessment

For all of us it is important that we have our work assessed. Critical self-assessment is essential, and one should learn to be self-critical at every stage in the component's manufacture. "It will do" or "it is the best I can do" is not good enough; your aim should be "is it as good as the best?"

To help you to determine what the best is, an independent critical appraisal is extremely important. Such an assessment will be available if you are enrolled with a college or engaged as an apprentice but for students working independently this might not be so easy to come by. One option is to attend your local BHI Branch meetings and speak to one of the professional members, another option is to attend one or more of the seminars run by the BHI at Upton Hall.

A third option is to take advantage of the Distance Learning Course "Tutor Feedback" option offered by the BHI and, if you have not taken up this option, you may wish to extend your purchase to do so (details can be found on the BHI web-site). Students who are not enrolled with a college or engaged as an apprentice will find it particularly beneficial. If you do, you may send your practical exercises for assessment and constructive criticism by an experienced BHI tutor. When to send your work for assessment is indicated at the end of each Practical Exercise.

It is vitally important that students sending their work for assessment clearly label their work and guidance is given at the end of each Practical Exercise. However, here are a few universal suggestions as to what you should and should not do:

- clean your work before packing it up. A smear of micro-crystalline wax can help ensure it remains corrosion-free,
- always label your work with your name and membership number. Sometimes a tie-on label is the most appropriate, for others a self-seal poly-bag clearly labelled with a permanent felt-tip pen is best,
- ideally discreetly scratch your Membership Number on each component,
- avoid the use of adhesive tape or adhesive labels on your components; this invariably marks the surface and may corrode it. It also makes the tutor's work more difficult if gummy remains have to be peeled off to complete the assessment,
- make sure your item is well-packed in a small cardboard box or Jiffy-bag (often cheaper on postage costs) and is well-sealed so it cannot work its way out of the packaging in transit,
- make sure your return address is enclosed.

Photographs

All of the opening photographs accompanying these practical exercises are of work actually completed by former students who we acknowledge with our grateful thanks.

10 Hand Removing Levers

The first practical work to be carried out is a simple exercise in filing flat and square to produce a pair of hand removing levers. Hand removing levers are miniature crowbars and are used in pairs to lever off the hands of a watch or small clock movement. They can be made in numerous sizes to suit movements of different types. We shall start by making a pair suitable for removing the hands of a pocket watch or small clock.

10.1 Materials required

- Silver steel rod 5 mm or $^3/_{16}$ in. dia. x 165 mm long (6 $^1/_2$ in. long).
- Brass bar 10 mm or $^3/_8$ in. dia, a short length (approx. 25 mm or 1 in.)...

Material may be supplied in Imperial or metric dimensions; use stock material that is most conveniently available to you.

10.2 Drawings, dimensions and instructions

Read the instructions and study the drawings right through to the end before starting work so that you have a full understanding of what is involved.

The drawing for this exercise is not drawn to an accurate scale so you should always use the written dimensions (Imperial or metric). Do not attempt to measure the drawings to ascertain the required dimension.

All dimensions are shown in both Imperial (inches) and metric (millimetres) units. They are not accurate equivalents and are not interchangeable. Irrespective of the dimensions in which the stock material is supplied, choose a set of units (Imperial or metric) to suit your measuring instruments and stick to them throughout the exercise.

10.3 Operations

1) Cut the rod into two lengths, each of which can be finished to 75 mm (3 inches) in length to make two identical levers – see Figure 139. The same work is to be carried out on each of these two lengths.

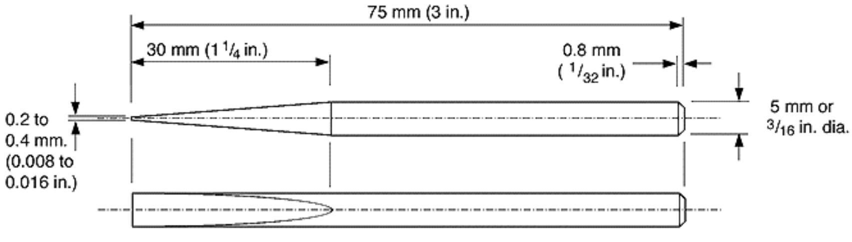

Figure 139 – hand removing levers before bending tip

2) Remove the burrs from the saw cut at one end so each rod can be clamped securely in the vice without being marked. File the other end of the rod flat and square. It may be a good idea to use brass or copper clams to protect the surface of the silver steel; much depends on the surface finish of the vice jaws and how hard the vice is tightened. If they are in any way marked or serrated, clams are essential.

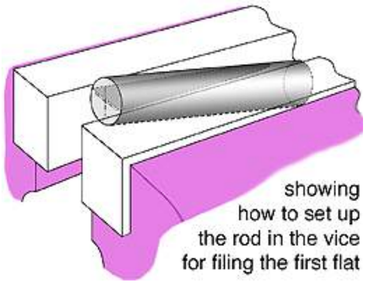

Figure 140 – filing the flat sides

3) The first operation is to taper the end you have just filed by making two flat surfaces coming to an edge at the extremity of the rod rather like the blade of a screwdriver. Measure off and mark a distance of 30 mm (1 $^{1}/_{4}$ in.) from the filed end. Clamp the rod in the vice with the mark at 30 mm (1 $^{1}/_{4}$ in.) level with the top of the jaws and at such an angle that very slightly more than half the diameter of the projecting part of the rod is above the level of the top of the jaws – see Figure 140. Now file a flat to produce the first tapered surface using a second cut hand file.

4) Turn the rod through 180 degrees, clamp again and file the second tapered surface. When filing this second surface (side), check regularly to ensure that the two flats are exactly opposite one another so that the flat tip is parallel not tapered.

5) Finish both flats with a smooth cut (No.4 cut) hand file making sure the ends meet properly to form a straight edge for the full diameter of the rod. At this point you should refer to Figure 144 to check what you are aiming for.

6) Trim the end perfectly flat and square so as to leave the tip 0.2 to 0.4 mm in thickness (0.008 to 0.016 in.). Complete this stage by draw filing.

7) Turning our attention to the other end of the rod, the next operation is to reduce the overall length of the lever to 75 mm. Saw off any excess material and then file the end perfectly flat and square.

8) File a small chamfer all round this end. To do this, clamp a block of wood in the vice with the top protruding above the vice jaws. Hold the rod against the block at an angle of 45 degrees and file a small flat at this angle. Then turn the rod through about an eighth of a circle (rotation) and file another similar flat. Continue by turning the rod and filing another flat after each movement. The result will be eight flats which should all be at the same angle. Now with a combined filing and turning action blend the flats into a smooth chamfered surface that is even all around the end; it may help if a notch is cut in the wooden block to locate the rod. The chamfered edge should be 0.8 mm ($^{1}/_{32}$ in.) measured both along the rod from its extremity and, if truly filed at 45 degrees, inwards from the outside surface.

Sawing and Filing

If you are unfamiliar with using a saw and file, Lesson 4 gives some detailed guidance. It also gives a description of "draw filing".

9) Grain the flats which form the taper with 400 grade (P400) wet and dry paper in the longwise direction. Take care not to round the edges of the flats by laying the paper flat on a hard surface and rubbing the surface to be polished lengthwise against the paper. Sticking the paper down to the hard surface helps considerably in reducing the rounding effect.

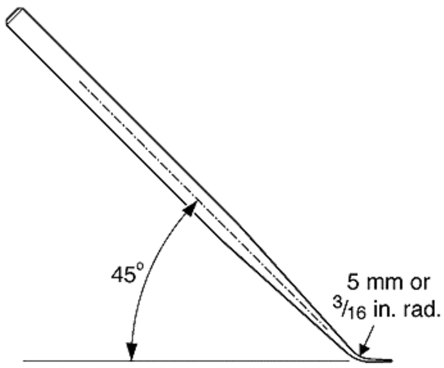

Figure 141 – the curved end

10) The next operation is to curve the flattened end of the lever to provide the crow bar effect as shown in Figure 141. A sketch of how this is done is shown in Figure 142. To do this clamp the lever in the vice against a short length of 10 mm or $^3/_8$ in. diameter brass rod with the tip of the lever positioned so that the flattened end of the rod is level with the outer surface of the brass rod. Make sure that the lever stands truly at right angles to the brass rod, which can be checked:

    a) either by holding the brass rod truly parallel to the vice jaws and resting the stock of an engineer's square on the top of the vice jaws,

    b) or, more directly (and hence potentially more accurately), by resting a small engineer's square with a thin stock on the surface of the brass rod.

    In both cases the rod is sighted against the square and adjusted to form an exact right angle. Before clamping in the vice, ensure that the ends of the brass rod are burr-free so as to ensure the clamping will be firm and (in the second option) not upset the accurate positioning of the stock of the engineer's square.

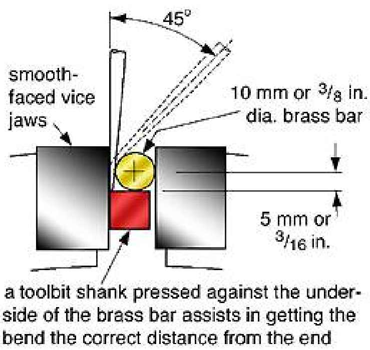

Figure 142 – bending in the vice

Figure 143 – a toolmaker's clamp

A small toolmaker's clamp: The jaws are 50 mm long and it is shown gripping a short piece of 12 mm dia. brass bar.

When using a toolmaker's clamp, it is essential to get the jaws as parallel as possible before finally tightening the outer screw (the right hand screw in the photo).

A toolmaker's clamp is primarily used to provide a light clamping or locating grip, and if you have strong fingers, it should rarely be necessary to use the tommy bar holes in the knurled screw heads. If you tighten the clamp with any significant force using a tommy bar, there is a danger of distorting the jaws.

11) Holding the rod so that the bend will come at exactly the same place in each lever is tricky. After getting the lever upright, check that the lower end of the lever is level with the lower edge of the brass bending former. A small length of square bar less than 10 mm ($^3/_8$ in.) across flats (such as a lathe toolbit) held between the vice jaws and below the bending former may help you sight if they are level. It will also be easier to achieve without vice clams, especially if they are soft-faced clams.

12) An alternative method is to fasten a toolmaker's clamp, Figure 143, to the curved sides of the rod so that it is exactly at right angles to the rod and the underside of the clamp is exactly at 10 mm ($^3/_8$ in.) from the flat end. See Figure 144. You should now rest the toolmaker's clamp on the top of the vice jaws (or clams), lift the brass bending former until it touches the toolmaker's clamp and tighten the vice to hold the work against the bending former in the correct position. Obviously the clamp needs to be removed after tightening the vice to allow the rod to be bent. Care should be taken to ensure the toolmaker's clamp is tight so that it cannot rotate and result in the bend not being in the exact position.

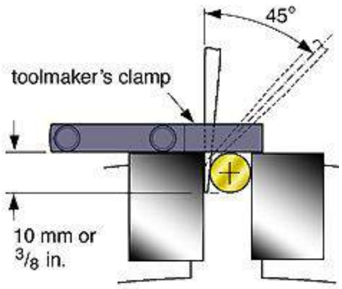

Figure 144 – an alternative method of bending in the vice

13) Now bend the lever to an angle of 45 degrees so that the tip will be curved to conform to the circumference of the brass rod. If a 45 degree square is not available, a very good approximation can be given by sighting along the edge of a 45 degree set square.

14) With the tip of a round seconds hole file (a very fine round file, smaller than a needle file), make a small semi-circular groove 0.4 mm deep ($^1/_{64}$ in. deep) centrally in the curved tip as shown in Figure 144. Remove any burrs formed in this process.

15) Using a fine oilstone on the flat tip, create a smooth radius right around the tip (top and bottom) that cannot mark the dial or underside of the hands as also shown in Figure 145.

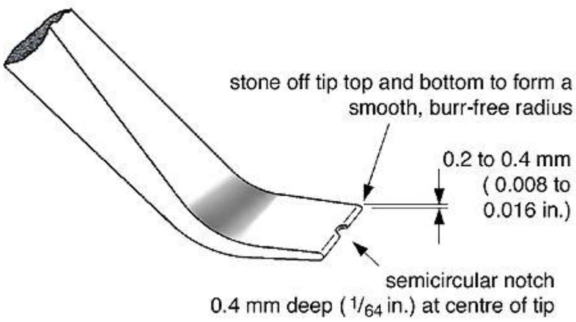

Figure 145 – detail of the tip

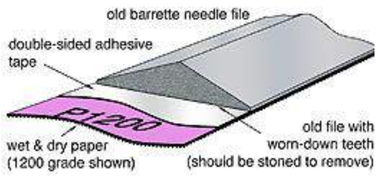

Figure 146 – preparing a finishing tool from an old needle file

Hardening and tempering the levers

Hardening and tempering is not part of this exercise.

To make the hand removing levers a fully functional tool, once your levers have been returned after assessment you may wish to harden and temper the tips as described for the Lesson 6 practical exercise.

If you do, then they should give you excellent service in your future career.

16) Finally re-grain the tips of the lever using 1200 grade (P1200) wet and dry paper. To grain the inside of the bend, a piece of wet and dry paper should be secured to an old barrette or crossing needle file with the teeth largely removed – see Figure 146. The wet and dry paper should be fastened to the file with double-sided adhesive tape to prevent the paper crinkling up. To prepare the "file", stick the double-sided adhesive tape to the file and then press onto the wet and dry paper of the appropriate grade. Then lay it on a piece of scrap wood and trim around the paper and tape using a sharp knife.
17) Alternatively, you can make a similar "abrasive paper file" using a crossing file. This may seem more appropriate for graining the hollow side of the hand removing lever, but the stiffness of the abrasive paper means it is more difficult to get the abrasive paper to stay stuck down at the edges.
18) Make both levers perfectly alike.

10.4 Assessment

Students who have taken up the BHI "Tutor Feedback" option may send their practical exercise for assessment and constructive criticism.

Make sure your levers are clean and wrap them separately in a protective piece of acid-free paper (or similar) before putting both wrapped levers into a self-seal polythene bag. Label the polythene bag with your name and membership number using an indelible pen (e.g. a permanent marking pen). Enclose the polythene bag in bubble-wrap or a padded envelope for sending to the tutor.

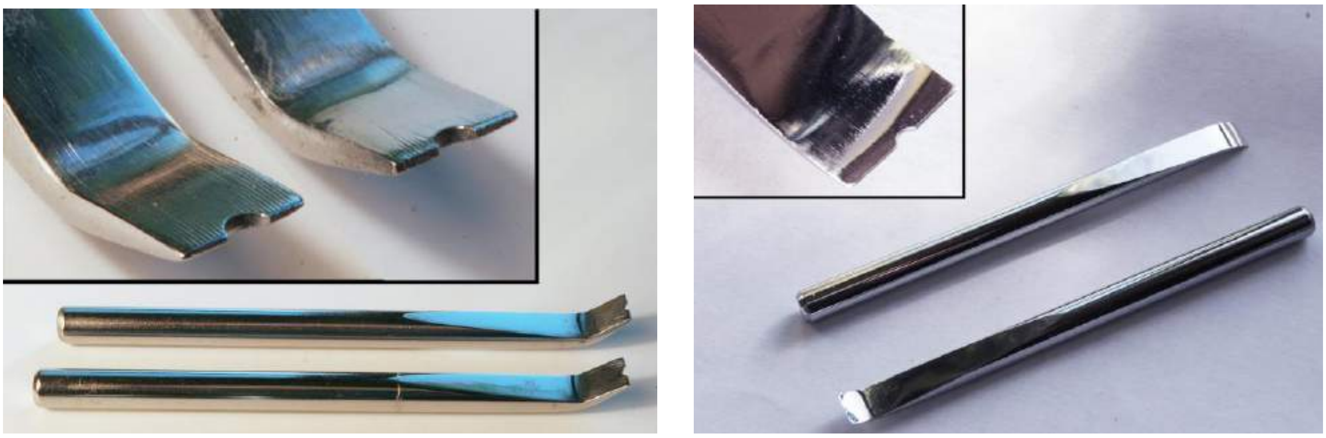

Figure 147 – Hand removing levers made by students. Both show a few imperfections and slight dimensional inaccuracies, but are nevertheless very good examples. Note the overall geometry of the tip curve (bend) is better in the left hand example; in the right hand example the curve is continuous right to the tip.

Written Exercise

11 Introduction to the Written exercises

The written exercises at the end of each Lesson are designed to permit you to revise what you have learned in preparation for an examination. The questions generally require relatively short answers so should not take up too much of your time. All the answers are in the Lesson, though occasionally it may be necessary to draw on knowledge gained in earlier Lessons for a complete answer.

To get maximum benefit from the written exercises there are a few points that we would make:

- read the question twice,
- try to answer it without referring to the Lessons. Refer to the Lessons only when completely stuck, and even then use the text and images to jog your memory rather than copying the answer,
- once you have written the answer, read what you have written and decide whether:
    a) it would be understood by a tutor or examiner,
    b) you have fully answered the question set?

For students who have taken the Tutor Feedback option you should:

- ensure that you have written your name and membership number on each piece of paper you send for assessment,
- note that any marks that the tutor awards are a guide only and do not represent the marks you might get in an examination. In an examination you will not have recourse to the Lessons, and the tutor cannot know how much you have answered from memory and logical thought, and what you have answered by reference to the Lesson text and images.
- if, having written your answer, there is anything you are unsure about that relates to the question, or any other point in the Lesson, add your question as a footnote and the tutor will respond to it.

There are also a few hints and tips we suggest:

- use sketches to illustrate your answer wherever possible.
- in your sketches make sure that it is clear which component is connected to which (if there might be doubt, make it clear through labelling (e.g. an arrow pointing to the third wheel in a gear train saying “third wheel fixed to arbor carrying third pinion”).
- always set out the steps in a calculation. Do not just write out the final answer otherwise you or your tutor cannot review your answer should you have made a mistake in order to find out where the error has been made.

Put your name on it!

The BHI receives a large number of scripts from students every week, all of which have to be logged and distributed to tutors for assessment.

It is essential everything you send in is clearly collated, and each page bears you name and membership number.

Written Exercise

12 Written exercise

Please answer each of the following questions. For the majority only a short answer is required: two or three sentences.

Students who have taken up the BHI "Tutor Feedback" option may send their answers for assessment and constructive criticism by an experienced BHI tutor. Make sure your name and membership number is clearly written on your answer sheet.

1) Which came first – the lantern clock or the longcase clock? How are they related?

2) Why do some clocks have repeating mechanisms, which make them strike the time on demand? How are they operated?

3) Explain the difference between an English Dial clock and a drop Dial clock.

4) Why was the balance adopted in preference to the pendulum for portable clocks?

5) What is a "railroad" watch? Describe the principal features relating to its timekeeping properties.

6) What is the name and purpose of the semi-circular weight in the back of an automatic watch? Briefly describe its action.

7) What do LED and LCD stand for? Why were LED quartz watches superseded by LCD watches?

8) Explain the difference between a resonant and a non-resonant oscillator. What is the principal advantage of the resonant oscillator?

9) A watch ticks five times per second. What is its frequency in Hertz? What is its frequency in beats per hour (bph)? Include your calculation and reasoning in your answer.

10) Summarise the basic divisions of the mechanical movement.

11) Name the device that sits between the train and oscillator, and describe its function in more detail.

12) a) Explain the role of the motion work.
b) The hour hand is carried on the hour wheel but the minute hand is <u>not</u> carried on the minute wheel. What is the minute hand mounted on?

13) Make a labelled sketch of the support arrangement for the top of a pendulum rod.

14) Explain the difference between a bridge and a cock.

15) How do you adjust the pallets so that a pendulum clock is "in beat"?

16) a) Make a labelled sketch of the winding mechanism on a typical timepiece clock.
b) Describe how the ratchet works.

17) How are pivots prepared for a long service life?

18) In an 8-day clock, the third wheel is the fourth wheel in the train (starting from the great wheel). Why?

19) Where is the hand-setting mechanism on a clock? How does it allow the hands to be set?

20) Name the different ways in which plates may be fastened to pillars.

21) When should eye protection be used?

22) What should you consider before letting visitors into your workshop?

23) a) Explain the difference between engineering files and precision files.
b) Why must a file with tang never be used without a handle?
c) Why might a safe edge be applied to a needle file?

24) Explain the difference between a cutting broach and a smoothing broach. Summarise how they are used.

25) What are taps and dies used for? How are they held?

END