## CONTENTS

<p>| General Notes | 4 |
| 1 | Suspect height estimation and using graphs | 7 |
| 2 | Introduction to forensic microscopy | 9 |
| 3 | The microscopy of fibres | 12 |
| 4 | Forensic examination of paint | 15 |
| 5 | Handwriting analysis | 18 |
| 6 | Fingerprinting techniques | 21 |
| 7 | Identification and matching of fingerprints | 24 |
| 8 | Forensic document examination | 28 |
| 9 | Document security | 30 |</p>
<table>
<thead>
<tr>
<th>Week</th>
<th>Session</th>
<th>Laboratory Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tuesday 1.30–3.30 pm</td>
<td>Module Induction Session</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Health and safety in the laboratory</td>
</tr>
<tr>
<td>2</td>
<td>Thursday 2-5 pm</td>
<td>Keeping a laboratory notebook</td>
</tr>
<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td>Constructing and interpreting graphs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suspect height estimation and using graphs</td>
</tr>
<tr>
<td>3</td>
<td>Thursday 2-5 pm</td>
<td>Introduction to forensic microscopy</td>
</tr>
<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Thursday 2-5 pm</td>
<td>The microscopy of fibres</td>
</tr>
<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Thursday 2-5 pm</td>
<td>Forensic examination of paint</td>
</tr>
<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Thursday 2-5 pm</td>
<td>Handwriting analysis</td>
</tr>
<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Thursday 2-5 pm</td>
<td>Fingerprinting techniques/</td>
</tr>
<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td>Forensic document examination</td>
</tr>
<tr>
<td>8</td>
<td>Thursday 2-5 pm</td>
<td>Identification and matching of fingerprints/</td>
</tr>
<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td>Document security</td>
</tr>
<tr>
<td>9</td>
<td>Thursday 2-5 pm</td>
<td>Forensic document examination/</td>
</tr>
<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td>Fingerprinting techniques/</td>
</tr>
<tr>
<td>10</td>
<td>Thursday 2-5 pm</td>
<td>Document security /</td>
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<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td>Identification and matching of fingerprints</td>
</tr>
<tr>
<td>11</td>
<td>Thursday 2-5 pm</td>
<td>Oral presentations</td>
</tr>
<tr>
<td></td>
<td>Friday 2-5 pm</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>No sessions: laboratory notebook submission deadline</td>
</tr>
</tbody>
</table>
1. **Introduction**

The laboratory programme for this module is designed to accompany the lecture material and to enable you to acquire some basic laboratory skills. At the end of this course you will be able to:

1. Demonstrate competence in basic forensic laboratory skills.
2. Maintain an effective laboratory diary.
3. Report experimental findings and draw conclusions from your work.

2. **Aims of the ‘Forensic Science Principles’ Laboratory Course**

The aims of the practical course are:

(i) To develop basic laboratory skills
(ii) To develop specific skills in core forensic techniques
(iii) To develop skills in scientific observation and the accurate recording of observations
(iv) To develop an appreciation of accuracy, precision and errors
(v) To develop skills in the critical assessment of experimental methods and procedures
(vi) To develop skills in constructing and using graphs
(vii) To develop skills in using a laboratory notebook
(viii) To gain a deeper understanding of selected topics from the lecture course

3. **Staff**

The following members of staff and postgraduate demonstrators are involved in the design and/or delivery of this laboratory course:

**Academic:** Dr Craig Adam (Module Leader), Dr David Thompson

**Technical:** Amy Cowles, Leanne Jones

**Demonstrators:** Sam Evans, Renata Lopez-Gatell

4. **Safety**

It is essential to adopt a positive approach to safety. The design of each experiment, even of a simple preparation, must include a consideration of the hazards involved. In addition to the departmental instructions on safety your attention is drawn to the following points:

- You have a legal obligation to work safely, to ensure that neither yourself nor your co-workers are exposed to hazard, and to comply with the safety regulations issued to you at the beginning of your first year.
- **The Control of Substances Hazardous to Health (COSHH) regulations** require that a risk assessment form be completed for all substances deemed hazardous to health.
- **Toxic chemicals.** In a laboratory, the safest approach is to regard all chemicals other than water as toxic and to treat them as such unless their safety is definitely established.
- **Protective clothing.** A lab coat and safety spectacles must be worn when appropriate. Wear rubber gloves when handling corrosive materials.
- **Fire.** Learn how to operate the fire extinguishers, and locate the positions of these extinguishers and the fire blankets in the laboratory.
- **Fume cupboards.** Carry out all processes involving dangerous and obnoxious materials, for instance, the development of fingerprints, in a fume cupboard. A toxic vapour in a fume cupboard is still dangerous. Ensure that the fume cupboard is working properly, and that the vapours do not escape into the laboratory.
Smoking, eating and drinking in the laboratory are forbidden.

Use of mobile phones in the laboratory is forbidden.

Ultra-violet lamps are safe when used as intended. Do not shine them directly in anyone’s face or look directly into the lamp at any time.

Light Sources used in microscopy can get hot with prolonged use. Always take care when touching the lamp housing.

If in doubt ask a demonstrator.

5. Laboratory Notebooks

You will need one bound hardback laboratory notebook for recording your results and observations exclusively for this module. It should ONLY be used for CHE-10039 this semester. All the laboratory assessment in this module is based on your completed notebook. The supervising staff member or demonstrator must sign your laboratory notebook at the end of each laboratory class.

Please ensure that your full name and residence address are clearly written, on your notebook (preferably on the front outside cover), number the pages, and keep an up-to-date contents page at the front of the book.

Lab books are intended to contain a record of what you have done and observed when you actually carry out experiments. Here are some general guidelines for recording experimental details, data and observations.

- You should have a lab book in which you keep your permanent lab records.
- You should always make records in your lab book contemporaneously e.g. at the actual time you are doing the experimental work
- Someone else should be able to open your lab book on any page and find out what you did on a particular day.
- Your notes should be concise, clear and legible.
- There should be a list of contents.

A commonly recommended style for lab books is to draft your data and observations on the right hand side page and then produce a more detailed record on the left hand side page.

**Before starting an experiment.**

- Make sure you understand what you are doing in the experiment and why
- Make sure you are aware of the hazards and know the lab safety procedures
- Check the timing for the experiment
- Make preliminary notes including date, title, aims, calculations, design of the apparatus in your lab book, which may help you with the experimental work.
- Do NOT simply write out all the instructions from this handbook; that is not good use of time

**During the experiment, note immediately in your lab book**

- anything that differs from the lab script
- observations and numerical data – before drawing any conclusions!
- clear reference to any additional information (graphs, spectra, etc., which should be included)

**After the experiment.**

- Complete the lab record as soon as possible (left hand side page). These should include final results, comments and conclusions.
Although you will carry out your experimental work with another student, and will inevitably share most of the data, all the words, diagrams and graphs you use to describe and explain what you have done should be your own.

If you miss a laboratory session you must speak to the lecturer concerned about how you can make up the work you missed. DO NOT copy up your partner’s work!

The work in your laboratory notebook from weeks 4 – 10 will be assessed and the mark obtained will contribute 30% to the overall mark for the module. You will be given formative feedback on the work from weeks 2 and 3 but no mark will be recorded from that.

6. Assignment of Experiments

You will carry out nine weeks of experimental work and will work in pairs or in teams as directed and according to the requirements of individual experiments. The laboratory programme is detailed on page 3.

7. Assessment

- You must complete your notebook each week as you carry out the experimental work
- It must be signed by a lecturer/demonstrator responsible for that class
- In weeks 3 and 7 only you should leave your book in the laboratory. In week 3 you will get formative feedback on your work in the first two weeks of the laboratory classes. In week 7 the work from the previous three weeks will be marked and will contribute to your final laboratory mark for the module. For most weeks you can do some further work on the notebook after the class BUT you should not write up reports in the book. Reports are NOT required for this module. The remaining weeks’ work will be marked at the end of the semester to give the final mark.
- Completed laboratory notebooks should be submitted via the School Office according to the procedures described in the Undergraduate Handbook in week 12 by:

**Friday 19th December 2014**

*You must pass the laboratory component with a mark of at least 40% to pass the module overall*

9. Late Work

A penalty will be applied for late submission of the laboratory notebook in accordance with the scheme described in the Forensic Science Undergraduate Handbook.
Experiment 1

Height estimation from shoe size and stride length

This work will be preceded by a short lecture on constructing and interpreting graphs

Introduction

It is fairly clear that shoe-print evidence may lead to an estimate of the height of a potential suspect either through the size of the print itself or by measuring the stride length from the distance between consecutive prints. In fact, such an approach is often more reliable than eye-witness’ estimates. The scientist needs to provide evidence however of how such conclusions are reached and what the reliability of the result might be. This means that experiments need to be designed and carried out both to validate the forensic methodology and to provide an estimation of the uncertainty in the result. In this case, calibration graphs from measurements obtained from an appropriate population can be used for this purpose.

The aims of this practical are:

1. To make and collate a set of measurements, for all forensic science students in the laboratory class, comprising:
   - Shoe length
   - Stride length
   - Height
   - Gender

2. To construct appropriate calibration graphs, determine whether they represent a linear correlation and to calculate the best-fit slope and intercept.

3. To investigate whether there are different calibrations for men and women.

4. To compare your graphical calibration with other methods and to determine whether shoe size or stride length provides the better precision.

Experimental

You and your partner will be part of a larger group of students who will make the experimental measurements together. You should help each other with the work. Each student should measure his or her own shoe length (to the nearest mm) and height (to the nearest 1 cm). All data should be represented using units of metres to **three significant figures**. To obtain a reliable measure of stride length you should use the floor markings and make 10 normal strides, measuring the distance travelled by one of your feet to the nearest 1 cm. From this length, a single stride length may be calculated. Keep a note of your own measurements in your lab notebook.

Each student is responsible for entering their own data into the tally for the whole class and copying the whole class data into their own laboratory notebook, according to the following headings:

<table>
<thead>
<tr>
<th>Male or Female</th>
<th>Shoe length (m)</th>
<th>Distance for 10 strides (m)</th>
<th>Length of 1 stride (m)</th>
<th>Height (m)</th>
</tr>
</thead>
</table>

You will analyse in detail **either** the male or the female data.
Data Analysis
Theoretically, height should be a linear function of stride length since our limbs are in rough proportion to our body trunk, though there is some variability. Stride length also depends on our speed of travel to some extent, which will further complicate any simple model. However, it is not obvious that foot size should be in proportion to height though larger and taller people may be expected to have larger feet than their shorter counterparts and vice versa. Your data may be used to test these propositions and, if a linear relationship is found, then fitting a straight line to the data will enable a calibration equation of the form:

\[ y = mx + c \]

E.g.

Height = \( m \times \text{stride length} + c \)

You will each draw TWO separate graphs – one for the shoe size and the other for the stride length for either the male or the female data. You should use standard units (m) for all measurements and in each case the height should be plotted on the y-axis. Scaled graph paper is provided.

Graph 1: Height versus shoe length
Graph 2: Height versus stride length

For each graph consider whether the points suggest a straight-line correlation. If so, draw a best-fit line through each. Measure the slope and y-axis intercept of each line from the graph to produce calibration equations (e.g. values of \( m \) and \( c \)) for each.

Review your data and graphs and answer the following questions:

1) Test your calibration equations on your own measurements by substituting your own shoe length and stride length into the appropriate equations and hence estimating your height. Which is the better method in your case?

2) The following statements are often made to describe such data:
   - There is a ratio of foot-length to height of 0.15 for homo-sapiens
   - Height = 2.4 times stride length

Draw a straight line on the appropriate graph to represent each of these conditions – note that both go through the origin with the slope suggested by the statement. How do these compare with both your data points and with the best-fit straight line you have already drawn? Explain to what extent they agree and how they may disagree.

3) Finally, describe the scatter of points around each best-fit line. Is the scatter greater for one graph than for the other? Confer with a colleague to determine whether the scatter is the same for both the males and females? Can either shoe size or stride length be used to suggest whether a suspect is male of female? Explain your answer.

4) Choose ONE of these sets of data and construct a graph using an Excel spreadsheet. Add a linear trend-line and display the resulting equation on the graph. Compare its slope and intercept with those you determined by hand.

Reference:
Essential Mathematics and Statistics for Forensic Science: Craig Adam, Chapter 5.1 – 5.3 and Appendix II for using Excel for graph construction.
Introduction to Forensic Microscopy

Introduction
The aim of this practical exercise is to familiarise yourself with the set-up, operation and use of the stereo-microscope in forensic science. The purpose of this instrument is to provide low power magnification with a three-dimensional perspective and it is used routinely for a variety of purposes, from examination of questioned documents to initial assessment of fibre and other trace evidence. You will be given a brief tutorial in using the microscope at the start of this session.

The Stereo Microscope
This instrument consists of two separate light microscope systems arranged to image a single sample and to interface with the human eye system. The position of the two eyepieces may be adjusted to match individual eye positions. These microscopes are set up with 10X magnification eyepieces and no auxiliary lens to give a magnification range of 7x – 45x.

Magnification = 10 × Zoom setting

The zoom facility enables the observer to continuously vary the magnification of the image and to read the magnification directly off the dial on the control knob. A consequence of increasing magnification is that the field-of-view is reduced. The exact working distance which is around 10.8 cm for this arrangement, is found by adjusting the focus control on the support column at the back until a crisp image is found. One of the eye-pieces contains a graticule or micrometer scale which, once calibrated for a particular magnification, allows you to measure the dimensions of objects in the field of view.

Illumination is an important part of microscopy. Both transmitted and reflected white light illumination are available and are controlled by switches on the rear right hand side of the base; the brightness of the latter is adjustable using the roller switch on the front right-hand side of the base.

Auxiliary lenses, alternative eyepieces and a variety of illumination systems may be used on these microscopes where the application demands it.

Care and Safety
Always ensure that the eyepieces are fully located in their holders. They are not fixed in position so if the microscope is lifted and turned on its side for any reason these may fall out and become damaged. The transmission illumination should not be left on for prolonged periods of time. Switch it off when not in use.

Setting Up (20 min)
Consult the manual:

ZoomMaster 65 Mini-manual

To ensure the microscope optics is correctly set up, go through the process described in this manual. The set up should be carried out using a simple clear image such as that from one of the typed card samples.

Remember:

1 mm = 1000 μm (micrometres or microns)
Practical Exercises

Carry out each of the following exercises and report your conclusions briefly in your laboratory notebook. Note that formal sample preparation will be dealt with in next week’s practical session. For the type of sample being examined today it is sufficient to place the material on the ground glass plate and cover it, if necessary, with a glass microscope slide to ensure a flat surface with uniform focus across it.

1. Magnification and measurement (50 min)
To make best use of the microscope it is essential that we can measure the dimensions in the magnified images we obtain. This is achieved using a graticule or micrometer scale in one of the eyepieces. This is marked in 100 scale divisions, arranged over a scale of 10 with each subdivided into 10. It is essential to calibrate the microscope so that, for each magnification (zoom) setting, the actual distance, in microns, corresponding to one graticule scale division, is known. To do this we use a stage micrometer which is really a very short and accurately machined, transparent ruler, calibrated in units of 0.1mm (100μm) over a length of 10mm – or alternatively, a very good quality ruler with 0.5mm markings or better. In the following exercise ignore the numbers on the graticule and use each marked unit on the graticule as one graticule unit.

You will now calibrate the microscope for each zoom setting from 0.7 to 4.5. There are various ways of doing this but the following is probably the simplest:

a) With the zoom at 0.7 obtain a focused image of the stage micrometer or ruler scale. By aligning this image with the graticule scale, determine the actual length in mm on the ruler which corresponds to 50 graticule scale units. Hence, calculate the length \( L \) corresponding to ONE graticule scale unit at this magnification \( M \). Start to record your data as a table. Note that it is very important that your image is crisply focused prior to each measurement.

b) Repeat this process for all subsequent zoom settings. At some magnifications it is easier to align 100 graticule scale units with the stage micrometer and hence calculate the length corresponding to ONE graticule unit.

There is an inverse linear relationship between magnification (\( M \)) or zoom setting and the calibration of one graticule unit (\( L \)) – \( L \) is inversely proportional to \( M \):

\[
L = \frac{K}{M}
\]
with $K$ constant. Plot a linear graph with $L$ on the $y$-axis and $\frac{1}{M}$ on the $x$-axis, to verify this relationship. Compare this equation with the standard straight-line equation through the origin $y = mx$ which shows why $m = K$ here. You can use this graph in future to work out $L$ for any zoom setting on this microscope. You will find it useful to memorise the values for the 0.7 and 4.5 zoom settings for quick use in the future!

2. Imaging of hair (40 min)
Next, you should (i) cut and (ii) pull a short length of a single hair from your head or elsewhere. Place the sample between two microscope slides. Try using both reflection then transmission illumination. Sketch what you see and, briefly, describe the appearance of each in your notebook. You should pay particular attention to the ends of each hair. Each sketch should occupy around a quarter of a page and be annotated to show the main features.

Using the calibrated graticule, measure the hair diameter at a few points long its length. Can you estimate the absolute uncertainty (error) in your measurement from your observations? Repeat this for your partner’s hair and compare values. What can this microscope usefully tell us about features in the size range of human hair?

3. Fibre retrieval and imaging (40 min)
The simplest method of retrieving fibres from a substrate such as a piece of clothing, carpet or furniture is the tape-lift. You and your partner should both provide tape-lifts but is it sufficient to analyse only one in detail in your laboratory notebook.

Cut a small piece of sticky tape, remove the backing and press the sticky side down lightly but firmly on part of your clothing. Lift it up and carefully press it, sticky side down on to a glass slide, ensuring that few air bubbles are retained. Examine this under the microscope. Describe the image and range of fibres – and any other traces – you observe on the slide. Are there any fibres or other evidence present which do not originate from the fabric of that piece of clothing? Try both transmitted and reflection illumination. In describing some individual fibres include a few estimates of the diameter and length. Note: choose your clothing surface sensibly; do not apply the tape to an expensive surface with some special finish (!) or to a fabric which is unlikely to retain or release any fibres.

If there is time at the end, use the low-power ultra-violet (UV) source to provide as an alternative illumination for your sample. Can you identify any other transferred fibres that were not evident when using white light?

*Note: the u.v. lamp is perfectly safe when used as described. DO NOT, however, shine it in anyone’s face or look directly at the light. Switch OFF when not in use.*

References

http://openlearn.open.ac.uk/mod/oucontent/view.php?id=407870&section=2.3

Experiment 3

Introduction to the Microscopy of Fibres

Introduction
Microscopy is one of the most important techniques used in fibre examination. Low magnification may be used to find and retrieve fibre evidence, as studied in the previous practical class, while higher magnification can facilitate identification of fibre types and carry out other types of analytical measurement on the sample. Many fibres necessitate the use of a high magnification compound microscope for a full examination but much can be learned about these techniques through the low power stereo microscope which has the benefit of ease of use.

In this practical exercise you will cover:

- Use of polarised light microscopy
- Preparation of permanent mounts of fibres
- Use of birefringence in fibre identification
- Use of the microspectrophotometer for fibre analysis

The microspectrophotometry will be done as an interactive demonstration with a member of staff whereby you will obtain your own set of data for analysis. This will be done in small groups at convenient points during the practical session.

Fibre Birefringence
This topic will have been covered in detail in the lectures. Recall that different fibres may have differing values of refractive index for light along and across the fibre. The difference in these values is the birefringence and it is responsible for the appearance of an interference colour when the fibre is viewed through crossed-polarised light. This colour observed depends on BOTH the fibre thickness and its birefringence and has nothing to do with any dye present in the fibre; that characteristic is analysed using the microspectrophotometer, in a separate measurement. The observation of birefringence, however, can be used to identify or match forensic fibre samples using the polarised light microscope.

Before you start, set up the microscope according to the standard procedures to ensure the image remains in focus across the zoom range (parafocality)

1. Polarised light microscopy (30 min)
This technique is often useful when imaging fibre samples. Without the sample present, the microscope is set up with transmitted light as follows. A piece of Polaroid is placed under the ground glass base plate and the lens cover, equipped with a second Polaroid is partially screwed into the lens cover. The upper Polaroid is rotated until a minimum in light intensity is observed (cross-polaroids). The field of view should be as dark as possible – the only light will be from the laboratory surroundings.

To demonstrate this technique carefully extract a single fibre from envelope A, put it on a microscope slide and place a cover-slip over it. Take care not to lose the sample while doing this!
Examine the fibre under high magnification, firstly with transmitted white light, then with crossed-polarised light. Comment on the visibility of the fibre and its appearance in both instances, particularly as the fibre is rotated in the field of view. What colour is observed when the fibre is a 45° to the polarisation direction?

You should also measure the fibre thickness using the calibrated graticule and white light illumination. It is essential that the fibre is precisely focused in the microscope for this measurement.

2. Mounting fibres and microscopy (40 min)
For proper examination and preservation of evidence such as individual fibres, we can mount these permanently on glass microscope slides using the following technique. This uses a mounting medium called Entellan. This is provided in xylene solvent which evaporates as the mount dries. In the small quantities you are using, this is a safe procedure in a normally ventilated laboratory.

Make sure you read the COSHH assessment for Xylene and copy the essential details into your notebook.

You are going to mount a single fibre from envelope A for microscopic examination.

It is important to note that you are intending to mount a single fibre – not a whole piece of the thread. Place the fibre in the centre of a microscope slide – beware that it might blow away in a draught! Using a wooden cocktail stick, you should lift a drop of mounting medium from the bottle. Let the first drop land on the fibre and repeat the process once more, if needed. You should need around one - two large drops to prepare the slide. Take a glass cover-slip in the tweezers provided and place it firmly on top of the sample and mounting medium, squaring it off. Do not press down on the cover-slip at surface tension should hold it down. Put the slide to one side and let it dry for 10 minutes or so.

When this is complete you should repeat the measurements that you made earlier with the unmounted sample (part 1) now with the fibre mounted in Entellan. Why do you think the detailed appearance of the image is different in these two cases when the fibre is the same material?

3. Interpretation of fibre birefringence (50 min)
Having measured the thickness and birefringent colour for fibre A, you should now repeat these measurements on fibre samples from envelopes B and C. It will be sufficient to prepare these only as dry mounts under a glass cover-slip. How does fibre C different visually from fibres A and B?

You should now interpret your data from these three fibres on the basis that they are drawn from the following two polymer types:

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Birefringence range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nylon</td>
<td>0.049 – 0.061</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>0.028 – 0.034</td>
</tr>
</tbody>
</table>

Using your data and the on-line Michel-Levy chart at:
identify which polymer corresponds to which sample. The easiest way is to locate your sample thickness of the vertical axis then move across horizontally until you intersect with the diagonal line representing the birefringence of each of the samples. At the intersection point the corresponding birefringent colour will be found.

Briefly discuss the differences you have found between fibres A and C.

4. Microspectrophotometry of fibres (40 min)

Rather than looking down the microscope at our sample, we can direct the light that has been transmitted through the sample into a spectrometer mounted directly on the microscope. This generates a visible light absorption spectrum for the fibre itself. This provides a quantitative measurement of the colour of the fibre which comes from the dyes present in it.

You will be guided through a demonstration of this instrument and acquire data on two fibre samples. Using the spectra you have obtained write a short paragraph on the conclusions you can draw from interpreting these spectra, explaining your reasoning clearly. Paste your graph and write your conclusions in your notebook.

References

Ch 3, Box 3.3 in Forensic Science: Jackson and Jackson, Pearson, 2008.
Experiment 4

The Forensic Examination of Paint

Introduction
Paint is a common form of trace evidence, often originating from vehicles, though house paint fragments and scrapes are also frequently found. The forensic examination of paint uses both physical and chemical techniques. Microscopy allows surface texture and colour to be assessed and the thicknesses of multi-layered samples may be measured. Chemical identification of binder and pigment materials may be carried out by micro-spectroscopic methods, in particular Fourier Transform Infra-Red (FT-IR) and Raman spectroscopy that are both sensitive to the various chemical functional groups within these components. UV-vis micro-spectroscopy may be used to objectively characterise colour but that will not form part of this present work.

In this experiment you will get experience in using microscopy and FT-IR spectroscopy to examine some domestic paint samples and interpreting the results from such complementary techniques.

Experimental techniques
We have already described in outline the techniques of vibrational spectroscopy in the lectures and explained how they are relevant to paint analysis. You have also gained expertise in the use of the stereo-microscope in two preceding, practical exercises. As far as chemical characterisation is concerned, FT-IR is sensitive to the various functional groups within the binder (resin) and pigment. The binder is usually a large organic polymer molecule such as an alkyd, acrylic or vinyl resin with many characteristic vibrational modes of bonds involving C, O, H and also N atoms. FT-IR shows particular sensitivity to these constituents and enables us to distinguish many types on the basis of a particular set of absorption bands in the IR spectrum. In domestic white paints, the pigment is usually inorganic in nature, for example the various crystalline forms of TiO$_2$ or CaCO$_3$ and, though some FT-IR signals may be quite broad, identification of the material is still possible.

Aims
The aims of this experimental session are:

1. To classify a set of seven different white paints on the basis of their microscopic appearance/characteristics and IR spectra
2. To identify their principal constituents and thereby determine whether these paints may all be discriminated from each other using these techniques.
3. To investigate the layer structure on a paint chip and thereby identify which two of these seven standard paints are present.
4. To evaluate the discriminating power of the microscope and the FTIR spectrometer for the analysis of these paints.

Experimental work
1. You are given SEVEN samples of different white paints on wood labelled A - G. You are given also the FT-IR spectra from these seven paints, THREE spectra from possible pigments and a data-sheet on the typical IR absorption wavenumbers found for these pigments and for TWO potential binders (see appendix). These FT-IR spectra are available on the Blackboard pages for this module in the laboratory section. You should print these off and use them to explain you results in your notebook. The tasks are:

(a) By looking at these paint surfaces and by using the microscope, characterise the physical appearance of all these paints. You should include a comment on the texture experienced by touch as well. The key headings are:
Colour – clearly white/ grey but what is the tone you detect?
Texture – is the surface rough/smooth and are there any bubbles or particles visible?
Reflectivity of light – does the surface appear glossy or matt and to what extent?

These results are best presented in a table using these three headings.

Using your results, construct a pair-wise comparison matrix and by counting the number of pairs that may be distinguished $N$ against the total number of samples $n$ calculate the discriminating power for the microscopy method using:

$$D = \frac{N}{n(n-1)/2} \times 100\%$$

(b) By noting the various features in the FT-IR spectra sort these into classes without particular reference to the standards.

(c) With the aid of the standard spectra and the absorption bands given in the appendix, identify the resin and pigment(s) present in each case. These results should be presented in a table similar to that in (a).

(d) On the basis of all the information you have accumulated are you able to distinguish each of these paints from all the others? Using your results construct a pair-wise comparison matrix and thereby calculate the discriminating power for the FTIR technique.

2. You are given two or more paint fragments that have fractured off the same painted surface. You should characterise these using microscopy and FT-IR spectroscopy to identify which paints are present.

**Write down the code for your samples in your notebook!**

Take one fragment and examine both faces by eye and by using the microscope. Then, very carefully cut across one edge to obtain a straight, flat surface across its thickness. Mount this using plastic clay on a glass side so that the freshly cut surface is uppermost. Examine this and measure the thickness of each layer.

Take two fragments to the FT-IR spectrometer and, using the ATR attachment, obtain a spectrum from the top face of one fragment and from the reverse face of the other fragment. You should scan from 400 - 2000 cm$^{-1}$ with a resolution of 4 cm$^{-1}$. The use of two samples may be necessary as pressure from the ATR may damage the face opposite to that being examined. Using the standard spectra, determine which resin and pigment(s) are present in each of these spectra.

Tabulate the results from these two techniques and then try to identify which two of the seven paints are present in your fragments. Note that there are several combinations being examined in the class so not everyone will get the same answer!

**References**

Ch 3, Section 3.5 in *Forensic Science*: Jackson and Jackson, Pearson, 2008.
Appendix: Forensic Examination of Paint

**FTIR Data**

**Binder (resin)**

<table>
<thead>
<tr>
<th>Resin</th>
<th>FTIR absorption (cm(^{-1}))</th>
<th>Vibrational mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyvinyl acetate resin</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1738</td>
<td>C=O stretch</td>
</tr>
<tr>
<td></td>
<td>1434</td>
<td>-CH(_2)- bend</td>
</tr>
<tr>
<td></td>
<td>1373</td>
<td>-CH(_3) bend</td>
</tr>
<tr>
<td></td>
<td>1240</td>
<td>C-O stretch in O=C-O</td>
</tr>
<tr>
<td></td>
<td>1021</td>
<td>C-O stretch in O-CH(_3)</td>
</tr>
<tr>
<td></td>
<td>605</td>
<td>O=C-O-CH(_3) bend</td>
</tr>
<tr>
<td></td>
<td>1122, 946</td>
<td>other modes</td>
</tr>
<tr>
<td>Ortho-phthalic alkyd resin type</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1730</td>
<td>C=O stretch</td>
</tr>
<tr>
<td></td>
<td>1467</td>
<td>-CH(_2)- stretch</td>
</tr>
<tr>
<td></td>
<td>1376</td>
<td>-CH(_3) stretch</td>
</tr>
<tr>
<td></td>
<td>1285</td>
<td>C-O stretch</td>
</tr>
<tr>
<td></td>
<td>1122</td>
<td>C-O stretch</td>
</tr>
<tr>
<td></td>
<td>1072</td>
<td>unassigned</td>
</tr>
</tbody>
</table>

**Pigment Data**

<table>
<thead>
<tr>
<th>Pigment</th>
<th>FTIR absorption (cm(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaCO(_3) (Chalk or Calcite)</td>
<td>~ 1400 (broad)</td>
</tr>
<tr>
<td></td>
<td>876</td>
</tr>
<tr>
<td></td>
<td>715</td>
</tr>
<tr>
<td>Kaolin (ite) clay (main peaks only)</td>
<td>1108</td>
</tr>
<tr>
<td></td>
<td>1028</td>
</tr>
<tr>
<td></td>
<td>1008</td>
</tr>
<tr>
<td></td>
<td>912</td>
</tr>
<tr>
<td></td>
<td>536</td>
</tr>
<tr>
<td></td>
<td>468</td>
</tr>
<tr>
<td>TiO(_2) (usually Rutile)</td>
<td>~ 500 – 800 (broad feature)</td>
</tr>
</tbody>
</table>

*Note that some small variation in these absorption wave-numbers is possible.*
Experiment 5
Handwriting Analysis

Introduction
This topic is a highly skilled activity which is reflected in the many years’ experience it takes to become a fully “expert” document examiner. However, the following exercises are designed to enable you to experience some of the techniques used by the professionals when examining handwriting evidence.

There are two parts to this laboratory exercise:

Firstly, you will carry out an assessment of a piece of handwriting to determine its individual characteristics and the range of variation in letter formation which it shows.

Secondly, you will analyse the case of a money withdrawal slip where fraud is suspected.

You should use a magnifying glass, linen tester or the stereo-microscope (usually at low magnification) when required but note that many of the observations may be made by eye. Write up your case-notes as you go along.

1. Assessment of Handwriting (1hr 15min)
As you are working in pairs you should each assess the other’s handwriting and then compare them by discussing their similarities and differences. In practice you may find it easier to work together on each!

To start, you should BOTH separately write out the following paragraph, in your normal handwriting, in your own notebook and then in your partner’s notebook so you both have the same two examples of handwriting to work on.

Example Text
“The problem with buck rabbits is that they have begun to kick friendly rodents regularly and frequently, without justification, and to eject them from their deep hideaways.”

Strategies for forensic examination

a. Review the writing as a whole; classify it as print, cursive or script or some mixture of styles.

b. Review the construction of letters focusing on the following aspects:

(i) The formation of the letters: d, g, k, b, y

(ii) Briefly comment on the style of dotting and crossing letters such as i, j, t

You should do this (i) by sketching each letter in enlarged form in your notebook and then annotating it, as you analyse its features; do not sketch every occurrence of each letter. A good method is to divide your page into two sections with a vertical line then sketch and discuss each
letter in a tabular format, with your own writing on one side and the corresponding letter from your partner’s handwriting, on the other side.

In this assessment make use of the indicators such as “tram-lines”, striations and ink build-up and most importantly assess how consistent the writer is or how much variability occurs in the style of each letter.

![Example of an annotated letter](image)

2. Case-Study (1): Suspected Fraud (45 min)

Mrs Anne Campbell lost her Post Office passbook and believes someone else has been falsely withdrawing money from her bank account. Mrs Campbell denies withdrawing the money herself.

You are supplied with the following evidence:

- National Savings Withdrawal Form (the Questioned Writing)
- Request handwriting specimens provided by Mrs Campbell.

Compare the questioned handwriting with the specimens to determine whether or not the author of the specimens also wrote the questioned handwriting.

**Strategy**

You should sketch out and annotate key letters in both (1) and (2) separately e.g. note letter shapes and proportions. Consider the consistency in construction of each letter, particularly B, M, A and Y. Look for similarities and differences between them. Draw a justifiable conclusion on the five-point scale discussed in the lectures.

*Note, that as these are photocopies you cannot successfully analyse the ink line or examine the writing under a high magnification – but in fact, in this case, you should not need to do so.*
2. **Case-Study (2): The Anonymous Letter (45 min)**

A malicious letter has been sent to a student of St Augustines’s School, Berkshire. The student who received the letter has been the victim of bullying for several months and it is thought that the letter was sent by a member of the same class. Handwriting samples from known bullies have been submitted for handwriting analysis together with the anonymous letter.

*Questioned letter*

*Specimen from Gary Bullimore*
*Specimen from Alex Goodson*
*Specimen from Christopher Rockingham*
*Specimen from Ivan Heeley*

This is a more typical handwriting exercise than the last one as extended pieces of identical text are available. For this case the focus is more on the general style and formation of words and phrases rather than individual letter formations.

First compare the general appearance of the questioned handwriting with each of the four specimens in turn and try to eliminate those which are clearly not a match, giving brief reasons in each case.

Then, for those remaining, make short notes and sketches on points of similarity and difference (e.g. why a particular writer could or could not have written the questioned letter). These should be whole words or phrases as well as individual characteristic letters. Hence identify which suspect wrote the anonymous letter, giving justification and an indication of the strength of your conclusion in your answer.

---

**Appendix**

**Five point scale for handwriting analysis**

1. Conclusive evidence that both are written by the same person
2. Supporting (strong) evidence that they are by the same hand but the possibility of different individuals cannot be ruled out
3. Inconclusive because of equivalent similarities and differences or lack of evidence to work on
4. Supporting evidence that different individuals wrote both the specimen and the questioned writing but the possibility of both being by the same hand cannot be ruled out.
5. Conclusive evidence that different individuals were responsible for the specimen and questioned documents
Experiment 6
Introduction to Fingerprinting Techniques

Introduction
The everyday use of fingerprinting as an identification method and as evidence in courts of law is based on the fact that no one has ever been found to have a sequence of ridge details that is identical to those of any other person. The aim of this practical session is to familiarise you with some basic fingerprinting procedures.

Safety note. Inks and powders used in this practical are non-toxic; however, sensible handling procedures should be followed while working with them. Make sure to wash your hands after the session.

Practical Exercises
Carry out the following exercises and report your observations and conclusions in the lab book. Attach relevant images of your fingerprints to your notes.

1. Superglue fuming of latent prints
Produce a latent print on a piece of plastic sheet or metal foil and submit it for cyanoacrylate ("superglue") treatment in the fuming cabinet. While this is proceeding continue with the next set of experiments.

2. Fingerprint patterns.
Look at the ridge pattern on one of your fingers unaided and then using a stereo microscope (i) at the lowest magnification, and (ii) at the highest magnification. Describe details you observe each time. Can you see the 1st, 2nd and 3rd level ridge characteristics?

Hold a glass for a few seconds. Visualise latent fingerprints left on the glass surface using magnetic powder and a brush. Lift the print with the sticky tape provided and attach it to your partner’s elimination print form. Examine the print using a stereo microscope. Using a VSC-4C instrument or a stand-alone camera, capture a magnified image of an ink print, save it as a *.jpg file, e.g. VZ01.jpg, and obtain a hard copy.
4. Ink prints.
Using ink pads and elimination print forms provided (practice with a photocopy first), produce a full set of ink prints.
Categorise your set of fingerprints as X/Y using the primary classification, often referred to as Henry system. Swap the forms with your partner and check each other’s work. Look at the ink prints using a stereo microscope. Can you still make out the 2nd and 3rd level ridge characteristics?

Once again capture a magnified image of an ink print - **for the same digit as in part (3)** - save it as a *.jpg file, and obtain a hard copy. Find and mark sixteen 2nd level ridge details. Compare this with the image of the enhanced latent print you obtained earlier and comment in your notebook on the second (and third) level detail in each, indicating examples of ridge characteristics as illustration.

5. Interpretation of Superglue prints
Examine the superglue –fumed prints (again, including using the microscope) and comment in your notebook on the detail revealed by this process.

Reference section

ARCH    WHORL    LOOP
RIDGE CHARACTERISTICS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Ridge Ending" /></td>
<td>Ridge Ending</td>
</tr>
<tr>
<td><img src="image2" alt="Bifurcation" /></td>
<td>Bifurcation</td>
</tr>
<tr>
<td><img src="image3" alt="Lake" /></td>
<td>Lake</td>
</tr>
<tr>
<td><img src="image4" alt="Independent Ridge" /></td>
<td>Independent Ridge</td>
</tr>
<tr>
<td><img src="image5" alt="Dot or Island" /></td>
<td>Dot or Island</td>
</tr>
<tr>
<td><img src="image6" alt="Spur" /></td>
<td>Spur</td>
</tr>
<tr>
<td><img src="image7" alt="Crossover" /></td>
<td>Crossover</td>
</tr>
</tbody>
</table>

Reference:


Ch 4, Section 4.1 in *Forensic Science*: Jackson and Jackson, Pearson, 2008.
Introduction

Once fingerprints have been enhanced and imaged from a crime scene, it is the job of the fingerprint identification expert from the forensic identification division of the police force to carry out the identification stage of the process. The questions to be answered include:

Do any of these prints 1. need to be eliminated from the enquiry?
2. match those taken from potential suspects?
3. match those of offenders on the police database?
4. match other, as yet unidentified, marks from other crime scenes?

In this practical exercise you will carry out the first two of these through the process of classification and manual matching on minutiae (2\textsuperscript{nd} level detail). Throughout this exercise all prints are from the right hand only.

The scenario of the crime

The case concerns the opportunity theft of money from an elderly lady who kept a large quantity of cash in a metal tin sealed with sticky tape in her kitchen. This lady has also recently received a threatening letter from someone who claimed to know about her savings. The CSI has carried out the routine examination of the scene, identified marks on the exhibits and completed the appropriate enhancement processing and imaging of the prints. She has taken ink prints of the householder herself and colleagues have provided similar sets of prints for four suspects who were in the vicinity at the time. The prints have been taken from the following five exhibits:

1. The kitchen door handle (fluorescent powder)
2. The surface of the tin (superglue fuming)
3. The handle of a chisel used to open the tin (superglue fuming)
4. The surface of the sticky tape (gentian violet)
5. The anonymous letter (ninhydrin)

You are provided with either two or three single digit marks from each exhibit.

Classification and identification of prints

Here we shall review and summarise some of the basic principles of the classification and matching of fingerprints. All prints may be classified initially into three main categories each of which may be further subdivided in various ways. The initial classification is based on whether the print shows a Loop, Arch or Whorl type pattern. Note that around 65\% of UK digits are loops, 30\% whorls and 5\% arches, so you are more likely to find a loop than any other pattern and the arch is relatively uncommon. These are illustrated on the following page with some further notes on each class. There are many variants, particularly of loops and whorls, some of which are illustrated in the additional example illustrations that will be available in the laboratory.

Once the class is established, individualisation is achieved by identifying and matching points of second level detail across the print both in terms of type and relative position within the print. A minimum of 8 points is required to initiate computer-based matching in the UK and there is statistical justification for at least 12 to fully justify a match. Countries that work to a numerical standard specify criteria from 12 to 18 matching minutiae.
This is a **Right Loop** print. If it is on the RH and starts from the little finger it is an *Ulnar* loop. If a right loop is on the LH, it starts from the thumb end and is a *Radial* loop. The opposite naming convention applies to the **Left Loop** print. A Loop has a core and one delta. The ridges enter and leave from the same side.

This is an **Arch** print. The ridges enter from one side and exit on the other. The core is hard to identify and there are no deltas. However, sometimes a **Tented Arch** is found which has a delta at the core of the print and is otherwise similar.

This is a **Whorl** print. It comes in several varieties of which this is the easiest to identify. At least one ridge goes completely round on itself, there is a core and two deltas are found, usually clearly on either side.

This is still a Whorl! It is a twin-loop whorl due to the ridge pattern in the centre. There are other types such as the accidental whorl and for the Henry classification any print that is not classed as a loop or arch becomes a whorl by default. A notable case is the **composite print** that appears as a mixture of the features of others with, for example, three deltas.
This print shows many minutiae or points of 2\textsuperscript{nd} level detail. Some of these are marked here with circles. By identifying a sufficient number of minutiae and their relative positions we may uniquely individualise a print. For example here we find:

1. A ridge ending at the core of the print
2. A further ridge ending on the left separated from the first by two ridges
3. Eight ridges further to the left there is a bifurcation
4. A lake is found above the core separated by two ridges from the first ridge ending
5. Above that and to the right we find an independent ridge, separated by two ridges
6. There are three characteristic independent ridges at this delta feature

We can also determine the ridge count along a straight line from the delta to the core. Here the ridge count amounts to 21.

**Aims of the practical exercise**

By inspection and matching of the marks from the exhibits against the five reference sets of prints you should:

1. Classify each of the five digits for each of the five standard sets of prints (30 min)
2. Identify whether the householder’s prints are present on any of these exhibits (1 h)
3. Identify whether the remaining marks came from any of the suspects and if so identify whom (1 h)
4. On this basis identify who handled the exhibits in this case. (15 min)
Procedures

Notes:
A. There are six different sets of marks spread amongst the class so most of you are working on different problems!
B. The term print is used to refer to a fingerprint taken from a known individual whereas the term mark refers to a full or partial questioned fingerprint from a crime scene.
C. The quality of these images varies due to the different enhancement methods used for marks on different substrates and this is meant to reflect to some extent the real-life experience.
D. You may find it helpful to use an acetate sheet to mark up a minutiae pattern which may then be compared with another by over-laying it. Note that these prints have not been scaled to be the same size so a perfect fit will not usually be obtained!

1. Classification of all reference prints
   By inspection and through comparison with the available examples, assign a class to each digit from the four suspects and the householder. In the case of loops say whether it is a right (ulnar) or left (radial) loop bearing in mind that all prints are from the right hand. Where possible state the form of whorl pattern. You should present your results in a table within your laboratory notebook.

2. Elimination of the householder (individual 1)
   Inspect the five prints from individual 1 and initially on the basis of class, identify any instances of these amongst the marks from the exhibits. Then any partial marks should be carefully compared on the basis of any distinct minutiae patterns with the prints from individual 1. All matching should be justified on the basis of FOUR corresponding points of second level detail sketched in your notebook.

3. Identification of remaining marks from exhibits
   You now will have some remaining unidentified marks and four sets of reference prints. You should start from marks that are classifiable and compare these across all suspects. Where possible agreement is found, you should confirm identification by finding FOUR corresponding points of second level detail as before. Finally, you will need to identify marks that are partial prints using characteristic minutiae patterns. Clearly is it is sensible to start with those prints from those suspects whom you have already associated with the scene!

4. Who handled what?
   You should complete your work by constructing a table that lists all exhibits and the marks from each in one column with a list of the suspect/ digit that you believe corresponds in the second column. In a third column you may briefly give your justification for the match e.g. class/ minutiae pattern.
Experiment 8
Forensic Document Examination

Introduction
In this laboratory class you will experience the use of three different techniques in the examination of documents. Although you will work with your usual partner, the whole class will be divided into three teams (with either three or four pairs to a team) and each team will spend up to 50 minutes on each activity in turn:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oblique Lighting</td>
<td>Team A</td>
<td>Team C</td>
<td>Team B</td>
</tr>
<tr>
<td>ESDA</td>
<td>Team B</td>
<td>Team A</td>
<td>Team C</td>
</tr>
<tr>
<td>VSC</td>
<td>Team C</td>
<td>Team B</td>
<td>Team A</td>
</tr>
</tbody>
</table>

The Case
As well as carrying out some other measurements, you will use the techniques to investigate a possible chequebook fraud. You are supplied with a set of four blank unused cheques as evidence because the previous cheque from this book is suspected of being altered. You are also given the questioned cheque itself. Carefully number the cheques from 1 to 4 in a top corner using pencil then separate them, taking care not to leave fingerprints on their top surface.

For each activity you should provide a sketch of the questioned cheque with annotation showing what you have found using that particular technique as a summary of your results.

Activity 1: Oblique Lighting
For this you will use a stereo-microscope with the goose-necked optical fibre lighting source. This allows you to point a bright, but adjustable intensity, white light at any angle to the document surface that you wish. There are two parts to this examination:

1. Each pair will take a pad of four pieces of paper, number them sequentially with (1) being the top sheet and (4) the bottom sheet, then write various types of information on the top sheet firmly (but not too hard!). You should include some individual characters e.g. numbers or capital letters of various shapes plus two or three short words in your normal hand. Do not let the others in your team know what you have written or where it is on the paper.

Exchange the first blank indented sheet (2) with another pair in your team and examine each other’s indented writing to attempt to decipher it. Make case notes of what you can make out. In particular, describe which letters or parts of letters are the easiest to see.

Then exchange sheet (3) from the same originator and repeat the process. If necessary, continue with sheet (4).

2. Now examine the top blank cheque on the unused pad. Investigate and decipher as much of the indented writing as you can. Sketch the cheque and what you can make out from it in your
notebook. Use rubber gloves when handling this to minimise depositing fingerprints on it which will show up in the ESDA measurements.

**Activity 2: Electrostatic Detection Apparatus (ESDA)**
You will use the ESDA technique to investigate the cheques on the blank unused pad. It is hoped that using ESDA will reveal the original writing on the top cheque, indented on the unused cheques below.

Place all four cheques from the pad in numerical order on the platen together, take an ESDA image of them and inspect the result. Copy any revealed features and writing into your laboratory notebook. Comment on any differences between the images from the cheques. You may use the scanner in the laboratory to obtain an electronic image from your ESDA trace.

Compare the usefulness of these two techniques in examining indented writing.

**Activity 3: Video Spectral Comparator (VSC4C)**
There are two exercises you should carry out with the VSC:

1. Using your own pen, you and your partner should write her or his first name, one above another, on a piece of paper. Insert this into the VSC and carry out:
   
   A. IR Absorption measurements
   
   B. IR Luminescence measurements

   in an attempt to distinguish between the series of inks. Your laboratory notebook should include a copy of the ink (including the name of the pen manufacturer) in question, together with the brief results of these tests. Ensure you label the results for each technique clearly and correctly.

   For example, you should give the high-pass filter setting at which the ink vanishes (if it does) and/or the conditions under which luminescence occurs.

2. You should use the VSC to investigate whether the questioned cheque in the fraud case has indeed been tampered with.

   First, carry out some IR absorption measurements, noting any changes to the image as a result of changing the high-pass filter.

   Second, use the spot illumination to check for IR luminescence differences across the writing on the cheque. Write up notes on your results.

   _Save an image of one of these measurements, print it out and paste it into your laboratory notebook._

**Overall conclusions**

Finally, write up half a page, in your notebook, summarising your conclusions on the questioned cheque case, drawing together the results from each technique.
Experiment 9
Document Security

Introduction
Throughout our lives we rely on the use of a great number of documents from the birth certificate and a passport to banknotes and concert tickets. Most of these documents have to be protected to minimize their misuse, fraud and counterfeit activities. A wide range of security features is built into most modern documents; these include watermarks, special inks, holograms, etc. The aim of this practical session is to demonstrate typical security features protecting various documents and thereby determine a full security profile for each document.

Practical Exercises

Safety note: UV lamps used in this practical are safe to use for up to eight hours a day without the need for special eye protection. However, sensible handling practice should be applied. Do not stare into the UV beam, and never direct the UV light into anybody's face.

You need to bring TWO different types of document with you for this practical, one of which should be a banknote while the other can be any relevant document, for example a passport or paper driving licence. Documents, particularly banknotes, can be provided by us if needed.

Carry out the following exercises and report your observations and conclusions in your lab book. While examining your documents, you should sketch appropriate details in your laboratory book and you should also capture some relevant images using a VSC-4 instrument or a digital camera, attach them to your work and annotate them with comments. The appendix on the next page provides some guidance on what you should be looking for in your investigations.

In the following you should illustrate your answers with sketches and preferably no more than FOUR photographs of key features taken from the document. Note that your comments and interpretation of these security features are more important than the number of images you provide! Deal with each document in turn and carry out the three examinations 1 – 3 on each, keeping your work for each quite separate in your notebook.

1. Visual inspection.

Look at the documents unaided and then using a magnifying glass, a stereo-microscope or using the zoom facility of the VSC-4. Which general characteristics and security features can you recognise? Sketch them for your report then explain their function and briefly how they work.
2. **Observations using transmitted light.**

Using transmitted light from a light box, on the microscope or from the VSC-4, check your documents for the presence of additional security marks. Sketch them for your report, explain their function and briefly how they work.

3. **UV examination.**

Examine your documents using a UV lamp or the UV sources in the VSC4. Can you recognise any fluorescent security features? You should sketch them for your report then explain their function and how they work.

**Appendix**

The following pieces of information are relevant to drawing up a security profile, particularly for a banknote.

**General information:**
- Country of origin
- Issuing bank (also the series number and the printers, if available)
- Denomination (and where it fits into the series)
- Serial number (including the style)
- Dimensions
- Front design (portraits, background, colour scheme)
- Back design (portraits, background, colour scheme)
- Signatures
- Other features of interest

**Security features:**
- Watermarks
- Security thread
- Foil, hologram, plastic insert
- Embedded fibres
- Microprint
- Intaglio printing
- See-through register
- Fluorescent inks
- Colour shifting inks

The following reference sites provide a great deal of up-to-date information about some major currencies, including their history, general design and security features:

http://www.moneyfactory.gov/newmoney/
http://www.bankofengland.co.uk/banknotes/index.htm
http://www.cbr.ru/eng/bank-notes_coins/bank-notes/