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Application of Absorption Spectra to Study Order of Sequence in Intersecting Printed and Pen Strokes

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ABSTRACT

This work is performed to establish chronological order in crossing strokes between printed stroke and pen strokes. Nine different types of pens including cello maxriter pen (black and blue), pilot pen (red and black), cello pointec pen (black and blue) and cello techno tip pen (red, black and blue) are used to produce pen strokes and for printed stroke Canon LBP 3300 printer is used. In the case of printed stroke, only black color stroke is applied. As a result, samples of both homogeneous and heterogeneous intersecting strokes are prepared. This work is based on the assumption that nature and peak characteristics of absorption spectra from crossing stroke should be similar to that of second stroke. Here, absorption spectra is generated by Video Spectral Comparator-6000 by using light of wavelength ranging from 400 nm to 1000 nm. From this experiment, it is found to be possible to find chronological order for heterogeneous crossing strokes (crossing stroke of different colors) only if printed stroke is over pen stroke. It means, only if print is done over writing strokes from red and blue pen, then order of sequence of writing can be determined whereas in other cases it is not possible.

Keywords: Chronological order, Heterogeneous, Homogeneous, Spectra, Stroke.

1. INTRODUCTION

Forensic document examiners use scientific theories and methodologies to establish authenticity of document and often face many challenging problems. One of them is determination of order of sequence of strokes in crossing lines which is not new problem. Establishment of chronological order in writing cross stroke plays vital role in criminal justice system. Hence, it is important to determine which stroke is executed later in crossing strokes [1].

Now a days, many researcher and document examiners are working for determining order of sequence in crossing strokes. Application of reflection spectra generated by Video Spectral Comparator-2000HR is found very effective to determine sequence of order in heterogeneous crossing strokes by ballpoint pens [2]. Also, M. Mann *et al.* discussed about the application of confocal microscope [3] and Docubox Dragon [4] to find order of sequence in crossing lines. G. S. Spagnolo described about potentiality of 3D laser profilometry for determining sequence of homogeneous crossing lines [5]. Also, R. Kaur et al. [6] used absorption spectra generated by Video Spectral Comparator (VSC)-2000 HR for establishing chronological order in crossing strokes between intersecting printed strokes and writing pens and obtained inconclusive and negative results. A. K. Gupta *et al.* [7] described about use of photography with glossy paper treated with Pyridine. Concept of chromaticity diagram is also used to determine chronological order in writing crossing strokes [8]. R. Giri et *al.* applied basic concept of chromaticity diagram to find chronological order between crossing printed and pen strokes. As a conclusion of this work, they reported that chromaticity diagram generated by VSC-6000 is very effective tool to find order of sequence in heterogeneous crossing lines only if printed stroke is over pen strokes otherwise negative and inconclusive results were obtained.

Our work is similar to the work of R. kaur et al. [6]. They performed the experiment taking laser printed strokes (black, blue, red and green) and writing strokes from ballpoint pen, gel pen, and fountain pen (black, blue, red and green). We carry out this experiment taking different printed and writing strokes with new version of VSC-6000 to establish more valid and convincing conclusion. We have compared our final results with the results of different previous works and also possible future work is explained in conclusion section.

2. THEORY

Light interacts with matter through many phenomena like reflection, refraction, diffraction, absorption, emission, scattering, fluorescence, phosphorescence etc [9]. Such interaction of light is applied in different fields of science and technology. The interaction of UV light having proper irradiance, wavelength and exposure time with microbes DNA/RNA could effectively destroy the structure of the nucleic acids and can deactivate the pathogens [10]. In this work, phenomenon of absorption of light of wavelength ranging from 400 nm to 1000 nm is studied. Visible light covers small part of the full electromagnetic spectrum.

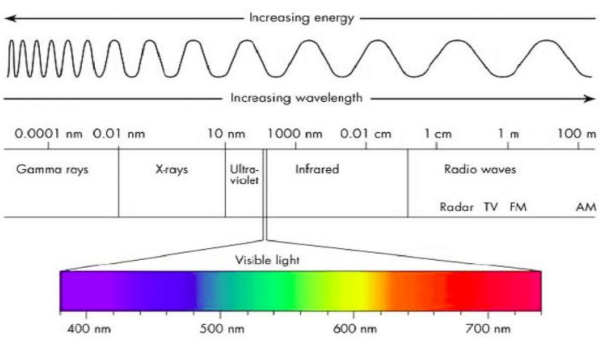

Fig. 1: Diagram of electromagnetic spectrum showing different wavelength.

When beam of light falls on any surface, there occurs reflection, absorption and transmission of light. It means, a part of it is reflected, a part of it is transmitted and rest of it is absorbed. Every surface has different tendency of absorption. Hence, absorption can be regarded as surface phenomenon i.e. absorbed ray essentially characterize the surface from which light is absorbed. In absorption, absorbed light is converted into energy. The process of absorption of light depends upon the state of material's atoms. All atoms of materials are vibrating at a specific frequency which is known as natural frequency [8]. If frequency of light is matched with this natural frequency of atoms, light is absorbed.

According to Hook's law, frequency of vibration of two atoms or masses connected through spring (bond) is given as

$$\nu = \frac{1}{2\pi}\sqrt{\frac{k}{\mu}} \quad \text{..........} (1)$$

'k' is force constant of the bond 'μ' is reduced mass. If m_1 and m_2 are masses of two atoms, then reduced mass is given as

$$\mu = m_1.m_2/(m_1+m_2) \quad \text{..........} (2)$$

Absorption of light by molecules results in vibration of an atom and atom interacts with neighboring atoms which results vibrational energy to be converted into thermal energy. Absorbance or coefficient of absorption (A) is the logarithm to the base 10 of reciprocal of transmittance (T) i.e.

$$A = \log_{10}^{(1/T)} = -\log_{10}^{T} \quad \text{..........} (3)$$

Here, transmittance (T) is the ratio of radiant power transmitted by the sample (I) to the radiant power incident on the sample (I_0).

Relation between absorption of light and frequency or wavelength of light is obtained from absorption spectra which may be a continuous spectrum, a line spectrum or a band spectrum [11]. Peak character of spectrum refers to the maximum or the highest spectral value of absorption to a particular frequency or wavelength for a given sample. In writing process, there is a deposition of thin layer of ink on paper and when two strokes cross each other, then surface on point of intersection corresponds to second stroke which is above first stroke. So, nature and peak characteristics of absorption spectra from the ink layer of crossing stroke should be similar to that of second stroke rather than first stroke.

3. MATERIALS AND METHOD

As study material, Canon LBP 3300 printer is used to produce black printed strokes and nine different types of pens found in local market of Nepal including cello maxriter pen (black and blue), pilot pen (red and black), cello pointec pen (black and blue) and cello techno tip pen (red, black and blue) are used for writing pen strokes. We make samples of crossing strokes on white photocopy paper.

Video Spectral Comparator (VSC)-6000 is used to produce absorption spectra for studying chronological order of our samples of crossing lines.

2.1 Video Spectral Comparator (VSC)-6000

VSC is very useful tool in document examination to analyze ink [12], reveal alteration in document [13-15], visualize hidden security features in currency [16-23], passport [24, 25] etc., determine chronological of crossing strokes [2, 6, 8], enhance handwriting on charred documents [26] etc.

At first power of VSC is switch on and appropriate setting is done. Image is zoomed to maximum for large image size and in spectrum command 'absorption' option is selected from main window menu. Then, absorption spectra is generated from three different points of first stroke; second stroke and crossing stroke taking reference of white background of photocopy paper. Then, average of thus obtained absorption spectra is taken with the help of software available in equipment. Once the required result is obtained, the image is saved.

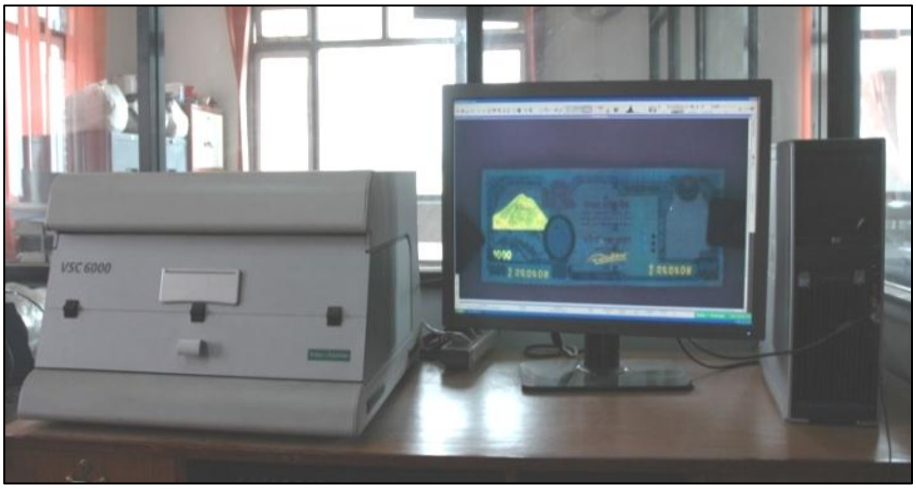

Fig. 2: Video Spectral Comparator (VSC)-6000 available in National Forensic Science Laboratory, Lalitpur, Nepal

4. RESULTS AND DISCUSSION

In this section, result obtained from our prepared samples is explained in detail. To make results more clear, this section is further divided into two subsections: printed stroke over pen stroke and pen stroke over printed stroke.

4.1 Pen Stroke over Printed Stroke

In this type of samples, we write above the printed lines. At first we print something on white photocopy paper by using Canon LBP 3300 printer and then above this print, straight lines are drawn crossing the printed stroke by different pens of different colors. While writing by black color pens, we get sample of homogeneous crossing strokes otherwise we get heterogeneous.

On the both homogeneous and heterogeneous crossing strokes, experiment is done to find chronological order of writing but in all samples, we get negative and inconclusive results indicating that experiment is failed to find sequence of order if writing stroke is over the printed stroke. According to our assumption, nature and peak character of crossing stroke should be similar to that of second stroke but in all such type of samples, we get result against the assumption as shown in Fig 3 and fig 4.

Figure 3 represents average of absorption spectra of crossing lines between black printed stroke as first stroke and second stroke by black cello pointec pen. From graph, it is found that nature of all lines is similar. We have expected to get absorption spectra from cross and second strokes similar in nature and peck character. But spectra from first, second and cross strokes are showing similar nature. So, it can be said that result is negative.

Similarly, Figure 4 represents average of absorption spectra of crossing lines between black printed stroke as first stroke and second stroke by blue cello techno tip pen. Second stroke shows peak absorption value nearly at 530 nm whereas cross stroke shows nearly at from 510 nm to 530 nm. Although, their peak character of absorption spectra indicate somehow similarity but nature of absorption spectra of cross stroke is totally different from second stroke. So, in this case also, inconclusive result is obtained.

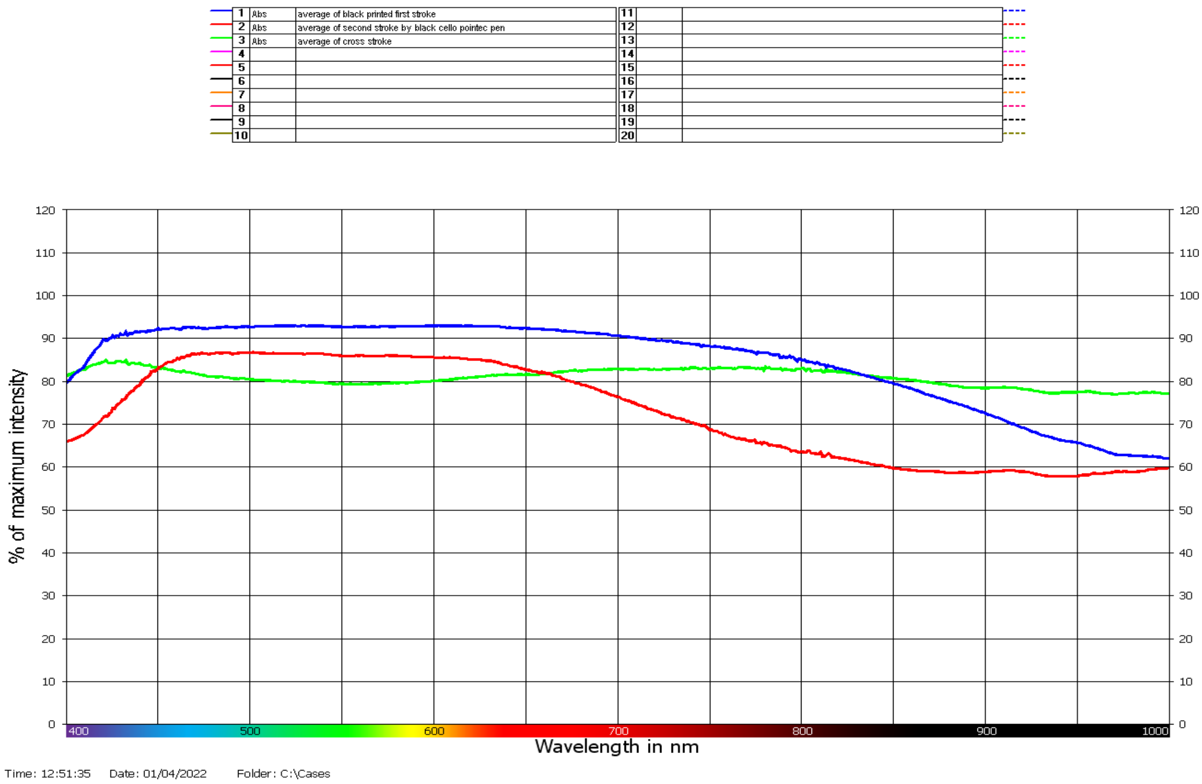

Fig. 3: Average of absorption spectra generated by VSC-6000 where line-1 (green line) represents for first black printed stroke, line-2 (red color) represents for second stroke from black cello pointec pen and line-3 (blue line) represents for crossing stroke.

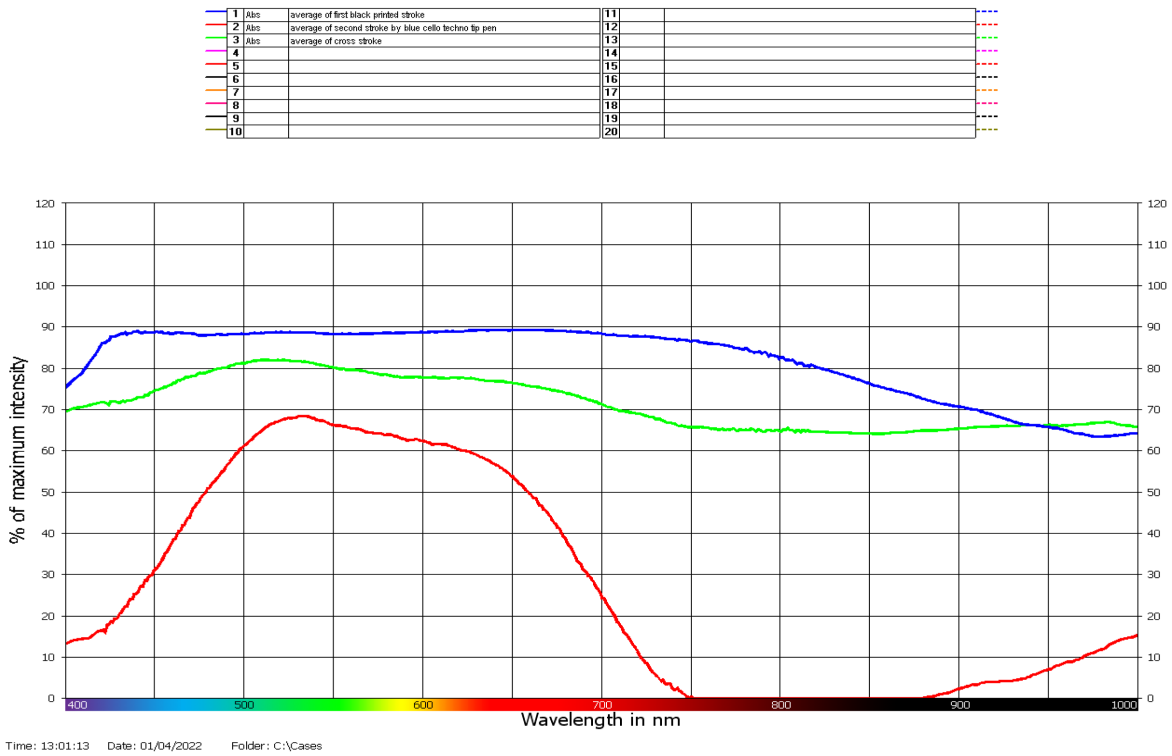

Fig. 4: Average of absorption spectra generated by VSC-6000 where line-1 (green line) represents for first black printed stroke, line-2 (red color) represents for second stroke from blue cello techno tip pen and line-3 (blue line) represents for crossing stroke.

4.2 Printed Stroke over Pen Stroke

Similarly, for the preparation of crossing strokes with printed stroke over pen stroke, we write straight line from our different pens of different colors on white photocopy paper then we get print on that same paper. Hence, we obtain both homogeneous and heterogeneous crossing strokes in this case also and experiment is done on all these samples.

For homogeneous samples, negative result is obtained indicating that experiment is failed to find order of sequence if we write by our black color pens and over them black printed stroke is crossed as shown in Fig 5. In this sample, print is taken over black cello pointec pen. From Fig 5, we find nature of all lines in graph is similar. Hence, again negative result is obtained. It indicates that it is not possible to find exact chronological order of two crossing lines if black printed stroke is executed over black pen strokes.

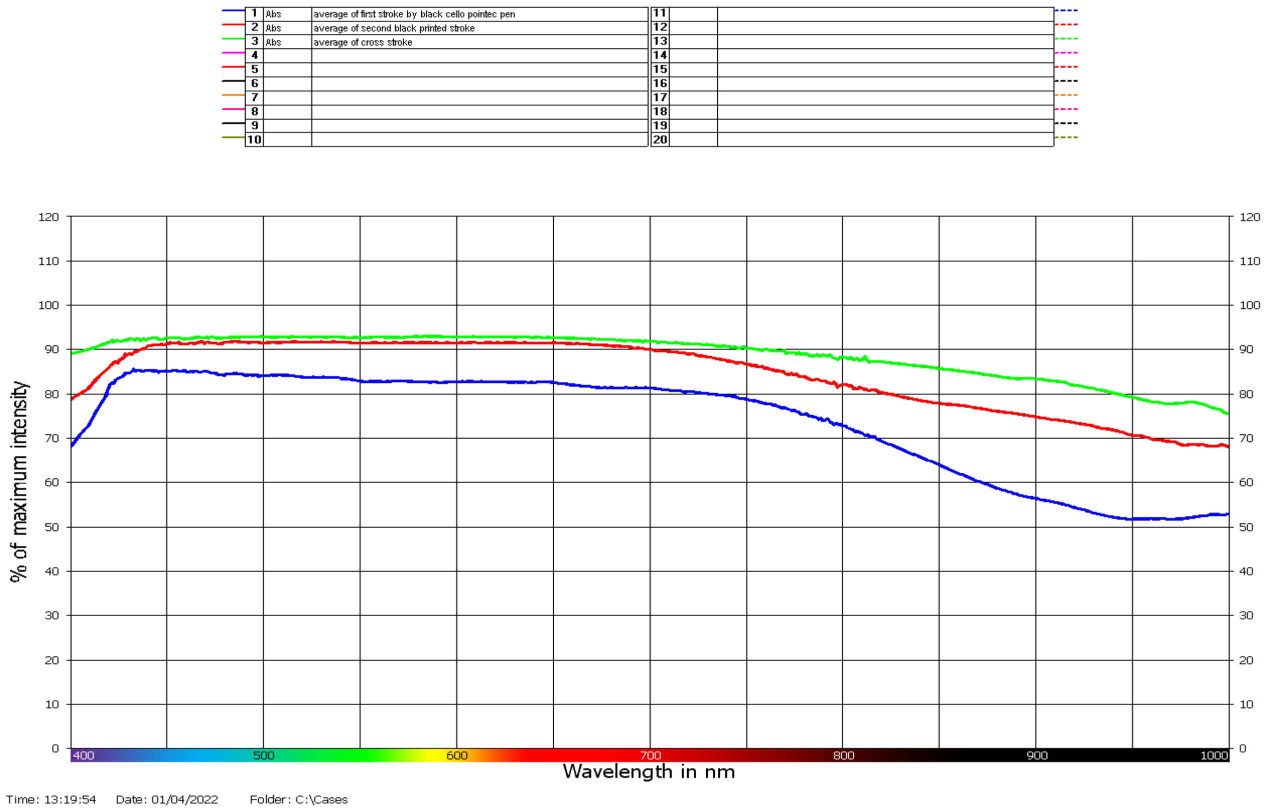

Fig. 5: Average of absorption spectra generated by VSC-6000 where line-1 (green line) represents first stroke from black cello pointec pen pen, line-2 (red color) represents second black printed stroke and line-3 (blue line) represents for crossing stroke.

But in case of heterogeneous crossing stroke, we get positive and conclusive results. When we write by our red and blue color pens and over them black printed stroke is crossed, then it is possible to find chronological order of strokes. In all such samples of heterogeneous cross stroke, nature of absorption spectra of crossing stroke is found to be similar with that of second black printed stroke according to our basic assumption as shown in Fig 6, Fig 7 and Fig 8.

In Fig 6, Fig 7 and Fig 8 first stroke is from blue cello maxriter pen, red pilot pen and red cello techno tip pen respectively whose corresponding absorption peak values are found nearly at from 530 nm to 580 nm, 520 nm and 535 nm. In these samples, second black printed stroke is executed over them. From these graph of absorption spectra, it is clearly seen that nature of second black printed stroke and crossing stroke is similar. It means, we can claim that print is done over pen strokes. So, for such heterogeneous samples of cross stroke where printed stroke is over pen stroke, it is possible to find order of sequence in crossing strokes.

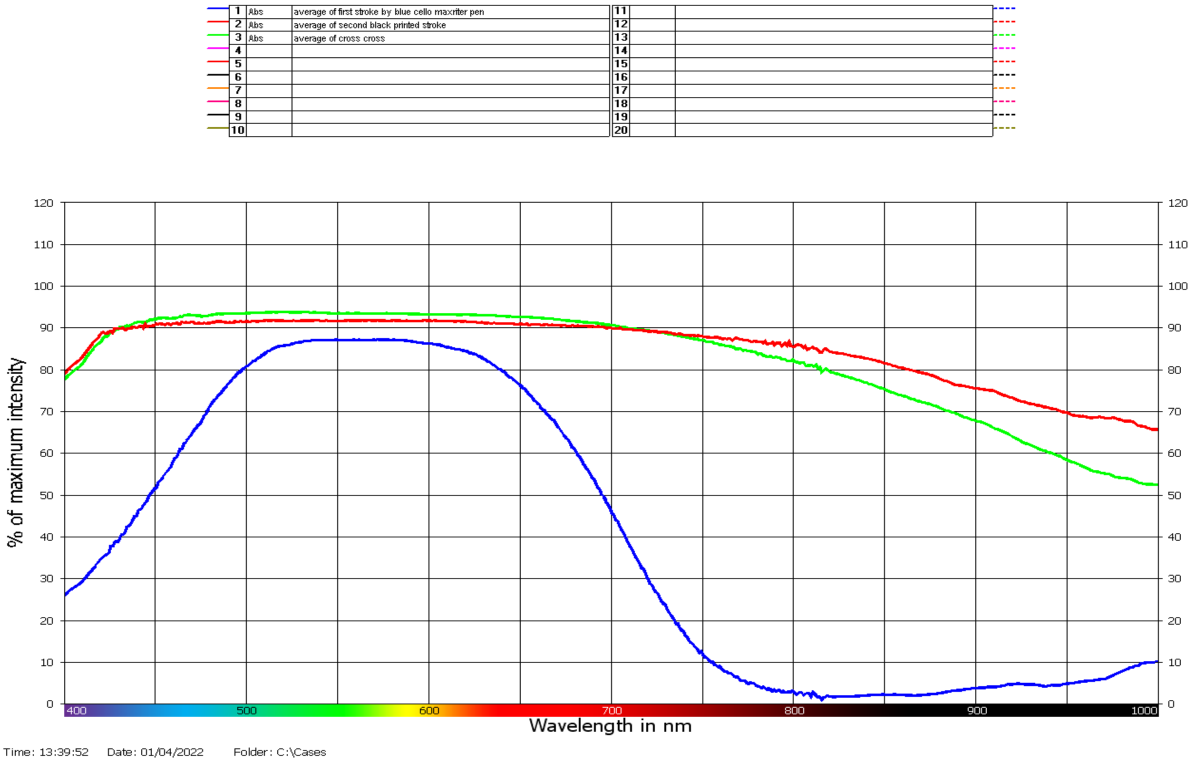

Fig. 6: Average of absorption spectra generated by VSC-6000 where line-1 (green line) represents for first stroke from blue cello maxriter pen, line-2 (red color) represents for second black printed stroke and line-3 (blue line) represents for crossing stroke.

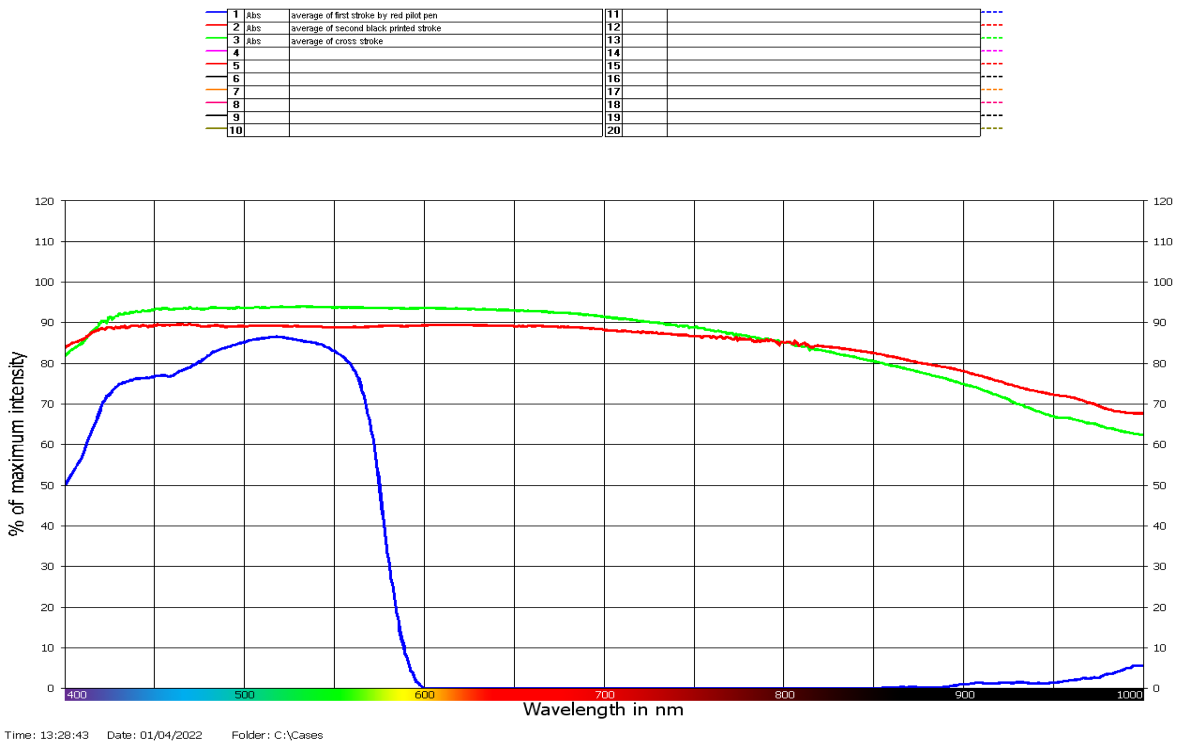

Fig. 7: Average of absorption spectra generated by VSC-6000 where line-1 (green line) represents for first stroke from red pilot pen, line-2 (red color) represents for second black printed stroke and line-3 (blue line) represents for crossing stroke.

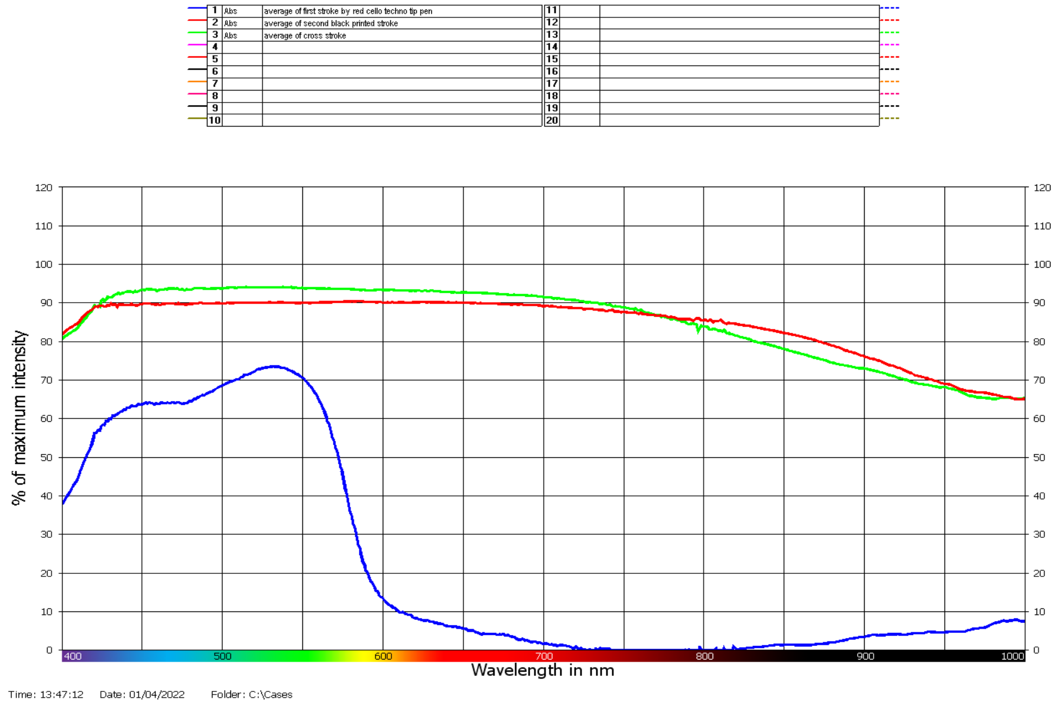

Fig. 8: Average of absorption spectra generated by VSC-6000 where line-1 (green line) represents for first stroke from red cello techno tip pen, line-2 (red color) represents for second black printed stroke and line-3 (blue line) represents for crossing stroke.

5. CONCLUSION

This experiment is done on nine different types of pens including cello maxriter pen (black and blue), pilot pen (red and black), cello pointec pen (black and blue) and cello techno tip pen (red, black and blue) for pen strokes and on Canon LBP 3300 for printed stroke to find chronological order in crossing strokes by analyzing absorption spetra generated by VSC-6000. Main working assumption is nature and peak characteristics of the crossing stroke should be similar to that of second stroke. We have concluded our results obtained from our chosen samples as follows:

- Completely negative and inconclusive results are obtained in all homogeneous and heterogeneous crossing strokes if pen stroke is written over printed stroke.
- Also in case of homogeneous crossing strokes where printed stroke is over pen stroke, negative and inconclusive results are observed.
- But we obtain positive and convincing results according to assumption in heterogeneous crossing strokes where printed stroke is over pen stroke.

In this experiment, we successfully find order of writing only if we print over red and blue pen strokes. As a conclusion, R. Kaur et al. [6] suggested not to use absorption spectra generated by VSC-2000-HR for determining order of sequence in printed and pen crossing strokes. Our result is highly similar to their result but we get positive result for heterogeneous crossing strokes where printed stroke is above pen stroke for our specified writing instruments. Our final results of this experiment is found very consistent with results of R. Giri et *al.* [8] obtained by applying concept of chromaticity diagram. We suggest other document examiners and researchers to repeat this experiment with other writing instruments to establish more valid conclusions.

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