

Non-Destructive Chemical Method and Simple Methods for Determining the Sequence of Intersecting Color Ballpoint Pen Stroke and Color Laser Printed Marking

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Abstract

Non-destructive chemical method and simple methods for determining the sequence of intersecting color ballpoint pen stroke and color laser printed marking has been done. Different chemicals compounds such as pyridine, ethyl acetate, 2-phenoxyethanol, methanol, and ethyl alcohol are used to treatment glossy paper for lifting technique. These chemicals enhance the lifting technique in comparison with using glossy paper only especially with ethyl alcohol. Simple techniques such as side lighting technique depending on embossing phenomena, microscopically with both transmitted and external 45° light and absorbance/reflectance techniques are used. According to the results of the study and blind test, it is recommended that using the previous techniques should be done in the following order: lifting technique using ethyl alcohol treatment, lifting technique without treatment, side lighting (in case of presence embossing), and microscopically. Absorbance/reflectance techniques were excluded because the results obtained are misleading. All used techniques are simple, non-destructive and can be photographically demonstrated.

Keywords: Forensic science; Questioned document; Non-destructive technique; Paper; Ink; Line crossing; Intersection; Lifting; Laser printer; Sequence; Document examination; Pyridine; Chemical method

Introduction

Document examiners are often asked to determine a difficult problem in questioned document examination; which is the determination of the order of intersected lines. The determination of the order of intersected lines is appropriate in cases of smelling a rat that the content of a document has been altered at a later date by adding a part to it, for example in a will or signed legal agreement (blank signature). Therefore, the sequence determination of the crossing strokes [1,2] can offer important information when investigating fraud.

Currently, we live in a new era of computer and digital technology. Modern and printing gadgets are used commonly with the other writing instruments in daily routine, personal, business and official work. These days; the forensic document examiners are encountering the problem of finding the sequence of handwriting strokes crossed with printed markings.

A number of approaches have been utilized by different examiners for the inspection the order of the intersection. Optical examination remains the most favored method because of its non-destructive, inexpensive and simple nature. The basis of this technique is to detect the modification of the intersecting lines as suggested by Villanova [3], Go down [4] and Hilton [5].

Forensic document examiners agree that results of some methods are better than others and this subject should be approached with caution. The combination of microscopic and optical methods which used in establishing some ink's properties such as color, absorption, luminescence and the gloss of the ink lines, gives a successful result in certain cases, and also advantageous, as they are simple, fast and non-destructive [6].

The intersection of ink lines is a dynamic process that is affected by many chemical and physical variables which establish how the two inks

will distribute and interact with each other and with the paper. In the case of ballpoint pens; the type of ballpoint pen, the writing pressure and ink used, as well as the ink's chemical composition greatly affect this interaction, the time between application of the ink lines, which is directly correlated to the drying process of inks, is also an important factor, the paper's properties (surface and structure) will clearly affect how the two inks will distribute across the paper [7]; Finally, external factors such as heat, humidity, and light can also be accountable. In the case of printers, the printing process plays an important role in the interaction of intersecting lines and so, the ink's properties such as drying efficiency and viscosity will be determinant factors.

Writers

Every person has her or his own writing habit that originates from two aspects. First, there is a massive diversity of writing organs, nervous systems and sense abilities among individuals, because of both congenital inheritance and acquired development. Secondly, each person has had their own personal time, quality and content in their handwriting training. These elements are limited by the individual's family conditions and education and will create both dissimilarities in writing handwriting's macro characteristics, and the ink lines' microscopic characteristics. The direction and position of the ballpoint pen, the speed, and pressure of the writing vary among writers even if

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they are using the same ballpoint pen. These factors make the line width; Groove depth and density of the ink distribution vary considerably.

Laser printing

Laser printers fundamentally use the attraction of opposite electrical charges in the printing process. The primary component of the laser printing system is a revolving cylinder or drum. This assembly is made of a photoconductive material, which is discharged by light photons of a laser beam. As described by Chiang et al. [8] laser printers work in six steps:

Charging: the revolving cylinder or drum that rotates at a constant angular velocity is charged by a positive charge with a roller or wire having an electrical current moving through it.

Exposition: as the drum revolves, a laser beam reflected by a mirror discharges certain points on the cylinder or drum, which will be the images and letters to be printed.

Development: after the image, letters or both have been created on the drum, these areas coated with positively charged ink (or toner) particles by the printer.

Transferring: Printing is finished by transferring the positive toner particles on the cylinder or drum to a sheet of paper negatively charged, which moves on a belt below it. We should note that, the toner is held on the paper only by gravity and a weak electrostatic force until the paper reaches the fusing phase.

Fusion: A fuser uses both heat and pressure to fuse the toner on the paper. The temperature can be up to 200°C (392°F), and the pressure is approximately 140 psi in the fuser assembly, so the toner is melted and forced into the paper by the heat and pressure of the fusing roller to produce a lasting image [9].

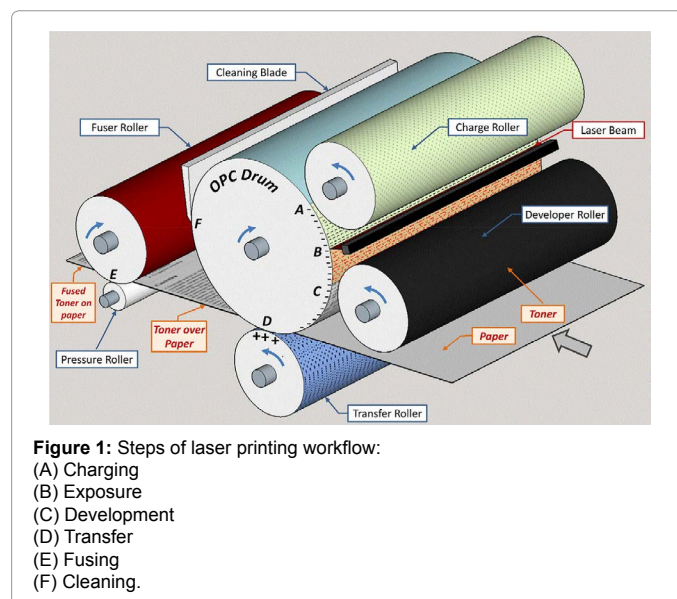
Cleaning: To print the next page, the drum is cleaned with a blade to remove any residual toner as shown in Figure 1.

In the working process of a laser printer, passing the paper through the fuser roll will make a noticeable change to the strokes, because the ink is heated and squeezed by the high temperature and pressure. Therefore, whether the lines were heated and squeezed can be determined by observing the microscopic shape of the ink distribution and, in consequence, the examiner can determine that paper with handwriting strokes was printed by a laser printer [10]. The speed of laser printers depends on many factors, including the graphic intensity of the job being processed, so it widely varies. The printing speed determines the fusing time of the toner. If the moving of paper through the fuser slowly, there is more roller contact time for the toner to melt, by the way, the fuser can work at a lower temperature.

Paper and ink

Paper is composed of interwoven fibers typically in sheet form. There are three ways paper can be made: Hand-made, mold-made and machine-made. The most machine-made paper is created from a mixture of fibers of softwood and hardwood [11].

The interaction between an ink and a paper substrate, especially printing inks, has been covered in the literature from different standpoints and applications [12-15]. It is a complex process, where physical and chemical reactions take places, such as evaporation of volatiles, polymerization, oxidation, cross-linking and even paper erosion [6]. Concerning writing pens, when an ink stroke is applied, it disperses throughout the paper surface and is absorbed into it. Oil-



based inks have the affinity for being absorbed partially only and most of the ink stay adherent to the paper surface, due to its high viscosity. Water-based inks, on the other hand, have the tendency for soaking into the paper fibers, like water into a sponge [16].

Handwriting on a paper sheet allows noticing how the ballpoint pen-tip, besides releasing the ink, deforms the paper. In other words, the writing pressure leads to leaving some impressions; several or less deep according to:

- Writing pressure (amount of pressure applied on the tip of a ballpoint pen during the act of writing)
- Underlying material (sheet of paper lying on a hard surface or on a paper block)
- Writing material (ballpoint pen, fountain or pencil, interact in a different way with the paper)
- Type of paper used (the production process controls the morphology and the size of the layers of paper fibers) [17].

So, the distribution of some fibers on the paper's surface may be changed because of writing material. These fibers will likely be crooked and protuberant. However, if the laser printing is done after the ballpoint pen has left its ink; it will be more difficult to find these altered fibers because of the heat and pressure of the fusing roller. If some fibers with protuberances and curvatures are seen, then the ballpoint pen ink must have been affixed after the toner. Therefore, this characteristic can be used to determine the sequence of printed marking and writing stroke as an additional and second method.

Lifting process

The procedure of transferring and examination of glossy paper lifts is basically the same as described by Igoe and Reynolds [18]. The Igoe and Reynolds technique firstly described at the 1979 meeting of the American society of questioned document examiners provided a genuine step forward in the determination of the order of some classes of writings. Godown, Linton [19] modified Igoe's technique by applying thymol solution coating on Kromekote paper with inadequate advantage. Scleung and Ymleung prepared a systematic study of the

lifting technique of intersecting ball pen ink strokes [20]. Gupta, et al. used strips of photographic glossy paper with white background. The glossy surface of the photographic papers was then treated with different solvents separately before being used for the transferring process “lift”. When pyridine was applied on the lifting photographic paper, the transfer of the part of the intersection was found to be best [21].

Examination of the document from the back

The previous method refers to the examination of the document from the front. But there is an attempt has been completed to determine the order of intersecting strokes from the back of the examined document depending on the embossing phenomenon. Differences in the shade of ink usually lead to serious problems in the determination of line order, as the darker stroke always appears to be on top of the lighter stroke. Hilton [5] stated that “What appears to be the obvious solution may not always be the correct answer; the line of deepest color usually appears on the top even if it was written first”. Examination of a document from the back however, is not affected by unconscious bias or optical illusions due to different shades of color of ink rather it depends upon only one factor, which is the ballpoint pen ink strokes should have been written with pressure sufficient to cause embossing on the bottom side of the paper. This depends on the amount of pressure applied to the ballpoint pen ink stroke, the thickness of the paper itself or the hardness or softness of the support underneath the paper.

The basis of the method is laser printer does not cause any embossing on the underside of a sheet of paper while, the pressure applied on ballpoint pen ink strokes is sufficient to cause embossing on the underside of paper sheet, so side lighting can be used to reveal raised or indented features within the surface of the document at the point of intersection, and it will be easy to recognize which of them is

the first. This phenomenon is not affected by factors such as the width of the stroke, the color of ink, type of paper.

Absorbance and reflectance techniques

The video spectral comparator is one such versatile instrument that assists in analyzing the inks by using reflectance/absorption spectra and IR luminescence techniques, etc. [22]. So part of the study has been done to see whether the sequence of intersecting laser printer marking and ballpoint pen ink strokes can be established by studying their reflectance/absorption spectra generated by using video spectral comparator (VSC6000/HS). It is presumed that; characteristics peak of the spectrum at the point of intersection would correspond to the pure ink spectrum which is produced above.

In the present study, an attempt has been done to determine the sequence of intersecting colored ballpoint pen inks strokes and colored laser printed markings, based on the difference in the composition of two writing media, using different non-destructive technique, ordinary glossy paper, chemically developed glossy paper by (pyridine, ethyl acetate, 2-phenoxyethanol, methanol, and ethyl alcohol), side lighting from DocuCentre 3000), microscopically with both transmitted and 45° light and using digital techniques (absorbance and reflectance) from video spectral comparator: VSC6000/HS.

Materials and Methods

Instrumentation and chemicals

Instruments and chemicals used are described in Tables 1-4.

Samples preparation

The samples were prepared in the following manner to study the

No.	Printers	Model	Serial no.	Producer	Colors of text from printers
1	Xerox Color Laser Printer	Phaser®6700DN	3170172948	China	Black, red, blue, green
2	HP Color Laser Printer	Laser Jet 4700	JP5NC19624	China	Black, red, blue, green
3	HP Color Laser Jet Enterprise	M553	JPBVK35168	Japan	Black, red, blue, green
4	RICOH Aficio	MP C6501 PCL6	192.168.1.51	Japan	Black, red, blue, green

Table 1: Showing description of different laser printers used.

No.	Brand of ballpoint pens	Producer	Colors of ballpoint pens ink
1	Bic® Cristal® Original 1.0 mm Ballpoint pen	France	Black, red, blue, green
2	Reynolds® (045, fine carbure, medium)	France	Black, red, blue, green

Table 2: Showing description of different ballpoint pens ink used

No.	Chemicals	Batch No.	Producer
1	2-phenoxyethanol>99%	101272636	Fluka (Sigma-Aldrich), Steinheim, Germany
2	Pyridine LR C ₅ H ₅ N, GC 99%	L03A/2045/1103/13	S.d fine-chem limited, Mumbai, India
3	Ethyl acetate	Jan-15	El Nasr Pharmaceutical Chemicals Co., Egypt
4	Methyl alcohol	Jul-14	El Nasr Pharmaceutical Chemicals Co., Egypt
5	Ethyl alcohol C ₂ H ₅ OH GPR 96%	3019	Chemajet, Alex., Egypt

Table 3: Showing description of different chemical used.

No.	Instruments	Producers
1	VSC6000/HS (Foster and Freeman)	The United Kingdom
2	Docucenter 3000 and an inbuilt PIA-6000 software	Switzerland
3	Nikon SMZ 1000 Stereomicroscope	Japan
4	Nikon digital sight DS-Fi1 (2/3-inch, color, 5,24 megapixel) color	Japan
5	The external light source adjusted at 45°	Japan

Table 4: Showing description of instruments used.

sequence of the strokes. Four colored laser printers and two brands of colored ballpoint pens ink were taken to make the intersections (Tables 1, 2). The exemplars (intersections) were prepared on a white paper, i.e. office paper, A4 (210 × 297 mm) Double-A 80 GSM, multipurpose printing paper (Photocopier, Laser Printers, Fax Machine, and Ink Jet). In the first; markings of laser printers consisting of each color (black, red, blue and green) were printed with different sizes (0.25, 0.50, 0.75, 1.0, 1.25, 1.50, 1.75 and 2.00 point), to simulate different format and frames which may intersect with handwriting in questioned documents as an actual case which has been examined, on the mentioned paper. Then strokes as circles of each color of ballpoint pens ink were made to intersect each color of each size of laser printed markings. This process was repeated to make exemplars in reverse order from that stated; where the intersections were produced by printing the laser marking (circles) with different sizes (0.25, 0.50, 0.75, 1.0, 1.25, 1.50, 1.75 and 2.00 point) over the ballpoint pen ink strokes (lines) of each colors, where; ballpoint pen ink lines (all colors) were placed first on another paper of the same type. Thus large samples of intersections were produced for the study.

Lifting technique

The procedure of transferring and examination of glossy paper lifts is basically the same as described by Igoe and Reynolds [18]. Because of the non-availability of Kromekote paper in Egypt, an ordinary glossy paper was used as the same way described above with Igoe and Reynolds and was modified chemically with: Pyridine, ethyl acetate, 2-phenoxyethanol, methanol, and ethyl alcohol separately.

The glossy paper (80 GMS) is securely put, where glossy side down, directly on each of the examined intersections. When securely fastened; A moderate and an even pressure is applied to the back of the glossy paper by rubbing it with a blunt instrument (for instance the cap of a pen) until all examined areas have been covered. The glossy paper is then lifted off the transfer area, and the obtained image (reverse of the original intersection) is examined with a simple lens of magnification (5X-10X) and captured with the digital camera of 5 megapixels and an inbuilt PIA-6000 software in Docucenter 3000.

Depending on the chemical difference in the composition of both color laser printer toners and ballpoint pen inks, and their reaction towards some chemical solvents; modification of glossy paper with pyridine, ethyl acetate, 2-phenoxyethanol, methanol, and ethyl alcohol separately has done in the following way: The glossy surface of the paper was treated by putting two drops of each solvent (Tables 3 and 4) separately, and spread with the help of spatula or painting brush to form a thin film of solvent over the glossy side of the paper strip. This paper strip was then immediately placed firmly (glossy side down) on the examined intersection. The back of the lifting paper was rubbed uniformly with a blunt instrument -weight applying moderate pressure. The paper is then lifted off and the reverse image of the stroke is inspected with the naked eye and also in low magnification (5X-10X) and captured with the digital camera of 5 megapixels and an inbuilt PIA-6000 software in Docucenter 3000.

Side lighting technique

The side lighting option in the Docucenter 3000 with its digital camera of 5 megapixels and an inbuilt PIA-6000 software is used. The sample was placed in the chamber, the light shield was opened and the side-light mirror was moved until the desired light angles are achieved. The image was displayed on the monitor and was zoomed to maximum (77X) to get the suitable sample size for an easier selection of samples to capture with the inbuilt PIA-6000 software for analyzing.

Microscopic technique

The physical characteristics at the point of intersections were observed under Nikon SMZ 1000 Stereomicroscope which has a transmitted light and supplied with image picks up device; Nikon digital sight DS-Fi1 (2/3-inch, color, 5.24 megapixels) color/non-cooled, made in Japan. The external light source adjusted at 45° to the plane of paper was used. The images were captured and were transferred to the computer with NIS-Elements microscope imaging software.

Absorbance and reflectance techniques

Using the spectrometer option in the VSC6000/HS (Foster and Freeman, UK) which displays a graphical plot of light intensity against wavelength (400-1000 nm) and Floodlight-measuring reflection or absorption spectra-was selected. Absorption and reflection spectra were plotted from different points of intersection (three points) viz. one spectrum each from the intersections was made for the study. The sample was put in the chamber and image was displayed on the monitor in VSC6000/HS software. The image was zoomed to maximum (162X) to get the largest sample size for an easier selection of samples to measure. Next, a white reference needs to be taken, and then position the sample so the area for examination is in the crosshairs.

The “absorption” spectrum option was selected. The absorption spectrum was created over the range of 400 to 1000 nm for first ink stroke or marking (A). The identical process was repeated from three different points of the same ink line (without intersection) and the generated spectra will be the averaged spectrum as calculated by using software tool in the equipment, as a result more accurate absorption measurements are obtained. In the same way, absorption curves were plotted for second ink stroke or marking (B) and for points of their intersections (i.e. A over B and B over A). All steps were repeated using the “Reflection” spectra [23,24] in the same way.

Blind test

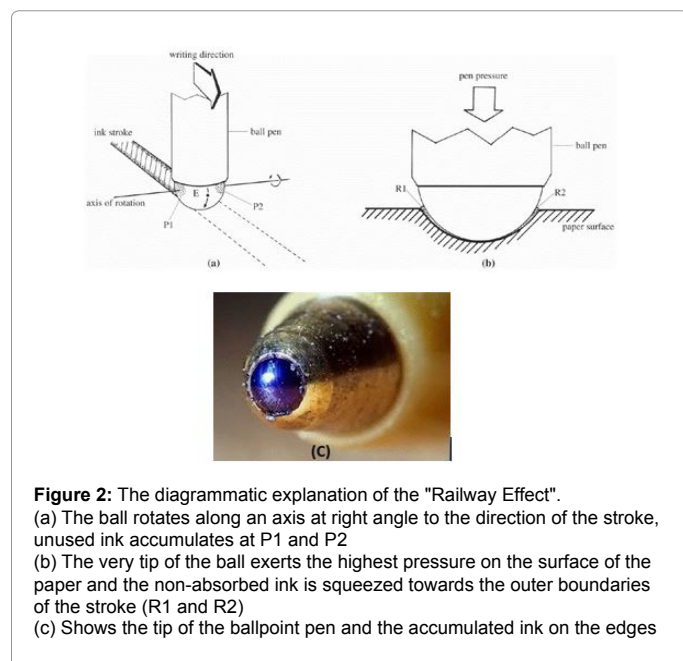
Blind-testing is an important tool that should be used by most forensic fields as an approach for validating method. The importance of such tests is hard to overstate, especially when the technique in question centers on questioned documents. A blind sample was prepared with the same ballpoint pens ink and the same laser printers. Blind tests were performed, in which the order of strokes was unknown prior to examining. Twenty questioned document experts, ten of them are a fresh expert, were asked to examine these unknown samples using previous techniques and come to one of the following findings-ink over toner, ink under toner, or inconclusive.

Results and Discussions

Lifting technique

The lifting technique and theory of the railway effect: A ballpoint pen consists of a small sphere of hard metal rotating freely in a closely fitted cage located at one end of a cartridge of ink. This design enables the rotating ball to draw out a continuous supply of ink onto a paper surface [20]. Because of the slow drying and the relatively high viscosity of ballpoint pen ink, it does not normally exude out of the pen by gravitational force or by capillary action.

When a stroke is being written, the ball of the pen rotates along an axis that is perpendicular to the general direction of the stroke (Figure 2). Since the ‘equator’ of the rotating ball has the largest circumference, it follows that any point at the equator (such



as 'E') rotates with the highest speed whereas those nearest the polar regions and away from the median (such as 'P1' and 'P2') rotate with the slowest speed.

As ink is continuously drawn by the rotating action of the ball, it accumulates in the Polar Regions that do not contact with the paper surface. However, as a result of the gliding movement of the ball along the paper surface, the ink place immediately next to the rim of the stroke will be drawn and incorporated into the stroke. In addition, during writing the very tip of the ball exerts the highest pressure on the surface. On a smoothed and coated paper, the slow-drying and viscous ink is not immediately absorbed into the paper and it is pressed towards the flanking edges (R1 and R2) of the stroke. Heavier deposits of ink will be present at both edges with less ink present at the center, hence creating the appearance of two parallel stripes of ink demarcating the outline of the stroke similar to the tracks of a railway [20].

In the lifting technique, the glossy side of a piece of glossy paper is positioned over the questioned intersection and then rubs with a moderate pressure with a blunt tool. Observation of the lifting image under low magnification shows a pattern of edge markings for both the new and old stroke at the intersection.

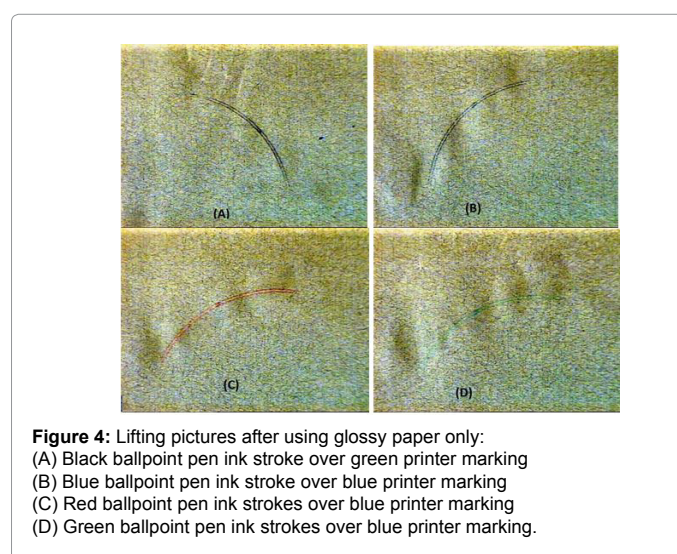
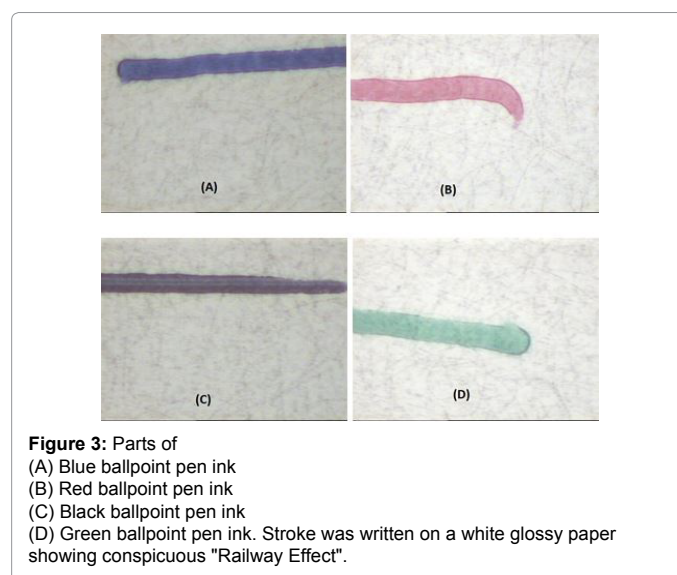
It is believed that transferring of ballpoint pen ink strokes to the glossy paper is precisely related to the railway effect. Figure 3 shows the effect of ballpoint pen ink stroke which was written on a glossy paper. When the stroke is cut through by a subsequent stroke or marking the original ink tracks of the first stroke are smudged or covered by the second stroke or marking and are replaced by the newly laid tracks of the second stroke of marking. As a result, the sequence order of the intersection is obviously visible.

Although the railway effect is generally not clearly visible on ordinary paper which has a greater affinity for ball pen ink, it is postulated that the tracks of ink are nonetheless present. For ordinary paper surfaces, the many tiny crevices and depressions that exist between the paper fibers can accommodate much of the ballpoint pen ink which under the writing force, is compressed and compacted into them, and so less ink is expected to be radiated to either side to form easily perceivable railway

tracks of the stroke. A ballpoint pen ink stroke is written on ordinary paper, therefore, consists of a central column of more tightly packed ink that is sandwiched at both sides by loosely laid streaks of ink.

As shown in (Figure 4), when rubbing the glossy paper with an appropriate force against the intersection, it becomes at the close contact with the ballpoint pen ink stroke tracks positioned at the top, but not with the laser marking at the bottom of the depression, more of which is melted with the constituents of the paper. Therefore, if the rubbing pressure is correct, the railway tracks of ballpoint pen ink stroke will be lifted only. At the intersection, where the toner of the first marking has been substituted by the newly laid rails of the second ballpoint pen ink stroke, a suitable rubbing pressure only transferred the ballpoint pen ink stroke tracks to the glossy paper.

Continuous edge marks (railway track) of the ballpoint pen ink establish that it was drawn over the printed marking. The determination of the sequence of intersections was depended on the difference in nature, the composition of the two writing media and the subsequent modification of one writing ink due to the presence of the other, so chemical solvent can be used to enhance the lifting technique.



Chemical treatment

Pyridine, ethyl acetate, 2-phenoxyethanol, methanol, and ethyl alcohol are good solvents for ballpoint pen inks facilitate the transfer of ink to the glossy paper. As pyridine a strong solvent, it can solve both printed marking and pen stroke, therefore both will be present in the glossy paper as a reversed pictures; Figures 5 and 6, in some cases especially when ballpoint pen ink stroke under the printed marking; presence both of them at the glossy paper as an inverted picture of the intersection, may lead to giving uncertain conclusion. Ethyl acetate solves both printed marking and pen stroke also, but its ability to solve the printed marking is higher, so the lifting picture will be mainly the printed marking and may lead to a doubtful conclusion. 2-phenoxyethanol is highly viscous compound (in comparisons with the solvents used) and its evaporation rate is slow, hence it leaves a smudge on the intersection point which may give undesirable effect on the questioned document. Both methanol and ethyl alcohol specifically solve the ballpoint pen ink stroke and don't affect the intersection point, and no telltale solvent marks were noticed with the naked eye, but methanol is more volatile than ethyl alcohol and once it is applied on the glossy paper as a film, it is evaporated before the lifting have done, which leads to repeat the trail many times, while ethyl alcohol gives sufficient time to complete the lifting process, in addition to its safe in concerning with health issues.

The clear edge prominence (railway track) of each ballpoint pen ink stroke is shown at the intersection. The prominence at the intersections established that ballpoint pen ink stroke is overprinted marking.

The continuity of the printed edge marks established that printed marking was drawn first (pen stroke under). But in some cases due to pyridine is able to solve both pen stroke and print marking it may lead to giving an uncertain conclusion as shown in (A) where the arrow is pointed. Figures 7 and 8 shows edge prominence in case of ballpoint pen ink over or edge breaks in case of it under with accuracy reached to the maximum.

The clear edge prominence (railway track) of ballpoint pen ink stroke is shown. The prominence at the intersections established that ballpoint pen ink stroke is overprinted marking.

The breaks in the edge marks of the horizontal line established that printed marking was drawn first (pen stroke under). Before applying the technique in an individual case the examiner should make

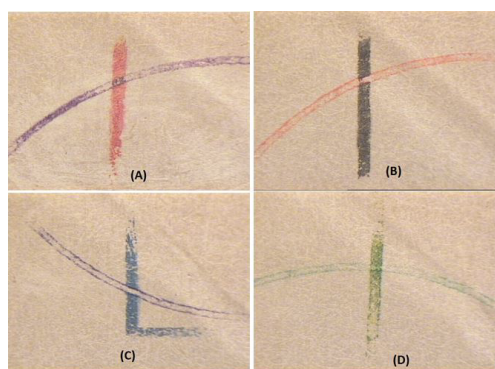


Figure 5: Lifting pictures after using pyridine:
(A) Blue ballpoint pen ink stroke and red printed marking
(B) Red ballpoint pen ink stroke and black printed marking
(C) Blue ballpoint pen ink stroke and printed marking
(D) Green ballpoint pen ink strokes and green printer marking.

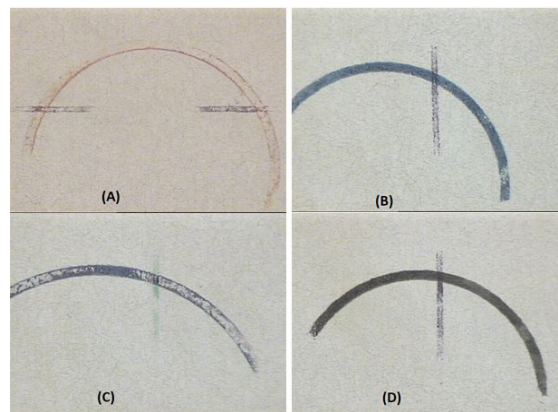


Figure 6: Lifting pictures after using pyridine:
(A) Black ballpoint pen ink stroke and red printed marking
(B) Blue ballpoint pen ink stroke and blueprinted marking
(C) Green ballpoint pen ink stroke and blueprinted marking
(D) Black ballpoint pen ink strokes and black printer marking.

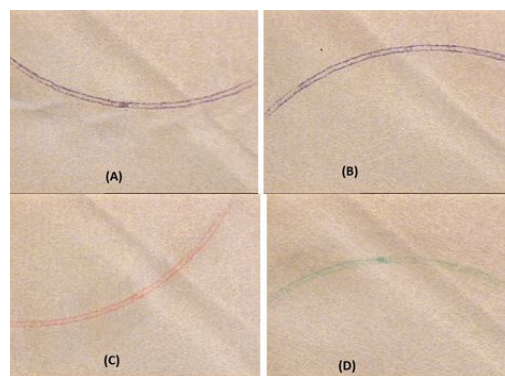


Figure 7: Lifting pictures after using ethyl alcohol:
(A) Black ballpoint pen ink and green printed marking
(B) Blue ballpoint pen ink pen and black printed marking
(C) Red ballpoint pen ink stroke and blueprinted marking
(D) Green ballpoint pen ink strokes and red printer marking.

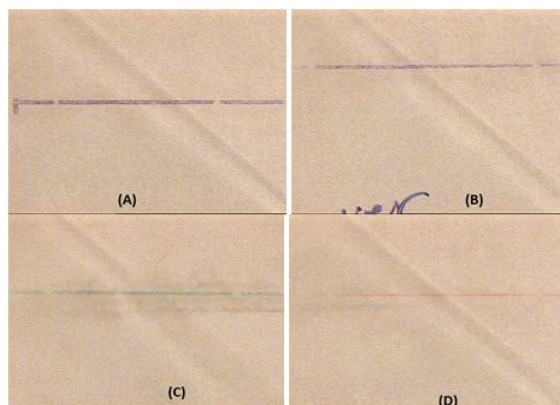


Figure 8: Lifting pictures after using ethyl alcohol:
(A) Black ballpoint pen ink stroke and printed marking
(B) Blue ballpoint pen ink stroke and black printed
(C) Green ballpoint pen ink stroke and blueprinted marking
(D) Red ballpoint pen ink stroke and blueprinted marking.

experimental trials under as the same conditions as possible to the questioned intersection. Similar quality paper and comparable writing instruments should be employed. Prior experiments should also be performed to standardize the lifting pressure. The authors suggested that making the known intersection at the examined document (in a place far away from the questioned intersection) as a reference for the lifting picture.

The age of the strokes did not seem to be a problem as successful lifts were obtained even from old documents. The quality of the paper was not standing as a barrier toward the study. Fruitful lifts could be done from the same intersection as the second time. The chemical composition of the ballpoint pen ink and the laser printer toner did not affect the transfer. The accuracy rate in sequence determination was excellent in some cases (ethyl acetate and methanol) and accepted with caution in other (pyridine and ethyl acetate) and undesirable in the rest (2-phenoxyethanol).

Side lighting technique

The embossing phenomena of ballpoint pen pressure are the guide for forensic document examiners (FDEs) to determine the sequence of intersecting using side lighting technique as in Figure 9, when it is clearly present. Figure 10 shows that side lighting technique is not affected by optical illusions or unconscious bias due to different shades of color of ink; rather it depends upon one factor only (embossing) which leads to the correct order of the intersecting.

Figures 11 and 12 shows that the laser printer does not cause any embossing on the underside of the paper while the applied pressure on ballpoint pen ink strokes is sufficient to cause embossing on the bottom of the paper surface. Although the laser printer doesn't cause any embossing on the paper but on the other hand it can reduce the

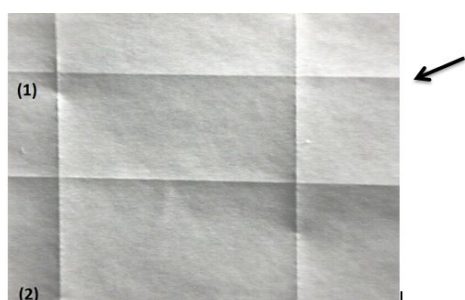


Figure 9: The embossing phenomenon on the underside sheet of paper. The lines were drawn in the order 1, 2 and the direction of the examining light is shown by the arrow.

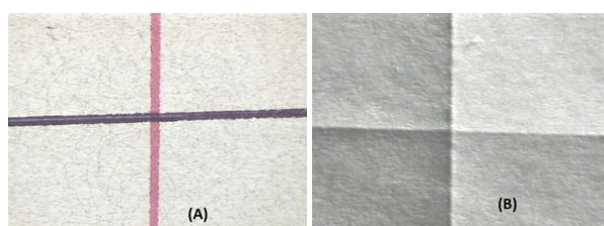


Figure 10: The back of intersection between red ballpoint pen ink and black ballpoint pen ink under
(A) Transmitted light
(B) Side lighting.

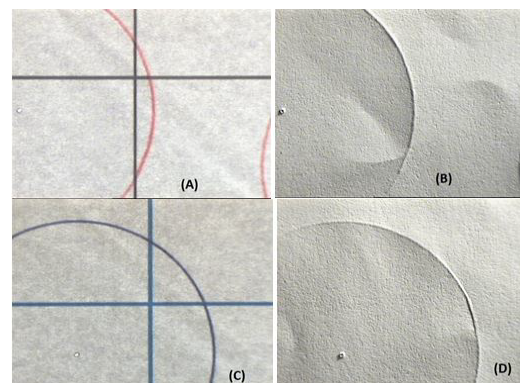


Figure 11: Back the intersection of:
(A) Green printed marking and red ballpoint pen ink stroke using transmitted light
(B) Green printed marking and red ballpoint pen ink stroke using side lighting
(C) Blue printed marking and blue ballpoint pen ink stroke using transmitted light
(D) Blue printed marking and blue ballpoint pen ink stroke using side lighting.

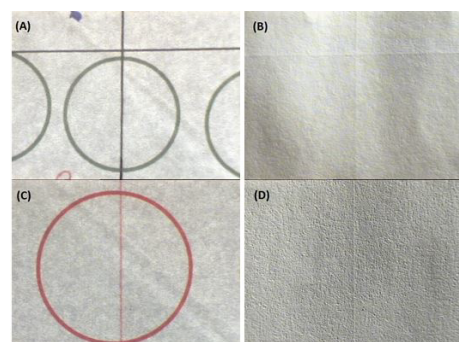


Figure 12: Back the intersection of:
(A) Green printed marking and blue ballpoint pen ink stroke using transmitted light
(B) Green printed marking and blue ballpoint pen ink stroke using side lighting
(C) Red printed marking and red ballpoint pen ink stroke using transmitted light
(D) Red printed marking and blue ballpoint pen ink stroke using side lighting.

embossing on the underside of paper as a result of pen stroke because of both the heat of the fusing roller which is reached up to 200°C (392°F), and the pressure which is approximately 140 psi in the fuser assembly [25]. So side lighting reveals these embossing features within the surface of the document at the point of intersection, and it will be easy to recognize which of them is the first.

The results of the examination show that the sequential of intersecting ball pen strokes with laser printer markings can be clearly and specifically determined from the embossing phenomenon on the paperback with the maximum success rate of the cases.

In (A) Optical illusion leads to incorrect results as the darker stroke generally dominates and appears to be on the lighter stroke regardless of their order i.e. black ballpoint pen ink is above.

In (B) No optical illusion present; the embossing shows the fact that red ballpoint ink is above.

It is clear that the embossing of ballpoint pen ink stroke is strong as evidence it was written above (after printing).

It is clear that the embossing of pen stroke is weak as evidence it was written under (before printing).

In cases where the document has lighter embossing of both of the intersected strokes, it is not recommended to use the side light technique to determine the sequence. However, where the embossing phenomenon is present clearly, that method is preferable because that is simple, non-destructive and gives reliable results.

Microscopic technique

Nikon SMZ 1000 stereomicroscope with transmitted light

One of the uniqueness of ballpoint pen ink is the presence of the ball. This ball is held in predesigned place at the tip of the pen by a housing that allows it to rotate freely during the writing action. As the ball rolls on the paper; ink is transported to the paper surface from the pen reservoir. As ink is continuously drawn by the rotating action of the ball, which controls the width and quality of the writing stroke produced, nearly irregular ink distribution at the stroke rim was executed. When the ball intersects with the toner marking (wax-based resinous ink) it accumulates the ink at its polar regions forming a regular ink distribution at the stroke rim as a result of the higher gliding movement of the ball along the toner surface in comparison with its movement on the paper surface before and after the intersection. This phenomenon can be easily shown by stereomicroscope with its transmitted light (Figure 13 C&D). Hence it was established that the ballpoint pen ink is above the laser toner marking.

Toner marking is electrostatically charged material when it is transferred onto the paper by the laser beam, the combination of heat and pressure which is utilized in the fusing section of the printer leads to fix a permeant thick layer onto the paper. This thick layer completely covers the intersection point with the ballpoint pen ink stroke (Figure 14 C&D) then it was affirmed that the ballpoint pen ink is under the laser toner marking.

Nikon SMZ 1000 stereomicroscope with external light

An external light was adjusted at 45° and was spotted at the intersection. The ballpoint pen ink strokes show distinguishable glossy appearance (specular reflection), while the laser printed marking appear as a compact layer. Figure 13 shows the continuity of specular reflection (shiny appearance) of the ballpoint pen ink confirms that it was drawn over the printed marking. Figure 14 shows the discontinuity of specular reflection of ballpoint pen ink establishes that it was drawn under the printed marking, this result agrees with the study of Saini et al. at the intersection of gel pen and laser printing [26].

In some cases, the high pen pressure leads to partially damage the laser printed marking in the intersection point. A crack may appear as a result of hitting the pen's ball with the toner marking as in Figure 15. If this phenomenon was found it was considered additional evidence that the ballpoint pen ink stroke is above the laser printed marking. In moderate or light pen pressure a gap may appear as a result of pen jumping due to the ink temporarily leaving the surface of the paper when the ballpoint pen ink hits the near side of the laser printed marking which is slightly embossed as in Figure 13. This is another proof that the laser printed marking is under the ballpoint pen ink stroke.

The study found that using both transmitted light and external 45° light established the sequence of intersecting ballpoint pen ink stroke and laser printed marking with the highest success rate. The technique is completely simple, non-destructive and the intersection sequence can be photographed for the demonstrations.

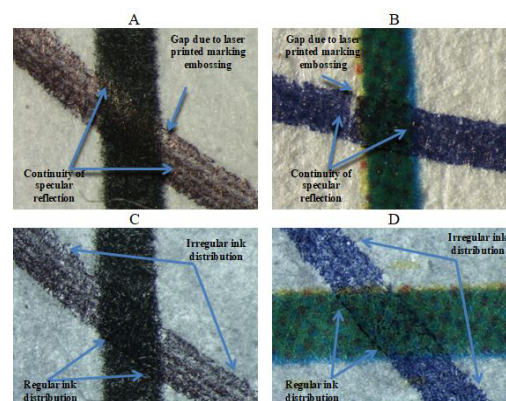


Figure 13: The intersection of:
(A) Black ballpoint pen ink stroke and black printer marking at the 45° light
(B) Blue ballpoint pen ink stroke and green printer marking at the 45° light
(C) Blue ballpoint pen ink stroke and black printer marking at the transmitted light
(D) Blue ballpoint pen ink stroke and green printed marking at the transmitted light.

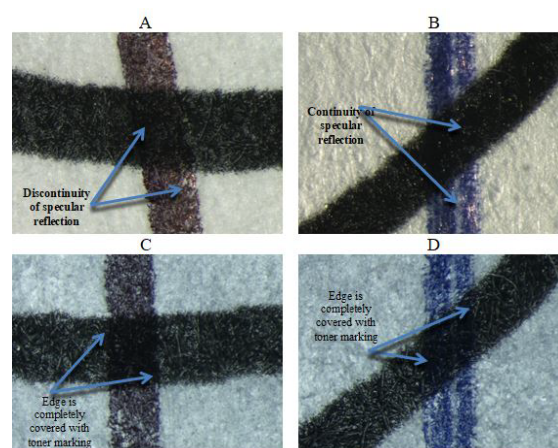


Figure 14: The intersection of:
(A) Black ballpoint pen ink stroke and black printer marking at the 45° light
(B) Blue ballpoint pen ink stroke and black printer marking at the 45° light
(C) Black ballpoint pen ink stroke and black printer marking at the transmitted light
(D) Blue ballpoint pen ink stroke and black printed marking at the transmitted light.

Continuity of specular reflection and regular ink distribution of ballpoint pen establish that it was drawn over the printed marking.

Discontinuity of specular reflection and absence of regular ink distribution of ballpoint pen establish that it was drawn under the printed marking.

Absorbance and reflectance techniques

Absorbance/reflectance spectra of laser printed markings and ballpoint pen ink stroke and their intersections point have been developed using VSC6000/HS over a range of 400 to 1000 nm. The absorption/reflectance curves obtained from the point of intersections have been classified into:

- Positive spectrum: when nature and peaks number of the

absorption/reflectance curve at the point of intersection similar to the peak of the pure ink which is produced later (above).

- Negative spectrum: when nature and peaks number of the absorption/reflectance curve at the point of intersection similar to the peak of the pure ink which is made first (under).
- Inconclusive spectrum: when spectrum from the point of intersection either has peak characteristics similar to or different from both pure inks [23].

The results obtained from the absorption/reflectance curves of intersections have been indicated that positive results have been obtained when laser printer marking above the stroke of a ballpoint pen ink. Spectra at the point of their intersections related to the spectrum of pure laser printer marking (Figure 16).

This result can be explained as the fact that the toner of laser printer marking forms a thick layer over the ballpoint pen ink stroke so that the absorption/reflectance spectrum at the point of intersection corresponds to the spectrum of the pure toner of laser printer markings. However, when the markings of laser printer were under the strokes of ballpoint pen ink of different colors negative/inconclusive results were obtained as shown in Figures 17-23. This is due to the spectrum of their intersection point still related to the spectrum of laser printer marking these results agree with experiments of Saini et al. [26] especially with

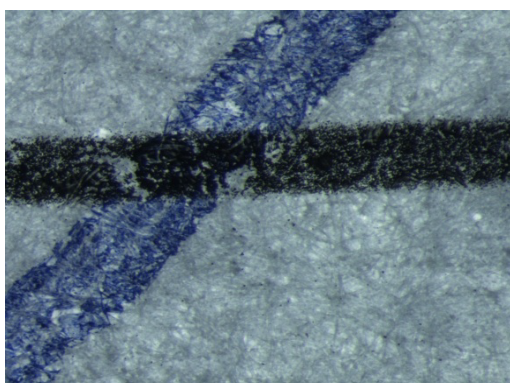


Figure 15: Partial damage to the laser black printer marking at the intersection, due to ballpoint pen pressure as an indication that the ballpoint pen ink stroke above the laser printer marking.

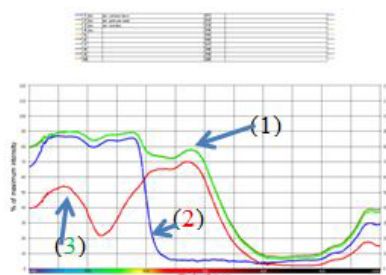


Figure 16: The absorbance spectra:
Line-3 corresponds to the spectrum of a green ballpoint pen ink
Line-2 corresponds to the spectrum of red laser printer stroke
Line-1 corresponds to the spectrum of green ballpoint pen ink under the red laser printer stroke.

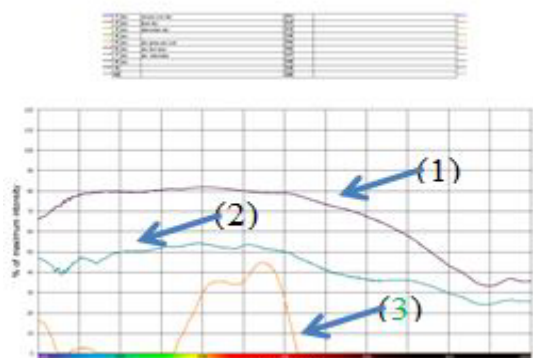


Figure 17: The absorbance spectra:
Line-3 corresponds to the spectrum of a green ballpoint pen ink
Line-2 corresponds to the spectrum of green ballpoint pen ink over the black laser printer stroke
Line-1 corresponds to the spectrum of black laser printer stroke.

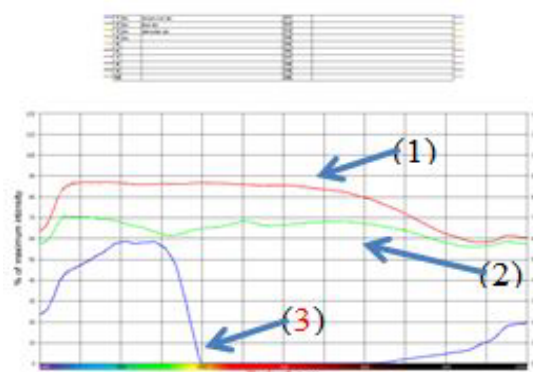


Figure 18: The absorption spectra:
Line-3 corresponds to the spectrum of a red ballpoint pen ink
Line-2 corresponds to the spectrum of red ballpoint pen ink over the black laser printer stroke
Line-1 corresponds to the spectrum of black laser printer stroke.

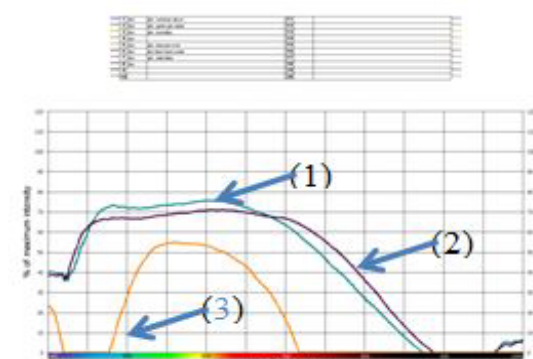


Figure 19: The absorption spectra:
Line-3 corresponds to the spectrum of a blue ballpoint pen ink
Line-2 corresponds to the spectrum of black laser printer stroke
Line-1 corresponds to the spectrum of blue ballpoint pen ink over the black laser printer stroke.

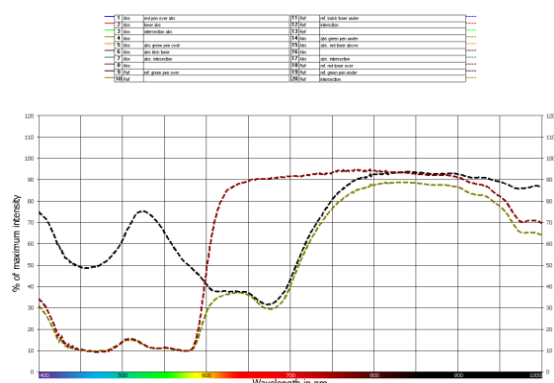


Figure 20: The reflectance spectra:
Line-1 corresponds to the spectrum of a green ballpoint pen ink
Line-2 corresponds to the spectrum of red laser printer stroke
Line-3 corresponds to the spectrum of green ballpoint pen ink under the red laser printer stroke.

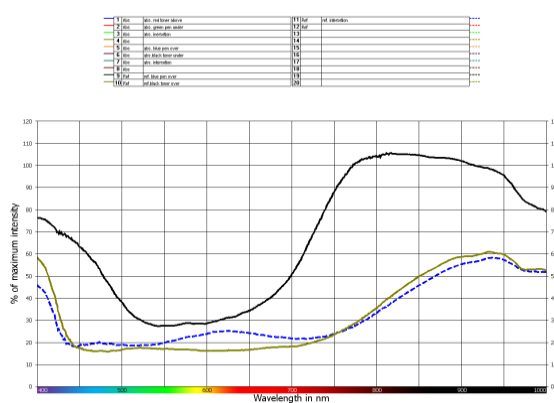


Figure 21: The reflectance spectra:
Line-1 corresponds to the spectrum of a blue ballpoint pen ink
Line-2 corresponds to the spectrum of black laser printer stroke
Line-3 corresponds to the spectrum of blue ballpoint pen ink over the black laser printer stroke.

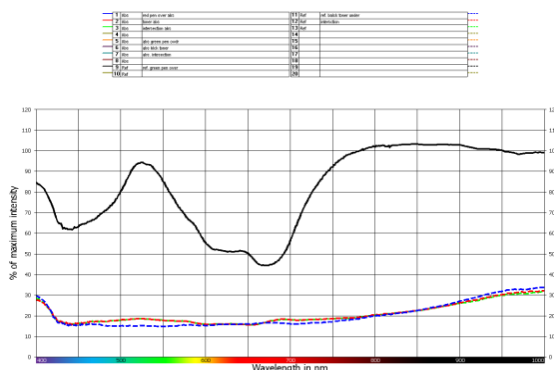


Figure 22: The reflectance spectra:
Line-1 corresponds to the spectrum of a green ballpoint pen ink
Line-2 corresponds to the spectrum of black laser printer stroke
Line-3 corresponds to the spectrum of green ballpoint pen ink over the black laser printer stroke.

the absorbance spectrum and disagree with the study of Vaid et al, which used a reflection spectra (Figures 17-23) [22].

These misleading results were obtained as a result of gliding the ball of the ballpoint pen over laser printer marking which leads to release most of the ink to rim of the stroke and hence form gaps or very thin layer at the center of the ballpoint pen ink strokes over laser printer marking [2,23] as shown in (Figure 24A), that enables the equipment to measure the absorption/reflectance spectra of a laser printer marking mainly (Figure 24B).

Thus, it is obvious that the results obtained are ambiguous because the absorption/reflectance spectra produced related to the spectra of laser printer marking whether these markings are executed first or later. Therefore, any endeavor to establish the sequence of intersecting of laser printed marking and ballpoint pen ink with VSC6000/HS has been unsuccessful (Figure 24).

In (A) Fine gaps or a very thin layer of green ink at the point of intersection present due to skipping when ballpoint pen ink stroke (glycol based) intersects the laser printer stroke (wax- resinous based ink) while in (B) the laser printer marking form a thick layer over the ballpoint pen inks.

This study has shown that the use of absorption/reflectance spectra from the VSC6000/HS does not succeed in achieving reliable positive results in the examination of the intersections under the study. As a consequence, the questioned document examiners should be cautioned during making any attempt to use the previous technique for solving these specified sequence problems.

Blind test

Blind testing has the potential to play an important role in our study nearly all the expert reached the exact order using the lifting technique with glossy paper treated with ethyl alcohol. Some of them prefer the side lighting technique and others reached the correct order with microscope supported with the transmitted light all of them agreed that the absorbance/reflectance technique is unfavorable.

Case study

Case no.18 & 22 for the year 2015 commercial the supreme court of Al-Khanka. The judgment asked for declaring if the signature has been done before or after the waiver data printed Figures (25 and 26).

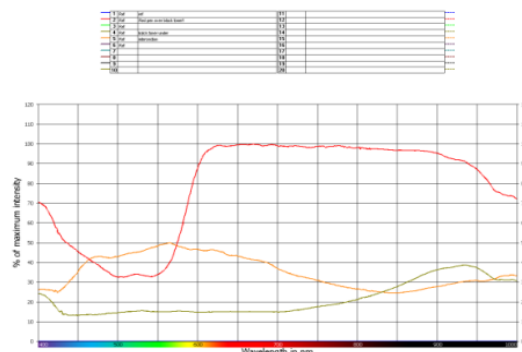


Figure 23: The reflectance spectra:
Line-1 corresponds to the spectrum of a red ballpoint pen ink,
Line-2 corresponds to the spectrum of red ballpoint pen ink over the black laser printer stroke,
Line-3 corresponds to the spectrum of black laser printer stroke.

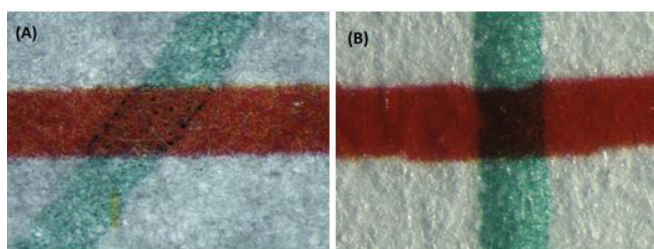


Figure 24: The intersection between:
(A) Green ballpoint pen ink and red laser marking,
(B) Red laser marking and green ballpoint pen ink stroke.

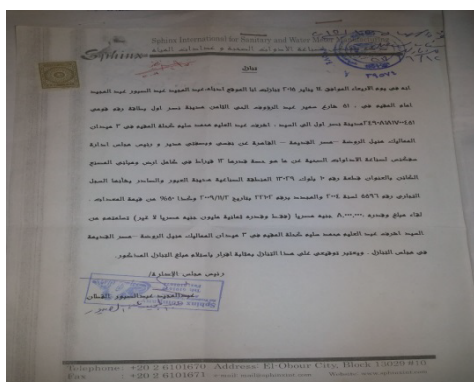


Figure 25: The questioned waiver. The financial value of the questioned waiver is 8000.000 EGP equal 454272.58 USD.

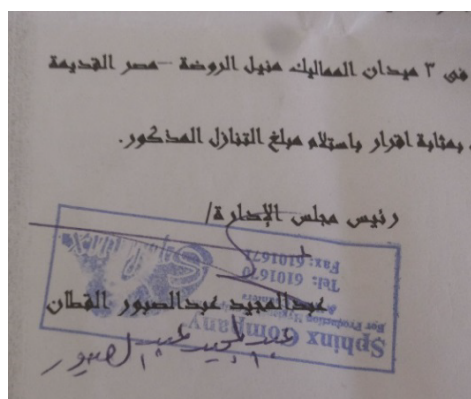


Figure 26: The intersection point between the blue ballpoint pen ink and black laser printed marking.

The government report stated that the signature was signed after the waiver data have been printed depending on the lifting technique with glossy paper modified with ethyl acetate.

Conclusions

The results of using non-destructive chemical method and some simple methods to determine the sequence of intersecting color ballpoint pen ink stroke and color laser printed marking has been as follow:

- Lifting technique was used: It was found that, continuous edge

marks (railway track) and breaks in edge marks of the ballpoint pen ink are able to determine whether it is above or under but the lifting pictures were not clear enough to photograph, so chemical treatment with pyridine, ethyl acetate, 2-phenoxyethanol, methanol, and ethyl alcohol (separately) was done: It was found that the accuracy rate in sequence determination was excellent in some cases (ethyl acetate and methanol) and accepted with caution in other (pyridine and ethyl acetate) and undesirable in the rest (2-phenoxyethanol). The easy availability of glossy paper to use as a lifting paper and the simplicity of the technique is a further advantage.

- Side lighting technique was applied: It was found that, the chronological sequence of intersecting can be clearly and specifically determined from the embossing phenomenon on the back of paper in most cases, but in cases where documents have light or no embossing of the ballpoint pen ink strokes, no attempt should be made to determine the sequence. However, where the embossing phenomenon is present clearly, this method is preferable, because it is simple, non-destructive and gives reliable results.
- Microscopically with both transmitted and external light source adjusted at 45° to the plane of paper were utilized. It was found that using both transmitted light and external 45° light established the sequence of intersecting ballpoint pen ink stroke and laser printed marking with the highest success rate. The technique is completely simple and non-destructive and the intersection sequence can be photographed for the demonstrations.
- Absorbance and reflectance techniques: The study has shown that the use of absorption/reflectance spectra from the VSC6000/HS does not succeed in achieving reliable positive results in the examination of the intersections under the study. As a consequence, the questioned document examiners should be cautioned during making any attempt to use the previous technique for solving these specified sequence problems because it is misleading.

According to the results of the study and blind test: It is recommended that using the previous techniques should be done in the following order, lifting technique using ethyl alcohol treatment, lifting technique without treatment, side lighting (in case of presence embossing), and microscopically.

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