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„Kirlian in the Classroom"

A Didactic exploration of Nature of Science

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Preface

During the writing of this thesis I had the dual sensation of having come full circle and setting out on a new path simultaneously. Twenty odd years ago, in my social circle, Kirlian Photography was somewhat like the forbidden fruit of inquiry. It offered to me enrichment and opened the world of scientific discovery in all its multi-faceted splendour. After so many years of gathering proverbial dust in the furthest corners of my memory, it again revealed itself as a gateway to exploring the essence of science. Only this time, through the eyes of this teacher, to a whole new generation of young people standing at the brink of their promising futures. It has been, and is, my ambition to awaken their curiosity by allowing them to stand in awe of the vastness of human knowledge, to be overwhelmed by the uncertain nature of this knowledge and to come to grips with some ways of learning more. Which brings me to humbly saying thank you to my teachers and mentors for their contribution to my continuing education. Prof. Dr. Martin Hopf for challenging me to write this work; Johann Geldenhuys for invaluable advice, conversations and technical support; Irene Solly, Christa Deinlein and Margot Nessmann, colleagues and true teachers, for their moral support; my children, Albert and Zané, for teaching me about what is really important; and my husband, Wolfgang, for loving me the way I am. Δόξα τω Θεώ

Abstract

This work is intended as a contribution to physics education in general but leans strongly towards creating an awareness of the Nature of Science, Scientific Method and the importance of evaluation of information and sources of information. The main feature of this study is the project laid out as detailed lesson plan for a three day activity series (or nine 50-minute teaching units) that could be presented vertically by a subject specialist (physics teacher) or horizontally as subject-overlapping with other disciplines. It includes background information, teaching material like worksheets and other media as well as an evaluation cycle to conclude the project. Through the topic of coronal discharge the reader (intended to be learners from a generation called "digital natives") will be introduced to various applications thereof while Kirlian Photography (named and assumed to be Gas Discharge Visualization – GDV - capturing images of changes in the so-called "bio-energy" or aura that is emitted by living and non-living organisms) will serve both as "hook" for generating interest and counter example of true science in practice. The results of two surveys (self-confidence and interest) administered after a brief introduction of this topic was given to students of a secondary school in Vienna, will be presented.

Zusammenfassung

Diese Arbeit ist als Beitrag zum Physikunterricht im Allgemeinen gedacht, aber es geht auch sehr stark darum ein Bewußtsein für das Wesen der Naturwissenschaft, der naturwissenschaftlichen Methodik und die Bedeutung der Bewertung von Information und ihrer Quellen zu erzeugen. Der Hauptteil dieser Studie ist ein Unterrichtsprojekt, das für eine dreitägige Serie (oder 9 fünfzig Minuten Einheiten) gedacht ist, die entweder von einem Fachspezialisten (Physiklehrer) vertikal oder überlappend mit anderen Fächern horizontal ausgeführt werden kann. Er enthält Hintergrundinformationen, Unterrichtsmaterialien (wie Vorlagen und andere Medienunterlagen), und auch einen Bewertungsbogen, um das Projekt abzuschliessen. Durch das Thema “Korona-Entladung” wird der Leser (der idealerweise schon der Generation der “Digital Natives” zuzurechnen ist) zu deren unterschiedlichen Anwendungen hingeführt. Dem gegenüber wird die Kirlian-Fotografie (die man als Visualisierung von Gasemissionen interpretiert, die angeblich Änderungen in der sogenannten “Bio-Energie” sichtbar machen würde, die von lebenden und nicht lebenden Wesen ausgesandt werden soll) als “Aufhänger” verwendet, um Interesse zu erzeugen, und auch als Gegenbeispiel zu einer korrekt verstandenen naturwissenschaftlichen Methodik. Dazu werden auch die Ergebnisse zweier Umfragen (Selbsteinschätzung und Interesse) präsentiert, die nach einer kurzen Einführung in das Thema unter Studenten eines Wiener Gymnasiums ausgeführt wurden.

1 Introduction

Science, together with its accompanying technology, has an increasingly prominent impact on society. Science is no longer only the domain of the highly specialized. The outcomes of science influences daily life, changes in society and impacts on political policy.[1]

1.1 Science Thinking – thinking science

The prevalent notion is that physics is hard to understand and merely "a series of disconnected facts and algorithms presented by (the authority) that must be memorized and have no connection to the real world." (Gray, KE. et.al. 2008) Changing these beliefs should be a matter of urgent classroom action. Students have contradictory ideas about physics and learning physics. (Lising, L & Elby, A. 2005)

According to Gray, while students know fairly well what physicists believe about physics and learning physics, they do not agree with these ideas, at least as they apply to their own personal contact with the discipline of physics and how they learn physics and its associated problem solving approaches. The author questions whether students´ formal and informal educational experiences provide them the opportunities to develop and practice thinking skills in science.

Physics only becomes useful through training in Scientific Method and the Nature of Science Enquiry. "Students who had high school courses that spent more time on fewer topics, concepts, problems and labs, performed much better in college than those who raced through more content in a textbook-centred course."(Sandler, PM & Tai, RH. 2000) It follows that taking the time to investigate a topic for scientific relevance by exploring what constitutes true science would foster not only self-confidence and interest in learners but also create a generation of young people with the critical thinking skills "essential to engage with many of the issues confronting contemporary society." (Tomei, A. et.al. 2007)

One approach is to integrate the History and Philosophy of Science (HPS) into physics teaching.[2] Teixeira states that HPS, promotes a more mature vision in respect of the students´

[1]Voter's understanding of Climate Change plays an increasingly important role in party politics.

[2]There appears to be much support for the idea of similarity amongst students´ spontaneous understanding of scientific concepts and the historical development of these concepts. (Teixeira, ES. et.al. 2012)

understanding of Nature of Science (Teixeira, ES. et.al. 2012) This understanding include both the strengths and limits of science. Students need to be educated to be critical consumers of scientific knowledge (Tomei, A. et.al. 2007). To engage with socio-science issues one requires a set of skills to locate, evaluate, interpret, and apply scientific information. As a critically important life skill, science literacy should be actively taught in classrooms to enable students to access and use information in a meaningful, responsible, and ethical manner. This is in step with the American Association of School Librarians (2007), in its *Standards for the 21^st^ Century Learner*, which highlights the importance of critical thinking skills that go beyond the procedural and technical competencies associated with subject content.

Physics subject content has an intrinsic right to be taught, as it is clearly the foundation of technological development. Should the traditional content-based teaching methods be substituted (in part) instead with an approach leaning more towards teaching scientific literacy while using content merely as examples of the Nature of Science in action, we would come closer to what Shamos reports Dewey had envisioned when he made the statement that "the special nature and methods of logical thinking characteristic of science would stimulate logical thinking skills in learners that would transcend the classroom situation into their other activities".[3] (Gräber, et.al. 2002)

There exists a subtle and ever-changing demarcation between "science" and "non-science". (Hudson, D. 2009) Popper took falsifiability as his criterion of demarcation between what is, and is not genuinely scientific: a theory should be considered scientific if, and only if, it is falsifiable. (Popper, K. 1934) In this work the author will present a detailed lesson plan devoted to creating in students an awareness of the Nature of Science. The main aim of this project is that students are assisted in creating their own set of criteria (e.g. falsifiability) for evaluating scientific theory and then challenging these criteria by evaluating Kirlian Photography as said direct application of coronal discharge.

The results of the surveys executed prior to the lesson design process have highlighted students´ interest in physics but also indicated a lack of confidence to become actively involved in their learning by "doing" science. This could be because students do not have the "know-how" to "do" and feels safe merely discussing the results of someone else´s experimentation. This work is therefore structured to afford the reader an overview of some physics subject content as well as educational material, from two unique vantage points: on

[3] Translated by author from German text.

the one hand that of a school student by means of chapter 2 and on the other that of professional scientists through chapters 3 and 4. Finally the lesson plan in chapter 5 includes the product of extensive training and teaching experience that culminates in activities structured to increase students´ self-confidence in “doing” physics by actually doing what professional scientist do. Students will learn about the Nature of Science while going through the very steps they are being taught.

2 Early case study: Kirlian Photography

2.1 First exposure to research

As part of the extramural activities during secondary school the author had the opportunity to participate in the annual national Expo Science competition, with 5 projects in 4 years. Since 1989 South Africa also competes internationally. This is a two day, science fair type competition where projects can be done individually or in groups. The categorized projects are exhibited next to each other in a large hall and participants then present their projects to a subject specialist panel of 6 (or more) judges and anybody else who happen to be interested. The standard of the competition is lifted even more with prices including e.g. full university scholarships. In order to ensure quality projects being exhibited, the competition eliminates projects first during annual school competitions and then during provincial exhibition days. Students typically spend 6 months to a year (in some cases longer) working on their projects. Every project can only compete once at national level. There is a very strong emphasis on research based projects that include an in-depth exploration of a topic preferably outside of the school curriculum. The main thrust of the project should be an own designed and executed experiment presented in a fashion similar to papers at scientific conferences.

At the age of 16 the author came across Kirlian Photography as a topic of controversial interest. Precious little was available in terms of literature due to the social, political and specially religious environment during this time. The apparatus was built and many hours spent in a darkroom while gathering data. After spending a year working on the project, it was successfully presented at the national competition in 1988 and chosen to compete at the International Science Expo in 1989, France. It was decided to improve the project by statistically analyzing the data and not only presenting the phenomena visually. This off course introduced aspects of the Scientific Method previously not explored. The paper that will be included in the following pages is the product of the success the project had internationally and was accepted for publication, pending editorial changes, by the South African Journal of Science. It is presented here as a first case study of an attempt to scientifically explore and explain aspects of images formed by Kirlian Photography. Later this paper will be used during the proposed lesson plan as case example to introduce students to the Nature of Science. The format of this chapter is that of a scientific paper and includes summary, references and acknowledgments, as it will serve as an example to students reading it during session 6 of the lesson series. It will have special significance in a class situation as it was written by a 17 year old secondary school student with the help of a physicist and statisticians, based on the own project done while still at school, therefor it should prove that at least this level of work is attainable.

2.2 Statistical analysis of corona discharge images

2.2.1 Summary

A scientific method is proposed for the study of changes in Kirlian photographic images of any given object whenever an external stimulus is applied to the object or its surroundings. Statistical methods are used to determine the confidence level of an observed change in the average area and colour distribution of the image. Two important criteria are proposed to validate an investigation: (1) At least 30 objects should be photographed under identical conditions to allow the Central Limit Theorem to apply and the sensitivity of the detection technique will correspondingly improve if the number of subjects are increased. (2) The data obtained from the images should be tested for randomness. If randomness is established for a given sample under a fixed external stimulus, then the quoted confidence level for the change will be valid. We investigated the change in the area and colour distribution of the image of the human finger pad when three different types of music are played. We found that the selected music types reduced the area of the image at a confidence level of 99.3%, while the colour distribution is changed at the 99.997% confidence level. Some music types influence the images significantly while others have no apparent influence.

2.2.2 Introduction

The technique of the photographing of objects with high voltage equipment was developed by Kirlian and Kirlian (Kirlian, S.D. and Kirlian, V. Kh. 1974) who have shown that grounded animate and inanimate objects placed in contact with a film on an electrode produces a colourful image if a pulsed high voltage is applied to the electrode. The cause of this image was a subject of many discussions and speculation: Kirlian and Kirlian described their photographing as a method for the conversion of non-electrical properties of the object into electrical ones, where changes are transferred from the object to the photographic plate. One can identify two schools of thought on this subject: Adamenko (Adamenko, V.G.1970) gave a natural physical explanation for these images by interpreting them as the result of cold electron emission which produces coronal discharges. The Inyushin school (Tiller, W.A. 1974) explains this phenomena in a rather unscientific way by means of “bioplasma” – a so-called fifth type of matter (apart from the well-known four states which are solids, liquids, gases and plasma) which is represented by subatomic particles in living organisms which affects the cold electron emission from a specimen. Furthermore, the state of bioplasma is strongly dependent on the condition of the organism and it is said to explain the modulation of Kirlian images when the state of the organism is changed. The Ademenko line of reasoning seems to be physically plausible and a detailed model may be developed which describes the motion of the accelerated electrons and/or ions in air. Tiller (Tiller, W.A. 1974) investigated this area from a solid state physics viewpoint and identified some fundamental problems: (1) the frequency of light emitted by electrons colliding with air molecules is in the X-ray range: if $E=10^7$ V.cm $^{-1}$ is the typical electric field strength involved and $\lambda_e = 0.25\mu m$ is the electron mean free path in air, the energy gained between collisions is $eE\lambda_e$ which may be converted to X-ray photos with energy = 0.4Kev, i.e. too high to explain the observed visible radiation. (2) The electron undergoes between 100 and 1000 collisions with the air molecules between the specimen and the high-voltage electrode and the information from the object will be destroyed after even the first collision if the observed light is the summed contribution of photos from all collisions. Any change in the condition of the object will then be undetectable by the Kirlian technique. (3) Moss and Johnson (Moss, T. and Johnson, K.L.1974) recalls the observation of Pratt and Schreider who have said that Xylonite which seals off visible light, infra-red and ultraviolet light, did not hinder the production of the corona on the film.

Other possibilities that may influence the Kirlian images of humans are galvanic skin response, skin temperature, peripheral vascular changes, or sweat. Moss and Johnson (Moss, T. and Johnson K.L. 1974) conducted extensive experiments by varying these parameters, and found that this photographing does not portray these physiological parameters. However, it was found that the image changes significantly from person to person. The state of health also changes the image. For example, a person with cancer produces virtually no image (Gennaro, L. Guzzon, F. Marsigli P. 1980). Ebrahim (Ebrahim, H.M.1985) also investigated the factors affecting the image and its potential application in medicine. Finally it was claimed that changes in the mental condition influence the Kirlian image (Moss, T. Johnson, K.L. 1974) (Gennaro, L. Guzzon, F. Marsigli, P.1980)(Swann, I.1974).

It was mentioned that inanimate objects also produce a corona. To see if these images change, a coin was put in boiling water, dried and photographed. It was also placed on ice and when dried, photographed. No change was seen. Plants alter within limits of cold, heat and gashing, where it would show red blotches. If the leaf or petal is monitored until dried out completely, there would be no image at all. Thus it is believed that non-living things do not change but living things such as plants, animals and humans would alter in conjunction with this environment (Moss, T. Johnson, K.L. 1974).

We attempted to introduce a scientific method for the analysis and interpretation of these coronal discharge images. When observing the images of different persons one sees clearly that they are not all identically with respect to total area and colour distribution. Measurable parameters of an image include total area of the ellipsoidal images and the relative areas covered by various colours. Kirlian photography may have met with scorn because these quantities fluctuate drastically from image to image and may not be able to draw firm conclusions from only one picture. By taking a large sample of images under fixed controlled external conditions, one may be able to draw some conclusions about a possible change of the values of the above mentioned parameters. A condition for the success of such an approach is that the measurable quantities should be independently and identically distributed under fixed external conditions, i.e. the data should be "random". As an application we have developed a simple experiment to determine whether music, which may influence the mental and possibly the physical condition, has any influence on the Kirlian image. This is done under controlled conditions as described in Section 3. A control image (in absence of any music) is taken and subsequent images (during the playing of various types of music) are normalized with the control image. This leaves a result which depends on the conditions applicable during the time when the music was played. The parameters which are tested for a change are the mean normalized area of the image as well as the mean relative area covered by different colours. From the images of 31 people, estimates of these parameters are constructed and from the Central Limit Theorem it follows that these estimates (they are mean values) will be approximately normally distributed if the data sample are randomly distributed. From the normality property it is easy to estimate the confidence level of a claimed influence. This will be discussed in Sections 2 and 5.

2.2.3 The Kirlian Device

The Kirlian device used in this experiment was built on certain specifications 5 and it has been modernized to occupy our needs for exposure time regulation, frequency control and potential difference domination. The power source delivers 220V AC which is transformed to 12V AC and then transformed to 12V DC using a diode. A time relay was fit into the system to enable the use of different ASA rated films. A pulse generator of =100 Hz is used to deliver the necessary breaks in the power flow. A motorcar's capacitor discharge system enables the 12V DC to reach an induction coil where between 20 000 – 100 000V can be generated. The amperage is about 0.03uA and a potential difference of 20 000V was used. From the negative pole of the coil a piece of wire is used as an earth and the high voltage output is connected to the copper plate (point of contact). The film is then placed on the copper plate with the emulsion exposed. The finger pad will then be placed in direct contact with the emulsion and the circuit is activated for four seconds with the use of the time relay.

2.2.4 Experimental method

All tests were done in darkroom with as little light as possible. Experiments with different film types have shown that Fuji-chrome slide films produced the best results. It does not really matter whether it is 100ASA or 50ASA as exposure time can be changed accordingly.

As the Kirlian device and the music centre were operated from the same general power source, the power to the music centre had to be kept constant so that there would be no change in the potential difference at the point of contact when switching between different types of music. The temperature in the room fluctuated between 17°C and 19°C which is typical of the range of operation by Ebrahim (Ebrahim, H.M. 1985)

In this experiment 32 people were asked to be photographed. A questionnaire was completed in which they had to state age, music preference and if they had any medical history of heart malfunctions, as a shock might give rise to a cardiac-failure. The ages varied uniformly between 13 and 40 with a majority of females. Only one subject showed signs of claustrophobia and was therefore withdrawn from the project. In this group no preference to one type of music was evident.

The pattern of work done is as follows: a control of neutral photo was taken in silence where after three different types of music was played. The control was necessary to isolate the effect of the music. However, sometimes two or more control photos were taken as some of the subjects had a fright if the power was put on for the first time. After the control approximately ten minutes were spent listening to Mozart's horn concertos, where after a photograph was taken. To produce a shrill contrast to the calm fluent sounds of Mozart, the noisy "pop" sounds of High Energy, Vol.7 was taken and the last 15 minutes on side two was played to obtain results. The third type of music used was Kitaro Silk Road. It is enlightening a "cosmic" sound that no lyrics, melody or definite beat. The subject also listened to this for about 10-15 minutes. After each listening session a photograph was taken. During this time nobody spoke and the subject only touched the film so no physical contact was made between the subject and the photographer.

2.2.5 Analysis of the area of the image

A fine grid was used to estimate the total area Ai of the i'th person for j = 1 (control) and j = 2, 3 and 4 for the "Mozart", High-Energy" and "Kitaro" cases respectively. The area was estimated by counting the number of pixels in the image. The number of pixels included, ranged between 53 and 136. This large range reflects the difference in finger pad area due to the large range in ages (between 13 and 40) of the subjects. Since we are only interested in relative areas, we have taken A_i^j to be equal to the number of pixels. The error on A_i^j is estimated as = $\sqrt{A\,i}\,/3$ which corresponds to percentage errors between 3 and 5 %.
To account for the difference in subjects, the areas were normalized as follows:

$$a_i^j = A_i^j / A_i^1 \tag{1}$$

The superscript j refers to an index and not a power. It is always of interest to see whether the data a_i^j (for i = 1, …. n persons and a given j > 1) are normally distributed. In the case of small sample sizes (n < 50), (Shapiro, S.S. Wilk, M.B. 1965) have shown that their W – test is a powerful test for normality against a wide variety of alternatives. The W – statistic for n < 50 is easy to calculate and the critical values are also provided by the authors. We have implemented this test and obtained W = 0.967, 0.979 and 0.945 for j = 2, 3 and 4 which corresponds to sample sizes of n = 31, 30 and 30 respectively. The reason why n = 30 for j = 3 and 4 is because of the lack of one image (they were not taken) for these values of j. the values of W corresponds to significant levels of 50%, 50 – 90% and > 10% respectively. We have thus no reason to reject normality for the three choices of j. It is however not necessary to require normality for the data – they should only be independently and identically distributed which means that the data should be "random".

If music j has no influence on the image (null hypothesis: H_0), we would expect the distribution of the estimate of the mean relative area

$$\bar{a}^{\,j} = \frac{1}{n} \sum_{i=1}^{n} a_i^j \qquad (2)$$

to approach to that of the normal distribution (according to the Central Limit Theorem) with mean one and a variance of

$$Var\left(\bar{a}_i^j\right) = \frac{1}{n^2}\, Var\left(\sum a_i^j\right) = \sigma_j^2/n \qquad (3)$$

if and only if a_i^j (i = 1, …, n) (for a given j) are independently and identically distributed and we need not to know the distribution of a^j

We expect them to be independent (since different persons are used), but we cannot simply assume them to be identically distributed. One therefore needs a non-parametric test for randomness: We propose the "Runs test" for randomness based on the sample median. In this case one counts the number of data groups (or "runs") for which all the values in a given group are either smaller or larger than the median value. Say the number of runs is r. Randomness is then rejected if r is either too small or too large (i.e. a "two sided" decision rule). The probability or "p-level" for randomness for a given r is calculated from the asymptotic formula of Kirch. In the case of small sample sizes (n < 100) the exact critical values given by De Beer may be used. Concerning a decision rule, we suggest that randomness may be accepted if the probability (or "p-level") is larger than 5%. We have calculated r for j = 2, 3 and 4 and the corresponding values were r = 16, 18 and 12 respectively. According to the table of critical values supplied we may accept randomness since the probability for randomness is more than 20% in all three cases.

On the basis of the above results we expect the claims associated with equations (2) and (3) to be valid and the null hypothesis for no change in the image may be tested by using the test statistic

$$Z = \frac{\overline{a^J} - 1}{\hat{\sigma}_j/\sqrt{n}} \tag{4}$$

which is asymptotically normally distributed with a mean of zero and a standard deviation of one. The estimate of the standard error is given by

$$\hat{\sigma}_j = [\frac{1}{n}\sum_{i=1}^{n}\left(a_i^j\right)^2 - (\overline{a}\ )^2\ ]^{½} \tag{5}$$

We have calculated Z_j and obtained the values -0.01, -3.13 and -1.53 for j = 2. 3 and 4 respectively. Only the case j = 3 (i.e. the "High Energy" music type) appears to be significant and the average area of the corresponding image is reduced by this external stimulus. Since we do not know a priori whether the image will reduce in area ($Z_j < 0$) or increase ($Z_j > 0$) we have here again a "two sided" alternative hypothesis and a valid test statistic for any change is
$x_3^2 = (Z_1)^2 + (Z_2)^2 + (Z_3)^2$
which is χ^2- squared distributed with three degrees of freedom if these three music types have no influence on the images. The null hypothesis of "no influence" is rejected for large values of χ^2. The corresponding value for our application is 12, 1 which corresponds to a confidence level of 99.3% that the selected types of music has an influence on the area of the Kirlian image.

2.2.6 Analysis of the colour distribution in the image

Red appears to be a dominant colour in many images and orange appears very seldom, but if present, it seems to be embedded in red. Other colours which usually go together are white, blue and sometimes pink. It also happens that a certain fraction of the interior of the image has zero brightness (i.e. black). We have thus investigated the distribution of the three colour indices l = 1 (red with orange), l = 2 (blue, white and pink) and l = 3 (black). The area A_i^j (l) of the colour contained in the image of person i if music type j is played is also measured using the grid. To measure the influence of music j alone on the image we subtract the corresponding colour contribution in the control image:

$$a_i^j(l) = \frac{A_i^j(l)}{A_i^j} - \frac{A_i^1(l)}{A_i^1} \quad , \quad j = 2,3,4 \tag{6}$$

The first term measures the fractional area contained by colour l for a given j and the second term measures the fractional area contained by colour l in the control image (j = 1). Since

$$A_i^j = \sum_{l=1}^{3} A_i^j(l) \tag{7a}$$

it can be shown that

$$\sum_{l=1}^{3} a_i^j(l) = 0 \tag{7b}$$

The appropriate null hypothesis, i.e. music j does not influence the colour distribution may be stated as

$$H_0 : \sum_{l=1}^{3} [E(a^j(l))]^2 = 0 \tag{8a}$$

Against the alternative hypothesis of influence

$$H_A : \sum_{l=1}^{3} [E(a^j(l))]^2 > 0 \tag{8b}$$

Due to the dependency implied by equation (1) it is difficult to construct a sufficient test statistic for H_0 againstH_A. However, expected changes in colours l = 1 and l = 2 prompted us to do the colour study. We therefore test (for j = 2, 3 and 4)

$$H_0 : \mathrm{E}(a^j(1)) = 0 \tag{9a}$$

Against

$$H_A : \mathrm{E}\left(a^j(1)\right) > 0 \tag{9b}$$

Although this is not a sufficient test statistic, one can still reliably estimate the change in colour l = 1 due to the effect of the music.

If a_i^j (1) for i = 1,… n area independently and identically distributed then the distribution of the mean under H_0

$$\bar{a}^j(l) = \frac{1}{n}\sum_{i=1}^{n} a_i^j\,(l) \qquad (10)$$

will approach to that of the normal distribution with a mean of zero and a variance of $(\acute{\sigma}_j(l))^2/n$ which may be estimated as in equation (5)

$$\hat{\sigma}_j\,(l) = [\tfrac{1}{n}\sum\nolimits_{i=1}^{n}\left(a_i^j\,(l)\right)^2 - (\bar{a}^{\,j}(l)]^{½} \qquad (11)$$

The appropriate test statistics for l = 1 are then

$$Z_j\,(l) = \sqrt{n}\;\bar{a}^{\,j}(l)/\hat{\sigma}_j\,(l) \qquad j = 2, 3, 4 \qquad (12)$$

which will be asymptotically normally distributed under H_0. Before applying equation (13), we tested whether a_i^j (l) (for the nine (l, j) combinations) are randomly distributed. The results are indicated in Table 1.

colour index ℓ	music type j: 2	3	4
1	24 (<5%)	11 (20%)	12 (>20%)
2	18 (>20%)	12 (>20%)	14 (>20%)
3	18 (>20%)	18 (>20%)	14 (>20%)

Tab. 1: Randomness

Results from the runs test for randomness for each music type j and colour index ℓ. The upper number in each square corresponds to the number of runs in each sample and the corresponding number in brackets is the p-level for randomness. The sample sizes involved are n = 31 for j = 2 and n = 30 for j = 2 and 3.

From Table 1 it is evident that only eight of the nine samples are acceptable for further analysis. The case ℓ = 1 and j = 2 (i.e. the red colour in the "Mozart" image) gave a p-level between 1 and 5% which means that equation (13) may not be applicable in this specific case and the latter should be excluded, or one should move on to the blue-white colour index (ℓ = 2) where randomness is acceptable. The values of Z_j (1) for j = 2, 3 and 4 were -0.87, -1.41 and -4.65 respectively. However, we reflect the first value due to the above reasons and the two sided hypothesis (i.e. a colour may either increase or decrease in area) is tested by constructing a χ^2 test statistic (similar to the area analysis):

$$x_2^2 = (Z_{3(1)})^2 + (Z_{4(1)})^2$$

which will a χ^2 distribution with two degrees of freedom if the colours do not deviate significantly from that in the control images. The χ^2 value equals 23.6 in this case and the null hypothesis is rejected at the 99.9993% confidence level. Another approach would be to take the l, = 2 case where randomness is acceptable in all three cases. The three value of Z j (2) are 0.313, 0.631 and 4.68 for j = 2, 3 and 4 respectively. Using the χ^2 statistic with three degrees of freedom, we reject the null hypothesis of no change at the 99.995% level. The general procedure outlined here is not above critic: we stated our initial hypothesis in terms of l, = 1. Due to the problems encountered with randomness we have moved on to the case l, = 2 where randomness is acceptable. It is as if one is performing one extra dependent (as implied by equation (7)) trial to arrive at the next result. We however state the 99.995% level, which may change only marginally in the light of the one extra dependent trial performed here. It is quite evident that the case j = 4 (i.e. "Kitaro") was mainly responsible for the change in both the l, = 1 and 2 colour indices. It is now of interest to estimate the fractional change in the colour indices for j = 4: The average area of colour l, = 1 has decreased with (19±4) % while the average area of colour 2 increased with (21±5)% and the average area of colour 3 remained the same within statistical errors (i.e. the absolute percentage change is only (3±3)%). The latter result is to be expected on the basis of equation (7b) with the l, = 1 and l, = 2 results and it is thus clear that that only the first two colour indices (which are correlated) are influenced. Density estimates of the 30 a_i^4 (l) values are shown in Figure 1 for all three colour indices. From this Figure is it quite clear that the relative area of the red colour reduces (relative to that in the control image) while blue-white-pink areas increase simultaneously with the same absolute amount. The black area remains invariant, which is expected from equation (7b) when considering the above information.

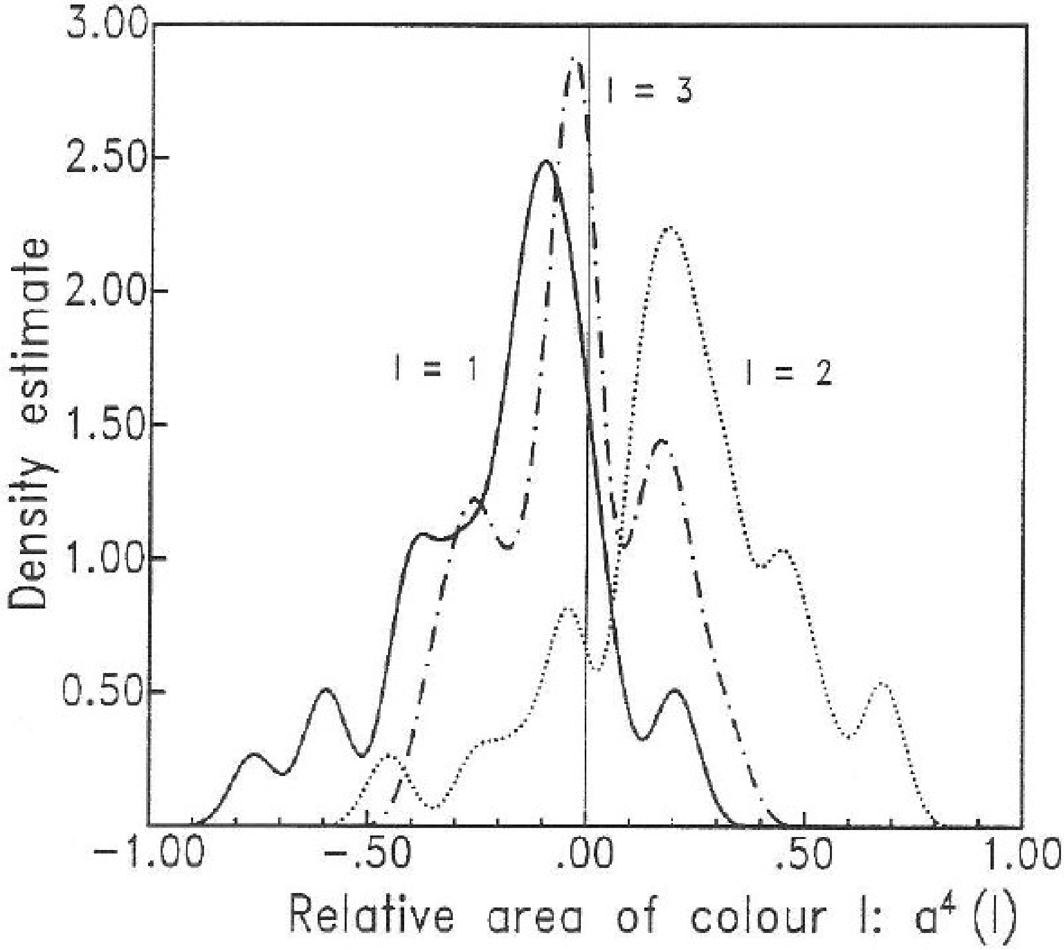

Fig. 1: Density estimates

Kernel density estimates of the relative areas a_i^j (l) for l = 1 (red and orange), 2 (blue, white and pink) and 3 (black) applicable to the case j = 4 which corresponds to the "Kitaro" type of music. The density function for black is centered around zero which implies no effect of the music on this "colour". The red – orange colour index is shifted to the left which implies a reduction in the area (relative to the control) while the blue – white – pink colour index is shifted to the right which implies and increase in the area.

2.2.7 Discussion

Kirlian photography is still a controversial subject which is investigated on a qualitative basis. There appears to be three basic measurable quantities: (1) total area, (2) colour distribution and (3) brightness. The latter aspect was not investigated in this study due to the lack of the necessary apparatus, but it is expected to be somewhat related to the total area. To investigate the influence of some external stimulus (whether it is in the physical, medical or social sciences), one may need large samples (say more than 30 independent subjects photographed under similar conditions) to draw reliable conclusions. The necessity for the large samples is that the fluctuations from image to image may be so large that no firm conclusion may be drawn from only one image if the effect is marginal. We have also shown how the randomness of the data may be tested before the significance of a given effect is calculated. If randomness of the sample cannot be achieved under given fixed external conditions, then it may be difficult to quantify such significance and the amount of change in the image also cannot be quantified. However, if randomness of the sample can be achieved, the Central Limit Theorem in Statistics may be used to test easily whether the mean area, mean relative area occupied by a given colour etc., deviate significantly from the expected mean in the case of no influence by the applied external stimulus.

We have applied this procedure to the results of a study of the influence of music on the Kirlian image. Although the subject of music belongs to the social sciences, it served as an example for the application of statistical techniques which leads to a scientific method whereby the results are quantified in terms of a confidence level of the change, the amount of change and the corresponding confidence interval. We have chosen three types of music: "Mozart", "High energy" (i.e. a type of "pop" music) and "Kitaro" (i.e. a type of "Cosmic" music) and it was found that the area of the Kirlian image do change (with respect to the control image) at a confidence level of 99.3%. In fact, only the "High energy" type caused a significant change which corresponds to an average decrease of (11, 5±3,7)% of the total area of the image.

The colour distribution in the images requires a slightly different approach: since the sum of the individual areas of colours equals the total area, the relative colour areas of a given image are dependent on each other and it is thus difficult to specify a sufficient test statistic for any changes in the colour area. However, on the basis of a priori knowledge we expected a change in red-orange against blue-white-pink and a test (also based on the Central Limit Theorem) was constructed to test for changes in for example red-orange. The relative area of the latter colour combination did change under the influence of music. However, it was found that only the "Kitaro" type caused this modulation and the average area of red-orange decreased with (19±4) %. The mean area of the blue-white-pink colours increased simultaneously with a similar amount, i.e. (21±5) %, while the black colour (i.e. the parts with no colour in the image) remained invariant with respect to that in the control image. The approximate confidence level for this change is 99.995%.

In one case (the red colour in the images for which "Mozart" is applicable) we failed to establish randomness. The effect is only marginally significant at a level between one and five percent and if that data are truly non-random, it may imply that they are not identically distributed and the 31 subjects were probably drawn from more than one population where personality and other unknown factors define a "population". It may be that the "High Energy" and "Kitaro" types of music dominate these differences while it is not the case with the "Mozart" type. Consequently one only rejects randomness in the "Mozart" case and a correction study between the results of the Kirlian images and quantified results from personality studies may shed some light on this speculative hypothesis.

No stone should be left unturned in the search for an explanation of the colourful images, the radiation mechanism involved and the source of charged particles streaming from the subject. Well defined colours (e.g. red) may be due to line emission from exited electron states in certain atoms. A sensitive spectrometer may be necessary to identify some well-known lines frequencies. The white colour may be due to bremsstrahlung of accelerated electrons passing past air molecules or the inverse Compton scattering of electrons on the red light, which give a broad band spectrum. Higher energy electrons will shift the spectrum to higher frequencies such that the low energy tail of the spectrum starts in the blue and extends into the ultraviolet region. The so-called "black" or invisible parts inside the image (i.e. where the pressure exerted by the finger pad is a maximum) may actually be the result of a radiation spectrum which already starts off in the ultraviolet or soft X-ray region and no overlapping with the optical window is there any more. The electrons responsible for this radiation may have the highest energies (due to a minimum distance between the skin and the high voltage plate where the finger pad pressure is highest). To determine which process is most important one may compare the bremsstrahlung and inverse Compton lifetimes with the acceleration time-scale of an electron. This basic outline of a detailed radiation model suffers from at least one difficulty: the blue colour are also found at the outer rim of the image where the electrons are expected to have a minimum energy (due to a maximum distance between the skin and high voltage plate) and from this tentative model we would always expected a reddish outer rim. Coming to the influence of music on the image, one should investigate the change in physiological conditions in the skin when the emotional state changes and less free electrons may yield a smaller image. The release of other types of ions from the skin during changing emotional states will result in different radiation spectra which may explain the changes in the colour distribution.

2.2.8 Acknowledgements

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2.3 Lessons learnt

It is through doing that we learn. The importance of acting like a scientist necessarily includes experiencing the Nature of Science although maybe not explicitly realizing this. A project like this highlights the experimental method, gathering unknown data with only a hypothesis as guide, examining the data, analysing these mathematically and being surprised by the results, putting forward reasons for the results and making conclusions based on own work – not merely replicating established experiments as happens so often as part of school curricula. Answering the ethical questions when presenting your work, while knowing how one can manipulate the experimental set-up, apparatus, method as well as the data to produce results one would have liked to achieve emphasizes the tentative nature of knowledge. Receiving validation through peer acceptance and the exhilaration of critically evaluating every aspect of your own (and others´) work in order to improve the contribution to the ultimate body of knowledge.

The proposed lesson plan in this study will challenge students to engage with the nature of science and scientific experimentation on their own individual levels of ability and interest. Some students will learn only a method for gathering and evaluating (hopefully) information from written sources while others will associate with scientists by not only designing an experiment but also conduct these experiments.

3 From Kirlian Photography to Corona discharge

The evolution of scientific theory does not emerge from the straightforward accumulation of facts, but rather from a set of changing intellectual circumstances and possibilities. (Kuhn, TS. 1996) Lay offers that true Science acts illogically by initially rejecting anything unproven, then when no other way exists, it engages with the problem or phenomenon and lastly when a scientific explanation has been found, believes it. He submits acupuncture as example. (Lay, P. 2000) This underscores what Kuhn calls incommensurability. The scientific paradigms preceding and succeeding a paradigm shift are so different that their theories are incommensurable. The new paradigm cannot be proven or disproven by the rules of the old paradigm, and vice versa. He further states that scientists spend most (if not all) of their careers in a process of puzzle-solving. This is pursued with great tenacity, with great confidence that the approach being taken guarantees that a solution to the puzzle exists. Kuhn calls this *normal science*. (wikipedia)

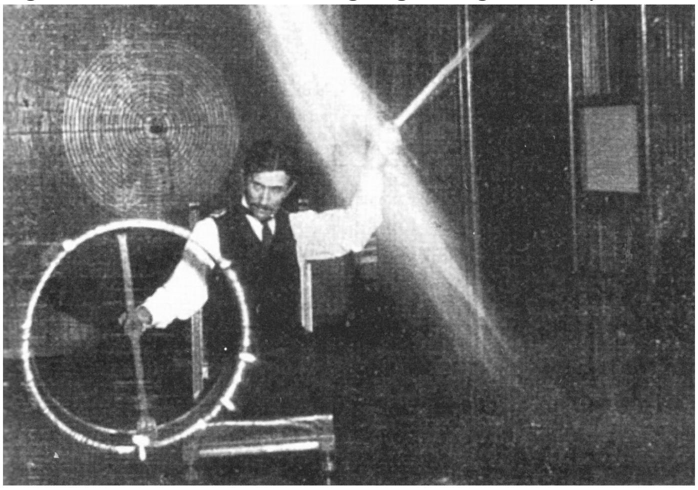
In this chapter the author wishes to present a very brief overview of the availability, scope and classification of literature published on the various topics relating somehow to Kirlian Photography. It is not meant in any way as being conclusive or comprehensive and reflects only what the author found striking or perceived (form own experience) to be relevant for this work within the time constraint.

3.1 Brief history

3.1.1 Tesla

Tesla, Nikola (1856-1943) is known to have been a researcher and inventor in the field of electricity. (Seifer, MJ. 1996) His inventions included the induction motor, the electrical-power distribution system, fluorescent and neon lights, wireless communication, remote control and robotics. Of interest to this work however was his involvement not only in above mentioned topics but also electrotherapy. Tesla recognized the medicinal worth of high-frequency electro-magnetic waves as reported by patients who claimed to have experienced relief of pain and arthritis but never registered any patents in this field. (u.A. 1994) During the time that alternative medicine offered electrotherapy as cure for even cancer, Tesla developed no less that 50 types of coils and experimented with light and other vacuum effects even x-rays. He wanted to imitate the aurea borealis in an attempt to create pure light by ionizing gasses in a fluorescent tube brought close to a Tesla coil. (see figure 2 & 3 – Seifer, MJ. 1996)

Fig. 2: Tesla(1898) with 500kV going through his body



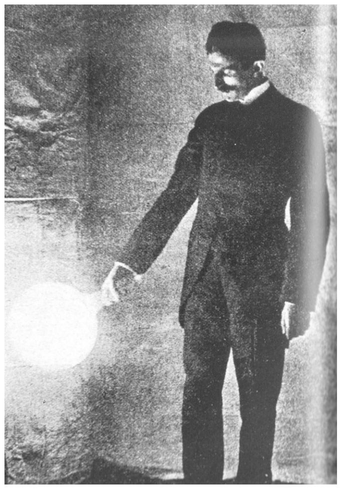


Fig. 3: Tesla´s cold wireless lamp

3.1.2 Lichtenberg

Lichtenberg figures are branching electric discharges that sometimes appear on the surface or the interior of insulating materials. After discharging a high voltage point to the surface of an insulator, he recorded the resulting radial patterns by sprinkling various powdered materials onto the surface. By then pressing blank sheets of paper onto these patterns, Lichtenberg was able to transfer and record these images as early as 1777. (Jörgensen, MO. 1934 and Amin, MA. 1947)

3.1.3 Kirlian

Simyon Kirlian is named as the accidental discoverer of the so-called Kirlian image formed on a photographic plate after it came into contact with a high-voltage discharge in 1939. (referenced observation by Tiller, WA & Boyers, DG. 1973, Lay, P. 2000, Chmela, H. 2000, McCarron-Benson, J. 1989 and almost every other reference mentioned under this chapter) These Kirlian images are used as evidence of the existence of an aura surrounding, or being emitted by living and inanimate objects. The relevance of these images seem to vary depending in which spheres of science you happen to be exploring. Although based solely in hearsay it is mentioned by various authors that Kirlian himself was reported explaining this phenomena as being the transformation of non-electrical properties of an object to electrical properties through the motion through a field that then transfers charge from the object onto photographic film. (Rebmann, A. 1996) This vague statement afforded many researchers the opportunity to pursue the presentation of colourful images under the auspices of being evidence of a new form of “energy”,”very weak bio-electromagnetic emission by bio-photons”, “bio-energy” or “bioelectrography”, to name but a few terms very loosely used in texts. (www.gdvusa.org/research2.html)

3.2 First observations - Google Scholar search results

When search results are tabulated using numbers of hits, a pattern emerges that could (in this case) simply imply the greater availability of information in digital format per time frame searched. The conspicuous difference in magnitude between key words hinting at physics and those with a more pseudo-scientific nuance however is noteworthy.

Some basic variations and mostly English terms were searched. Search options were further specified to exclude citations and patents. Table 2 represents the number of hits for the indicated searched terms on 29 June 2012.

Tab. 2: Some Google Scholar search results

Searched terms	**Number of hits for 1980 - 1990**	**Number of hits for 1991 - 2000**	**Number of hits for 2001-2012**
Corona discharge	5530	11700	16000
Korona entladung	23	43	219
Corona discharge applications	2790	6440	15700
Corona discharge fundamentals	1760	4060	14200
Corona discharge theory	2660	4950	15100
Corona discharge plasma	2420	5820	14100
Corona discharge photography	1340	2320	7090
Corona discharge imaging	828	3090	14600
Corona discharge imaging photography[4]	675	1330	4460
Corona discharge plasma fundamentals theory applications	258	649	2170

4 Ebrahim, H. 1982 Kirlian Photography: an Appraisal. Mr. Ebrahim was consulted during the research phase for chapter 1. Never mentioned as having published again on this topic after 1982.

Corona discharge plasma fundamentals theory applications imaging	150	337	1730
Corona discharge plasma fundamentals theory applications imaging photography	88	166	651
Corona discharge plasma fundamentals theory applications imaging photography Kirlian	1 (book)	1 (book)	12
Corona discharge plasma fundamentals theory applications imaging photography GDV	1 (scientific)	0	3 (non-scientific)
Corona discharge Kirlian photography	6 (3 books)	45	141 (42 in past 2.5years)
Korona entladung Kirlian fotografie	1	12	47
Corona discharge Kirlian	6	45	144
Korona entladung Kirlian	0	8	14
Kirlian Photography	86	208	788
Kirlian fotografie	22	95	333

These numbers is of use merely to indicate a trend and to make a cursory evaluation of the state of interest in these various aspects.

3.3 Method for choosing references for this study

As such the data in table 1 was used to determine that it would not be beneficial to this study to evaluate each item per search term as it would be cumbersome and time-consuming. It is seldom the goal of any study to read and know all existing articles on a topic (Marder, MP. 2011) It should be mentioned that a detailed literature study and evaluation using cross-referencing and clearly defined criteria for selection would greatly improve the intended goal of the lesson plan in chapter 5.

References mentioned here were chosen based primarily on interest and perceived importance to the general theme. No citations have been followed. To this end four divisions were initially created namely Coronal discharge (as being the theoretical foundation with preference to established physics peer reviewed journals), coronal discharge applications (other than Kirlian Photography), Coronal discharge cross-over (references impersonating true science and as such not published in well known peer reviewed journals) and Kirlian Photography (references offering information under the explicit name). References were eliminated from these categories when judged to not being clear, authoritative, giving a good overview of a field or answering some questions posed during this study. (Marder, MP. 2011) Others were included precisely because they were none of these and could thus be used to illustrate the aspect of reliability in scientific research or the lack thereof. (Walker, IR. 2011)

Wesiack uses a reference to Kuhn´s work to underline his opinion that determined scientific progress can only be achieved through a shift in paradigm. (Wesiack, W. 1994) He further states that organised science has to measure all research methods within its realm. This would mean that all results and conclusions must be evaluated in light of the knowledge available. In this case whether the claims made by researchers pertaining to Kirlian images, within the scope of coronal discharge, are reliable.

Both German and English material have been used for referencing purposes although the vast majority of works are in English. This reflects the proportion of English and German material available.

While sifting through the articles deciding what is relevant and what is not, the author started with what is written about Kirlian photography and how it is explained. Some time was spent trying to find scientific published material that offered clear methodology, tests done for parameters influencing the images and then research about these changes that can be observed. In order to verify the claims made, it became necessary to investigate the actual physics mentioned. To this end scientific articles mentioned under the heading “Corona Discharge” includes works where either the terminology found in Kirlian related articles are used (e.g. Plasma, discharge, electron avalanche, streamers, glow-discharge etc.) or where the author found articles considering some of the parameters needed for explaining the actual Kirlian images.

“*Normal people* do not yet have an awareness of the significance that plasma physics have in science today. Not only because it is a younger branch of physics and has therefore not found its way into school textbooks but also because of the abstract nature of its theories.[5]" (Wienenger, H.1980) Wienenger continues to say that in his opinion it is not possible to teach even the most elementary of concepts in any significant way as the school curriculum is lacking the core content required for plasma physics. The author will endeavour to include some of these articles into chapter 5 as support and proof in order to give the students the opportunity to interact with true scientific articles covering theoretical physics as control variable for evaluating any other material under investigation.

3.4 Corona Discharge – some theoretical aspects

3.4.1 Preliminary observations

There seems to be enough evidence that plasmas and electric discharge is well researched and it is interesting to note that the work done by e.g. Peek is quoted in popular internet sites as authoritative with regards to calculations of conditions required for corona discharges. (Mayerhoff, E. 2007) Wikipedia devotes an entry to Peek´s law (Peek, FW. 1929) for example with reference to inception voltage, irregularity of object surface, distance between electrodes, thickness of electrodes, air density, temperature and pressure as variables for a corona discharge. (wikipedia) Mayerhoff presents a very brief summary of corona and its effects using only the most basic terminology and offering a schematic of a corona detection system. Wikipedia offers uncluttered popularly written information under the search term "Corona discharge" (wikipedia). This could be used as first introduction to students, maybe as a reading exercise to make them familiar with some subject vocabulary.

Seen chronologically there exists no clear advance of the focus of articles published of research of the mechanisms behind corona discharge to more application orientated topics. This is interesting to note as it illustrates an aspect of Nature of Science. Illustrating the co-evolution of theory and application Goldman describes the following anecdote. "Gas discharges have been used for chemical purposes ever since Birkeland´s *electric gun* (really a linear motor) short-circuited during a crucial demonstration in Oslo around the turn of the century. The resulting DC arc was blown out in a gigantic fan by the magnetic field, dispersing the assembled dignitaries and all hopes of defence contracts. However, it also gave

5 Translated by the author from the original German text.

Birkeland the extended but thin slab of hot plasma he needed to convert air to nitrogen oxides." (Goldman, M. et.al. 1985)

The following is a brief discussion of some chosen material arranged by age to further illustrate the above statement.

3.4.2 Plasmas – the basics

A brief summary of plasma physics including what it is and how it is created is made accessible to a reader with rudimentary knowledge using clear language and precise descriptions by Wienenger. The mechanism of ionization is explained and a whole chapter devoted to gas discharges. Types, mechanisms, energy distribution, intensities and wavelengths are included. Plasmas as electrical switches are discussed as well as some other applications. (Wienenger, H. 1980) He offers schematic insight into the electric current-potential characteristics through all discharge types.

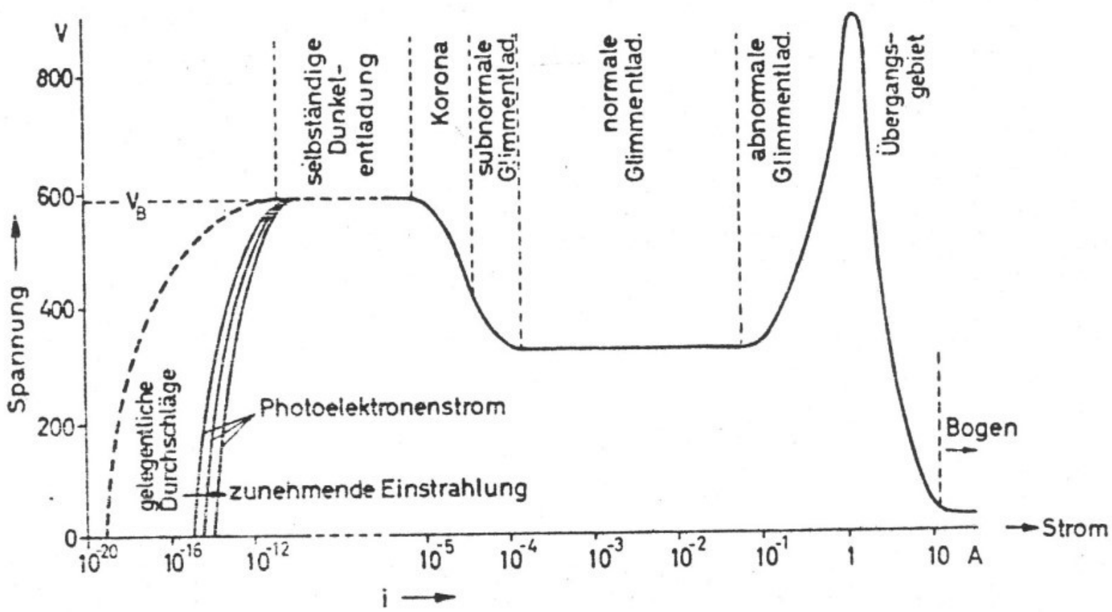


Fig. 4: Strom-spannungscharakteristik des gesamten Gasentladungsbereiches.

Of special interest is the description of glow-discharge which is said to be the type of discharge recorded during the Kirlian process.

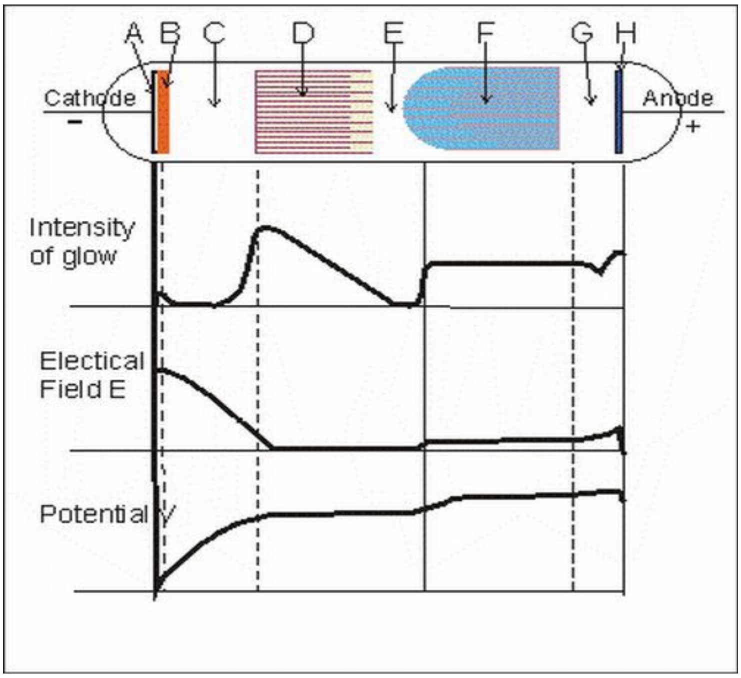


Fig. 5: A simple glow discharge configuration

Source: (Salsac, L. & Nelis, T. 2006)

Translated freely from the German text by the author and elaborated upon by Salsac & Nelis, these areas include:

The **Aston Dark Space (A)** is a thin region close to the cathode. The electrical field is strong in this region accelerating the electron away from the cathode. The Aston dark space has a negative space charge, meaning that electrons outnumber the positive ions in this region. The electron density and energy is too low to efficiently excite the gas, it consequently appears dark.

In the **Cathodic Glow, (B)** the electrons are energetic enough to excite the neutral atoms during collisions. The cathode glow has a relatively high ion density.

The **Cathode dark space (C)** is a relatively dark region that has a strong electric field, a positive space charge and a relatively high ion density. In this region the electrons are accelerated by the electric field. Positive ions are accelerated towards the cathode. They cause the emission of secondary electrons. These electrons will be accelerated and cause the creation of new ions through collision with neutrals.

The **Negative Glow NG (D)** is the brightest intensity of the entire discharge. Electrons carry almost the entire current in the negative glow region. Electrons that have been accelerated in the cathode region to high speeds produce ionisation, and slower electrons that have had inelastic collisions already produce excitations. The negative glow is predominantly generated by the slow electrons. The NG is the region where most exciting and ionising collision processes occur because of the high density for both negative and positive charged particles in this area. At the end of the negative glow, the electrons have lost most of their energy, excitation and ionisation processes cease to exist.

The **Faraday dark space (E)** separates the negative glow from the positive column. The electron energy is low in this region. The net space charge is very low, and the axial electric field is small.

The **Positive Column (F)** is a luminous region that prolongs the negative glow to the anode. It has a low net charge density. The electric field is just large enough to maintain the degree of ionisation to reach the anode. It is the positive column that lengthens to form a long, uniform glow region.

The **Anodic glow (G)**is slightly brighter than the positive column. The anode glow is the boundary of the anode sheath.

The **Anode dark space (H)** or anode sheath is the space between the anode glow and the anode itself. It has a negative space net charge density due to electrons travelling towards the anode. The electric field is higher than in the positive column.

Goldman writes a corona discharge is, per definition, a gas discharge where the geometry confines the gas ionization processes to high-field ionization region(s) around the active electrode(s). He continues to discuss types of DC coronas and their features including unipolar current density distributions, energy, momentum and mass transport in unipolar coronas.

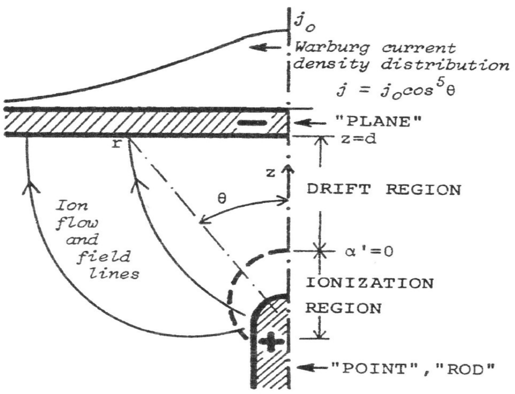


Fig. 6: A typical point-to-plane geometry.

here shown with positive point, and some commonly used terms. The surface α' = 0 marks the outer limit of ionization region. (Goldman. 1985)

3.4.3 Some variables of corona discharge

Corona process applications emphasize one of two aspects of the discharge: the ions produced or the energetic electrons producing the plasma. The ion identities depend on the polarity of the discharge and the characteristics of the gas mixture, specifically on the electron attaching species. The electron energies depend on the gas characteristics and on the method of generating the corona. In an application using ions, the corona induced plasma zone occupy a small fraction of the total process volume while a process using the electrons will fill most of the volume with the plasma. (Chang, JS. et.al. 1991)

Work devoted to the comparison between numerical and experimental determination of the velocity profile of an ionizing front (primary streamer) in a DC positive point-to-plane corona discharge in dry air at atmospheric pressure was found to discuss parameters such as nature of gas, pressure, inter-electrode gap and curvature radius of the active electrode. (Grange, F. et.al. 1995) Optical measurements of the velocity was performed using a photomultiplier and a single-slit device. The simulation results were supported by experimental results. Front velocity in most of the gap is about $2x10^7 cm.s^{-1}$ and the profile presents an increase when the streamer leaves the point electrode and when it reaches the cathode.

Further results of experimental investigations of the DC corona discharge in multipoint-to-plane geometry in air flowing transversely to the electric field was presented in Journal of Electrostatics. It was found that for positive polarity the time-averaged discharge current increases within the range of the gas velocity from 0 to $0.5m.s^{-1}$, and then decreases again. The corona onset voltage also increases by about 25% for a velocity of $4m.s^{-1}$, as compared to still air. As the gas velocity increases the pulsed current amplitude of the onset streamers decreases, but it increases in the breakdown streamers. (Jaworek, A & Krupa, A. 1996)

Streamers are growing filaments of weakly-ionized non-stationary plasma produced by an ionization front that moves through the non-ionized matter. (Dujko, S. et.al. 2010) They have applications in diverse areas of science and technology ranging from their role in creating the lighting and transient luminous events in the upper atmosphere to industrial applications such as those used for the treatment of polluted gases and water. Subject overlapping research offers further application possibilities to this field. During an optical study of active species produced by a pulsed streamer corona discharge in water it was found that radical formation was very dependent on the discharge conditions (applied voltage polarity peak values, discharge electrode tip curvature radius) and on the physicochemical parameters (pH, conductivity of the water and additives). The radical density increased greatly when gas was bubbled in the discharge region. In this study analysis of optical emission spectra was used for the detection of O, H and OH radicals. These radicals play in important role in the killing of bacteria and the degrading of organic compounds. (Sun, B. et.al. 1997)

It is interesting to note that an article was produced on the fundamentals of corona discharge as late as 2001. When comparing this work to that of Wieninger it is clear the depth of knowledge had increased multi-fold. Veldhuizen (author of multiple articles in this field) mentions in the introduction that this article also indicate where knowledge of the processes involved is still marginal or even lacking. Only volume discharge is discussed and not surface discharge that plays a role in configurations using the dielectric barrier or the packed bed reactor. The developmental steps during the growing of a positive corona is discussed in detail. The paper states that corona current stops after the streamer head reaches the cathode but many processes continue to occur in the gap after the discharge has stopped. e.g. Attachment, recombination, diffusion, vibrational relaxation, metastable quenching and radical reactions. Some of these aspects are further explored by Dujko in reduced electric fields ranging from 1-1000 Td (1Td = 10^{-21} Vm^2) where it is found that attachment dominates the ionization in this energy region. (Dujko, S. 2010) Of special relevance to this study is the remarks made in the conclusion: "From all the information given above one may get the idea that the situation is well known. This is, however, not the case. Many processes are only estimated or assumed." (van Veldhuizen, EM. 2001) It goes on to explain that e.g. Field emission, photo-ionization, diffusion, recombination and collisional de-excitation are still topics for further investigation. It is in light of these and other such remarks that the lesson plan in chapter 3 will endeavour to assimilate criteria for measuring the reliability of research.

A numerical model of the negative corona plasma along a thin wire in dry air is presented in the work of Chen & Davidson. The electron number density and electric field are determined from solution of the one-dimensional coupled continuity equations of charge carriers and Maxwell´s equation. The electronic kinetic energy distribution is determined from the spatially homogeneous Boltzmann equation. A parametric study is conducted to examine the effects of linear current density, wire radius and air temperature on the distribution of electrons and the Townsend second ionization coefficient. (Chan, J & Davidson, JH. 2003) Dujko uses a multi-term theory for solving the Boltzmann equation and a Monte Carlo simulation technique to investigate the electron transport in mixtures of molecular nitrogen and oxygen.

3.4.4 Nature of science perspective

Looking at the sources referenced by all of these authors one cannot help but be overwhelmed by the sheer load of papers and books produced on this very small part of physics. Students would benefit to consider the effort of the scientific community in relation to their own learning. Nobody is able to know, understand and apply all scientific knowledge available, but rather the individual determines his own width and depth of interaction with knowledge according to his degree of science literateness[6]. (Gräber, W. et.al. 2002) Furthermore, it is the opinion of the author that the degree to which results are published and the depths into which these research projects go in this particular field of physics (as an example), should inhibit any pseudo-scientific comparisons between science and non-science. It is therefore an educational goal that students should learn to discern for themselves why they choose to believe or reject presented evidence.

3.5 Coronal discharge Applications – other than Kirlian photography

Wikipedia mentions a list of commercial and industrial applications and sneaks in Kirlian photography as one of these. In this section however the focus is on applications other than Kirlian photography including any applications using the GDV (gas discharge visualization) device based on the Kirlian technique. There is no shortage of examples.

3.5.1 Ozone

"Many chemical products can be synthetized by corona discharge, but ozone is so far the only one of industrial importance" (Goldman, M. et.al. 1985). Ozone is a highly reactive, potent biocide that has recently received regulatory approval for many food contact

6 Translated by the author from the German text.

applications. (Palou, L. et.al. 2007). It is used primarily for the purposes of sanitation and to control post harvest diseases. Industries use ozone to enhance shelf-life and safety of food products, to sanitize equipment, packaging materials and processing environment. (Kim, JG. 2003). The interest and use of ozone in dentistry and oral hygiene has seen a dramatic increase in recent years. (Azarpazhooh, A. et.al. 2008 and Baysan, A. Lynch, E. 2004) Waste water disinfection remains a promising field for the application of Ozone. (Buffle, MO. 2006) Although there are numerous examples of the use of ozone it is hardly the only application of corona discharge of industrial importance .

3.5.2 Surface treatments

Coronas are widely used as chemical reactors for surface treatment of polymers, in particular to increase wettability and their adhesivity to ease printing, painting, sealing, coating etc. From the point of view of printing, the dense and impervious structure of extrusion coatings is challenging. Flame and corona treatments increase the surface energy by introducing oxygen containing functional groups on the surfaces of low density polyethylene and polypropylene more than helium and argon plasma treatments. In the case of flame treatment higher surface energy and oxidation level lead to better print quality, i.e. toner adhesion and visual quality. (Tuiminen, M. et.al. 2010) Atmospheric pressure plasma is highly suitable for treating the surfaces of thermally sensitive polymers. In a further application, plasma in a controlled gas atmosphere offers a replacement for wet-chemical adhesion promoters. (Förster, F. 2010) Hardly any materials such as PP, PE, PA, PET, single-layered or multi-layered, metal coated, as part of laminate or similar would be printable without corona treatment. (www.softal.de)

3.5.3 Imaging

Electro-photography is mentioned as being one method of arranging 100 million pigmented plastic particles on a sheet of paper to faithfully replicate an original. (Pai, DM. & Springett, BE. 1993) Processes and phenomena involved are discussed with specific reference to the gaseous ionization during the charging step. As part of the Nature of Science topic underlying the lesson plan in chapter 3 it is important to note the definitions and terminology as used by established physicists.

The journal of Non-crystalline Solids already published papers investigating electro-photography as early as 1980. A photo-receptor made of a thin layer of P-doped Si prepared by glow discharge of SiH_4 when placed between two metal electrodes (Ni/Cr) was adequate to give sufficient charge-retentivity (t_d = 30sec) for negative corona and using its photo-discharging characteristics. Excellent photo-sensitivity (4erg/cm^2 for half-decay) and wide spectral sensitivity (<750nm) were attained. (Shimizu, I. et.al. 1980)

Electrostatic imaging is a technique which provides a method for determining indented impressions on paper used for forensic purposes. (Ellen, DM. et.al. 1980)

Electromagnetic Discharge Imaging (EDI) is used for the non-destructive detection of imperfections and inhomogeneities in solids. Even on a layer of opaque insulation material damage can be detected. The results however are influenced by a host of variables associated with the waveform generator, the dielectric air gap and the specimen type. (Sih, GC. & Michopoulos, JG. 1986)

Studies about measurement techniques for investigation of corona charging are stimulated by industry demand related to adjustment of Xerox-photography processes, development of electrets, and assessment of poly-ethylene films for cable insulation. Corona discharge has a wide range of applications, such as charging the photosensitive layer and the toner particles in photocopying machines, modifying the wet-ability of plastics films, and conditioning the electrets for air filters. In all these situations, it is important to evaluate the surface charge density and compare it to the dielectric rigidity of atmospheric air. (Tabti, B. et.al. 2009) In the case of corona-charged insulating films, as with 0.3mm thick PP sheets deposed directly on the surface of the grounded plate electrode, the surface potential decreases faster when higher initial grid potential is used. Thermal conditioning seems to improve the corona charging of non-woven PP media.

3.5.4 Corona creating motion

Corona generation is a requirement for a functional EHD thruster. Electro Hydro Dynamics is the study of the flow of a fluid under the effect of an electric field. It is mentioned that the principle of ionic air propulsion with corona generated charged particles has been known since 1709 and published in print. De Seversky patented the Ionocraft (patent no: US3130945) in

April 28, 1964. Other patents include US patent no: 2949550 titled "Elektrokinetic Apparatus" by Townsend Brown on 3 July 1957 and Brown & Bahnson´s design US patent no: 3223038. Various improved versions have been designed. (http://blazelabs.com) This could possibly be of some interest to students and will be explored in chapter 5.

3.5.5 Automotive industry

Natural fibre composites are used for door panels, seat backs, dashboards and interior parts by the automotive industry. Compared to glass op mineral fibres, natural fibres exhibit many advantages such as low abrasiveness, renewable character and low density. (Ragoubi, M. et.al. 2012) Many authors have focussed their investigations on the chemical treatment of fibres to increase their compatibility with polymeric matrices. (Gandini, A & Belgacem, MN. 2011) The hydrophobic character of polyolefins is not consistent with hydrophilic reinforcements as natural fibres and therefore different modifications have to be carried out for a better compounding. Fibre-matrix adhesion is improved by using physical treatments such as plasma, laser, corona and vacuum UV bombardments. Treatment of fibres by corona discharge results in a surface oxidation and an etching effect as shown by X-ray photo-electron spectroscopy and scanning electron microscopy. This leads to an improvement of the inter-facial compatibility between matrix and filler. (Ragoubi, M. et.al. 2012)

Goldman also mentions radical chemistry (to improve combustion by the products of silent discharge), diagnostic techniques (to detect and measure gas contaminants by what is called plasma chromatographs and fire detectors based on this principle) and electrostatic applications (unipolar corona drift regions contain ions of one sign only, and no plasma, is the obvious reason for their extended use as chargers in electrostatic apparatus, like precipitators, paint guns, fertilizer projectors, separators, xerographic copiers, voltage generators, and even lightning protectors.

3.6 Coronal discharge cross-over applications and Kirlian photography

3.6.1 Nature of Science in cross-over articles

Under cross-over the author understands articles that mentions the Kirlian method of producing images captured on film or a digital camera but without defining what is measured or how the apparatus functions and the software works. The articles offer their results without defining and exploring all the parameters influencing the images, apparatus or software. Making a connection between astrological topics, hermetic philosophy and natural science is not new to our generation (Thorndyke, L. 1951) nor is it without importance. Finding the inter-connection between macro- and micro-cosmos (or the universe and the human body) is probably the motivation behind philosophers and scientists exploring their environments by thought or experiment. Psychologists, psychiatrists, and biologists are looking for ways to measure the influence of as wide a variety of things on the human body as is conceivable. "Extravagant claims are being made about the (Kirlian)[7] process based upon very little information. To sort out this controversy will require careful experimentation under well-controlled conditions leading to completely reproducible results." (Boyers, DG. Tiller, WA. 1973)

Cross-over articles, when measured to the criteria of having a hypothesis, repeatability and predicting results, variation of single variables and comparison to some standard theoretical model, fails to produce valid conclusions of their results (Walker, IR. 2011). Most articles appear in peer-reviewed journals (meaning researchers in the same field of interest). This highlights the importance of the scrutiny of the scientific community, accreditation governing bodies and the responsibility of scientists´ contributions to the expansion of knowledge. The lesson plan in chapter 5 will endeavour to afford the students the opportunity to "participate in authentic activities similar to those in which professionals participate" (Swarat, S. et.al. 2012) as a means to create an awareness of the Nature of Science and processes involved in true science.

"Plasma discharge phenomena can be observed both in organic as well as inorganic systems, the main difference between these being the fact that, under the same experimental conditions images of living organisms change whereas those of inorganic systems remain the same." (Assumpcao, R. 2008) These changes are well documented in a multitude of experiments, some of which will be mentioned in the following pages. Comparison between results from these studies however is not possible because the apparatus is never described clearly and not standardised. This effectively eliminates the scientific community as validating body in published works. Which begs the question: what does it mean when work is published in peer-reviewed magazines?

[7] Inserted by author for clarification

Another feature of cross-over articles is the various terminology used for what is essentially Kirlian photography (Kirlian, SD. Kirlian, WC. 1961). e.g. High voltage (HV) plasma imaging (Assumpcao, R. 2008), Gas discharge visualization detecting electro-photonic glow (Mazurkiewicz, J. Tomasik, P. 2012; Korotkov, K. 2002), electro-photography (Hovsepian, W. Rupert, P. 2011), corona discharge imaging (Kwark, C. Lee, CW. 1994), corona discharge photography (Boyers, DG. Tiller, WA. 1973), Aura photography (Stanwick, M. 1996). In the author´s opinion this, together with the fact that articles as well as websites use physics terms connected to aspects of alternative medicine or spiritual literature, create the the impression that these articles are authoritative as far as explaining the results are concerned. When using these articles during the lesson plan care will be taken to discuss how students decide what information to trust. (Hargittai, E. et.al. 2010)

3.6.2 Description of the selected content

As a diagnostic tool, Kirlian photography has some potential of contributing to the larger understanding of the human condition. Opinions differ however as to what exactly is measured. Stanwick argues against the diagnostic use of these produced images and deliberately mentions paranormal and Kirlian photography in one breath. (Stanwick, M. 1996). “Recently, aura images are used to find out the energy levels of the body which is then used to diagnose diseases.” (Rajesh, R. et.al 2011). They further mention the changes in the “subtle energy distribution of the individual” and makes the statement that “the result shows that the aura images are effectively treated as medical images”.

Other medical related topics include depression and anxiety in learning English a a second language (Hovsepian, W. Rupert, P. 2011 & Kostyuk, N. Meghanathan, N. et.al 2010), exploring the “alteration of the sympathetic nervous system in autistic children” (Kostyuk, N, Rajnarayanan, RV. et.al. 2010), rhythmic changes to biochemical properties in saliva (Hacker, GW. et.al. 2011), interaction between ultra-weak electromagnetic radiation from organisms and water (Berden, M et.al. 1997) which showed that water “non-chemically exposed to growing and dying spruce seedlings influences the germination of seeds and their growth”.

It is mentioned that the Gas Discharge Visualization method “is made possible thanks to a technological application of quantum physics. (Korotkov, K. 1998) The GDV method could “detect quantum changes parallel to the body´s clinical changes in pathologies where the patient had a below normal level of energy, after being treated with systemic medicine” (Rangel, JAO. Del Castello, O. 2005)

Biometrics is the field of science which brings together biology, physiology, psychology, computer science, mathematics, statistics and engineering. “The biometric models existing nowadays are based on fingerprint, face, iris, voice, signature, hand geometry, palm, and vascular pattern recognition” finding applications in “security, forensic, convenience and medical biometrics.” (Kostyuk, N. Cole, N. et.al. 2011) GDV is said to be a method to “monitor patients and compare their natural photonic emission before and after surgeries, cancer treatments, energy healing, physiotherapy etc”.

According to Priya, “researchers have found that the changes in the colour, brightness and patterns of light detect the changes in the emotional conditions of humans.” (Priya, B. Rajesh, R. 2011) Using sectioning analysis of pictures of fingers and a system loosely based on acupuncture points, software gives the appearance of the whole aura of a person. This “Kirlian image captures the distribution of human bio-energy field called an aura”.

A device called the “Geowave device” was tested using the GDV system and it was found that “in the geopathic zone, the detected areas of glow were statistically significantly smaller than in the more neutral zone. The corona projections showed well-recognisable points of body energy deficits in the geopathic zone, mostly associated with the lymphatic system.” (Hacker, GW. et.al. 2005)

During a study to determine the effect of long term exposure to different garments on the corona discharge created around a human finger tip, it was found that neither the mood of volunteers nor the exposure to textiles had an influence on coronal parameters. “This can be associated with the adaptation of the human body to a given textile set. It is also possible that they provoke a sensor reaction only at the beginning of the contact and that it diminishes after a certain period of time depending on the set of clothes, so that it is impossible to register this reaction by means of corona discharge films.” (Ciesielska, I. 2010)

3.6.3 Reliable results and conclusions?

Studying controversial topics using controversial apparatus could lead to some interesting results. Interpreting these results however could prove to be difficult. “Homeopathy postulates that infinitesimal amounts of active substances diluted in water or alcohol produce substantial changes in living organisms.” (Assumpcao, R. 2008) Using the so called, HV plasma images, this study records results in table format pertaining to “(a) size of the corona discharge halo, (b) density/concentration of the concentric lines and (c) the observed colour”.

Another example of where physics language is used together with Kirlian images is made by a very competent looking article. (Mazurkiewicz, J. Tomasik, P. 2012) “The (electromagnetic) field induces a plasma (around animate objects) which can be seen in a 'native' state solely by some people who frequently combine this ability with therapy involving biofield, so-called bioenergothrapeutics. Commonly, gas discharge visualization (GDV) of *such*[8] plasma under a high voltage is applied..” The first of three conclusions made in this article states that “'Native' plasma and that induced by external electric field differ from one another not only by the concentration of excited species.”

In his book titled Kirlian Photography, Peter Lay mentions that the readers should decide for themselves how to interpret the images obtained.[9] Throughout the text he mixes physics and spiritual jargon in such a way as not to commit his own opinion or interpreting any of his pictures. While this could be helpful in the lesson series in chapter 5 it could be a frustrating resource for teachers to use.

Some articles (typically not published later than 1995) have obtained results for research exploring some physical aspects that could influence images formed by a Kirlian device. Sweat composition and sweat rates are compared while mention is made that mental and physical well-being could influence images. (Ebrahim, H. & Williams, R. 1982) Using the

[8] Italics added by the author for clarification, not part of original text.
[9] Translated from the original German text.

device as a possible biomedical imaging tool is investigated while effects such as electric field intensities and their frequencies, on the resulting image is observed. (Kwark, C. & Lee, CW. 1994)

With reference to the images formed by Kirlian photography: “one has only to read the work of Loeb to realize that we are dealing here with the corona discharge phenomenon called 'streamers'.” (Boyers, DG. & Tiller, WA, 1973) After carefully considering many aspects they conclude by saying: “We should note that although it now seems possible to account for the majority of the strange colour effects observed in Kirlian photography, one cannot be certain that this is the only or the proper explanation. Whether or not other new energies are also involved must be determined by the careful experiments of the future.” As a quotation this is valuable as it illustrates various aspects of the Nature of Science. As a work of research it is valuable as it systematically considers most, if not all, aspects to be investigated when trying to explain or interpret Kirlian images.

3.6.4 Investing in Kirlian?

Lastly, this search delivered 58 patents using the search words “Kirlian photography” “Kirlian” or “GDV”. The oldest of these being filed in 1975 titled “Glow pattern viewing cell and apparatus for living organisms.” (US patent. 3994283), although in the patent application of Larry Azure (US patent. 7979121 B2) filed in 2006 titled “Method and apparatus for physiological treatment with electromagnetic energy.” mention is made of patents from 1971 (US patent 3615454A). As part of the abstract it explains that “A photonic accumulator is positioned proximate the subject to receive biophotons emitted there from and to activate the biophotons with a light source.” Far from making the ultimate connection between Kirlian photography and physics some patents use expressive language hinting at the full understanding of the inventor. “Electron avalanche putative energy analyzer” (US patent 2009/0292196 A1) describes “a device and method of detecting and analyzing a vital field (that) places an avalanche diode in the path of vital waves in the vital field.” The latest patent produced by this search is titled “Light therapy device and system for preparing and applying a therapeutically effective liquid” was filed in 2011. (US patent App 13195205) It offers “a light therapy device for applying an image (produced by Kirlian and/or corona discharge photography) of a therapeutically effective aqueous liquid.” This image is then projected onto an object “in particular a living being”.

Patents serve a double purpose for this study. Firstly it illustrates science as part of the discovery and application of knowledge process as well as the legal vs. scientific community as protectors of intellectual property. Secondly, it offers a wealth of vocabulary for students to explore.

4 Nature of Science

“Science´s greatest achievement has been its success as a way of knowing. Its capacity to provide evidence for reliable beliefs has made it one of the paradigmatic discourses in contemporary society, and one to which many other forms of knowledge aspire.” (Osborne, J. 2001)

Science and specifically physics is not the accumulation of facts, knowledge and theories in an exclusively logical way. It is not the observation of phenomena only and it does not hold all the explanations to how the world works. Science is the practice of questioning and exploring with the goal to learning something by unravelling the woven threads of the known and the unknown and spinning it back into the fabric of being, which inevitably leads to asking more questions. The insight that science is not static, absolute or finite but a perpetual renewal of information, subject to continuous revision and the spirit of creative reasoning, these two aspects form the essence of the Nature of Science.

This is however the opinion of the author and an overview of other literature will be presented in this chapter.

4.1 What is Science?

The question of what is science can only be answered after the question what is physics? Seen purely semantically physics is the science dealing with properties and interactions of matter and energy, according to the Concise Oxford Dictionary. It is seen as the description of the behaviour of the non-living Nature in as far as no material change occurs[10]. (Wiesner, H. et.al. 2011) If this is our definition of physics what then is a general answer to what is science? “The most common answer to this question in the literature is: 1) body of knowledge, 2) method, and 3) way of knowing”. (Lederman, NG. 2006) From this it should be understood that although physics is science, not all science is physics. What does physicists learn about science while practising physics. What are the requirements a scientist needs to contribute to the body of knowledge?

10 Freely translated by the author from the German text.

Scientist´s nature of science views demonstrate connections between individual authentic scientific contexts but their views are not necessarily consistent with any particular philosophical position nor does it suggest a predictable relationship between Nature of Science views and science discipline. (Schwartz, R. Lederman, N. 2008) At a general level Nature of Science views are not different among science disciplines or investigative approaches. The variations do occur however and develop at levels of specificity to individual contexts and experiences as opposed to broader discipline levels. Schwartz mentions that theoretical physicists stood apart from the rest and that this “suggests something about their experience, be it knowledge, research experience, scientific community.” It was further interesting to note that with an average of 25years experience, the scientists engaged in this study reported that “scientists do not typically reflect on their practice.”

It becomes important to then consider what is the nature of science. Is there an ultimate Nature of all Science? Much research had been devoted to this question.

Quoting McComas et.al, a list is presented as summary of what is the consensus about the nature of science.[11] (Wiesner, H. et.al 2011) These are:

- Science knowledge has a tentative character
- Development of scientific knowledge is not only gained through observations, empirical evidence, rational thinking and critical reflections
- There exists no exclusive way to practice science and therefore no universal methodical algorithm to gain knowledge
- the function and status of 'Law' and 'Theory' in science is fundamentally different
- Physical results are examined and accepted through the scientific community of peers (Replicateability)
- Observation and theory are two sides of the coin. They are not mutually exclusive.
- Through the historical developmental phase of physics one can distinguish between an evolutionary phase and a revolutionary phase.
- Physics is part of the social and cultural tradition of a community
- Physical ideas are influenced by social and historical contexts.

[11] Freely translated by the author from the German text.

These characteristics can also be used as educational goals and therefore be used as evaluation tools for the effectiveness of the teaching environment.

4.2 Why is it necessary in the classroom?

Reform documents and other teaching material emphasize the promotion of contemporary views of the Nature of Science. “Within the framework of situated cognition, the assertion is that engagement in inquiry activities similar to those of scientists provides a learning context conducive to developing knowledge about methods and activities through which science progresses, and, in turn, to developing desired views of Nature of Science.” (Swartz, R. Lederman, N. 2004)

From the research of Schwartz & Lederman it is clear that “engaging in authentic scientific enquiry as a successful member of the scientific community is not necessarily sufficient in and of itself to ensure informed conceptions of Nature of Science, or conceptions the same as others within the scientific community.”

It would be naïve to not see that teachers and educators can contribute on multiple levels to the furthering of a scientific minded citizenry. The target of science literacy should be to develop generalized Nature of Science views. This general classification should include: “1) understanding of the core categories of Nature of Science, as described in reform documents; 2) understanding connections among Nature of Science aspects and science experience; and 3) recognizing that aspects may manifest themselves in a variety of ways, that is variability by content.” (Schwartz, R. Lederman, N. 2008) An approach is needed to make students and teachers reflective.

Science literacy is the term used for a level of cognitive involvement with science that should be accessible to the majority of people within the community the dimension of which are described in a wide variety of literature including the National Science Education Standards (NRC. 1996) and Benchmarks for Scientific Literacy (AAAS. 1993) Although Shamos wishes to convince his readers that Science Literacy is a myth and as a goal in itself useless he supports the concept of development of critical thinking through the logical nature of the sciences as proposed by Dewey some hundred years ago. (Shamos, MH. 2002) The dimensions of science literacy illustrate where subject specific content and Nature of Science converges. As long as science literacy is the goal within a reflective educational environment it will continue to be something every member of the community will have access to. Bybee proposes a balanced approach in the classroom between the functional, conceptual and multi-dimensional aspects of science literacy. (Bybee, RW. 2002) Science teachers can achieve this balance by not looking for a 'one sentence' description for either Nature of Science or Scientific Literacy but rather students could be schooled explicitly and implicitly using an exposition of aspects.

Bybee includes this list for consideration[12]: (Bybee, RW. 2002)

Nominal Science Literacy

- identify notions and questions as natural science but displays however false themes, problems, information, knowledge or understanding
- False notion of scientific concepts and processes
- Lacking or unsupported explanations of science phenomena
- Topical opinions about science are naïve

Functional Science Literacy

- Use scientific vocabulary
- Defines scientific concepts correctly
- Memorises technical terminology by heart

Conceptual and procedural science literacy

- Understands scientific concepts
- Understands procedural knowledge and skills in natural science
- Understands the relation between the individual parts within a scientific discipline and the conceptual structure
- Understands the fundamental principals and processes of science

Multi-dimensional science literacy

- Understands the specifics of natural science
- Distinguishes between natural science and other disciplines
- Knows the history and character of natural science as discipline
- Has a strong grasp of natural science in society.

Unfortunately the big picture is cause for concern. Professional scientists as well as teachers “ (a) do not possess adequate conceptions of NOS, irrespective of the instrument used to assess understandings; (b) techniques to improve these conceptions have met with some success when they have included either historical aspects of scientific knowledge or direct,

[12] Freely translated from the German text

explicit attention to nature of science; and (c) academic background variables are not significantly related to (individuals′) conceptions of nature of science.” (Lederman, NG. 1992) Precisely this fact makes is absolutely vital to focus attention on the importance of the explicit introduction of the Nature of Science at all levels of education today.

The intellectual discovery of the Nature of Science has a strong affective impact on practitioners of science be they students, educators or professional scientists. In the case of teachers this translates into a better classroom climate. “Classes of the more effective teachers were more supportive, pleasant, and “risk free,” with students expected to think analytically about the subject matter presented. These classes were typified by frequent inquiry-oriented questioning, active participation by students in problem-solving activities, frequent teacher-student interactions, infrequent use of independent seat work, and little emphasis on rote memory/recall.” (Lederman, NG.1992)

4.3 Nature of Science in:

Many science teachers view their high school physics courses “as valuable preparation for introductory college physics” (Sandler, PM. Tai, RH. 2001) and a career in the sciences. How does the Nature of Science manifests itself during an academic career in science?

4.3.1 :The community

One need only read a couple of scientific articles to realise that individual scientists seldom publish research without reference to prior research done or other authors. Furthermore the number of authors listed on a single article has no upper limit and this is a distinct feature of the Nature of Science. Science is not practised in isolation. It is embedded in a society that exists within a cultural, political and religious environment. Phrases like “...there are other aspects that some researchers include or delete..” or “previous studies carried out..” or even “..and about which several observers can reach consensus with relative ease” not only have the function of supporting a specific point of view but is direct evidence of the dependence of science on the community that explores it. It is also precisely the reason all scientific papers have lists of references. This highlights the social and cultural tradition within which science is practised. It indicates the members of the particular community and from this one can construct the social, historical and cultural heritage associated with the research.

4.3.2 :The work

Practising science starts with asking a question and then looking for the answer(s). “Science starts with curiosity about the world.” (Marder, MP. 2011) “The knowledge of science, no matter how much supported evidence exists, may change in the future” (Lederman, NG. 1992) This tentative nature of knowledge is the driving force behind the continued effort to critically evaluate existing and new explanations attempting to make sense of our world. “Observations (and investigations) are motivated and guided by, and acquire meaning in reference to, questions or problems. These questions or problems, in turn, are derived from within certain theoretical perspectives. Often, hypothesis or model testing serves as a guide to scientific investigations.” (Lederman, NG. 1992) He continues to say that “what is important is that (we) understand the evidence for current beliefs about natural phenomena.”

Creativity and innovative thinking however is of critical importance as science, “contrary to common belief, is not a totally lifeless, rational, and orderly activity. Science involves the invention of explanations, and this requires a great deal of creativity by scientists.” (Lederman, NG. 1992) He continues to clarify that “Observations are descriptive statements about the natural phenomena that are 'directly' accessible to the senses (or extensions to the senses)...” as integral part of empirical science. Observations however is only the flip side of the coin. The other side, equally important is theory. The one leads to the other but without a prescriptive direction.

The moments in science, when a particularly creative individual (or group of individuals) step beyond the known and accepted is coined to be “revolutionary” (Kuhn, 1996). Developing these and other ideas are said to occur during the “evolutionary” phase of science, so called 'normal science' (Popper, 1963). Methods of practising science differ between different disciplines but the spirit of 'making sense of it all' is the common denominator. “A central canon of the scientific method (however) is that experimental results, if they are to be recognised as scientific facts, must be reproducible by independent investigators working in other laboratories.” (Walker, IR, 2011) This is unfortunately not always possible for a multitude of reasons. It is not only the reproducibility of results that lends scientific knowledge its tentative nature. “It follows that scientific knowledge is never absolute or certain. This knowledge, including “facts,” theories, and laws, is tentative and subject to change. Scientific claims change as new evidence, made possible through advances in theory and technology, is brought to bear on existing theories or laws, or as old evidence is reinterpreted in the light of new theoretical advances or shifts in the directions of established research programs." (Lederman, NG. 1992)

There will always be new questions or old ones to re-examine. "At its heart science is simple. Science is about checking." (Marder, MP. 2011)

4.3.3 :The presentation of results to community

The formal presentation of scientific work to the community has a strong prescriptive nature and follows a format that is both universally accepted and deviated from within the different disciplines of the sciences. This format is what is taught in schools under the title "scientific method" although sadly, students don´t often have the opportunities to experience the reality of this precedence from texts at their disposal. This is due to the fact that publishers expect the sale of intellectual property and with this one act show blatant ignorance to the true nature of science which is that of the searching enquiring mind. Every science includes a unique vocabulary which effectively excludes any lay-person to come to grips with content and draws a line between peers and non-peers. The general society outside of the scientific community has to rely on popular writers who spend much time and energy condensing research into its essence and precisely because of their style and formatting becomes excluded from the very community they have qualified from.

A quality criterion for selecting some studies and excluding others is that "the selected studies had already passed the criteria of peer-review in acknowledged journals." (Teixeira, ES. 2012) The goal of peer review is to provide a critical review of the process as well as the conclusions other scientist have come to. Does the acceptance of a society of like minded individuals make the knowledge they present valid or true? Is it enough that arguments "are provided in well-known reform documents, the pages of referenced journals and conference rooms at professional meetings"(Lederman, NG. 1992)? It happens sometimes that the social nature of science can lead to collective prejudices. "Unlike other errors, (prejudice) is not widely appreciated, and generally not accounted for." (Walker, IR. 2011) Confirmation bias and 'intellectual phase locking' are terms used to describe aspects of this phenomenon that is not peculiar of the scientific process exclusively.

This leads to further considerations. How does a community of peers react to referenced and well supported criticism from scientists outside their community? By putting forward "reasons where claims made are justified by relating them to the data on which they are based.

Evidence for any claim consists of at least two components – data and warrants. Warrants are essentially the means by which the data are related to claims providing the justification for belief." (Osborne, J. et.al. 2001) In other words, by argumentation. "Argument and argumentative practice is a core activity of scientists. Dialogic argument has a key function in the social construction of scientific knowledge and the interpretation of empirical data." (Driver, R. et.al. 2000) It is the "rational means of resolving controversy" (Siegel as quoted by Osborne).

4.3.4 :In the classroom

Some studies show that educators only teach about the Nature of Science implicitly. "The interaction between teacher´s NOS understanding and their instructional practices occurs without the teachers being aware of it. i.e. unconsciously." (Beauchamp, J. 2011) "This necessitates a focus on individual classroom interventions aimed at enhancing learners´NOS views." (Lederman, NG. et.al. 2002). The aim of this study is therefore is to design a project and lesson plan where the focus is on teaching aspects of Nature of Science through the context of plasma physics by using Kirlian photography as vehicle of introducing students to critical assessment of scientific claims. "Three factors were identified as important for Nature of Science developments: 1) reflection, 2) context, and 3) perspective. (Schwartz, R. Lederman, N. 2004) According to McComas & Olsen, a qualitative analysis of recent science education standards documents from several countries has demonstrated that there is a high degree of agreement about the elements of the Nature of Science that should be communicated to students. (McComas, WF. Olson, JK. 2002) Several important aspects of the NOS include the empirical and tentative nature of science, the distinction between observation and inference and the role of subjectivity and creativity in science. (Abd-el-Khalick, F. et.al. 1998)

The classroom environment should offer the student the chance to step into the scientific community as an active member of a learning society. The "process of sifting through and interpreting evidence to arrive at a defensible interpretation of events" (Osborne, J. et.al. 2001) is a feature of science that needs to be highlighted in the educational environment. "The ability to construct and comprehend hypothetico-predictive arguments (an aspect of procedural knowledge) is necessary for the construction of conceptual knowledge (an aspect of declarative knowledge) because such arguments are used during concept construction and conceptual change" (Lawson, A. 2003) The methods used to teach the traditional content can easily be adapted in order to emphasize all or some aspects of the Nature of Science. Of special importance will be evaluation exercises that focus on the reflective aspects of NOS.

4.3.4.1 When NOS is best introduced?

No clear statement could be found as to when the topic of Nature of Science should first be introduced to students. It seems current research is aimed at what different groups of people understand about the Nature of Science and if this is reflected in teaching practices. To make a guess as to initiate this into the curriculum one would need some deeper insight into the cognitive abilities and developmental stages of different age groups. From personal experience there seems to be a differentiation line between the 3rd and 4th classes in gymnasium type schools. Research should be done to determine susceptibility to a direct approach for the younger learners or a more understated method by always placing emphasis on Nature of Science as an evaluating tool while teaching introductory science concepts. The 4th graders mentioned in this study enjoy challenging their teachers by often asking for ultimate proof while in a learning situation. They clearly have an intuitive knowledge of the nature of science and it is the recommendation of this study that NOS be taught directly and specifically and also very early in the school year. These students although naturally critical seem to lack the ability to follow through with logical consequential thought processes. Reasoning (or argumentation) should be a strong focus at this level. "From a cognitive perspective, constructing arguments is central to the process of thinking." (Osborne, J. et.al. 2001)

4.3.4.2 Constraints

The lack of explicit mention being made to Nature of Science by teachers in the actual classroom environment and planning of lessons is due to various factors. Participants in one study articulated "viewing the Nature of Science as less significant than other instructional outcomes, preoccupation with classroom management and routine chores, discomfort with their own understandings of the NOS, the lack of resources and experience for teaching Nature of Science, cooperating teachers´ imposed restraints, and the lack of planning time." (Abd-el-Khalick, F. et.al. 1998) Furthermore it was found that other constraints also exist and are "related to an intrinsic interaction between educators´ perspectives on the Nature of Science, pedagogy, and instructional outcomes."

Teacher preparation programs has an important role to play to educate future and current teachers on the importance of Nature of Science as well as providing experience and material on teaching and assessing NOS. According to Abd-el-Khalick "such experiences should be based on practical understandings of how students learn and what it takes to modify instructional activities to reinforce the development of adequate understandings of the Nature of Science." The importance of both cognitive and meta-cognitive processes should be explored. "Talk is used as a meta-cognitive strategy to help clarifying thinking but the talk strategy is more likely to be implemented face-to-face with friends than with the class teacher" (Bowler, L. 2010) Students are often hindered not only by the strong social component attached to meta-cognitive knowledge but also by " a lack of procedural knowledge related to information problem solving and a lack of conceptual knowledge" in the area of NOS. (Bowler, L. 2010)

Lack of resources is a problem on multiple levels. As Nature of Science is not an explicit part of any textbooks available to students and teachers it is necessary for either the teacher or student or both parties to search for and gather relevant material. It is mandatory for teachers to" focus on instructional and practical implications of skill at differentiating more from less useful sources of information during the initial information gathering and selecting in the context of 21st century Internet sources." (Braasch, JLG. et.al. 2009) "Factors such as availability of equipment and time to learn new skills (and interest in those skills) play their part in determining the extent to which ICT merges smoothly into physics teaching". (Regan, T. 2010) Much research has been done about how students look for and evaluate information from websites and how they assess credibility. (Hargittai, E.et.al. 2010; Brand-Gruwel, S. et.al. 2009; Walraven, A. et.al. 2009)

Constraints however are not obstructions but merely challenges that need to be met by academic researchers and in-service educators alike. The author is of the opinion that the only real constraint is a lack of commitment on the part of teachers and educational institutions to spend the necessary time to integrate and expand on their already vast experience .

4.3.4.3 Possible methodology

" A 'grasp of practice' serves as a reasoning resource for inquiry and citizenship abilities associated with the nature of science understanding." (Ford, M. 2008). It makes sense therefore to design a situation in which "reactions of scientists and lay-people to science-related claims in the popular media can be compared, underlining the appropriate ways scientists tend to criticise such claims."

One obvious method follows logically from the above. Research based teaching: This offers complex problem-situations for which students then try to find a solution by imitating professional scientists.[13] (Höttecke as quoted by Wiesner, H. et.al. 2011) Peterßen states that without a comprehensive and solid foundation of cognitive knowledge, Psychomotorical proficiency and affective information (attitude and outlook) the student will not be in a position to solve problems.[14] (Peterßen, WH. 1999) Problem-solving involves the "deliberate, planned, intentional, goal directed, and future-orientated mental behaviour that can be used to accomplish cognitive tasks." (Bowler, L. 2010) When using this method it is important to take into consideration the four types of knowledge involved during problem-solving: "Factual, procedural, conceptual and meta-cognitive" (Anderson as quoted by Bowler, L. 2010) Bowler further states that students who monitor their activities are more likely to be successful in their learning. Keeping a research diary could be one helpful component during this exercise. This affords the student the opportunity to reflect and the educator a method for evaluation which will be mentioned again later.

Another method for improving students´ confidence in science could be to displace them to a place and time in history, create the contextual environment and consider the possibility of their being in a much better position to develop scientific concepts. "It is noteworthy that coursework in the History of of science has been suggested by many as a possible way to enhance conceptions" of the Nature of Science. (Abd-el-Khalick, F. et.al. 1998) He continues that they hesitate to recommend this as it is solely based on intuitive assumptions, anecdotal evidence and has virtually no support from empirical literature. If students are expected to learn about the nature of the scientific enterprise from the History of Science they will have to be guided to make a conceptual leap.

13 Translated freely from German text.
14 Freely translated from German text.

Stating it as an aim to enhance this area of research, Teixeira offers a systematic review of studies that investigate teaching experiences applying History and Philosophy of Science (HPS) in physics classrooms. (Teixeira, ES. et.al. 2012) It is mentioned in the conclusions that although favourable results were found when looking at the effects of the didactic employment of HPS on the areas of argumentation and meta-cognition, comparatively few studies provide the pedagogical references to justify the use of these strategies, and few were concerned with assessing the students´ prior or achieved knowledge of HPS.

The author suggests the use of so-called controversial topics such as for example Kirlian Photography, which is ideally situated between true science and the para-normal. Other themes could maybe include psychological phenomena, evolution or gene-manipulation. Jewetts´ book title actually offers the direction when thinking about themes: *Physics begins with another M....Mysteries, Magic, Myth and Modern Physics*. (Jewett, JW. 1996)

Educators have to remember that their own lack of knowledge does not have to exclude any topics as an open-ended teaching method has much potential to bring across the Nature of Science. It could even be considered positive when the teacher experiences new topics through the eyes of his/her students, enquiry being a central aspect of the Nature of Science.

4.3.4.4 Evaluation

The critical question is how to evaluate educational outcomes, be it cognitive knowledge gained, the level of scientific literacy achieved or the depth of understanding the Nature of Science.

As an 'authentic learning environment' (Berger, V. 2006) the classroom as well as the laboratory contribute to the development of a sense of the Nature of Science such that these could be used during evaluation procedures. The seventeen functions of experiments (Berger, V. 2006) in the classroom can be used to test as outcomes. In itself these are also fields of research within science education and physics didactics. These are (in no order of importance)[15]:

1. creating interest
2. introduction to the natural scientific thought- and work processes
3. increasing motivation

[15] Freely translated from German text.

4. furthering self-confidence
5. opportunity for primary experiences
6. reminders of facts and principles
7. promotion of reflective and critical faculties
8. heightening effective learning through practical activities and multiple access possibilities
9. promoting of situational and problem solving rational argumentation
10. promoting trust in own skills
11. promoting the self-responsibility and independence
12. development of cooperation and communication skills
13. connecting Theory and the Empirical
14. securing of knowledge
15. building of practical skills
16. recognition of general principles and invariables
17. individualizing of learning and adaptability of skills profile.

Measuring each or some of these points however becomes a serious research project in itself in order to develop instruments of evaluation. “Empirical studies are currently addressing: The structure of student competencies, assessment and measurement models for competencies, the development of competencies and the definition of proficiency levels.” (Köller, O. Parchmann, I. 2012)

A more practical method for evaluating the effectiveness of a lesson series about the Nature of Science uses one of the methods to promote a reflective attitude towards science. During the lesson-series or project students should be asked to keep diaries of their day to day activities and their thoughts about these. Bowler suggests that each participant draw a time-line, as visualizing exercise, and along this line describe four elements of the learning process using different coloured pens. These four elements could be a)their actions, b) the reasons they took these actions, c) the questions they asked themselves, and d) the feelings they experienced. Lastly they should be asked to identify the point at which they felt they had a focus on the topic. (Bowler, L. 2010) It is recommended that a follow-up interview is done to somehow verify the content of the time-line.

Most importantly, the evaluation phase of a lesson-series in Nature of Science should also be a learning experience in own right. Learning is a life-long objective of education and as such evaluation should be an integrated and continuous internal and occasionally external activity. Evaluation is one aspect of the nature of science and does not measure achievement but rather development. This is true for both teacher and learner. Every participant in the learning environment should do an "estimation of effectiveness" (Peterßen, WH. 1999) of the program.

Without this most reflective of steps, the whole concept of teaching Nature of Science is worthless. The goal of educating citizens to critically engage in the social problems facing a technologically advanced society and be able to form own opinions and re-direct own activity towards responsible interaction with information cannot be accomplished without ongoing lifelong evaluation.

4.3.5 : Life

"A scientifically informed citizen is not easily swayed by science-related claims in the media, yet is keenly aware of the information that would increase confidence in them. Thus, at a most basic level, a scientifically informed citizen is able to understand scientific claims as tentative, as deserving a fitting degree of confidence and scepticism – a stance that is neither gullible nor inflexible, but appropriately critical." Ford, M. 2008)

This lies at the very heart of the contribution science teachers can make to the community. It is not merely the stimulation of interest in sciences, nor the furthering of students into scientific industrial positions and research. Science teachers give the basis of scientific knowledge every secondary school educated person will have during his/her life, but ultimately it is the educators who shape the world view and the confidence with which individuals and communities will engage in life-long learning. "Individuals and societies have to make personal and ethical decisions about a range of socio-scientific issues, such as genetic engineering, reproductive technologies and food safety, based on information through the press and other media." (Osborne, J. et.al. 2001) Through a grasp of the Nature of Science the individual will come to see the inter relations between society and knowledge. He will be able to critically evaluate the variables contributing to own personal problems and develop strategies to cope with these. He will be able to find his own position of importance within his different communities by taking co-responsibility for the reaction to media reports and news by applying the principals of the Nature of Science into a broader context.

"A genuine interest in science is an important part of scientific literacy." (Swarat, S. et.al. 2012) They continue to make the statement that lack of interest in science "impedes students from becoming scientifically literate citizens, as they are unlikely or even unable to engage with important science-related societal issues." Student (and therefore also adult) attitudes and beliefs about physics and learning physics are shaped by their classroom experience. (Adams, WK. et.al. 2006) Gender plays a determining role in interest in physics. (Lavonen, J. et.al. 2005 & Wodzinsky, R. 2002) According to Adams women score lower on statements involving "real world connection" but higher on "sense-making/effort" type questions. Men score significantly higher in interest in physics. The most interesting topics, especially for girls, were connected with human being. (Lavonen, J. et.al. 2005) Women also seem "better at identifying what ideas physicists believe but they are less inclined to feel that these ideas are valid or relevant for their experiences." (Gray, KE. et.al. 2008) All students who found content to be "personally meaningful" also found it to be interesting. Three main sources of creating interest are "novelty, autonomy, and social involvement". (Swarat, S. et.al. 2012) Therefore it is not the topic of physics that is important but the degree to which students find it of personal meaning. Explicit teaching of the Nature of Science seem to be an "approach that show science is useful (and valuable) in everyday life" (Lavonen, J. et.al. 2005) Related to the international ROSE study there are four distinct values to consider: "a) the 'green' value set linking ethical concerns, the environment, and scepticism about interfering with nature. b) 'techno-investor' who demonstrates enthusiasm for investing in technology (especially space-related) and in science research. c) the 'science-orientated' value set reflects interest in science programs on TV and in science-fiction, and a belief that a 'scientific way of thinking' can be widely applied. d) The 'Alienated from science' set, associated with mostly young women in the workforce who are not interested in a job related to science." (Haste as quoted by Baram-Tsabari, A & Yarden, A. 2009)

Without critical rational discussion, little progress can be made towards a genuine debate about socio-scientific issues. "Much of what we do in science is based on a belief that the study of science will produce good analytical thinkers" (Osborne, J. 2001). Kuhn (1999) summarizes the sentiments of the author most eloquently: "to achieve control of their own thinking is arguably the most important way in which people both individually and collectively take control of their own lives.”

5 Kirlian in the classroom

Experience in teaching has offered the author the insight that teaching is not static and being successful means you have made use of enough variation during the time you had the privilege of engaging with your students that some of them look forward to joining your class during the next year. It is always the aim that they learn something, that they gather and improve the skills they will require for their futures, that they become engaged in their learning and that your contribution to their education makes a small difference to the level of success they will achieve. This chapter aims to be a tool by which students will come to experience the Nature of Science.

The actual lesson series differs in lay-out from the rest of this study as part of the assignment was that this section should be such that a teacher can take it out of the main work and be able to use it in an actual class situation.

5.1 Exposition of some aspects of lesson series

The lesson plan was designed to progress in difficulty. The aim is to have both cognitive and meta-cognitive activities that is not too complicated leaving the slower students feeling so overwhelmed that they don´t even start but simultaneously contains enough of a challenge on some level for gifted students to not instantly feel bored. Being able to complete tasks gives everybody a boost in self-confidence. The size of the font of the worksheets is bigger to make reading easier but also to invoke the association with being easy as normally the hand-outs from primary school is printed in larger letters.

5.1.1 Introductory session 1 – the puzzle

Puzzle building is a skill most children learn at a young age and it is associated with, hopefully, enjoyment, a sense of play, being easy and something everybody can do. To make sure this is taken to the next level, handicaps are introduced. Communication becomes important as also keeping careful notes on the activities. The goal is to emphasise that all people do not have the same strengths and weaknesses but that everybody can contribute to the process. Verbalising intent and suggestions clearly forms part of the skills acquired or enhanced. Puzzle building has the aspects of hypothesis, experiment and critical evaluation built into every piece you pick up and put down. Fitting pieces by no means suggests that it is right and seldom offer an idea of the final picture. As scientists we often play around making the pieces of information fit to form a pattern. Having a puzzle inside a puzzle strengthens the idea that different communities and different scientists all contribute and work towards understanding and explaining how our world works. It stresses the importance of communication, research, literature as form of communication, peer evaluation and the tentative nature of our knowledge. What they thought was a finished puzzle turned out to be a part of a bigger picture.

There are six individual puzzles which range in puzzle size to introduce some differentiation. The The group 1 puzzle has only four pieces, A4 paper, with what is hoped to be a very clear indication of what it is part of. It is hoped that group 1 will intuitively know that the end result will be for all groups to combine their puzzles. Hopefully they will be curious enough when they are finished to want to know if this prediction of there´s is right. The topics on each puzzle also range in level of difficulty. The words found on all pieces contain some of the vocabulary needed for this project. From own experience it is known that most often students struggle to internalise new words in physics or to express themselves when explaining something exactly because the importance of terminology is not stressed enough. Ones memory needs time to accommodate new information and this is done (if a little too quickly) during the time it takes to do worksheet 1 and 2. This puzzle will be useful for as long as cellphones dominate the students lives. When new technology takes preference this puzzle will be all but obsolete. Learning occurs optimally when all senses are involved and the brain is actively crossing from left to right hemisphere. How memory becomes first short term and then long term is a process of making the new connections and then reinforcing these subtly. This is done during session 2 of this project.

5.1.2 Session 2 – vocabulary

All the words required for worksheet 3 can be found somewhere on the big puzzle. Finding the words is not difficult, but it could be that some or all of the words are new, if not the words then the meaning or content of the word. Worksheet 3 and 4 aims to offer one method of clarifying the meaning of words or finding some information about new topics. It is hoped that students will realise that many words (e.g. Field) in a dictionary has a different meaning altogether to what physicists understand under the term. This is to stress the importance of not only using the terminology correctly but to emphasise how words are used to create association in the mind of a reader or listener and how these associations contribute to our judgement on relevancy and manipulates our trust. Furthermore many misconceptions stem from the fact that students are not given the opportunity to accommodate new vocabulary and while the teacher tries to explain new concepts the student is very often left feeling frustrated because the words used are new and the student cannot hold onto either word or explanation.

5.1.3 Session 3 – method for exploring new topics

Worksheet 5 is less about the actual applications than it is about meta-cognitively becoming aware of the process or method for exploring new topics. The first step was to find definitions or meaning for new terminology. During this exercise students gather the very basic information and is asked to evaluate the usefulness or relevance of the information. Often websites don´t indicate the author which should cause great caution in students. Intellectual property is the cause of many court cases and authors normally want to be associated with the product of their creativity or skill. Reading is hard work for a lot of people and students often rely on visual images, colour and brand names when judging what information to use. It is hoped that the six different groups would have different approaches and that students can learn from each other.

5.1.4 Session 4 and 5

An introduction to any new topic can be made accessible by asking questions about it. These two worksheets offer a possible structure for getting to know the topic of Kirlian Photography but can be applied to any topic really. It is important to note the use of vocabulary and so consider the scientific method behind any researched phenomena. Students are given the opportunity to make value judgements while exploring the controversial topic. Students are also made aware of the fact that a literature study is not just about gathering information but about keeping detailed records and that “better” sources offer this information required freely and clearly. Students don´t always know how to do effective searches on the internet. These worksheets hope to bring this aspect home to the students.

5.1.5 Session 6 and 7

Students are now considered to have some working knowledge as background to the topic of Kirlian photography. During session 6 and 7 students, guided by questions in the worksheets, will become familiar with real scientific articles of obviously different standards. These sessions aim to bring together the previous sessions´ work but also to give the students a frame within which to work when confronted with information that is above their level of understanding. It is the hope of the author that students become fearless in their learning and have some tools to enable them to engage with science from their level.

5.1.6 Session 8

This session is included at this point in the project because now students should be able to ask questions that afford them the opportunity to attempt to find answers from own research. Loosely seen the lay-out of the project follow a format that any researcher would follow when engaging in a new field of interest. Getting to know the vocabulary, finding out what other scientists have already said about the topic, critically evaluating sources and then designing own experiments to be able to accept or deny claims made by a society of peers, or of course, to contribute to the existing body of knowledge. Therefore the scientific method is strengthened through participation as well as explicitly focussing attention to the steps included in the method.

5.1.7 Session 9

Evaluation of knowledge, information, results offered in scientific publications and content taught by teachers should be a critical outcome in school curricula. In session 9 students have the opportunity to evaluate their own progress, the work of the group as well as the effectiveness of the project. This gives helpful indicators to teacher wishing to improve their didactic skills. It also gives the students another glimpse into aspects of the nature of science.

5.2 Educational Material

Kirlian Photography

Corona Discharge or Aura?

Exploration of the Nature of Science

5.2.1 Table of Contents

5.2.2 Materials Needed

Required:

Internet access for PhET simulations and YouTube and others

Overhead projector for transparencies

Computer for video presentation

Glue

Coloured pens (when students don´t have their own)

A3 sheets of paper

6x A5 notebooks

Optional for clarification:

Van der Graaf Generator

High Voltage power supply

Connecting cable with crocodile clips

Petri dish

Metal Electrodes with different shapes

Transformer oil

Grass seeds

Kirlian Camera or GDV apparatus (or the parts required to build one)

5.2.3 Science Education and Content Outcomes

Following recommendations to the Nuffield Foundations[i] including some Content Standards as set out by the National Science Education Standards as well as aspects from the Revised National Curriculum Statement the following outcomes are expected.

Recommendation 1

The primary goal of science education across the EU should be to educate students both about the major explanations of the material world that science offers and about the way science works. Science courses whose basic aim is to provide a foundational education for future scientists should be optional.

Outcomes

- Identify questions and concepts that guide scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Recognise and analyse alternative explanations and models.
- Communicate and defend a scientific argument

Recommendation 2

More attempts at innovative curricula and ways of organising the teaching of science that address the issue of low student motivation are required. These innovations need to be evaluated. In particular, a physical science curriculum that specifically focuses on developing an understanding of science in contexts that are known to interest girls should be developed and trialled within the EU.

Outcomes

- Work effectively with others as members of a team, group, organisation and community
- Organise and manage themselves and their activities responsibly and effectively
- Use science and technology effectively and critically showing responsibility towards the environment and health of others

i Osborne, J et.al. Science Education in Europe: Critical Reflections. A report to the Nuffield Foundation. London. 2008

- Demonstrate an understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation

Recommendation 3

EU countries need to invest in improving the human and physical resources available to schools for informing students, both about careers in science – where the emphasis should be on why working in science is am important cultural and humanitarian activity – and careers from science where the emphasis should be on the extensive range of potential careers that the study of science affords.

Outcomes

- Participate as responsible citizens in the life of local, national and global communities
- Be culturally and aesthetically sensitive across a range of social contexts
- Explore education and career opportunities
- Develop entrepreneurial opportunities

Recommendation 4

EU countries should ensure that the emphasis in science education before the age of 14 should be on engaging students with science and science phenomena. Evidence suggests that this is best achieved through opportunities for extended investigative work and "hands-on" experimentation and not through a stress on the acquisition of canonical concepts.

Outcomes

- Design and conduct scientific investigations.
- Record observations and compare to expected results
- Attempt an explanation to satisfy the condition that results should be repeatable as cornerstone of true science

Recommendation 6

EU governments should invest significantly in research and development in assessment in science education. The aim should be to develop items and methods that assess the skills, knowledge and competencies expected of a scientifically literate citizen.

Outcomes

- Perform self evaluation in the form of confidence and interest survey before and after the project.
- Participate self consciously in teacher assisted peer-evaluation.
- Offer proof of the level of cognitive retention of theoretical facts and explanations
- Complete a written report inclusive of progress diary and suggestions to better the project.

5.2.4 Teacher-guide

Teacher Guide

Teacher presentations and centre-based explorations introduce students to the basic concepts of coronal discharge and the Nature of Science and the Scientific Method.

Background

Students explore the concepts of static electricity, electric fields and coronal discharge through activities, internet and experiments. This includes making predictions, recording observations and data and drawing conclusions.

The final outcome of formulating multiple criteria describing the Nature of Science and the Scientific Method could be achieved through the topic of Kirlian Photography as possible example of coronal discharge imaging.

Concepts

Nature of science

- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.
- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines.

- Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans.

Scientific enquiry

- Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific inquiries. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists.
- Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories.
- Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.
- Mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating results.
- Results of scientific inquiry—new knowledge and methods—emerge from different types of investigations and public communication among scientists. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge. In addition, the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation.

Content

- History of the development of the modern atomic model
- Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.
- The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons.
- Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus. These outer electrons govern the chemical properties of the element.
- Bonds between atoms are created when electrons are paired up by being transferred or shared. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.
- The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.
- Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.
- Chemical reactions may release or consume energy. Some reactions release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as forming images on emulsion film.
- A large number of important reactions involve the transfer of electrons between reacting ions, molecules, or atoms. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone.
- The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel.

- Between any two charged particles, electric force is vastly greater than the gravitational force.
- Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infra-red radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.
- Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts. These wavelengths can be used to identify the substance.
- In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. Semiconducting materials have intermediate behaviour. At low temperatures some materials become superconductors and offer no resistance to the flow of electrons.

Time

This is a project designed for 3 days or nine 50minute teaching units. It falls, of course, under every teachers´ discretion to spend more or less time depending on the interest level of his or her group.

Target Groups

It is taken as fact that students have never explicitly heard mention of Nature of Science. Therefore it is thought that this program is well suited for any high school class from ages 13 and up. Even if the introductory activity seem somewhat like a game to older students, the point will still come across.

Differentiation

Some differentiation is made to accommodate weaker or slower learners, some activities require more reading while others require students to construct and conduct experiments. Group formation suggestions are made in the teacher-guide to each activity. It is only important that each participant to this project feels that he/she had made a contribution to the whole. It will be part of the groups´ activities to identify strengths and decide how to best make use of these to reach the goals set.

It is the authors wish that each student realises that every individual has strengths and that these contribute to the successful functioning of a society. Weaknesses can become strengths through practice or simply accepted.

The activities builds in level of difficulty and depth of content although assignments in worksheets seem relatively easy.

Procedure

Step One: Preparation

- Familiarize yourself with the guide and the equipment. Make copies of the student guides (containing student worksheets, information sheets, articles) assessment pages and transparencies. Use links suggested on information sheets and make printouts of some of the content.
- Make a day-by-day schedule for the unit according to the skill level of your students and the time you can allot to the activities each day. Each activity is explained in detail beginning on the next page, with the materials needed.
- Collect all materials listed on page 2 of this guide.
- Cut the 6 puzzles (printed on both sides of A4 page) along the lines indicated to create puzzle pieces. Take one piece of each puzzle and put it together with another puzzle.
- Set up 6 centres and divide your students into six groups. Each day, set out the materials the students will need to conduct the days´ activities.

Background Information: corona discharge

Dictionary Definition: corona discharge

An electrical discharge characterized by a corona, occurring when one of two conducting surfaces (such as electrodes) of differing voltages has a pointed shape, resulting in a highly concentrated electric field at its tip that ionizes the air (or other gas) around it. Corona discharge can result in power loss in the transmission of electric power, and is used in photocopying machines and air-purification devices. See also electric arc.

Edited From Wikipedia:

A corona is a process by which a current flows from an electrode with a high potential into a neutral fluid, usually air, by ionizing that fluid so as to create a region of plasma around the electrode. The ions generated eventually pass charge to nearby areas of lower potential, or recombine to form neutral gas molecules.

When the potential gradient (electric field) is large enough at a point in the fluid, the fluid at that point ionizes and it becomes conductive. If a charged object has a sharp point, the air around that point will be at a much higher gradient than elsewhere. Air near the electrode can become ionized (partially conductive), while regions more distant do not. When the air near the point becomes conductive, it has the effect of increasing the apparent size of the conductor. Since the new conductive region is less sharp, the ionization may not extend past this local region. Outside this region of ionization and conductivity, the charged particles slowly find their way to an oppositely charged object and are neutralized.

If the geometry and gradient are such that the ionized region continues to grow until it reaches another conductor at a lower potential, a low resistance conductive path between the two will be formed, resulting in an electric arc.

Corona discharge usually forms at highly curved regions on electrodes, such as sharp corners, projecting points, edges of metal surfaces, or small diameter wires. The high curvature causes a high potential gradient at these locations, so that the air breaks down and forms plasma there first. In order to suppress corona formation, terminals on high voltage equipment are frequently designed with smooth large diameter rounded shapes like balls or toruses, and corona rings are often added to insulators of high voltage transmission lines.

Coronas may be *positive* or *negative*. This is determined by the polarity of the voltage on the highly-curved electrode. If the curved electrode is positive with respect to the flat electrode we say we have a *positive corona*, if negative we say we have a *negative corona. The* physics of positive and negative coronas are strikingly different. This asymmetry is a result of the great difference in mass between electrons and positively charged ions, with only the electron having the ability to undergo a significant degree of ionising inelastic collision at common temperatures and pressures.

Background Information: Nature of Science

- Science knowledge has a tentative character
- Development of scientific knowledge is not only gained through observations, empirical evidence, rational thinking and critical reflections
- There exists no exclusive way to practice science and therefore no universal methodical algorithm to gain knowledge
- The function and status of 'Law' and 'Theory' in science is fundamentally different
- Physical results are examined and accepted through the scientific community of peers (Replicateability)
- Observation and theory are two sides of the coin. They are not mutually exclusive.
- Through the historical developmental phase of physics one can distinguish between an evolutionary phase and a revolutionary phase.
- Physics is part of the social and cultural tradition of a community
- Physical ideas are influenced by social and historical contexts.

Day 1:

Session 1: Introduction to Nature of Science

MATERIALS NEEDED FOR EACH CENTRE: 1x A3 sheet of paper, 1x A5 notebook, 1x blindfold, 2x kitchen towels, 1x ear muffs, one set of puzzle pieces

Objective: ***To form a concept of the aspects of the Nature of Science***

- Introduce Nature of Science as a topic of exploration. Discuss what students think they know about "what is science?". What do they think Scientists think about Science?
- Distribute the Student Guides to the students and have them write their names on the cover.
- **Go to Worksheets 1 & 2**. Review the procedures for the activities with the students. For younger students, review one worksheet at a time, then have the students complete the activity before moving to the next worksheet.
- Emphasize the taking of notes during each phase of the activities, especially predicting the outcome before they begin to do the activity. Individual diaries should include these four elements a)their actions, b) the reasons they took these actions, c) the questions they asked themselves, and d) the feelings they experienced.
- Assign students into groups and groups to the centres. (Weaker students to first puzzle, advanced students to sixth puzzle.) Monitor as they carry out the activities.
- Create floor space large enough to fit individual puzzles into one giant puzzle. (125cmx60cm)
- Review these concepts: scientific knowledge is tentative; nature of Facts, Hypotheses, Law and Theory; Scientific Method; observations and inferences; human error; Results; Peer evaluation.

Session 2: Introduction to vocabulary

MATERIALS NEEDED FOR EACH CENTRE: a puzzle, a dictionary, access to internet through student cellphones.

Objective: ***To become familiar with (possibly) new vocabulary and terms from the content topic of this project.***

- Review topics discussed in previous session.

- Introduce science as having an own vocabulary and explain how without the knowledge of what words mean we cannot communicate effectively with other scientists.
- **Go to worksheet 3 & 4.** Review the procedures for the activities with the students. Highlight importance of keeping of an activity diary.
- Assign students to groups by making sure that there is at least one member from each of the built puzzles in each group. (each new group will now consist of at least one member from the puzzle 1 group, at least one member from the puzzle 2 group etc.) Monitor as they carry out the activities.
- Review these concepts: new vocabulary (let students name these); the importance of definitions for general consensus of meaning of these terms; processes involved while searching for definitions and meaning of words.

Session 3: Exploring application aspects of corona discharge

MATERIALS NEEDED FOR EACH CENTRE: 2x A3 sheet of paper; access to internet through a PC or Laptop.

Objective:

1. ***To become familiar with different applications of corona discharge.***
2. ***Becoming aware of the (gathering) search phase of research (including new vocabulary)***
3. ***Becoming aware of the importance of verification of information (content, date, author credentials, nature of publication)***

- Review topics discussed in previous sessions.
- Assign the same students from session 2 into the same groups.
- **Go to worksheets 5.** Make it clear to the students that session 3 entails doing 1 worksheet per group. There is one resource per group. Every group continues working on their theme from session 2.
- While students start on the worksheet corresponding to the topic they had in session 2, put the A4 puzzle pieces up against a wall as constant reminder of topics and visual strengthening of Nature of Science concepts.
- Monitor their progress.

- Have one student from each group report back to the class about their application topic.
- Have another student from each group offer a brief summary of A3 poster about “actions during search phase of research”.
- Gather A3 posters on “actions during search phase of research”. Put these up on a wall.
- Review the comparison between the puzzle pieces and “observations and theories” in science and between the puzzle-building exercise and aspects of Nature of Science.

Everybody can be a scientist. A puzzle can be finished by an individual or by multiple contributors. The final solution to the puzzle can be achieved from any angle, or any side. Science is all about designing methods for finding and organising the individual pieces, studying the results of what other puzzle builders have achieved and considering what possible final picture could emerge. Ones position within the community and within the time continuum dictates the level of effort and commitment. Then, once a picture appears, scientists consider if this is the only picture possible. Or if there are other pictures that could maybe become a “big picture”. Even with pieces missing scientist can predict what the “big picture” could be by making hypothesis, running simulations and creating theories and of course designing experiments to gather data to support or deny results that lead to conclusions that are always open to critical evaluation by other scientists. All of which could prove to be wrong or simply outdated when new evidence presents itself.

DAY 2:

Session 4: Introduction Kirlian Photography

MATERIALS NEEDED FOR EACH CENTRE: access to internet through student cellphones or a PC or Laptop.

Objective:

1. ***To gain an overview of the topic Kirlian Photography***
2. ***To explore the experimental set-up for Kirlian Photography***
3. ***To identify variables that could influence the Kirlian images produced.***

- Review application topics discussed during session 3.
- Introduce Kirlian Photography by explicitly stating that any videos or images seen are results as presented by unknown individuals in a public forum such as YouTube and

that their conclusions have not been verified by you as teacher. Students should be urged to "put their scientists´ hat on" and watch critically.

- Show video: YouTube: "Auras on SciFi Network´s "Proof positive" (14.14min)
  http://www.youtube.com/watch?v=1yx6PaLTKTk
- Show video - YouTube: "Kirlian Photography Explanation" (18.38min)
  http://www.youtube.com/watch?v=qDOi1BLoN3U
- Show video series – YouTube: Kirlian Photography device part 1 (1.55min)
  Kirlian Photography using sheet film part 2 (5.15min)
  Kirlian Photography using polaroid part 3 (2.56min)
  Kirlian Photography using digital camera part 4 (3.57min)
  http://www.youtube.com/watch?v=5F-4X-5W2VM
- **Go to worksheet 6.** Monitor students as they complete work individually but with conversation allowed.
- Revise the idea of critically evaluating information. Ask students why they simply believe what teachers tell them? Explore how they would go about testing information. Let students offer variables they think (hypothesise) could influence Kirlian images produced.

Session 5: Doing an online literature study

MATERIALS NEEDED FOR EACH CENTRE: access to internet through student cellphones or a PC or Laptop.

Objective:

1. ***To form an impression of the status quo of Kirlian Photography in literature***
2. ***To develop a method for finding information on this topic.***
3. ***Creating a list of terminology used by various authors about Kirlian Photography.***

- Introduce the idea of doing an online literature study as method of gathering information on a topic of interest or study. Discuss different search engines, key words, google scholar etc.
- **Go to worksheet 7**. Read the assignment aloud. Monitor as students work in their groups.
- Review this session by writing all the vocabulary that students identified on the board or overhead.

Session 6: Case Study 1– Article exploring Kirlian Photography

MATERIALS NEEDED FOR EACH CENTRE: 1.) article no.1 from student guide. 2.) access to internet through student cellphones or a PC or Laptop. 3.) coloured markers

Objective:

1. ***To be exposed to an attempt to scientifically explore Kirlian photography by statistically analysing the changes in these images.***
2. ***To apply knowledge from literature study and Nature of Science to form some critical comments about the conclusions and validity of article as contribution to real science.***
3. ***To verify and add to the list of variables that influence image formation of Kirlian Photos.***

- Review variables discussed during session 4.
- Read abstract of article aloud. Then allow enough time for students to read the article for themselves. It is suggested they use coloured markers to highlight new terminology and to indicate where they feel the content is beyond their understanding.
- **Go to worksheet 8.** Briefly mention that the goal is not understanding but rather to investigate which variables the author used and whether these are conclusive.
- Explore the possibility of gaining information from text that contains content that students are not familiar with.
- Form a discussion panel by arranging chairs in a circular shape where everybody can see each other.
- Discuss the observations of each student and their critical evaluation of the article.
- Review this session by mentioning the aspects of the Nature of Science as stated in the background information and which of these were applicable during the session.

DAY 3:

Session 7: Case Study 2 – Exploring physics of Kirlian Photography

MATERIALS NEEDED FOR EACH CENTRE:

1.) **article no.2 from student guide. 2.) access to internet through student cellphones or a PC or Laptop. 3.) coloured markers**

Objective:

1. ***To explore the physics concepts behind corona discharge, plasmas and sparks***
2. ***To be exposed to a peer reviewed scientific article containing some explanations for images formed by using Kirlian Photography.***
3. ***To apply knowledge from literature study and Nature of Science to form some critical comments about the conclusions and validity of article as contribution to real science.***
4. ***To verify and add to the list of variables that influence image formation of Kirlian Photos.***

- Introduce students to the Scientific Method. Mark the main aspects in the article using coloured markers.
- Allow enough time for students to read the article for themselves. It is suggested they use coloured markers to highlight new terminology and to indicate where they feel the content is beyond their understanding.
- **Go to worksheet 9**. Briefly mention that the goal is not understanding but rather to investigate which variables the author used and whether these are conclusive.
- Strengthen the idea of gaining some information from text that contains content that students are not familiar with.
- Form a discussion panel by arranging chairs in a circular shape where everybody can see each other.
- Discuss the observations of each student and their critical evaluation of the article.
- **Transparency**. Review this session by mentioning the aspects of the Nature of Science as stated in the background information and which of these were applicable during the session.

Session 8: Experimental design

MATERIALS NEEDED FOR EACH CENTRE: 1.) access to internet through student cellphones or a PC or Laptop 2.) All material listed under optional.

Objective: 1.*To discuss possible ways to clarify some of the open questions from session 6.*

2.To design an experiment to either verify or deny some or all claims made by author of scientific article from session 6.

NOTE*:* This session can be extended to accommodate the designing and building of an own Kirlian device when interest exists. Or when a device is available, to carry out the various experiments designed by students. Please ensure a scientific report is written by each student should you opt for expanding this session.

- Review topics discussed in previous sessions.
- **Go to worksheet 10**. Point out that during this session students are free to experiment and interact with all apparatus. It is suggested they are given the website for the "phet" simulations site: http://phet.colorado.edu/en/simulations/category/physics/
- Assign students into groups and monitor their actions.
- Review this session by allowing each group to present their experimental design.
- Close the session by briefly highlighting the goals of every session and evaluating if these were met.

Session 9: Evaluation

MATERIALS NEEDED FOR EACH CENTRE:

Objective: 1.*To evaluate the effectiveness of the project.*

2.To compare what students consider to be key concepts of corona discharge

3.To evaluate students understanding of the Nature of Science and the Scientific Method.

- Have each student complete the self-assessment and group-assessment on page 39
- Evaluate effectiveness of this unit using the unit exam on page 40
- Have each student draw a draw a time-line, as visualizing exercise, and along this line describe four elements of the learning process using different coloured pens. These four elements could be a)their actions, b) the reasons they took these actions, c) the questions they asked themselves, and d) the feelings they experienced. Lastly they should be asked to identify the point at which they felt they had a focus on the topic.

Transparency 1: **Nature of Science**

- **Science knowledge has a tentative character**
- **Development of scientific knowledge is not only gained through observations, empirical evidence, rational thinking and critical reflections**
- **There exists no exclusive way to practice science and therefore no universal methodical algorithm to gain knowledge**
- **The function and status of 'Law' and 'Theory' in science is fundamentally different**
- **Physical results are examined and accepted through the scientific community of peers (Replicateability)**
- **Observation and theory are two sides of the coin. They are not mutually exclusive.**
- **Through the historical developmental phase of physics one can distinguish between an evolutionary phase and a revolutionary phase.**
- **Physics is part of the social and cultural tradition of a community**
- **Physical ideas are influenced by social and historical contexts.**

5.2.5 Students Guide

Student Guide

Project: Kirlian Photography

Corona discharge or Aura

Exploring the Nature of Science

Name:____

Class:________________________

Group members Session 1:

____

____

____

____

____

Session 1 Worksheet 1

Activity: Puzzle building

Objective: To form a concept of the aspects of the Nature of Science

Procedure:

- ♦ Assign the role of group leader to one member of the group. The group leader will take notes during this activity.
- ♦ Blindfold one group member, loosely tie the hands of one group member in front of him, loosely bind the mouth of one group member and put ear muffs on one group member. (Firstly, this is to make you aware that everybody has at least one weakness but that the group as a whole can compensate for these weaknesses. Secondly, this is to emphasise the role of good communication between group members)
- ♦ Predict what picture will form. Write this down.

____

- ♦ Build the puzzle as a team. You may have to find a missing piece and/or an extra piece from another group.
- ♦ Write down what picture did form.____________________

Session 1 Worksheet 2

Activity: Puzzle building (continued)

Objective: To form a concept of the aspects of the Nature of Science

Procedure:

- Write down the method used by the group to solve the puzzle. Check with the group-leader´s notes.

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- Walk around and look at each of the 6 puzzles. Predict what picture will form when all 6 are put together.
- Write this down.

  ____

- Now build the giant puzzle on the floor. There might be pieces missing.
- Write down what picture it formed.

  ____

- Can you be sure even with pieces missing?

  ____

- When can you be absolutely sure?

  ____

- Compare the aspects of building your puzzles with what scientist do. Fit the descriptions from column B to those of column A.

	Column A (Puzzle-building)			Column B (Science)
1	Individually shaped pieces		a	Experimental method
2	Arranging by colour or size		b	Scientific peer evaluation
3	Fitting two or more pieces		c	Making conclusions
4	Looking for missing pieces		d	Measurements from experiments (data, facts)
5	Working as a group		e	Results
6	Predicting a picture		f	Literature study (gathering information from other scientists)
7	Writing down what picture formed		g	Hypotheses

- What do you think physicists do? (describe the job of a scientist)

  ____

  ____

- Do you think building a puzzle is like being a scientist?

  ____

- Explain your answer:

  ____

Session 2 Worksheet 3

Activity: Word search

Objective: To become familiar with (possibly) new vocabulary and terms from the content topic of this project.

Procedure:

- Find and circle as many words from the puzzles as you can.

D	I	S	C	H	A	R	G	E	Q	W	E	R	T	P
A	S	D	F	A	T	O	M	G	H	J	K	V	L	H
Y	R	O	E	H	T	T	S	Z	U	I	S	O	P	O
A	S	F	D	F	G	H	U	R	T	Z	C	L	U	T
Y	X	L	I	G	H	T	N	I	N	G	I	T	X	O
E	C	A	M	E	R	A	T	Z	U	I	E	A	L	G
S	D	M	F	G	H	N	M	K	Z	T	N	G	E	R
T	N	E	M	I	R	E	P	X	E	Z	C	E	H	A
E	F	G	P	O	W	E	R	L	I	N	E	S	H	P
R	G	H	N	K	L	O	Z	T	R	W	Q	Y	C	H
S	H	R	O	U	D	O	F	T	U	R	I	N	G	Y
D	R	T	H	J	I	Z	K	L	N	G	R	W	W	S
P	H	O	T	O	C	O	P	Y	D	O	H	T	E	M
E	R	T	Z	C	V	N	R	G	H	J	K	C	B	P
Q	N	O	R	T	H	E	R	N	L	I	G	H	T	S

Hint:

8→ 3← 6↓

Session 2 Worksheet 4

Activity: Word search

Objective: To become familiar with (possibly) new vocabulary and terms from the content topic of this project.

Procedure:

- Write down 10 other words found on the puzzles.
- Use your dictionary to write down the definition of each word.

Session 3 Worksheet 5

Activity: Exploring applications of corona discharge

Objective:

- To become familiar with different applications of corona discharge.
- To become aware of the (gathering) search phase of research.
- To become aware of the importance of verification of information (content, date, author, nature of publication)

Procedure:

- Read the attached teacher-handouts (or go to the websites indicated in the information sheet) and answer the following questions. You may search the internet for more information on this topic. Group work.
- What is the topic?

  ____

- Who is the author?

  ____

- What date was it published?

  ____

- Write the web address where this information came from:

  ____

- Do you believe the information?

  ____

- Explain your answer:

  ____

  ____

- Write 3 other web addresses you consider to have useful information about this topic.

  ____

  ____

  ____

- How did you find these? Explain your method.

  ____

  ____

  ____

  ____

- What is corona discharge?

  ____

  ____

- Briefly explain the physics of this application.

  ____

  ____

  ____

  ____

  ____

- In your group make an A3 poster with the theme: “our actions during search phase of research”. Use colour.

Information Sheet

puzzle no.1 Ozone

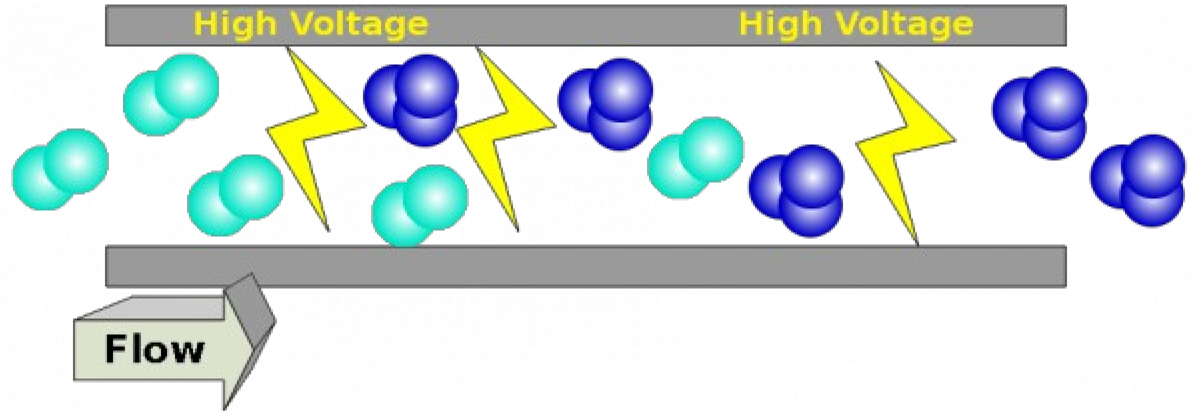

Fig. 7: Corona discharge makes ozone.

Source: (http://www.ozonesolutions.com/info/ozone-production-in-nature)

http://www.plasmafire.com/

http://www.wedeco.com/en/expertise/ozone-technology/ozone-oxidation.html

puzzle no.2 EHD Thrusters

Fig. 8: Flying object?

Source: http://jnaudin.free.fr/html/advprop.htm

http://blazelabs.com/l-intro.asp

http://www.zamandayolculuk.com/cetinbal/liftersvacuum.htm

puzzle no.3 Discharge detection

Fig. 9: Detecting discharge

Source: http://zaviation.ca/products/std/ultrasonics.htm

http://www.pdghelicopters.com/corona-discharge-patrols.html

http://www.industrycortex.com/products/results/static-electricity-discharge

puzzle no.4 Shroud of Turin

LANGUAGE: Italiano English Español www.vaticaninsider.com

VATICAN INSIDER

LA STAMPA.it :: Monday 12 March 2012

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03/ 9/2012

Radiation could have created Holy Shroud image

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An expert in the field has published a new study that suggests radiation as the likely cause of image formation on the Shroud

ANDREA TORNIELLI

PADUA

The Shroud of Turin, the linen sheet which, according to tradition, Jesus' body had been wrapped in and carries the imprint of a man who was crucified in the same way described in Gospels, is still a mystery. A recently published study has concluded that the most likely hypothesis for the explanation of the origin of the image imprinted on the shroud is radiation, particularly the "corona discharge effect."

This is according to Giulio Fanti, Professor of Professor of *Mechanical* and Thermic *Measurements* at the Department of *Mechanical* Engineering of the University of Padua who has been carrying out research on the Shroud for a number of years. The academic has presented the results of his study in an article that has just been published by the

THE HOLY SHROUD

Fig. 10: Vatican Insider

Source:http://shroudofturin.wordpress.com/2012/03/12/could-corona-discharge-have-created-shroud-of-turin-image/

http://www.sci-news.com/physics/scientists-suggest-turin-shroud-authentic.html

puzzle no. 5 Copying

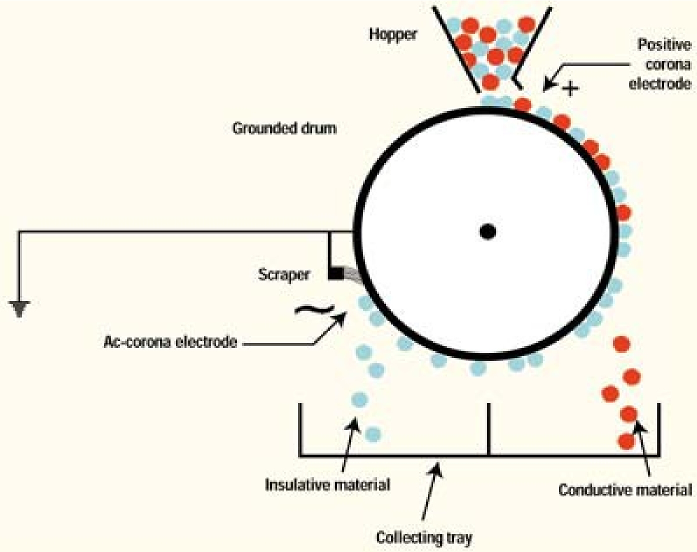

Fig. 11: Copying

Source: http://www.ce-mag.com/archive/2000/novdec/mrstatic.html

http://www.refillplanet.eu/main/index.php/support-ink-and-toner/cathowprincartwork/item/319-how-laser-printers-work

http://www.physics.hku.hk/~phys0607/lectures/chap06.html

puzzle no.6 Corona and adhesives

Fig. 12: Corona and adhesives

Source: http://www.adhesives-equipment.com/partners/3DT.php

http://plasticsnetwork.files.wordpress.com/2007/12/corona-treatment.pdf

http://www.softal.de/content/en/downloads/10_10MoleculFunctionalizationPolymer.pdf

Session 4 Worksheet 6

Activity: What is Kirlian Photography?

Objective:

- ♦ To gain an overview of the topic Kirlian Photography
- ♦ To explore the experimental set-up for Kirlian Photgraphy
- ♦ To identify variables that could influence the Kirlian Images produced.

Procedure:

- ♦ Watch the videos carefully. Make notes of aspects that strike you as interesting or strange.

  ____

  ____

  ____

- ♦ Do you believe what is said during the TV program "Proof Positive"? Give a reason for your answer:

  ____

  ____

- ♦ Describe the experiment that the TV program did. What was their goal, hypothesis, apparatus, variables, measured results, and their conclusions. Does the conclusion make a statement about the goal?

*Goal:*____

*Hypothesis:*____

Apparatus:____

Variables:____

Results:____

Conclusion:____

____

____

____

- Describe the experimental method and apparatus in as much technical detail as you can.

  ____

  ____

  ____

  ____

  ____

- Did you notice that the commentators use words but sometimes mean something else than physics? Discuss in your group what does these words mean: Low ampere current, high voltage, frequency, wavelength, energy, electrode, earthed, corona, aura. Add your own words for further discussion. ______________________________

____

____

____

____

- Kirlian images do record something on film. Is it bio-energy, aura or simple corona discharge or both or something else? To start exploring a possible answer we need to think what variables could influence the formation of the image on a film or even video screen. List as many as the group can come up with. Do not criticise or discuss these, just write these factors down.

____

____

____

____

____

____

- If you had you own Kirlian device, what would you like to investigate?

  ____

Session 5 Worksheet 7

Activity: What else is written about Kirlian Photography?

Objective:

- To form an impression of the status quo of Kirlian Photography in literature
- To develop a method for finding information on this topic
- To create a list of terminology used by various authors about Kirlian Photography.

Procedure:

- Discuss strategies to follow to best find information about this topic on the internet.
- Write down 2 books, 3 articles, and 5 websites offering useful information about Kirlian Photography. Complete the reference card on each worksheet with relevant detail.

Reference Card	Today´s Date:
Type: Book _____ Article ________	Website:______________________________
Title:	
Author:	Accessed on date:
Information about author:	Website last updated on:

Publisher: Date:	Magazine name:
Location:	Volume: No: Page numbers:
Numbers of pages used:	Keywords used:

- Are you in a position yet to explain Kirlian Photography? Support your answer with reasons.

  ____

  ____

- Do you think it could be useful to us in some way? Why?

  ____

- In order to create a list of the vocabulary used in this field of interest write down a list of as many keywords as possible that you have come across while reading about this topic. (e.g. Give different names for Kirlian images, Kirlian camera and Kirlian photography)

____

____

____

____

____

- Describe step-by-step the strategy your group followed to find information on this topic?

____

____

____

Session 6 Worksheet 8

Activity: Case study 1: Article exploring Kirlian Photography

Objective:

- To be exposed to an attempt to scientifically explore Kirlian photography by statistically analysing the changes in these images.
- To apply knowledge from literature study and Nature of Science to form some critical comments about the conclusions and validity of article as contribution to real science.
- To verify and add to the list of variables that influence image formation of Kirlian photos.

Procedure: Article: Statistical analysis of corona discharge images

- Read the abstract again: In one sentence say what is it that the article will be telling you about.

____

____

- Which properties of these images were used to analyse data?

____

____

- What variable was investigated during this study? __________

- What other variables are mentioned in this article? ____
____

- In your opinion, does this study include all possible variables and how these influence the images produced? ____________

- Is the apparatus and method followed during this experiment clear to you? ___________
Explain:

____

____

- Do you believe the results and conclusions of this study? _____
Give reasons for your answer:

____

____

- Do you think if someone else did this experiment that they would get the same results and come to the same conclusion? Explain your answer:

  ____

  ____

  ____

- If the same experiment is done but using a different "camera" would the results be the same? Explain your answer:

  ____

  ____

- Mention other variables you can think of that could influence the images formed.

____

____

Session 7 Worksheet 9

Activity: Case study 2: Article exploring physics behind Kirlian Photography

Objective:

- To be exposed to a peer reviewed scientific article containing some explanations for images formed by using Kirlian Photography
- To apply knowledge from literature study and Nature of Science to form some critical comments about the conclusions and validity of article as contribution to real science.
- To verify and add to the list of variables that influence image formation of Kirlian photos.
- To explore some physics concepts like corona discharge, plasmas and sparks (streamer).

Procedure: view online: http://dx.doi.org/10.1063/1.1662715

- Read the abstract again: In one sentence say what is it that the article will be telling you about.

___

___

- Which properties of these images were discussed?

____

____

- Which variables was investigated during this study?

  ____

  ____

- What other variables are mentioned in this article?

  ____

  ____

- In your opinion, does this study include all possible variables and how these influence the images produced?

  ____

- Is the apparatus and method followed during this experiment clear to you? _________

Explain: _______________________________________

____

- Do you believe the results and conclusions of this study?

  ____

  Give reasons for your answer:

____

____

- Do you think if someone else did this experiment that they would get the same results and come to the same conclusion? Explain your answer:

  ____

  ____

  ____

- Mention other variables you can think of that could influence the images formed.

____

____

- When comparing the two articles, which do you think is more scientific? Give reasons for your answer:

  ____

____

____

- Now look back at the references you gathered during your literature study. Do you still think they contain valid information? Explain your answer:

  ____

____

____

- Mention one application for Kirlian photography that could benefit society.

  ____

- What did you learn about electric- and corona discharge, plasmas, sparks (streamers), charged electrodes and the energy field between them?

Session 8 Worksheet 10

Activity: Experimental design

Objective:

- To discuss possible ways to clarify some of the open questions from session 6.
- To design an experiment to either verify or deny some or all claims made in the article from session 6.

Procedure:

- It is suggested that you play with all the apparatus available to you during this session. This would help you better understand aspects of charge, charged electrodes, electric field (and lines) between different shaped electrodes, corona, electric discharge, sparks etc.
- On your group discuss possible ways of clarifying any open question from session 6.
- Design an experiment that you would like to do in order to verify or deny some or all claims made during session 6. The idea is that as scientists we want to know what exactly we are observing and measuring and make conclusions about our results. This includes in this specific case: how and why these images are formed.

- Can you answer this question: Is this phenomena only a corona discharge effect or are we seeing interaction of some new form of energy? ____

Student Assessment

How well did you work? Did you do your part in your group?

Tick the right box

Your work

	yes	maybe	no
1. I did all my own worksheets			
2. I followed instructions			
3. I kept my diary			
4. I asked questions			
5. I listened to others			
6. I contributed to my group			
7. I offered my suggestions			

Your group

	yes	maybe	no
1. We worked together			
2. We helped each other			
3. We listened to each other			
4. We completed group assignments			
5. We contributed to class discussions			

What did you like best:

____

____

Evaluation Form

Carefully consider whether these statements below are true or false:

In your opinion – this project has succeeded in:

- creating greater interest in some aspects of physics ____________
- introducing you to the natural scientific thought- and work processes ____________
- increasing your motivation ____________
- increasing your self-confidence ____________
- being an opportunity for first hand experiences ____________
- offering reminders of facts and principles ____________
- promoting your reflective and critical thinking skills ___________
- heightening effective learning through practical activities and multiple possibilities to enter the main topic ___________
- promoting real life problem solving, rational thinking and argumentation skills _______

- promoting trust in your own skills ___________
- promoting your sense of self-responsibility and independence ___________
- developing of your cooperation and communication skills __________
- connecting Theory and the Practice in physics ___________
- offering you the opportunity to gather knowledge (learn something new) ___________
- building of your practical skills ___________
- creating awareness of general principles and invariables in physics ___________
- individualizing your learning (learn at your own level) ___________

Other comments you would like to share:

____

____

____

____

Answer key:

Session 1 Worksheet 2

1(d) 2(a) 3(e) 4(f) 5(b) 6(g) 7(c)

Session 2 Worksheet 3

- Find and circle as many words from the puzzles as you can.

D	I	S	C	H	A	R	G	E	Q	W	E	R	T	P
A	S	D	F	A	T	O	M	G	H	J	K	V	L	H
Y	R	O	E	H	T	T	S	Z	U	I	S	O	P	O
A	S	F	D	F	G	H	U	R	T	Z	C	L	U	T
Y	X	L	I	G	H	T	N	I	N	G	I	T	X	O
E	C	A	M	E	R	A	T	Z	U	I	E	A	L	G
S	D	M	F	G	H	N	M	K	Z	T	N	G	E	R
T	N	E	M	I	R	E	P	X	E	Z	C	E	H	A
E	F	G	P	O	W	E	R	L	I	N	E	S	H	P
R	G	H	N	K	L	O	Z	T	R	W	Q	Y	C	H
S	H	R	O	U	D	O	F	T	U	R	I	N	G	Y
D	R	T	H	J	I	Z	K	L	N	G	R	W	W	S
P	H	O	T	O	C	O	P	Y	D	O	H	T	E	M
E	R	T	Z	C	V	N	R	G	H	J	K	C	B	P
Q	N	O	R	T	H	E	R	N	L	I	G	H	T	S

Hint:

8→ 3← 6↓

6 What students say

6.1 Background to survey

The included surveys are not directly linked to the thrust of this dissertation. They rather serve as an indication of the *status quo* of current learners in a specific school in Vienna. Though this survey is not sufficiently extensive to allow rigorous statistical analysis, it provides a descriptive view into the 'world and practice of Science as perceived by the learners involved. One cannot extrapolate from their confidence an understanding what Science is about. One can, nevertheless, find important guidelines to direct future analysis and constructive action to remedy a potentially serious dilemma before a science-illiterate future community causes havoc.

Science teaching might not prepare learners for either careers in science, nor an ability to 'live with science' in a modern society.

6.2 The Survey

Since little formal research has explored the effect of introducing 'meta-science' into science syllabi, this survey is an exploratory venture that aims to 'map out' the perceptions of learners. By necessity, the survey design had to relinquish 'rigorous design methodology' in favour of fishing for unorthodox insights.

Three classes, grades 6, 4 and 3 completed their questionnaires after a short exposure to the lesson plan as included in this document. The outcome shows that learners' lack perception and understanding of how science, and scientist, work.

6.2.1 Class descriptions

Demographically the three classes consist of students attending the bilingual program as Real Gymnasium learners. This means their main academic focus is in the sciences. All students have a working to excellent use of the English language. As bilingual students they are exposed to team-teaching, which means that the majority of their lessons are being taught by two teachers (being native speakers of either English or German) and subject matter is taught in both these languages. Students vary in age from 13-16years and comprise 3 classes. Here named class 3, 4 and 6 (as this corresponds to their year level in secondary school). They are unequally represented with regards to gender and nationality but very often have at least one parent with migration background.

Students are introduced to the subject of physics in the 3rd year of their secondary schooling that includes 8 years. The 3rd and 4th classes have a total of three physics lessons of 50minutes each per week. The 6th class however has only two lessons of 50minutes each per week. The author was responsible for teaching introducing physics to the 3rd class for one year (without a German native speaker) and the 6th class for 2years (with only intermittent attendance by German native speaker) at the time of writing this work. The 4th class has been taught by another English native speaker teacher from England and the author acted as team teacher for 3years (in physics, mathematics and biology).

Socially these students are well adapted and most have strong personalities. Academically they present like any class of students with the expectation of completing tertiary educations. Of more interest is the class personalities that become evident when sharing a class with them.

The 3rd class is busy and it takes great effort to keep their attention from wandering. They are very easily distracted and take every opportunity to digress from subject matter. Traditional teaching with these students seem to exaggerate their hyper-active nature. It took considerable time and the design of explicit activities to teach them how to “Be still”. e.g. Listening audiobooks where they have to sit in complete silence. This was of course done as positive reinforcement for completing other tasks to satisfaction. Some teachers simply make these students write copious amounts of work during class in order to keep them occupied. The author found that the 3rd class wants to be challenged. When one starts a lesson or topic by saying that this topic is perhaps above their understanding and should really only be introduced much later in their schooling, they seem to rise to the occasion. They had to do individual projects in the science fair style and as individuals and as a class they impressed and surprised all their teachers by staying actively engaged throughout the 6 hour day. No behavioral problems could be reported. Their verbal presentations improved greatly during the day and they were clearly proud of their work.

The 4th class is academically very strong and demanding. The class is hardworking with a really good work ethic. If you give them an assignment they do it. The only challenge with them is that as a teacher you have more answers than they have questions. This is a wonderful characteristic of the this class. They are lateral thinkers and enjoy exploring any topic in greater depth. Individually there are some students outspokenly uninterested in physics. Some nine students from this class regularly attend the physics Olympiad group as weekly extramural activity.

The 6th class is a serious class focusing strongly on the final evaluation at the end of year eight and on their own individual educational future. They are mostly relatively quiet and accept what is offered in terms of teaching content without much ado. The individual students with greater interest About 6 of them) enjoy strong debate on any topic within and outside the scope of physics while attending physics Olympiad as extramural activity. It is interesting that during regular class though these students assume the class personality. As a class they prefer being able to discuss topics but are not very motivated to show any understanding or mathematical skills with writing exercises. The group interest in physics is low.

6.2.2 Survey design

The outlay was done taking into consideration that children and young adults seldom enjoy filling in any surveys. Therefore the choice was made to have only one sheet of A4 paper and to incorporate one survey on either side of it. This restricted the number of items on each list somewhat. It was created before the introduction was given and loosely counts as preparation and planning for said introduction.

The number of items on each survey was merely a coincidence. With regards to the self-confidence survey the items were selected to include brief content topics, mentioning practical aspects of scientific method as well as introducing more philosophical ideas e.g. “true science”. The most important aspect of this survey is that it mentions a variety of specific skills that is required and that the skills range from simple skills (e.g. Naming) to complex (e.g. Discuss and evaluate). This follows known models like e.g. Bloom´s taxonomy. Maybe these skills should have been highlighted on the survey as to focus attention on their importance. The interest survey merely includes some randomly selected topics that could possibly be related to Kirlian photography. A marked interest in any or some of these topics could be interpreted as a possible angle from which to present the content.

The number of four choices for answering the self-confidence survey was chosen because from personal experience it is known that students often choose a mid-way without actually reflecting on their choice simply as a method to complete the task. Having four options hopefully forced a student to make a considered choice. The interest survey also has a possibility of four options to choose from but in this case the descriptions at the top were given to aid students in determining to which degree they perceive their own level of interest. Choosing the “0” would clearly mean that a student has no interest in mentioned topic. Choosing the options “1” to “3” would imply interest. The levels of which can be interpreted as being: “1” interested but in an inactive listening way, “2” interested in a somewhat more involved way that would include own activity but without producing any real evidence of learning, “3” interested enough to engage in hands-on activity where some evidence of learning will be produced. This could be seen as growing levels of involvement in own learning as well as interest indication per topic.

The items listed on the self-confidence survey can be categorized as follows:

- Prior knowledge, curriculum related physics (all three classes) – items 1,2,5,9 and10
- Prior knowledge, curriculum based (6^{th} class) – items 3 and 4
- Explicitly taught to 3^{rd} and 4^{th} class, by way of experience 6^{th} class – item 7
- Mentioned during introduction – item 6
- Related to practical aspects of physics – items 7, 9, 10
- Philosophical – item 8
- Information technology – items 11 and 12

The items listed on the interest survey can be categorized as follows:

- Curriculum based – items 1-7, 15
- Extended curriculum based – items 8, 10, 11, 14 and 17
- General knowledge – items 9, 12, 13, 18 and 19
- Philosophical – item 16
- Mathematically inclined – items 20 and 21
- Information technology – item 22

6.2.3 Method of testing

The method of taking these surveys differed among the three classes. The classes were selected because of accessibility. The author teaches or co-teaches all three classes. Firstly a very brief 40minute introduction was made. This took the form of a narrative with support of internet pictures. The introduction started by reviewing the atomic model with electrons in orbitals around the atom-nucleus, ionization and static electric discharge, electric field lines and ultimately reference was made to the electric field between two parallel oppositely charged plates before continuing to lightning, fire and other plasmas with some applications of corona discharge. At least half of the time was spent explaining Kirlian photography and showing pictures from the internet. From personal experience the author highlighted some aspects of photos on display.

In each case however some time (days) elapsed between giving the introduction to this topic and completing the survey. The students knew that this survey would form part of this study and that it was important to take the time to actually consider every response. Most of them took the maximum time available, which was about 20minutes. The reason for the time limit is that none of these students have written a test in physics that has been longer than 20minutes due to regulations in the Austrian school system. Conversation was allowed but discouraged. They had to write down their names to diminish the possibility of inaccurate answering.

6.2.4 Criticism of surveys

These two surveys should, at the very least, have been carried out twice. Once before introduction to the topic, and a second time after the introduction. This would have enabled at least some measure of comparison. Further it should have followed an identical repetition of the introduction. As a matter of practicality it needs to be mentioned that no two lesson are ever the same. This is due to the nature of the teacher but also to the different personalities of the classes. Another hemming factor is the developmental gap between the classes tested.

6.3 Results

6.3.1 Self-Confidence

Note: in all cases the vertical axis denotes the number of learners in a class of 10 that correspond to the x-axis groupings. This normalization of data means that multiplying the values on the y-axis translate into percentages. Descriptors on the x-axis has been changed from what was stated on survey to make the meaning clearer here. “High” therefore corresponds with the descriptor “very” on the survey when asked how confident the students felt.

Fig. 13: Overall average level of confidence (classes combined)

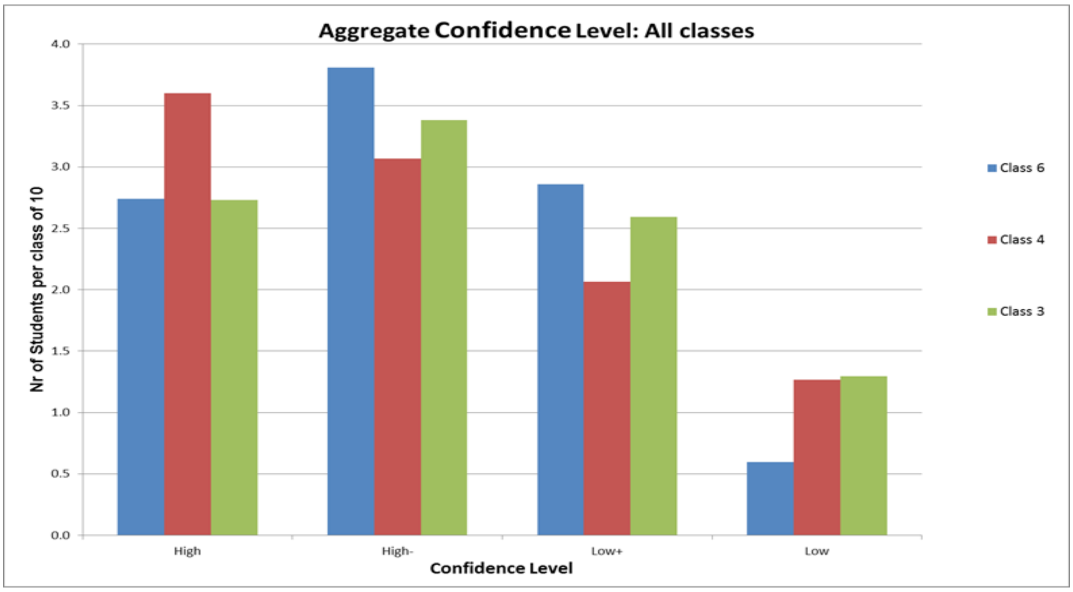

Fig. 14: Aggregate confidence per class

6.3.2 Interest

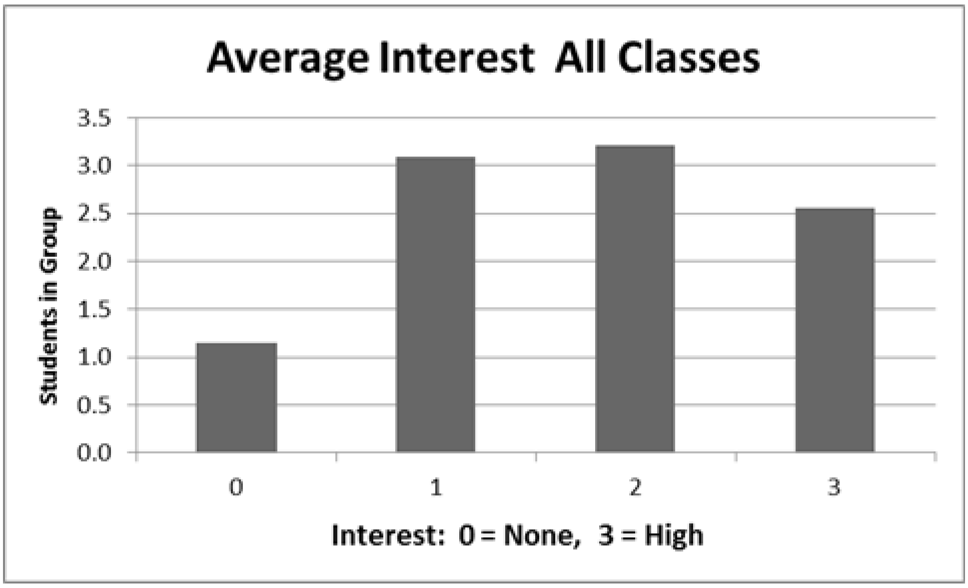

Fig. 15: Average interest (classes combined)

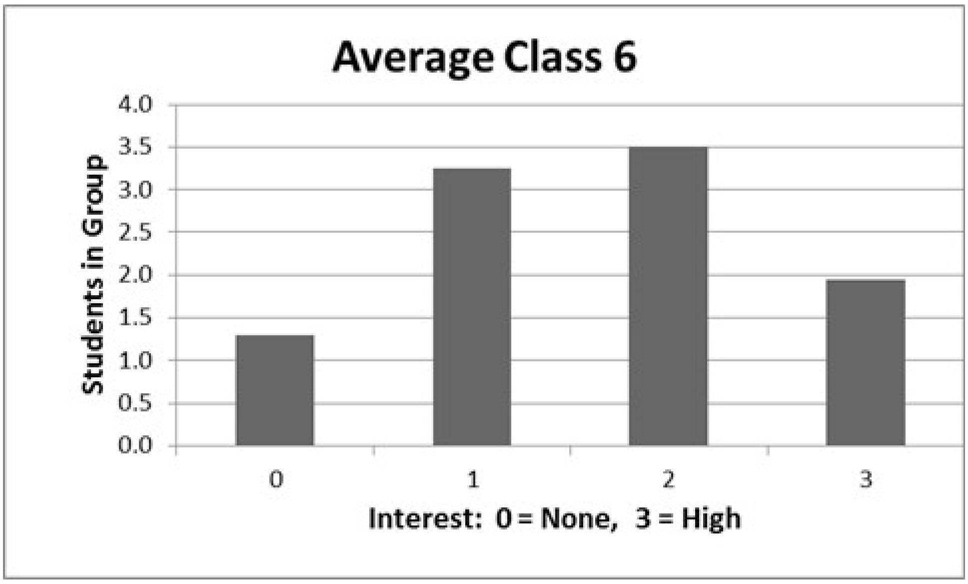

Fig. 16: Average interest class 6

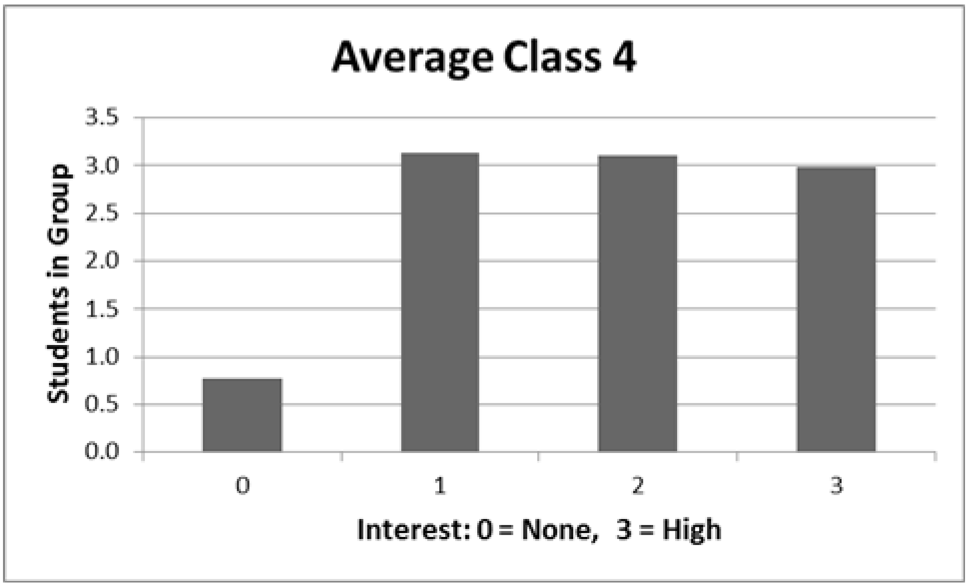

Fig. 17: Average interest class 4

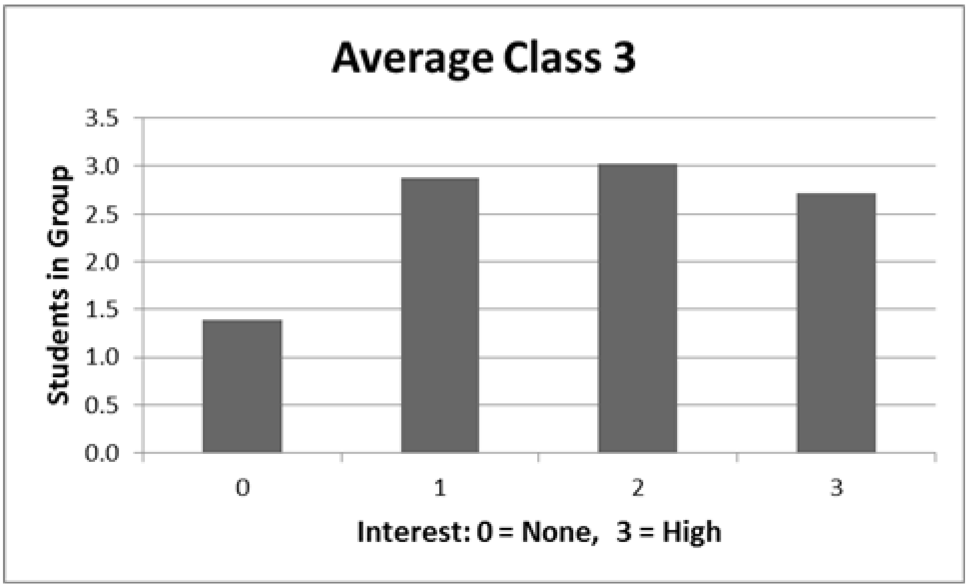

Fig. 18: Average interest class 3

6.3.3 Interpretation of Results

Since the sample sizes available were small, formal statistical analysis must be ruled out.

However, the descriptive statistics of the questionnaires provide useful information about misconceptions about science, as well as the lack of basic scientific 'hard skills' require to advance the scientific (and other) fields of human intellectual endeavour.

These gaps in perception and knowledge have to be corrected. The descriptive statics, in conjunction with the formal view of science, points towards a potentially better way of teaching Science.

We now contemplate the Statistical interpretation of the data acquired.

6.3.4 Data Manipulation

Since participating learner classes varied between 7 and 25, a simple aggregation of data would have skewed retrieved information. The results arising from a class of 7 will easily be suppressed by a simple aggregation with results of a class of 25.

6.3.4.1 Normalization

All classes were normalized to a common class size of 10. As a result, almost all classes were occupied by 'fractional students' — a single learner would progress to carry greater or smaller 'virtual learner' numbers, depending on the originating class size.
Once this is done, classes can be compared, and manipulated, on equal footing.

6.4 Discussion

The average confidence of all students participating in survey is on the medium high scale. This however is somewhat misleading. The perceived confidence levels differ drastically between classes and there forms a clear pattern of how the students´ confidence develops moving from the third class up in age to the six class. It is interesting because one is tempted to think because the age difference between 13 and 16 is relatively small, and for all intents and purposes, these students can all be described as young teens, that the patterns should be similar. The differences can partly be explained when taking the class personalities into account. The 3rd class students have only had the briefest of introduction to the world of physics and are moderately confident because they have not had the contrary proven yet. They don´t know how difficult physics can be yet. In their enthusiasm and with limited exposure they feel able to cope with what comes their way as this has been their experience thus far.

Both the 3rd and 4th classes have more students who feel not confident at all while the 3rd and 6th classes have fewer members who have a high level of confidence. The 6th class has had more experience and knows better what they can and can´t do so that the low value for low confidence is due to a better self-knowledge. The 3rd and 4th class on the other hand has less experience and do not really have an understanding of what are capable of. They are confident because they are inexperienced. This is a very important reason why students should be exposed to learning critical thinking and evaluation skills at a very early stage of their educational careers. The question arises whether the 6th class is past the worst of their adolescence and have become more mature than the younger students.

Class 4 presents a dramatically different pattern than the other two classes. They show not only a linear negative gradient in pattern of distribution of confidence but shows clear over confidence. This could possibly be explained by the nature of this class. Being over confident corresponds to how they behave in class and to the challenging questions they endeavour to ask. It is not clear if this is in an attempt to prove their evident abilities or because of this ability. There is a spirit of outdoing one another in this class with little logical follow through thought once they have embarked upon a line of questioning.

Students are clearly comfortable about their own abilities and confident that they possess the required skills to understand the topics in this survey. It becomes clear however that they are not confident to actually engage in the “doing” of science. While 12% of students indicated having “no interest” on this survey only 25% showed enough interest to “apply ideas about this topic in problems or experiments”. It is clear that while it seems a very positive outcome in terms of level of interest it is unsettling that students are mostly keen only on either passively listening to information or at most discussing various aspects of science. Science is an interesting and even exciting subject but they do not feel the confidence to actually applying the conversations or exploring the topics by putting themselves in the shoes of scientists and actually doing something in class. They show keen interest but without the necessary commitment to take their learning (or listening) to the next level and applying themselves. They are learning to immerse themselves in the results of someone else´s scientific endeavour in order to comfortably discuss science superficially without learning to understand the principals in science by “doing” something. They are not interested in producing evidence of their understanding of science.

The very nature of science lies in the activity of doing science. Scientific method is science! Only through doing science can one begin to form an understanding of the principals and inter-relatedness of scientific knowledge. Is our physics curricula and teaching practices enforcing the misconceptions students form because they are not getting enough exposure to the actual nature of science by not doing enough themselves. This study shows that although students are on average interested in physics in general, they do not feel confident enough to want to do something. They don´t want to do something in class because they cannot and thus have low self-confidence which translate into not being interested in doing physics. It would be worth doing further research to ascertain which aspects of the physics curriculum and/or didactic methods employed by educators lead to the maximum interest lying in the "reading about and discussing" range of interest in physics and not in the "doing and experimental" range. Could this be the reason so few students choose to study physics at tertiary level and consequently not follow a career in the sciences?

In conclusion the results from this preliminary survey point a finger in the direction of finding better ways to teach physics. If a student only hears and talks about physics, learning can occur, but without doing and applying knowledge there can be no real in-depth understanding. In the absence of understanding, little doing can happen. Ultimately, without doing science students will loose the self-confidence they possessed when they started their schooling.

7 Conclusion

Education needs to explicitly teach and develop problem solving skills of students. It has become critical to consider what children of all ages learn, what they should learn and what they need in order to learn. As a result it is necessary to have a good overview and understanding of the thought processes and methodology of physics in particular and science in general. The current school curriculum does not offer enough opportunities for students to learn by doing and learning to think from doing. Their main interest lies in reading and discussing physics topics. This lack in confidence is a direct result of the teaching they are exposed to. The current generation of learners seem to be doomed to never become more than parrots of science instead of being practitioners of science. Education today is not doing enough to produce scientifically literate citizens of a society that will be forming political, social, and environmental policy in the near future.

The lesson plan designed for this study can only be successfully implemented when students and teachers have access to the whole story. The authors´ own understanding was shaped exclusively by extramural exposure to the nature of science. Chapter two is included in this study to serve as case study and to strengthen students self-confidence as they will be able to identify with a 16 year old student interested in physics, who had received much the same education as them. Chapter 2 and 3 serve as information both of content and nature of science to enable students to ask better questions for investigation. The old cliché states that to ask a meaningful question is to know half of the answer already. It was the explicit aim of this study to expose students to conflicting opinions and claims made by seemingly scientific material. Students placed in this position of contradiction necessarily have to make some form of paradigm shift in order to be able to ask the critical questions that will facilitate their own understanding of both the topic and the nature of science. They must begin to think what they need to do in order to gain understanding because when there are contradicting opinions presented they cannot simply sit back and listen to learn.

The results from the survey done during the course of this study supports the importance of explicit education of the nature of science. Students need learn the what, why and how of doing science for their self-confidence to increase to the level of interest in active self exploration of scientific content. The lesson plan presented is an attempt at precisely this. To give students a method of how to emerge themselves in new information, learn to ask relevant questions and critically evaluate all scientific claims. Their understanding of the nature of science is strengthened by actively engaging in this type of activity while learning about the activity. The survey offers an answer as to when the nature of science should be introduced to students. The younger the better. By the time students reach the 6^{th} class a staggering 12% show no more interest in physics while in the 4^{th} class this number shrinks to 7,5%. While between 27 – 30% of the junior secondary students are still interested in “applying ideas in problems and experiments” only 20% of the senior secondary students share their enthusiasm.

Over-emphasis on exciting qualitative results of Science enchant learners, but they are taught to develop feeling of inadequacy since they lack the background to gain confidence in solving problems. Students need to taught 'hard science' in context, together with a history of science -- evolution of Nature of Science -- to encourage a generation of informed citizens and, hopefully, a generation of scientists with sufficient 'wonder' to allow them to advance the frontiers of science. "The only way to extend the limits of the possible, is to step beyond them into the impossible." (British author and scientist, Arthur C Clark)

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9 Appendices

Appendix I: Course related Self-confidence Survey

Your Name: ____________________________
Class:____________

The table below contains a list of skills that you are expected to develop to succeed at this project. For each skill,please circle your current level of self-confidence in that skill.

Skill	*How confident do you feel? (circle one)*			
1. Interpret atomic model with energy fields and orbitals	Very	Somewhat	Not very	Not at all
2. Describe ionization using orbital model and electron configuration	Very	Somewhat	Not very	Not at all
3. Draw electric field lines between two parallel charged plates	Very	Somewhat	Not very	Not at all
4. Write an equation expressing the relation between energy and capacitance	Very	Somewhat	Not very	Not at all
5. Explain what is a plasma	Very	Somewhat	Not very	Not at all
6. Name examples of coronal discharge in everyday life	Very	Somewhat	Not very	Not at all
7. Define what is meant by “scientific method”	Very	Somewhat	Not very	Not at all
8. Discuss what is meant by “true science”	Very	Somewhat	Not very	Not at all
9. Write a goal for an experiment	Very	Somewhat	Not very	Not at all
10. Examine and evaluate the results and conclusions of an experiment	Very	Somewhat	Not very	Not at all
11. Use internet to search for information	Very	Somewhat	Not very	Not at all
12. Choose reliable sources from internet	Very	Somewhat	Not very	Not at all

Appendix II: Topics Interest Survey

Your Name: ____________________________
Class:___________

The table below contains a list of topics that we will cover in this course. Please circle the number after each topic below that best represents your level of interest in that topic.

The numbers stand for the following responses:
0 = No interest at all.
1 = Interested in an overview of this topic.
2 = Interested in reading about and discussing this topic.
3 = Interested in applying ideas about this topic in problems or experiments.

Project topic	Level	Of	Interest	
1. Atomic model	0	1	2	3
2. History of development of atomic structure model	0	1	2	3
3. Ionization of atoms, air and other molecules	0	1	2	3
4. Electric fields between electrodes	0	1	2	3
5. Capacitance	0	1	2	3
6. Electric discharge	0	1	2	3
7. Lightning	0	1	2	3
8. Polar lights	0	1	2	3
9. Shroud of Turin	0	1	2	3
10. Sun spots and electron winds	0	1	2	3
11. Applications and use of coronal discharge in real life	0	1	2	3
12. Kirlian photography	0	1	2	3
13. Alternative medicines	0	1	2	3
14. Plasma as 4th phase/state of matter	0	1	2	3
15. Scientific method	0	1	2	3
16. True science	0	1	2	3
17. Coronal discharge	0	1	2	3
18. Photography	0	1	2	3
19. Photo-chemistry	0	1	2	3
20. Reliable data analysis	0	1	2	3
21. Statistics	0	1	2	3
22. Internet as source of information	0	1	2	3

Appendix III: Raw survey data

Self confidence survey

question	class	very	somewhat	not very	not at all	total
1	6	0	3	3	1	7
	4	1	9	8	7	25
	3	1	8	9	0	18
2	6	0	0	7	0	7
	4	0	5	9	11	25
	3	3	4	9	2	18
3	6	3	3	1	0	7
	4	11	11	2	1	25
	3	4	8	4	2	18
4	6	0	1	5	1	7
	4	2	5	8	10	25
	3	3	3	9	3	18
5	6	4	1	2	0	7
	4	4	9	11	1	25
	3	2	6	5	5	18
6	6	1	3	3	0	7
	4	5	8	5	7	25
	3	3	7	3	5	18
7	6	3	3	1	0	7
	4	7	14	4	0	25
	3	4	8	5	1	18
8	6	0	3	1	3	7
	4	9	10	5	1	25
	3	2	6	8	2	18
9	6	1	5	1	0	7
	4	16	5	4	0	25
	3	10	3	2	3	18
10	6	1	6	0	0	7
	4	13	6	6	0	25
	3	9	7	1	1	18
11	6	4	3	0	0	7
	4	21	4	0	0	25
	3	11	5	0	2	18
12	6	6	1	0	0	7
	4	19	6	0	0	25
	3	7	8	1	2	18

Interest survey

Question	class	0 no interest	1 interest in overview	2 interest in reading about	3 interest in applying ideas about this	total
		at all	overview of topic	and discussing topic	Topic in probelems or experiments	
1	6	1	2	3	1	7
	4	1	8	10	6	25
	3	3	7	5	3	18
2	6	2	3	2	0	7
	4	2	12	11	0	25
	3	2	6	8	2	18
3	6	2	4	1	0	7
	4	2	8	12	2	24 !
	3	3	5	6	4	18
4	6	2	2	3	0	7
	4	2	8	8	7	25
	3	4	5	8	1	18
5	6	2	3	2	0	7
	4	2	9	8	5	24 !
	3	6	7	4	1	18
6	6	0	3	3	1	7
	4	1	11	10	2	24 !
	3	1	4	5	8	18
7	6	0	4	0	3	7
	4	0	1	2	22	25
	3	0	1	7	11	19
8	6	1	1	2	3	7
	4	1	1	5	18	25
	3	2	5	4	7	18
9	6	0	3	3	1	7
	4	2	3	9	11	25
	3	3	6	6	3	18
10	6	0	1	4	2	7
	4	0	13	5	7	25
	3	4	6	3	5	18
11	6	2	2	3	0	7
	4	3	6	11	4	24 !
	3	3	5	5	5	18
12	6	0	0	4	3	7
	4	1	6	6	12	25
	3	2	5	2	9	18
13	6	0	2	4	1	7
	4	3	6	10	6	25
	3	2	4	5	7	18
14	6	1	2	1	3	7
	4	1	11	8	5	25
	3	4	6	6	2	18
15	6	1	4	2	0	7
	4	3	15	4	3	25
	3	3	4	9	2	18
16	6	1	4	2	0	7
	4	3	9	8	5	25
	3	2	5	9	2	18
17	6	1	5	1	0	7
	4	0	10	11	4	25
	3	0	8	6	4	18

18	6	0	0	2	5	7
	4	3	6	6	10	25
	3	2	3	5	8	18
19	6	0	2	1	4	7
	4	0	10	8	7	25
	3	2	4	5	7	18
20	6	1	3	2	1	7
	4	5	8	6	6	25
	3	3	5	7	3	18
21	6	2	0	5	0	7
	4	5	7	8	5	25
	3	3	7	4	4	18
22	6	1	0	4	2	7
	4	2	3	3	17	25
	3	1	6	1	10	18

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Susann Brailey
Manager, Rights and Permissions
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-----Original Message-----

From: Juanina Oppel-Equiluz [mailto:oppel-equiluz@gmx.at]

Sent: Tuesday, July 24, 2012 7:10 AM

To: AIPRights Permissions

Subject: for use in lesson series for masterstudy

To: Office of Rights and Permissions American Institute of Physics Suite

Dear sirs,

I am a physics teacher and physics-education student of the University of Vienna. As part of my Masters thesis i have developed a lesson series related explicitly to the teaching of the Nature of Science. This topic is introduced via the theme of Kirlian Photography.

I ask your permission to copy this article as part of a worksheet dedicated to exploring variables influencing the formed images. This will be submitted as part of my thesis.

It is further important to mention the possibility of this lesson series actually being used in actual high school classrooms by current teachers. This project has no commercial value whatsoever.

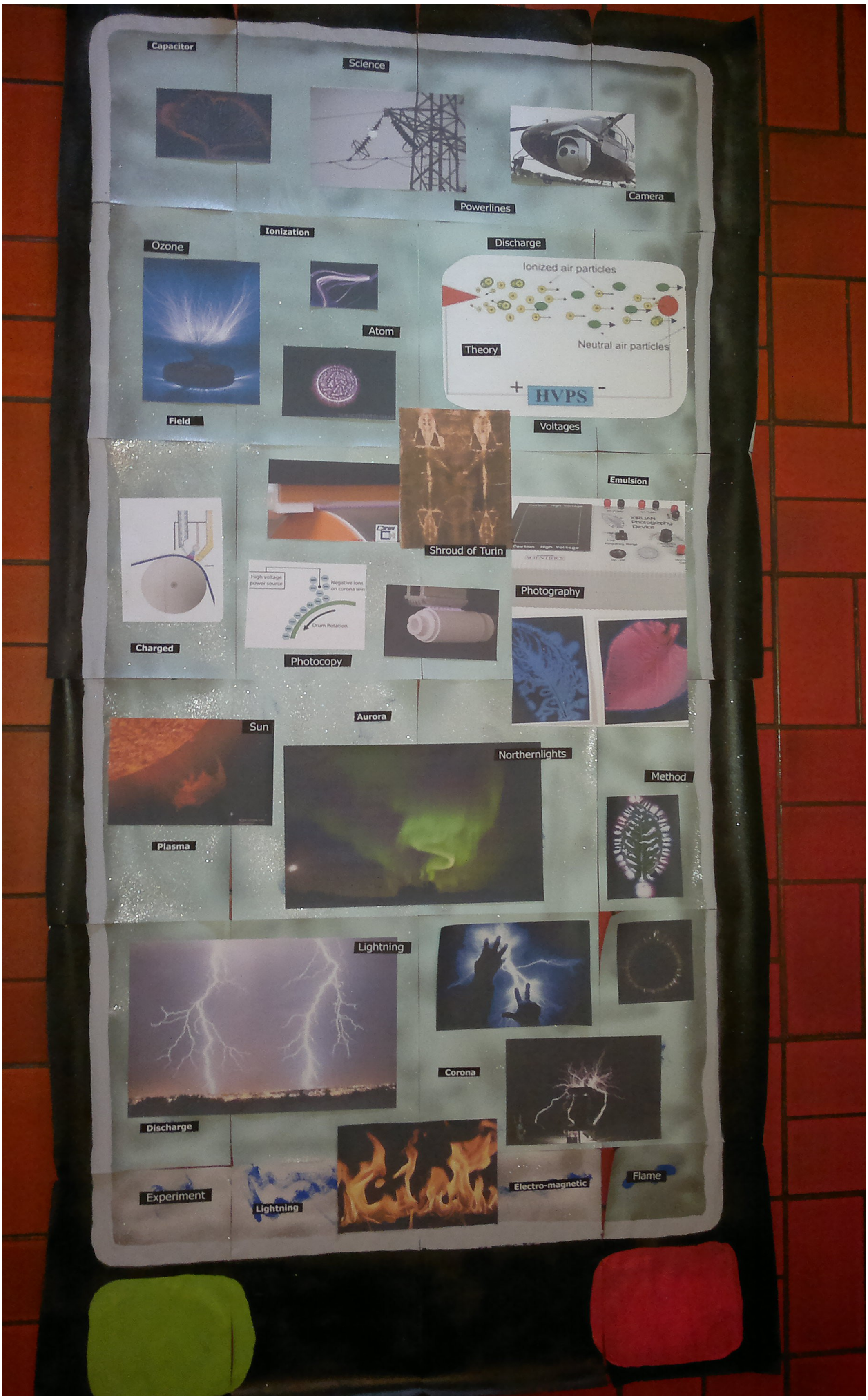
Citation: J. Appl. Phys. 44 no. 7, 3102 (July 1973); doi: 10.1063/1.1662715
title: Corona Discharge Photography
Authors: David G. Boyers and William A. Tiller

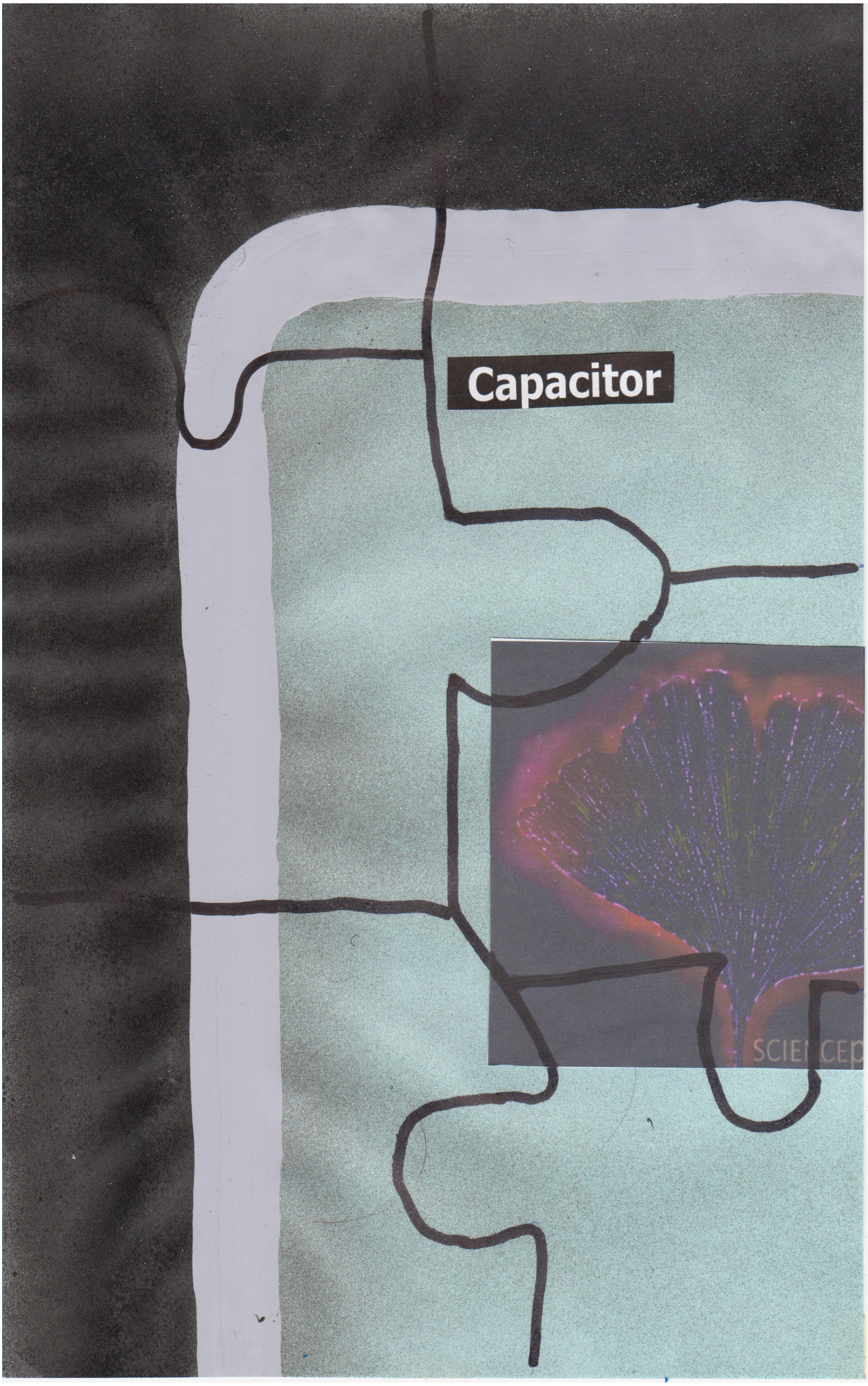
Your faithfully

Juanina Oppel-Equiluz
B.Sc. H.E.D. B.Ed(honns). B.A.(honns)
Northwest University South Africa

Appendix IV: Educational material (Puzzle)

Fig. 19: 24 Puzzle pieces

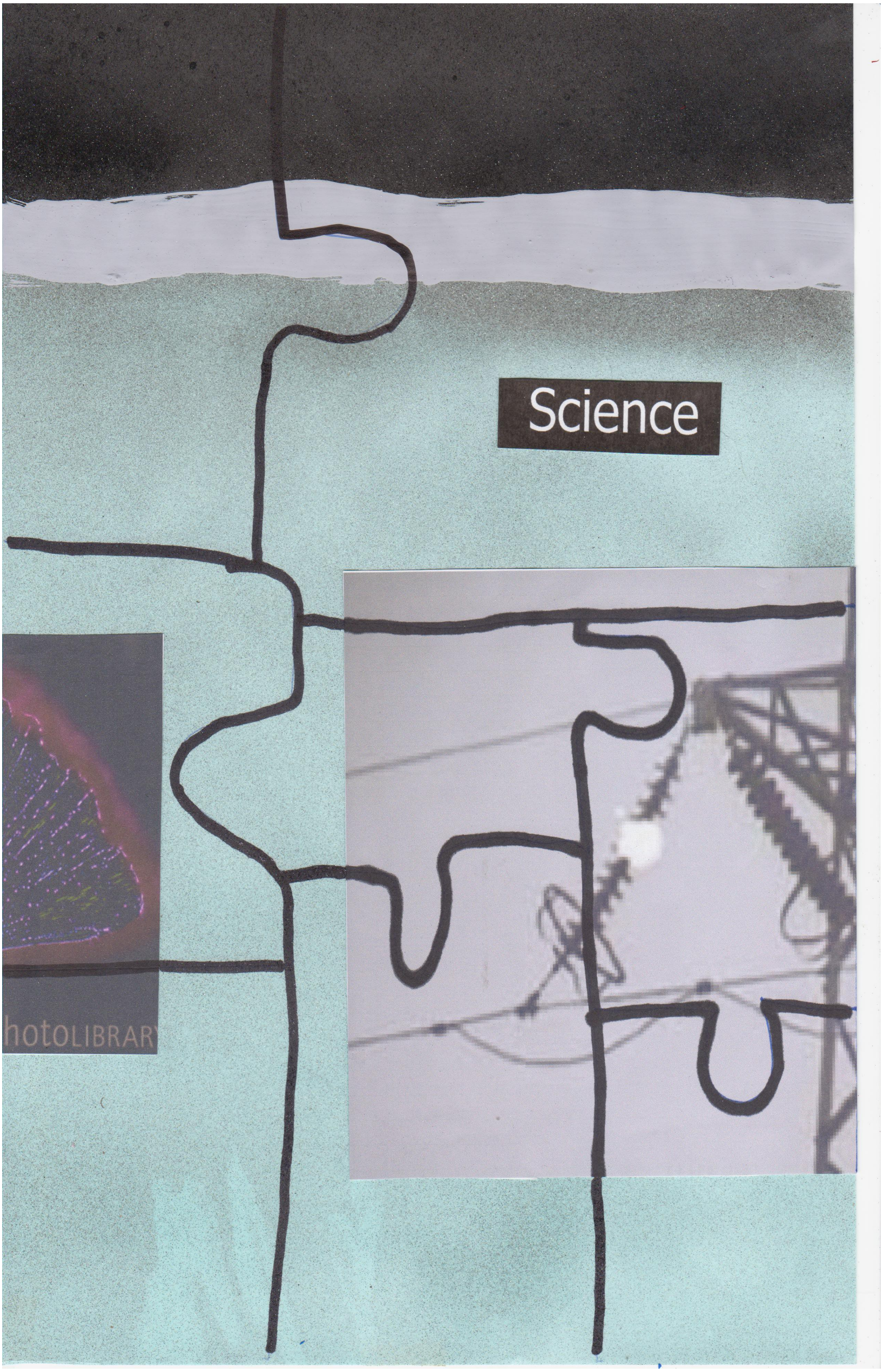




Capacitor

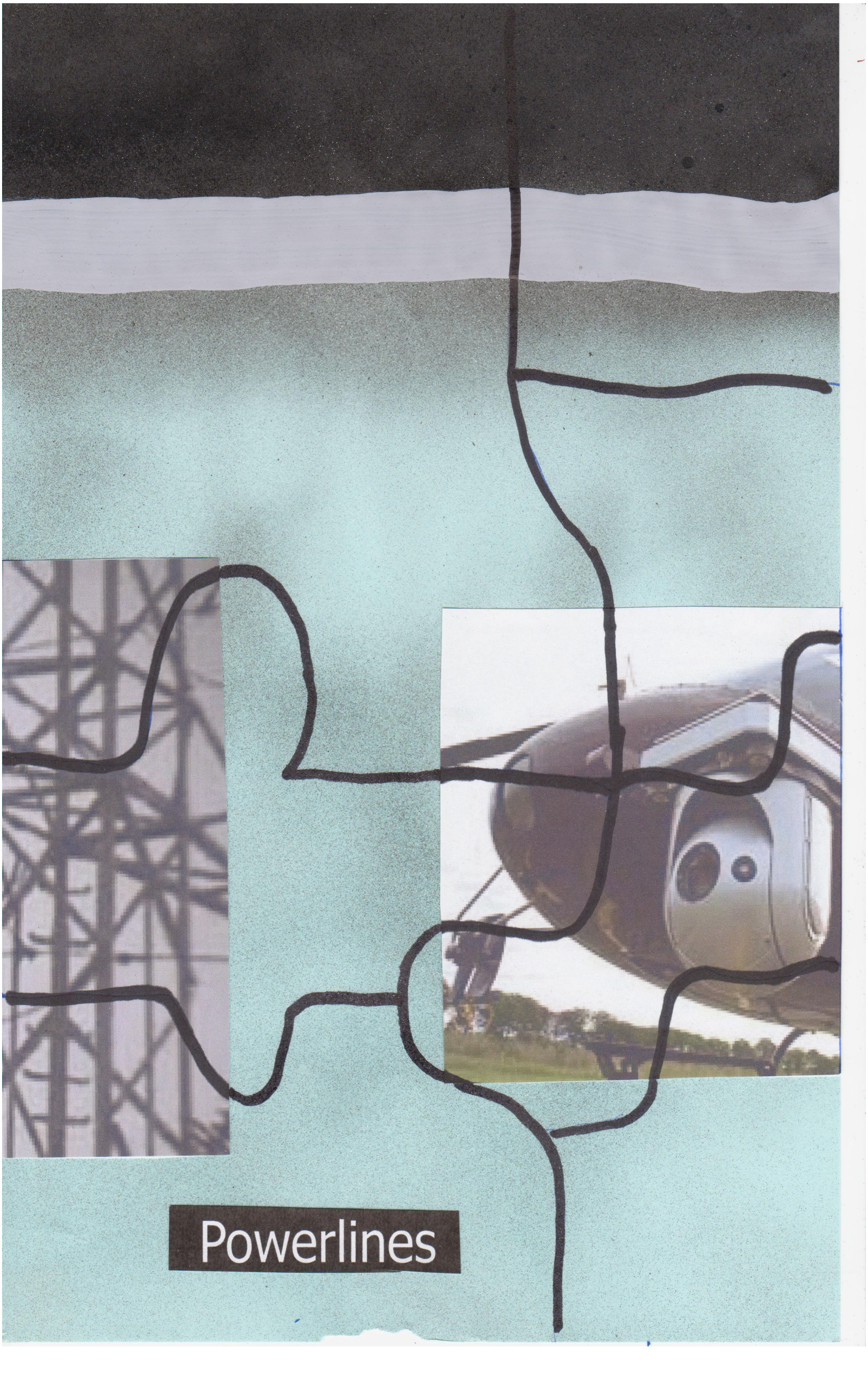
1st Row Top left corner

Group no. 2


Science
hotoLIBRARY

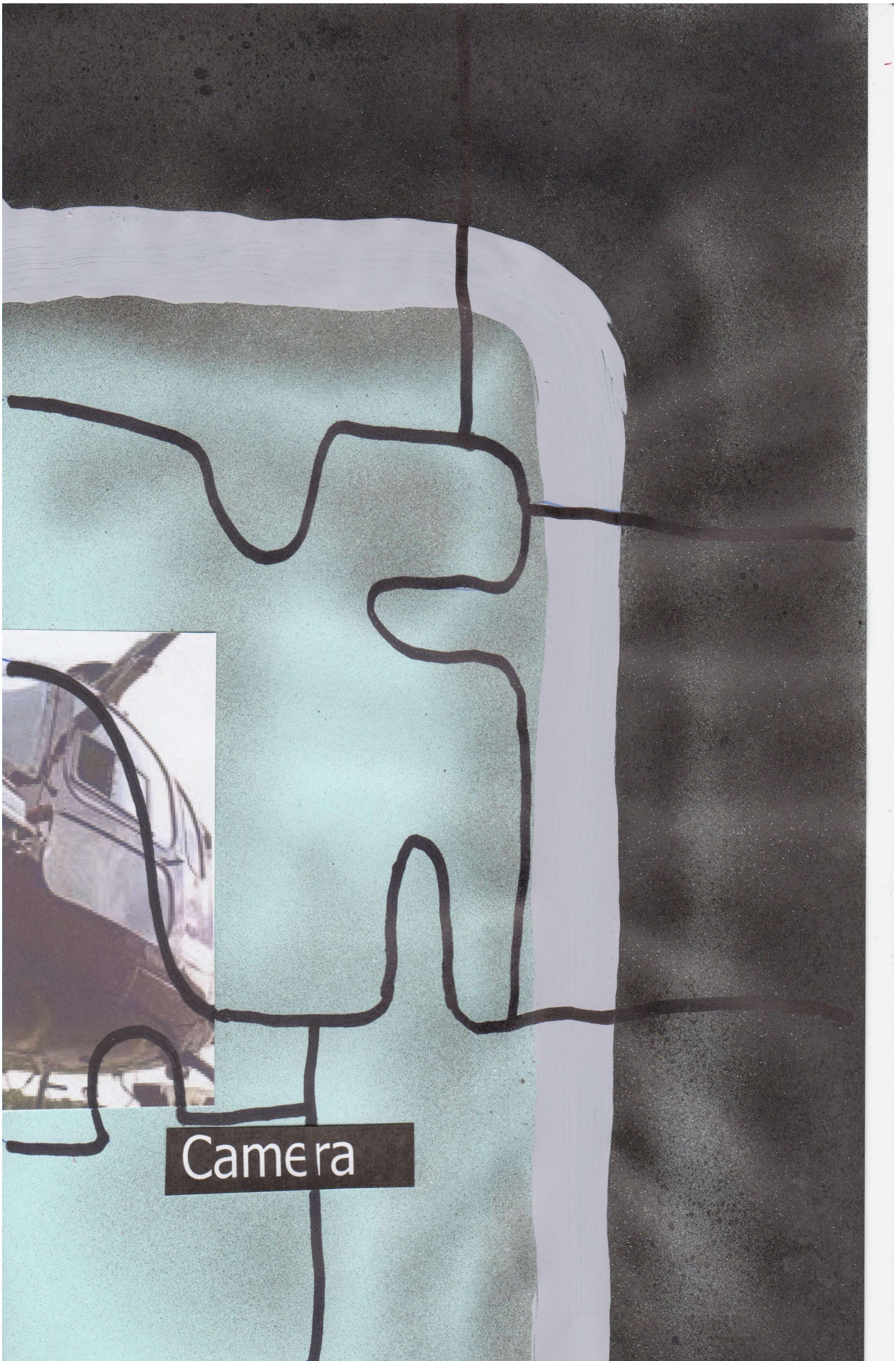
1st Row 2nd from left

Group no. 2


Powerlines

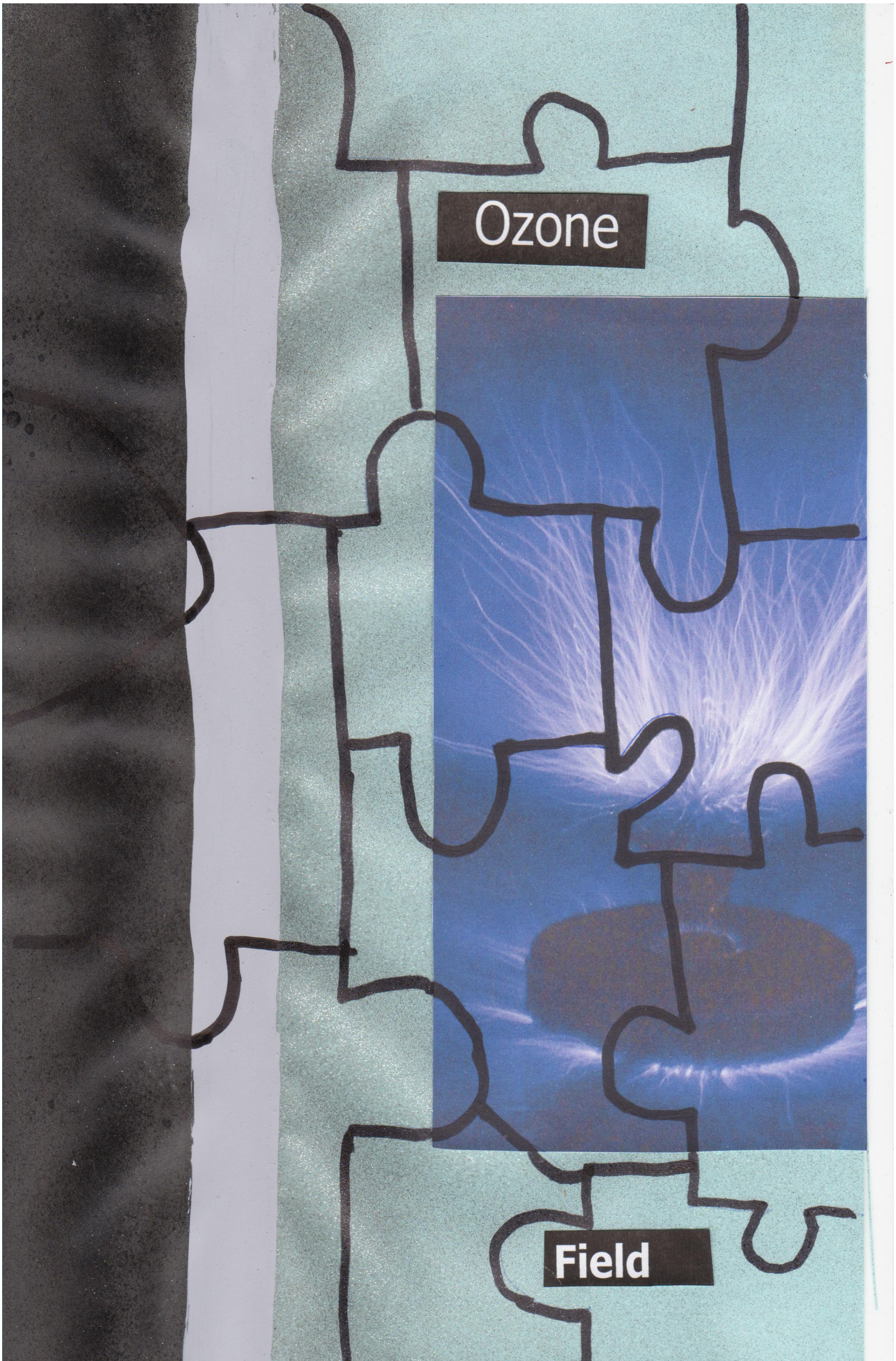
1st Row 3rd from left

Group no. 2


Camera

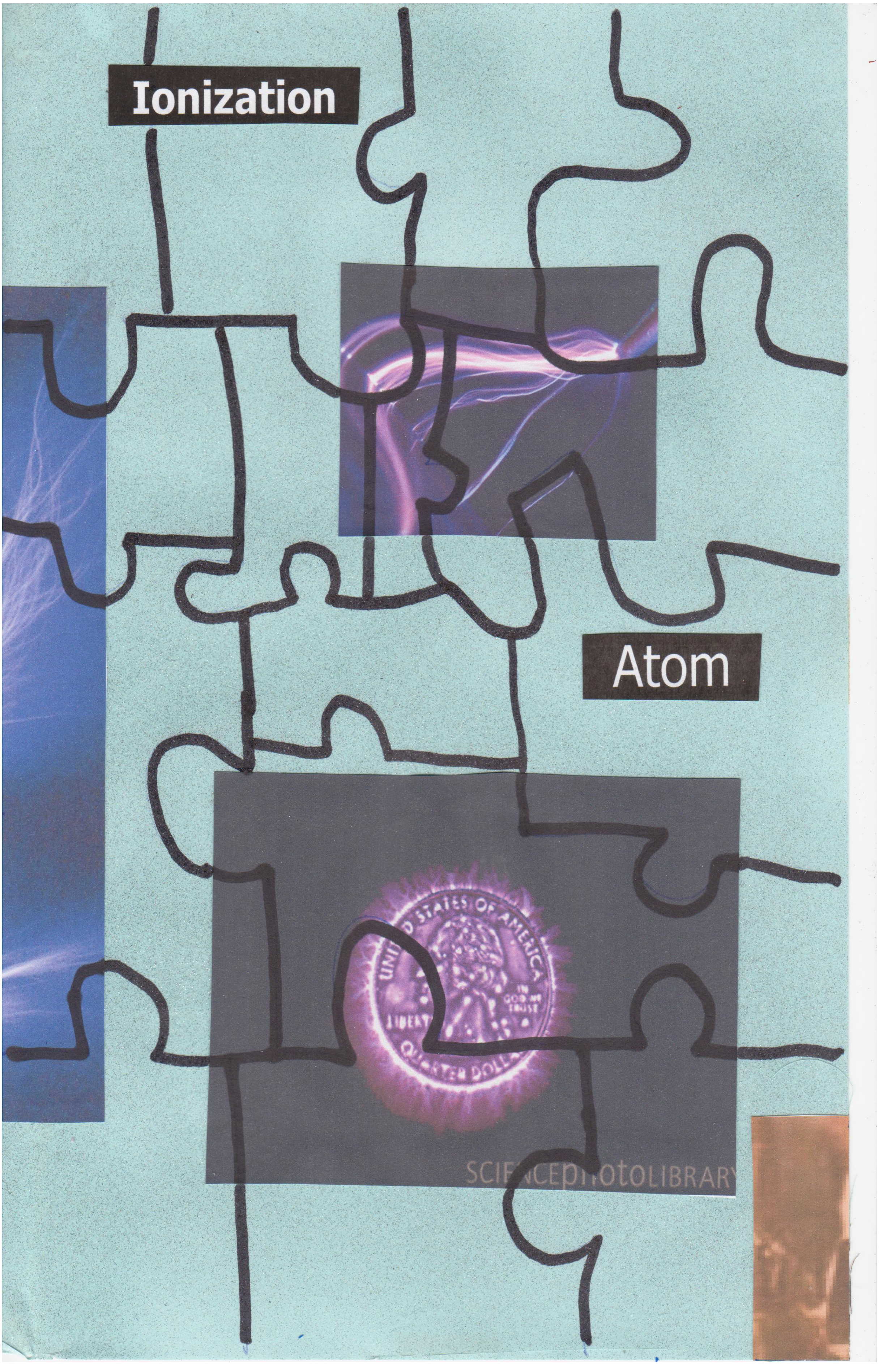
1^{st} Row corner right

Group no. 2


Ozone
Field

2nd Row 1st left

Group no. 4



Ionization
Atom
UNITED STATES OF AMERICA
LIBERTY
IN GOD WE TRUST
QUARTER DOLLAR
SCIENCEphotoLIBRARY

2nd Row 2nd from left

Group no. 4


Discharge
Ionized air part
Neu
Theory
+
HVPS
Voltages

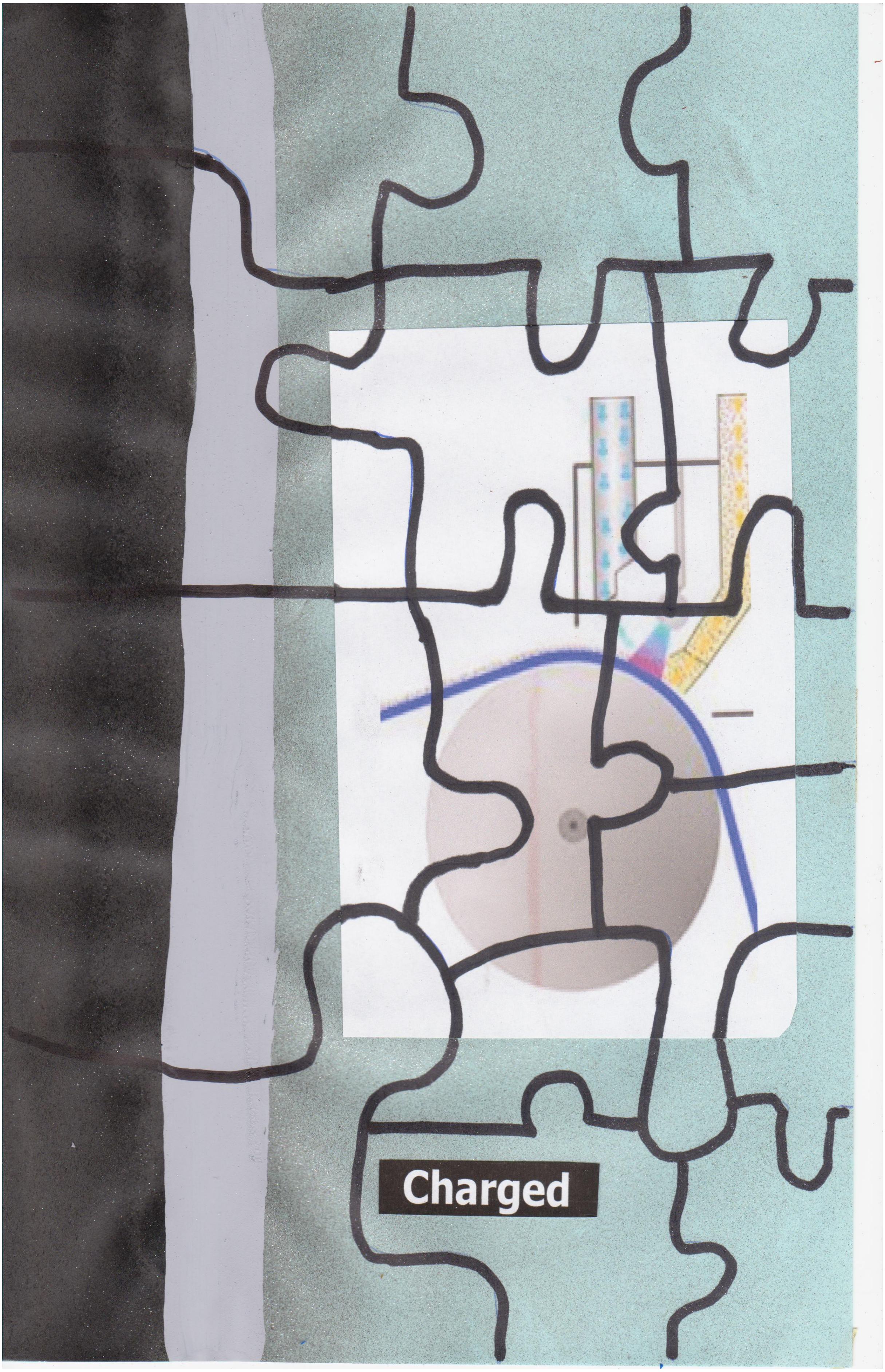
2nd Row 2nd from left

Group no. 4


tral air particles

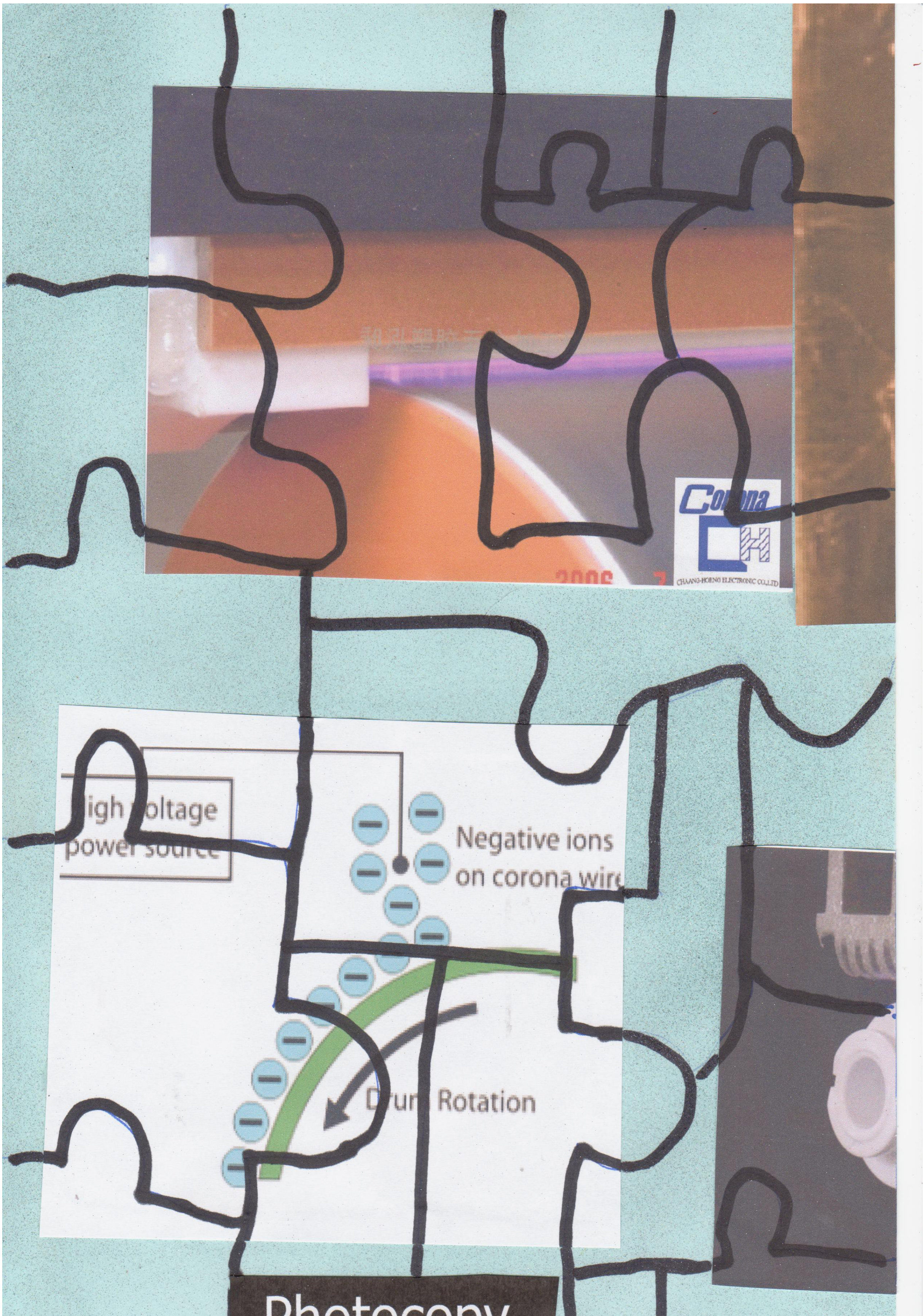
2nd Row Right

Group no. 4


Charged

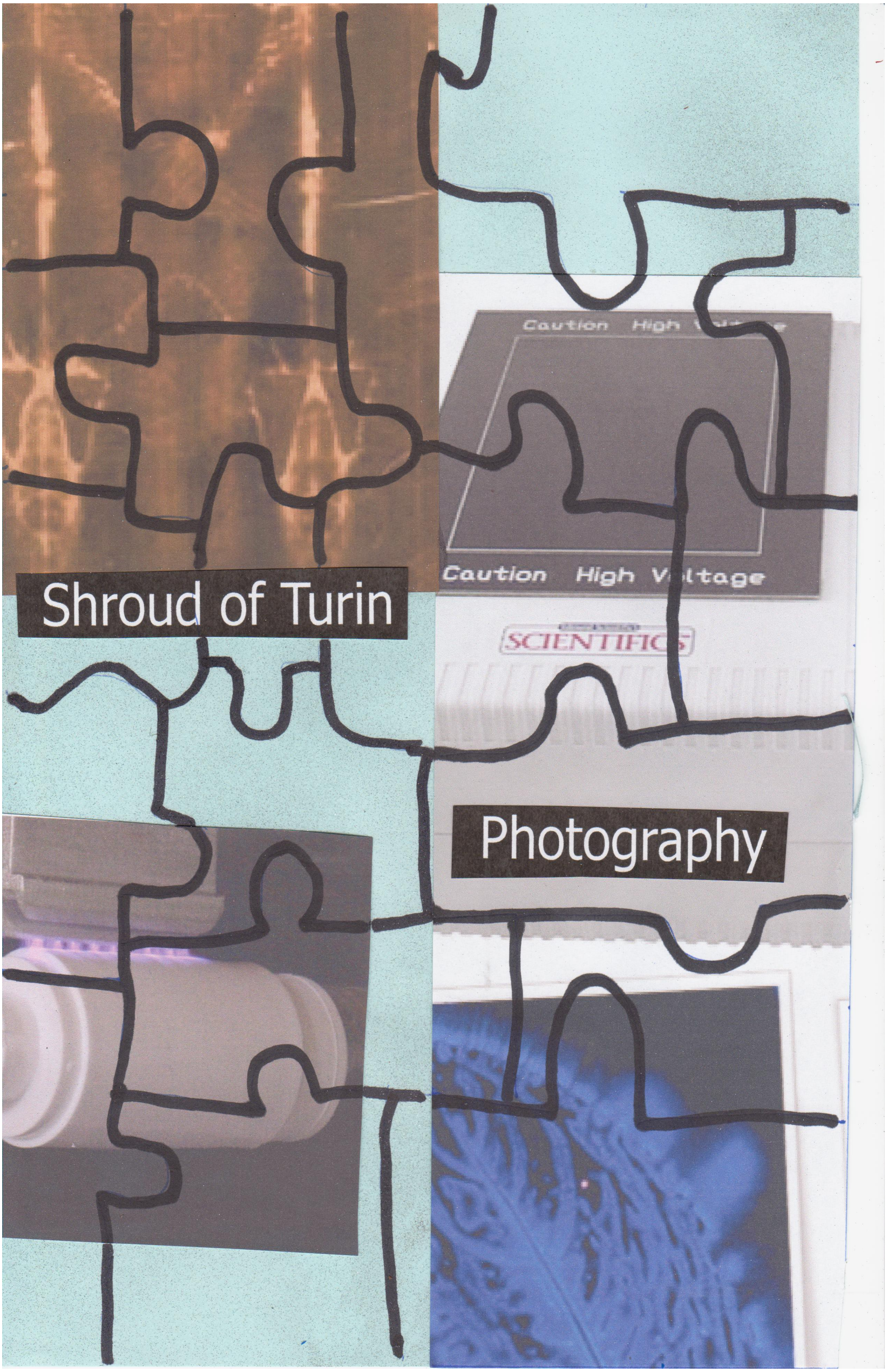
3rd Row 1st from left

Group no. 3


Corona
Negative ions
on corona wir
Rotation
Photocopy

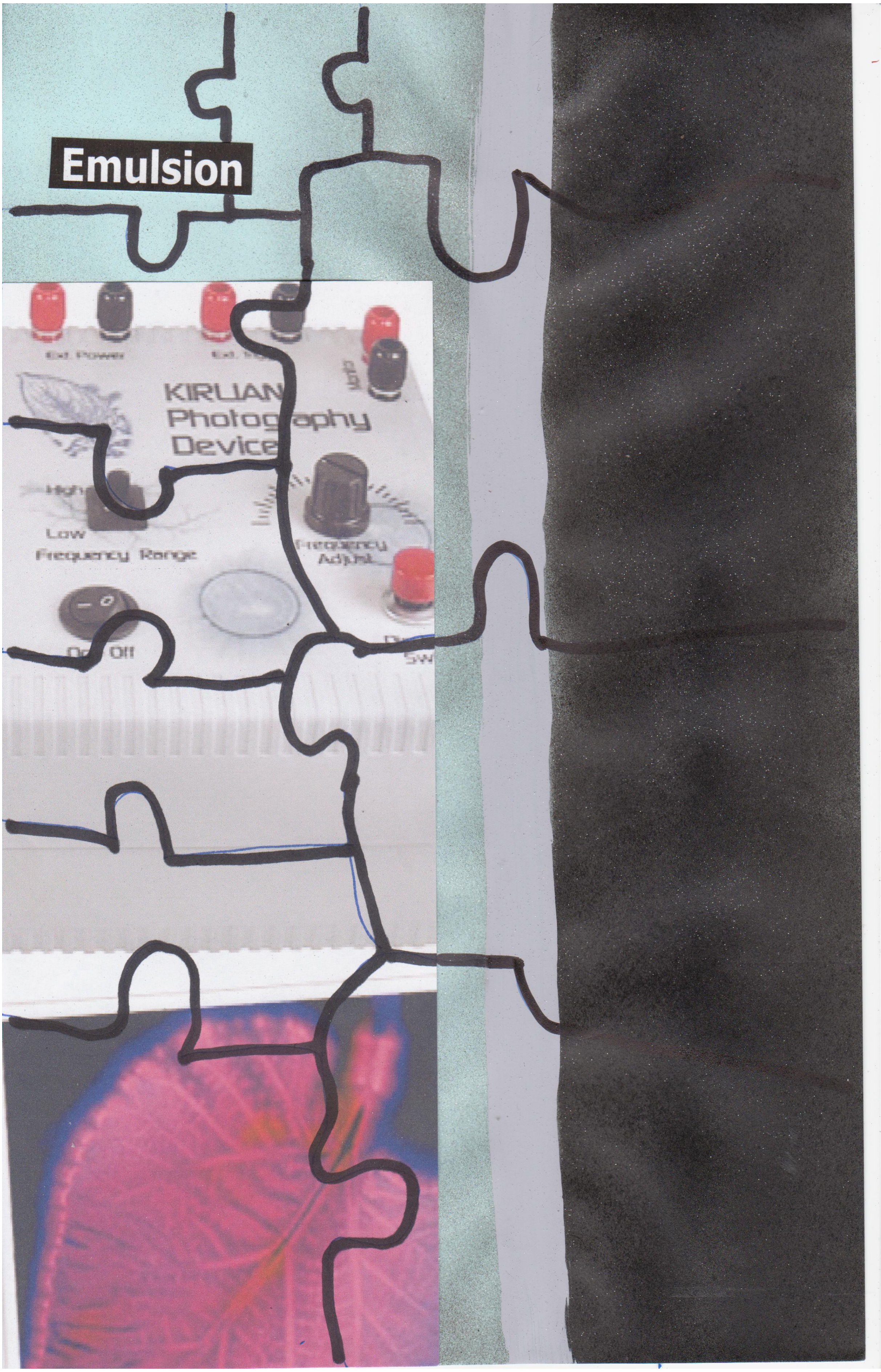
3rd Row 2nd from left

Group no. 3


Caution High Voltage
Caution High Voltage
SCIENTIFICS
Shroud of Turin
Photography

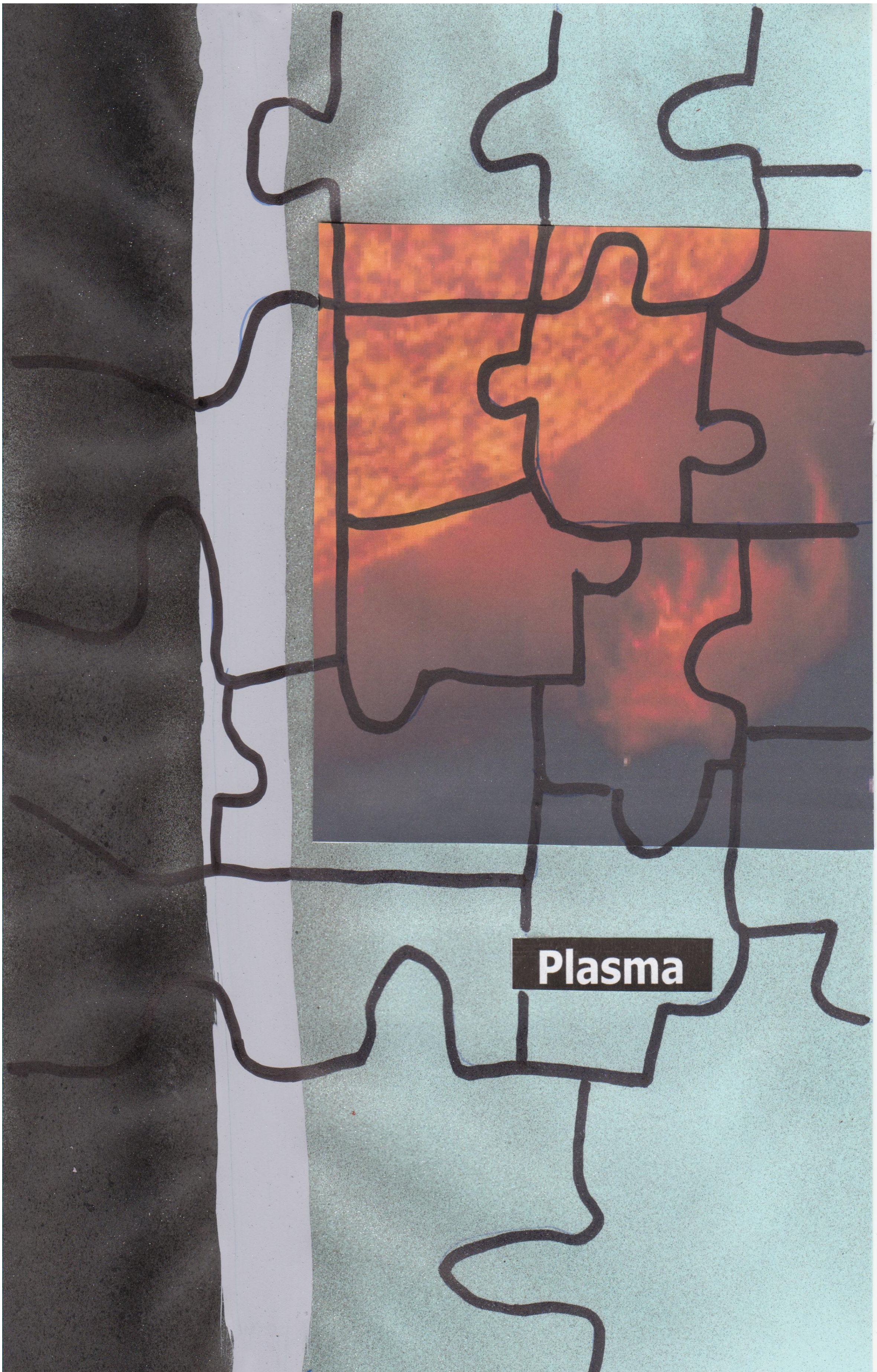
3rd Row 3rd from left

Group no. 3


Emulsion
KIRLIAN
Photography
Device
High
Low
Frequency Range
Frequency
Adjust
On Off
Ext. Power

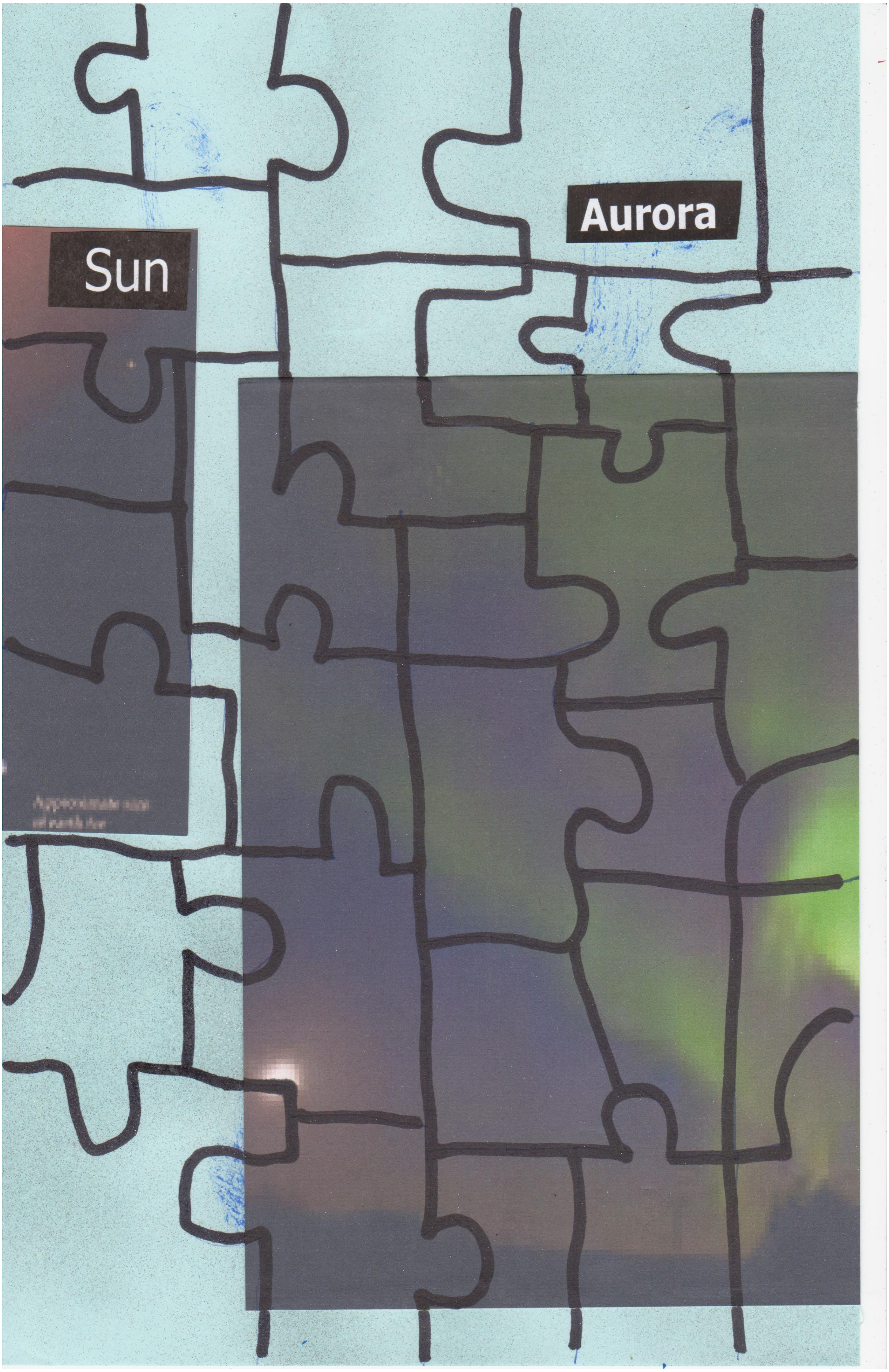
3rd Row Right

Group no. 3


Plasma

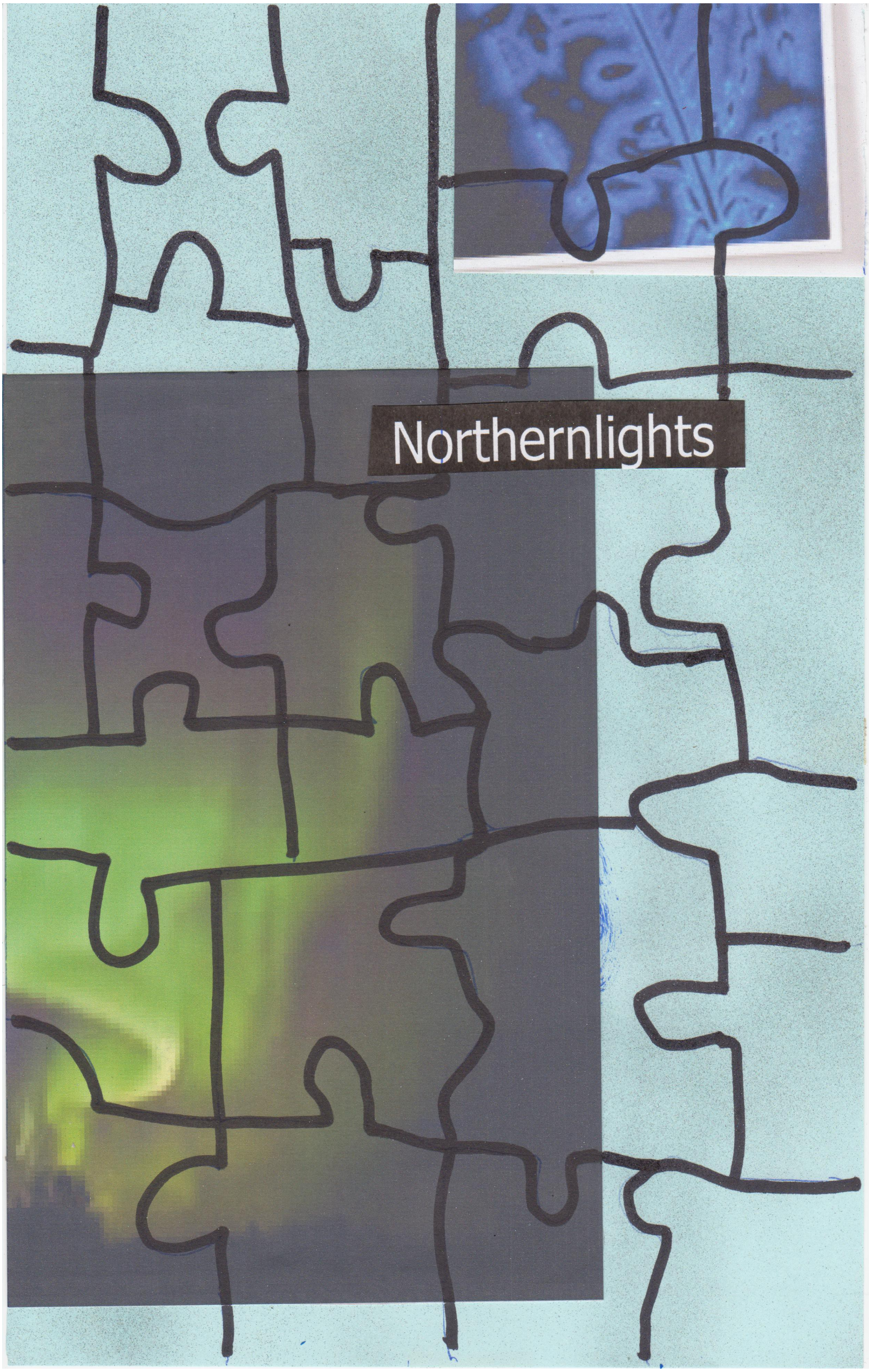
4th Row 1st from left

Group no. 6


Aurora
Sun

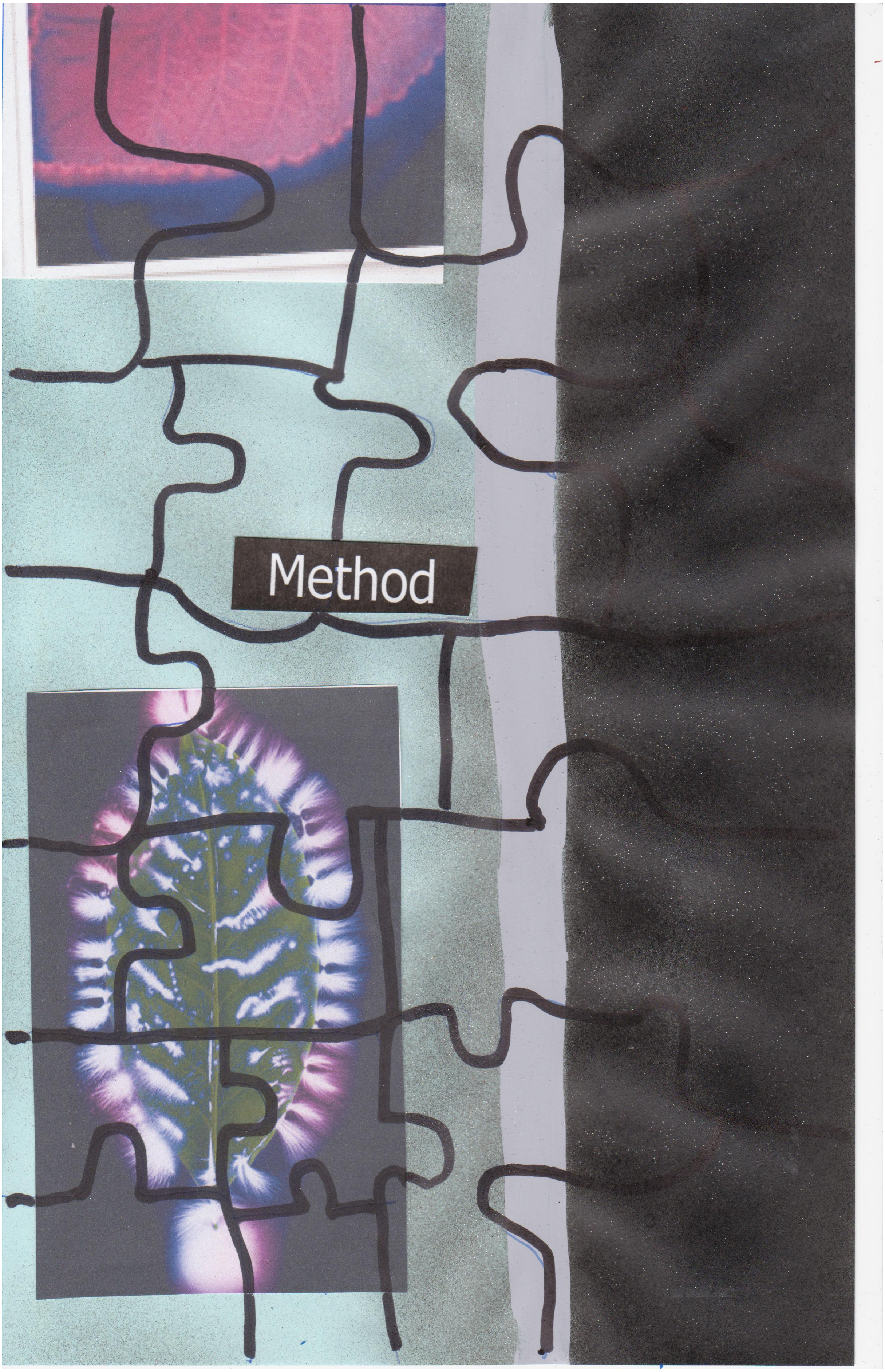
4th Row 2nd from left

Group no. 6


Northernlights

4^{th} Row 3^{rd} from left

Group no. 6


Method

4th Row 3rd Right

Group no. 6


Discharge

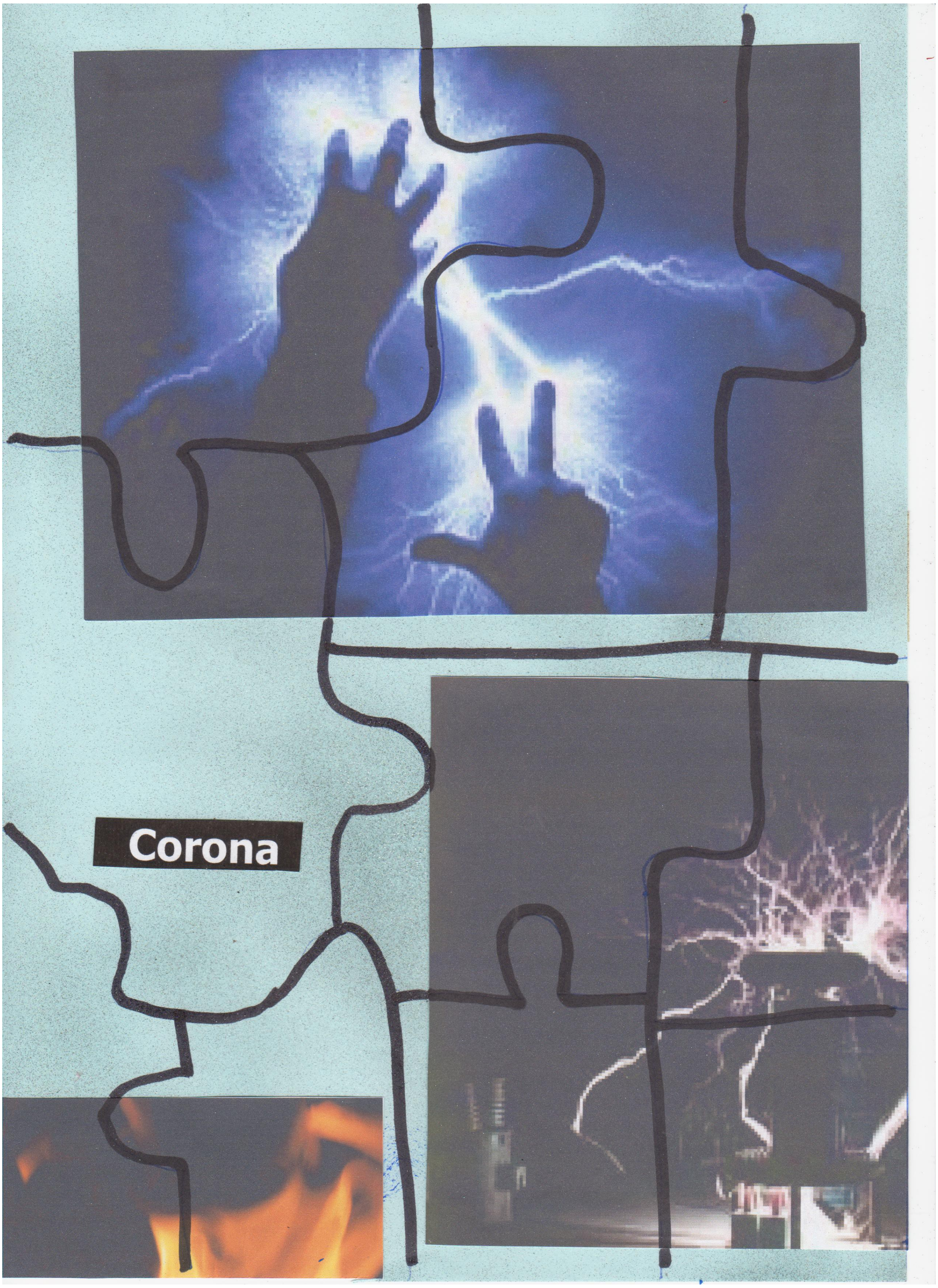
5th Row 1st from left

Group no. 3


Lightning

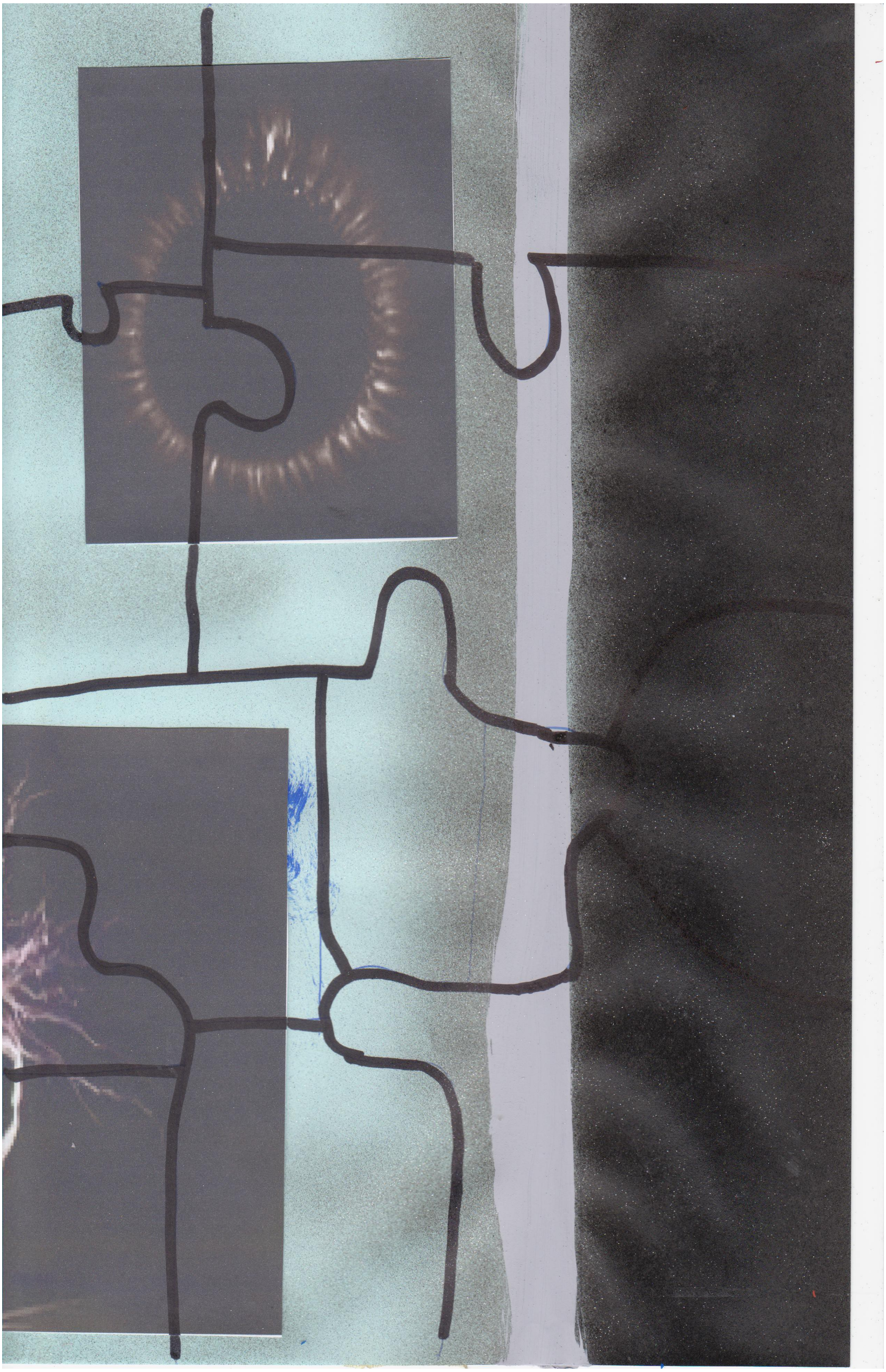
5^{th} Row 2^{nd} from left

Group no. 3


Corona

5th Row 3rd from left

Group no. 3



5th Row Right

Group no. 3


Experiment

6th Row 1st from left

Group no. 1

L


Lightning

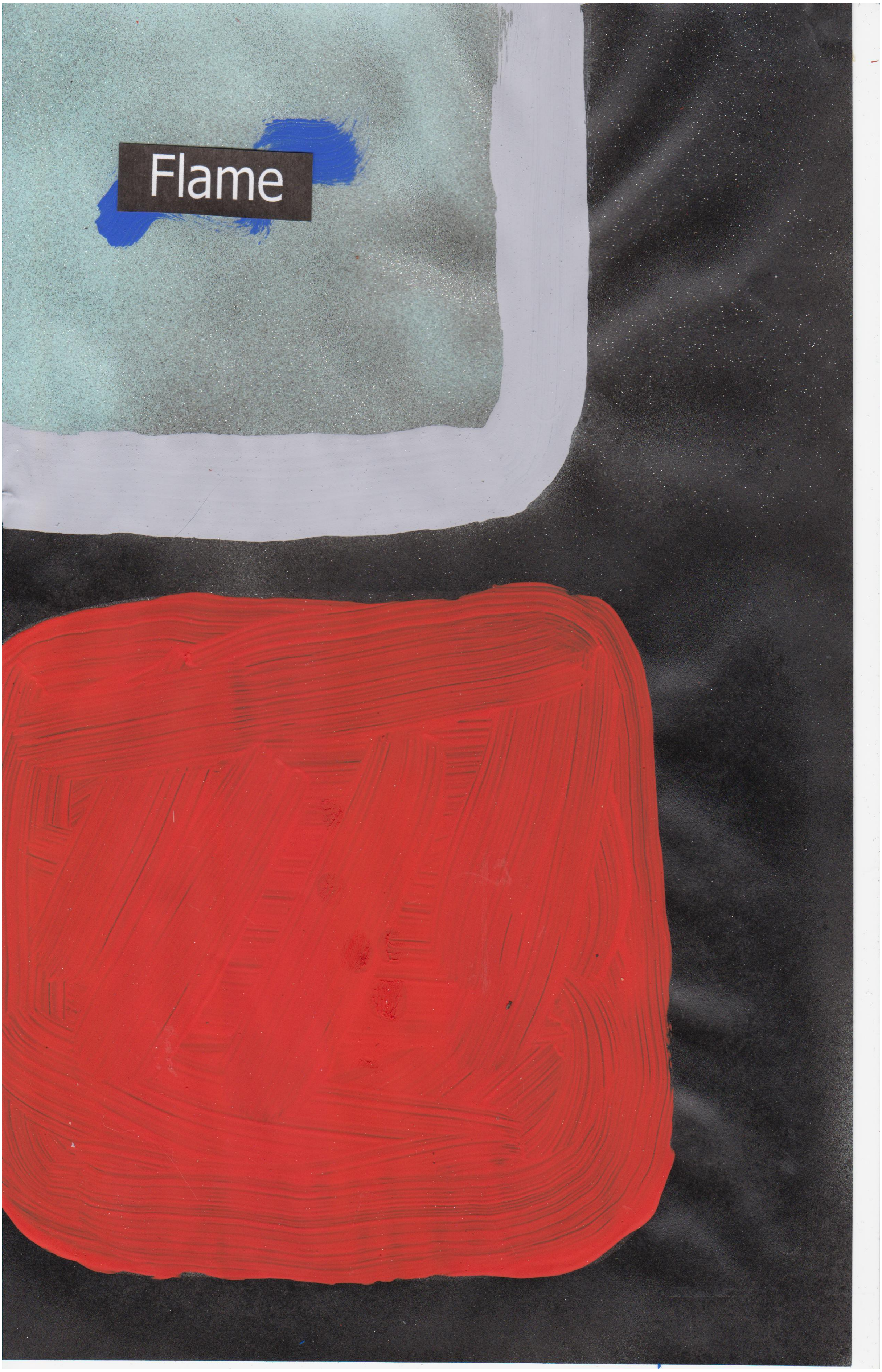
6th Row 2nd from left

Group no. 1


Electro-magnetic

6th Row 3rd from left

Group no. 1


Flame

6th Row Right

Group no. 1

10 Curriculum vitae

Born 14 August 1971 in Randfontein, South Africa

Education

1989 Senior Certificate Examination, Potchefstroom Gimnasium, South Africa

1993 Baccalareus Scientiae, Northwest University, South Africa

1994 Higher Education Diploma(post grad), Northwest University, South Africa

1996 Baccalareus Educationis (post grad), Northwest University, South Africa

2001 Honns. Baccalareus Artium (post grad), Northwest University, South Africa

Professional biography

1999-2000 Research assistant, Physics Dept. Northwest University, R.S.A.

1994-2006 Teacher – Secondary School (Physics, Chemistry, Mathematics, Technology)

2007-2009 Project Coordinator Exports (SEW Eurodrive, South Africa)

2009-current Teacher – Theodor Kramer Gymnasium GrG22 Wien (Physics, Mathematics)