# A

# PATH OF

# DISCOVERY

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*A Program of a Waldorf Grade School Teacher*

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## Volume Six - Grade Six

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*Including lesson indications, articles, verses, poems, etc.,.*

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## ACKNOWLEDGEMENTS

My acknowledgements and thanks to the authors and poets whose works I have freely included or quoted from in this volume.

# INTRODUCTION

Grade Six signals the first beginnings of pubescence. There are already obvious indications that the child's etheric (life) forces are strongly at work in the metabolic/limb system, especially with regards to the girls, many of whom are learning to live with their monthly cycle. This growth process is also accompanied by a strongly developing 'Will', which is frequently exercised by challenging the 'authority' (inner strength) of the adults in the child's life.

Grade Six students develop an intense interest in the world at large, from the plight of the less fortunate and the struggles of individuals in creating a better future, to the lavish excesses of the wealthy and the shallow successes of 'pop' idols. Students are beginning to search for a 'meaning' to their existence and for ways in which they can contribute to the welfare of the Earth and of Humanity.

How great then is the task of parents and teachers in presenting the phenomena of the world as being both 'good' and 'beautiful', as a counter to that which might be considered 'bad' and 'ugly' in society at large. Real conceptual thinking is not yet fully developed in the child and it would be wrong to teach the child about phenomena in such a manner. This problem is perhaps nowhere more obvious than in the teaching of science which has assumed such a formidable presence and influence in our daily lives.

The task is made even the more challenging through the fact that in Steiner-Waldorf education, the Human Being is placed central in the teaching of science, whereas main stream scientific thought is almost totally divorced from life's realities. Generally speaking, it is only through cold intellectualism that the marvels of the scientific world are able to be accessed. Little consideration is given with regards to the presentation of concepts in a manner which enables them to accessed by our faculties of Feeling and Willing.

Our task as educators is to present the world to the child in a truly 'creative' fashion, via a humanistic, wholistic approach which ensures that the Head, Heart and Hands act as equal partners in revealing the wonders of creation to the student.

*"The development of a child's sense of wonder requires*
*the companionship of at least one adult who can share it,*
*rediscovering with them the joy, excitement and mystery*
*of the world we live in..."*

Rachel Carson
(Author: *'Silent Spring'* )

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## THE CURRICULUM - An Overview

The lessons in Grade Six, which include a study of

**Ancient Rome** - from it's Beginnings to it's Fall.
**Geography** - history, culture and economics of one's Homeland.
**Geology** - igneous, sedimentary and metamorphic rock.
**Astronomy** - an imaginative approach, not a NASA approach!!!
**Physics** - Sound; Light/Color; Heat; Magnetism and Electricity.

will carry the child through this transition from childhood to early adolescence.

In Mathematics, the students will further consolidate their understanding of common fractions, decimal fractions and associated problem solving. They will also be introduced to percentages and simple interest, and the use of equations such as PRT/100 = I *(see 'Mathematics" for explanation).* This work will eventually lead over to the abstractions of algebra to a point where most students will be familiar *(if not comfortable!)* with a problem such as: *4a + 6 = 2a + 8. What is the value?*

Grade Six is an opportune year in which to present the students with 'challenges' which encourage them to develop their capacity for working independently and for showing initiative. My class were required to complete such a 'challenge' each term (4 terms) in the form of the following 'projects' which generally required a lot of effort. Incidentally, it is important to set a date for completion of a project and for the adult to abide by that date! My students were penalised for lateness!

**Roman History:** research, design and create a small mosaic no larger than 30 cm x 30 cm. Use only natural or recycled materials, such as stones, pebbles, broken tiles, broken glass etc.,.

**Physics (Sound):** create an 'original' musical instrument (string, wind or percussion) and teach yourself to play a melody or rhythm on it.

**Geometry:** create an imaginative 2 or 3 dimensional representation of a 24 division of a circle *(the use of plain string, nails and a wooden board is not considered 'imaginative'!!).*

**Geography:** research an aspect of your country's history, culture or economic geography and translate this into a self-created text book *(main lesson book).*

**Charity:** students to use their own initiative in raising funds for the "class charity". Adults to only offer encouragements and moral support!! The effort which some of the students put into this project was phenomenal! Altogether they raised almost $2,000 over a period of 4 weeks!

# MATHEMATICS

## Percentages, Interest and Discount

*"...the actual power of judgment that lets us count on reasoned, intellectual understanding belongs to the last of the three periods (sic: of childhood). That is why we use the twelfth year, when the child is moving towards an understanding based on judgment, in order to let this merge with what still requires some kind of instinct, even though this is already strongly overshadowed by the power of judgment. Here we find the twilight instincts of the soul that have to be overcome by the power of judgment.*

*We must take into account that during this stage the human being has an instinct for the calculation of interest rates, for what can be raked in as profit, for the principle of discount and so on. This appeals to the instincts; but we must let the power of judgment be much stronger than this, so during this period we must deal with the relationships that exist between the element of calculation, the circulation of commodities and the ownership of property and wealth, in other words percentage and interest-calculations, discount calculations and similar matters..."*

"Practical Advice to Teachers" (Lecture 14 - Stuttgart 1919) Rudolf Steiner.

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It can be noticed that the feelings of students towards this crucial subject can go through remarkable changes as they progress through the different grades, changes which can frequently be attributed to the accumulative effect of the teaching which they have experienced. Whether these changes are positive or not, depends to a great extent on the enthusiasm which the teacher has brought to his/her teaching. Has this subject also been *"A Path of Discovery"*, not just for the student, but for the teacher also?

I often think that one of the blessings for the grade school child is that their class teacher is not (necessarily) a specialist in any subject! This is not to imply that specialist teachers do not make good teachers, on the contrary! However, when a class teacher or any teacher for that matter, struggles with a subject, enters a realm which is "unknown" or where he or she may take faltering steps, then that subject becomes alive.

How our mathematics lessons are prepared and presented, sends a strong message to our students. If we as teachers and parents can show genuine enthusiasm for exploring mathematical ideas, to look upon this challenge as a joint venture of tutor and student. To be willing to be unconventional in our approach, to use a variety of methods and materials in exploring the unknown, then all this will be beneficial in the development of positive working skills in our students. Working together to discover new worlds can become a joyful experience for all concerned.

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## Decimal Fractions - a review

The Math section of volume five of *"A Path of Discovery"* focussed on the conversion of common fractions to decimal fractions, and how the four processes could be applied to problem solving with respect to decimals. This whole area needs to be thoroughly reviewed as early as possible at the commencement of a new school year. I chose to schedule a "Math Morning (Main) Lesson" as the first block of the year.

Within a matter of three weeks, we had progressed through the entire Grade Five curriculum once again, brushing-up on the weaker areas as we went along to the point where it was possible to introduce the division and multiplication of decimals by decimals, an area which was only briefly touched upon last year.

Having already learnt in Grade Five how to covert Common Fractions to Decimal Fractions, we now turned our attention to the reverse process, i.e. converting a decimal to a fraction. This is a very simple process.

If we take for example, a decimal fraction such as

.80 we write the digits of the decimal on the Numerator line:

80 and write down a 1 for the Denominator. Then for every digit in the Numerator we write a 0 next to the 1 on the Denominator line, thus:

80/100

The next stage is to Reduce the fraction to its lowest terms:

$$\frac{80}{100} \div \frac{20}{20} = \frac{4}{5}$$

Reversing this process once more, we arrive at:

$$\frac{4}{5} \times \frac{20}{20} = \frac{80}{100}$$

Referring once again to our work of last year in changing Common Fractions into Decimal Fractions, we see that:

$$\frac{80}{100}$$

becomes **0.80** or **0.8** as the "zero" to the right is valueless.

We are now ready to progress to Percentages!

Students will be familiar with the Latin word "cent" not only because of its usage as a denomination of currency, but also for its connection with everyday words and things such as centigrade, centimetre, century, centurion, centipede, etc,. The transition from 80/100 to 80% was explained to the class somewhat along the following lines:

Percent means "a part of 100". Our equation 80/100 signifies that there are 80 parts out of a possible total of 100 parts or 100 per cent. However, 80/100 can be written much more easily if we omit the "slash" between the 80 and 100. Having done this, we then move the figure "1" and place it at an oblique angle between the two zeros, thus 0 / 0......we have arrived at a new mathematical sign for 100:

%

Let us now rewrite our original 80/100 as a percentage:

$$\frac{80}{100} = 80\%$$

However, it is not always quite so simple converting a Common Fraction to a percentage by this method. Let us take a look at a Common Fraction such as:

$$\frac{4}{16}$$

We need to first change this into a Decimal Fraction which is accomplished by dividing the Numerator (4) by the Denominator (16) as follows (see: Volume 5 for further explanation and examples):

```
   0.2 5     =   0.25
16)4.0 0 ÷
   3 2
     8 0
     8 0
     0 0
```

From what we learnt earlier, we know that 0.25 is the same as $\frac{25}{100}$.

Therefore: $\frac{25}{100} = 0.25 = 25\%$

Let us reverse this process:

$$25\% = 0.25 = \frac{25}{100}$$

Time to practise changing Percentages to Decimals and then Simple Common Fractions:

$$15\% = 0.15 = \frac{15}{100}$$

$$23\% = 0.23 = \frac{23}{100}$$

If we have a number such as our earlier 80/100, this can also be written in the following manner, having **first** divided both the Numerator and Denominator by 10:

$$\frac{80}{100} \div \frac{10}{10} = \frac{8}{10}$$

As long as we **KNOW** and **UNDERSTAND** that we have divided both Numerator and Denominator by 10, we can speed-up the process by the simple expedient of "cancelling out" one zero against another zero:

$$\frac{80}{100} = \frac{8}{10}$$

We are able to convert this into a Decimal Fraction by the same method as before, i.e. division of the Numerator by the Denominator to arrive at 0.8

$$\frac{8}{10} = 0.8 = 80\%$$

Remember that $\frac{8}{10}$ is the same as $\frac{80}{100}$

Change the following into %'s:

0.7 = 70%

0.5 = 50% etc, etc,.

Now reverse the process:

40% = 0.4

90% = 0.9

75% = 0.75

Having progressed to this stage, students can now begin to find the percentages of given numbers.

Most readers will recollect the formula for this process, which is:

(P(the given number) X R (the % amount)) ÷ 100

or

$$\frac{PR}{100} = \text{Answer}$$

If were to take a simple number, such as 124 and asked our students to find 12% of that amount, they would be required to complete the following:

```
 124
  12 x
 248
124  +
1488
```

```
       --14.88
100)1488.00
    100
     488
     400-
      880
      800-
       800
       800-
       ---
```

Answer: 14.88

And that was an easy one!! What of the student who still has problems with long division? By this method, it is unlikely that such a student would be able to solve the problem without getting into a muddle.

But the solving of problems do not need to follow such a complicated route. Instead, we dispense with the division and solve the problem purely by the use of multiplication and addition, as follows:

Firstly, the student makes use of the skills recently acquired in converting Percentages into Decimal Fractions, thus:

12% becomes .12

We now multiply the Multiplicand of 124 by the Multiplier .12, thus:

```
 124
 .12  x
 248
124   +
14.88          Ans: 14.88
```

Where to put the Decimal Point in the answer has been fully explained in Grade Five and will have been thoroughly revised prior to the introduction of Percentages.

By using the above method, we have by-passed the need for long division, having completed the division process "in-our-heads" by converting the Percentage to a Decimal Fraction.

The students should be given all sorts of practical problems to solve, using either of the above methods, but I suggest that the second method is much preferable, being the simplest and quickest. It will be seen to be especially useful when dealing with larger numbers and money.

It would be good if practical problem solving were in some way directly related to the child's own experiences. Matters which are a commonality for the class are a good starting point. For instance:

14% of the class have brown hair. How many?

85% of the class drive to school each day. How many?

25% of the teachers are male. How many?

The teacher must of course work-out these problems beforehand, otherwise unforeseen problems can arise!

I set several challenges for the class which involved a child having to go to the School Office (by prior arrangement!!) to obtain certain figures on enrolment, modes of transport, even the number of teachers by gender and age (no names for the latter!!!). I had produced sheets with the relevant details which had been left with the secretary. She cheerfully entered into the spirit of things by "searching" for the information in her files to hand to the class couriers. Incidentally, such little diversions can be a wonderful release for the student who is no longer able to sit on her/his chair and is longing to run outside!

Having gotten this far, our students will wish to know how to apply these new skills in different ways. I would suggest that now is an opportune moment to introduce "Bar Charts". How would we be able to make a "picture" of the number relationships of each of the classes in our school! The school where I teach has a relatively high enrolment, somewhere between 480 and 500, so I opted for the "500" figure to enter on my prepared sheet for the office, presented as follows:

## STUDENT NUMBERS BY AGE AND CLASS

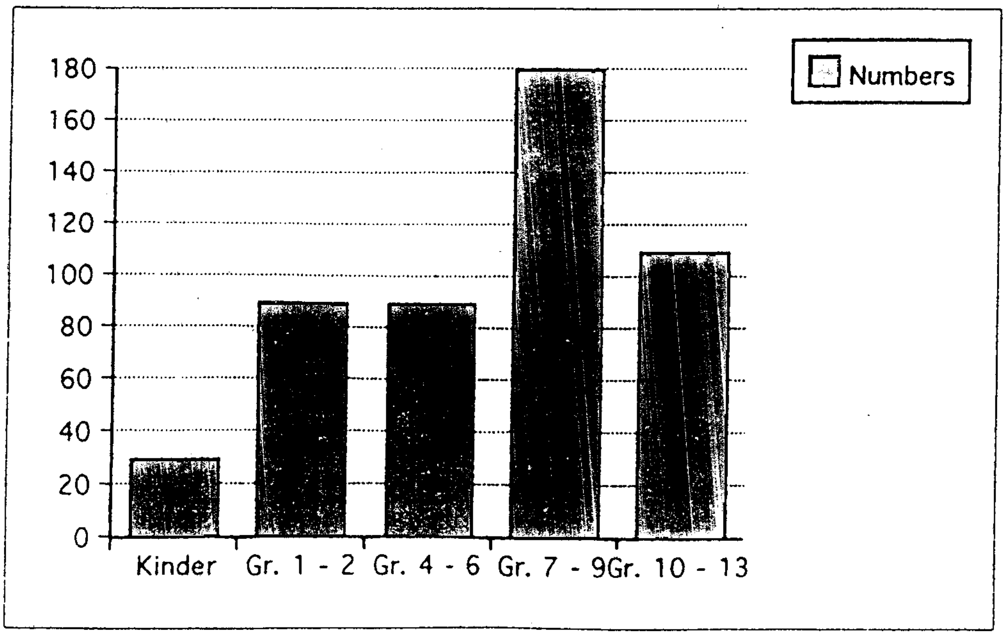
| CLASS | AGE | NUMBERS | % |
|---|---|---|---|
| Kindergarten | 5 - 6 | *30* | 6% |
| Classes 1 - 3 | 6 - 9 | *90* | 18% |
| Classes 4 - 6 | 9 - 12 | *90* | 18% |
| Classes 7 - 9 | 12 - 15 | *180* | 36% |
| Classes 10 - 13 | 15 - 18 | *110* | 22% |
| | **TOTAL:** | **500** | **100%** |

The figures in *italics* were those arrived at by the class after having solved the problems, e.g. 6% of 500

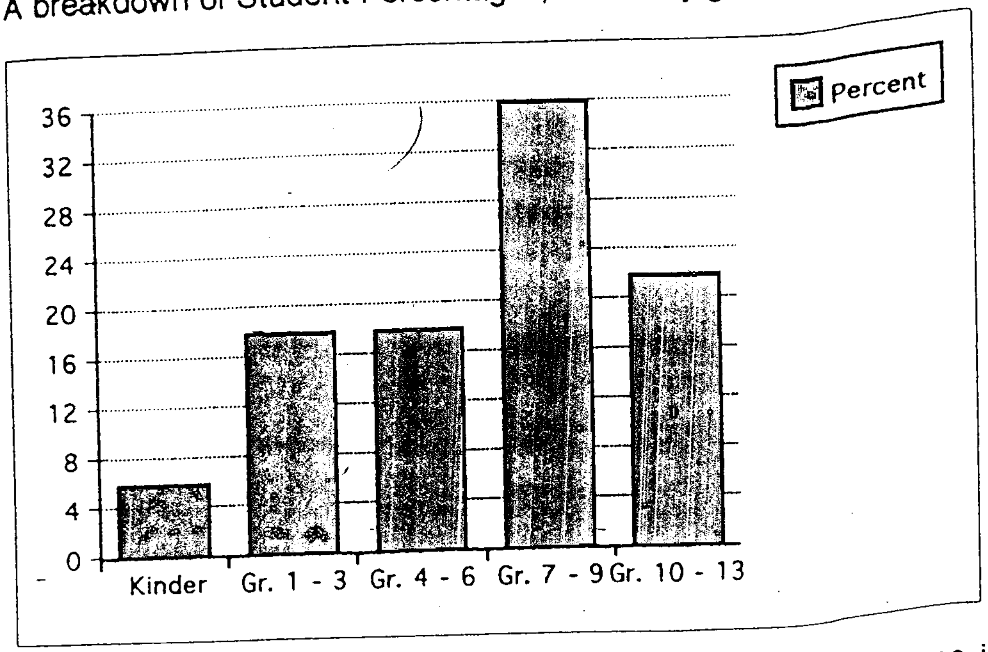
I choose to take the "Number" of students as the first piece of information to be incorporated into our first Bar Chart *(see below)*.

The second Bar Chart showed the same information, but in %'s rather than Numbers *(see below)*.

A breakdown of Student Numbers, shown by grades:



A breakdown of Student Percentages, shown by grades:




The students will have observed that both charts are the same in shape, although each chart furnishes us with different information. There is of course no reason why such charts cannot be created in a more imaginative, colorful format (maybe as Pictographs). It is purely for convenience that I have produced them as shown.

At the conclusion of this Morning Lesson block, the class were given a Math Quiz which enabled me to assess their progress and to pin-point areas which would require further attention in our thrice weekly practise periods *(a sample Quiz page is shown at the end of this section)*.

In addition to practising the new work which has been introduced in the Morning Lesson, students need also to practise skills in other areas of math, especially the interpretation of written information.

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The second Morning Lesson Math block could be called "**Business Math**". Some time could fruitfully be spent in presenting and discussing the history and meaning of **Economics**, together with our monetary and the banking systems.

**Economics** would include our desire for certain goods and services. When we receive such goods and services, then we become the **Consumers**. Those who supply us with our goods and services are known as **Producers**.

For the **Producers** to be successful in supplying the **Consumers** with goods and services, they in turn require **Resources**. These are divided into three main categories:

**Natural resources** - such as food, water, fuel (gas, coal), wood, etc,.

**Human resources** - skills of the farmer, miner, lumberjack, carpenter, etc,.

**Capital resources** - this could include those items which are required by the Producers to create what is required by the Consumers, e.g. What tools does the carpenter require to make the desks which we have in the classroom?

**Specialisation** - refers to those persons who specialise in the production of one or another item of goods or service, such as a farmer, builder or computer technician.

**Interdependence** - those who specialise are of necessity dependent on others for supplying their needs, such as the farmer who requires a barn. Or the builder who requires milk and vegetables.

**Barter** - an example could be where the farmer who requires a new barn would trade a certain amount of farm produce in return for the barn. The impractibility of barter where very large quantities of goods exchange hands should be discussed.

Naturally, all the above should be presented in a lively and imaginative manner, with as much pupil participation as is possible through discussion, question/answer sessions and "mock" bartering scenarios. The latter will no doubt especially appeal to the "traders" in the class who have their bartering sessions in the playground...........despite the teachers disapproval of such activities!! One could also mention the recent revival of "green" money, but beware of politicising!

We now arrive at the advent of money as we know it. Consideration should be given to the movement of money in society, through buying and selling, lending and borrowing, and gift money....both giving and receiving....how different these latter two experiences are!

This will lead to class work incorporating the different types of financial transactions, such as price increase (mark-up), price decrease (discount), simple interest paid on loans, tax liability (personal, goods and services). All of this work will involve the children in working with %'s. Furthermore, it is an opportunity to introduce the simple "book keeping" ledger, along with the creation of a "budget".

Reviewing our work from the previous Math block enables us to move quickly forward into the world of finance by finding the $% of a given $ amount. We can refer to this $% as the "Interest" paid to us on a deposit in a Savings Account, which of course leads us straightaway to the formula:

$$\frac{PR}{100} = I$$

which we met earlier in a slightly different format.

It is then but a short step to introducing T as signifying the period of time over which I is to be paid or received. This gives us a new formula:

$\frac{PRT}{100} = I$ which when expanded means:

**(Principle x Rate x Time) ÷ 100 = Interest**

As with our previous work in this area, we will dispense with the involved process of first multiplying and then dividing, and instead opt for the quicker and simpler method of working with a decimal fraction. At this stage, we shall only work with Simple Interest.

The following is an example of the type of problem which students should be able to comfortably work with by the conclusion of this main lesson.

What is the Interest on $1,240 at 8% over 3 years?

Rewrite this as:

$1,240 x .08 x 3 = I

$1,2 4 0
.0 8 x  don't bother to multiply with the zero.

9 9.2 0
3 x
2 9 7.6 0 = I

Answer: Interest = $297.60

Further problems could be set where the **I** for Interest is changed to **D** for Discount, **C** for Commission or **T** for Tax as the need dictates. The class should develop sufficient self-confidence so that they are able to "switch" from one category to another without any difficulty whatsoever.

The next Math Morning Lesson block will cover the introduction of Algebra.

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# ALGEBRA

## Week One:

Towards the end of Grade Six, the teacher should be able to make a smooth transition from problems involving "profit and loss" where capital letters have frequently been used as a substitute for numerals. (e.g. I = PRT/100), to the use of lower case letters in the teaching of algebra.

Algebra is frequently viewed by those who are unfamiliar with it, as yet another obstacle to be feared. In actual fact, algebra serves to *simplify* the maths process! Let us look at the following problem, set out in two different ways:

1. *Sheldon has two pairs of board shorts and six T-shirts in the cupboard. He has another pair of shorts in the wash, along with four T-shirts. He has just returned home with one new pair of board shorts and two additional T-shirts. How many pairs of board shorts and how many t-shirts does Sheldon have? Or*

2. *2b + 6t + b + 4t + b + 2t*

The answer to the first question is:

**4 pairs of board shorts and 12 T-shirts**

The answer to the second is:

**4b + 12t**

The student's attention should be directed to the fact that the second problem is merely a "simplification" of the first. That we have substituted "letters" for actual "items".

Have the children create several other such problems for themselves. First in a written format and then in an algebraic format. Once they have gained confidence in working with "letters" instead of "items", it should be possible to lead over to abstractions which have no immediate relationship to concrete articles, for example:

**4a + 5b + 3a + 2b = 7a + 7b**

The fact that we may use more than two letters does not matter. We simply group to letters together into their "family" groupings:

**4h + 3n + 5 m + 5h + 3m + 2p + n + 2h = 11h + 8m + 4n + 2p**

The problem is no greater if we decide to use subtraction as well as addition:

6p + 4q - 2p - q = 4p + 3q

Simplify:

7r + 4s - r + 2s - r - s + 4r = 9r + 5s

Taking this problem solving a step further, the student can be led to the solving of problems where "negative" numbers are involved. This process may require greater explanation as we are proceeding into abstractions:

9s - 6s - 8s = - 5s

Maybe the above could be explained as follows:

*Hannah has seen a nice "tank top" in the store. It costs $12. However, Hannah has left her $9 at home, which in anycase would not be enough to enable her to purchase the "top". However, her sisters offer to help her out, as long as she promises to repay them. Sally lends her $6 and Crystal $8. On arriving back home, Hannah first repays Sally her $6. But she is only able to repay Crystal $3. which leaves her $5 in debt to Crystal.*

It would be advisable for the students to work with such "problems" for the first couple of days of this Morning Lesson, so that they acquire confidence before proceeding to the next stage of algebra shorthand.

We know that 2 x "board shorts" can be written as 2 x b or as 2b by using letters as a form of "shorthand writing".

We could reverse 2 x "board shorts" to read "board shorts" x 2. However, if we wish to write either of these phrases in algebra shorthand, we are required to write the number in front of the letter, i.e 2b

Use algebra shorthand to rewrite the following:

| | | | | |
|---|---|---|---|---|
| **z** multiplied by **4** | = | *z x 4* | = | *4z* |
| **3** multiplied by **y** | = | *3 x y* | = | *3y* |
| **c** minus **5** | = | *c - 5* | | |
| **6** added to **f** | = | *f + 6* | | |

If we direct the students attention to work which has been undertaken in both math and geometry lessons, they can be reminded that when calculating "area", the answer is given as a squared number, for instance a rectangle measuring 3 meters by 2 meters has an area of 6 meters square or $6m^2$., e.g.

$$3m \times 2m = 6m^2$$

Therefore, **m** x **m** can be written as $\mathbf{m^2}$

Likewise, **m** x **m** x **m** can be written as $\mathbf{m^3}$

Rewrite the following in a shorter way:

$r \times r \times r \times r \quad = \quad r^4$

$a \times a \times b \times b \times b \quad = \quad a^2 \times b^3 \quad = \quad a^2b^3$

Let us once again combine letters and numbers in our equations:

$2 \times d \times 2 \times d \times d \quad = \quad 2 \times 2 \times d \times d \times d \quad = \quad 4d^3$

Introduce "brackets" to gather groups of numbers or letters together:

$(e \times e) \times 4 \times 4 \quad = \quad e^2 \times 16 \quad = \quad 16e^2$

$(2 \times 2) \times (g \times g \times g) \quad = \quad 4 \times g^3 \quad = \quad 4g^3$

The above should provide sufficient challenge for a group of students during the first week of the Algebra Morning Lesson.

**Week Two:**

It would now be wise to introduce the order of operations the student. If we are required to simplify an algebraic sentence which contains more than one process (+, -, x), it is necessary to to simplify the multiplication section first. The remainder of the simplification process proceeds as normal. For example:

$3r \times 4 + 4r \times 2 + 6r \times 3$ is the same as

$12r + 8r + 18r$ which in turn is the same as

$38r$

Create a variety of practise problems for the student to solve before moving on to the next stage.

It was at this point that I introduced "substitution" into the lesson. That is to allocate of a specific value to a specific letter. For example:

Substitute a= 3 to solve $6a + 3a - 10$
This is the same as $(6 \times 3) + (3 \times 3) - 10$
Which is the same as $18 + 9 - 10$
Which is in turn $27 - 10 = 17$

Substitute $s = 2$ to calculate $3s^2 + s + 4$
This is the same as $(3 \times s \times s) + s + 4$
Which after substitution is $(3 \times 2 \times 2) + 2 + 4$
This in turn becomes $12 + 2 + 4 = 14 + 4 = 18$

Students should now be able to solve problems such as:

Substitute **a = 3 km** in **P = 5a**
to calculate the perimeter (P) of a large square paddock.
or

Substitute **S = 120 kph** and **T = 3 hours**, in **D = ST**
to find the distance **(D)** travelled by a train .
etc,.

Progressing to more involved equations, the students should now be ready for challenges such as:

Find the value of $\frac{(s + t)^2 + s}{t}$, if $s = 4$ and $t = 2$.

Begin with the brackets: $(s + t)^2$ is the same as $(4 + 2)^2$, which is the same as $6^2$, which in turn equals **36**

therefore, $\frac{(s + t)^2 + s}{t} =$

$$\frac{36 + 4}{2} =$$

$$\frac{40}{2} = 20$$

## Revision

If $a = 3$, $b = 4$ and $c = 2$, find the value of:

1. $a + b + c$
2. $2a + 2b + c$
3. $ab + bc$
4. $ac + 5 + b$
5. $(bc) \div c$
6. $2b \div 2c$
7. $a^2 + b^2 + c^2$
8. $\frac{ab^2 + c^2}{b}$

## Week Three

### Linear Equations - find the missing number!

After having worked with the above, the next stage might, at first glance, appear to be a retrograde one! However, the students enjoys what at first seems a mere continuation of the daily "mental arithmetic" which has been practised nearly every day during the class teacher period.

Allan thinks of a number and adds 4. the answer is 12.
What was the number Allan first thought of? 8

or

$a + 4 = 12$. What is the value of a? 8

The problems were identical, however algebra has been used to solve the second equation. Give the students a variety of problems where they have to find the "missing number". Follow this by setting them an array of algebraic equations to solve, e.g.

| | | | |
|---|---|---|---|
| **b + 6 = 15**. | Find **b** | **s + 12 = 34**. | Find **s** |
| **y - 7 = 12.** | Find **y** | **z - 14 = 21** | Find **z** |
| **a x 3 = 18** | Find **a** | **b x 5 = 30** | Find **b** |
| **e ÷ 4 = 3** | Find **e** | **f ÷ 8 = 5** | Find f |

Write the following as algebraic equations and then solve them:

1. Alice thinks of a number. She adds 8 and tells you that the answer is 15. What number did she first think of? Write and solve this as an algebraic equation.

2. 6 packs of equal size, contained a total of 72 apples. How many apples were there in each pack, assuming that each pack held exactly the same number?

Create other such problems for the students to solve.

**Expansion of brackets:**

Look at and discuss the following examples with the students:

2(a + 3) is the same as 2a + 6

It can be seen that we have multiplied what lies within the brackets with the 2 at the beginning of the equation. We can apply this to other problems, such as:

4(2b + 12) is the same as 8b +48
or
3(5s - 20) is the same as 15s - 60

Set other similar problems for the students to solve. Then proceed to more advanced equations, e.g:

$$3(c + 2) = 21$$
thus, $3c + 6 = 21$

to finally solve this equation *(which is to find the value of* ***'c'****)*, we must eliminate the **+ 6**. To achieve this, we simply subtract (-) the **+6**, i.e:

$$\begin{aligned} 3c \quad +6 &= \quad 21 \\ -6 &= -\ 6 \end{aligned}$$

for whatever is done to one side of the equation must be done to the other side too!

The answer will therefore be:

$$\begin{aligned} 3c &= 15 \\ \text{then } c &= 15 \div 3 \\ \text{therefore } c &= 5 \end{aligned}$$

**Solution of Equations:**

Remember, whatever is done to one side of the equation, must be done to the other side as well! Have the students solve problems where the aim is to end up with the 'letter' on one side and the 'number' on the other, e.g.:

If $5t + 15 = 4t + 20$, what is the value of 't'?

$$
\begin{array}{rrcrr}
5t & +\ 15 & = & 4t & +\ 20 \\
 & -\ 15 & = & & -\ 15 \\
5t & & = & 4t & +\ 5 \\
-4t & & = & -4t & \\
t & & = & & 5
\end{array}
$$

Solve the following equations:

$6r + 12 = 3r + 18$

$9p + 12 = 4p + 37$

$14b - 13 = 5b + 5$

$17s - 5 = 10s + 16$

What I have attempted to describe above, should be sufficient work to occupy the class for the full three week morning lesson block. In actual fact, there may even be more material than the average class is able to assimilate over such a short period of time and it might be necessary, even beneficial, to spread the material over another morning lesson block. Some teachers even leave algebra *(especially that which I have outlined for the third week)*, until Grade Seven, although I firmly believe that Grade Six is the right time to present this area of study to the students.

Teachers and parents are encouraged to create their own problems for the students to solve, many of which will have been introduced in an imaginative manner through story or examples from everyday life *(which I have omitted to include here)*. Examples are of course available in many text books. I would suggest that the teacher only use these as a last resort at this stage. However, once the Algebra Morning Lesson block has come to a conclusion, there is no reason why good text book questions cannot be given in practice lessons or as homework.

# SCIENCE

## PHYSICS

*"In our work with children of primary school age, we must see to it that we engage the rhythmic system only. The rhythmic system never tires, and is not over-exerted when we employ it in the right way, and for this rhythmic system we need not an intellectual, but rather a pictorial method of presentation, something that comes out of the imagination. .....We must make the lifeless things live through imagination and always connect them with real life...."*

**"The Kingdom of Childhood"** Rudolf Steiner (Torquay 1924)

Science has become such an integral part of our lives, that educators are faced with a challenging, if not formidable, task when presenting this subject for the first time. As Dr. Manfred von Mackenson writes: *"The aim of conventional education is to lead the child into particular fields of knowledge. Waldorf education has the opposite: to transform fields of knowledge into "education" in a way that encourages the child's healthy development."*

Our task as Waldorf educators, either as teacher or parent, is to search for a manner in which the inherently dead and abstract world of conventional scientific thinking, is metamorphosed into a science which nourishes the soul and spiritual development of the student. To go any way towards fulfilling this ideal, educators must be able to call forth from within themselves, powers of imagination and inspiration which will bring life and freshness into their teaching. Such inspiration is best acquired by serious study of the child's current stage of development as presented in the educational and philosophical writings of Rudolf Steiner.

Work over the previous years will have gone some way towards laying a firm foundation for the introduction of the science curriculum in Grades Six through Eight. However, the first introductions to science actually comes in Grades Four and Five, when the students are introduced to the realms of animal and plant studies. These lessons, with the Human Being taking a central position, will have evoked feelings of wonder, of awe, of reverence; feelings which will have been experienced by the child in the depths of the Soul.

This Soul Nourishment needs to continue through the proceeding years and it is therefore imperative that the educator present the science lessons through the 'qualitative' aspect of the subject. The 'quantitative' aspect can only be presented at a later stage when the child has the capacities to relate to abstract thought and processes.

All of our scientific teaching, especially in these first years, will best be conveyed to the child through 'phenomena'....and the larger and more impressive the better. To quote the late Fritz Julius (my science lecturer during Teacher Training): "If you are going to make a "bang", then make it a BIG BANG!!"

Waldorf science is a synthesis, in these early years, of some of the most important discoveries of the past centuries. As educators, we will strive to integrate the known and accepted scientific concepts contained in scientific publications and text-books, into a wholistic conception of the world. Only when we have gone some way towards achieving this should we consider the material as being ready for presentation to the student. Our responsibility is to awaken in our children, feelings of wonder, awe and reverence for the marvels of Creation.

*******

Less than fifteen years ago, there was very little in the way of written material on the subject of 'science teaching' for the benefit of new Waldorf teachers. Today, there are an increasing number of quality Waldorf publications dealing with this particular subject (see: Bibliography). I am therefore somewhat hesitant at putting forward yet more suggestions and ideas. However, I will endeavour to present proven experiments which I believe can be easily recreated by my readers, with the simplest of house-hold items and at very little expense.

## ACOUSTICS

In the beginning was the Word;
And the Word was with God,
And the Word was God.
All things were made by Him;
And without Him was not anything made
That was made.

**St. John's Gospel**. Chap. 1, v. 1 - 3

****

"In many cultures the primal act of creation begins with the word or the song whose vibrations animate the void. In the Sufi tradition, it is said that Allah brought all things into existence by calling out their names, thus, when the sacred names are pronounced one partakes in that primordial act....

Sound, vibration, and song are believed by many to be the creative, generative forces within the cosmos. In those societies that understand time as a cycle, acts of creation must be renewed and the songs repeated again and again."

**"Blackfoot Physics"**. F. David Peat (Pub: Fourth Estate.1996)

******

The first strand of the science curriculum presented to Grade Six, is "Acoustics", with a focus on the following areas:

1. The Nature of Sound and It's Effect on the Human Being
2. Natural and Manufactured Sounds
3. Pitch and Volume of Sound
4. How Sound Travels
5. Creative Power of Sound
6. The Human Voice

The presentation of the above sub-strands would take place over a period of five Morning Lessons:

**Day 1** Silence
Different Sounds

**Day 2** Review/Recount
Sounds and Feelings
Musical instruments

**Day 3** Review/Recount
Pitch and Volume

**Day 4** Review/Recount
How Sound Travels

**Day 5** Review/Recount
Creative Power of Sound
- Vibration experiments
- Chladni Plate experience

The Human Voice (Larynx)

**Day One:**

Ask the students to observe a period of absolute silence for 2 - 3 minutes (a real blessing for a Monday morning!). The students are then asked to state whether or not we were able to experience "absolute" silence. The resulting contributions will show that we have not had such an experience, everyone has heard a wide variety of sounds which we can readily identify. The students attention can be drawn to the phenomena that absolute silence is a virtual impossibility.

We are able to "switch-off", make ourselves oblivious to many of the sounds around us. Sometimes we become so immersed in what we are doing, that we do not consciously hear what is going on in our immediate environment. On the other hand, we have the capacity to be SELECTIVE about what we listen to (quite apart from switching-off the radio or stereo!). We are able to SELECT the sound we wish to focus on out of a host of other sounds.

As well as having this capacity to SELECT, we are also able to RECOGNISE different sounds; for instance the voice of a parent or friend. This ability to RECOGNISE also assists us in DISTINGUISHING sound, e.g. the sound of wind, as against that of the rain.

Now would be an appropriate moment to have the students sit quietly with eyes closed, and possibly facing in the opposite direction, whilst the teacher or parent creates a variety of different sound with inanimate objects, these could include:

| | |
|---|---|
| Crash | a dish falling and breaking |
| Pop | removing a cork from ~~a~~ bottle |
| Bang | piercing a blown-up balloon |
| Thud | a heavy weight falling on a solid wooden surface |
| Clang | the beating of an iron,bar with a hammer |
| Tinkle | a fork or spoon against a wine glass |
| Tick | a clock or metronome |
| Crunch | a foot stepping on corn flakes |
| Rustle | dried leaves or sheets of newsprint |
| Splash | a stone falling into water |
| Trickle | water running slowly into a bucket/bowl of water |
| Patter | water from a watering-can falling on paper secured over an empty bowl |
| Etc.,. | |

**<u>Day 2:</u>**

We hear many sounds, such as the sound of the wind, the crack of lightening, the roll of thunder and the patter of rain, to mention but a few. The sounds which go on around us have the power to affect the Human Being. A piece of chalk scratching over the surface of the chalkboard is very nerve wracking for some people. Harmonious singing or instrumental music can arouse pleasurable feelings, whilst an unidentified bang or other such loud noise has the possibility to instil fear. The crying of a little child may awaken feelings of compassion.

However, too much sound can prevent us from being selective. We may even be very unappreciative of some sounds, such as loud shouting or screaming, the screeching of a poorly played violin or the nerve-grating sounds of some Popular music. What one person enjoys, another may not!

Whatever our preference, we should also bear in mind that sounds which are too loud can do serious damage to our ears, damage which may never be healed! *(The "Ear" as a sense organ is studied in Grade 7 or 8)*

Let individual students recreate some of the inanimate sounds which they listened to on Day One. Have the class participate by expressing what "feelings" the different sounds conjure up.

Introduce a variety of musical instruments. In a class, it is highly probable that there is at least one violinist, 'cellist, pianist and maybe a few who play "wind" instruments. Have them bring their instruments to school for this lesson and prepare them for the playing of a short piece of music to the class *(try to arrange for pieces with different "moods")*. If this is an impossibility, then as a last resort, have the children listen to short pieces you have prerecorded on a cassette tape.

**Day 3:**

At this stage, we could lead the students to a better understanding of the different categories of sound, such as "inanimate" (stones, plants, musical instruments, etc.,) and "animate" (insects, birds, animals).

Lead the students into the mysteries of Pitch and Volume. Here one will need to have a variety of equipment, such as wine glasses, glass bottles, tubes (e.g. either glass, metal or bamboo).

A set of Pan Pipes would be useful....especially if you have learnt to play them for the occasion! Instruments such as the xylophone and African marimba would also be useful.

A demonstration of possible variations in the pitch of a note can be demonstrated by using eight identical bottles. By blowing across the top of one of the empty bottles, we can determine the pitch of the note produced. Having ascertained what this note is, one can then pour a small quantity of water into the second bottle. By blowing across the top, we can judge when we have produced the next note in our scale. Follow this procedure with the remaining six bottles until one reaches the octave of the original note.

It can be seen that in each bottle we have displaced a certain amount of air in favor of water, thus reducing the length of the air column. The shorter the air column, the higher the note produced. Compare this to the Pan-pipes and the family of recorders (sopranino, descant, treble, tenor and bass).

If we now lightly strike the sides of the bottles, we find that the note in the bottle with the shortest column of air, but greatest amount of water gives us a deep tone. One can compare this to the metal or wooden strips on the xylophone or marimba (comparing the amount of water in the bottle to the length of the bars).

One can demonstrate this phenomena by creating a simple instrument with "pins"! Arrange several pins in a row on a small plywood box. Play music on this instrument by lightly plucking the pins. You will obtain lower notes from the longer pins and higher notes with of the shorter ones.

This experiment can be created on a larger scale by the use of nails and a larger wooden "sounding box". Make another observation with the common pocket comb ( one which has "teeth" of decreasing size).

Moving on to sounds produced by friction, rather than those produced by "blowing" or "hammering (drumming)", we can pluck a single "open" string of a guitar or violin and notice that the longer the string is, the deeper the resulting note. When the length of the string is altered by placing a finger on the finger-board, the string is effectively shortened and the ensuing note is higher.

A new phenomena arises when one considers the "thickness" of individual strings. The "thicker" the string, the deeper the note. This is caused by the speed of vibration, for a thick string vibrates at a much slower rate than does a a thin string, such as the "E" string on the violin. When we "pluck" a string, we cause it to vibrate. The hairs on the violin bow have the same effect, for each hair is covered by minuscule "hooks" which catch the string for the briefest of moments before releasing it again.

**Day Four**

Students can now experience the "movement" of sound through air, solids and water.

**Air:** Let one student whistle; other students in the room will hear the sound distinctly. The sound is carried around the room by the air.

Another experiment which appeals to students, involves a garden hose. Unwind it to it's full extent (the longer the better!). One student can speak into one end of the hose, whilst a second student at the other end will hold the hose to his/her ear. What has been said by the first student is clearly understood by the second. The air inside the hose is the carrier of the sound.

**Solid:** Secure two tin cans minus the lids. A small hole is punched into the center of the base of each can, through which is threaded several yards (meters) of thin string. Attach a toothpick or match to the ends of the string in a manner which prevents the sticks from slipping through the holes.

Extend the string and cans to their full length and hold the string taut. Now use the cans as telephones. Sound travels through the the string and through the air inside the cans. The base of the can acts as a membrane.

**Water:** This experiment is best done as homework! Ask the students to take a bath or go for a plunge in a swimming pool that evening. Whilst in the water, they should immerse their heads so that their ears are completely submerged. If a second person is available, have the person strike a metal object, such as a bell under the water, but some distance from where the first person is. The first person should hear the sound clearly through the water. In fact, sound travels almost four times as quickly in water as it does in air!

**Speed of Sound:** We can conduct an experiment to illustrate the speed of sound by having one student walk a good distance away from, but still in sight of the class. He or she can then take a large hammer and apply a forceful blow to a piece of metal. The onlookers will observe that they see the action of the blow a few moments before hearing the sound. This tells us that sound is not instantaneous, but requires time to travel. This can be related to a thunderstorm when we see the lightning but only hear the clap or rumble of thunder some moments later.

**Day 5:**

On this, the last day, we should give consideration to the role of "vibration" in the creation of sound. This is best accomplished by numerous simple experiments.

Place a school ruler or a piece of wood of similar length and thickness, on a table so that about three-quarters of it juts out from the table edge. Hold down firmly the end resting on the table. With the free hand, bend the other end of the ruler and release quickly. The ruler vibrates up and down. Note what sound you hear. Again place the ruler so that half juts out from the table edge. Repeat the experiment and note the sound. Is it different to the previous one?

Using the same piece of wood, drill a small whole at one end and thread a piece of string through, knotting it into a loop large enough for the index finger to go through. Hold your arm away from the body and twirl the strip of wood in a large circle above your head. First slowly, gradually increasing the speed. What sound is produced? Does the sound vary? If so, how? In Australia, a teacher or student may have a "Bullroarer", a traditional Aboriginal instrument using the above principle and which was used for transmitting messages over long distances.

Another very simple "home" experiment involves the use of drinking straws *(they don't have to be natural straw, although that would be preferable).* Flatten one end of a straw and then cut both corners to form a sharp arrow point. The end now somewhat resembles the reed of a wind instrument. Place the straw into the mouth so that the flattened end is free of any obstruction (lips, teeth, tongue). By blowing through the straw, one should be able to obtain a note. Several straw flutes could then be made, each straw being shortened in length so as to obtain different notes. With practise, a group of students should be able to play a simple melody together. I also introduced the ancient "jaws harp", the harmonica and carpentry saw.

**Sound and Energy:** Whenever sound is produced, energy is also created. This is best illustrated by showing how ripples travel across the surface of water. Maybe a pond or large pool of water is to hand. Failing this, a large bowl can also be used, but the results will not be quite as dramatic. To produce a series of ripples, throw individual pebbles into the pond, or let a series of drops of water fall into the bowl. The observer will see how the ripples travel across the surface of the water.

One is able to illustrate this movement of energy even more clearly if a light-weight piece of wood is first placed on the surface of the pond water, or a toothpick on the surface of the bowl of water.

When the ripples occur, the piece of wood will be seen to remain in the same place, albeit bobbing up and down in time with the ripples. The students are thus able to conclude that it not the water that is moving, but rather the energy which has been created.

It can then be brought to the students awareness that when we create sound, we also cause ripples to occur in the surrounding air, although we are unable to see them.

Our final experiment will involve the marvels revealed by the Chladni Plate, a flat piece of metal which is clamped firmly in the center to a table. By taking a small, 3 -4 cm (1 inch) cylinder of dowelling rod, it is possible to clamp the plate in such a manner that it does not come into contact with the table, but remains parallel to it.

Sprinkle a small amount of lycopodium (spores) powder, fine dry salt or other fine dry powder onto the surface of the plate. With an old violin or 'cello bow, begin to "bow" across the edge of the plate, exerting enough pressure so that the plate eventually begins to emit a tone. Try to maintain this tone and at the same time, observe the power on the surface. With each tone produced, a magical form or pattern will appear. The higher the tone, the more complex the patterns become. This reveals to us the true "formative power" of sound.

**The Human Voice:** Relate the above mentioned creative, formative power to the human voice. Let each student sing a low toned "Ah", then one at middle pitch and eventually at high pitch. What do they feel? Vibration of the larynx? What shapes are they creating in the air around them? What forms are they able to create and release into the world?

Try this same experiment with each of the vowels. Students will discover that it is only these five sounds which can be said to be truly created by our larynx. The sounds of the consonants are formed towards the front of the mouth.

As Human Beings, we are able to produce sound at will. Unlike the animal world, humans are able to use their consciousness in creating sound. We are able to sing, recite or draw forth sounds from inanimate objects, such as musical instruments.

We have the responsibility to ensure that the sounds which we produce with our voice or with musical instruments, are those which create beauty in our environment, rather than creating forces which are able to bring ugliness and destruction into the world.

**********

*A final activity in this section would be for the students to create an original instrument, as homework over the next two weeks, which can either be blown, struck or plucked.*

## AND THE WALLS CAME TUMBLING DOWN!

*"Then the Lord said to Joshua, "See, I have delivered Jericho into your hands, along with its king and its fighting men.*
*March around the city once with all the armed men.*
*Do this for six days.*
*Have seven priests carry trumpets of rams' horns in front of the ark.*
*On the seventh day, march around the city seven times,*
*with the priests blowing the trumpets.*
*When you hear them sound a long blast on the trumpets,*
*have all the people give a loud shout;*
*then the wall of the city will collapse and the people will go up,*
*every man straight in."*

*".....When the trumpets sounded, the people shouted,*
*and at the sound of the trumpet, when the people gave a loud shout,*
*the wall collapsed; so every man charged straight in,*
*and they took the city."*

**Joshua** 6. v.2 - 5 and v. 20

**********

## Equipment Required

### Week One - SOUND:

**Day 1**

**Inanimate Objects - optional choices**

| Sound | Object |
|---|---|
| Crash | China plate or bowl |
| Pop | Party "poppers" |
| Bang | Balloon(s) and pin |
| Thud | Heavy weight (stone/wood/metal) and cushion |
| Clang | Metal bar and hammer |
| Tinkle | Glass jar/wine glass and fork/spoon |
| Tick | Clock or metronome |
| Crunch | Packet of cornflakes and large tray |
| Rustle | Dried leaves and cardboard box |
| Plop | Bowl, water and small pebble |
| Splash | Bowl, water and large stone (and mop!) |
| Trickle | Bowl, water and watering can |
| Patter | Watering can, water, bowl covered with cling-film (or similar) to resemble a "drum" |

The sound words are contextual related to the phenomena. We learn the words without experiencing the phenomena. Hence words remain empty. We need to relate to phenomena. Each culture has its own sound words! Relate these when teaching foreign languages.

**Day 2**

**Musical Instruments - optional choices**

| | |
|---|---|
| Wind | Recorders<br>Flute<br>Clarinet<br>Trumpet<br>Saxophone |
| Percussion | Drums<br>Xylophone<br>Marimba |
| Plucked: | Violin<br>'cello<br>Double bass<br>Guitar |

**Day 3**

**Pitch and Volume**

Wine glasses
Glass bottles
8 test tubes and rack
Pan Pipes
Wind chimes

**Day 3** continued

Recorders *(sopranino c'; sopranino f'; descant, treble, tenor and bass)*
Xylophone
Marimba
Violin or 'cello

**Day 4** **How Sound Travels**

Whistling
Garden hose
Tin cans; string; toothpicks
Fork/spoon *(bent)*; string
Hammer and metal plate

*Deep container (bath) and water* *Homework?*

**Day 5** **Vibrations**

30 cm *(12 inch)* ruler(s) wooden
Bullroarer *(make one/buy one?)*
String
Drinking straws
Clarinet/Saxophone *(or similar)*
Bowl *(large)*; pebbles; toothpick
Tibetan Singing Bowl and stick · see on the net
Fine *(crystal)* wine glass *(and vinegar to wet a finger)*
Carpentry saw *(can you "play" one!)* how to play → wikipedia
Violin/'cello bow *(old)* and rosin
Jaws harp
Harmonica

**Creative/Destructive Power of Sound**

Chladni plate *(make one/buy one!)*
'cello/violin bow *(old)* and rosin
Lycopodium powder/dry fine salt/talc powder
Fine *(crystal)* wine glass *(can you create enough vibration in the correct frequency (tone) to break the glass?)*

***********

## LIGHT AND COLOUR

"In the beginning, God created the heavens and the earth,
and the earth was without form and void,
and darkness was upon the face of the deep.

And God said: Let there be light,
and there was light
and God saw that the light was good.
And God divided the light from the darkness
And God called the light Day and the darkness He called Night;
And the evening and the morning were the first Day.

**Genesis.** Chap. 1, v. 1 - 5

*****

There are many beautiful prayers concerning the advent and significance of light handed down to us from numerous cultures around the world. The first of the following two prayers is an ancient Fire Blessing (40,000 years old) kept alive through the oral traditions of the Australian Aboriginal peoples and recently translated into the English language:

**Fire Blessing**

May the Light be in our thoughts, making them
true, good and just.

May the Light be in our eyes:
May it open our eyes to share what is good in life.

May the Light be on our lips, so that we may speak the truth in kindness;
that we may serve and encourage others.

May the Light be in our ears;
so that we may hear the flow of water and all creation.

May the Light be in our arms and hands
so that we may be of service and build up love.

May the Light be in our whole being -
in our legs and in our feet,
enabling us to walk the earth with reverence and care;
so that we may walk in the ways of goodness and truth,
and be protected from walking away from what is true.

**********

This second prayer is from the First Nation people of the Sioux. One cannot help but notice the startling similarities between this and the first prayer:

Great Spirit.
Fill us with the Light.
Give us the strength to understand
And the eyes to see.
Teach us to walk the earth
As relatives to all that live.

******

The second strand in the Class Six science curriculum, is "Light and Color". The focus would be centered on the following areas:

1. Light in our Lives
2. The Source of Light
3. Primary Colors
4. Secondary Colors
5. Prismatic Colors
6. The Path of Light

The presentation of the above sub-strands would take place over a period of five Morning Lessons:

**Day 1**
Light in our Lives
The Source of Light
Aboriginal legend
Sunrise experience

**Day 2**
Review/Recount
Light is Invisible
Light thru Darkness
Darkness thru Light

**Day 3**
Review/Recount
After Images
Complimentary Colors
- Black and White
- Primary/Secondary Colors

**Day 4**
Review/Recount
Prismatic Color experiments
The Rainbow

**Day 5**
Review/Recount
Colored Shadows
The Path of Light
Camera Obscure

**Day 1** **Light in our Lives**

Fortunately, the majority of us have experienced the light of the day and the darkness of night; the light of summer and the darkness of winter; the brightness of the waxing moon and the dimming of the waning moon. We have seen a great fire burning, such as those lit in festive celebration, on St. John's Day, the Fourth of July or Guy Fawkes day, to name but three. We have gazed at the glowing embers after the flames and smoke has long since gone, and we have seen each other in the light of the fire.

But have we actually SEEN the LIGHT on these occasions or have we even seen the light of the Sun?

Let us imagine the whole of the cosmos illumined by one great light and we out there with our backs to the source of light, so we are unable to see it. We turn our gaze out into the space which is illuminated. Could we see the light? In the 21st century, we know that we would only see darkness, that the "sky" appears black. We are only able to see the light when an object crosses our line of sight. When this happens, the light which is out there, is able to shine.

Although for practical purposes, our experiments involving light and colour will have to be conducted in a classroom environment, it would naturally be so much more effective if students could experience the phenomena of light, by arising early whilst it is still dark, so as to experience the birth of a new day.

## How the Sun was Made

*For a long time there was no sun, only a moon and stars. That was before there were humans on earth, only birds and beasts, all of which were many sizes larger than they are now.*

*One day, Dinewan the emu and Brolga the native companion (n.b. also a bird) were on a large plain. There they were, quarrelling and fighting. Brolga, in her rage, rushed to the nest of Dinewan and seized from it one of the huge eggs, which she threw with all her force up to the sky.*

*There it broke and burst into flame as the yellow yolk spilt and lit up the whole world to the astonishment of every creature on it. They had been used to the semidarkness and were dazzled by such brightness.*

*A good spirit who lived in the sky saw how bright and beautiful the earth looked when lit up by this blaze. He thought it would be a good thing to make a fire every day, and from that time he has done so. At night he and his attendant spirits collect wood and heap it up. When the heap is nearly big enough, they send out the morning star to warn those on earth that the fire will soon be lit.*

*The spirits, however, found this warning was not sufficient, for those who slept saw it not. Then the spirits thought someone should make some noise at dawn to herald the coming of the sun and waken the sleepers. But for a long time they could not decide to whom should be given this office.*

*At last one evening, they heard the laughter of Goo-goor-gaga (kookaburra) ringing through the air.*

*"That is the noise we want," they said.*

*Then they told Goo-goor-gaga that, as the morning star faded and the day dawned, he was every morning to laugh his loudest, that his laughter might awaken all sleepers before sunrise.*

*If he would not agree to do this, then no more would they light the sun-fire, but let the earth be ever in twilight again.*

*But Goo-goor-gaga saved the light for the world.*

*He agreed to laugh his loudest at every dawn of day, and so he has done ever since, making the air ring with his loud cackling:*

*"Goo goor gaga, goo goor gaga, goo goor gaga"*

**From:** Australian Legendary Tales. K. Langloh Parker (1974)

## The Source of Light

By experiencing a sunrise, we are posed with various questions, such as:

*Why does the sun look red at sunrise*
*(and yellow at noon and red again at sunset)?*

*Why does the sky look blue from earth?*

*Why does the sky appear pale blue at the horizon and a deeper blue above our heads?*

### Sunrise

If it is impossible to arrange for all students to experience a sunrise *(which could be achieved by a teacher brave enough to organise a sleep-over in the classroom!)*, then the teacher will need to recreate this experience in the classroom.

The room must be pitch-black. It is of paramount importance that not even a glimmer of light should be allowed to sneak into the room via a pin hole in the blinds or from any other source. Total darkness is required. Have the students squat in a circle in the darkness (and stillness!) and carefully observe what takes place, as well as experiencing the sharpening of senses other than sight, such as hearing and touch.

The teacher will have organised a controllable source of light. This requires prior preparation, but is simple enough to make. Set up an electric spotlight bulb in a light socket mounted on a board and placed on the floor in the middle of the circle, with a cable long enough to reach the nearest wall outlet.

Somewhere along this cable, have an electrician connect a "dimmer switch".

The source of light is best surrounded by a cylinder made out of heavy dark card. At the appropriate moment, the teacher will turn the dimmer switch so that a very, very faint glow begins to appear from the bulb, projecting a glimmer on the ceiling. Gradually turning the switch more and more, the glimmer will become brighter and brighter until it is shining at full strength. One requires a strong bulb for this experiment.

Although nowhere as effective or spectacular as a sunrise, this simple experiment nevertheless reveals some interesting observations with regards to light and darkness. To quote from Manfred von Mackensen's book on Grade Six physics (1):

*"...a first, pale glimmer appears on the ceiling - the beholder's gaze drift longingly out there, without actually being able to discern sort of visible objects. Brightened further, it seems as though the nce gets nearer. So also with a sunrise: a heavens dawns which st seems distant; darkness still holds fast to the earth. Initially, enerally perceive non-spatial, plane, shadow-like forms; later we make out indefinite, schematic, but already weakly embodied ts. However, in between the latter lies an impenetrable darkness h still envelops our gaze.*

*Now, the color of things first comes to view, not yet related to rightness of the distance, but rather floating over the surface of by) objects, which are still swimming in darkness. These colors do orrespond with the colors of the sky, which are as yet still pale and*

*Only much later are we able to clearly discern anything in the s in between. Now objects can be grasped, set down, or also de) thrown at a target with some certainty. The first shadows in nature. "Day-light" now prevails, and we are able to live our ives."*

## Light Is Invisible

Having either experienced a sunrise or participated in an indoor experiment, now direct the students to consider the question of whether light is visible or his is an easily conducted experiment in a dust-free, darkened room. Using powerful torch with a narrow beam or a slide projector, project a beam of an opposing wall or screen.

Although we are able to see the disc of light projected on the wall or screen, not able to see the actual path of light. This path only becomes visible solid object crosses it's path. Two chalkboard erasers when knocked r above the known path of the beam, will let chalk powder fall gently the beam. When this happens, the path of light is immediately made s the particles of dust reflect the light. Students are able to conclude that nvisible until reflected by a physical substance.

## Seeing Light through Darkness

Let us try to answer the question as to why the sun is red at sunrise and sunset.

Darken the light from a projector with layers of white tissue paper. As the layers mount up, the light shining through is darkened. First its whiteness is changed to yellow, then to orange and finally red.

Set-up a small aquarium full of water. Cover the side furthest from the viewer with a sheet of opaque white paper. Shine a beam of light through the end of the aquarium, into and through the water at right angles to the viewer. Slowly pour milk or soapy water (not washing detergent) into the tank. The color of the light should change to yellow, then orange and finally red, depending on the amount of milk added to the water.

Students can conclude that when seeing light through darkness (the tissue or milky water) the warm colour arise. This is what we are able to observe at sunrise and sunset when the light of the sun shines through the thicker layers of the atmosphere closest to the earth's surface, caused by moisture and dust particles. At midday, the sun shines through the atmosphere which is less dense.

## Seeing Darkness through Light

Why does the sky appear blue from our position on earth?

Replacing the water in our tank, and also replacing the white background for one which is black, we again shine the light through the water at right-angles to the viewer. Adding milk to the water enables us to observe the beginnings of the colour blue. As more milk is added, the blue becomes lighter.

We can conclude that when we see darkness through light, it appears to become lighter. We should observe that the sky appears "lighter" close to the earth's surface. The clearer and drier the air, the deeper the blue of the sky becomes.

## COLOR

**Day 3** **After Images**

After the above experiments, we can move forward into the realm of color. For us to be able to experience and appreciate the beauty of color, our eyes must first become accustomed to the intensity of the surrounding light. If this is interfered with in any way, then the eye will produce colors of its own which can be just as intense as those around us.

Stepping forth into the brilliance of the light of the sun from a darkened room, can be an alarming and a mildly painful, experience. Our eyes are unable to adjust to the change in light intensity and everything takes on a whitish-pinkish hue. If we leave the brilliance of the sunlight and enter a darkened environment, then we experience blackness tinged with green.

In his book "What is Color?", the Goethean scientist Michael Wilson wrote:

*"The following experiment causes the eye to produce its own series of colors. Gaze for some moments at the intersection of the window-bars seen against a very bright hazy white sky towards the sun. Examine the after-effects* (a) *with the eyes shut and covered by something dark, and* (b) *with the eyes open and gazing at a white surface in the shade of the room.*

*In the case of* (a), *the first impression is a positive echo or after-image, i.e., dark bars and light spaces. These spaces are pale cobalt for the first few seconds, changing rapidly to a strong and slightly yellowish green. Slowly the green becomes dull and more olive, eventually changing to a deep purple. At the same time the dark bars become greenish, and* lighter *than the spaces. The image has now changed from positive to negative, and we are left with purple spaces and light green bars. The purple may become more bluish as it fades away.*

*In* (b), *the after-image is negative from the first moment and is seen as deep violet-grey spaces and light or possibly yellowish bars. The spaces change slowly from violet-grey through emerald green, dull yellow-green, salmon-pink to dull rose-pink, while the bars tend to show something of the opposite color to the spaces. The final pattern of pink spaces and green bars corresponds exactly to the final stage of* (a).

*In both series the image may tend to become lost but can be revived again by opening or shutting the eyes once or twice. Individuals vary somewhat in the colors and changes which they see, but the above description is certainly common to a number of observers.*

*The polarity of the colors is much more evident when the eyes are open and looking at a neutral surface, but it is at all times the dominating feature of the whole sequence of impressions. Thus we see that the eye is not a mere passive receiver of external impressions, but in its resonance to the stimulation of light, it will produce colors in its own rhythm.*

*The eye perceives light and color very largely in terms of differences and contrasts. Every color has its own opposite or "complimentary" color."*

## COMPLIMENTARY COLORS

It is worthwhile preparing a series of slides for the following experiments.

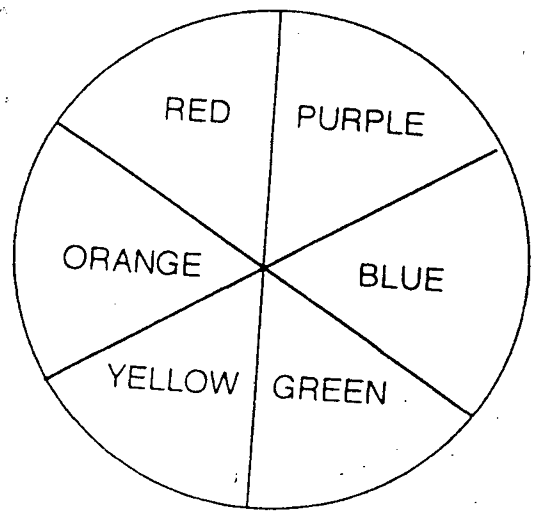
### Black and White

With a projector, project an image of a white spot surrounded by black onto a screen. Close your eyes and observe that you see a black spot on the white screen as an after-image.

Project an image of a black spot onto the white screen. It will be observed that a white spot now replaces the black spot as an after-image.

### Primary and Secondary Colors

Project spots of each of the primary colors (red, blue and yellow) onto the screen. Observe the after-images. List the colors which you have experienced and arrange these colors in relationship to each other in a color circle.



I spent some time creating an entire set of slides for Light and Color experiments, using a standard "office hole-punch" to punch out circles from pieces of colored stage lighting filters. These were attached to glass projector slides with a minute dab of clear glue.

The experiments can of course be conducted effectively by painting/coloring large circles on individual sheets of paper.

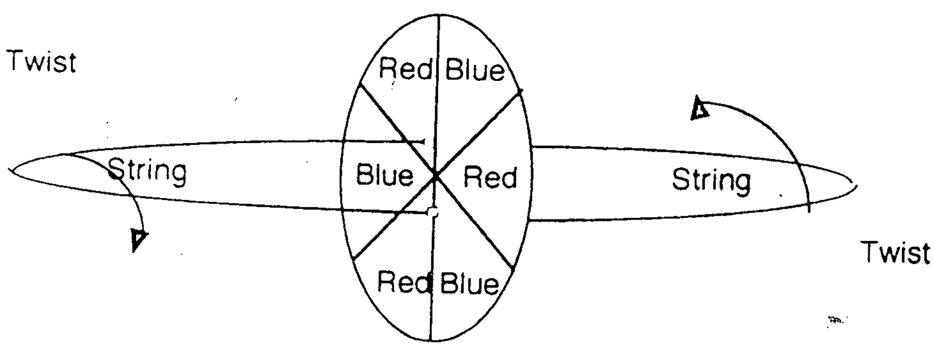
In both instances, the observer is required to look intensely at the color disc before transferring their gaze to a blank sheet of paper. The best results are achieved if the observer holds his/her focus and the demonstrator switches the papers. This is easily accomplished when using a slide projector. Incidentally, the strongest color impressions are obtained with the slides.

All of the above work (from sunrise through to primary/secondary colors) should be followed-up with watercolour painting exercises where students can re-experience the magic of color combination when painting "wet-on-wet".

Further color experiences can be achieved by the students making their own "color tops". Radial segments are colored alternatively red and yellow on one side, and blue and yellow on the other (or red and blue). When spun, the student will observe that orange appears on the first side and green (or purple) on the second side.

By using two projectors, color combinations can be demonstrated on the screen using individual slides for each of the three primary colors.

**Color Spinning Top**




## Prismatic Colors

In this section of the lesson, we are dealing with the conflicting theories of Newton and Goethe. It should be borne in mind that they are just that: theories. Rudolf Steiner spoke at great lengths in favor of Goethe's scientific research and parents and teachers are encouraged to research these writings for themselves *(see: Bibliography - Physics)*.

Although the Waldorf approach follows more the Goetheanistic theory, I am of the opinion that care should be taken not to put forward Goethe's ideas as being "fact". For this reason, I believe that the following experiments should be be presented as "questions" to be dwelt upon in preparation for further study in the later high school years.

**Day 4** **Prismatic Experiments**

The prism should be held in front of the eyes so that one 60° edge is pointing downwards. The line of sight will then pass through the two inclined planes. It will be noticed that the object being viewed appears to be below our actual line of vision.

Have the children look through the prism at a clear blue sky. The sky will appear as normal. However, if a cloud crosses our line of vision, the edges of the cloud become edged with brilliant colors.

Have the students look through the prism at a square of black card placed on a considerably larger white card, but with the lower edge of the black being adjacent to the lower edge of the white card. The prism should be held so that it's axis is parallel to the top edge of the black card at it's boundary with the white card. A band of color will be seen with a turquoise next to the white and blue-violet next to the black. What color arises at the point where these two colors meet?

Now move the position of the black card to the top edge of the white card so that white appears beneath the black. This time we observe a brilliant red next to the black and a pure yellow below. What is the transition color?

Referring to our earlier experiments with complimentary colors, we see that the two bands of color which we have seen are complementary to one another.

Taking a second piece of square black card and placing it about 2 inches (5 cm) below the first piece, then the identical sequence of colors is seen as was apparent with our first experiment.

Slowly move the first black card down towards the second. Carefully observe that where the red, orange and yellow spectrum meet the purple, blue and turquoise spectrum and new color arises. What is this color? *(green)*

Repeat this last experiment with smaller white squares of card placed upon a larger black card. What are the results? *(magenta)*

Using the your own larger reproductions of Goethe's black/white patterns *which I include on a separate page)*, have the students conduct their own series of experiments.

It is of course possible to prepare slides for most of the above experiments which can be projected onto a screen. This is especially useful when teaching a large group of students.

**The Rainbow**

Standing in a garden or field with the sun behind you on a summer morning whilst the dew is still on the ground, one is able to see, a little to the left or right of one's shadow, a colored droplet hanging delicately from a leaf or grass blade. This droplet acts as a prism and with a slight movement of the head, we are able to see all the prismatic colors.

From our previous experiments, we know that there must be boundaries of light and darkness for these colors to appear. The question is: Where is this boundary?

We can only conclude that the boundary is the round disc of the Sun. The colored drops in reality only appear in a circle around the shadow of your head, either as droplets on the ground or in droplets falling as rain. The image of the Sun's disc is transformed into a circle of colors through the magical properties of water. When we move, then "our" rainbow moves with us. Each of us sees a different rainbow in the sky! If we were to observe a rainbow from great height, we may see it as a complete circle.

Sometimes the rainbow appears to be so close that we feel as though we are able to reach out and touch it. But as we know, the rainbow retreats as we advance and the possibility of finding that "crock of gold" remains as illusive as ever!

**Day 5 Colored Shadows**

This series of experiments is best conducted in a darkened room with at least two projectors and a screen.

First project a white light onto the screen and hold a cut-out shape in front of the light so that the dark shadow is easily seen. This could be a cut-out black card figure attached to a long piece of thin dowel.

Project a white light onto the screen and with the second projector, project a red light. Hold the cut-out in the path of these two lights. Two shadows will appear, one green and the other black.

Conduct this experiment with a variety of colored filters. Note the colors which arise.

If possible, obtain a third projector. Use one for your white light source. Into the second and third, place different colored filters, *e.g. red and blue*. What are the results?

In my previous class, we concluded this Morning Lesson block by performing a simple "shadow play" *(The Enormous Turnip)* with students and large cut-outs. We obtained a huge white sheet which was pinned-up across the front of our school stage, onto which were projected light from three different sources as per the last experiment. I was fortunate in being able to utilise our school stage lighting! The results were well worth the trouble and a spontaneous "performance" was shared with Grade Five!.

**The Path of Light (Camera Obscura)**

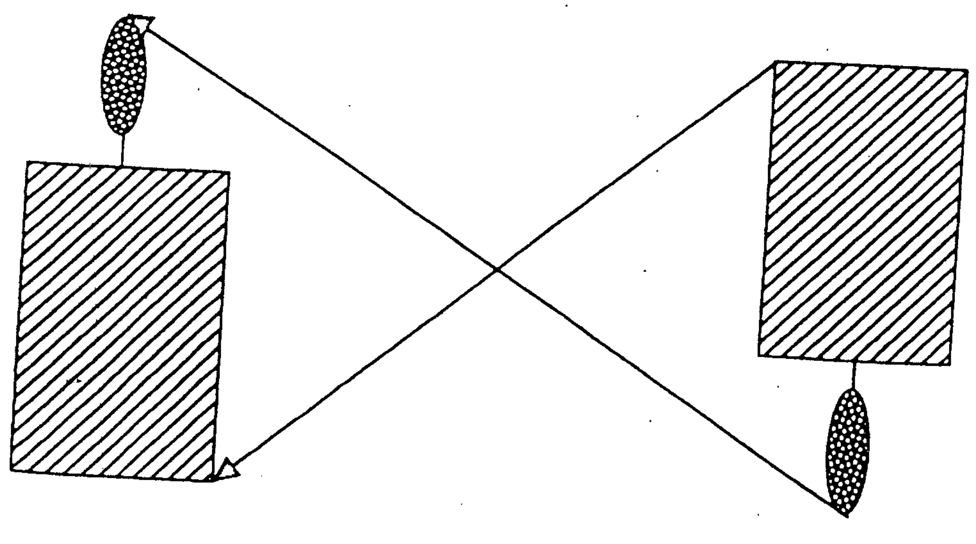
Finally, we turn our attention to the path of light, to show that it takes a direct route.

Obtain a solid cardboard box and cut-out a square section from one end. Next cover the square hole with a sheet of tracing paper *(architect's draft paper is good)*. In the center of the end of the box opposite the paper, pierce a small hole with a pin or small nail. Hold or place the end with the hole against the window.

For this experiment to be really effective, it is important that the rest of the window is blacked-out and the room made as dark as possible. Light should be able to enter the box via the small hole *(enlarge if necessary)*. An image of the outside scene will appear on the white screen, but upside down.

It is also possible to conduct this experiment by placing a lit candle a little distance from the hole. The resulting image will be of an inverted candle flame. Try passing a pencil between the source of light and the box and observe the results.

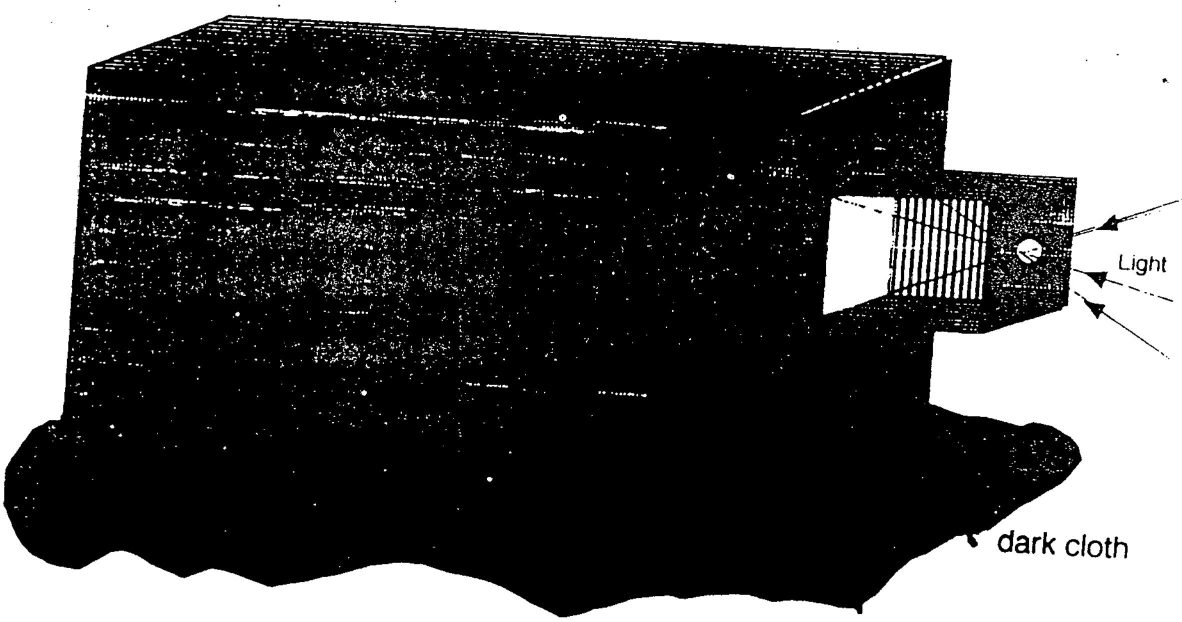
This experiment confirms for us that reflected light from the illuminated object (candle in this instance) takes a direct path.



A slight adaptation of the "pin hole" camera as described above, can be made by each of the students as "homework" for this section:

Taking a cardboard box which is large enough for a child to put over their head, have them create a small screen in one end of the box. Over this, attach a smaller box with one end removed enabling the 2nd box to fit over the screen. Attach the box with adhesive tape to the large box. The small box should now have five solid sides ensuring that the screen is enclosed. In the end of the small box opposite to the screen, pierce a small hole.

Around the lower rim of the large upturned box, attached a piece of dark cloth, so that when the child inserts his/her head into the box, the cloth is draped over their shoulders thus preventing any light entering the enclosed space. The child should then have a unique view of an upside down world! They will delight in trying to find their way (safely!) around familiar surroundings using their "camera obscura".




## Colour
(Unknown)

Colour is a lovely thing,
Given to soothe our sight,
Blue for sky, green for grass,
And brown for roads where wee folks pass;
Golden sun that shines o'er head,
Silver for moon, for sunset red,
Soft cool black the night!

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## Equipment Required

### Week Two - LIGHT AND COLOUR

**Day 1**

**Source of Light**

Blackouts for windows (or pitch-black room)
Controllable light source (with dimmer switch)
Cardboard cylinder

**Day 2**

**Light is Invisible**

Flashlight(s)
Projector (1)
Chalkboard erasers (2)
Chalk
Tissue paper (white)
Aquarium
Water source
Milk (milk powder) or soap
Large sheets of paper (white and black)

**Day 3**

**Colour - Primary/Secondary**

Projectors (2)
Slides - coloured filters
White paper sheets for students
White card (for circles for students)
Rulers; pencils; colour pencils
Compasses
Scissors

**Day 4**

**Prismatic Colours**

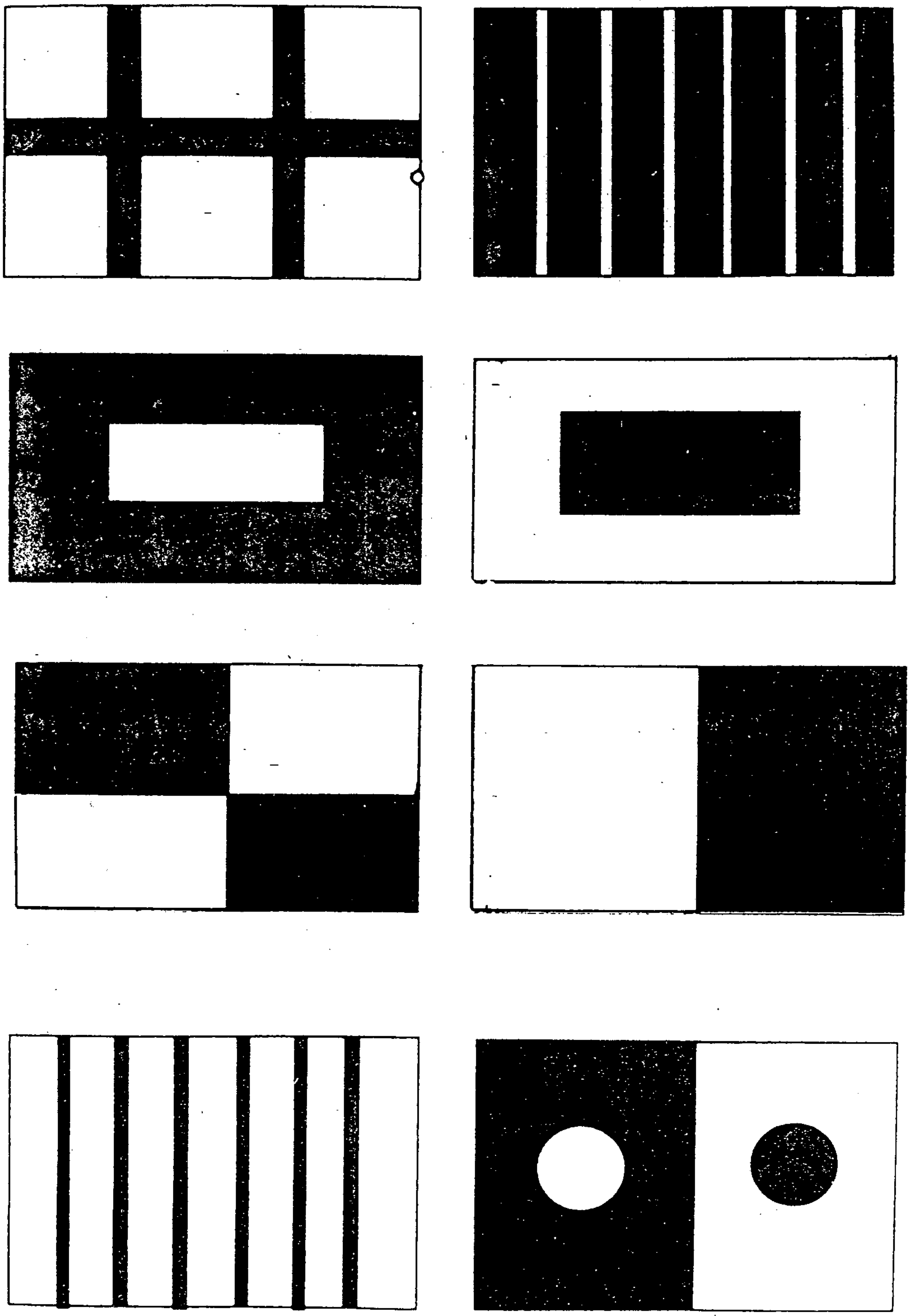
Prisms (1 per student)
Large "water" prism
White card squares - large (1 per student)
Black card squares - small (1 per student)
Goethe's prismatic experiment patterns (slides or 1 set per student
Projector (1)

**Day 5**

**Coloured Shadows/The path of Light**

Projectors (3)
Slides - coloured filters
Thin dowel rod (1 metre)
Black card (for silhouette)
Candle and matches
Tissue paper or architect's paper
Cardboard boxes (large & small); adhesive tape; dark cloth

## Eight of Goethe's Prismatic Experiments



## PAINTING LESSONS TO COMPLEMENT THE LIGHT AND COLOR MORNING LESSON

It is important for the children to "experience" more consciously the different "moods" of color, and therefore the Waldorf "wet-on-wet" technique would best serve this purpose, without any use of techniques and "tricks-of-the-trade" to enhance their pictures. Control of color and brush is, I believe, all important, but even more so are the inner experiences they will gain from these exercises.

In connection with the "Light and Color Morning Lesson", it would be excellent if the students could intensify their artistic work, by water colour painting on damp paper (almost dry), giving particular attention to the following exercises:

1. Taking the "expanded" rainbow as the starting point, begin by painting a Lemon Yellow horizontally across the centre of the page. Proceed by adding "warm" colours above the yellow and "cool" colours below, so as to experience how colours give rise to the elements of Light and Warmth above and Water and Earth below. Colours thus painted should of course blend with one another at their meeting point thus giving rise to secondary colours.

2. Continuing with a variation on the above exercise, the children could again begin with the Lemon Yellow, but when adding the Ultramarine Blue below (to create green), have them curve the blue so that it gives the image of a chalice upon a blue of water. From within the chalice emerge the warm colours. We can imagine ourselves standing on the earth, with the green hills rising on either side of us and the warm air and light above.

3. The next stage eliminate the green and instead have the Crimson Red merge with the Ultramarine Blue to give rise to violet. Crimson Red will also (in places) appear as clouds to merge with the Lemon Yellow and the last half of the Crimson Red sun can be seen disappearing into the violet-red below. Finally, apply a soft wash of Ultramarine Blue at the top of the paper, but avoiding the blue meeting with the yellow.

4. Virtually eliminating all traces of yellow, apart from a very gentle "wash" across the centre of the paper, once again paint the sunset but with the addition of further blue both to the upper and lower portions of the page. Leaving only an "after-image) of the setting sun.

5. Out of the blue, go deeper into the darkness with Prussian Blue and Ultramarine, eliminating all but wisps of Crimson Red which are reflected in the darkening sky and the waves of the ocean below.

6. The next painting will have eliminated all traces of Crimson Red. Using Ultramarine and Prussian blue, have the students paint a "moon" above the surface of the ocean waves, so that the moon is reflected on the waves themselves.

7. Introducing a delicate Gold Yellow, as a narrow horizontal strip across the center of the page, "loosen-up" the blues so as to create the impression of gentle hills upon which the "light" of the soon to rise sun is reflected.

8. Intensifying the use of Gold Yellow, add Lemon Yellow and allow it to merge with the blue of the hills so that a delicate green arises, by adding "wisps" of gentle Cinnabar Red to the blueness of the sky, the first colors of a new day are visible.

9. The final painting will be of the Crimson Red sun bursting forth in all its glory from behind the green earth.

10. Working with the reds and yellows, have the class paint an impression of a desert environment .

11. Working with the blues and yellows, have the class paint an impression of a forest environment.

*****

## HEAT

### *God Himself is Created by Heat*

*In the beginning was darkness swathed in darkness;*
*All this was but unmanifested water.*
*'Whatever was, the One, coming into being,*
*Hidden by the Void,*
*Was generated by the power of Heat.*

From: **The Rig-Veda.** Book One.

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"...We may compare the perception of heat to perception in other realms. I have already called attention to the fact that when we perceive light, for instance, we note this perception of light and color to be bound up with special organs. These organs are simply inserted into our body, and we cannot therefore speak of being related to color and light with our whole organism. Likewise with acoustical or sound phenomena, we are related to them with a portion of our organism, namely the organ of hearing. To the being of heat we are related through our entire organism. This fact conditions our relationship to the being of heat. And when we look more closely, when we try, as it were, to express these facts in terms of human knowledge, we are obliged to say that we ourselves are really this heat being. In so far as we are human beings moving around in space, we are ourselves this heat being. Imagine the temperature were to be raised a couple of hundred degrees: we would be unable to be identical with that temperature state. It would be similar if we were to consider the temperature lowered by a hundred degrees. Thus the heat condition belongs to that within which we are continually living, which we experience as a matter of fact but do not take into our consciousness. Only when some deviation from the normal condition occurs do we become conscious of it in some form."

From the: **"Warmth Course."** Rudolf Steiner (1920)

## Quotation

".....I am that living and fiery essence of the divine substance that flows in the beauty of the fields. I shine in the water, I burn in the sun and the moon and the stars. Mine is the mysterious force of the invisible wind......I am life."

Hildegarde of Bingen (as quoted in **"Creation Myths"**. David MacLagan)

The final strand of this part of the Grade Six science curriculum, will look briefly at "Heat".

1. Warmth in our Environment
2. Warmth and our Feelings
3. Warmth and the Physical Body
4. Transforming Power of Heat
5. Convection/Conduction/Radiation of Heat
6. Expansion through Heat/Cold (Air, Metal and Ice)

The presentation of the above sub-strands would take place over a period of five morning lessons:

| | |
|---|---|
| **Day 1** | Introduction<br>Experience of Hot and Cold |
| **Day 2** | Review/Recount<br>Temperature<br>Melting by Heat (ice cubes)<br>Melting by Pressure (ice cubes) |
| **Day 3** | Review/Recount<br>Conduction<br>Radiation |
| **Day 4** | Review/Recount<br>Convection<br>Expansion through Heat (Air/Water)<br>Expansion through Heat (Metal) |
| **Day 5** | Review/Recount<br>Expansion through Cold (Ice)<br>Conclusion and Review of the 3 weeks |

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**Day 1: Warmth In Our Environment**

When we contemplate the phenomena of "warmth" in this lesson, we must of course also give equal consideration to the flip-side, which is "cold".

Our very existence depends on our maintaining a balance between the extremes of warmth and coldness. Our bodily temperature is maintained at a steady 98.4°F (36.8°C) and any variation either above or below this level causes us discomfort in one form or another. The greater the variation, the greater our discomfort, for we are unable to tolerate excessive fluctuations in temperature.

Our prime source of Light and Heat is of course the Sun. All life on Earth is inextricably intertwined with the Cycles of Day and Night and of the Seasons, which themselves are determined by the movement of the Sun in it's yearly cycle.

Most of the warmth which we experience comes directly from the Sun, but we are also able to gain warmth from the Sun's Energy which has been stored, in a metamorphosed state, within substances upon or within the Earth's surface. These sources of "stored heat" can be found in plants (wood) and mineral (fossilised fuels).

The creation of warmth in not confined to combustion, but can be created in various other ways. From lessons in Geology, students will have heard (or will hear) about the heat forces at work within the center of the Earth. How immense pressure within the Earth creates so much heat that the very rocks themselves are melted.

Heat can be created when two substances are rubbed together causing friction. If certain chemicals are brought together, they are able to combine to produce heat.

Warmth (or the lack of it) not only determines the changes in our environment, but also makes a difference to us as Human Beings. How we "feel" inwardly is influenced by the external temperature we experience. It is interesting to make comparisons between the character of peoples who live in the coldest wastes of the North, with those living in a sun-drenched tropical paradise. We can easily see just how great an influence warmth and cold has upon us. I lived for a few years in Ontario, Canada and had the opportunity to experience a few cold winters where (with the wind-chill factor included) temperatures could fall on rare occasions to -40°C. Such coldness, stifles the "will" and one experiences a slowing down of one's life forces. For the past 6 years, I have been living in New South Wales, Australia and the warmth of the climate is in sharp contrast to that of Ontario, where the lowest day-time temperature in my coastal environment rarely falls below 15°C, whereas in the summer it can peak at around 40°C (in the shade!). In this climate, one has a feeling of being relaxed and laid-back (also not necessarily good for "will" activities!) in the summer, with energy forces being greater in the winter months.

Warmth and coldness therefore, affects our "willing" and "feeling" lives. We even go so far as relating the experience of warmth to our language in the form of expressions, such as accusing someone of being a "hot-head" or another as a "cool-dude". Students could be involved in compiling a list of such terminology, which might include:

warm hearted
cold hearted
hot temper
cold indifference
heated argument
warm as toast
cold as ice
etc.,.

Reviewing our previous work with sound and color, students could discuss how their feelings are influenced by the type of sounds which they experience. Which sounds engender feeling of warmth or feelings of coldness? What feelings are aroused by color. How do we or would we feel being totally surrounded by a "blue" or a "red" environment. How does color affect our inner relationship to the world.

It can be brought to the students attention that it is only the human being and the higher animals which generate their own heat. Creatures of the lower animal kingdom such as reptiles, must "fit in" to their environment. They are dependent on the external temperature for their survival. If it is too hot, then they seek shelter. If too cold, then they will hibernate until the warmer weather arrives once more.

This could then lead to consideration of the human body. If we view the human being as having three internal systems, we can conclude that the Metabolic System is where the greatest amount of warmth is generated. The least amount of physical action takes place in the head, where the Nerve-Sense System is predominant and is therefore the coolest part of our body. We only become conscious of the head when we are unwell and develop a temperature. The equilibrium between the Nerve-Sense System and the Metabolic System, is of course the Rhythmic System where the work of the heart, blood and lungs is most active.

## Experience Hot and Cold

Our first experiment could be a recreation of that found in the first chapter of Rudolf Steiner's **"Warmth Course"**. Here he suggests that we take three identical containers and fill them with water. In the first the water will be hot (warm), in the second: tepid. And in the third ice-cold.

Have a student place one hand in the "hot" water and the other hand in the "ice" cold water, and leave them immersed for about one minute. Then have the student remove either hand and place it immediately in the tepid water. Have him/her determine whether the water is warm or cold to touch. Remove the first hand and now immerse the second hand into the tepid water. What does the student experience?

## Day 2: Temperature

Reviewing what was heard and experienced the previous day, lead the students into a discussion on the effects of temperature and how we experience it.

Introduce the "thermometer" and recreate the experiment of yesterday and use the thermometer to determine the different temperatures of the water in the three containers. Did the center container really contain both warm and cold water?! Ask a child to thread a needle after having her/his hands in ice cold water!

In a safe environment, light a few candles and ask the students to carefully observe the flame, preferably in a darkened room. Have them describe the flame in detail, from the blue which burns near the wick around which is a pool of melted wax, through to the yellow at the top of the flame. Do they see the aura of light which surround the flame?

Have the students carefully bring their hands close to the flame so as to experience the warmth. Where is the flame at its hottest? What effect does the flame have on their hands, apart from warming them? The closer we bring our hands to the flame, the brighter they become and the darker, and larger are our shadows.

We can conclude that just as day and night are related, so too are light and warmth.

### Melting by Heat

Place a few cubes of ice into a container of water (preferably a laboratory glass flask, although an old fashioned kettle would suffice). Apply heat.

Observe how the ice begins to melt, giving off a vapour. If a glass flask is used, droplets can be seen forming inside the flask. Steam escapes from the flask and white "clouds" appear. Eventually, both water and ice will have vanished from the vessel. Discuss.

We can conclude that heat is able to transform solid substances (ice) into liquid form. It can also transform liquid into a gaseous state (steam). If we were using a kettle, we will most probably have noticed that the lid was rattling during the boiling process. We can therefore also conclude that energy was created through the boiling process. Discuss how "inner warmth" is able to affect human conditions.

## Melting by Pressure (Ice)

Take two ice-cubes and hold them firmly in either hand. Bring the two cubes together and apply as much pressure as possible. What takes place immediately below where the two faces meet? Drops of water appear indicating that the pressure which we are applying is actually generating sufficient heat for the ice to melt. When that pressure is released, the ice cubes immediately freeze together. Discuss.

## Day 3: Conduction of Heat

Today we will turn our attention to Conduction of Heat. The first experiment is impressive....if successful!

### Experiment #1:

Have a student make a container of about 25 cm square out of ordinary paper. Fill the paper container about half full with water and place it on a metal tripod over the flame of a bunsen burner (this could be a candle under a tripod made out of a tin can). Notice that the water will begin to boil without the flame burning the paper container. Discuss.

The paper effectively conducts heat from the flame to the water. Its failure to ignite relies on the fact that its kindling temperature is above the boiling point of water 212°F (100°C).

### Experiment #2:

Obtain lengths (about 6 inches/15 cm) of metal rods (steel; brass; copper; aluminium; nickel; iron) and one wood dowel. Apply a small piece of wax to one end of each of the rods and then press the head of a thumb-tack (drawing-pin) onto the wax.

Take the rods and place then evenly around the tripod erected over the bunsen burner, so that the ends of the rods without the thumb-tacks are equidistant from the flame. Observe which thumb-tack falls off first, which second and so forth.

Discuss the observations. The conclusion is that heat travels along the rods at different rates. Which rod is the best conductor of heat. Which is the poorest?

### Experiment #3:

Have a student hold a rod (or piece) of copper in one hand and a rod (or piece) of iron in the other. Insert both into a flame. Which is the best conductor?

Relate this experiment to the copper bottomed kitchen saucepan.

**Radiation of Heat**

Obtain two pieces of tin-plate. Paint one black and the polish the other (or apply a sheet of silver foil with adhesive). To the reverse of each sheet, attach thumb-tacks with a small piece of was. Have the sheets standing upright at about 6 inches (15 cm) distance apart with the black and silver sides facing one another. Place a source of heat between the two sheets and observe what takes place. Discuss.

The heat is reflected by the silver sheet onto the black sheet which absorbs not only the heat from the heat source but also that reflected from the silvered sheet. Discuss and relate to everyday items, such as clothing and the color of automobiles.

**Day 4: Convection of Heat**

Experiment #1:

Obtain a large glass flask and fill three-quarters full of water. Place this upon your tripod. Using a long glass tube (or drinking straw), drop a small piece of *Potassium Permanganate* (obtainable from the pharmacy) down the tube/straw so that it settles onto the bottom of the flask. Try to ensure that the crystal does not come into contact with the water before it is on the bottom. This can be achieved by inserting the crystal into a tilted tube/straw prior to inserting it into the flask of water. Hold a finger firmly over the top of the tube/straw, thus preventing the water from entering. Release your finger once the tube/straw is firmly on the base of the flask. The crystal should fall to the bottom and you can then slowly remove the tube/straw so as not to disturb the crystal.

Begin slowly heating the flask from the bottom. Observe what happens to the crystal. Color will rise up in a beautiful swirling, circular motion. This is the process of convection.

Discuss its application. Room heaters.

Experiment #2:

Construct a simple windmill from paper and a pin. Hold this above a flame and observe how the rising heat with strike the vanes and cause the windmill to turn.

Discuss the energy created by heat.

## Expansion through Heat (liquids)

Having obtained three similar laboratory flasks (or medicine bottles), each fitted with a cork through the centre of which is passed a tube (strong clear straws would suffice). Fill each flasks (bottle) with a different liquid, eg. colored water, cooking oil; milk.

Insert the corks into the flasks so that the bottom end of the tube is below the surface of the liquid. The other end of the tube will be sticking out above the cork. Place the three flasks in a pan of water and gradually heat. When sufficiently heated, the liquid inside the flasks will rise up the tubes. The rise inside the tubes will indicate the difference in expansion rates of the different liquids.

## Expansion through Heat (gases)

Take one of the flasks from the last experiment and replace the contents with fresh water. Push the glass tube further into the water until the tube is just above the bottom of the flask. A hand, when placed against the side, will have the effect of expanding the air inside the flask. This will force the water water further up the tube. When the hand is removed the level of the water in the tube will fall. Discuss.

Other methods to show the expansion of gases (air), can be:

1. to stretch a rubber balloon over the neck an empty flask/bottle. Heat the flask <u>very</u> gently and watch the result.

2. Inflate a balloon only partially and place for awhile in the warmth of the sun or hold over the heat of an electric stove. Observe the results.

## Day 5: Expansion through Heat (solids)

The following simple experiments are easily conducted at home.

<u>Experiment #1:</u>

Obtain a length of copper tubing around 4 feet (1.5 m) long and lay it on a workbench or kitchen table so that it is parallel to one side and leaving one end of the pipe jutting out into space. Taking a clamp, fix the tube firmly to the surface of the table. It should still be possible to raise the other end of the pipe high enough to slip a 1 ft (30 cm) length of stout wire (knitting needle or piece of wire coat hanger) underneath in a manner which will leave about 6 inches of the wire poking out into space. To the middle of a 1 ft a thin strip of wood (preferably balsa), apply a dab of fast drying adhesive. Quickly attach the wood to the jutting out end of the wire. We now have an arrow which will indicate the smallest of movement of the pipe. Now blow steadily down the pipe at the fixed end. The warm air will cause the pipe to expand and this expansion will be detected by the "pointer" which will move accordingly.

Experiment #2

Obtain a metal "ball and ring" from the physics lab. Show the students that the ball is unable to fit through the ring. Heat the ring over an intense flame and then attempt to pass the ball through the ring.

Heat the ball and we find that it no longer passes through the ring.

Experiment #3:

The above experiment can easily be conducted with household items as follows:

Insert a large wood screw into the end of a block of wood and obtain a screw eye just large enough to slip over the head of the screw. Secure the screw eye to the end of another piece of wood.

Heat the head of the screw in a flame, remove and try to fit the screw head through the screw eye. Note the result.

Whilst the screw head is still hot, heat the screw eye and try to place it over the screw head. Note the result.

Cool down the screw head and try to insert it into the heated screw eye. Note the result.

Cool both the screw head and the screw eye and try to insert the one into the other. Note the result.

Experiment #4:

A pair of iron and brass strips riveted together and attached to a wooden handle is heated over a flame. We observe that the strip will bend. This is because of the difference in rate of expansion of the two metals.

**Expansion through Cold (Ice)**

Experiment #1:

Take a drinking bottle *(recyclable)* and fill it to the very brim with cold water and place in the freezer, ensuring that no water is spilt. Remove the next day. What are your observations?

Experiment #2:

Obtain a small metal can complete with screw-on cap. Fill it to overflowing with water and screw the cap on tightly. Put it into the freezer! Leave for some time until the water in the can has had time to freeze solid. What are the results?

## Equipment Required

## Week Three - HEAT

**Day 1** **Experience of Hot and Cold**

3 containers; water; heat source

**Day 2** **Temperature**

Thermometer (domestic)
Candles; matches/lighter

**Melting by Heat/Pressure**

Ice cubes; water
Container; heat source

**Day 3** **Conduction of Heat**

Sheets of paper (or paper cups)
Water
Tripod (metal)
Bunsen burner (or candle); matches/lighter
Rods (copper; iron; wood)
Wax
Thumb tacks (drawing pins)

**Radiation of Heat**

Tin plate (2 pieces)
Black paint
Silver paint (or silver foil and adhesive)
Heat source (bunsen burner preferably)

**Day 4** **Convection of Heat**

Glass flask/medicine bottle and
Stopper with hole thro the center
Glass tube (or transparent drinking straw)
Water
Tripod (metal)
Bunsen burner (or candle); matches/lighter
1 gm Potassium Permanganate crystals
Paper; pins; scissors
Japanese paper lantern; night-lights;
Thread (cotton); jar lid (light weight)
Hammer and nail to puncture holes in the rim of the lid

**Expansion of Liquids**

Glass flasks/medicine bottles (3) and
Stoppers with holes thro the centers
Glass tubes (or transparent drinking straws)(3)
Cooking pan
Water; heat source
Cooking oil; milk; other

**Expansion of Gases**

Glass flask/medicine bottle
Stopper with hole thro the center
Glass tube (or transparent drinking straw)
Water
Balloons

**Day 5**

**Expansion of Solids**

Copper tubing
Clamp
Stout wire/knitting needle
Wood strips (balsa)
Adhesive (quick drying)
Ball and Ring (physics lab. equip.)
Large wood screw and screw-eye to fit same
2 blocks of wood
Strip of riveted iron and brass (physics lab. equip.)
Heat source (preferably bunsen burner)

**Expansion through Cold**

Glass container or similar
Can with screw top
Water
Freezer
Ice-box
Ice
Salt
Patience!

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# MAGNETISM

This is the last physics block period for Grade Six, which will last for two weeks. During this short period of time, the students will be led to a basic appreciation and understanding of the mysterious worlds of magnetism and electrostatics.

Depending on the expectations of individual schools or the demands of the state educational department *(as in Australia)* with regards to syllabi content in Grade Seven, it might be advisable to include a third week with a focus on the first elements of Current Electricity.

The first strand of this physics block will look at "Magnetism" and will follow the following program:

**Day 1**
Introduction
What is Magnetism?
Magnetising an Iron Rod
Artificial Magnets
Floating Magnets on Water

**Day 2**
Review/Recount
A Magnet Floating on Air!
Hanging Compass
The Exertion of Magnetic Force

**Day 3**
Review/Recount
How do Magnets react in Space?
Attraction and Repulsion
The Law of Magnetism
Force Fields

**Day 4**
Review/Recount
The Mysterious Compass
Shielding Magnets
- non-magnetic materials
- magnetic materials

**Day 5**
Review/Recount
A Simple Magnetic Motor
A Simple Eddy Current Motor
Conclusion and summary of week's work

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## Magnus, the Shepherd

*In Ancient Greece over 4,000 years ago, Magnus, an elderly shepherd was alone in the hills of northern Greece guarding his flock from wolves which dwelt in that land. The terrain was rough and covered by many rocks and boulders. Therefore, it was necessary for Magnus to have sturdy footwear. He made his own shoes and to add strength to them, he had hammered metal nails into the wooden soles. He had also hammered a large nail into the base of his staff to increase it's strength.*

*As Magnus wandered through the hills, he would always seek out a high spot from where he could keep a wary eye on his charges. This particular day, Magnus had clambered to the top of a large, black rock. Standing there, he had a wonderful view of the surrounding landscape and his flock. Eventually, Magnus decided to move from the rock. However, one can well imagine his astonishment when he found that he was hardly able to move his feet!! They appeared to be held fast by the black rock, as was his staff also!!*

*Eventually, Magnus broke free from this "magical" rock and excitedly reported his experience to everyone he met.*

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This type of rock which we now know as "magnetite", was first found in the region of Northern Greece called Magnesia. Pliny, a Roman writer who lived about 2000 years ago, wrote saying that the rock's name is borrowed from Magnus, the shepherd!

This unique rock, which has the power to attract iron ore, is also known as "lodestone", an old English word meaning "leading stone". It was soon realised that this rock, which had the ability to attract objects made of iron could, when floated on water, point in a north-south direction thus creating the first primitive compass. Magnetite was also considered to possess magical healing powers and was also believed to have the power to dispel evil forces!

**Day 1:**

Experiment #1: **Magnetite**

Magnetite is quite a common ore in many parts of the world and is thus quite easily obtainable from stores such as "Hearthsong".

It would be good to obtain such a piece of magnetite for the first experiments in magnetism. Sprinkle iron filings onto a sheet of white paper and gradually bring the magnetite closer to the filings. Notice how the ore attracts the filings. Try picking up larger items made of iron. What happens when the ore is placed near a compass. Do all parts of the lump of iron ore affect the compass in the same manner?

Experiment #2: **Magnetising an Iron Rod**

Obtain a length of iron rod and test it with a compass to ascertain whether it is magnetised or not. Hold the rod in a north-south direction and tilt it slightly. Strike the rod several times with a hammer and once again test with the compass. The rod should now be slightly magnetised. If it isn't, then repeat the process. When you have successfully induced magnetism into the rod, it should be possible to pick up lightweight pieces of iron, such as filings, needles, nails, etc.,.

The rod can be usually be demagnetised by holding it in an east-west direction and striking it several times with the hammer.

Experiment #3: **Artificial magnets**

The easiest way to obtain artificial magnets is by ordering direct from a scientific goods supplier. However, it is still possible to obtain good magnets from old loudspeakers or telephone receivers, maybe obtainable in your local "junk" store!

Artificial magnets come in a variety of shapes and sizes, such as U-shape, horseshoe, straight and bar magnets.

Experiment #4: **Making a Simple Floating Compass**

Magnetise a sewing needle by stroking the needle several times in one direction with a piece of magnetite or a small artificial magnet.

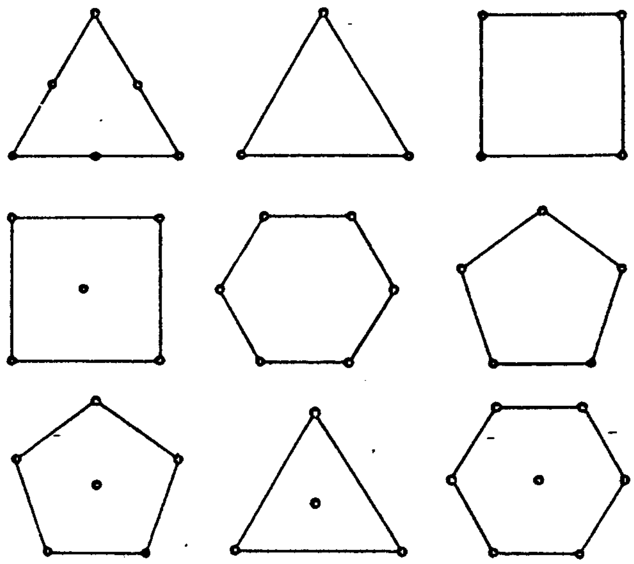
Place the magnetised needle on a disc of cork, obtained by cutting a wine bottle cork into slices. If cork is not available, a small piece of styrofoam works equally well. Place the cork and needle compass into a bowl of water so that it floats freely on the surface. Check the orientation of the needle with another compass.

Experiment #5: **Experiments with Floating Magnets *(Optional)***

Several needles need to be magnetised, so that all points have the same polarity and all eyes have the opposite polarity. Begin magnetising the needle by stroking with one end of the magnet towards the end of the needle. After several strokings, turn the needle around and stroke from the center to the other end of the needle using the opposite end of the magnet.

Push each needle vertically through a disc of cork so that the cork floats with the points of the needle all pointing downwards and with about 1 cm of needle remaining above the surface of the cork.

Bring one end of a strong magnet above the floating needles and observe. Try the experiment using the other end of the magnet. Experiment with different numbers of floating magnets. Keep a record of the different patterns which you are able to create.



**Day 2:**

Experiment #6: **A Needle Floating on Air**

Thread a small sewing needle and then draw the needle over one pole of a bar magnet which is resting on a flat surface. Let the needle remain on this pole until it is thoroughly magnetised.

Take hold of the thread and carefully lift the needle until it hangs from the thread directly over the opposite pole. With very careful manipulation and some patience, it is possible to make the needle float in the air above the other pole.

Ask a student why this happens.

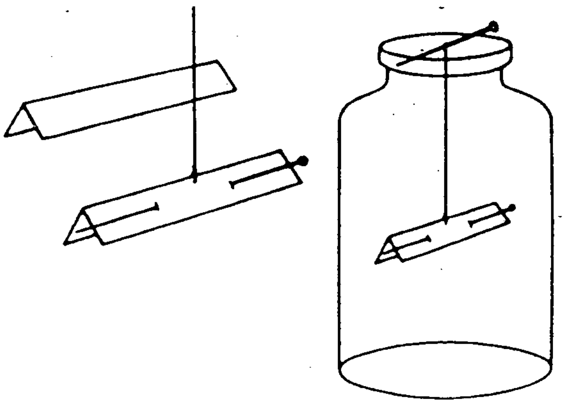
## Experiment #7: Making a Hanging Compass

As a hanging compass is very susceptible to the movement of air, it is wise to create one which is protected from air movement.

Obtain a glass jar. Fold a piece of thin card lengthwise in half so that it will fit easily through the neck of the jar and will also swing freely within the jar without touching the side.

Magnetise a long sewing needle which is a little longer than the piece of card. Push the needle lengthwise through the card and suspend the card and needle on a thin thread so that it is balanced. Tie the end of the thread to a piece of wood which is then placed across the neck of the jar.

Have a student check the orientation of the needle with a compass.



## Experiment #8: Where is magnetism the strongest?

A question may be posed as to whether the magnetic attraction in a bar magnet is greater at any one point along it's length. We are able to ascertain this by conducting the following experiment:

Obtain a small, sensitive spring balance and hang a piece of soft magnetic wire over the hook of the spring balance. Place a bar magnet on a sheet of math graph paper. Test the pull required to lift the magnet off the paper from points 2 cm apart along the length of the magnet.

Record your results as a graph showing the "pull" required and the distance along the magnet from one end. Where, if anywhere, is the magnet the strongest?

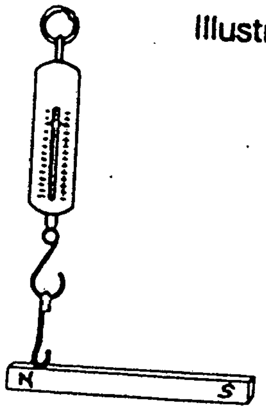



Illustration for Experiment #8

**Day 3:**

Experiment #9: **How do magnets act in space?**

Create a "cradle" from non-magnetic material. Suspend a bar magnet in the cradle so that it is able to hang freely. Bring another bar magnet near the suspended magnet. Observe and record the results.

Experiment #10: **Attraction and Repulsion**

Take a magnet and bring one end close to the north pointing end of a compass needle. Test to see which end of the magnet repels the compass. Mark that end of the magnet "N" for *north pole.* Repeat this exercise with a second magnet and mark is likewise. The unmarked ends of the magnet are the *south poles.* It is also acceptable to mark the poles: + for north and - for south.

Suspend one magnet in a cradle as per the previous experiment. Bring the north end of the second magnet close to the north end of the suspended magnet. Observe and record the results.

Bring the two south poles of the magnets close together. Observe and record the results. Bring the south pole of the held magnet close to the north pole of the suspended magnet. Observe and record the results. Bring the north pole of the hand held magnet close to the south pole of the suspended magnet. Observe and record the results.

Have students comment on their observations. What conclusion are they able to make?

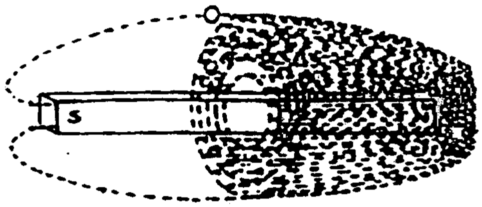
**The Law of Magnetism**

The law or rule of magnetism is that:

Like poles repel and unlike poles attract

## Experiment #11: **Force Fields**

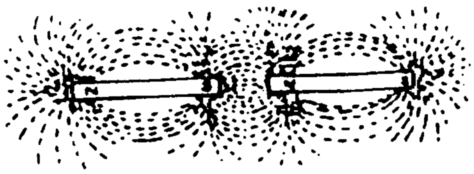
From our experiments, we are able to conclude that there is an area of force (a magnetic field) surrounding a magnet. This force field is three-dimensional, meaning that it surrounds the magnet on all sides. If one is able to acquire a Magnetic Field Chamber, it is possible to see this force field. Such a chamber will cost in the region of $US20 and should be available from a science supply wholesaler/retailer.



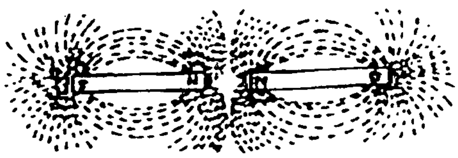

Although it is difficult to make the surrounding force field visible in it's entirety e of a Field Chamber, we are nevertheless able to reveal the lines of the force field by the use of fine iron filings.

Place a bar magnet beneath a sheet of white paper. Using a salt-shaker, carefully sprinkle iron filings onto the paper immediately above and around the magnet. The force field becomes visible in a two-dimensions.

Repeat the experiment, but this time place two magnets beneath the paper with **unlike** poles facing one another, but far enough apart so that they cannot join together. Sprinkle iron filings onto the paper and observe. The lines of force join up and the magnets are attracted to one another.



Repeat the experiment again, but this time with the **like** poles of the magnets facing one another. Sprinkle iron filings onto the paper and observe. The lines of the force field push away from one another and the magnets are repelled.



## Day 4:

### Experiment #12: The Mysterious Compass

Just as the ends of a magnet are called the north and south poles respectively, so too are the north and south extremities of the Earth also called the north and south poles.

The terms "north pole" or "south pole" are used in relation to the magnet because the north pole of the magnet is north-seeking, in that it always points to the magnetic north. Likewise, the south pole of the magnet seeks out the south magnetic pole. One could perhaps picture a giant magnet piercing through the center of the earth. The sphere of the Earth surrounding it could be likened to a huge magnetic force field.

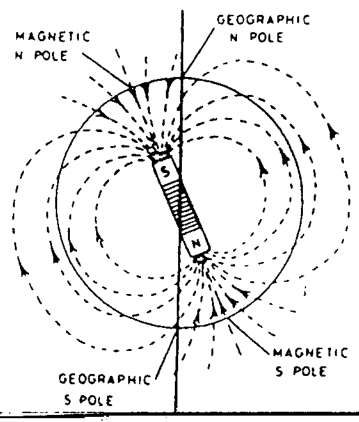
That a magnet seeks out the magnetic poles was apparent to Chinese sailors many hundreds of years ago. They were aware of the magical qualities of magnetite and would suspend a piece in the air so that it could orientate itself in a north/south direction, just like a compass needle.

Interestingly, a compass is absolutely useless at the poles, for the lines of the force field point straight up to the sky!

The strength of the magnetic force varies as the Moon moves around the Earth. In addition, the magnetic poles shift their position slightly from year to year. In fact, scientists have discovered that the Earth's magnetic field reverses itself about every 200,00 years. Whether the change takes place gradually or whether there is a period of time when there is no magnetic force at all, remains a mystery yet to be solved!

The Earth's magnetic force field also gives rise to the beautiful Aurora Borealis or Northern Lights which are visible in the night skies in regions of the northern hemisphere close to the Arctic Circle

This movement of the Magnetic Pole was confusing to early explorers, for they presumed that the magnetic pole and the geographic pole were one and the same. In fact. it was partly because of this misunderstanding of the nature of the magnetic pole that Christopher Columbus discovered North America!!!



## Experiment #13: Shielding Magnetism - nonmagnetic materials

Our experiments have shown that a magnet will attract items such as a nail, a needle, a paper clip, etc,. Would the magnet be able to attract them if there was an intervening shield?

To determine whether this is so, we can place a paper clip on a piece of stiff paper, and the magnet underneath. Immediately we are able to see that the paper has no effect whatsoever upon the magnetic field of the magnet. By moving the magnet, we are able to move the paper clips around with ease.

Have students experiment with a variety of different materials to determine which are able to shield the paper clip from the magnetic force.

Our conclusion is that anything which is not in itself affected by the magnetic force, is unable to act a shield. The lines of magnetic force are able to flow through non-magnetic material with ease.

## Experiment #14: Shielding Magnetism - magnetic materials

If we wish to shield an object from the magnetic force field, then it follows that we must use something which is a good conductor of magnetism, such as iron and steel.

Thus, in order to shield something from these force fields, we create a barrier out of a magnetic material so that the force lines are attracted to this material, rather than to the object which we are trying to shield. The lines of force in a magnet always follow the easiest path.

Students could test this theory by constructing a shield around a small compass as follows:

Find a metal screw-on lid from a jar. Into it's center, place a small compass so that the rim of the lid acts as a shield. Next take two bar magnets and place one on either side of the lid, so that the North pole of one and the South pole of the other face the lid. Notice any effect that the magnets may have on the compass when they are put into position.

If the effect is significant, then obtain a larger lid into which you are able to place the original one (plus compass!). Note the effect of the magnets on the compass. If the shielding is not as successful as one would wish, then obtain an even larger lid into which you can place the other two. It will be noticeable that the magnetic force of the compass becomes less after the addition of each tin lid. It is far easier for the force lines to travel around the metal of the lids, rather than to cross the empty space (through air) to reach the compass. It is frequently necessary to shield sensitive instruments from magnetic force fields.

**Day 5**:

Experiment #15: **A Simple Magnetic Motor**

From the knowledge that they have acquired, students could now be directed to the practical application of magnetic force fields in powering a very simple motor.

Suspend a small bar magnet horizontally in a thread cradle. Hold the end of the thread so that the magnet hovers over the top of a compass lying on a flat surface. Hold the magnet steady so that the compass needle is at rest.

Next twist the thread holding the magnet several times (30 or so) and release so that the thread is able to unwind. Observe how the compass needle will spin in unison with the magnet. This is brought about by the attraction of the poles of the compass to the opposing ones of the magnet.

Experiment #16: **A Simple Eddy Current Motor**

Earlier experiments will have shown that the force fields of a magnet will have no effect on a piece of aluminium. However, the following experiment will show that the magnet is nevertheless able to exert some sort of force upon this metal. To have success with this experiment, we require a reasonably powerful horseshoe magnet. Attach the magnet to a piece of string about 60 cm long *(the length is not important to the success of the experiment)*.

Obtain a stubby length of cork and through the center of it's diameter, insert a short needle so that the point goes through and beyond the surface of the other side. Place the cork on a flat surface with the point of the needle uppermost.

Acquire a small, round aluminium foil baking pan. Invert the pan and balance it on the tip if the needle.

Bring the magnet to a position immediately above, but not touching, the foil pan. Twist the string holding the magnet several times (at least 30) and then release. Observe what takes place.

As the magnet spins, it creates what are known as eddy currents. These currents will produce a magnetic field upon the surface of the pan. The force field of the magnet will act upon this force field, causing the lid to spin.

The faster the magnet is made to spin, the greater is the force field created on the surface of the lid, which in turn increases the speed of lid's spin.

This principle was used in the construction of speedometers.

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S POLE

## Equipment Required

## Week One - Magnetism

**Day 1**

A piece (or pieces) of Magnetite
Iron filings
White paper or card
Paper clips, steel sewing needles, iron nails (various sizes/weights)
Iron rod
Hammer
Compasses - 1.6 cm approx. *(1 per student)*
Magnets - straight, bar, horseshoe
Cork or styrofoam
Sharp knife/blade
Bowl and water

**Day 2**

Cotton/nylon thread
Glass jar
Thin card/thick paper
Steel sewing needles
Wooden stick (pencil would be ideal)
Bar magnets *(1 per student)*
Spring balance
Pliable wire (wire coat hanger ideal)
Ruler
Graph/squared paper
Pencil

**Day 3**

Bar magnets
Cotton/nylon thread
Compasses
Iron Filings
Magnetic Field chamber (avail. from science supply stores)
White card/thick paper

**Day 4**

An orange!
2 knitting needles (of different color)
Compasses
Magnets
Paper clips, needles, nails
Paper, plastic, rubber, leather, glass
Iron, steel and tin lids of various sizes

**Day 5**

Bar magnet and Horseshoe magnet (large)
Compasses
String/thread
Cork and small sharp needles/pins
Aluminium foil baking pans (small)

## ELECTROSTATICS

*"…..we choose as our starting-point, among the various modes of generating electricity, the one through which the existence of an electric force first became known. This is the rousing of the electric state in a body by rubbing it with another body of different material composition……..we become aware of a certain kinship of electricity to fire, since for ages the only known way of kindling fire was through friction. We notice in both cases that humans had to resort to will-power invested in their limbs for setting in motion two pieces of matter, so that, by overcoming their resistance to this motion, we release from them a certain force which we can utilise as a supplement to our own will. The similarity of the two processes may be taken as a sign that heat and electricity are related to each other in a certain way, the one being in some sense a metamorphosis of the other.*

**'Man or Matter'** Ernst Lehrs. Ph.D. (1950)

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We don't have to go too far back in history to realise that daily life was very different. There were none of the modern conveniences such as radio or tv. Light was produced by candle, paraffin lamp or gas. Heating was obtained from wood or coal fires, which were also the only means available for cooking and heating water.

In the 21st century, we have luxuries never dreamt of, even as recently as 50 years ago!! Electricity has become an important and integral part of our lives, something which we take for granted..

The word "electricity" comes from the Greek word for 'amber' *(electron).* The Ancient Greeks knew that if one rubbed amber with wool, it had the power to attract light-weight objects…..in some ways similar to the attraction of iron by magnetite. It was also observed that rubbed (excited) amber would also produce little sparks when touched with a dry finger!

The phenomena of magnetism and electricity was something which fascinated William Gilbert, doctor to England's Queen Elizabeth the First. He wrote a scientific book on the subject in 1600, although now we would laugh at some of the ideas which he put forward, such as his belief that the planets were held in place by magnetism! It was William Gilbert who coined the word 'electrics', from the Greek *'electron'*, to describe how some substances can be charged with static electricity. This in turn gave rise to the term 'electrostatics'.

This, the second strand of this particular morning lesson block, will consider the phenomena of Static Electricity and will follow the following program:

| | |
|---|---|
| **Day 1** | Introduction<br>Creating Static Electricity<br>Static Electricity surrounds us<br>Research into Electrostatics |
| **Day 2** | Review/Recount<br>The Attractive Power of Static Electricity<br>Coulomb's Law<br>How do Electrons flow? |
| **Day 3** | Review/Recount<br>A paper Electroscope<br>A Metal Leaf Electroscope<br>Volta's Electrophorus |
| **Day 4** | Review/Recount<br>Sparks from Static Electricity<br>Van de Graaff Machine<br>Some Facts |
| **Day 5** | Review/Recount<br>Leyden Jar<br>Conclusion and summary of week's work |

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**Day 1:**

Experiment #1 **Creating Static Electricity**

An electrical charge is built up when two materials are rubbed together. The Greeks knew this well from their experiments with amber.

Take a piece of amber and 'excite' it by rubbing with a piece of woollen cloth or fur. Have a small pile of very small pieces of paper to hand. Hold the 'excited' amber close to the paper pieces and observe what happens. Repeat the experiment using a piece of silken cloth. Record your results.

Conduct a series of such experiments by 'exciting' other objects, such as a plastic comb, a plastic pen, a piece of wax, a glass or china dish or any other non-metal object. Use wool, silk and flannel cloths to 'excite' each object. Keep a careful record of your observations.

Experiment #2 **Static Electricity Surrounds Us**

Conduct numerous experiments to show that static electricity surrounds us, that it is everywhere.

Obtain a balloon and inflate it. Rub it against your hair and then bring it near to your heap of paper bits. Comb your hair and repeat the experiment. Rub a plastic pen on your clothes and test for static electricity.

Cut two lengths of newspaper from a sheet, each about 5 cm wide and 30 cm in length. Hold both pieces together between a finger and thumb. With the finger and thumb of your free hand, stroke the entire length of the paper strips. Note what happens.

Experiment #3 **Research Into Electrostatics**

Experiment to see what the effect of static electricity has upon:

a. a table-tennis ball

b. a fine, continuous stream of water

c. a silk thread (the end held between finger and and thumb)

d. a fluorescent tube

**Day 2:**

Experiment #4 **The Attractive Power of Static Electricity**

Obtain a balloon, inflate it and rub it briskly against a woollen sweater or a piece of fur. Bring the balloon close to a smooth wall and observe the result. The balloon is attracted to the wall and remains where you place it. Try this experiment by rubbing the balloon against various materials.

Take a sheet of ordinary newsprint and place it against a smooth wall. With a pencil or the edge of a ruler (not metall), stroke the total surface of the sheet several times.

Observe how the paper now clings to the wall. Raise a corner of the sheet with a finger and thumb and then let it go. Observe what happens.

The obvious questions now are: "Why does the balloon or a sheet of newspaper stick to the wall? Why do strips of newspaper stick together? Etc.,. To answer these questions, we need to conduct some very carefully observed experiments.

## Experiment #5 **Coulomb's Law**

Obtain two balloons *(it would be helpful if the balloons were of a neutral color )*, inflate and tie securely. Attach a long piece of silk thread to each balloon.

Rub both balloons with a piece of fur or wool and then let them hang freely in the air. Bring the two balloons close together. Note what happens. By rubbing the balloons with fur, we have induced a negative charge in each of the balloons. We note that **"like charges repel"**. *When writing this down, it could prove helpful to use the color blue to signify a negative charge.* Discharge the balloons by touching them with your hand.

Take one of the balloons and rub it with fur or wool. Rub the second balloon with "cling-film" sandwich wrapping. Hold the balloons by their threads so that they are hanging free. Bring them close to one another. Note what happens. The balloons are attracted to one another. When they eventually touch, they will be discharged and hang down normally.

The balloon which had been rubbed with fur or wool had acquired a greater electrical charge (positive +) than the balloon which had been rubbed with "cling-film" (negative -). Therefore, when the two balloons were brought together, the one with the positive charge gave-up some of its electrons to the balloon with the negative charge. **Unlike charges attract** *(red).* The result was to bring about a balance of electrons in both balloons. Attraction and repulsion therefore ceased.

The above experiment shows us how an "electroscope" works.

## Experiment #6 **How do electrons flow?**

The previous experiment shows us the results of the movement of electrons. But as they are invisible, it is not easy to understand what actually takes place. The following experiment can illustrate this quite adequately:

Obtain two plastic containers and punch a hole near the base of each. Make the holes large enough so that you are able to connect the two holes with a pliable tube. Pinch the tube in the center with a clothes peg.

Fill one container with water. The clothes peg should prevent the water flowing into the empty container. When ready, remove the peg and note what happens.

When does the water stop flowing? This is the principle of the movement of electrons from positive to negative.

**Day 3:**

Experiment #7 **A Paper Electroscope**

Cut a strip of light-weight paper (newsprint would be good) about 30 cm long and 8 cm wide. Fold it in half, crease the center fold and hang loosely over the edge of a wooden ruler. This folded paper now becomes our 'electroscope'.

Lay the 'electroscope' on a flat surface and stroke with fur or wool. Lift the paper electroscope carefully by the ruler. Observe.

Charge a plastic pocket comb with fur or wool. Bring the charged object ɔtween the hanging leaves of the electroscope. Observe.

Obtain a thin glass test tube, glass rod or a small glass bottle. Charge it by rubbing with silk and bring the charged object between the hanging leaves of the electroscope. Observe.

Repeat the experiment a few times to ensure that your observations are correct. What are your conclusions?

Experiment #8 **A Gold Leaf Electroscope**

Obtain a narrow necked jam jar and a very tight fitting cork. Through the center of the cork, push a length of copper wire. Bend the end of the wire into an "L" shape over which you will be able to hang either a piece of tissue paper, aluminium foil or preferably gold leaf *(obtainable from an art supplier).*

Insert the cork firmly into the jar so that the "leaf" on the copper wire is able to hang freely within the airtight jar. To ensure that the jar is airtight, wax could be melted around the rim of the jar to act as a sealant.

Charge a plastic comb or other such object as described above and touch the end of the copper wire extending through the cork. Observe how the "leaf" reacts. Repeat this experiment with different charged objects and record the results.

Experiment #9 **Volta's Electrophorus**

Obtain a small aluminium pie dish. Attach it to a length of wooden dowel with a thumb tack through the center of the base, resulting in the dowel being fixed centrally to the inside of the dish.

Obtain a slightly larger styrofoam plate. Turn it upside down and rub the underside briskly with a piece of fur or wool. Take hold of the wooden dowel handle of the "electrophorus" and place it firmly on the styrofoam. Touch the inside of the dish momentarily with a finger, then lift the electrophorus away. Discharge it against your electroscope. Recharge and discharge against a knuckle!! *Do not be dismayed if you have no reaction. The atmospheric conditions have to be perfect for this, and other electrostatic experiments, to work.*

**Day 4:**

Experiment #10 **Obtaining Sparks from Static Electricity**

Obtain four glass tumblers and a strong square wooden board (approx. 45 cm2). Stand the inverted tumblers on the floor in a square and place the board on top. The platform should be near to *(but definitely not touching)* a metal pipe or radiator Test the platform for stability!

o

Ask a student to stand on the board. Stroke his or her back with a piece of fur quite vigorously for about one minute.

Call for a volunteer to step forward and have the first student who has been 'charged', place her/his finger lightly on the tip of the volunteer's nose. Watch the sparks fly!! The 'charge' could be as high as 10,000 volts....maybe even more!! Don't explain volts and watts at this juncture!

Repeat this experiment using other materials to 'charge' the student. Have the student 'discharge' her/himself by touching the metal pipe or radiator. Watch for sparks. Naturally, the results will be better in a darkened room.

It should be noted that for this experiment to be successful, it is necessary for everything to be bone dry. *Obviously, such an experiment will not work on a humid day or in a damp environment, as with all other electrostatic experiments!*

Experiment #11 **The Van de Graaff Machine** *(optional)*

Most schools will possess a Van de Graaff machine which is able to generate a continuous supply of static electricity. The generator can give off a nasty shock, so treat with respect!

Have a student with plenty of dry, clean hair stand on the insulated platform used in Experiment #8. She or he should place both hands firmly upon the dome of the generator. With the control set at the lowest reading, turn the generator on and gradually turn up the control.

Observe the student's hair. It should stand on end!

Discharge the generator BEFORE the student removes his/her hands. A probe is supplied with the generator for this purpose. Follow the instructions for its usage.

Other experiments, such as the following one, can be conducted with the generator to involve the entire class.

## Experiment #12 The Van de Graaff Machine *(optional)*

Have the class form a large circle so that the student at the generator is part of that circle. The student at the generator will have one hand placed firmly on the dome, the other hand will have a finger nearly touching an outstretched finger of the first person in the circle That student will then hold out her/his other hand so that a finger is nearly touching the finger of the next person. This is to be repeated around the circle until arriving at the last person, who of course only holds one hand out!

Turn the generator on and increase the power. The power should go right around the circle, jumping from finger to finger with a little "crack" which is in fact the result of a spark jumping the gap between the two fingers! Those who are brave enough might like to experiment with having a finger held close to their nose!! They can still pass the charge on via their finger.

Conclusion: The Van de Graaff machine is able to generate static electricity though the friction of the belt. The charge thus generated is stored in the "dome" which acts like the "electrophorus". Once a significant charge has been built up, it is possible to create a tremendous spark on discharge.

This can be likened to electrical storms. The rise and fall of water droplets within a cloud create an electrical charge which is accumulated within the cumulus clouds. Eventually, the positive charge will seek a negative charge, towards which it is attracted. A tremendous spark is released, heating the surrounding air so that it suddenly expands with a loud noise (thunder).

### Some facts

The Van de Graaff machine is able to generate 30,000 volts per cm of distance between the dome and the electrode. If the electrode happens to be a finger which is held 5 cm from the dome, then the owner will receive some 150,000 volts!

Lightning generates 10,000 per cm (due to water vapour in the air). The average length of a lightning strike is around 3 km. Convert this into cm and we have some 300,000 cm.

A simple multiplication of 10,000 volts by 300,000 cm gives us the staggering figure of 3,000,000,000 volts!!! Three thousand million volts!!

One could now briefly explain the difference between the two:

VOLTS - potential WATTS - amperage

**Day 5:**

Experiment #13 **The Leyden Jar**

Whilst the electrophorus and the Van de Graaff machine are able to hold a small charge for a short period of time, scientists pondered as to how a charge could be stored for an extended period of time. This was discovered by a scientist at the University of Leyden in Holland, in the year 1745. The invention became known as the Leyden Jar.

There are several ways of making such a jar, but perhaps the most simple is the following:

Obtain an empty film canister. Tightly wrap two-thirds of both the inside and outside of the container in aluminium foil *(including the bottom of the container)*. Make sure that the foil is secure. Pour water into the container until it is nearly full and put on the lid. Insert a sharp nail *(preferable;y copper)* through the lid so that it touches the water and leaves about 2 cm sticking out above the lid.

Charge the Leyden jar by first charging your electrophorus. Bring the electrophorus near the nail so that a spark jumps across the gap. Repeat this several times to build-up an accumulation of static charge in the Leyden Jar.

Discharge the jar by holding the foil covered outside. Touch the nail lightly with a finger!! *Remember, atmospheric conditions have to be perfect!!*

**Equipment Required**

**Week Two - Electrostatics**

**Day 1**

Amber
Fur
Woollen cloth
Silk cloth
Flannel
Light weight paper
Comb (plastic)
Pen (plastic)
Glass/china dish
Wax
Balloons
Newsprint
Scissors
Table tennis ball(s)
Silk thread
Fluorescent light bulb
Water faucet/tap

**Day 2** All the above, plus:
Ruler (not metal)
Colored pencils
Cling film (plastic wrap)
Containers (2)
Hole punch (large nail)
Pliable tube (rubber)
Clothes peg or spring clip

**Day 3** All the above, plus:
Glass test tube or glass rod or small glass bottle
Jam (preserve) jar (narrow neck)
Cork (to fit jar)
Copper wire (medium thickness)
Tissue paper
Aluminium foil
Gold leaf
Aluminium pie dish (small) - one per person
Dowel (30 cm length) - one per person
Styrofoam plate - multiple

**Day 4** All the above, plus:
Glass tumblers (4)
Solid wooden board (approx: 45 cm2)
Van de Graaff Machine

**Day 5** All the above, plus
Film canisters (one per person)
Nails (thin copper) - approx. 4 cm long (one per person)

A lot of patience if also required!!

As said previously on numerous occasions, the atmospheric conditions must be perfect for any of the electrostatic experiments to work.

Do not be too disheartened if you have more failures than successes. That is all part of the scientific experience. Progress is only made through trial and error...some of the greatest scientific discoveries have been accidental, such as 'electromagnetism'!

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## CURRENT ELECTRICITY

*"The discovery and application of electrical forces was unavoidable and an evolutionary necessity. However, this 'release' in the electrical sphere demands from human beings themselves enhanced alertness of consciousness and increased efforts to muster inner resources by sustained spiritual work in order that the down-pressing forces connected with electricity can be countered and equilibrium restored. This is because a spiritual force is hidden in the natural energy of electricity that has the tendency to diminish human moral values, a force that attempts to drag human beings down to a less than human level leading into subnature; that is, into a morally low and spiritually dark domain....."*

Rudolf Steiner. **'Anthroposophical Leading Thoughts'** (#183 -5)

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As I wrote earlier, it is not necessary to proceed with this section of the physics curriculum until Grade Seven. However, because of other pressures (often external), it might be necessary to begin looking at current electricity already in Grade Six. I therefore include what I consider to be sufficient ideas and work for an introductory one week morning lesson block:

| | |
|---|---|
| **Day 1** | Introduction: Current viz a viz Static Electricity<br>Galvani and the Galvanoscope<br>The Taste of Zinc and Copper<br>Volta and the Voltaic pile |
| **Day 2** | Review/Recount<br>An Electric Lemon/Potato/Banana<br>Making a Simple Voltaic Cell |
| **Day 3** | Review/Recount<br>A Series of Voltaic Cells (Battery) |
| **Day 4** | Review/Recount<br>Heat and Light |
| **Day 5** | Review/Recount<br>The Motor Effect and Electromagnet<br>Conclusion and summary of week's work |

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**Day 1:**

**Experiment #1 Making a Galvanoscope**

In our previous work with Static Electricity, I tried to show how electricity flows, although this might seem to be a contradictory term when applied to static electricity! By constructing a simple Galvanoscope, it will be possible to see the effect of the flow of an electric current.

Obtain a matchbox and remove the drawer and then split the case apart lengthwise. Wind about 20 turns of thin insulated copper wire around the matchbox and case, leaving about 30 cm before starting the first turn and after the last turn. Fix the matchbox structure to a piece of wood with two thumb tacks. Prior to pressing the tacks fully into the board, wind the bared ends of the wires around the tacks, thus making them into electrical contact points for use as terminals. Leave a few centimeters of bare wire hanging loose from each terminal.

Place a small compass with a dab of glue on it's base, into the matchbox drawer so that the compass is positioned beneath the top coil of wire. The Galvanoscope is now ready for use!

**Experiment #2 The Taste of Zinc and Copper!**

Obtain a strip of thin zinc and another of copper (4 cm x 10 cm). Clean both strips with wire-wool. Attach a plastic or wooden clothes peg to the end of each to act as temporary handles.

Place the zinc strip on your tongue. Remove and repeat the process with the copper strip. Next, place both strips in the mouth at the same time and allow then to touch one another. Experience the acidic taste! This comes about because the two metal create an electrical current to flow!!

Attach the terminal wires of your galvanoscope to the end of each of the strips. Holding the metal strips by their peg-handles, reinsert them into your mouth. Is it possible to record any electrical current?

**Experiment #3 Volta and the Voltaic Pile**

Tell the students about the research of Count Alessandro Giuseppe Volta and his work with Luigi Galvani in determining why a dead frogs leg should twitch when lying between two pieces of metal. Galvani, being a biologist, thought that a current of electricity had been produced by the frog!

Volta, being a physicist, thought otherwise. He was sure that the electrical current had been produced by the reaction of the metals and the liquid contained in the frog. In 1800, he set out to prove his theory.

Experiment #3 - continued

Volta made a pile of zinc and silver discs, each separated by a piece of cloth previously soaked in brine (salty water). Testing it with Galvani's invention....the galvanoscope...he was able to prove that the pile did indeed produce an electrical current. His theory had been proven as fact. This "voltaic pile" became the first ever "battery". The word battery means "a group of things working together".

Students can reconstruct the voltaic pile by obtaining a like size coins of two different metal, or alternatively, a number of zinc and copper discs. Fold some blotting paper or paper towels into pads which are slightly smaller than the coins or disc. Immerse the pads in a solution of salt water. Remove and place one of the discs/coins of one metal under the damp (not wet!) pad and a disc/coin of the second metal above the pad. Add another pad and repeat the process. Continue until all discs/coins are used up.

Hold the "voltaic pile" firmly between thumb and forefinger. Have a second person apply the ends of the terminal wires of the galvanoscope to the top and bottom of the pile and observe the results. Make sure that when handling the terminal wires, that you do not cause a "short", i.e. hold them with a wooden clothes peg insulator. Also try to prevent salt water from trickling over the edges of the coins, for this could lessen the effect..

**Day 2:**

Experiment #4 **An Electric Lemon!**

Obtain a good sized, juicy lemon. Roll around in the palms of your hand to distribute the juices. Clean the strips of zinc and copper used in the "mouth test". Insert them into the side of the lemon, leaving a gap between the two metals. Attach the terminal wires of your galvanoscope to each of the strips with the clothes pegs. Does the 'scope record any electrical current?

Repeat the experiment using other fruit and vegetables, such as a banana and potato. Record your results.

Experiment #5 **Making a Simple Voltaic Cell**

Obtain a jam/preserve jar. Fill three-quarters full with (preferably) dilute sulphuric acid. *If this is not possible, then the experiment can be conducted with a strong solution of citric acid ...........citric acid crystals can be purchased from the local grocer.*

Clean and then attached your zinc and copper strips to a block of wood with small nails, leaving about 4 cm of the strips protruding above the wooden block. The piece of wood should bridge the top of the jar and allow the metal strips to hang, unobstructed, in the acid solution.

Experiment #5 - continued

Hydrogen bubbles will begin to form around the zinc element. The cell will cease to function once the zinc element is covered with bubbles. If you are using dilute sulphuric acid, a few crystals of potassium dichromate added to the solution will remove the gases.

If using citric acid and/or vinegar, you can safely take the elements out and wipe them clean before replacing them in the liquid once again.

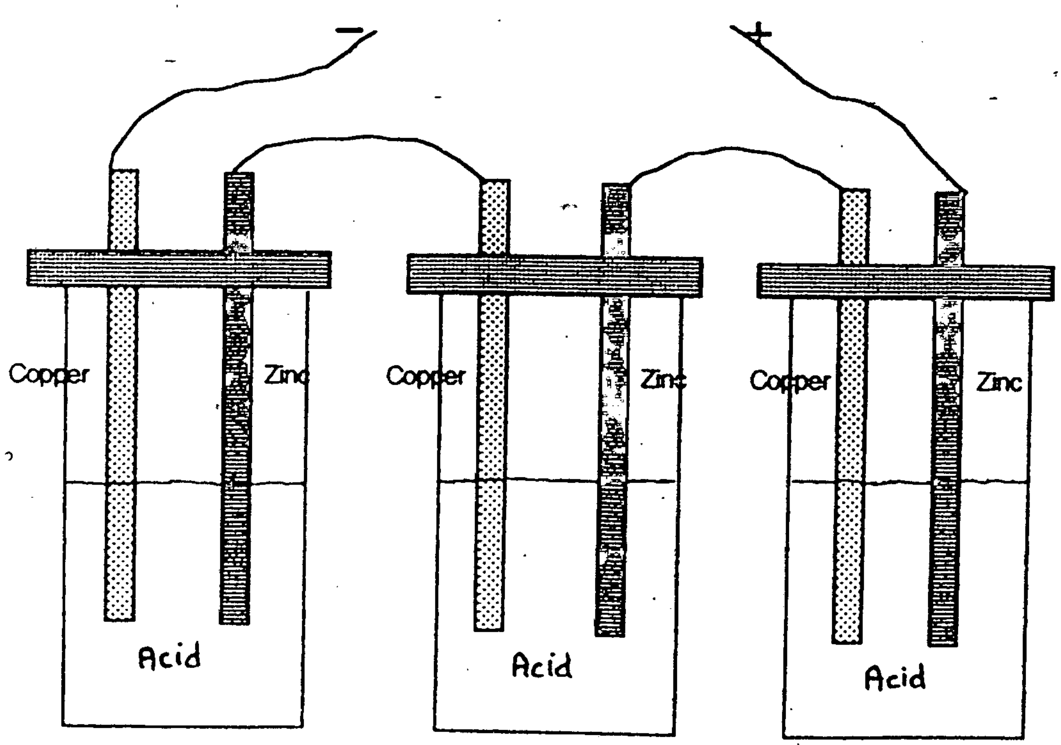
Remember to remove the elements when you have finished your experiment, otherwise the acid will slowly corrode the metal elements.

**Day 3:**

Experiment #6 **A Series of Voltaic Cells**

Make at least three Voltaic cells similar to the one in the previous experiment. Connect them together as per the diagram below, using crocodile clips. When the cells are connected in a "series", the total voltage is the sum of the voltages of the three (or more cells).

Connect the two lead wires to your galvanoscope.



**Day 4:**

Experiment #7 **Light and Heat**

Using a series of voltaic cells as a power source, conduct the following experiment to show how we are able to obtain both light and heat from electricity.

Obtain a small bottle and cork. Make two small holes through the cork and push two strands of bell wire through the holes, having first removed any insulation. Join the ends of the two wires with a very thin piece of fuse wire. This will serve as a very crude model of an electric light filament. Insert the filament firmly into the neck of the bottle.

Now connect one of the wires leading from the "electric lamp", to your voltaic battery. Do not connect the second wire. Instead, use this as your "switch" by connecting to the battery for a few moments. With care, it should be possible to light up the lamp several times before the filament is consumed.

Draw the students attention to the similarity of the filament and the filaments used in a toaster or on an electric fire *(have one or the other to hand).* As well as obtaining light from electricity, we are also able to obtain heat.

**Day 5:**

Experiment #8 **The Motor Effect**

The final experiments will be a foreshadowing of work to be undertaken in Grades Seven and Eight.

Firstly, make a larger Galvanoscope, using a larger compass and significantly increase the number of coils surrounding the compass.

Connect the two terminal wires to your voltaic battery*(add 2 more cells for greater potential voltage)* and note the result.

This simple experiment shows us that there is a relationship between electricity and magnetism. This was first discovered by Christian Oersted in 1820, some twenty years after Volta invented the battery. Oersted's discovery was purely accidental, for he was actually showing students in the university that there wasn't any connection between the two! However, during the course of the demonstration and without being aware, he moved the compass into the wrong position. When he then switched-on the electric current, the compass reacted just as we have seen today. Oersted was of course amazed!

Oersted conducted many experiments researching the magnetic effect of an electric current.

Experiment #9 **The Electromagnet**

It was left to American Joseph Henry of the Smithsonian Institute, along with Englishman William Sturgeon to use Oersted's discoveries to invent the electromagnet which was to have immense practical benefit for the emerging industrialised world.

Obtain a good length of insulated bell wire and begin wrapping it around a 13 - 15 cm nail. Leave about 30 cm of wire hanging loose at the beginning of the coil. Wrap the wire tightly around the nail from top to bottom and vice versa, finally leaving about 30 cm hanging loose. Secure the wire with tape so that it doesn't unwind.

Remove about 5 cm of insulation from the ends of the loose wires. Attach one to the positive pole of your battery and the other hold in your free hand ready to make a temporary connection with the negative pole.

Hold the wire-wrapped nail.....the electromagnet....over a small pile of iron filing or very small nails and make a connection with the loose wire and the negative pole of the battery.

If there is enough charge, then the iron filings or small nails will immediately jump to the end of your electromagnet. Break the connection with the battery and the filings or nails will fall off.

The electrical current has in fact "magnetised" the nail...that is, it has turned the nail into a magnet!! However, once the current is switched off, the magnetic force is removed and the nail returns to normal once again!

If your battery is not powerful enough, maybe it is time to "cheat" and use a manufacture battery....but it would be better if this could be avoided.

What tremendous potential such an invention had and in fact still has. Can any student tell where an electromagnet might be used?

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## Conclusion:

This effectively brings this physics morning lesson block to its conclusion.

Future studies in Grade Seven will look more closely at
the relationship of magnetism and electricity.
This will eventually lead to the Simple Electric Motor.

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## Equipment Required

### Week Three - Current Electricity

**Day 1**

Matchboxes (1 per student)
Wooden boards (1 x 10 cm x 10 cm)
Insulated copper bell wire (large coil)
Box of thumb tacks/drawing pins
Button compasses (1 per student)
Glue (quick drying)
Copper strips (electrodes) (1 per student)
Zinc strips (electrodes) (1 per student)
Wooden/plastic clothes pegs
Copper discs (10)
Zinc discs (10)
Filter or Blotting paper (paper towel)
Salt
Water
Bowl

**Day 2**

All the above, plus:
Lemons/Apples/Bananas/Potatoes
Preserve/jam jars (6)
Blocks of wood (6 x 2 cm x 2 cm x 12 cm)
Small nails/tacks
Small hammer
Dilute sulphuric acid and
Potassium dichromate or
White vinegar (1 liter)
Citric acid (1 liter) or crystals sufficient to make 1 liter

**Day 3**

All the above, plus:
Crocodile/alligator clips (2 dozen)

**Day 4**

All the above, plus:
Bottles or test tubes (1 per student)
Corks (1 per student)
Cork hole punch
Fine fuse wire
Electric toaster

**Day 5**

All the above, plus:
Large compass
Wooden board (15 cm x 15 cm)
Cardboard
Large nail
Iron filings
6 volt battery

## STUDENT WORK

A considerable amount of time will have been spent in the conducting of experiments, observation, discussion and the arrival at conclusions. This, the first of the physics Morning Lessons will have led us into an entirely new way of recording what has been heard, seen and hopefully learnt. I therefore set out a format for my students to follow when writing-up their individual records of the morning's work. An example of this is shown below and it should only be viewed as an indication of how students could record their observations.

**Experiment** *(Write in the number and name of the experiment here)*

**Aim(s):**

*Here students will briefly describe what the "aim(s)" of this experiment are. The teacher will, in all probability, write this on the chalkboard for the students to copy down.*

**Materials and Equipment:**

*Here students will make a list of all the items required to conduct this experiment. They will take care in ensuring that nothing is forgotten.*

**Method and Observations:**

*Here students will describe (as briefly as possible) how the experiment was conducted and any observations they were able to make.*

**Results and Conclusions:**

*If an experiment was successful, students will have a possible answer to the question previously described in "Aims".*

*This should be written this down in a short, clearly understood paragraph.*

**Teacher's Comments:**

# POEMS AND VERSES

## O ROMA NOBILIS

O ROMA NOBILIS
ORBIS ET DOMINA
OMNIUM URBIUM,
EXCELLENTISSIMA.
SALUTEM DICIMUS
TIBI PER OMNIA!
TE BENEDICIMUS,
SALVE PER SAECULA

## ONOBLEROME

ONOBLEROME,
THE CIRCLE AND MISTRESS
OF ALL CITIES,
MOST EXCELLENT.
SALUTES WE CALL
TO YOU AMONG ALL;
TO YOU WE GIVE BLESSING,
SALUTES THROUGH THE YEAR.

## From HORATIUS

(Thomas Babington Macaulay, Lord Macaulay)

Alone stood brave Horatius,
But constant still in mind;
Thrice thirty thousand foes before,
And the broad flood behind.
"Down with him!" cried false Sextus,
With a smile on his pale face.
"Now yield thee," cried Lars Porsena,
"Now yield thee to our grace."

Round turned he, as not deigning
Those craven ranks to see;
Nought spake he to Lars Porsena
To Sextus nought spake he;
But he saw on Palatinus
The white porch of his home;
And he spake to the noble river
That rolls by the towers of Rome.

"Oh, Tiber! father Tiber!
To whom the Romans pray,
A Roman's life, a Roman's arms,
Take thou in charge this day!"
So he spake, and speaking sheathed
The good sword by his side,
And with his harness on his back,
Plunged headlong in the tide.

No sound of joy or sorrow
Was heard from either bank;
But friends and foes in dumb surprise,
With parted lips and straining eyes,
Stood gazing where he sank;
And when above the surges
They saw his crest appear,
All Rome sent forth a rapturous cry,
And even the ranks of Tuscany
Could scarce forbear to cheer.

But fiercely ran the current,
Swollen high by months of rain:
And fast his blood was flowing;
And he was sore in pain,
And heavy with his armour,
And spent with changing blows:
And oft they thought him sinking,
But still again he rose.

Never, I ween, did swimmer,
In such an evil case,
Struggle through such a raging flood
Safe to the landing place:
But his limbs were borne up bravely
By the brave heart within,
And our good father Tiber
Bare bravely up his chin.

And now he feels the bottom;
Now on dry earth he stands;
Now round him throng the Fathers
To press his gory hands;
And now, with shouts and clapping,
And noise of weeping loud,
He enters through the River Gate,
Borne by the joyous crowd.

They gave him of the corn-land,
That was of public right,
As much as two strong oxen
Could plough from morn till night;
And they made a molten image,
And set it up on high,
And there it stands unto this day
To witness if I lie.

It stands in the Comitium,
Plain for all folk to see;
Horatius in his harness,
Halting upon one knee:
And underneath is written,
In letters all of gold,
How valiantly he kept the bridge
In the brave days of old.

## THE RIDER AT THE GATE

(John Masefield)

A windy night was blowing on Rome,
The cressets guttered on Caesar's home,
The fish-boats, moored at the bridge, were breaking
The rush of the river to yellow foam.

The hinges whined to the shutters shaking;
When clip-clop-clip came a horse-hoof raking
The stones of the road at Caesar's gate;
The spear-butts jarred at the guard's awaking.

"Who goes there?" said the guard at the gate.
"What is the news, that you ride so late?"
"News most pressing, that must be spoken
To Caesar alone, and that cannot wait."

The Caesar sleeps; you must show a token
That the news suffice that he be awoken.
What is the news, and whence do you come?
For no light cause may his sleep be broken!"

"Out of the dark of the sands I come,
From the dark of death, with news from Rome.
A word so fell, that it must be uttered
Though it strike the soul of the Caesar dumb."

Caesar turned in his bed and muttered,
With a struggle for breath the lamp-flame guttered;
Calpurnia heard her husband moan;
"The house is falling,
The beaten men come into their own."

"Speak your word," said the guard at the gate;
"Yes, but bear it to Caesar straight,
Say, 'Your murderer's knives are honing,
Your killer's gang is lying in wait.'

Out of the wind that is blowing and moaning,
Through the city palace and the country loaning,
I cry: 'For the world's sake, Caesar, beware,
And take this warning as my atoning.

Beware of the Court, of the palace stair,
Of the downcast friend who speaks so fair,
Keep from the Senate, for Death is going
On many men's feet to meet you there.

I, who am dead, have ways of knowing
Of the crop of death that the quick are sowing.
I, who was Pompey, cry it aloud
From the dark of death, from the wind blowing.

I, who was Pompey, once so proud,
Now I lie in the sand without a shroud;
I cry to Caesar out of my paid:
"Caesar, beware, your death is vowed."

The light grew grey on the window-pane,
The windcocks swung in a burst of rain,
The windows of Caesar flung unshuttered,
The horse-hoofs died into wind again.

Caesar turned in his bed and muttered,
With a struggle for breath the lamp-flame guttered;
Calpurnia heard her husband moan:
"The house is falling,
The beaten men come into their own."

## From: JULIUS CAESAR - Act 3; Scene 2.

(William Shakespeare)

Marcus Antonius:

Friends, Romans, countrymen, lend me your ears;
I come to bury Caesar, not to praise him.
The evil that men do lives after them,
The good is oft interred with their bones;
So let it be with Caesar. The noble Brutus
Hath told you Caesar was ambitious;
If it were so, it was a grievous fault,
And grievously hath Caesar answer'd it.
Here, under leave of Brutus and the rest,
For Brutus is an honourable man;
So are they all, all honourable men;
Come I to speak in Caesar's funeral.
He was my friend, faithful and just to me:
But Brutus says he was ambitious;
And Brutus is an honourable man.
He hath brought many captives home to Rome,
Whose ransoms did the general coffers fill:
Did this in Caesar seem ambitious?
When that the poor have cried, Caesar hath wept;
Ambition should be made of sterner stuff:
Yet Brutus says he was ambitious;
And Brutus is an honourable man.
You all did see that on the Lupercal
I thrice presented him a kingly crown,
Which he did thrice refuse: was this ambition?
Yet Brutus says he was ambitious;
And, sure, he is an honourable man.
I speak not to disprove what Brutus spoke,
But here I am to speak what I do know.
You all did love him once, not without cause:
What cause withholds you then to mourn for him?
O judgment! thou art fled to brutish beats,
And men have lost their reason. Bear with me;
My heart is in the coffin there with Caesar,
And I must pause until it come back to me.

## From JULIUS CAESAR - Act 5: Scene 5.
(William Shakespeare)

Marcus Antonius:

This was the noblest Roman of them all:
All the conspirators, save only he,
Did that they did in envy of great Caesar;
He only, in a general honest thought
And common good to all, made one of them.
His life was gentle, and the elements
So mixed in him that Nature might stand up
And say to all the world: "This was a man!"

*****

The following poems could be used in conjunction with the Physics Lesson:

## THE WORLD CREATING WORD
(Clifford Monks)

In the beginning was the Word;
The source of all that now is heard.
When from each thing that is around,
We conjure forth its own true sound.

Each thing a letter of that Script;
That God the Word has 'round us writ.
An alphabet which sounding brings
Orchestral Oneness to all things.

## SONG FOR ST. CECILIA'S DAY
(Thomas Dryden)

From Harmony, from heavenly Harmony
This universal frame began:
When Nature underneath a heap
Of jarring atoms lay;
And could not heave her head,
The tuneful voice was heard from high,
Arise, ye more than dead!
Then cold, and hot, and mist, and dry
In order to their stations leap,
And MUSIC's power obey.

From Harmony, from heavenly Harmony
This universal frame began:
From Harmony to harmony through
All the compass of the notes it ran;
The diapason closing full in MAN.

## GENESIS
(Chapter 1, Verses 1 - 5)

In the beginning God created the Heaven and the Earth
And the Earth was without form and void;
and darkness was upon the face of the deep;
And the Spirit of God moved upon the face of the waters;
And God said, "Let there be light" and there was light.
And God saw the light that it was good;
and God divided the light from the darkness.
And God called the light Day and the darkness he called Night.
And the evening and the morning were the first day.

## TO SEE THE LIGHT
(Wolfgang v. Goethe)

If the eye were not of the Sun,
How could it see the light?
If God's own power were not in us;
How could we delight in the Divine?

## THE SUN
(William Shakespeare)
From: Titus Andronicus, Act 2, Sc. 1.

As when the golden sun salutes the morn,
And, having gilt the ocean with his beams,
Gallops the zodiac in his glistering coach,
And overlooks the highest-peering hills.

## MOONLIGHT
(William Shakespeare)
From: The Merchant of Venice, Act 5, Sc. 1.

How sweet the moonlight sleeps upon this bank!
Here we sit and let the sounds of music
Creep in our ears; soft stillness and the night
Becomes the touches of sweet harmony.

## ORDER

(William Shakespeare)
From: Troilus and Cressida, Act 1, Sc.3.

The heavens themselves, the planets, and this centre
Observe degree, priority, and place,
Insisture, course, proportion, season, form,
Office, and custom, in all line of order....

## From THE RIME OF THE ANCIENT MARINER

(Samuel Taylor Coleridge)

### Part the First

It is an ancient mariner
And he stoppeth one of three.
"By thy long grey beard and glittering eye,
Now wherefore stopp'st thou me?

The Bridegroom's doors are opened wide,
And I am next of kin;
The guests are met, the feast is et:
Mayst hear the merry din."

He holds him with his skinny hand,
"There was a ship," quoth he.
"Hold off! unhand me, grey-beard loon!"
Eftsoon his hand dropt he.

He holds him with his glittering eye -
The Wedding-Guest stood still,
And listens like a three years' child:
The Mariner hath his will.

The Wedding-Guest sat on a stone:
He cannot choose but hear;
And thus spake on that ancient man,
The bright-eyed Mariner.

"The ship was cheered, the harbour cleared,
Merrily did we drop
Below the kirk, below the hill,
Below the lighthouse top.

The Sun came up upon the left,
Out of the sea came he!
And he shone bright, and on the right
Went down into the sea.

Higher and higher every day,
Till over the mast at noon - "
The Wedding-Guest here beat his breast,
For he heard the loud bassoon.

The bride hath paced into the hall,
Red as a rose is she;
Nodding their heads before her goes
The merry minstrelsy.

The Wedding-Guest he beat his breast,
Yet he cannot choose but hear;
And thus spake on that ancient man,
The bright-eyed Mariner.

"And now the STORM-BLAST came, and he
Was tyrannous and strong:
He struck with his o'ertaking wings,
And chased us south along.

With sloping masts and dipping prow,
As who pursued with yell and blow
Still treads the shadow of his foe,
And forward bends his head,
The ship drove fast, loud roared the blast,
And southward aye we fled.

And now there came both mist and snow,
And it grew wondrous cold:
And ice, mast-high, came floating by,
As green as emerald.

And through the drifts the snowy clifts
Did send a dismal sheen:
Nor shapes of men nor beasts we ken -
The ice was all between.

The ice was here, the ice was there,
The ice was all around:
It cracked and growled, and roared and howled,
Like noises in a swound!

At length did cross an Albatross,
Thorough the fog it came;
As if it had been a Christian soul,
We hailed it in God's name.

It ate the food it ne'er had eat,
And round and round it flew.
The ice did split with a thunder-fit;
The helmsman steered us through!

And a good south wind sprung up behind;
The Albatross did follow,
And every day, for food or play,
Came to the mariner's hollo!

In mist or cloud, on mast or shroud,
It perched for vespers nine;
Whiles all the night, through fog-smoke white,
Glimmered the white Moon-shine."

"God save thee, ancient Mariner!
From the fiends that plague thee thus! -
Why look'st thou so?" - "With my cross-bow
I shot the ALBATROSS."

With 7 parts totalling some 144 verses, it would be a real challenge for a class to learn the above poem in it's entirety. However, I had my class learn Parts One and Two together. Thereafter, it was a weekly task for half the group (on a week-on/week-off basis) to learn a verse each as homework for the following week. In this manner, the "class" learnt almost the entire poem during the course of one term.

## SONNET 125
(William Shakespeare)

When, in disgrace with fortune and men's eyes,
I all alone beweep my outcast state,
And trouble deaf heaven with my bootless cries,
And look upon myself and curse my fate,
Wishing me like to one more rich in hope,
Featur'd like him, like him with friends possess'd,
Desiring this man's art, and that man's scope,
With what I most enjoy contented least;
Yet in these thoughts myself almost despising,
Haply I think on thee, and then my state,
Like to the lark a break of day arising
From sullen earth, sings hymns at heaven's gate;
For thy sweet love remember'd, such wealth brings,
That then I scorn to change my state with kings.

## SONNET 119
(William Shakespeare)

Like as the waves make towards the pebbled shore,
So do our minutes hasten to their end;
Each changing place with that which goes before,
In sequent toil all forwards do contend.
Nativity, once in the main of light,
Crawls to maturity, wherewith being crown'd,
Crooked eclipses 'gainst his glory fight,
And Time that gave doth now his gift confound.
Time doth transfix the flourish set on youth,
And delves the parallels in beauty's brow,
Feeds on the rarities of nature's truth,
And nothing stands but for his scythe to mow.

And yet to times in hope my verse shall stand,
Praising thy worth, despite his cruel hand.

(These Sonnets are numbered according to the order set forth in Sir Denys Bray in his book "Shakespeare's Sonnet Sequence" [now out of print])

*****

Although the focus of this collection of material is biased in favour of works of outstanding merit, it should not be presumed that material always needs to be of the same standard, nor always of a "serious" nature! The following light-hearted poem by Marriott Edgar (1880 - 1951) appeals to the sense of humour of the Grade Six student, especially if recited with an English "North Country" accent!

## THE LION AND ALBERT
(Marriott Edgar)

There's a famous seaside place called Blackpool,
That's noted for fresh air and fun,
And Mr and Mrs Ramsbottom
Went there with young Albert, their son.

A grand little lad was young Albert,
All dressed in his best; quite a swell
With a stick with an 'orse's 'ead 'andle,
The finest that Woolworth's could sell.

They didn't think much to the Ocean:
The waves, they were fiddlin' and small,
There was no wrecks and nobody drownded,
Fact, nothing to laugh at at all.

So, seeking for further amusement,
They paid and went into the Zoo,
Where they'd Lions and Tigers and Camels,
And old ale and sandwiches too.

There was one great big Lion called Wallace;
His nose was all covered with scars -
He lay in a somnolent posture
With the side of his face on the bars.

Now Albert had heard about Lions,
How they was ferocious and wild -
To see Wallace lying so peaceful,
Well, it didn't seem right to the child.

So straightway the brave little feller,
Not showing a morsel of fear,
Took his stick with its 'orse's 'ead 'andle
And pushed it in Wallace's ear.

You could see that the Lion didn't like it,
For giving a kind of a roll,
He pulled Albert inside the cage with 'im,
And swallowed the little lad 'ole.

Then Pa, who had seen the occurrence,
And didn't know what to do next,
Said "Mother! Yon Lion's 'et Albert,"
And Mother said "Well, I am vexed!"

Then Mr and Mrs Ramsbottom -
Quite rightly, when all's said and done -
Complained to the Animal Keeper
That the Lion had eaten their son.

The keeper was quite nice about it;
He said "What a nasty mishap.
Are you sure that it's *your* boy he's eaten?"
Pa said "Am I sure? There's his cap!"

The manager had to be sent for.
He came and he said "What's to do?"
Pa said "Yon Lion's 'et Albert,
And 'im in his Sunday clothes, too!"

Then Mother said, "Right's right, young feller;
I think it's a shame and a sin
For a lion to go and eat Albert,
And after we've paid to come in."

The manager wanted no trouble,
He took out his purse right away,
Saying "How much to settle the matter?"
And Pa said "What do you usually pay?"

But Mother had turned a bit awkward
When she thought where her Albert had gone.
She said "No! someone's got to be summonsed" -
So that was decided upon.

Then off they went to the P'lice Station,
In front of the Magistrate chap;
They told 'im what happened to Albert,
And proved it by showing his cap.

The Magistrate gave his opinion
That no one was really to blame
And he said that he hoped the Ramsbottoms
Would have further sons to their name.

At that Mother got proper blazing,
"And thank you, sir, kindly," said she.
"What, waste all our lives raising children
To feed ruddy Lions? Not me!"

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# RECOMMENDED READING LIST

## AGE 12 - 14 and older

## (dependent on reading ability)

| | |
|---|---|
| EXPLORABOOK (Science) | John CASSIDY and the Exploratorium of San Francisco |
| Eagles Egg | Rosemary SUTCLIFFE |
| Blood Feud | ditto |
| Dragon Slayer | ditto |
| The High Deeds of Finn MacCool | ditto |
| The Eagle of the Ninth | ditto |
| Warrior Scarlet | ditto |
| Dawn Wind | ditto |
| Three Legions | ditto |
| The Silver Branch | ditto |
| The Lantern Bearers | ditto |
| The Mark of the Horse Lord | ditto |
| Frontier Wolf | ditto |
| The Shining Company | ditto |
| Flame Coloured Taffeta | ditto |
| The Trumpeter of Krakow | Eric P. KELLY |
| The Story of Mankind | Hendrik Van LOON |
| The Voyage of Doctor Dolittle | Hugh LOFTING |
| The Dark Frigate | Charles HAWES |
| Tales from Silver Lands | Charles FINGER |

| | |
|---|---|
| Shen of the Sea | Arthur CHRISMAN |
| Smokey the Cow Horse | Will JAMES |
| Gay-Neck: The Story of a Pigeon | Dhan MUKERJI |
| Hitty: The first Hundred Years | Rachel FIELD |
| The Cat Who Went To Heaven | Elizabeth COATSWORTH |
| Waterless Mountain | Laura ARMER |
| Young Fu of the Upper Yangtze | Elizabeth LEWIS |
| Invincible Louisa | Cornelia MEIGS |
| Dobry | Monica SHANNON |
| Caddie Woodlawn | Carol BRINK |
| Rosanna of the Amish | Joseph W. YODER |
| Underground to Canada | Barbara SMUCKER |
| The White Stag | Ian SEREDY |
| Thimble Summer | Elizabeth ENRIGHT |
| Daniel Boone | James DAUGHERTY |
| Call It Courage | Armstrong SPERRY |
| The Matchlock Gun | Walter EDMONDS |
| Adam of the Road | Elizabeth GRAY |
| A Handfull Of Thieves | Nina BALDWIN |
| Carrie's War | ditto |
| The Shining Stars (Legends of the Zodiac) | Ghislaine VAUTIER (Adapted: K. McLEISH) |
| Shiloh | Phyllis R. NAYLOR |
| Ice Fair | Hope SIMPSON |

| | |
|---|---|
| Black Fox of Lorne | Margeurite D'ANGELI |
| Many Waters | ditto |
| The Callow Pit Coffer | Kevin CORSLEY-HOLLAND |
| Journey From Peppermint Street | Meindert DE JONG |
| The House Of Sixty Fathers | ditto |
| Never Cry Wolf | Farley MOWAT |
| Sounder | William ARMSTRONG |
| Alice's Adventures in Wonderland | Lewis CARROLL |
| Tom Sawyer | Mark Twain |
| Huckleberry Finn | ditto |
| Nory Ryan's Children | Patricia REILLY GIFF |
| Lily's Crossing | ditto |
| The Court of the Stone Children | Eleanor CAMERON |
| The Endless Steppe | Esther HAUTZIG |
| Ella Enchanted | Gail CARSON LEVINE |
| Theatre Shoes | Noel STREATFIELD |
| Dancing Shoes | ditto |
| When Zachary Beaver Came To Town | Kimberley WILLIS HOLT |
| The Shakespeare Stealer | Gary BLACKWOOD |
| Tom Brown's Schooldays | Thomas Huges |
| Coral Island | R. M. BALLANTYNE |
| The Key To The Indian (Sequel to: The Indian In The Cupboard) | Lynne REID BANKS |
| A Gathering of Days: A New England Girl's Journal 1830 - 32 | Joan W. BLOS |

| | |
|---|---|
| Tuck Everlasting | Natalie BABBIT |
| Goody Hall | ditto |
| The Eyes of Amarylis | ditto |
| Knee Knock Rise | ditto |
| The Search For Delicious | ditto |
| I Though My Soul would Rise and Fly - The Story of Patsy, a Freed Girl - | Dear America Series |
| The Coal Miner's Bride - The Diary of Anetta Kaminska - | ditto |
| The Journal of William Thomas Emerson - A Revolutionary War Patriot - | ditto |
| The Picture of Freedom - The Diary of Clotee, a Slave Girl - | ditto |
| Tucket Adventures (series) | Gary PAULSEN |
| Hatchet (series) | ditto |
| The Voyage of the Frog | ditto |
| The Fourteenth Summer | ditto |
| Harris and Me | ditto |
| Nightjohn | ditto |
| The Car | ditto |
| Canyons | ditto |
| Tasting the Thunder | ditto |
| Ice Race | ditto |
| Dogsong | ditto |
| Foxman | ditto |
| The River | ditto |

| | |
|---|---|
| JIP: His Story | Katherine PATERSON |
| Come Sing, Jimmy Jo | ditto |
| Flip-flop Girl | ditto |
| The Great Gilly Hopkins | ditto |
| Lyddie | ditto |
| Park's Quest | ditto |
| Jacob Have I Loved | ditto |
| <u>Australian Publications (ap):</u> | |
| Playing Beatie Bow | Ruth PARK (ap) |
| Picnic At Hanging Rock | Joan LINDSAY (ap) |
| Over Sea, Under Stone | Susan COOPER (ap) |
| The Dark is Rising | ditto |
| Greenwatch | ditto |
| The Grey King | ditto |
| Silver On The Tree | ditto |
| Pagan's Crusade | Catherine JINKS (ap) |
| Pagan In Exile | ditto |
| Pagan's Vows | ditto |
| Billabong Series (14 titles) | Mary Grant BRUCE (ap) |
| The Book of Samuel | Ursula DUBOSARSKY (ap) |
| The True Story of Lilli Stubeck | James ALDRIDGE (ap) |
| Lady Dance (a story of the Middle Ages) | Jackie FRENCH (ap) |
| Walking the Boundaries | ditto |
| Beyond the Boundaries | ditto |

<u>My Story Series:</u>

| | |
|---|---|
| A Banner Bold - The Diary of Rosa Aarons - Ballarat Goldfields, 1854 - | Nadia WHEATLEY (ap) |
| Surviving Sydney Cove - The Diary of Elizabeth Harvey - Sydney, 1790 | Goldie ALEXANDER (ap) |
| The Tale of Two Families - The Diary of Jan Packard - Melbourne, 1974 | Jenny PAUSACKER (ap) |
| Plagues and Federation - The Diary of Kitty Barnes - The Rocks, Sydney, 1900 | Vashti FARRER (ap) |

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The availability of titles in this list may vary from country to country.

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# BIBLIOGRAPHY

## ROMAN HISTORY


1. Christianity as Mystical Fact - and the Mysteries of Antiquity — Rudolf Steiner
2. World History in the Light of Anthroposophy — Rudolf Steiner
3. The Great Initiates — Edouard Schure (out of print)
4. Roman Lives — Dorothy Harrer
5. Teaching History — Christoph Lindenberg
6. The Waldorf Approach to History — Werner Glas (o.o.p.)


## MATHEMATICS and GEOMETRY


1. Teaching Mathematics in Rudolf Steiner Schools — Ron. Jarman
2. The Waldorf Approach to Arithmetic — Hermann v. Baravalle
   we have: Teaching of Arith & W. School plan
3. Teaching Mathematics to Age 14 — Roy Wilkinson
4. Maths Lesson for Elementary Grades — Dorothy Harrer
5. Algebra — Amos Franceschelli
6. `Mensuration — ditto
7. Famous Mathematicians — Frances Benson Stonaker
8. Geometric Drawing and the Waldorf School Plan — Hermann v. Baravalle
9. Geometry and the Imagination — A. Renwick Sheen
   we have by David [illegible]
10. String, Straightedge, and Shadow - The Story of Geometry - — Julia E. Diggins (o.o.p.)
11. Sacred Geometry — Robert Lawlor
12. A Path of Discovery - Vol. 5/Gd. 5 — Eric K. Fairman

## PHYSICS

| | | |
|---|---|---|
| 1. | The Kingdom of Childhood | Rudolf Steiner |
| 2. | Light Course | Rudolf Steiner |
| 3. | Warmth Course | Rudolf Steiner |
| 4. | Theory of Color | Wolfgang von Goethe |
| 5. | What is Color? | Michael Wilson |
| 6. | Color and Healing | Gladys Mayer |
| 7. | The Individuality of Color | Elizabeth Koch<br>Gerard Wagner |
| 8. | The Temperaments and the Arts | Magda Lissau |
| 9. | Introduction to Physics in the Waldorf School | Hermann von Baravalle |
| 10. | A Phenomena Based Physics (6th Grade) | Manfred von Mackensen |
| 11. | Goethean Science in the Waldorf Curriculum<br>- a Conference Report 1978 | Manfred von Mackensen |
| 12. | Man or Matter | Ernst Lehrs. Ph.D |
| 13. | Teaching Physics | Roy Wilkinson |
| 14. | Sensible Physics Teaching | Michael D'Aleo<br>Stephen Edelglass |
| 15. | Physics is Fun | Roberto Trostli |
| 16. | Curriculum for Waldorf Schools | E.A. Karl Stockmeyer |
| 17. | SCIENCE in Education<br>- a collection of 'Child and Man' articles<br>we have Vol. I | Ed: Brien Masters (SWSF) |
| 18. | Waldorf Science Newsletters | Ed: David Mitchell and<br>John Petering (AWSNA) |
| 19. | Voices of the First Day - Awakening in<br>the Aboriginal Dreamtime | Robert Lawlor |

| | | |
|---|---|---|
| 20. | Blackfoot Physics | F. David Peat |
| 21. | The Sacred Balance - Rediscovering our place in Nature | David Suzuki |
| 22. | Benjamin Franklin - Man of Science | Irmengarde Eberle |
| 23. | Safe and Simple Electrical Experiments | Rudolf F. Graf |
| 24. | The Exploratorium Science Snackbook | Paul Doherty and Donald Rathjen |
| 25. | Who's who in: Science and Technology - a guide to famous scientists - | Bob Fowke |
| 26. | Science in Their Eyes | J.M. Brice |
| 27. | Famous Physicists | A.L. Mann and A.C. Vivian |
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# COMMON FRACTIONS; DECIMAL FRACTIONS AND PERCENTAGES QUIZ

**Name** ______________________________

Please convert the following Common Fractions into Decimal Fractions. Show all your written calculations:

1/2

=

3/7

=

9/12

=

Please convert the following Decimal Fractions into Percentages. Show all your written calculations:

0.24

=

0.5

=

0.05

=

1.25

=

Please convert the following Common Fractions into Percentages. Show all your written calculations:

2/5

=

3/10

=

5/8

=

Please convert the following Percentages into Decimal Fractions. Show all your written calculations:

14% =

25% =

55% =

98% =

Please convert the following Percentages into *Simple* Common Fractions. Show all your written calculations:

40% =

4% =

1% =

Please solve as much as you can of the following challenging problem:

Show 2/5 of 600 as a:

Decimal Fraction of 600 =

Percentage (%) of 600 =

Write the amount which comprises two-fifths of Six Hundred =

What is the remaining amount? =

What does this remaining amount represent as a % of the original 600? = %

**********

# FINAL MATHS QUIZ - Part 1

Name:__________________________

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**Show ALL the "workings" used in the solving of all the following problems.**

1. A cake stall holder sold 325 cakes, each costing .75c. How much money did the stall holder raise?

2. Thirtyone students raised $2418.62 for their favourite charity. If each one had raised EXACTLY the same amount, what would that amount have been?

3. 12% of the 50 customers who bought jewellery at the School Fair were parents. How many parents bought jewellery?

4. What is 109.22 x 18 plus 356.68 minus 122.64? Divide your answer by 4.

5. Change 0.22 into a percentage = %

6. Add together 2/8 and 0.25 and 50%, to make = %

7. Find the Interest payable on $3,654 at 14% for 2 years.
(Remember PRT/100=I)

8. Find the missing numbers:

1, 3, 6, 10, ____, ____, 28, ____.

9. Find the average age. 1 boy is 12. 2 girls are 11 and another boy is 9. What is the average age of the group?

10. A small paddock measures 52 m in width and 74m in length. What is the area of the paddock in $m^2$?

# FINAL MATHS QUIZ - Part 2

Name:______________________________

1. How many lines of symmetry do each of the following shapes have? Write your answer in the centre of each shape.

2. Name the following angles (right-angle; obtuse; acute or reflex):

3. Solve the following:

$a + 4 = 5$ What is 'a'? ________

$b - 100 = 1$ What is 'b'? ________

$3c = 6$ What is 'c'? ________

$d/4 = 6$ What is 'd'? ________

$6a + 3a + 10a =$ ________

4. Write the following as an algebraic equation:

   Your friend thinks of a number. She adds 9 and tells you that the answer is 12. What number did she first think of?

5. Find the value of the following, if a = 4 and b = 2:

   $6a - 3b =$

6. Find the value of the following, if a = 6, b = 4; c = 8 and d = 2

   (i) $ab + bc + 2 =$

   (ii) $b^2 + c^2 - a^2 =$

7. Solve: $3g + 1 = 10$. What is the value of 'g'? Show ALL the "workings" used in solving this problem.

8. Solve: $6y - 13 = 11$. What is the value of 'y'? Show ALL the "workings" used in solving this problem.

9. Solve: $6a + 12 = 3a + 18$. What is the value of 'a'? Show ALL the "workings" used in solving this problem.

o

10. Solve: $14p - 13 = 5p + 5$. What is the value of 'y'? Show ALL the "workings" used in solving this problem.

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## PHYSICS QUIZ #1

**Name:** ______________________

## SOUND

1. We are able to RECOGNISE different sounds and IDENTIFY their source. Give examples:

| | RECOGNISE | IDENTIFY |
|---|---|---|
| Example | Tinkle | Bell |
| 1. | | |
| 2. | | |
| 3. | | |
| 4. | | |
| 5. | | |

2. Briefly describe how the PITCH of a tone is affected by the column of air in a tube:

3. Briefly describe a practical experiment which demonstrates how sound travels through AIR or through a SOLID:

## LIGHT

4. Is Light VISIBLE or INVISIBLE? Briefly describe how you could prove which is correct:

5. If prismatic colours arise through the interaction of LIGHT and DARKNESS, which would be correct (circle the answer which you believe to be right):

WHITE creates: **WARM** or **COLD** colours

DARKNESS creates: **WARM** or **COLD** colours

6. Name the Secondary colours for the following Primary colours:

| Primary | Secondary |
|---|---|
| RED | |
| YELLOW | |
| BLUE | |

## HEAT

7. Draw and colour a small candle and flame. **Label** the different areas, such as the Warmest, the Brightest, etc.,.

8. Rearrange the following metals in their order of CONDUCTIVITY, from "highest" to "lowest":

STEEL - BRASS - COPPER - ALUMINIUM - NICKEL - IRON

1. 2. 3.

4. 5. 6.

9. Describe a simple experiment which can prove that AIR expands when heated:

# FINAL PHYSICS QUIZ

**Name:** ______________________________

## GENERAL KNOWLEDGE

1. Briefly describe a practical experiment which demonstrates how sound travels through AIR or through a SOLID:

2. Is Light VISIBLE or INVISIBLE? Briefly describe how you could prove which is correct:

3. Name the Secondary colours for the following Primary colours:

| **Primary** | **Secondary** |
|---|---|
| RED | ______________ |
| YELLOW | ______________ |
| BLUE | ______________ |

4. Describe a simple experiment which can prove that AIR expands when heated:

## MAGNETISM

5. Describe how to maker a Simple Floating Compass:

6. Define the 'Law of Magnetism'- is it *(put a 'x' one box only)*:

a. Like poles attract and unlike poles attract

b. Like poles attract and unlike poles repel

c. Like poles repel and unlike poles repel

d. Like poles repel and unlike poles attract

/4

## STATIC ELECTRICITY

7. What are the following used for when working with electrostatics?:

a. Electroscope -

b. Electrophorus -

c. Leyden Jar -

8. Define 'Coulomb's Law:

## CURRENT ELECTRICITY

9. Draw 3 Voltaic cells and connect them to make a 3 cell battery. Label each part of the diagram. Use colour and +/- signs to make your illustration more understandable:

(**Useful words:** electrode; electrical lead; terminal; crocodile clips, citric acid; copper; zinc)

10. Hans Christian Oersted made a discovery which led to an Englishman William Sturgeon and American Joseph Henry inventing something which utilised both magnetism and electricity. Their invention was to have an enormous impact on the development of the industrialised world. What was their invention?

11. Briefly describe how to make what you have written as your answer to the last question. Draw a simple diagram to illustrate your written work:

## SEMESTER ONE - TERM ONE

| Duration | Studies | Contents | Objectives/Outcomes |
|---|---|---|---|
| 26 hrs | Mathematics - Decimals | Decimal fractions (Revision)<br>Charts/Graphs (Revision)<br>Percentages (Introduction)<br><br>Roman numerals | To develop:<br>* a knowledge and ability to communicate in mathematical language<br>* skills in computation and problem solving, with practical applications |
| 40 hrs | History - Ancient Rome:<br>Aeneas<br>Founding of Rome<br>Romulus and Remus<br>The Seven Kings | Stories (Aeneid)<br>Composition development.<br>Grammar - conditional and participle phrases and types of clauses.<br>Direct/indirect speech.<br>Latin - "O Roma Nobilis"<br>"Vergil's "Aeneid" (lines from) | To develop:<br>* a sympathy and tolerance for cultures other than their own.<br>* knowledge of human society and culture.<br>* communication (language skills: oral/written).<br>* social skills (group work and and cooperation, etc.,).<br>* map making skills |
| 36 hrs | Environmental Science - Geology - Sedimentary<br>Igneous<br>Metamorphic | Gain knowledge of the many kinds of soils, rocks, crystals and gems by listening, looking at pictures and studying rocks.<br><br>Field trips to areas of geological interest | To develop:<br>* knowledge of the mineral world - in the immediate environment and in the world's landscapes<br>* an awareness of our dependence on minerals<br>* a sense of wonder for this hidden realm |

# SEMESTER ONE - TERM TWO

| on | Studies | Contents | Objectives/Outcomes |
|---|---|---|---|
| 8 hrs | **Mathematics -**<br>Percentages .<br>Interest<br>Discount | Concept and calculations.<br>Commercial arithmetic<br>Equivalent %'s/fractions/decimals<br>Respective advantages of %'s,<br>Fractions and decimals | To develop:<br>* a knowledge and ability to communicate in mathematical language<br>* skills in computation and problem solving, with practical applications |
| hrs | **Science and Technology -**<br>Physics - Sound<br>Light<br>Heat | Through a wide variety of practical experiments, students observe and investigate cause and effect in the realm of acoustics, light and warmth.<br>To have fun with science | To develop:<br>* through observation, the ability to set aims, record results, interpret data and draw conclusions<br>* a sense of wonder for the secrets that lie behind the physical world |
| hrs | **History -**<br>.Ancient Rome -<br>All Roads lead to Rome.<br><br>Drama - | Roman Government<br>Rome and Carthage<br>Julius Caesar<br>The Christians<br><br>A Class (Roman) Play | To develop:<br>* a sympathy and tolerance for cultures other than our own.<br>* knowledge of human society and culture.<br>* communication: language skills.<br>* confidence in public speaking<br>* cooperation, group work and acting skills.<br>* map making skills. |

## SEMESTER TWO - TERM THREE

| uration | Studies | Contents | Objectives/Outcomes |
|---|---|---|---|
| 20 hrs | Mathematics - Algebra | The use of symbols.<br>Open sentences. True or false.<br>Solving simple equations.<br>Simplifying expressions.<br>Parenthesis | To develop:<br>* a knowledge and ability to communicate in mathematical language<br>* skills in computation and problem solving, with practical applications |
| 30 hrs | Science Astronomy | Earth's movement<br>Day/night; year/seasons<br>Sun/planets of the Solar system<br>Daily observations of the Sun, Moon and stars<br>Scale models of the planets<br>Field trips to observatory and overnight camping to observe the stars and constellations | To develop:<br>* knowledge of the earth in space; the solar system and universe<br>* knowledge of the constellations of th Milky Way and Zodiac<br>* a sense of reverence and wonder for the heavens<br>* communication (language skills; oral/written)<br>* social skills (group work and cooperation<br>* map making skills (the heavens) |
| 30 hrs | Mathematics Geometry | Metamorphosis of form, mainly within the circle<br>5, 8, 10, 12, 16, 24 and 48 division of the circle<br>Spiral forms arising from arithmetic and geometric progressions<br>Metamorphosis of triangles and quadrilaterals | To develop:<br>* an appreciation for movement, change and metamorphosis in geometry<br>* an understanding for the relationshi of geometry to both plane surface and 3-dimensional forms |

| | | | Objectives/Outcomes |
|---|---|---|---|
| [illegible] hrs | <u>Science and Technology -</u><br>Science 2 - Static electricity<br>Magnetism | Through a wide variety of practical experiments, students will observe and investigate cause and effect in the realms of static electricity and magnetism<br>To have fun with science | <u>To develop</u><br>* the principles of electricity and magnetism<br>* to nurture a sense of wonder for the secrets which lie behind the physical world |
| 38 hrs | <u>Social/Environmental -</u><br>Geography of Australia | Australia and its connection to the wider world.<br>Aboriginal Studies<br>Australian Democracy<br>Government<br>Field trips | <u>To develop</u><br>* knowledge of countries and cultures other than Australia<br>* moral concerns for other peoples<br>* civic participation<br>* skills at acquiring information |
| 30 hrs | <u>Mathematics</u><br>Revision and practise | Decimal fractions<br>Percentage<br>Interest and Discount<br><u>PRT</u><br>100<br>Algebra | <u>To develop</u><br>* a knowledge and ability to communicate in mathematical language<br>* skills in computation and problem solving, with practical applications |

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