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1 Introduction

This manual is designed for teachers and aides working in science classrooms with students who are blind or have a visual impairment. It is composed of three main sections: background educational information, adaptations of laboratory tools and skills, and full experiments. It is designed to be a reference throughout the school year.

Each section has different uses. The understanding of one is not dependent upon knowledge of the others. The section on general background information is designed for teachers with no previous experience in teaching students with visual impairments. It briefly discusses the differences in learning styles and educational considerations. This section also offers general recommendations for the classroom.

Contained in the section on adaptations are suggestions for modifying laboratory tools and skills. These suggestions include descriptions of specific adaptations for commonly used equipment. This section also presents devices designed specifically for use by blind and visually impaired students. General guidelines are presented for creating additional adaptations.

The final section is a collection of redesigned experiments, which highlight some of the adaptations from the previous section. These experiments are designed for use by the whole class, not as separate experiments for the blind or visually impaired student.

The intent of this manual is to improve the accessibility of laboratory experiments. The manual is a compilation of information and experience from many different sources, in the hope that this knowledge will be made easily accessible.
A Note on the Research

The background information provided in this manual has been compiled from various sources in Denmark and the United States. This research encompassed the learning styles of blind and visually impaired students, and the guidelines for teaching and devising adaptations. Sources included written materials such as books, journal articles, and Internet web sites, interviews with teachers and specialists, and classroom observations.

In the United States, research was conducted on the learning styles of the blind and visually impaired and on the integrated educational model. The primary sources of info were printed materials and interviews with teachers who are trained as specialists in the education of the blind and visually impaired. Contacts were also made with relevant organizations via email.

A study of the integrated educational model was also performed in Denmark through classroom observations and interviews with teachers who have had experience with blind and visually impaired students. Several schools were visited, and various science classes at different grade levels were observed. Teachers demonstrated some of the experiments that are commonly used in their science classes, and provided examples of standard laboratory equipment. Interviews were also conducted with an educational consultant, and regular contact was maintained with the Visual Impairment Knowledge Center.

Several lab manuals formed the basis of the analysis of existing experiments. Teachers identified the experiments and subjects that they considered to be most important. The experiments and their component skills and apparatus were analyzed for accessibility, based on the considerations suggested by the previous background research.

A more detailed version of this background research can be found in “Modifying Science Experiments For The Visually Impaired,” a project completed in conjunction with the Visual Impairment Knowledge Center in Hellerup, the Educational Consultants for Visual Impaired Students in Storstrøms Amt, and Worcester Polytechnic Institute in Massachusetts, USA. A copy of this document is available in the Visual Impairment Knowledge Center.
2 Teaching the Blind and Visually Impaired

Having a blind or visually impaired student in your classroom can be challenging, but it can be beneficial for both the students and you. With the right teaching methods and assistance, the student can fully participate in your classroom. To effectively instruct a visually impaired student in the classroom, you must be aware of the differences in their learning style.

2.1 How Blind and Visually Impaired Students Learn

Blind and visually impaired students have a specific learning style. This style stems from the student’s unique perception of the world. To better understand the learning style of blind and visually impaired students, consider the following situation.

Think about entering a room. Within seconds you have ascertained who is in the room and what activity they are doing. Also, you notice the surroundings: how the furniture is arranged, where there is an empty chair, and the food sitting on the table. In gaining all of this information you utilize very little verbal information and almost no tactual information. Yet you are able to construct a complete understanding of the situation, including the interrelationships of the different objects in the scene. Instead of visual information a blind or visually impaired person would rely on the auditory cues, verbal communication, or information gained from maneuvering around the room. By any of these methods they will have difficulty in constructing the entire scene because they do not have information about areas they are not in direct contact with.

The unique perception of the world is best exhibited in the difference between abstract and concrete conceptualization. Sighted people create abstract concepts by putting many
characteristics in a group. This abstract concept can be used to classify and understand objects not previously encountered. For instance, there are many types of birds that can be represented in a number of different shapes and positions. Yet, sighted people can classify them as birds because they have an abstract concept of a bird. This abstract concept is a model in our mind that can be manipulated, rotated, stretched or represented in a two dimensional form.

The blind student has a concrete concept of the world. The objects that are tactually explored and identified will have meaning but a picture of the same object will be difficult to identify. For instance, an outline of a bird is identifiable to a sighted person, but a blind person exploring a raised line diagram of the same picture may be unable to determine it to be a bird or define which points are its wingtips and which is its head.

There is also a concrete association between an object and the manner in which it is originally introduced. The initial characteristics such as its use or size are understood, but it is difficult to extend the concept of the object to having a different form or use. Because of this, there is difficulty in perceiving the inter-workings of a system, and how each object relates to and affects the others.

As with blind students, visually impaired students tend to conceptualize concretely. Since abstract concepts are based on visual information; a student’s ability to form these concepts depends on their amount of residual vision.

Another consideration in the learning style of blind and visually impaired students is the time required to collect and process information. As discussed earlier, visual acquisition of information is very rapid. Conversely, tactual and audible methods can be time consuming and limited. When learning about something tactually the student must be able to explore all parts of
the object. When learning audibly a student must have an accurate description to obtain a clear understanding.

2.2 Basic Teaching Guidelines

The keys to creating a productive learning environment for a blind or visually impaired student are not extraordinary, and they are a benefit to the class as a whole. In fact, most teachers remark that having a blind or visually impaired student in class has made them a better teacher for all students. You do not have to, nor should you, alter your curriculum or standards when you have a blind or visually impaired person in your classroom. Modification is in the presentation of material.

Blind and visually impaired students need verbal descriptions of everything. This refers to reading and explaining what you put on the blackboard or what you hand out on paper. You should also refer to everyone and everything by name or description, rather than pointing or using vague terms such as “this” or “that.” Whenever you are explaining, make sure you speak clearly and distinctly because the student may have a difficult time following you if they are also reading along, taking notes, etc.

Organization of the class and of material is very important for the blind or visually impaired student’s understanding. To aid the student’s mobility through the room, the furniture should maintain in its configuration. Also, the student needs to have a firm mental picture of where objects are in the laboratory so they are able to locate them independently. Therefore, every object should have a permanent location. For the blind or visually impaired student to accurately follow the material in class it must be presented in an organized fashion. Lesson
plans prepared in advance will enable you to ensure a progression in a logical fashion that is easy to follow both orally and in text.

Using real examples provides concrete reinforcement for blind and visually impaired students. Two-dimensional representations and verbal descriptions do not convey as much information as real, three-dimensional objects. It is best to provide these objects whenever possible. To aid in the students understanding of the interactions between objects, demonstrations should relate to the student’s daily life or experiences.

The blind or visually impaired student often has suggestions regarding their learning methods, based on previous experience and personal preferences. You should consult with the student before and during the course to obtain feedback on their participation and comprehension.

The student’s peers can be useful resources as well. Not only should the student have a sighted lab partner, but they should also have help from their classmates during the lectures. The classmates can explain what is happening during a demonstration, or help the student find the correct place in the textbook or handout quickly. The assistance of a sighted peer is sometimes more beneficial than the minimal experience gained by performing the task unaided. You should determine which skills and experiences are important to the student’s understanding of the lesson material, and avoid spending too much time on adaptations that will not contribute significantly to the student’s education. For example, digital displays can be read by a lab partner without affecting the student’s participation in the experiment. This type of relationship is beneficial to both students, as both can still participate equally in the classroom.
These teaching methods not only make the classroom accessible to the blind or visually impaired student, but they also improve the learning experience for the rest of the students.
3 General Guidelines for Making Adaptations

Adaptations can be applied to activities, items, or environments. Their purpose is to maximize the visually impaired student’s participation in various functions without making drastic alterations. In general, adaptations can: alter the physical environment, change the rules, change the strategy, change the routine, reduce the complexity, provide cues, or offer personal assistance. This section also describes certain general principles that you should keep in mind when making adaptations.

3.1 Principles of Adaptation

The first rule for making adaptations for a blind or visually impaired student is ‘minimization of adaptation’. Adaptation emphasizes the disability of the student. This emphasis creates a gap between the blind or visually impaired student and their peers, which can hinder the student’s social interactions. Another reason for minimizing adaptation is because this simplifies the work for you, the teacher. If adapted materials are significantly different from the original materials, you will have to make special provisions when referencing the material in class. Also, if adaptations are too detailed, they will take too long to develop and will appear cluttered to the student. When designing a complex adaptation, consider the significance of the information compared to the effort involved in utilizing the adaptation.

The second rule for adaptations is the ‘avoidance of adaptation for basic skills’. Every student should be allowed to participate in every part of the classroom experience, which is why adaptations for some students are necessary. However, modifications can easily overcompensate and overlook the blind or visually impaired student’s ability to perform basic skills. You must
also be careful when adapting material because sometimes an adaptation will not portray the information that was intended.

3.2 Adaptations for Visually Impaired Students

When working with a student who has low vision, the goal is to optimize the use of their residual vision. This objective is accomplished differently for every student, depending on the specific condition. Because their vision is limited the student will not be able to collect information rapidly; therefore, less detail is optimal. Too much detail can create a confusing picture.

**Increasing useful vision**

There are four main considerations that can affect the function of the eye. They are illumination, contrast, size, and the presence of glare.

- **Illumination** - Items that are not well lit are harder to see. The illumination can be improved by changing the intensity or color of the light. These properties can be changed by using different types of bulbs, additional lights or lamps, or by increasing the wattage in existing lights.

- **Glare** - Glare is the reflection of light. This excess light interferes with the ability to focus on one area. A white piece of paper reflects a full spectrum of light, creating a lot of glare. Black paper with lines cut out of it reduces the glare from the rest of the sheet so the person can focus on the line they are reading. Glare can also be reduced by diffusing direct light through various filters.

- **Contrast** - Some color combinations contrast more sharply than others; for instance, it is difficult to see yellow writing on a white paper. To increase the contrast, use very dark blue or black on white boards, or white on black boards. For reading, a yellow filter will increase the contrast of black on white, so yellow sunglasses or a yellow filter can be used.

- **Size** – For many low vision students, size is a considerable problem. There are many ways to increase size. Simple methods include enlarging papers using a copier and obtaining large-print
textbooks. Mechanical aids are available as well. These devices include telescopes, microscopes, telemicroscopes, electric-magnifiers, CCTV, and computers with magnification programs. Hand-held magnification devices are particularly useful in the laboratory. In choosing a device, you must consider how easy it will be to use.

Specific low vision types
Most adaptations are only useful for certain types of visual impairments. Adaptations that are beneficial to one student may actually limit another student’s useful vision.

- **General vision reduction** – Many students require information to be enlarged to an accessible size, and/or brought closer to them.

- **Distorted vision** – A student may have an area of the eye that has distorted vision. Therefore, information must be placed in a position that student can access it. This may mean that writing on the board is easier to read if it is concentrated around the periphery instead of the center. Always consult the student as to what is best for them.

- **Reduced field vision** – Reduced field vision covers various conditions in which you can see only what is in a certain section of your field of vision. Tunnel vision is the most common form of this condition, in which only the central section is visible. Students with this type of vision will not benefit from images being made larger because they are unable to view the entire picture at once. The most effective strategy is to place all information close together.

- **Light Sensitive** – Some students with low vision are sensitive to light and will be hindered by excess light. These students will also be excessively affected by glare.
3.3 Adaptations for Blind Students

A major component of adaptations for blind students is texture. Texture can be used in a number of different ways. Braille, for example, conveys the most information, but it requires special equipment and an understanding of the system. It is primarily used for documents or labels that require written text. A low-tech method of texturing is simply using different types of materials, such as sandpaper and felt.

If the information is not easily portrayed through words, a common adaptation is raised line drawings. These drawings are often used in geometry, or any subject in which graphs are prevalent. They can be made on heavy-weight paper, plastic, or thin metal sheets, but require special devices to make them. You must be careful when using raised line drawings, however; this is one type of adaptation that is very prone to miscommunicating information.

Audible information can also be used for adaptations, and can be especially useful in a laboratory environment where an experiment is constantly changing and the student needs constant cues. Audible information is also useful for general studies in the form of talking books. While these books are useful as a complement to written text, they are not a replacement, and should not be used exclusively unless no other written material is available. Tape recorders can be used to record lectures and to take notes, which can be referenced at later times.

3.4 RNIB Questions

The Royal National Institute for the Blind, in London, has developed a set of questions designed to assist in the creation of adaptations for blind and visually impaired persons. They highlight the key features that an adapted device should have in order to be used successfully. Many of the

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1 “30 Questions to ask yourself when designing for the visually impaired”; RNIB; April 2000; http://www.rnib.org.uk/wesupply/products/30q.htm
questions also pertain to other types of materials, including text and other apparatus and instruments. The questions have been presented here in the most pertinent format for educational use.

30 Questions to Ask Yourself When Designing for the Visually Impaired

Visual information
1) Are printed characters legible and clearly visible?
2) Do the colors contrast enough?
3) Are electronic displays legible and clearly visible?
4) Are status and warning lights clearly visible?
5) Are different status and warning lights distinguishable from each other?
6) Are symbols large enough to be read by visually impaired people?

Tactual information
7) Is the Braille legible? Have you considered:
   • Achieving the correct standard Braille 3D profile.
   • Positioning Braille in uncluttered areas.

8) Is the Braille optimally positioned in its role as labeling?
   • Is it near enough to be identified with the feature for which it serves as a label?
   • Is it far enough from the feature such that it can be read in an uncluttered area?

9) Are the tactual markings distinguishable?
10) Are the tactual markings optimally positioned in their role as labeling?
   • Is it near enough to be identified with the feature for which it serves as a label?
   • Is it far enough from the feature such that it can be read in an uncluttered area?

11) Can contrasting textures be readily identified?

Instructions

12) Are the instructions available in all appropriate mediums?
   • Large print (A minimum of 14 point Helvetica or Arial font)
   • Good quality Braille
   • Audio tape
Handling

13) **Is the device easy to orientate?**
   - Can a visually impaired person easily locate the front, back, top, and bottom?

14) Does the device have any sharp edges or rough surfaces?

Controls/Indicators

15) Are the controls easily distinguishable by touch?
16) Are the controls easy to operate?
    - 17) Have you considered the pressure required to operate buttons/controls?
       - Too light a pressure does not give adequate tactual feedback.
       - Too heavy a pressure may reduce tactual sensitivity of a Braille reader’s fingers after prolonged use.

Auditory information

18) Are the audible tones readily distinguishable?
19) Is the speech quality suitable?
20) Is the volume range suitable?

Vibratory output

21) **Are the vibration patterns emitted from the device readily detectable?**
22) Are contrasting vibration signals distinguishable?

Physical dimensions and build

23) Is the device durable enough, given the anticipated everyday wear and tear?
24) Have you considered the weight of the device?

Cleaning

25) Is the product easy to clean and maintain?

Packaging

26) Does the packaging allow for easy access to the device, its instructions, and its component parts, by the visually impaired person?
Power supply

27) Could a visually impaired person replace batteries required for the device?

28) Could a visually impaired person charge batteries required for the device?

29) Are power leads and their respective sockets readily distinguishable and/or clearly labeled?

30) Are main power connections robust?
4 Laboratory Adaptations

There are many skills and tools that are common to any science laboratory, as well as many dangers. Thus safety precautions, skills, and tools should be the first considerations when modifying any experiment.

4.1 Safety Concerns

There are many safety hazards present in any lab. These are present for every student and are not specific to blind or visually impaired students. However, because the blind or visually impaired student cannot identify these hazards readily, special attention needs to be paid to the safety of this student. A sighted partner can assist in identifying safety concerns. All precautions will improve the general safety of the lab.

Chemicals

Proper identification and use of chemicals is one of the greatest safety concerns for all students. The initial step to correct use is to obtain the correct chemical. Therefore, chemicals should always be kept organized in the same place. They should also be labeled in a way accessible to the students in the class, which includes print, enlarged letters, and Braille. A syringe made for measuring chemicals can be very helpful. When pouring the chemical, a funnel can be used to create a larger target area. Also, a conductivity sensor can be used to identify the top of the object, so as not to overfill it.

Glass

Glass apparatus is used in most chemistry experiments and is both fragile and unstable. To make glass objects safely accessible, they should be consistently stored in a secure manner. When in use, the glass objects should be placed in stands or clamps so they cannot be
unintentionally knocked over. For low vision students, contrast can assist in identifying the objects and their size. A piece of black paper placed behind the apparatus will create contrast with surroundings.

Heat sources
The obvious danger with heat sources is the possibility for a student to be burned or for the heat source to come in contact with a flammable material. The most common heat sources in a lab are Bunsen burners and matches. For those with low vision, the Bunsen burner can be made safer by identifying the inlet and outlet with contrasting non-flammable paint. Another safety modification for low vision students is the use of wire gauze to identify the position of the flame. Wire gauze will glow brightly where it passes through the flame. The gauze can be held in a clamp attached to a stand or laid on a tripod placed around the Bunsen burner. The tripod configuration also has the added feature of providing extra protection around the burner. Another concern with Bunsen burners is the possibility of the fire going out. The student should be instructed how to listen for the sound of a lit burner and to recognize when it stops. Hot plates are an alternative to Bunsen burners that are more stable. The use of matches can be made safer by using long handled ones or long tapers to keep the student’s hand away from the flame.

Movement
Many Newtonian physics experiments contain moving objects. A blind or visually impaired student may not be able to ascertain whether there are any obstacles in the eventual path of the object. For instance, a rolling cart’s trajectory may lead off an edge or into an object that is fragile. Another example is a balloon or rocket released into space that cannot be tactually observed. A sighted partner or instructor should check any setup arrangements before an experiment is conducted.
**Power cords and connecting wires**

Power cords are dangerous because they provide an unexpected obstacle for the blind or visually impaired. Cords can trip people, upset machines or other devices, and cause objects to move or fall. To avoid these situations, power cords should be kept out of the way. Some options are to keep the equipment as close as possible to the outlet and the cord gathered and secured in place. If the cord must cover a distance then it can be run along the ceiling or taped down on the floor.

The dangers of electrical devices with connecting wires are the same as those with power cords. Wires should be kept as short as possible, especially because they can complicate the student’s mobility around the devices.

**4.2 Skill Modification**

Below is a list of suggestions for modifying basic laboratory skills. Some modifications involve simple devices or are designed for more specific situations, but most are meant to be as general as possible. Many of the modifications, while not necessary for partially sighted students, make laboratory procedures easier, quicker, and safer for all students with visual impairments. Because most of these skills involve minimal adaptation, the student will need to practice in order to perform the skills quickly and effectively.

- **Balances:** Double and single pan manual balances can usually be used without much adaptation, as long as the pointer is able to be touched. The student will need to practice how to read the position of the pointer without moving it.

- **Building circuits:** The identification of components is the most difficult part of this procedure, so the student will most likely need a sighted partner to choose the appropriate resistors,
capacitors, transistors, etc. Raised line diagrams can be used to interpret circuit configurations. The students may be able to construct circuits without much assistance by stringing wire between metal pins previously arranged on a board. They should also be able to follow the path of the circuit by touch in order to check their work. They can either install small speakers in addition to or instead of light bulbs, or they can feel the light bulbs as they heat up. If the electrical device is more advanced, involving soldering or preprinted circuit boards, the student will more likely have significant difficulties with the process.

- **Building models:** The student should have little difficulty in constructing models using molecular modeling kits or other modeling systems such as LEGOs. Usually, the model components for such systems have distinctly different shapes. If the pieces are unfamiliar, the student should be allowed to explore a model before building their own, to understand how the components fit together. The use of three-dimensional models can be beneficial to the student’s understanding of certain scientific concepts. It should not be assumed, however, that these models are self-explanatory – the student may not make the connection automatically between the properties of the model and the properties of a real object.

- **Constructing apparatus with basic parts (test tubes, flasks, stands, clamps):** Once the student has identified the necessary apparatus, they should be able to set up an experiment without much assistance. They might need extra time, however, because much of the positioning cannot be gauged quickly by touch. If a sighted partner is assisting with a complex setup, the student should work on one section of the apparatus. The process may become confusing if the sighted partner moves components around on the lab bench.
• **Estimating units:** Students need to have a clear understanding of the sizes of standard units, so they can choose appropriately sized apparatus. Length is typically a familiar concept to them, but area and volume are more difficult concepts. Full-scale models of such units as cm², cm³, and L should be available for the students to explore and reference.

• **Handling flames (matches, splints, candles):** Some blind or visually impaired students may be able to light matches without any assistance. Alternatively, a partner or assistant teacher can light a long wooden splint or wax taper for them. Once the match or splint is lit, either the student can employ the flame in the experiment, or the partner or assistant teacher can guide the student’s hand to the appropriate place. The student should take part in this procedure whenever possible, instead of always relying on the sighted person. When using a Bunsen burner, the student must learn to check the gas line very carefully to make sure it is attached securely. The match should always be lit before the gas is turned on. It should be possible for the student to position a lit match near the top of the burner, resting a finger lower on the barrel if necessary, and then turn on the gas. The student should be able to hear the sound of the gas igniting. While the burner is lit, the student should be consciously aware of the sound it makes, in case the flame goes out. In a loud classroom, it is important for the sighted partner to also keep a close watch on the burner, in case the student is unable to hear the sound of the flame. While a burner is lit, the student should learn to only search for objects (particularly the burner itself) by running their hands on the surface of the lab bench, in order to avoid touching or knocking over the hot barrel.

• **Identifying and locating apparatus:** Most apparatus can be easily identified by touch or with limited sight. Once the apparatus is in use, it may become more difficult to identify and locate if
it is being heated, is placed inside another object, is full of a substance that could be knocked out, etc. It is therefore important for the apparatus to remain in the same place while in use, so the sighted partner must be conscientious when moving objects around.

- **Identifying containers and labels:** All students should be taught to place containers in specific locations. Blind and visually impaired students should not be taught to rely on the position of a container to identify it, however, as this is only meant to make identification quicker. The student must check the label carefully every time, especially for warning indicators.

- **Identifying gas evolution:** Because most gases are usually invisible, all students should be able to identify the evolution of a gas from solution in an experiment by sound and sometimes by smell. Blind and visually impaired students can also use matches and splints with the rest of the class to identify gases, because usually a whooshing or poofing sound (often loud) accompanies the extinguishing or lighting of the match.

- **Identifying light patterns and paths:** Students with residual sight should be able to participate in experiments regarding the nature of light, especially if a bright light bulb or laser is used. If the contrast is strong enough, the student should be able to see phenomena such as reflection, refraction, and diffraction patterns. If the student cannot adequately perceive light patterns, raised line drawings illustrating the phenomena are the best adaptation for understanding the concepts. An audible light sensor can also help to determine interference patterns, indicate refraction paths, etc.
Measuring with and reading instruments:

- **Rulers:** Students should have rulers with tactual markings at various units, and need to practice with them to be able to read them quickly and accurately.

- **Graduated cylinders, beakers, flasks, etc.:** For nontoxic, non-staining liquids, using a finger to measure the depth of the liquid should be safe. Tactual lines or scratches on the inside of the apparatus would be adequate in this case for determining liquid level. It is a good idea, however, to invest in a conductivity device for use with all liquids. The height of the device’s electrodes would be determined by laying the electrodes against the outside of the apparatus along the scale, positioning the ends of the electrodes at the proper volume reading, and noting the position of the top of the apparatus on the electrodes. The electrodes would then be placed inside the apparatus, keeping the same positioning relative to the top, and the liquid would be poured in until the sound was heard. This technique can be used with most types of volume measuring apparatus, depending on the length of the electrodes.

- **Meters in general:** If the pointer on the meter can be touched, then the student can learn to read the scale by touch with practice. Often, it might be adequate for the student to feel that the pointer moves a relative distance, while the sighted partner records the actual reading. If the meter is behind plastic or glass, a sighted partner or assistant teacher will have to obtain the reading.

- **Perceiving motion (falling, rolling, flying, etc.):** It is difficult for a student to follow a moving object by touch. In order to collect measurements of horizontal motion, the student should be able to mark the starting and finishing positions. By lightly touching a cart or other object as it
is set into motion, the student can get a sense of its initial speed. If the experiment does not involve the object coming to rest by itself, the student can get a sense of instantaneous speeds by stopping the object with their hand. Objects in slow horizontal or vertical motion can be followed by touch in some situations. When studying vertical motion, objects should be dropped onto a surface that will make distinct sounds, such as a thin sheet of metal. If the students are exploring rockets, a long, lightweight string can be tied to the rocket that the student can let run lightly through their hands to convey a sense of speed and direction. If an air track is used, the student should be allowed to experiment with it, pushing the slider with and without air to see how far it travels and how many times it rebounds at the ends of the track. Often, an air track is used to illustrate constant velocity by taking long-exposure photographs of a slider with a blinking light bulb on it. The student can measure between the light bulb images if a pin or other marker is placed in the same position on each one, preferably by a classmate.

- **Spring scales**: Properly modified, spring scales should be relatively easy for the student to read using tactual markings. They can be more difficult to use if the scale is being used to pull an object and the pointer is moving fairly rapidly, or if the scale is being moved by another student.

- **Stopwatches**: The student can use a stopwatch without modification, although they will need a partner to read the output.

- **Thermometers**: Students with residual vision can often use an alcohol thermometer, which is available in several colors. The student would have to try several thermometers to see if any were readable, depending on the color and degree of magnification that the casing provides. Even if students cannot see well enough to read a thermometer, they should learn how to
properly place thermometers to illustrate the theory of heat transfer in various substances (beakers of water, distillation apparatus, solids, etc.).

- **Using liquids:** If liquid is in a large bottle, some liquid should be first poured into a smaller container, especially if small, exact volumes are to be used. The smaller container should preferably be wide-mouthed. If a narrower neck must be used, a funnel is very important, particularly if the liquid is caustic. The student should always hold both the bottle and the receiving container. It should be easier for the student to rest the mouth of the bottle on the edge of the container to ensure that both stay properly oriented. If, however, the student tends to let the bottle slip when pouring, then they should adopt the technique of touching the mouth of the bottle to the edge of the container to orient it, then moving the mouth further over the opening of the container and supporting the bottle entirely with their hand while pouring.

- **Using pendulums:** It would be difficult for a student to continually follow the motion of a pendulum bob by touch. They should still explore the motion as much as possible by: holding a hand at each end of the pendulum’s swing and feeling how it strikes each hand alternately, using their own arm as a pendulum and feeling it strike a partner’s hands, suspending a pendulum from their hand and feeling the amplitude decrease over time (possibly suspending it between their knees while sitting, so they can feel the bob continuing to swing after it stops hitting their knees), and feeling the frequencies of different lengths suspended from their hand. If a device is set up which will emit a sound or click when the pendulum passes through it, the student can participate in most experiments that require the counting of swings or the measuring of frequency. Some experiments might also be feasible using an analog metronome.
• **Using solids:** Students can remove small portions of powdered solids in wide mouthed jars with metal spatulas, which is preferable. If the solid is in a narrow necked jar, it should be poured out carefully into a beaker or onto a piece of paper that can be folded to dispense the solid into another apparatus. The amount can be more easily adjusted this way, and it is more reliable than pouring directly from the bottle. Large solids should not pose problems, although shaking them out onto a piece of paper first is still a good precautionary measure.

4.3 **Basic Tool Modification**

**No Modification**
For low vision students the addition of bright colors can be useful in identifying any of the tools listed below.

• **Carts:** Carts are large objects that can be brightly colored so that students with residual vision can follow their motion. Many carts make sound ordinarily as they move which can help the severely visually impaired or blind student identify its position or state of motion.

• **Clamps and stands:** Clamps and stands, as used in chemistry, should be tactually familiar. The student with visual impairment is able to use these without any modification.

• **Cranaks:** A crank handle is used in Newtonian physics experiments usually to move objects attached by a string. After the student has explored the apparatus, it can be used without modification. Be certain that you guide the student to understand the connection between the crank, string and object. Severely visually impaired or blind students will not be able to crank
and perceive the object’s motion at the same time, but can lightly touch the object as someone else cranks as well as taking a turn cranking.
• **Electrical Components** - resistors, capacitors, transistors, integrated circuits, batteries, wires, clips, wire coils: Electrical components do not need to be modified for use by the student. However, many components are color coded, such as resistors, and require identification by sighted students.

• **Funnels:** Funnels can be used to create a greater accuracy when transferring a liquid or solid from one container to another.

• **LEGOs and modeling kits:** Both LEGOgs and modeling kits require no modification because their components are brightly colored and entirely identifiable tactually.

• **Microphones:** Microphones are audible input devices and can be used easily by students with any level of visual impairment.

• **Pulleys:** Pulleys are often used in a series. Because there are many connections, the student will need to be given enough time to understand how they are all connected. Remember that creating a whole picture from tactually gathered information takes longer.

• **Springs:** Springs are often used in studies of mechanics. The student can obtain a strong understanding of the properties of springs by experimenting with them.

• **Tuning forks:** Tuning forks are audible and tactual devices that give no visual output. The one consideration is their placement in experiments in relation to other objects.

**Labeling**
• **Beakers, Flasks, Test Tubes, and Graduated Cylinders:** To make these glass objects more accessible to those with low vision they can be marked. The markings can be made with either colored paint or colored tape. To further emphasize the container, placing a black piece of paper behind it can increase the contrast. Tactual marking can be also be added to the container. These can be raised lines at intervals or Braille numbers indicating the level. Since all of the objects are glass, they pose the risk of being dropped or inadvertently knocked over. This risk exists for all students and can be helped by careful placement of containers away from the edges of counters, placement in sturdy stands, and an uncluttered workspace.

• **Bottles (liquids):** Whenever possible, plastic bottles with nozzles should be used. Otherwise, bottles containing liquids should be of a type that does not leak when being poured. Having a lip on the mouth of the bottle usually helps in orienting the bottle to another container for pouring, although some lips cause the bottle to drip.

• **Distance measures:** General distance measures, such as rulers, meter sticks, or tape measures, can be easily adapted. They can have tactual markings made by placing various sizes of pins, etchings, or bumps to demarcate the fundamental units on the scale. For long distances meter wheels are useful because they click audibly with every revolution. Strings with regularly spaced knots can also be used to measure distances. Protractors only need tactual markings. Compasses can be used in conjunction with adapted rulers to produce the desired radii. Highly contrasting lines or enlarged number markings can aid the low vision student.

• **Gas sources:** In most labs the gas source is located at each lab station. Since there are many configurations of the sources, you will need to make modifications that suit the lab you work in.
If there are other nozzles or handles nearby, they should be identified tactually and associated with their particular nozzles by tactually identifying the nozzles as well. When connecting hoses the student should have a tactual measure of the amount that the hose needs to be pushed on.

- **Labeling containers:** Plastic labeling tape printed with Braille and/or tactual markers can be used to label containers. Tactual markers can be used either to label a particular substance or to indicate the type of material or associated safety risk (acid, base, flammable, poison, etc.). Large, distinctly colored warning labels can be used with partially sighted students. Containers should be organized and students should be taught to return them to a specific location, but this does not replace labeling the container itself. If possible, the shape of a particular container should be some indication of the substance inside (screw lid = solid, glass stopper = acid, plastic stopper = non-caustic liquid, etc.)

**Analog dials and labeling**
- **Air pumps:** Air pumps are used when filling balloons or rockets for force experiments. The students with visual impairment need no modification for the use of this device. Some air pumps have analog air pressure meters that can be seen with magnification or read by the lab partner.

- **Devices With Digital Readouts:** At present the following devices have a digital readout that is inaccessible to students with severe visual impairment. Some companies currently make synthetic speech components, and it is possible that they will be included in other devices in the near future. As with other products, all dials and connections should be labeled in a way accessible to the students in the class. Although the devices’ outputs are inaccessible, the
student will be able to use them in a laboratory provided that their partner will read the digital readout.

- Low-volt power source
- Signal generator
- Sound activated timer
- Thermometers
- Stopwatches
- Voltmeter
- Ammeter
• **Geiger counters and radioactive sources:** The Geiger counter has an audible output. The blind or visually impaired student should be able to independently complete experiments using this apparatus with the exception of reading the numerical output, provided that the dials on the Geiger counter and the radioactive material are labeled.

**Tactual or Audible Modifications**

• **Balances:** Manual single or double pan balances with pointers that can be touched (i.e. are not inside a casing) should be used. The pointer should be close enough to the scale to be able to touch both with one finger. Use narrow tactual markings to denote the various angles on the scale, and make sure that the height of the marking makes it either flush with or higher than the pointer. This will help the student to use the least amount of pressure to feel the pointer, reducing the problem of accidentally moving it from rest or preventing it from coming to rest accurately.

• **Light sources such as flashlights, bulbs, and LEDs:** Bulbs and LEDs are most commonly used in electricity experiments to identify when there is current following through a circuit. This can easily be adapted by adding a sound source. A small speaker, piezo buzzer, or motor will emit a sound when a current is run through them, and like a light, the sound will get stronger with a stronger current. Flashlights that produce a greater amount of light should be used by students with low vision.

**Special Equipment**
• **Circuit diagrams:** Circuit diagrams can be represented as raised line diagrams. Difficult circuits can be very confusing as raised line diagrams. Also, the elements of the circuit will need to have distinct tactual differences in shape to be distinguished.
• **Matches, splints, and tapers:** Always get long handled matches, splints and tapers. This way the student’s hands are away from the flame. Butane gun lighters are another alternative to matches, which keep the flame far from the student’s hands and extinguish automatically.

• **Periodic table:** The periodic table is used frequently in all chemistry classes. It is available in a Braille version.

• **Prisms, mirrors, and lenses:** These objects are for the manipulation of light and its qualities. The objects themselves have no modifications, but their effects can be measured with a light probe. The light probe will beep when it is directed at light. Thus the student can identify where the light beam is before the prism or mirror and after. Another way to make these more accessible is to produce raised line drawings of phenomena.

• **Syringe:** A syringe that is made for measuring chemicals can be of great use. For a visually impaired student to use such a device it is helpful to put tactual markings on the plunger indicating how much liquid is contained in the device. Tactual markings can be notches with Braille numbers as labels. Once a student learns to use this, it is a safe way to measure and transfer liquids of all kinds.

4.4 **Advanced Tool Modification**

In some cases, more advanced devices and more complicated adaptations can be useful in particular types of experiments. These require more time and/or more funds
than simple adaptations. Most of them do not exclude use by sighted students, and in fact sighted students may enjoy using them.

- **Air Tracks:** Air tracks can be very easily adapted for use by students with some residual vision, by using brightly colored sliders and/or sliders with light bulbs attached. Sliders with light bulbs are very common because they are very useful for experiments demonstrating constant and changing velocity and acceleration. It is much more difficult for severely visually impaired and blind students to fully utilize an air track, but they can explore it through touch and gain an understanding of the nearly frictionless surface.

- **Bunsen burners:** Bunsen burners are one of the highest safety risks in a chemical laboratory. Therefore, extra precautions should be taken to prevent accidents. It is always a good idea to place a tripod around the burner to prevent hands from getting too close. The ring of the tripod also helps the student to locate the flame when heating test tubes or placing other small objects in the flame. If the student has residual sight, a piece of plain wire gauze placed on the tripod will glow bright orange in the flame. The student may need assistance from a sighted person to adjust the flame properly. If the burner has a valve at the bottom for adjusting airflow, the handle should be painted a bright color to make it easy to locate, but even students with residual sight may not be able to see the flame adequately to adjust it themselves. Techniques for lighting burners are described in the "Skills Modification" section, but self-igniting burners are also available. These are triggered by various stimuli including the flow of gas, activation of a motion sensor, or depression of a foot pedal. These can be expensive but they are the safest type of
burner, especially because some models turn off automatically after the stimulus stops.

- **Light Sensors:** Any sort of light sensor that is connected to a sound source is useful for severely visually impaired and blind students when performing experiments dealing with light. Light sensors can be used with the super-sensitive switch described in the "New Devices" section. The apparatus can be arranged so that the sound intensity is relative to the amount of light being sensed. The sensor can also be set up such that a sound is produced when a minimum amount of light is sensed, which is useful in illustrating interference patterns with dark and light bands or the diffraction pattern from a grating.

- **Multivibrator:** The multivibrator is described in the "New Devices" section, and is an adaptation for use with liquids. It emits a sound when its electrodes are placed in ionic solutions, and is useful for qualitatively determining the concentration of solutions and for titrating acids and bases when precipitates are formed.

- **Oscilloscopes:** Oscilloscopes cannot be directly adapted, because they are designed specifically for a visual output. Some oscilloscopes may have limited audible outputs, usually for indicating the frequency of the waves. In order to give the student an understanding of the frequency and amplitude of the source wave, a vibrator can be connected. The vibrator has a piston that moves vertically depending on the frequency and amplitude of the source wave. A long piece of fabric elastic stretched between the piston and another stationary object will generate a wave that can be felt, especially if a standing wave is generated.
• **Pendulums:** Pendulums, if possible, can be replaced with analog metronomes, as these are designed to emit clicks with every swing and have adjustable lengths. If the student will be using hanging pendulums, then it may be a good idea to use lightweight wire instead of string to suspend the bob. This will allow the student to touch the pendulum lightly at the top to sense the motion, without affecting the swing of the pendulum too severely. Wire will also keep the bob swinging in the proper plane better than string when set in motion by the student, because it will be difficult for the bob to be displaced sideways.

• **pH Meters:** pH meters are very useful tools in chemistry laboratories, because the paper indicators are based entirely on color changes. Low vision students may be able to distinguish between very simple red and blue indicators, but the more versatile paper indicators have much more subtle color changes that may be impossible to distinguish for most visually impaired students. On the other hand, electronic pH meters may be easier for visually impaired students to use than paper indicators, and are much more accurate. Some electronic pH meters are available with voice synthesis, but the current models are too inaccurate for use in a laboratory setting, so it is recommended that you use regular electronic pH meters with blind and visually impaired students as well and have a sighted assistant read the output.

• **Raised Line Drawings:** Raised line drawing kits and heat-sensitive paper are infinitely useful in the lab. These products are usually used by the teacher or other adapter for preparing materials for the lab such as diagrams and graphs. During the lab, however, the student can draw their own diagrams of their equipment or other
results with a manual kit. Graphing is a very important skill and tool for conveying experimental data, and should be accessible to the student. They can either graph manually with a kit, or they could input their data points into a computer program that produces graphs. The computer graphs can then be printed out and transferred onto heat-sensitive paper that will produce raised line graphs of the student's data. The lab partner's results can also be transferred into raised line drawings, if the results from an experiment are visual (magnetic field lines, free body diagrams, etc.), so that the student can interpret the results themselves.

• **Spring Balances:** Spring balances are easy to adapt to be read by the student, although they require some time investment. Usually, the scale and pointer are enclosed inside a plastic or metal case. The section of casing above the pointer must be removed. Depending on how deeply the scale is recessed, it may be possible to directly adapt it to be read by touch. More likely, though, the student will not be able to accurately read the original scale, so a tactual scale will have to be etched or added on the side of the casing.

• **Supersensitive Switch:** The supersensitive switch is also described in the "New Devices" section, but it can be used with a number of types of experiments. It has two contacts that can be connected to electrodes, sensors, or other electrical components, and will emit a sound when the circuit is closed. It cannot be used for titrations, however, as it will continue to emit sound when the solution is neutral because it is more sensitive than the multivibrator. A much simpler version of the
super-sensitive switch will work with any conductive solution (including tap water), and is described in the "New Devices" section.

• **Timers:** Timers should be relatively simple to adapt. Because the timer already uses a pin to make dots with carbon paper, it can make indentations in the paper tape as well. A piece of plastic with a small depression would be placed under the paper tape so that the pin can press the paper into the depression. The timer cannot simultaneously use carbon paper, as the carbon paper would be deformed as well, but this adaptation is not permanent so the timer can be used for both sighted and visually impaired students.
4.5 New Devices

Multivibrator
A multivibrator is an electronic device that measures the strength of an electrical connection. This model uses both visual and auditory outputs, which helps a visually impaired student participate in the laboratory and understand the concepts behind the experiment.

List of Supplies and Components
1 x Circuit board, approximately 6 x 8 cm
3 x Transistor, BC547B
2 x Resistor, 1 kΩ
2 x Resistor, 10 kΩ
1 x Resistor, 33 kΩ
2 x Capacitor, 100 micro-Farads
2 x LED’s
1 x Small speaker, 8Ω impedance
1 x Female socket, red
1 x Female socket, black
2 x Wire, 6 cm in length
1 x Small box, approximately 7 x 9 x 5 cm (length, width, height)
1 x Soldering iron
1 x Solder, 25 cm in length
1 x Drill with 7mm drill bit

Building Instructions
1) Use the soldering iron to fix the resistors, LED’s, capacitors, and transistors to the circuit board in the manner depicted in Figure 1. Make sure that the transistors are connected in the proper fashion, with the base, collector, and emitter (b, c, & e) positioned appropriately. Also, be sure that the LED’s are soldered in such a way that they can be bent to reach the same edge of the circuit board.
2) Solder one wire into each point labeled with a capital letter.

3) Drill 2 x 7mm holes into a side of the box where you want the two connector ports to be located.

4) Drill 2 x 7mm holes into a side of the box where the LED’s can reach.

5) Attach female connector ports to the circuit board in the following fashion: red port to A, black port to B.

6) Insert the circuit board into the box, bend the LED’s to protrude from their holes, and fasten the ports through their holes.

7) Cut a hole in the lid of the box large enough for the speaker and affix the speaker to the lid.

8) Attach the speaker to the circuit board using the soldering iron and solder.

9) Close the box.

Figure 1: Multivibrator

Implementation Instructions
The multivibrator has a very simple setup. It needs a 9 Volt, direct current power source. The black port can be connected directly to the negative connection. The red port is connected to the experiment, which is in turn connected to the positive connection of the power source. This setup is extremely useful in qualitatively measuring the electric conductivity of a solution.
Supersensitive Switch

A supersensitive switch is an electronic device in which one electrical connection triggers another electrical connection to occur. This device can be used to inform the user with light, motion, or sound, when an electrical connection is made.

List of Supplies and Components
1 x Circuit board, approximately 5 x 7 cm
2 x Transistor, BC547B
1 x Resistor, 200Ω
1 x Small speaker, 8Ω impedance
1 x Female connector port, red
2 x Female connector port, black
3 x Female connector port, blue
6 x Wire, 6 cm in length
1 x Small box with lid, approximately 6 x 8 x 5 cm (length, width, height)
1 x Soldering iron
1 x Solder, 15 cm in length
1 x Drill with 7mm drill bit

Building Instructions
1) Use the soldering iron and solder to fix the resistor and transistors to the circuit board in the manner depicted in Figure 2. Make sure that the transistors are connected in the proper fashion, with the base, collector, and emitter (b, c, & e) positioned appropriately.

2) Solder one wire to each point labeled with a capital letter.

3) Drill 6 x 7mm holes into the sides of the box, in sets of three on opposite sides.
4) Attach female connector ports to the wires connected to the circuit board in the following fashion: red port to A, blue ports to B, C, and D, and black ports to E and F.

5) Insert the circuit board into the box, and fasten the ports through the holes in a fashion similar to the layout in the circuit board diagram.

6) Cut a hole in the lid of the box large enough for the speaker and affix the speaker to the lid.

7) Attach the speaker to the circuit board using the soldering iron and solder.

8) Label the connection ports with the letters used in the circuit diagram.

9) Close the box.

**Figure 2:**

![Supersensitive Switch Diagram](image)

**Implementation Instructions**

To use the supersensitive switch, it must first be attached to a power source. A 4.5 Volt, direct current source should be used, the positive to the red connector (A), and the negative to one of the two black connectors (E or F). Ports B and C are used to connect to the rest of the experiment. When a connection between B and C is made electrically, the speaker will make a noise. This can be useful for anything
from testing electrical connections on electromagnetic experiments to finding chemical solutions that are electrically conductive.

**Simple Conductivity Device**

This device is very simple to construct, but limited in use. When the “electrodes” are placed in contact with a conductive material, the device will emit a noise. The intensity of the noise is qualitatively proportional to the level of conductivity of the material.

**List of Supplies and Components**

- 2 x Wooden pencil, sharpened
- 2 x Wire, 10-12 cm in length
- 1 x Wire, 5 cm in length
- 2 x Small alligator clip
- 1 x Small speaker or piezo-buzzer
- 1 x 9 Volt battery
- 1 x 35mm film canister or similar container (optional)

**Building Instructions**

1) Carefully cut away a section of the wooden pencils, about 8 cm from the eraser (depending on the sizes of the battery and speaker). The 1-2 cm section should expose the graphite center only on one side of the pencil.
2) Tape the two pencils together with the exposed sections facing the same direction.
3) Solder an alligator clip to each long wire. Attach one wire to a terminus of the 9 Volt battery. Attach the other wire to the small speaker or piezo-buzzer.
4) Connect the battery to the speaker with the short wire. The battery may be placed in a container, such as a 35mm film canister, to protect the connections. Cut a hole in the lid for the wires.
5) Tape the battery and the speaker to the pencils, above the exposed sections. Attach an alligator clip to each exposed section. This should create an electrical circuit that is broken between the two pencils.

**Implementation Instructions**

This device is small and self-contained, and therefore is simple to use. The intensity of the noise emitted by the speaker will be proportional to the amount of
electricity conducted through a material. This device can therefore be used to demonstrate the relative conductivities of various substances. Depending on the speaker, the device may emit a sound when placed in tap water, so it would not be an accurate device for indicating neutral solutions. It can, however, be used as a measuring device for the height of liquids, as described in section 4.2 “Skill Modification: Measuring with and reading instruments.”

Figure 3: Simple Conductivity Device
5 Specific Experiments

The following experiments are provided in regular laboratory manual format. They are for use with the entire classroom and contain small modifications that make them accessible to the blind or visually impaired student.
5.1 Pendulums

The focus of this experiment is to explore periodic motion through pendulum measurements.

Materials:
- Stand with rods
- String 70cm
- 2 Washers or Nuts of different weights
- Ruler
- Scale with audible output
- Photodetector with electronic counter (optional)\(^1\)

Instructions:
• Weigh nuts or washers, record data.
• Attach rod to stand 75 cm above the table level.
• Attach the string so that it is 70 cm long and attach the washer or nut.
• Using the ruler pull the pendulum out to a height of 10 cm and release.
• Measure the period. To count the cycles leave the ruler in place to hear when the pendulum returns. Use an audible stopwatch to count the time it takes for ten cycles. Alternatively, use the electronic counter to count the time for ten cycles.
• Record data.
• Repeat for amplitude of 15 and 20 cm.
• Change fulcrum length, lower rod to 40 cm above the table level, and retie the string at 35 cm long.
• Take data for all three amplitudes.
• Repeat for second nut or washer.

Data Collection:
Nut One Weight______ grams

\(^1\) Available from Søren Frederiksen a/s Ølgod, Jutland. Can be connected to an amplifier and loudspeaker to produce audible output.
<table>
<thead>
<tr>
<th>Nut One</th>
<th>Time 10 cycles</th>
<th>Time for one period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fulcrum length 70 cm</td>
<td>Amplitude 10 cm</td>
<td>Time/10</td>
</tr>
<tr>
<td></td>
<td>Amplitude 15 cm</td>
<td>Time/10</td>
</tr>
<tr>
<td></td>
<td>Amplitude 20 cm</td>
<td>Time/10</td>
</tr>
<tr>
<td>Fulcrum length 35 cm</td>
<td>Amplitude 10 cm</td>
<td>Time/10</td>
</tr>
<tr>
<td></td>
<td>Amplitude 15 cm</td>
<td>Time/10</td>
</tr>
<tr>
<td></td>
<td>Amplitude 20 cm</td>
<td>Time/10</td>
</tr>
<tr>
<td>Nut Two</td>
<td>Time 10 cycles</td>
<td>Time for one period</td>
</tr>
<tr>
<td>Fulcrum length 70 cm</td>
<td>Amplitude 10 cm</td>
<td>Time/10</td>
</tr>
<tr>
<td></td>
<td>Amplitude 15 cm</td>
<td>Time/10</td>
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<tr>
<td></td>
<td>Amplitude 20 cm</td>
<td>Time/10</td>
</tr>
<tr>
<td>Fulcrum length 35 cm</td>
<td>Amplitude 10 cm</td>
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<tr>
<td></td>
<td>Amplitude 15 cm</td>
<td>Time/10</td>
</tr>
<tr>
<td></td>
<td>Amplitude 20 cm</td>
<td>Time/10</td>
</tr>
</tbody>
</table>
5.2 Evolution of Gases

The reaction of certain metals with other chemicals, such as acids, produces gas that escapes from the solution. Hydrogen, oxygen, and carbon dioxide can be produced in this way. A simple flame test can help to identify these gases.

A. Evolution of Hydrogen

Materials:
- Stand
- Test tube clamp
- Large test tube
- Funnel (optional)
- Hydrochloric acid (HCl)
  (in the range of 2N - 6N)
- Magnesium ribbon
- Matches
- Wooden splints

Instructions:

- Clamp the test tube vertically to the stand.
- Carefully pour 3-4 milliliters of HCl into the test tube, using a funnel if necessary. The test tube should have liquid in it to a depth of about 2 finger widths.
- Drop a piece of magnesium ribbon into the test tube. What do you see in the liquid? What do you hear?
- Wait about a minute for the gas to collect. Light a splint from a match. Place the flame above the mouth of the test tube. What happens?
B. Evolution of Carbon Dioxide

Materials:
- Stand
- Test tube clamp
- Large test tube
- Funnel (optional)
- Hydrochloric acid (HCl),
  (in the range of 2N - 6N)
- Marble chips
- CO₂ indicator (optional)
- Matches
- Wooden splints

Instructions:

• Clamp the test tube vertically to the stand.
• Carefully pour 3-4 milliliters of HCl into the test tube, using a funnel if necessary. The test tube should have liquid in it to a depth of about 2 finger widths. Place 1 drop of CO₂ indicator into the acid, if desired. What color is the liquid?
• Drop a marble chip into the test tube. What do you see in the liquid? What do you hear?
• Wait about a minute for the gas to collect. Light a splint from a match. Place the flame above the mouth of the test tube. What happens?
C. Evolution of Oxygen

**Materials:**
- Stand
- Test tube clamp
- Large test tube
- Syringe, 10 ml
- 3% Hydrogen peroxide solution
- Potassium Iodide (KI) or Manganese Dioxide (MnO₂)
- Matches
- Wooden splints

**Instructions:**

- Clamp the test tube vertically to the stand.
- Use the syringe to transfer 3-4 milliliters of hydrogen peroxide solution into the test tube (the test tube should have liquid in it to a depth of about 2 finger widths).
- Put a small amount of KI or MnO₂ into the test tube (just enough to cover the bottom). What do you see in the liquid? What do you hear?
- Wait about a minute for the gas to collect. Light a splint from a match, then blow out the flame gently. The end of the splint should be glowing red. Hold the splint well away from the end, and place the end about 2-3 cm inside the test tube. What happens? If nothing happens, try placing a lit splint above the mouth of the test tube. What happens?
5.3 Distillation of Salt Water

The focus of this experiment is to discover the properties of distillation, boiling, and condensation.

Materials:

- Laboratory Stand
- Clamp
- 2 Test tubes
- Thermometer
- Right-angled glass tube
- Two-holed Rubber Stopper
- 2 Beakers, 250 mL
- Graduated cylinder, 100 mL
- Tripod
- Wire Gauze
- Water
- Salt
- Multivibrator (optional)

Instructions:

- In one of the beakers, add about 100 mL of water, add approximately 2 grams of salt, and stir. Place the electrodes of the multivibrator (if available) in the salt solution, and take note of the intensity of the sound.
- Once stirred, put approximately half of the salt water into one of the test tubes.
- Set up the apparatus as shown. Clamp the test tube with the salt water to the laboratory stand. Place the beaker with cold, fresh water onto the tripod, using the wire gauze to balance the beaker on top.
- Light the Bunsen burner. Allow the water to heat to a boil. After a few moments, there should be water collecting in the second test tube.
• Once approximately half of the water has gone from one test tube to the other, turn off the Bunsen burner.
• Test the water in the distilling and collecting tubes with the multivibrator. Compare these sounds to the sound of the original salt solution.

Data Collection:

Taste the salt water still in the beaker. How salty is it?  
__________________________

Place the bottom of the first test tube into cold water. Once cooled enough to touch, taste the water in the test tube. How does the saltiness relate to the water in the beaker?  
__________________________

Taste the water in the second test tube. How does the saltiness relate to the water in the beaker?  
__________________________

Is the sound of the multivibrator in the remaining salt solution louder, softer, or the same as in the original solution?  
__________________________

Is the sound of the multivibrator in the distilled water louder, softer, or the same as in the original solution?  
__________________________

Did you expect to hear a sound? Why?
What conclusions can you make from these observations? ____________________________
____________________________________________________________________________________________________________
____________________________________________________________________________________________________________

5.4 Conductivity of Acids

The focus of this experiment is to discover which acids are conductive and which acids are not.

Materials:
- Low voltage power source
- Multivibrator
- 3 Electrical cords
- 2 Alligator clips
- Electrode beaker
- Graduated cylinder, 100 mL
- Hydrochloric Acid, HCl, 1M
- Sulfuric Acid, H₂SO₄, 1M
- Acetic Acid, 1M
- Citric Acid, 1M
- Oxalic Acid, 1M

Instructions:
• Attach the power source’s positive direct current connection to an electrode in the electrode beaker using an electrical cord and an alligator clip.
• Attach the power source’s negative direct current connection to the negative connection of the multi-vibrator using an electrical cord.

Figure 10: Conductivity Setup
• Attach the positive multi-vibrator connection to the unoccupied electrode in the electrode beaker.
• Measure out 25 mL of hydrochloric acid in the graduated cylinder, and pour into the electrode beaker.
• Turn on the low voltage power source to 6 Volts.
• After making observations, turn off the power source, properly dispose of the hydrochloric acid, rinse the electrode beaker with distilled water, and repeat, using sulfuric acid, acetic acid, citric acid, and oxalic acid.

Data Collection:

For each acid, did you hear a sound from the multi-vibrator? If so, how loud was it?

<table>
<thead>
<tr>
<th></th>
<th>HCl</th>
<th>H2SO4</th>
<th>Acetic Acid</th>
<th>Citric Acid</th>
<th>Oxalic Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

How is electricity conducted through the acid? Why do some acids conduct better than others do?

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
5.5 Conversion of Energy

**Electrical energy can be converted into heat energy.**

**Materials:**
- Thermometer
- Beaker with lid and heating element
- Water
- Ammeter
- Voltmeter
- Power source
- Switch
- Stopwatch

![Figure 11: Heating Element Setup](image)

**Instructions:**
- Fill the beaker with 100g of water.
- Construct a circuit connecting the power source to the switch to the beaker’s electrodes to the ammeter in series. Connect the voltmeter to the ammeter and the switch in parallel with the beaker.
- Place the thermometer through the lid of the beaker into the water and read the initial temperature. Place your hand(s) around the beaker before the temperature is read.
- Set the power source to 5 volts. Close the switch for 5 minutes. Keep your hand(s) on the beaker during this time.
- Write down the reading on the ammeter during the warming period in the chart below.
- Write the final temperature after the 5 minutes have passed in the chart below.
- Did you feel any temperature change?
- Calculate the number of joules of energy absorbed by the water and the joules of energy that the power source produced.
- Repeat the experiment with 10, 20, and 30 volts. If the beaker becomes too hot for you, let go – you only need to record whether you could feel a temperature difference.
**Data Collection:**

<table>
<thead>
<tr>
<th>Energy Absorbed</th>
<th>Volume of water</th>
<th>Temperature change</th>
<th>Energy</th>
<th>in kg</th>
<th>in J</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (J) = 0.001</td>
<td>* 100g</td>
<td>* _______ºC</td>
<td>=</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E (J) = 0.001</td>
<td>* 100g</td>
<td>* _______ºC</td>
<td>=</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E (J) = 0.001</td>
<td>* 100g</td>
<td>* _______ºC</td>
<td>=</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E (J) = 0.001</td>
<td>* 100g</td>
<td>* _______ºC</td>
<td>=</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Produced</th>
<th>Voltage</th>
<th>Amps</th>
<th>Time</th>
<th>=</th>
<th>Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (J) = 10</td>
<td>* 5V</td>
<td>* ______ A</td>
<td>* 5 * 60 s</td>
<td>=</td>
<td>______ J</td>
</tr>
<tr>
<td>E (J) = 10</td>
<td>* 10V</td>
<td>* ______ A</td>
<td>* 5 * 60 s</td>
<td>=</td>
<td>______ J</td>
</tr>
<tr>
<td>E (J) = 10</td>
<td>* 20V</td>
<td>* ______ A</td>
<td>* 5 * 60 s</td>
<td>=</td>
<td>______ J</td>
</tr>
<tr>
<td>E (J) = 10</td>
<td>* 30V</td>
<td>* ______ A</td>
<td>* 5 * 60 s</td>
<td>=</td>
<td>______ J</td>
</tr>
</tbody>
</table>
5.6 Wave Generation

The focus of this experiment is to explore waves and resonance frequencies.

Materials:
- Sound tube with speaker and microphone
- Signal generator with tactual labels
- Oscilloscope with tactual labels
- Connecting wires

Instructions:
• Connect the signal generator to the speaker in the sound tube.
• Connect the oscilloscope to the microphone in the sound tube.
• Turn the signal generator to 2000 hertz and listen to the noise given by the sound tube.
• Extend the sound tube until the noise reaches a maximum level.
• Record the length of the tube at this point.
• Students with sight can note the change in wave pattern on the oscilloscope.
• Continue to extend until the noise reaches another maximum.
• Record the length of the tube at this point.
• Repeat for the length of the tube.
• Change the frequency to 3000 Hz and repeat the process. Then change to 4000 Hz and repeat the process.

Data Collection:

<table>
<thead>
<tr>
<th></th>
<th>2000 Hertz</th>
<th>3000 Hertz</th>
<th>4000 Hertz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of tube:</td>
<td>Difference of lengths</td>
<td>Length of tube:</td>
<td>Difference of lengths</td>
</tr>
</tbody>
</table>
6 Resource List

Organizations for the Blind and Visually Impaired

Closing the Gap
Specializes in use of technology for those with disabilities.
www.closingthegap.com

Comprehensive company listings for producers of adaptive equipment
http://www.hicom.net/~oedipus/blind.html#alpha/
http://www.nyise.org/speech/vendors.htm
www.abledata.com

Databases for general blindness and visual impairment sites
www.trace.wisc.edu
http://edtech.sandi.net/epd/VIResources.html
http://www.rdcbraille.com/webdis.html

Emerging technology sites
http://www.ece.udel.edu/InfoAccess/
http://www.touchgraphics.com/

Remedia Publications
www.rempub.com
Provide teaching materials for blind and visually impaired students, as well as teacher information and idea exchange

Resources for Parents and Teachers of Blind Kids
Members.home.net/ddays/blindkids.html
Provides links to many sites with information or materials for education of blind and visually impaired students.

Science and Experimental Resources

Barrier Free Education
http://rush.arch.gatech.edu/index.html
Offers complete laboratory experiments modified for various disabilities, as well as general teaching suggestions and information.

CAST: Center for Applied Special Technology
http://www.cast.org/
Provides guidelines for teaching, tools, and further resources.
Disability Books
http://www.manasota.com/books/
Source of literature about various disabilities and assistive technologies, as well as audio books.

DO-IT Program, University of Washington
http://www.washington.edu/doit/
Offers resources and presentation materials for K-12, science, and mathematics teachers, as well as suggestions regarding the use of technology in the classroom and related links to other web sites.

EASI: Equal Access to Software and Information
http://www.rit.edu/~easi/index.htm
Gives explanations of common tactile graphics and lab equipment, as well as suggestions for teaching math.

Inclusion in Science Education for Students with Disabilities:
http://www.as.wvu.edu/~scidis/sitemap.html
Suggests strategies, organizations, resources, books, and videos about a variety of disabilities.

National Center to Improve Practice in Special Education through Technology, Media and Materials (NCIP) – Spotlight on Voice Recognition
http://www2.edc.org/NCIP/vr/toc.html
A newsgroup regarding voice recognition technology.

The Science Access Project (SAP) University of Oregon
http://dots.physics.orst.edu/
Offers downloadable scientific tool software with audio output, such as graphing calculators, for the computer.

Science and Disability Web Sites
http://people.delphi.com/LUNNEY/RELSITES.HTM
Consists of a list of web sites that contain information regarding disabilities and science (several of the links on this site are outdated). Many of the sites below are also listed on this site.

Science Education for Students with Disabilities
http://www.as.wvu.edu/~scidis/organizations/sepd_main.html
An online newsletter about science education.
Danish Organizations for the Blind and Visually Impaired

The Institute for the Blind
Rymarksvej 1
DK-2900 Hellerup
Tel + 45 39 45 25 45,
ibos@ibos.dk
www.ibos.dk

Refsnæsskolen
Kystvejen 112
DK-4400 Kalundborg
Tel +45 59 57 01 00

Synskonsulenternes Samråd

Individual Contacts
Bendt Nygaard Jensen
Dorte Silver
Videncenter for Synshandicap
Rymarksvej 1
DK-2900 Hellerup
Tel +45 39 46 01 01
Fax +45 39 61 94 14

Hans Nørgaard
Syncentralen
Institut for Synshæmmede
Kuskevej 3
DK-4760 Vordingborg
Tel +45 53 77 33 33
Fax +45 53 77 39 09

Eric Brown
Poul Gaardhøje
Lindebjergskolen
Store Valbyvej 248 B
Gundsølille
DK-4000 Roskilde

Bendt Gufler
Lindebjergskolen
Nygårdsvej 62
DK-4700 Næstved