Experiments and Demonstrations

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Latest Edit 9/12/2014

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1 Introduction

Here we present experiments and demonstrations for students of all ages, people who want to know and understand. This list will be edited and revised over time. The rather grand idea is to have a kind of Science Museum that would function like a public library, with experiments, demonstrations, and apparatus, serving as the books. We shall give Internet references and YouTube links. We invite general participation in this endeavor. Ideally this might be done in a Wiki on the net, where contributors could add and edit

entries. Temporarily, we could use email, sending information to a central point. Perhaps I might serve temporarily as such a point:
jdemery@member.ams.org
In order to generate notice we need to physically construct apparatus for demonstrations.

Secondly, perhaps a subgroup of us will pursue the acquisition of resources and the creation of a formal plan for this activity. Below we make a start on a list. We realize that some elements of this list are familiar and obvious cliches.

As we create experiments and do demonstrations, we should record them with pictures and videos, that would be placed on our website.

2 The Exploratorium

The Exploratorium in San Francisco is a model for science museums. There was a NOVA program in the early eighties on the exploratorium and its founder Frank Oppenheimer. He is the brother of J. Robert Oppenheimer. This program is called "The Palace of Delights," and can be viewed on the Exploratorium WEB site:
http://www.exploratorium.edu/frank/index.html

3 Household Science

Ignorance of elementary science makes people do very silly things in ordinary life. This can be quite irritating. Does a fan cool the air? Can you clean a greasy plate by soaking it in water? What is soap? What does a detergent do? Can you increase the temperature of boiling water by turning up the flame? What is it about oil or fat that prevents burning food in a frying pan? If your dog chews the electric cord, can the juice leak out? What is the difference between AC and DC, and between analog and digital. What is radiation? If you open just one window, will the cool air come in? Does a penicillin shot cure a cold? If one is driving down a flat icy road in a straight line, can the car suddenly go off the road and crash into a tree? Schools should make a special effort to erase these implied misconceptions.

4 Mathematical Puzzles and Curiosities

We should devise physical puzzles and models that illustrate mathematics. One could demonstrate a mean spirit by creating a race between two people to solve the fifteen puzzle, after one of the puzzles has been modified by physically transposing two of the numbers. This makes that puzzle impossible to solve. One could show how to construct an algorithm to make magic squares, and then write a computer program that performs the algorithm. We could present a proof that all triangles are isosceles, and so show that mathematics is about thinking, not about rapid and accurate calculation. We could present the proof that a horse has no legs. Or we could create coin puzzles to show that money can be interesting.

5 Making a Polymer

Elmer's glue (polyvinyl acetate) and Borax can be used to cross-link a polymer, and make a material similar to silly putty.
http://www.stevespanglerscience.com/experiment/00000039

Ethylene is the compound H_2CCH_2, an unsaturated hydrocarbon with a carbon double bond.

Vinyl is the univalent chemical radical CH_2CH, derived from ethylene.

The acetate anion, $[CH_3COO]-$, is a carboxylate and is the conjugate base of acetic acid. The acetate ion is formed by the deprotonation of acetic acid:

$$CH_3COOH \rightarrow CH3COO^- + H^+$$

polyvinyl acetate, PVA, is the polymer chain

$$(H_2CCHOOCCH_3)_x$$

As an emulsion in water, PVA is sold as an adhesive for porous materials, particularly wood, paper, and cloth. It is the most commonly used wood glue, both as "white glue" and the yellow "carpenter's glue."

PVA is widely used in bookbinding and book arts due to its flexibility, and because it is non-acidic, (unlike many other polymers) is used extensively in paper, paint and industrial coatings when it is referred to as vinyl acrylic.

It is slowly attacked by alkali, forming acetic acid as a hydrolysis product. Boron compounds like boric acid or borax will form tackifying precipitates by causing the polymer to cross-link.

Retrieved from

`http://en.wikipedia.org/wiki/Polyvinyl_acetate`

6 Chemistry 101, The Elements

Click the link below and study chemistry with a song by Tom Lehrer.
http://www.privatehand.com/flash/elements.html

7 The Current and Voltage of A Lemon Battery

A battery made from a lemon, a zinc galvanized nail, and a copper coin generates a voltage. But is there enough current to illuminate a light bulb?

YouTube Create a Lemon Battery

YouTube Lemons for Mr. Wizard

8 Electrophoresis

Large molecules often have charges on their surfaces. An electric field gradient due to a voltage difference, in a wet paper towel, or more professionally in a gel, can lead to the separation of molecules due to a variation in their speed of migration. This is widely used in biology.

Reference:
http://en.wikipedia.org/wiki/Electrophoresis

9 Radiation, Geiger Counters, Photoelectric Cells, Light Meters, Solar Cells

The photoelectric effect can be demonstrated with an electroscope and a source of ultraviolet light. The electroscope is statically charged. The electrode of the electroscope is exposed to intense ultraviolet light. The photons discharge the electroscope.

10 Chaos in Chemical Reactions.

The Belousov-Zhabotinskii reaction in chemistry. Reference:

Ordinary Differential Equations, Oscillating Chemical Reactions, and Chaos By Niki Kittur and Modified by Roger Ahn, emails: adkittur@princeton.edu and rogerahn@princeton.edu
http://www.cs.princeton.edu/courses/archive/fall00/cs323/assign/ass3/ass3.pdf

YouTube Oscillating Chemical Reaction (Belousov-Zhabotinsky)
Wikipedia http://en.wikipedia.org/wiki/Belousov-Zhabotinsky_reaction

11 Joule-Thomson Effect

As a gas expands, the average distance between molecules grows. Because of intermolecular attractive forces (see Van der Waals force), expansion causes an increase in the potential energy of the gas. If no external work is extracted in the process (free expansion) and no heat is transferred, the total energy of the gas remains the same because of the conservation of energy. The increase in potential energy thus implies a decrease in kinetic energy and therefore in temperature.

A second mechanism has the opposite effect. During gas molecule collisions, kinetic energy is temporarily converted into potential energy. As the average intermolecular distance increases, there is a drop in the number of collisions per time unit, which causes a decrease in average potential energy. Again, total energy is conserved, so this leads to an increase in kinetic energy (temperature). Below the JouleThomson inversion temperature, the former effect (work done internally against intermolecular attractive forces) dominates, and free expansion causes a decrease in temperature. Above the inversion temperature, the latter effect (reduced collisions causing a decrease in the average potential energy) dominates, and free expansion causes a temperature increase.
This is from:
http://en.wikipedia.org/wiki/Joule-Thomson_effect

For example, if a tank of CO_2 is opened to the atmosphere, one can see a spray of fine dry ice particles emerging at about 78 degrees C.

Here is a link to an experiment:
http://www.earlham.edu/ chem/chem341/c341_labs_web/joule_thomson.pdf

Reference:
Shoemaker, Garland (and Nibbler) "Experiments in Physical Chemistry", various editions.

12 An Amplified Thermocouple

One can make a thermocouple linked with an operational amplifier to measure temperature. Such a device might be used to study the refraction of infrared radiation by measuring the temperature increase due to the radiation.

13 Laser Ray Tracing, Scattering, and Defraction

One can demonstrate the operation of a system of lenses and mirrors by using a laser pointer. Dry ice can be used to make a fog that scatters the light and makes the laser paths visible. Laser scattering in and on the surface of materials can be studied also.

14 Wireless Computer Connections

Wireless routers and computers provide a means for studying electromagnetic wave transmission, antennas, and data signal packets.

15 Geometric Optics

Many simple experiments in optics can be constructed using projectors, lenses, and mirrors.

16 Accelerometer Experiments

Some of the new computer game devices include accelerometers. These are used to sense the arm and hand motion of the player. These devices can be interfaced to computers to study various kinds of physical motion.

17 Air Table, Momentum Conservation, Elastic Collisions

A fan blowing air through small holes in a sheet, or in an angle iron, can be used to get very low friction. Such devices can demonstrate momentum conservation, conservation of energy and other mechanical principles.

18 Wheatstone Bridge Measurements

A Wheatstone bridge is a very sensitive device for measuring resistances, and detecting voltages. This could be a nice construction project. One project is to measure the internal resistance of batteries. Looking at the difference between alkaline, lead-acid, nickel-cadmium, and nickel metal hydride batteries.

19 Static Electricity

The following links concern static electricity experiments.
http://www.howstuffworks.com/vdg.htm
http://en.wikipedia.org/wiki/Van_de_Graaff_generator
http://scitoys.com/scitoys/scitoys/electro/electro6.html

Some of the classic devices for static electricity demonstrations are the Windhurst machine, the Van de Graff generator, and the Tesla coil. One can demonstrate the lighting of a fluorescent bulb with an intense electric field, make hair stand on end and so on.

Honeywell apparently has three Van de Graff generators that may be checked out and demonstrated outside of the plant.

20 Experiments With Cathode Ray Tubes

Perhaps an old computer monitor, or an old TV could be used to study electron motion and the deflection with magnets and electric fields.

21 Piezo Electricity

Piezo electricity has many very important applications, where extremely small movements are to be generated and measured such as in say atomic force microscopes, in electronic pickups, in microphones, in lighting devices, in motors. It is also is a route into the study of crystallography. Suggestions from our Piezo experts are solicited.

22 The Optical Activity of Crystals

The optical activity of crystals leads to double refraction and other amazing effects. Quartz is an optically active crystal, but only slightly so. Kansas City has several companies that manufacture quartz crystals, and perhaps could be consulted about crystal properties, piezo oscillators and so on. Birefringence was discovered in the calcite crystal in the 19th century. Reference: http://en.wikipedia.org/wiki/Birefringence

23 Young's Double Slit Experiment.

This is the classic experiment demonstrating the interference of light and thus its wave nature.

Perhaps apparatus could be constructed for this experiment. This might be combined with a photoelectric device to demonstrate the dual wave and particle nature of light.

24 Oscilloscope Measurements

Looking at the electric wave motion in an electronic circuits is very interesting and informative for students. One can study electronic discharges, and the resonance of circuits. By feeding two signals of different frequencies and phases to the horizontal and vertical deflection circuits one can view Lissajous figures, and measure phase differences. The demonstrations that one can do with an oscilloscope are almost unlimited.

25 Oscillators, Vibration

One can do demonstrations of both electrical oscillations and mechanical vibrations in various ways. A simple mechanical experiment would be to use a spring and a weight. Determine the spring constant by measuring the deflection caused by a weight of known mass. Then measure the frequency of vibration and compare to the formula value.

One can an oscilloscope to show the damped wave motion of an RLC circuit. Alternately, one can demonstrate resonance using a variable frequency source. One can use a tuning fork to demonstrate resonance and relate this to musical theory.

One can demonstrate the motion of coupled pendulums. Then one may analyze this motion by calculating eigenvalues with a computer program.

Reference:
http://www.stem2.org/je/vibra.pdf

26 Antennas, Radio, Radio Astronomy

The Linda Hall radio club could perhaps participate in demonstrations of radio transmission and antennas.

There are many sources for experiments in this area. A vary nice book on the history and science of radio and with an introduction to electrical engineering is
The Science of Radio: with MATLAB and ELECTRONICS WORKBENCH by Paul J. Nahin.

Nahin is a professor of Electrical Engineering at the University of New Hampshire. He has written a number or vary interesting books on several subjects. Linda Hall Library in Kansas City is just chock full of such books. Nahin knows his subject. The book does not suffer from being written by a journalist. Journalists typically just report second hand information without having real understanding. Most popular books on science suffer from this journalistic torture.

27 Polarized Light Experiments

A cheap pair of sunglasses that use polaroid, are a source for experiments in polarized light. Reflected sunlight from a surface tends to be polarized. So the glare from a reflected surface is eliminated with a pair of sunglasses made from polaroid, when the axis of the polaroid is at an angle of 90 degrees from the angle of the polarized glare.

A sugar solution also polarizes light and so the concentration of the solution can be determined by the angle by which polarized light is rotated.

28 Studying Stress by Using Polarized Light

Under stress, some materials can rotate polarized light by various amounts. This is the technique that was used in the "Light Shows," that were presented at rock concerts. Using a projector, beautiful images are possible.

29 The Ballistic Galvanometer and Its Modern Equivalent

The ballistic galvanometer is a galvanometer with a large moment of inertia. It can be used in an experiment to measure magnetic B and H curves of an iron body in the shape of a toroid. The deflection of the galvanometer pointer is delayed by the inertia, but because of this, it measures the total charge passing through the galvanometer. This is an old device no longer used, but interesting in itself.

This experiment is often described in electrical measurement books. This is also a demonstration of magnetic hysteresis, and heating losses in transformers.

30 Computer Interfacing and Data Collection: LabWindows

It would be very nice to have a computer with a device for data collection that could be controlled by LabWindows. Many interesting demonstrations and experiments could be generated with such equipment.

31 Measuring Field Intensity

Michael Faraday introduced the concepts of electric and magnetic fields. This solved the mysterious action at a distance of Newton's theory of gravitation. Various demonstrations should be constructed for demonstrating the various classical electric fields **E** and **D**, and the classical magnetic fields **B** and **H**. Most modern physics theories are field theories

32 Magnetic Measurements, Hall Sensors

Hall sensors can be used to measure magnetic fields. They are used in automobile ignition circuits. An older way of measuring magnetic fields was with the "snatch" coil, which used Faraday's law of induction.
http://en.wikipedia.org/wiki/Hall_effect_sensor
http://en.wikipedia.org/wiki/Hall_effect

James Clerk Maxwell put Faraday's ideas into mathematical form via has famous set of equations, which are called Maxwell's equations.

The Maxwell Equations in MKS form are

$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t},$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t},$$

$$\nabla \cdot \mathbf{D} = \rho,$$

$$\nabla \cdot \mathbf{B} = 0.$$

33 Quantum Mechanical Spooky Action at a Distance

http://en.wikipedia.org/wiki/Action_at_a_distance_(physics)
According to Albert Einstein's theory of special relativity, instantaneous action-at-a-distance was seen to violate the relativistic upper limit on speed of propagation of information. If one of the interacting objects were suddenly displaced from its position, the other object would feel its influence instantaneously, meaning information had been transmitted faster than the speed of light.

One of the conditions that a relativistic theory of gravitation must meet is to be mediated with a speed that does not exceed light speed. It could be seen from the previous success of electrodynamics that the relativistic theory of gravitation would have to use the concept of a field or something similar.

This problem has been resolved by Einstein's theory of general relativity in which gravitational interaction is mediated by deformation of space-time geometry. Matter warps the geometry of space-time and these effects are, as with electric and magnetic fields, propagated at the speed of light. Thus, in the presence of matter, space-time becomes non-Euclidean, resolving the apparent conflict between Newton's proof of the conservation of angular momentum and Einstein's theory of special relativity. Mach's question regarding the bulging of rotating bodies is resolved because local space-time geometry is informing a rotating body about the rest of the universe. In Newton's theory of motion, space acts on objects, but is not acted upon. In Einstein's theory of motion, matter acts upon space-time geometry, deforming it, and space-time geometry acts upon matter.

34 Quantum Double Slit Experiment

It would be quite interesting to present a physical demonstration of this experiment. See http://en.wikipedia.org/wiki/Double-slit_experiment

Feynman, Richard P. **The Feynman Lectures on Physics**
Tipler, Paul (2004). Physics for Scientists and Engineers: Electricity, Magnetism, Light, and Elementary Modern Physics, 5th ed., W. H. Freeman.
Gribbin, John (1999). Q is for Quantum: Particle Physics from A to Z. Weidenfeld and Nicolson.
Feynman, Richard P. (1988). QED: The Strange Theory of Light and Matter. Princeton University Press.
Sears, Francis Weston (1949). Optics. Addison Wesley.
Hey, Tony (2003). The New Quantum Universe. Cambridge University Press.
Frank, Philipp (1957). Philosophy of Science. Prentice Hall.
Greene, Brian (2000). The Elegant Universe. Vintage.

Wikipedia has a nice article and an animation:

35 Laser Cooling and Trapping

Some of the original work on laser cooling used lasers from old fax machines.

Laser cooling is a technique that uses light to cool atoms to a very low temperature. It was simultaneously proposed by Wineland and Dehmelt and by Theodor W. Hnsch and Arthur Leonard Schawlow in 1975, and first demonstrated by Letokhov, Minogin and Pavlik in 1976. One conceptually simple form of laser cooling is referred to as optical molasses, since the dissipative optical force resembles the viscous drag on a body moving through molasses. Steven Chu, Claude Cohen-Tannoudji and William D. Phillips were awarded the 1997 Nobel Prize in Physics for their work in laser cooling. See the link:
http://en.wikipedia.org/wiki/Laser_cooling

36 Mechanical Lissajous Figures.

Mechanical figures can be created by a pendulum that has modes in perpendicular directions. See the large such pendulum at the Exploratorium. If a string is suspended from two points, and a second string is tied to the center of the first string, and a weight suspended from the last string, then one has a pendulum that swings at two different frequencies. This is because when swinging in and out the length of the pendulum is longer than when it swings from side to side. So its in and out period is longer than its side ti side period. Hence is one starts the pendulum by both pulling it out and by moving to the side it will move in a Lissajous pattern. See the document
http://stem2.org/je/lissajous.pdf

37 Vibration and Oscillation, Normal Modes

For a system of harmonic oscillators one can assume a solution of the form $e^{i\omega t}$. By doing this one obtains a symmetric matrix. If we find the eigenvalues of this matrix, we can diagonalize it, by a change of variables, so that the original equations written in the transformed coordinates are uncoupled. That is each equation only depends upon one variable, and so is easily solved. These transformed coordinates are called normal coordinates. See any book on vibration theory or the document:
http://stem2.org/je/vibra.pdf

38 Quantum Dots

A quantum dot is a semiconductor whose excitons are confined in all three spatial dimensions. As a result, they have properties that are between those of bulk semiconductors and those of discrete molecules. I don't know if there is a simple experiment that can be performed in this area.

http://en.wikipedia.org/wiki/Quantum_dot

39 Nanotechnology

Nanotechnology is a rather nebulous field. The Dummies book on Nanotechnology gives a pretty good outline of the scope of nanotechnology. Vaguely, nanotechnology is technology that involves very small distances on the order of a nanometer. But is different than the chemistry and physics of molecules and atoms. The field is supposed to have developed after Richard Feynmann, the Physicist, proposed a challenge and a reward for someone to construct a tiny tiny motor. I think Feynman's paper is called something like "There's Plenty of Room at the Bottom." This whole field is rife with hype.

40 Explanation of Experiments

Sometimes the problem with amazing science demonstrations, which feature great sparks and bangs, is that there is an absence of explanation, and so an absence of real understanding. So the gravity experiment of throwing a student from the school roof (perhaps onto a pile of mattresses) could be quite amazing, certainly at least to the student. But it is not a real explanation of gravity. So we must give an explanation of the science behind the experiment. And also one should not worry greatly about the explanation being "over the head of the student." The idea should be to spark the curiosity, and to motivate one to greatly desire explanation, and to motivate one to pursue the studies that would lead to an understanding. The idea often given in writing classes, that the writing should never be geared above the audience level, is wrong. This advice might be suitable for the people going into advertising writing, but not for those who want to encourage the attainment of real knowledge. As Einstein said, "An explanation should be as simple as possible, but no simpler."

41 Companion Computer Programs.

Computer programs should be given to illustrate the experiments. Computer programs that generate numbers and plots and graphic images are always helpful and can be written for almost all demonstrations. Such programs are companions to physical experiments. And we should write a collection of these.

42 Losses in Transmission Lines

Mathematical analysis of the behavior of electrical transmission lines grew out of the work of James Clerk Maxwell, Lord Kelvin and Oliver Heaviside. In 1855 Lord Kelvin formulated a diffusion model of the current in a submarine cable. The model correctly predicted the poor performance of the 1858 trans-Atlantic submarine telegraph cable. In 1885 Heaviside published the first papers that described his analysis of propagation in cables and the modern form of the telegrapher's equations.

This is from:

http://en.wikipedia.org/wiki/Transmission_line

Show how a transmission line connecting two computers will not reliably transfer data if it is too long.

43 Demonstration of Fluorescence

Fluorescence is a luminescence that is mostly found as an optical phenomenon in cold bodies, in which the molecular absorption of a photon triggers the emission of another photon with a longer wavelength. The energy difference between the absorbed and emitted photons ends up as molecular vibrations or heat. Usually the absorbed photon is in the ultraviolet range, and the emitted light is in the visible range, but this depends on the absorbance curve and Stokes shift of the particular fluorophore. Fluorescence is named after the mineral fluorite, composed of calcium fluoride, which often exhibits this phenomenon.

This is from:

http://en.wikipedia.org/wiki/Fluorescence

44 Speed Control of Electric Motors

We can demonstrate speed control in a battery powered electric drill, by viewing the wave shape of the input voltage. The behavior of fractional horsepower AC induction motors can be demonstrated by measuring the current and the voltage and showing the phase angle between them under various loads to calculate the power factor.

45 Gyroscopes

A weighted bicycle wheel, and a rotating stool may be used to illustrate the properties of a gyroscope. The weight can be supplied by winding wire many times around the rim. However, the cost of wire is now very high. So perhaps someone can think of another method. Also we would need some hand grips that would screw onto both sides of the axel. Also a motor to give the wheel a nice spin would be welcome. Also one of the hand grips should have an eyelet at the end so that the wheel could be suspended on one side by a single rope, thus apparently defying gravity.

46 The Conservation of Angular Momentum

One can build a low friction rotating platform using skateboard wheels, to demonstrate the spinning ice skater effect. The victim would stand on the platform with arms extended, while clutching barbells in each hand. After having been given a good spin, the arms are drawn in, to dramatically increase the angular velocity. A rotating stool with good bearings could also be used if the legs were removable.

47 Extracting and Amplifying DNA

One could present models of the structure of DNA, of proteins, of viruses and so on. Then from mouth scrapings, one may lyse the cells to release the DNA. Then amplify the amount of DNA using the polymerase chain reaction (PCR), which was developed in 1983 by Kary Mullis, who received the Nobel prize for this, and who once was at the KU Medical Center, and whose son and ex-wife remained in Kansas City after he left for surfing in San Diego, and whose son attended Pembroke-Country Day school.

48 Chromatography

One can demonstrate elementary chromatography using leaves, or colored inks. Water moves upward in a paper towel by surface tension and the water carries molecules of the ink upward at varying speed depending on the size and properties of the various pigment molecules, and thus separates the molecules. These separated molecules give the towel various colors. By drying the towel, the various sections can be removed and the molecules thus isolated.

49 Genomic Computations

See the book called **Genomic Perl,** which describes various genomic computations. The Perl program could be run on a computer to demonstrate various genetic properties.

50 Electrochemistry and Electroplating

One could demonstrate the potentials of various metals, the working of batteries, the plating of metals and show the electrolysis of water (the electric separation of oxygen and Hydrogen.
http://en.wikipedia.org/wiki/Electrolysis_of_water

51 Constructing an Antenna

We can construct a cheap antenna capable of creating strong signals from the new weak digital television signals. Using reflection to increase the antenna gain. We might Investigate the concept of antenna temperature, the parabolic antenna, Black body radiation, radio astronomy, and model the spherical giant radio telescope at Aricebo in Puerto Rico.
http://en.wikipedia.org/wiki/Arecibo_Observatory

52 Reconstructing Ancient Experiments.

We could reconstruct the Hertz experiment that lead to the discovery of electromagnetic waves. And reconstruct the experiment by William Herschel that lead to the discovery of Infrared radiation by sensing heat from refracted sunlight through a prism.

Herschel discovered infrared radiation by passing sunlight through a prism and holding a thermometer just beyond the red end of the visible spectrum. This thermometer was meant to be a control to measure the ambient air temperature in the room. He was shocked when it showed a higher temperature than the visible spectrum. Further experimentation led to Herschel's conclusion that there must be an invisible form of light beyond the visible spectrum.
From: http://en.wikipedia.org/wiki/William_Herschel

53 The Equipartition of Energy.

The Equipartition of Energy is a result from the kinetic theory of gases and statistical mechanics.

Here is a link to my document on Statistical Mechanics:
www.stem2.org/je/statmech.pdf

This shows that various gases have different specific heats depending upon the degrees of freedom of molecules. I don't know if we could create a simple experiment demonstrating this.

54 The Wilberforce Pendulum.

A helical spring connected to a mass can oscillate up and down, and can oscillate in a rotational mode. With proper choice of the parameters, energy can be periodically transferred between the two modes. The system rotates for a while, then stops and goes into translational oscillation. A reference for the physics and mathematics of this is:

Wilberforce pendulum oscillations and normal modes, Richard E. Berg and Todd S. Marshall, Lecture-Demonstration Faculty, Department of Physics and Astronomy, University of Maryland, College Park, Maryland 20742, Am. J. Phys., Vol 59, No 1, January 1991.
http://faraday.physics.utoronto.ca/PHY182S/WilberforceRefBerg.pdf

Download A Quicktime Movie: **Wilber big.mov** from the University of Illinois:
http://demo.physics.uiuc.edu/LectDemo/scripts/demo_descript.idc?DemoID=191
Go to more info, then select big.mov. If the quicktime plug in has a problem, right click on big.mov, and select "save target as" and execute the movie outside of the browser using quicktime (file saved as "wilberbig.mov").
http://www.stem2.org/je/wilberbig.mov

55 The Magnetron

Perhaps we could make use of the magnetron from an old microwave oven for microwave experiments. I don't know if this is possible.

56 Coupled Pendulums

See the example in the 1983 NOVA program on the Exploratorium, which is available on the Internet. Or see a picture of the coupled pendulum demonstration that I made, and an analysis of it in
www.stem2.org/je/vibra.pdf

57 Mechanical Linkages

See the Quicktime movie from Cornell university on the net. See the pictures of the straight line linkage, and the inversion in a circle linkage, that I constructed. See the pictures on stem2. See also my related Watt mechanism, pantograph, and ellipse drawing mechanism.
Peaucellier-Lipkin Linkage:
http://kmoddl.library.cornell.edu/tutorials/05/
See file peaucellierlipkin.mov in the directory movies on the C drive.

58 Gear Motion

I have an animation program showing the tooth motion in mating involute gears. Originally this program was written for an Apollo Workstation, and was quite beautiful. Physical models of large gears, made say of wood, would demonstrate the rolling motion of gear teeth in involute gears. This would also demonstrate the transmission of constant rotational velocity. It is an interesting fact, that one of the first, if not the first, PhD in Physics, that was granted by an American university, was granted to the great J. Willard Gibbs by Yale. The subject of his thesis was involute gears. Gibbs went on to invent Vector Analysis and much of Statistical Mechanics.

59 Tribology or Friction

The coefficient of friction can be greater than one, because the attraction of the surface molecules of two bodies can be very large. Two metal blocks machined very smooth after being brought together can require great force to separate. Friction is still not completely well understood theoretically.

60 Steering Control, Steering Geometry

The application of steering geometry to robotics is of interest to students in the high school robotics projects. We might be able to get one of the robotics kits in order to help the students understand steering geometry. Currently it looks like steering is accomplished in the robots by just controlling the speed of the motors that drive the wheels?

61 Mechanical Advantage, Energy, Transmissions

Many physical devices can be presented to demonstrate mechanical work, energy, force, and acceleration. This could include jacks, screws, wedges, levers and so on.

62 Ignition Coil, Spark Plugs

An old automobile ignition circuit could be demonstrated with breaker points coil and so on. In the same way a small engine magneto from an old lawn mower engine could be used.

63 Metallurgy and Welding

One could etch with acid to show grain boundaries in metals, which would be examined with a microscope. Welding could be demonstrated, although this could be a little dangerous if not done in the proper place, and also there is the danger of eye damage from ultraviolet light. Properties of steel could be studied in various ways. Iron could be heated to locate the Curie point where it is no longer magnetic. The process of hardening steel could be demonstrated with an acetylene torch or a carbon arc torch.

It is interesting that as voltage is increased in a carbon arc there is a region of negative resistance. Early days radio because of this used a carbon arc to get a continuous oscillation for wave generation. This was called the arc transmitter.

64 Plasma

In physics and chemistry, a plasma is typically an ionized gas. Plasma is considered to be a distinct state of matter because of its unique properties. Ionized refers to presence of one or more free electrons, which are not bound to an atom or molecule. The free electric charges make the plasma electrically conductive so that it responds strongly to electromagnetic fields.

Plasma typically takes the form of neutral gas-like clouds (e.g. stars) or charged ion beams, but may also include dust and grains (called dusty plasmas).[1] They are typically formed by heating and ionizing a gas, stripping electrons away from atoms, thereby enabling the positive and negative charges to move more freely.
From: http://en.wikipedia.org/wiki/Plasma_(physics)

Perhaps we could demonstrate a plasma cleaning chamber.

65 Induction Heating and Eddy Currents

Some topics that could be demonstrated are heat treating, the skin effect, eddy currents in the electric power meter.

66 The Mathematics of Robotics

Rotation and translation matrices. The general affine transformation. Rotational degrees of freedom.

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67 Precision Measurement

Micrometers, gauges, optical methods, interference fringes, Newton's rings, measuring flatness. Glass blocks. Sine blocks. Newton fringes to measure flatness.

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68 Interferometers

One might demonstrate the ability to measure distance by counting light interference fringes. Or perhaps determining the flatness of a surface by observing Newton fringes. Another topic in this area is the Michaelson-Morley experiment and its connection with Special Relativity.

69 The Statistics of Experimental Error

The computer could demonstrate concepts in experimental error, response surfaces, and the design of experiments. Perhaps the statistical programming language which is called the R language could be used. Elementary concepts include that of standard deviation, mean, the normal distribution, survey sampling, statistical quality control and so on.

70 The Design of Experiments

Demonstrate that statistical theory can be used to minimize the necessary trials in an experiment to obtain a given statistical accuracy. Perhaps some simple experiments could be devised to demonstrate the importance of the design of experiments.

71 Black Smithery, Building a Forge

One might construct and demonstrate a gas forge that uses gas welding tips, or construct a traditional coal forge showing how a temperature can be reached to weld iron by supplying air with bellows or a blower. Place here references from the web.

72 The Carbon Arc

The carbon arc has been used in big spot search lights, in welding, in movie projectors, and in early radio transmitters. Perhaps some device could be constructed that is not too dangerous. A problem with carbon arcs is that as the arc burns it uses up the carbon rod, so one often needs some automatic gap controlling mechanism.

73 Optics, Telescopes, and Microscopes

Demonstrations topics and objects include: mirrors, lenses, shapes of mirrors, chromatic aberration, lense matrices, achromatic lenses and so on.

74 Solar Heating

Some topics are: Solar panels, Connecting to the power grid, Direct current, Inverters to give AC

75 The Atmosphere, The Greenhouse Effect, Ultraviolet, Infrared

Properties of atmospherical gases, absorbtion, scattering

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76 Entropy

Thermodynamics and Statistical Mechanics.

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77 The Calculus of Variations, The Brachistochrone, Hamilton's Principle

The Brachistochrone is the curved path that minimizes the time for a mass to from one point to a lower point under gravity. Reference: http://www.stem2.org/je/brachistochrone.pdf

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78 Scanning Electron Microscope

http://www.stem2.org/je/sem.mov

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79 Simple and Compound Pendulums

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80 Stopping Wave Motion With a Stroboscope

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81 High Speed Photography

Motion too fast for the eye can be studied. The PBS Nova series airs "Edgerton and His Incredible Seeing Machines," a program based on a film originally produced by Nebraska Educational Television that explores the career and inventions of Harold Eugene Edgerton of MIT and documents the development of stroboscopic photography. Edgerton and His Incredible Seeing Machines NOVA explores the fascinating world of Dr. Harold Edgerton, electronics wizard and inventor extraordinaire, whose invention of the electronic strobe, a "magic lamp," has enabled the human eye to see the unseen. Original broadcast date: 01/15/85

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82 The Fountain Pen, Capillary Flow

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83 Parabolic Solar Collectors

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84 Observing Brownian Motion

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85 The Climbing Spark of Scifi Movies

Use a high voltage transformer to demonstrate this effect. A transformer from an old neon sign works. Jacobs Ladder (Climbing Spark) The classic Frankenstein high voltage climbing spark.

http://www.phys.ufl.edu/demo/demobook/electricalpages.htm ....
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86 Nitrogen Triiodide Chemistry Demonstration

The first step is to prepare the NI_3. One method is to simply pour up to a gram of iodine crystals into a small volume of concentrated aqueous ammonia, allow the contents to sit for 5 minutes, then pour the liquid over a filter paper to collect the NI_3, which will be a dark brown/black solid. However, if you grind the pre-weighed iodine with a mortar/pestle beforehand a larger surface area will be available for the iodine to react with the ammonia, giving a significantly larger yield. The reaction for producing the nitrogen triiodide from iodine and ammonia is:

$$3I_2 + NH_3 \rightarrow NI_3 + 3HI$$

You want to avoid handling the NI_3 at all, so my recommendation would be to set up the demonstration in advance of pouring off the ammonia. Traditionally, the demonstration uses a ring stand on which a wet filter paper with NI_3 is placed with a second filter paper of damp NI_3 sitting above the first. The force of the decomposition reaction on one paper will cause decomposition to occur on the other paper as well. For optimal safety, set up the ring stand with filter paper and pour the reacted solution over the paper where the demonstration is to occur. A fume hood is the preferred location. The demonstration location should be free of traffic and vibrations. The decomposition is touch-sensitive and will be activated by the slightest vibration. To activate the decomposition, tickle the dry NI_3 solid with a feather attached to a long stick. The decomposition occurs according to this reaction:

$$2NI_3(s) \rightarrow N_2(g) + 3I_2(g)$$

In its simplest form, the demonstration is performed by pouring the damp solid onto a paper towel in a fume hood, letting it dry, and activating it with a meter stick. Tips: Caution: This demonstration should only be performed by an instructor, using proper safety precautions. Wet NI_3 is more stable than the dry compound, but still should be handled with care. Iodine will stain clothing and surfaces purple or orange. The stain can be removed using a sodium thiosulfate solution. Eye and ear protection are recommended. Iodine is a respiratory and eye irritant; the decomposition reaction is loud. NI_3 in the ammonia is very stable and can be transported, if the demonstration is to be performed at a remote location. How it works: NI_3 is highly unstable because of the size difference between the nitrogen and iodine atoms. There is not enough room around the central nitrogen to keep the iodine atoms stable. The bonds between the nuclei are under stress and therefore weakened. The outside electrons of the iodine atoms are forced into close proximity, which increases the instability of the molecule. The amount of energy released upon detonating NI_3 exceeds that required to form the compound, which is the definition of a high yield explosive.

What You Need:

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up to 1 g iodine (do not use more),
concentrated aqueous ammonia (0.880 S.G.),
filter paper or paper towel,
ring stand (optional),
feather attached to a long stick.
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http://chemistry.about.com/od/demonstrationsexperiments/ht/triiodide.htm

87 Photoelectric Effect

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Photoelectric effect by Andrew
http://www.youtube.com/watch?v=Rjc_oXFT448
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http://www.youtube.com/watch?v=4bscKD7V0Vg&NR=1

88 Metalurgy: Heated Iron Wire

http://www.stem2.org/je/hotwire.pdf

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http://physicslearning.colorado.edu/PiraHome/Sutton/PDFs/start.pdf
Files are in directory: (c:/je/pdf/demonstrationexperiments)

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