

Part II: Exploration

Day 15: class discussion

Materials;

- Article "What Astronomers Do" (appendix C) one per student
- Overhead projector film (optional)
- Pictures of Astronomers (make sure you have a good mix of men and women)
- Web Page worksheet

Ask the class the question: What do astronomers do?

List all reasonable answers from the class on an overhead film or board.

Have the class read "What Astronomers Do" Appendix B

Use slides "Astronomers of the Past" and "Women Astronomers" Astronomical Society of the Pacific or gather images of astronomers from the web. (see Appendix B for resources)

Assignment: Astronomer web page, each student will produce a web page on an astronomer. **Suggestion:** have the girls research women astronomers and the boys research male astronomers. Each student in the class should do a different astronomer. Students should be given a couple of weeks to complete this project.

Web Page

Minimum requirements:

- a. Name with birth year and year died (if applicable)
- b. Picture
- c. Information about childhood, parents, birthplace, interests, education, etc.
- d. Family, husband or wife, children (if any)
- e. Scientific pursuits and accomplishments (include any awards earned)
- f. References
- g. Links to related sites and information

Additional points will be awarded for:

- a. Banner heading
- b. Additional images related to the scientific accomplishments
- c. Background image or color that enhances the overall web page
- d. Information and/or links to information about associates.

Astronomer Web Page

You will be adding to the class Space Web Page this time you will create a page on an astronomer. Please select an astronomer; you must get the teachers approval before you start your research. Below is a checklist for the web page and a timeline.

Astronomer: _____
(girls must choose a female astronomer and boys must chose a male astronomer)

Minimum Requirements

- Astronomers name
- Date of birth and date of death (if applicable)
- Parents
- Birth place
- Education
- Scientific accomplishments/awards
- References
- Links

Bonus Points

- Banner heading
- Background image or color
- Images related to scientific accomplishments
- Information or links to information about associates

Make sure that you do not make you web page overly busy.

Timeline

Due Dates: (write in the dates below)

Chose astronomer

Story board of web page

Bibliography

Web page completed

Day 16 and 17: class discussion

Materials:

- Article "Tools of the Astronomer" (appendix B) one per student
- Overhead film (optional)

Ask the question: What tools do astronomers use?

List all reasonable responses on the overhead or blackboard.

Have the students read "Tools of the Astronomer" After the students have finished reading the article return to the list made earlier. Ask the students if they want to add to the list.

Once the students have completed the list review some of the tools uses by astronomers:

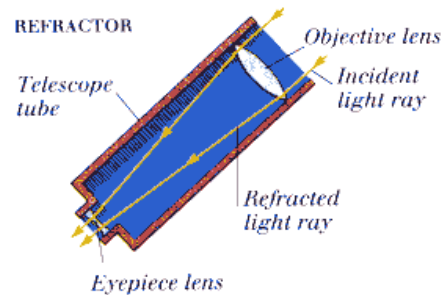
Background information for teachers

Optical telescopes

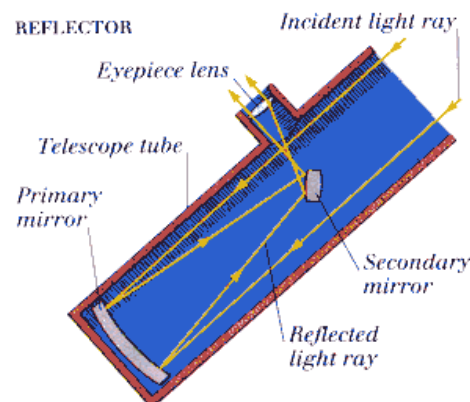
Newtonian Reflector: ??The reflector telescope (also referred to as a Newtonain after the astronomer Sir Isaac Newton) is the most common type of large-aperture telescope. A reflector focuses light by using mirrors. It is essentially a hollow tube with a large mirror at one end and a smaller mirror at the other end. The smaller mirror reflects the image through an eyepiece located on the side of the tube. Since reflectors do not contain glass lenses, they are light weight and inexpensive to manufacture. This simple design provides tremendous light-collecting capability at low costs. Reflectors are the expensive type of telescope per aperture size. They are quite easy to make. Many amateur astronomers consider their own telescope as somewhat as a rite of passage. Although they are not as good as refractors for planetary observing, reflectors are ideal for observing faint deep-sky such as nebulae and galaxies. The mirrors require alignment for optimal viewing, but can easily be adjusted. they have no glass lens on the front of the tube, reflectors as susceptible to dew as other telescopes. They can be both the equatorial mount as well as the Dobsonia n Due to their low cost, Newtonian reflectors are a good for someone just starting out in astronomy.

?

Reflector: ??Reflector telescopes can usually be distinguished by their long, narrow tubes. Unlike reflectors, refracting telescopes use a series of lenses to focus the The weight of the glass lenses, in addition to the length of tube, limits refractors to small apertures. Refractors with apertures larger than 4 inches can be quite expensive and quite large. These telescopes are almost exclusively used with equatorial mounts. The advantage of the refractor is in its ability to provide a sharp image with a lot of detail. This makes them ideal for lunar and planetary observing and photography. Their small aperture size means they are not quite as well suited for deep-sky observing. For the beginner interested primarily in the planets, they can make a good choice. Due to their design, however, they are much more expensive than their Newtonian reflector counterparts. If you are more interested in galaxies and nebulae, you will probably be better off going with a reflector.



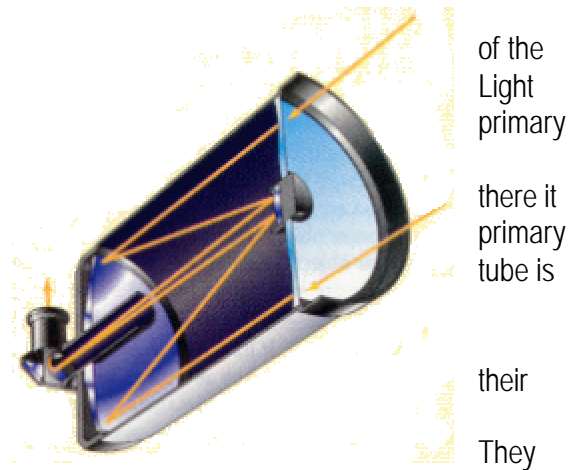
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Schmidt-Cassegrain: The Schmidt-Cassegrain is a relatively new design that manages to catch the best of both worlds. It contains elements of both the reflector and the refractor. This design uses two mirrors to bounce the light up and down the tube and then through an opening in the back where the eyepiece is located. The front tube contains a glass lens known as the corrector plate. Light enters through the corrector plate where it strikes the mirror in the back of the tube. It is then reflected to a small secondary mirror attached to the front corrector plate. From there it is then reflected through a small hole in the back of the primary mirror. Because the light path is essentially folded in half, the tube is much shorter than it would be in a reflector of the same aperture size. Schmidt-Cassegrains have become increasingly popular with amateur astronomers because of their small tube size to aperture ratio. With their motorized fork mounts, these telescopes are ideal for astrophotography.



They cost a little more than reflectors, but much less than a refractor of the same aperture size. These telescopes are popular in 8 and 10-inch apertures, and can be found as large as 14 inches. Many of the newer models have built-in computers that can locate objects by entering their coordinates onto a keypad. The Schmidt-Cassegrain is a great all-around performer for both planetary and deep-sky observing.

(source: http://www.seasky.org/astronomy/astronomy_equipment.html#Telescopes)

Spectroscopy

Spectroscopy is one of the astronomer's most valued techniques. It may sound as an overstatement, but about 90% of everything we know about stars has been learned through spectroscopy.

The aim of this paper is to briefly explain what is meant by spectroscopy—stellar spectroscopy in particular—and to summarize the results of an actual research project involving the observation and photography of the spectra of two first-magnitude stars, namely, Sirius and Betelgeuse. The theoretical function of spectroscopes is also described, as well as types of this instrument, which are currently utilized by astronomers.

A *spectrum* is the result of dispersing a ray of light into its constituent colors. Spectroscopy, then, is the study of spectra. The importance of spectroscopy is that as light is broken into its components, spectral features—such as absorption and emission lines—may be identified, which tell us a great deal about a celestial body's velocity, composition, etc. For example, Wien's law may be used to get a blackbody's temperature, given only the shape of a *spectral curve*—that is, the curved line seen in a plot of intensity versus wavelength—and the location of its peak.

Among the earliest experiments on spectroscopy were Isaac Newton's 1666 observations of the solar spectrum. He used a prism to disperse the Sun's rays, obtaining a luminous band with a continuum of colors, very much like a rainbow. Though he never detected features such as lines or bands in the solar spectrum, he correctly established that what we call white light is actually a mixture of six primary or fundamental colors.

The first detailed observations of the solar spectrum were made by the German optician Josef von Fraunhofer in 1814. Using a prism spectroscope he was able to see a large number of dark absorption lines in the Sun's spectrum (which had been discovered by the British chemist William H. Wollaston around 1802, but

disregarded as gaps between colors). Though lacking the necessary theoretical knowledge to account for these lines, he catalogued about 600 of them [Freedman, Kaufmann, 2002], introducing in the process an alphabetical classification system that is still sometimes used.

Later, Fraunhofer made pioneering observations of some of the brighter stars, which became a puzzle to him because of the significant differences he noticed among the various stellar spectra. It would not be until half a century later that an appropriate explanation was given for the mysterious lines seen in the stars' spectra.

In 1859, the German physicist Gustav Kirchoff (in collaboration with the German chemist Robert Bunsen) suggested that Fraunhofer's lines were due to the presence of specific chemical elements, each of them generating a unique pattern of spectral lines.

Years of experimentation—and classification of the lines of the elements known at the time—revealed the existence of *three* fundamental kinds of spectra. These are correspondingly described by what we now call Kirchoff's laws:

1st law— A hot solid, or an opaque gas under high pressure, produces a *continuous spectrum* (that is, a complete array of colors devoid of any dark or bright lines).

2nd law— A hot, transparent gas, produces an *emission-line spectrum* (that is, a spectrum characterized by bright, narrow lines against a dark background, which depend on the elements present within the gas).

3rd law— A cool, transparent gas, in front of a source of a continuous spectrum, produces an *absorption-line spectrum* (that is, a complete array of colors with dark, narrow lines, depending on the elements present within the gas).

With Kirchoff's laws it was finally understood that the emission spectra seen from vaporized substances in laboratories and the absorption spectra seen in stars were actually related to each other. It may be said that the modern science of spectroscopy was born as a result of these three laws.

Another half a century later, in 1913, the Danish physicist Niels Bohr would give a new model of the atom that would finally explain *why* specific elements actually absorb or emit light at discrete wavelengths. He stated that electrons within an atom do not move randomly around the nucleus, but in orbits at specific distances where their position is stable. A change or transition from an orbit into another would require a change in energy, which would then be manifested as a *photon*, namely, a particle of light. An electron jumping from an inner orbit would then *emit* a photon with a specific wavelength—corresponding to its energy—thus causing an emission line, while an electron moving to an outer orbit would, in turn, *absorb* a photon, producing an absorption line at the corresponding wavelength. We call these jumps *electronic transitions*.

In the 1860's, the first comprehensive observations of stellar spectra were initiated. The British astronomer William Huggins saw prominent absorption lines in the spectra of Betelgeuse and Aldebaran, which—in the case of Aldebaran—enabled him to establish the presence of at least 9 elements. Around the same time, the Italian astronomer and Catholic priest, Father Pietro Angelo Secchi, developed a classification scheme for stellar spectra which used the Roman numerals I to V to describe the relative strength of the various absorption lines which were visible. His sequence went from the blue end of the spectrum to the red, and it paralleled more or less the modern spectral sequence.

Later, in the 1890's, the American astronomer Edward Pickering—together with Annie Jump Canon, Williamina Fleming, Antonia Maury, and others—began compiling the well-known Henry Draper Catalogue, which—once finished—would give spectral types for about 225,300 stars [Kaler, 1998, *Stars*]. Pickering's early system was similar to Secchi's scheme, but used instead capital Roman letters, running from A to Q. Annie Jump Canon later refined the system, dropping a few letters, to get the standard O-B-A-F-G-K-M spectral sequence that we

have today, and also added sub-classes—labeled as numbers from 0 to 9—for better precision.

The modern spectral sequence is essentially a two-ended continuum defined by the relative strength of hydrogen absorption lines in a star's spectrum. Because the electronic transitions that occur in the atoms of stellar atmospheres greatly depend on temperature, the sequence is also one of temperature and color.

The standard spectral classification system—as finally defined by Canon—runs as follows:

Spectral class O—?Blue stars with temperatures over 31,000 K, sometimes called *helium stars*.

Spectrum is characterized by ionized and neutral helium absorption lines, with little or no hydrogen.

Spectral class B—?Blue-white stars with temperatures ranging from 9,750 to 31,000 K. Spectrum is characterized by neutral helium absorption lines—no ionized helium—with hydrogen becoming more noticeable.

Spectral class A—?White stars with temperatures ranging from 7,100 to 9,750 K. Spectrum is characterized by very strong hydrogen absorption lines—the *Balmer series*, strongest between A1 and A2—with no helium lines. Ionized metals begin to appear in the more latter types.

Spectral class F—?Yellow-white stars with temperatures ranging from 5,950 to 7,100 K. Spectrum is characterized by hydrogen absorption lines—not as strong as in class A—and ionized metals, such as the Calcium II lines (Fraunhofer H and K).

Spectral class G—?Yellow stars with temperatures ranging from 5,250 to 5,950 K. Spectrum is characterized by weakening hydrogen absorption lines and strengthening metallic lines, in both neutral and ionized states.

Spectral class K—?Orange stars with temperatures ranging from 3,950 to 5,250 K. Spectrum is characterized by strong metallic lines—Calcium II is strongest in K1—both in neutral and ionized states. Molecular lines (mainly Titanium Oxide) begin to appear in latter types.

Spectral class M—?Red stars with temperatures ranging from 2,000 to 3,950 K. Spectrum is characterized by neutral metal and molecular lines. Titanium Oxide absorption bands are very prominent. Hydrogen lines are gone.

[Temperature values in the table above have been taken from Kaler, 1998, *Spectra*.]

Other spectral types exist, such as WC and WN for blue, hot Wolf-Rayet stars, featuring emission lines in their spectra, and classes C—formerly N and S—and R, for red giant variables. Two new classes, namely L and T, have been recently introduced for cool dwarfs shining feebly in the red and infrared parts of the spectrum. These feature absorption lines and bands due mostly to molecules such as metallic hydrides and methane. Now that we have seen the fundamentals of stellar spectroscopy, I will be describing the kind of instrument that actually makes this possible, and present a few results of what actually can be done even with relatively modest equipment.

A *spectroscope* is an instrument used to generate a spectrum, namely, a dispersion of light into its constituent colors. Strictly speaking, the term *spectroscope* refers only to a device utilized for visual observation of spectra. Photographic recording of spectra is achieved via a *spectrograph*, while a digital recording is obtained via a *spectrometer*. [However, throughout this paper, the term "spectroscope" will be taken to mean all three devices.]

Two types of spectroscopes are now currently in use among astronomers: prism-based spectroscopes and grating-based spectroscopes. While early spectroscopes were mostly of the prism type, most units now employ exclusively diffraction gratings (or in special cases, a combination of both). A brief description of each type follows:

Prism-based spectroscopes—?This was the kind of device originally used by Newton and by major observatories of the late 19th and early 20th centuries. A prism is a triangular-shaped piece of glass using the principle of *refraction*—as stated by Snell's law—to disperse a light beam into its components. This happens because a ray of light is refracted (or bent) as it passes from air to glass, and this refraction is slightly different, depending upon the specific wavelength of light.

One big disadvantage of prism-based spectroscopes, however, is that the incoming light is not *linearly dispersed*, meaning that the distances between the various constituent wavelengths are not equal. The blue end of the spectrum tends to be stretched, while the red end is compressed.

Grating-based spectroscopes—?Their invention is credited to Fraunhofer, but it was not until well into the 20th century that these devices came into frequent use. A diffraction grating is a solid surface with a large number of evenly spaced, parallel lines etched on one side (usually from 200 to 1,000 per mm). It uses the principle of *diffraction*—as stated by Bragg's Law—to disperse the constituent colors of light.

This happens because a ray of light is subjected to bending by diffraction (or interference) as it reaches the grooves on the grating, to an amount that is dependent, again, upon the specific wavelength of light.

Gratings are further classified as either reflection or transmission gratings. Reflection gratings are made of solid, metallic surfaces—where light rays are reflected—but they are very fragile. Transmission gratings, on the other side, let the light rays pass through them. They are more resistant, but also very expensive, which is why they are not frequently seen in astronomical applications.

While grating-based spectroscopes—unlike prisms—actually generate a proportionally dispersed spectra, they do suffer from the fact that the resulting dispersion is spread among a number of different spectra. Successive, fainter spectra are referred to as a first-order spectrum, second-order spectrum, and so on. This effect, of course, may give rise to significant light losses.

An important part of many spectroscopes is the *slit*, a narrow rectangular aperture, whose primary purpose is to act as the entrance gate of the spectroscope. A slit is necessary to obtain the spectra of extended objects such as nebulae and galaxies, but at the same time that it cuts through an object's excessive size, it also reduces its brightness, allowing the detection of between 1 to 10% of the incident light [Kitchin, 1998]. Stellar spectroscopy may sometimes be done without a slit, allowing in this case the detection of as much as 75% of the incident light.

All kinds of spectroscopes in use today operate either on the refraction or dispersion principle. Many special adaptations of the prism and grating types—have been constructed, however, to suit special needs. *Echelle spectroscopes*, for example, use diffraction gratings in which the surface grooves are further apart than with ordinary gratings. This allows spectra of high dispersion to be obtained, though limited to a small wavelength range. A more complete spectrum may be obtained, however, by overlapping the successive wavelength ranges produced by adjacent orders of the spectrum. The *spectroheliograph* (an instrument invented in 1924 by the American astronomer George Elery Hale) uses a diffraction grating along with several lenses to achieve a very high dispersion image of the Sun, which is tunable over the whole range of visible light.

Prisms and gratings have been combined to produce hybrid spectroscope designs. A *grism*, for example, is a right-angle prism with a transmission grating at its base. Grisms have been successfully used with telescopes where in-line presentation of the spectrum is required—the Hubble Space Telescope NICMOS camera, for example—but like prism spectroscopes, they suffer from non-linear dispersion.

It has also been noted that an ordinary CD or DVD compact disk—which has approximately 600 grooves per mm—may act as a very modest diffraction grating, revealing some of the more prominent features of the solar spectrum [Tonkin, 2002]. Pictures have even been taken this way showing a good number of absorption lines, but precautions should be taken not to view the Sun directly using this technique.

As part of this project, I assembled a simple spectroscope and utilized it to record the spectral lines of two bright stars. A description of my instrumentation and technique appears below.

Instrumentation—?I used a Celestron 200 mm f/10 Schmidt-Cassegrain telescope, together with a 26 mm Plössl eyepiece and a standard Celestron (mirror-type) star-diagonal. A Nikon FM-2 manual SLR camera was utilized for recording the spectra, using Fujicolor Superia 400 color negative film, and Kodak Tri-X 400 black and white negative film. The spectroscope itself consists of a diffraction grating for stellar spectroscopy made by Rainbow Optics, which screws into the bottom of a standard 1.25-inch eyepiece. This is a transmission grating with about 200 grooves per mm [Gavin, 2003], and it has been blazed to concentrate about 75% of the incoming light into just one of the first-order spectra. The spectroscope also includes a cylindrical (or astigmatic) lens which elongates the resulting spectra to allow for direct visual observation.

Observing site and circumstances—?The observing site is located within the urban area of San Juan, Puerto Rico, at a longitude $66^{\circ} 04'$ west of Greenwich, and latitude $18^{\circ} 22'$ north of the equator. The observations were carried out during the nights of November 18, 2003 and November 20, at approximately 02:30 and 01:30 local time, respectively. Thin high clouds—the remains of a strong low pressure system that affected the eastern Caribbean region during the first two weeks of November—prevailed during each of the observing sessions, but did not appreciably affect the visual or photographic appearance of the spectra.

Technique—?I targeted two first-magnitude stars of different spectral type: Sirius, a bluish-white, main-sequence star, and Betelgeuse, a well-known red supergiant. Each of the two stars was observed within one hour of its local transit, so that they would be visible at a sufficiently high elevation above the horizon (55° and 79° , respectively), in order to minimize any possible atmospheric degradation. I attached a 26 mm eyepiece to the telescope, which gave an exit pupil of 2.6 mm—ideal for spectroscopic work—and then screwed the diffraction grating at the far end of the star diagonal, in order to produce a longer, better resolved spectral image. Focusing was made by using the star itself, although the final precise focus was achieved by moving the focuser very slightly to the inside—which is recommended by the grating's manufacturer—in order to allow the stellar absorption lines to become sharply focused.

The SLR camera was mounted on a separate tripod and pointed to the telescope by means of the afocal coupling technique. The resulting focal length of the system was 3,850 mm and the f-ratio, f/19.25. Four exposures were made of each spectrum—two each, in both color and monochromatic film—and the time was set at 8 seconds with no tracking (to allow the spectral image to gain width by the natural drifting due to the rotation of the Earth). The film was taken to a local photo laboratory for standard developing, and the resulting spectrograms were then scanned directly from the negative strip using a Nikon CoolScan IV film scanner. These were later computer-processed with the scanner's own NikonScan v3.1 software for increased contrast, and were also partially rotated to achieve a full horizontal orientation, using Corel PhotoHouse v2 software.

A *spectrogram* is basically a photograph of a spectrum, but the term may be taken to mean any representation of a spectrum, digital or otherwise. [For the purpose of this paper, however, the terms "spectrogram" and "spectral image" are synonymous].

The spectrograms which resulted from my research appear below.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 1. Color spectrogram of Sirius.

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QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 2. Monochromatic spectrogram of Sirius.

Copyright © 2003 Armando Caussade.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 3. Color spectrogram of Betelgeuse.

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QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Figure 4. Monochromatic spectrogram of Betelgeuse.

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Although, at first sight, color spectrograms appear prettier (see figures 1 and 3), it becomes clear that the absorption lines reveal themselves much better in black and white. The color images also show a number of artifacts (dark bands at the transition areas of the main colors) that would actually hinder an analysis of the spectra [Tonkin, 2002]. So, I chose instead to use the monochromatic images for the analysis.

These spectrograms show a clear set of absorption lines and bands from which a spectral type may be ascertained. [Comparisons were made with sample spectra from Tonkin, 2002]

Sirius' spectral image, for example (see figure 2), has a very prominent set of lines that are—without a doubt—those of the Balmer series, which is a spectral signature of ionized hydrogen. Six such lines are clearly seen, converging rapidly towards the blue end of the spectrum, with a faint seventh and eighth line also visible at close inspection of the negative. No helium or metallic lines, however, appear to be visible. So, according to the spectral type descriptions given previously, it may be safe to establish Sirius' spectrum as of type A.

Betelgeuse's spectrogram (see figure 4) looks very different. Instead of lines, we mostly see dark bands, which is a signature of cool, red stars. The three prominent bands in the green—near the middle of the spectrum—are, very probably due to Magnesium Hydride and Titanium Oxide. The dark, wide feature on the right is harder to identify, but may be the Titanium oxide band located at 547.0 nanometers. No hydrogen lines appear to be present. Spectra such as this begin to appear in late class K—progressing into class M—but because of the strength of the molecular bands, it seems logical to establish Betelgeuse's spectral type as of type M.

A number of additional stars were also inspected visually, by attaching the cylindrical lens, which came with the diffraction grating in front of the eyepiece. Canopus and Procyon, for example, also exhibited a set of Hydrogen (Balmer) lines, but these appeared weaker than those of Sirius, which is consistent with their spectral type of F0 and F5, respectively. Regulus—at spectral type B7—also showed a weak, although distinct set of Balmer lines.

The most striking of all spectra, which I observed, however, was that of the 2nd magnitude Wolf-Rayet star ? Velorum. This object barely rises above the horizon for observers in the northern hemisphere (its elevation at the time of the observation was only about 15°) but nonetheless, its spectrum showed a very intense emission

line in the blue, and two other bright, twin lines in the yellow. The British astronomer Ralph Copeland said—around 1867—of this star's spectrum, that it is "...incomparably the most brilliant and striking in the whole heavens."

Spectroscopy is an invaluable tool that is accessible for almost any kind of telescope and ancillary equipment. A small telescope equipped with an SLR camera or CCD and a grating spectroscope may be used to obtain sufficiently good spectral images from brighter stars as to allow the determination of their respective spectral classes. Not only that, but such an instrumentation will allow a diligent observer to reproduce for himself many of the great discoveries and observations made by astronomers as recently as a couple of decades ago.

REFERENCES

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Source: <http://www.armandocaussade.com/astrometry/spectroscopy.html#spectroscopy>
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Radio Astronomy

Nikola Tesla (United States electrical engineer and inventor (born in Croatia but of Serbian descent) who discovered the principles of alternating currents and developed the first alternating-current induction motor and the Tesla coil and several forms of oscillators) in the Colorado Springs lab recorded cosmic waves emitting from interstellar clouds and red giant stars. He observed repeating signals conducted by his transceiver. He announced that he received extraterrestrial radio signals. Tesla stated that he received signals from planets in some of the scientific journals of the time. The scientific community did not believe him, primarily because research of cosmic signals did not exist (what is known today as radio astronomy), and the community of science rejected Tesla's data. Tesla spent the latter part of his life trying to signal Mars. One of the earliest modern investigations into extraterrestrial sources of radio waves were by Karl Guthe Jansky, an engineer with Bell Telephone Laboratories, in the early 1930s. The first object actually detected was the center of the Milky Way, followed by the sun. These early discoveries were confirmed by Grote Reber by 1938. After World War II, substantial improvements in radio astronomy technology were made by astronomers in Europe and the United States, and the field of radio astronomy began to blossom. One of the most notable developments came in 1946 with the introduction of radio interferometry (see e.g. Nature 158 pp 339 1946) by Martin Ryle's group in Cambridge (who obtained a nobel prize for this and later aperture synthesis work), also the Lloyd's mirror interferometer developed independently in 1946 by Joseph Pawsey's group at the University of Sydney (see Nature 157 pp 158 1946).?

DevelopmentsRadio astronomy has led to substantial increases in astronomical knowledge, particularly with the discovery of several classes of new objects, including pulsars (A degenerate neutron star; small and extremely dense; rotates very fast and emits regular pulses of polarized radiation), quasars (A starlike object that may send out radio waves and other forms of energy; large red shifts imply enormous recession velocities) and

(Click link for more info and facts about radio galaxies)

radio galaxies (Radio galaxies are a heterogeneous group of radio-emitting objects often called Fanaroff and Riley (FR) galaxies after Bernie Fanaroff Julia Riley. Most of them have huge symmetrical lobes from which the greater part of the radio emission comes. Some of them show a jet or jets (the most famous example being the giant galaxy M87 in the Virgo cluster) coming directly from the nucleus and going to the lobes. The jets are believed to be the visible manifestations of the beam of high-energy particles that power the lobes. The radio emission is synchrotron radiation, implying that the radio lobes and jets contain relativistic electrons and magnetic fields.). Such objects represent some of the most extreme and energetic physical processes in the universe.??Radio astronomy is also partly responsible for the idea that (cosmology) a hypothetical form of matter that is believed to make up 90 percent of the matter in the universe; it is invisible dark matter (does not absorb or emit light) and does not collide with atomic particles but exerts gravitational force) is an important component of our universe; radio measurements of the rotation of galaxies suggest that there is much more mass in galaxies than has been directly observed Vera Rubin). The (cosmology) the cooled remnant of the hot big bang that fills the entire universe and can be observed today with an average temperature of about 2.725 kelvin) cosmic microwave background radiation was also first detected using radio telescopes. However, radio telescopes have also been used to investigate objects much closer to home, including observations of the (A typical star that is the source of light and heat for the planets in the solar system) Sun and solar activity, and radar mapping of the planets.??Radio telescopes can now be found all over the world. Widely separated telescopes are often combined using a technique called interferometry in order to obtain observations with much higher resolution than could be obtained using a single receiver. Initially telescopes within a few kilometres of each other were combined (Mullard Radio Astronomy Observatory), but since the 1970s telescopes from all over the world (and even in Earth orbit) have been combined to perform Very Long Baseline Interferometry.??The United States government has established an institution to conduct radio astronomy research in the US, titled the National Radio Astronomy Observatory (commonly abbreviated as NRAO). This institution controls various radio telescopes around the United States included the world's largest fully mobile radio telescope, the Green Bank Telescope. The United States government has also set aside a national radio quiet zone for radio astronomy research centered around Green Bank, West Virginia. As a result, Green Bank is now the home of NRAO's primary facility.?

source: http://www.absoluteastronomy.com/encyclopedia/r/ra/radio_astronomy.htm

Infrared

Infrared astronomy, study of celestial objects by means of the infrared radiation they emit, in the wavelength range from about 1 micrometer to about 1 millimeter. All objects, from trees and buildings on the earth to distant galaxies, emit infrared (IR) radiation. The study of such radiation from celestial objects is of particular importance for several reasons. Cosmic dust particles effectively obscure parts of the visible universe, such as the center of our galaxy, the Milky Way, but this dust is transparent in the IR wavelengths. Most of the energy radiated by objects ranging from interstellar matter to planets lies in the IR wavelengths; IR observations are therefore significant in studying asteroids, comets, planetary satellites, and interstellar dust clouds where stars are forming. Finally, because the expansion of the universe shifts energy to longer wavelengths, most of the visible radiation emitted by stars and galaxies during the early stages of the formation of the universe is now shifted to the IR range; studies of the most distant objects in the IR spectrum are necessary if astronomers are to understand how the universe was formed.

The beginnings of IR astronomy can be traced to the discovery of IR radiation in the spectrum of the sun by English astronomer Sir William Herschel about 1800. It is reported that Irish astronomer Lord William Rosse detected IR radiation from the moon about 1845. As early as 1878 the American inventor Thomas Alva Edison observed a solar eclipse from a site in Wyoming using a sensitive IR detector, and during the 1920s

the first systematic IR observations of celestial objects were made by Seth B. Nicholson, Edison Pettit, and other American astronomers. However, modern IR astronomy did not begin until the 1950s because of the lack of appropriate instrumentation. Since then, special interference filters and cryogenic systems (to minimize IR interference from the radiation emitted by the equipment itself) have been introduced for ground-based observations, and aircraft, balloons, rockets, and orbiting satellites have been successively employed to carry the equipment above the water vapor in the earth's atmosphere.

The Kuiper Airborne Observatory (KAO), operated by the National Aeronautics and Space Administration (NASA), had its first flight in 1975. Named for the American astronomer Gerard P. Kuiper, the KAO was a C-141 jet transport that carried its 36-inch (91-cm) telescope to altitudes of up to 45,000 ft (13,720 m). Before it flew its last mission in 1995, the KAO was instrumental in the discovery of the rings of Uranus, the atmosphere around Pluto, and the definitive detection of water during the crash of comet Shoemaker-Levy 9 into Jupiter. Also sponsored by NASA is the Infrared Telescope Facility, a 10-ft (3-m) IR telescope located at an altitude of 14,000 ft (4,270 m) on the summit of Mauna Kea in Hawaii; established in 1979, it effectively is the U.S. national IR observatory. Also near the summit of Mauna Kea is the 12.5-ft (3.8-m) United Kingdom Infrared Telescope (UKIRT), the largest telescope in the world used solely for IR observations.

The first IR satellite to be launched (1983) was the Infrared Astronomical Satellite (IRAS), a joint venture of the United States, Great Britain, and the Netherlands. Orbiting the earth for 10 months, IRAS performed an all-sky survey that yielded catalogs of hundreds of thousands of IR sources, more than half of these previously unknown, including asteroids and comets; detected a new class of long-lived "cool" galaxies that are dim in the visible region of the spectrum; located a protoplanetary disk around a nearby star; and showed clearly for the first time the bulge near the center of the Milky Way. In 1989 the second IR satellite, the Cosmic Background Explorer (COBE), was launched by NASA. Operating through 1993, COBE detected small temperature variations in the cosmic microwave background radiation that provided vital clues to the nature of the early universe and its evolution since the "big bang." The European Space Organization launched the Infrared Space Observatory (ISO) in 1995. Operating until May, 1998, ISO monitored nearby planets, asteroids, and comets. It found water vapor in the atmospheres of Saturn, Neptune, Uranus, and Titan, Saturn's largest moon; detected water vapor and fluorides in the interstellar medium; and studied the "cool" galaxies first seen by IRAS. The near-infrared camera multiobject spectrometer (NICMOS) was placed aboard the Hubble Space Telescope in 1997. Consisting of three cameras and three spectrometers, it has been used to study interstellar clouds where stars are being formed, young stars, and the atmospheres of Jupiter and Uranus.

The Spitzer Space Telescope, a cryogenically cooled satellite observatory with a 2.8-ft/0.85-m telescope, was launched in Aug., 2003, and placed in a solar orbit in which it trails the earth by 5.4 million mi (8.7 million km); it is expected to have a two-to-five-year operating lifetime. Future plans for IR astronomy include a KAO replacement, the Stratospheric Observatory for Infrared Astronomy (SOFIA), a joint project of NASA and the German space agency, DLR, that consists of a Boeing 747-SP aircraft modified to accommodate a 8.2-ft/2.5-m reflecting telescope (the largest airborne telescope in the world). SOFIA is expected to go into service in 2004 and have a 20-year lifetime.

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Source: <http://www.infoplease.com/ce6/sci/A0825201.html>

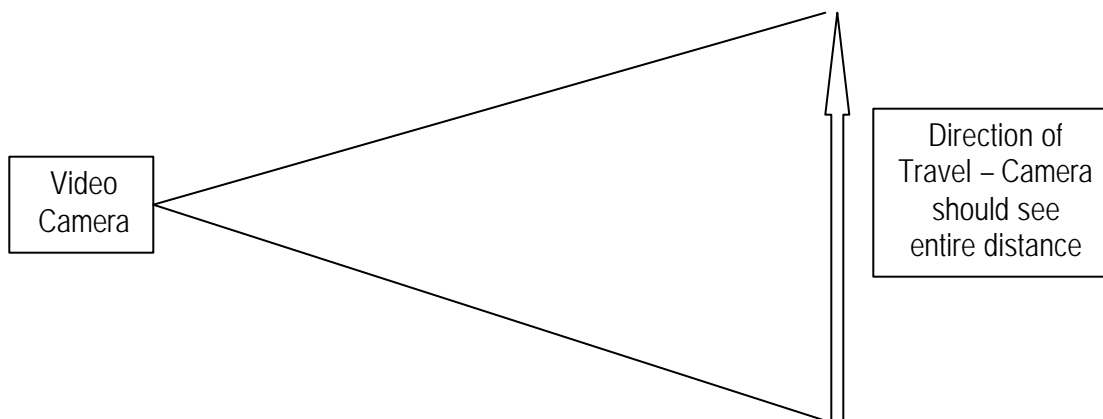
Day 18: activity

Velocity Lab

There are two different lab included here. Pick the one the best fits your school situation. The first lab need a large hard surface playground area to complete (Speed), the second lab can be done in a classroom (Can You Calculate the Speed of Your Pet?). The labs can be found in Appendix A.

Homework: Formula Challenge (Appendix D)

In order to extend these to be used with Squeak the activities should be video taped. Set the camera at right angles to the direction of movement.



The camera becomes a timer in these activities so take the still clips at regular time intervals. iMove works well for this purpose. The stills (jpeg files) can be imported into Squeak for the activities.

The students can measure the distance travel in a given time interval. This will re-enforce the concept of velocity. (See B.J. Conn and Kim Rose). The eToy created by the students will make an excellent assessment of student learning and understanding.

The use of still images in Squeak can expand students understanding of concepts presented in both physic and math.

Day 19 & 20: activity

Acceleration Lab (Appendix A)

This lab will take 2-50 minute periods to complete. Make sure you provide exploration time for the students after they construct their cars. They will need to practice use of the stopwatches and their timing techniques in order to get consistent results.

Extension

Video tape the fan car using the same technique as the velocity lab. The clips from the video can be imported into Squeak. This will allow students to see the acceleration of the car and measure distances more

accurately. They can then program their own car to accelerate in an eToy. This will make an excellent assessment of learning.

Day 21 +: squeak excursion

Squeak is an "idea processor", a language, a tool and a media-authoring environment. ... Squeak is a "deep" system and has different entry points for different kinds of users. eToys represents the entry level of Squeak and provides the opportunity for students to gain a deeper understanding of the concepts of math and science. Download Squeak free of charge at www.squeakland.org. Make sure you have the current version. There are several excellent resources on the Squeakland website including; glossary, quick start guide, student projects, sample projects, etc.

The resources for these activities include:

"Powerful Ideas in the Classroom: using Squeak to enhance math and science learning", B.J. Allen-Conn and Kim Rose. 2003. Viewpoints Institute, Inc., CA. (ISBN 0-9743131-0-6)

Randy Caton, NASA Connects, <http://connect.larc.nasa.gov/squeak.html>

Alan Kay and Kim Rose, Viewpoints Institute. A tutorial "Drive a Car":
http://www.squeakland.org/school/drive_a_car/html/Drivecar12.html

Any eToy can be deconstructed to see how the programming was done.

Learning Squeak will be ongoing process I suggest letting the students explore the environment by leading them through some very simple activities. This means drawing objects and then programming them to move. There are many wonderful examples on the Squeakland web site of projects generated by students. These projects can be downloaded and deconstructed so that students can gain a deeper understanding of the programming process using Squeak. An example of this is the following.

Speed and Acceleration eToy

Procedure:

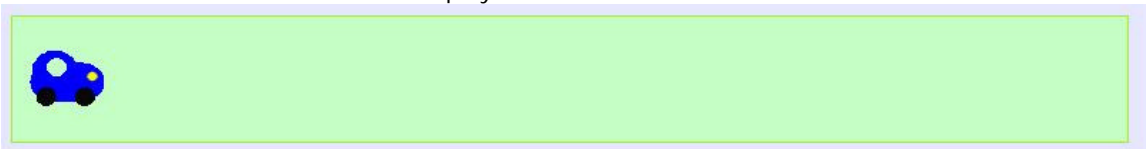
1. Using the paint tool in the Navigator Tab, draw an object (like a car).



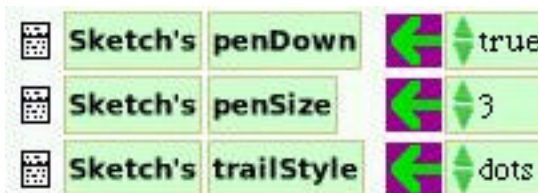
2. Bring up the halo around the car. Change the direction vector from vertical to horizontal (with the arrow pointing to the front of the car).



3. Click on the blue "eye" to bring up the tiles.
4. Drag a playfield from the supplies tab and place on the "world". Resize the play field to make a long horizontal track for the car. Name the playfield "TestArea".
5. Drag a second playfield onto the "world" and name this area "Home". Home will be the reset position
6. Place the car in the "TestArea" playfield.



4. Bring up the tiles on the car (right click on the car to get the halo and then click on the blue eye)
5. From the pen use category change the following tiles
 - a. "penDown" to **true**
 - b. "penSize" to **3**
 - c. "trailStyle" to **dots**

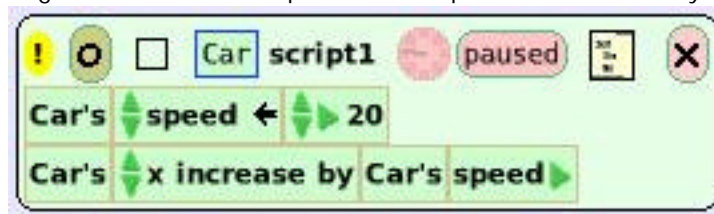


6. You are ready to write your first script.
 - a. Bring up the Home halo click on the blue eye.
 - b. Drag out an empty script
 - c. Open Collections and drag "Home includes: dot" into the empty script.
 - d. Bring up the halo on the car and click on the orange rectangle. Drop the "Car" tile into the script over the "dot".
 - e. Open pen use and drag "clear pen trail" tile into script

- f. Open the halo on the "TestArea" click on the orange rectangle to get a TestArea tile and drop the tile into the script so that the script reads "TestArea clear all pen trails"
- g. Rename the script to Reset.

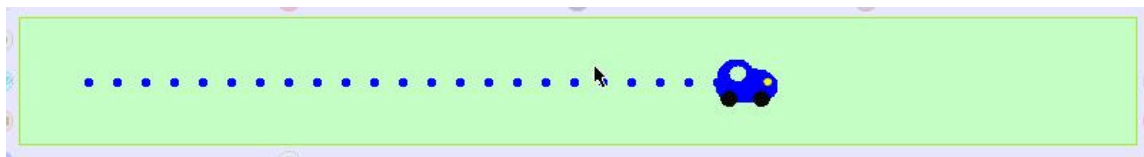


8. Drag the stop-step-go tile from the supplies tabs. This will control all script set to pause. (scripts set to normal will not be effected)
9. Placed the car in the TestArea and you are ready to write you next script to set the car running.
10. Drag a second empty script from the car viewer. This script will be a constant speed test of the car.
 - a. Drop the forward by tile into the empty script. Set the # forward to 20 to start with.
11. Drag a second empty script from the car viewer. You will need the following items for this script.
 - a. The car needs a variable called "speed".
 - b. The speed will need to be set to a number.
 - c. The car's 'x' should increase by the 'car's speed'.
12. To create a variable click on the "v" at the top of the viewer. Name the variable "speed".
 - a. Drag the variable by the ← into the empty script. Set the number to 20.
 - b. From the basic menu drag the "car x" from the viewer and drop it into the script.
 - c. Change the x to "x increase by" (pull down menu).
 - d. Now drag the variable "car's speed" and drop next to "increase by".



This script moves the car along the x-axis with the stated speed.

1. Drag the car into the "TestArea" and start script1 ticking. The car will leave a trail of dots evenly spaced.

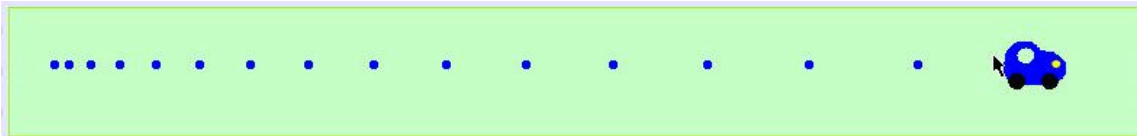


2. Now your ready to write a script for acceleration. Drag another empty script from the car viewer. It is very similar to the first script.
 - a. Drop the variable speed into the script. This time you want the speed to increase by a number say 5
 - b. Next drop the Car's x into the script, modify to increase by and then drop the car's speed where the number is.
15. Set the first script to "normal". This will mean that this script will not run when you click "go"
16. Clear all the pen trails and click go again.



This script moves the car along the x-axis with an increasing speed.

3. Start the second script ticking.



The possibilities are endless when it comes to using Squeak and eToys in your classroom. The only limitations are the amount of time you can commit to the process. For the purposes of this ETP I am outlining the sequence that could be used to ensure a deeper understanding of the underlining concepts. To be effective the Etoys activities should follow hands-on activities in the classroom. Please refer to the outline at the beginning of the lesson plans, these resources will be available on line as soon as the proceedings of SqueakFest 2005 are published.

Vectors

This is intended as background information on vectors. Junior High students may or may not have been exposed to vectors. High school student should have an understanding of vectors for physics.

What follows is information from NASA on vectors as well as on-line resources for teachers and students alike.

This is an excellent resource for physics the site has animations to illustrate many of the concepts presented here. <http://www.physicsclassroom.com>

Another site with information about vectors:

<http://em-ntserver.unl.edu/NEGAHBAN/EM223/note2/note2.htm>

The images presented here are from the NASA web site:

<http://www.grc.nasa.gov/WWW/K-12/airplane/vectors.html>

Start by discussing the differences between scalar and vector. This is best done by giving examples.



Scalars and Vectors

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A scalar quantity has only **magnitude**.

A vector quantity has both **magnitude** and **direction**.

Scalar Quantities

length, area, volume
speed
mass, density
pressure
temperature
energy, entropy
work, power



Vector Quantities

displacement, direction
velocity
acceleration
momentum
force
lift, drag, thrust
weight



In comparing vectors and scalars you can compare two scalars vs. comparing two vectors



Comparing Two Scalars Ratios

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The **ratio** of scalar quantity **A** to scalar quantity **B**
is equal to $\frac{A}{B}$

Examples from aerospace:

ratio

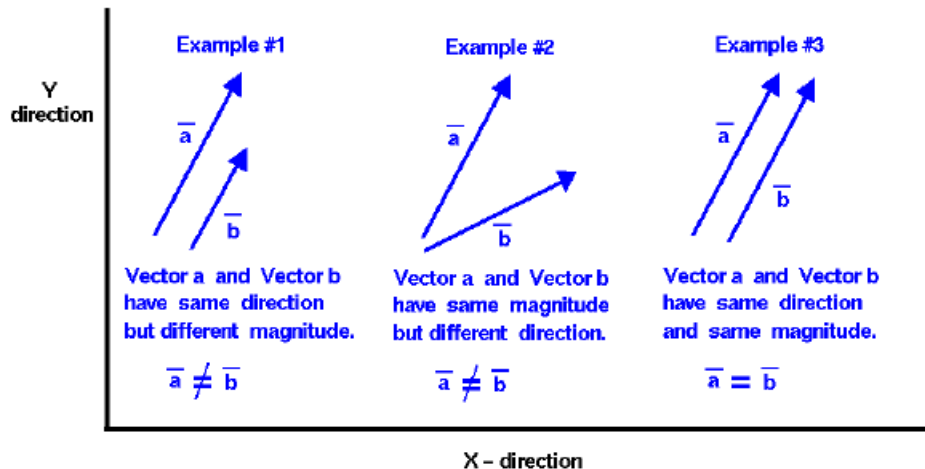
Mach Number	object speed to speed of sound
F / W Ratio	thrust to weight
Aspect Ratio	square of span to wing area
Glide Ratio	altitude change to distance change
Specific Fuel Consumption	fuel flow rate to thrust
L / D Ratio	lift to drag
Lift Coefficient	lift to area X dynamic press.
Reynolds Number	inertial force to viscous force



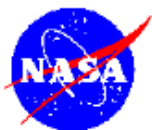
Comparing Two Vectors

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A **vector quantity** has both **magnitude** and **direction**.



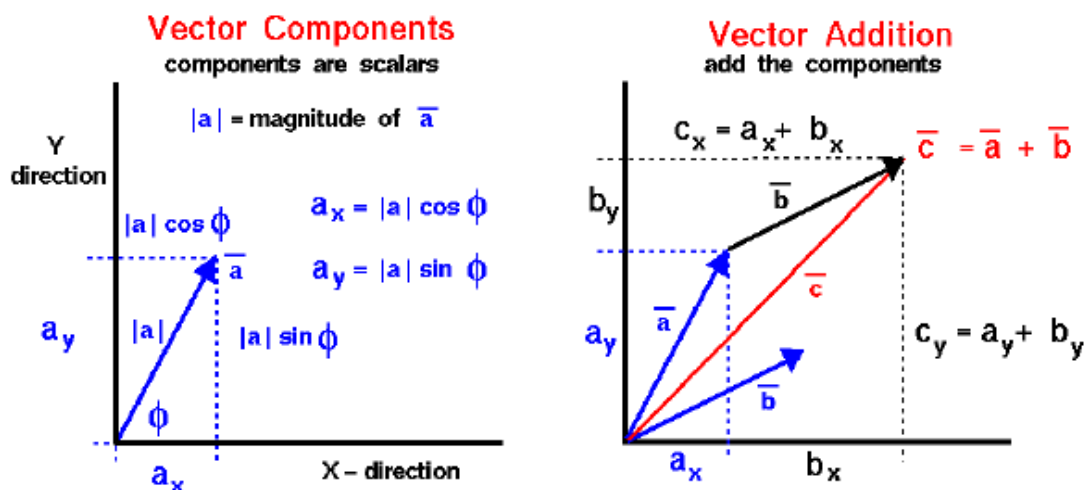
Once students understand the differences and what vectors are you can discuss how to use vectors.



Vector Components and Addition

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A **vector quantity** has both **magnitude** and **direction**.



These ideas can be modeled in Squeak to give student a hands-on experience to enhance understanding.

A note on Vectors in Squeak

If your students need additional background about vectors this is a good place to do it. What follows is background information as well as how to modify Squeak to enable vectors. (Vectors are not “turned on” in Squeak as it comes from Squeakland, you need to open the preferences to allow vectors.

- Open Squeak.
- Right click to get the halo on the world (blank page)
- Click on the red menu icon on the top left edge of the halo
- Open “desktop menu”.
- Click “Help”
- Open “preferences”
- Click on “scripting” in the shaded area at the top of the menu.
- Click on “useVectorVocabulary”



If you want to keep these settings you will have to save the preferences from the preference menu. By enabling vectors you will find an additional category in the viewer.

Squeak is open ended, as students explore they will discover many features hidden in menus. Let the students explore as much as possible as this will re-enforce the learning.

Newton's Laws and Space Exploration: an excursion

NASA and Sonoma State University has produced a series of lessons around the Swift satellite: <http://swift.sonoma.edu/education/>. This site has lessons, images and other resources related the Swift Telescope, "Gamma-ray bursts (GRBs) are the most powerful explosions the Universe has seen since the Big Bang. They occur approximately once per day and are brief, but intense, flashes of gamma radiation. They come from all different directions of the sky and last from a few milliseconds to a few hundred seconds. So far scientists do not know what causes them. Do they signal the birth of a black hole in a massive stellar explosion? Are they the product of the collision of two neutron stars? Or is it some other exotic phenomenon that causes these bursts?"

With Swift, a NASA mission with international participation, scientists will now have a tool dedicated to answering these questions and solving the gamma ray burst mystery. Its three instruments will give scientists the ability to scrutinize gamma-ray bursts like never before. Within seconds of detecting a burst, Swift will relay a burst's location to ground stations, allowing both ground-based and space-based telescopes around the world the opportunity to observe the burst's afterglow. Swift is part of NASA's medium explorer (MIDEX) program and was launched into a low-Earth orbit on a Delta 7320 rocket on November 20, 2004."

<http://swift.gsfc.nasa.gov/docs/swift/swiftsc.html>

This is a set of 3 posters with classroom activities to accompany each poster. The activities were created to complement each other as an overall unit, whether in science or math. Newton's Second Law of Motion is complemented with a separate set of activities, entitled Newton's Law of Gravitation.

Newton's First Law of Motion: http://swift.sonoma.edu/education/newton/newton_1/index.html
Newton's Second Law of Motion: http://swift.sonoma.edu/education/newton/newton_2/index.html
Newton's Third Law of Motion: http://swift.sonoma.edu/education/newton/newton_3/index.html
Newton's Laws of Gravitation: http://swift.sonoma.edu/education/newton/newton_3/index.html

Newton and Squeak

There are several eToy projects related to the application of Newton's Laws. These can be found on my web page <http://server.stcharlesschoolsc.org:16080/~dtrimble/>. Click on the Squeak icon to go to the project page. These project are in various states of completions. Randy Caton created many of the projects. Randy is a physics professor at Christopher Newport University and also does work for NASA Connect at the Langley Center for Distance Learning. These projects are meant to share and you are free to copy, share, and/or modify, additional projects were created by me and by Alan Kay as part of my IISME fellowship and again your are free to copy, share, and/or modify these projects as well.

A large collection of student projects can be found at <http://www.squeakcmi.org/> (click on projects to get to their superwiki). Most of these projects have nothing to do with this ETP but will give you some idea of the versatility of Squeak. Additional student projects are found on the Squeakland web site <http://www.squeakland.org>.

Gravity

There are many experiments or demonstrations available for students to explore gravity.

Galileo and Gravity

You can recreate Galileo's experiments using various objects with different masses. A second or third story window is ideal, put you can use a single story roof.

Materials:

Several objects with different masses (softball, baseball, shot put, etc.) **make sure that the mass of one of the object is significantly more or less than the others.**

Stopwatch

Video camera optional

Procedure:

1. Pass the objects around to the students, have each group predict which objects will hit the ground first. **Students usually are under the misconceptions that the heavier object will hit the ground first.**
2. Drop various objects (tennis ball, croquet ball, shot put, etc.) two at a time side-by-side.
3. Each group should record the time it take for each object to hit the ground. It may be necessary to repeat several time to get good measurements. Have each group record their observations.
4. Optional. Record the experiment using a video camera. Stills from the video taken at equal interval can be imported into Squeak where students can make measurements and them recreate the experiment.

Listen to the rhythm of the falling weights

This is from the Teacher's Institute, Exploratorium snack book.

Introduction

You can space weights along a string so that they make a regular rhythm of beats when they strike the ground.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Left, string one: equally spaced weights
Right, string two, weights spaced to fall with equal time intervals.

Materials:

Some string, such as parachute cord (1/8 to 1/4 inch diameter, 3 to 6 mm) two pieces about 9 feet, or 3 m, long.

10 Weights to clip on the string, such as 1/2 ounce (15 gram) fishing weights, or binder clips.

A ruler

Optional, a cookie sheet

Procedure:

1. On string number one, clip the weights at the following distances from one end, "the bottom end".
50 cm, 100 cm, 150 cm, 200 cm, 250 cm
2. On string number two clip the weights at 10 cm, 40 cm, 90 cm, 160 cm, 250 cm
3. Optional place the cookie sheet on the floor, drop the weights on the cookie sheet.

4. Hold string one by the weight at 250 cm so that the bottom of the string barely touches the floor. Notice that there is no weight at the bottom end near the floor. You may have to stand on a step stool to hold the string high enough off the floor.
5. Drop the weights and listen to the rhythm of the falling weights.
6. Notice how the rhythm goes faster and faster as the weights fall.
7. Now repeat the drop with string two. Hold it by the weight at 250 cm from the bottom so that the bottom of the string barely brushes the floor or the cookie sheet. Notice that there is no weight at the bottom.
8. Drop the string and listen for the rhythm.
9. Notice that the rhythm has a constant beat. There is a constant time interval between the weights as they hit the floor.

What's Going On?

The weights fall under gravity, they accelerate downward. Each weight falls a distance proportional to the square of the time that it falls. Thus equally spaced weights will hit with a shorter and shorter time interval between them. In order to hit after equal time intervals the weights must be spaced with a distance that increases proportional to a square. Notice that the distances of the weights are spaced proportional to the squares of the number of each weight, 1, 4, 9, 16 etc. So string two has weights spaced to fall at equal time intervals under free fall while string one is spaced at equal distances.

Math Root

For string two:

An object falls from rest with constant acceleration, g then the distance it travels at a time t is

$$d = 1/2 gt^2$$

So if a weight falls a distance d it takes a time

$$t = (2*d/g)^{0.5}$$

For a weight to fall for exactly twice this time it travels

$$d = 1/2 g t^2 = 1/2 g (2*(2*d/g)^{0.5})^2 = 1/2g 4 2d/g = 4d$$

show that after three time intervals the weight falls a distance of **9d**.
and so on.

For String one:

The time it takes the lowest weight at $d = 50$ cm to fall to the ground is

$$t_1 = (2*d/g)^{0.5}$$

The time it takes for weight number 2 at twice the distance from the ground $2d$ to hit the ground is:

$$t_2 = (2 \cdot 2d/g)^{0.5} = 2^{0.5} \cdot (2 \cdot d/g)^{0.5} = 2^{0.5} t_1$$

Show that the time it takes weight 3 to hit the ground is

$$t_3 = 3^{0.5} t_1$$

and for weight n is

$$n^{0.5} t_1$$

Going Further:

You can record the sound of the falling weights and analyze them on a computer.

Sound1 is the sound of the equally spaced weights recorded on a computer and turned into an mp3 file. You can definitely hear that the last interval is shorter than the first.

[sound1](#)

Sound2 is the recording of the string two with weights spaced along distances proportional to the square of the weight number.

[sound2](#)

Projectile Motion: Horizontal and Non-horizontal

If I shot a bullet from a gun that is aimed horizontally and drop a bullet at the same time which bullet will hit the ground first? Most students will say the bullet shot from the gun. Here is an experiment to set the record straight (*or curved as the case may be*).

[Check out Appendix B for background information \(this can also be used for student reading\) as well as worksheets in Appendix D.](#)

Materials:

Vertical Accelerations Demonstrator
Steel Balls (2 each)
Ring stand
Washers (2)
A wooden ruler, 30 cm or 1 ft. long, it should be stiff

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Included here are two set-up for the same experiment. The first uses a commercially available apparatus from: Arbor Scientific:

Product ID: P3-3520
Product Name: Vertical Acceleration Demonstrator
Price: \$24.00
Product ID: P3-3521
Product Name: Spare Steel Balls - Pair
Price: \$2.25

Two balls are mounted on the apparatus. When you release the spring, one is dropped directly down while the other is projected horizontally.

The second use an apparatus made from materials found in most science classrooms.

When the ruler is hit sharply, one washer drops to the floor while the other is launched to the side.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Introduction

If you shoot a bullet horizontally out over a lake, and drop a bullet at the same instant, both bullets will hit the water at the same time. The same experiment can be done in a classroom with rulers and washers.

Procedures

Set-up 1

1. Push the pin into the center of the ruler.
2. Place the ruler near the corner of the table, parallel to one edge of the table, about 2.5 cm (1") from the edge, so that about half the ruler sticks over the edge of the table.
3. Put one washer on top of the ruler about 5 cm (2") outside the edge of the table. When the ruler moves out from under this coin it will drop straight to the ground.
4. Put the other coin between the ruler and the edge of the table near the end of the ruler.
5. Hold the pushpin in one hand.
6. Hit the end of the ruler that is outside the table so that the ruler rapidly rotates about the pushpin, dropping one coin to the floor while shooting one coin to the side rapidly.
7. Notice that both coins hit the floor at the same time.

Set-up 2

1. Mount the accelerator on a ring stand.
2. Use the lever on top to compress the spring
3. Place the 2 steel balls on each side.
4. Release the spring and observe the two steel ball. You should hear them hit at the same time.

Extension:

1. You can double the weight and compare how far the washer or steel ball carries.
2. Video the experiment to use in Squeak.

What's Going On?

Objects accelerate toward the surface of the earth at the same rate regardless of their motion. The moving coin and the initially stationary coin fall to the ground in the same time.

Gravity Well

Round and around faster and faster.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

A bowling ball in a gravity well spirals into the center more slowly than smaller balls.

Many science museums have a "Gravity Well" exhibit. A toy coin bank version of the gravity well is also available. Balls rolled in the well model the behavior of planets orbiting the sun in nearly circular orbits. Planets far from the sun travel at low velocity over a large circumference and take a long time to orbit. Planets close to the sun travel a short distance at a high speed during each orbit.

Here is how to explore a gravity well.

You can also explore orbits in different force fields, rolling balls in spherical bottomed bowls or balloons, or in straight-sided funnels. Balls rolling inside a sphere travel so slowly as they near the bottom of the sphere that the orbital period remains the same even though the circumference of their orbit is small.

Introduction

A gravity well is a curved funnel. Roll balls around this funnel and they will display some of the properties of orbiting bodies.

Material:

- A gravity well, (a small version of a gravity well is available from Educational Innovations, www.teachersource.com.)
- Marbles or other balls.

Procedures:

1. Roll a marble around so that it moves in a circle near the top of the gravity well.
2. Notice that the marble keeps rolling in a circle but that it slowly drops down into the gravity well.
3. As the marble drops lower into the well it goes around the circle in a shorter time. This becomes dramatically apparent when the marble approaches the center of the well. Where it zips around so fast it becomes a blur.
4. If you roll two marbles, one slightly nearer the center than the other you can observe their relative velocities, the outer one is slower and the inner one is faster.

What's Going On

Friction removes some of the energy of the rolling marble causing it to drop down into the well.

When the marble drops down into the well some of its gravitational potential energy is converted into kinetic energy.

The potential energy of the marble is converted to kinetic energy so that as the marble drops down it has a higher velocity. Not only does the marble go around in a smaller circle as it drops down into the gravity well, it travels around at a higher velocity. The result is that the marble completes orbits much more rapidly near the center of the well.

So What?

Spacecraft orbiting the earth behave the same way as balls in the gravity well. If the spacecraft begin to run into the atmosphere, friction causes them to drop into a lower orbit. As they drop into the lower orbit they speed up due to the change in gravitational potential energy. So we have the amazing situation where friction causes an object to speed up.

Because the marbles do not slide frictionlessly around the gravity well, but roll instead, they do not follow exactly the same orbits as orbiting satellites. If instead of rolling the marble in a circle, you roll it in a path that goes close to the center and then farther away you will see that the marble does not repeat the same elliptical path each time which a satellite would do when orbiting a planet, instead it moves around tracing out the pattern of a three petal flower, perhaps a fleur de li.

Math Root

Force

The force of gravity, F_g , on a satellite in orbit falls off as the inverse square of distance between the satellite and the center of the planet, r .

$$F_g \propto 1/r^2$$

That is, if you double the distance of a satellite from the center of the earth the gravitational force on the satellite toward the center of the earth will be one-fourth as large.

If you place a marble at rest on the gravity well it will be on an inclined plane that exerts a force on the marble toward the center. Far from the center the inclined plane is very gentle and the force toward the center is small, near the center the inclined plane is steep and the force is large. The gravity well is designed so that the force on the rolling marbles follows an inverse square law.

If you use a heavy ball such as a bowling ball and use just three fingers to hold the ball at each radius by pushing outward horizontally, you can feel how the inward force increases as the distance from the center of the well decreases.

Energy

You can also look at the potential energy, U , versus distance, r . Near a planet the gravitational potential energy is proportional to $-1/r$.

$$U \propto -1/r$$

The potential energy is near zero at great distances from the center and drops to large negative values as the center is approached. (The potential energy is defined to be zero at large distances.)

Near the surface of the earth gravitational potential energy is proportional to height, $U = mgh$. Where m is mass and g is the constant acceleration of gravity. The gravity well is located near the surface of the earth. So, the depth of the gravity well, h , is proportional to the potential energy, thus $h \propto -1/r$.

This is the equation for a hyperbola of rotation.

Going Further

Try different Shape funnels

Roll a ball in a large cooking wok, a balloon or another segment of a sphere. As the ball approaches the center it slows down. However the circumference of the orbit also decreases and so the period of one orbit remains the same at all radii.

Try rolling a ball in a straight-sided funnel too, how does its speed change? Notice that while dropping to a lower place the kinetic energy and so also the speed increases, the ball drops because of frictional energy loss, so we cannot use pure conservation of energy to explain the motion of the balls.

Use balls with different masses and different mass distributions.

Try rolling around balls with different diameters, masses, and distributions of mass such as bowling balls, basketballs, or cue balls, notice how friction and the kinetic energy of rotation effect the orbits of these balls.

Mix the initial directions of motion

Revolve balls of different mass in different directions at the same time. Notice how the initial mix of velocities becomes uniform in direction due to collisions. The same thing happened in the early solar system.(Although the objects in the early solar system almost all began with the same direction of revolution.)

Explore tides

Use two or three identical balls.

Start them at rest, touching each other along a radial line near the rim. (You can use two pencils to line up the balls.) Then release them all at the same time. Notice how they move apart. The one nearer the center is on a steeper slope and so accelerates toward the center faster than those further out. In the same way the outermost ball accelerates toward the center more slowly. This is the essence of the tidal force.

Start three balls at rest all at the same distance from the center and separated slightly. (Rest them on a pencil perpendicular to a radial line.) Release them all at once and notice how they move closer together. This is also the result of the tidal forces.

Model warped space

The gravity well looks like the diagram used to represent a black hole. It is called an embedding diagram. The presence of a mass "warps" space-time. Visualize a flat clear planar surface on top of the gravity well, place a dot representing the black hole on the center of this surface. Place two dots on this surface along a radial line from the black hole. The distance measured between the two dots is not the distance measured along the flat surface, it is the distance measured along the curved surface of the gravity well. When a mass is present then more distance appears between two points in space. See [Curved Space](#). (However, balls do not roll around the gravity well as they would orbit a black hole!)

Paul Doherty, 2001

Additional Lessons:

There are many lessons related to Space Exploration available on the web I am including several here

1. Orbit Model: <http://octopus.gma.org/surfing/satellites/orbit.html>
2. Asteroid Orbits: http://www.nasaexplores.com/show_912b_teacher_sh.php?id=030109170446
3. Orbit and Artificial Satellite: <http://www.bu.edu/satellite/classroom/lesson02-2.html>
4. Flight Paths of Orbiting Satellites: <http://www.cee.hw.ac.uk/~diana/mirador/AskERIC/SPA0008.html>
5. Satellite Designers Wanted: <http://octopus.gma.org/surfing/satellites/design.html>
6. Launch a Satellite: <http://octopus.gma.org/surfing/satellites/launch.html>
7. How do We Launch Artificial Satellites? <http://www.bu.edu/satellite/classroom/lesson05-1.html>
8. Daily Motion of the Sun: http://www.nasaexplores.com/show_912_teacher_st.php?id=030102140711
9. Predict a Satellite Pass: <http://octopus.gma.org/surfing/satellites/predict.html>
10. Start the Space Flight Time Line: <http://www.bu.edu/satellite/classroom/lesson01.html>
11. How does a Satellite Stay in Orbit? <http://www.bu.edu/satellite/classroom/lesson05-2.html>
12. Designing Space Exploration: http://www.nasaexplores.com/show_912_teacher_st.php?id=031015161045
13. Tracking Satellites using Latitude and Longitude: <http://www.teachers.net/lessons/posts/1616.html>
14. Why do Satellites Stay in Orbit? <http://www.teachers.net/lessons/posts/1616.html>

Day 31: Satellites

Start with a brainstorming session. Ask the class the following questions:

Question: What do you know about Space Exploration?

Question: What do you think you know about Space Exploration?

Question: What would you like to know about Space Exploration?

Write down all reasonable student responses under each category. Use different colored pens for Earth based exploration and Space based Exploration.

Class discussion about Space Exploration.

Why Explore Space? Here is an answer from Janet Wood, NASA/JPL

Why Explore Space?

- It is part of our nature as human beings that we want to explore and try to better understand the world in which we live. Space exploration is the logical extension of that need.
- Through the exploration of the solar system, we can begin to unravel the mysteries of our universe, and to better understand our place in the cosmos.
- Space exploration provides us with knowledge about the origins of our solar system, our own planet Earth, and about human origins, and helps to answer questions that have intrigued humankind throughout the centuries.
- Solar system exploration is important because it provides us with an unparalleled opportunity to make advancements in science and technology, which can be a benefit to all of humankind, such as in the areas of communications and remote sensing.
- Space technology has become an integral part of our daily lives. Cellular technology, for example, is dependent on satellite communications, Satellites are also used to monitor changes in Earth's climate and ocean circulation, for weather forecasting, in aviation and marine navigation, and for military reconnaissance.
- The space program provides an opportunity for nations to work together in international cooperation through participation in joint missions, thereby promoting peace and understanding between governments and their people.
- Many governments are currently involved in the development of space technology including Russia, Japan, the European nations, and India. In the near future, other nations will be added to this list. It is vital to our national interest that the United States remains the leader in developing new space technologies in order to insure the peaceful exploration of space by all.

[Janet Wood - Solar System Ambassador](#)

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Break the class into group to generate a list of reason why we should explore space. Have the group then share their discussions with the class. Generate a list from this whole class discussion.

These lists will be used as the foundation for the web pages the students will generate.

The home page should have information about Space Exploration, timelines, why we explore space, and the future of space exploration. The page should include information about programs from around the world, not just the United State.

Resources:

- A timeline can be found at: <http://my.execpc.com/~culp/space/timeline.html>
- Timeline of artificial satellites and space probes: <http://www.answers.com/topic/timeline-of-artificial-satellites-and-space-probes> (this site has links to information about the satellites)
- Solar System Exploration: <http://solarsystem.nasa.gov/index.cfm> (listed by date, target, or alphabetically)

These resources have links to information about the satellites or probes.

Space Exploration Web Page.

You will be adding to the class Space Web Page this time you will create a page on a satellite or space probe. Please select a satellite or space probe; you must get the teachers approval before you start your research. Below is a checklist for the web page and a timeline.

Satellite/Probe: _____

Minimum Requirements

- Satellite/Probe name
- Image of satellite/probe
- Date launched or to be launched
- Agency – who launched the satellite/probe
- Mission
- Successful or failure
- Duration of mission
- References
- Links

Bonus Points

- Banner heading
- Background image or color
- Images related to mission (images sent from satellite/probe etc.)
- Information or links to information about related missions

Make sure that you do not make you web page overly busy.

Timeline

Due Dates: (write in the dates below)

Chose satellite/probe

Story board of web page

Bibliography

Web page completed
