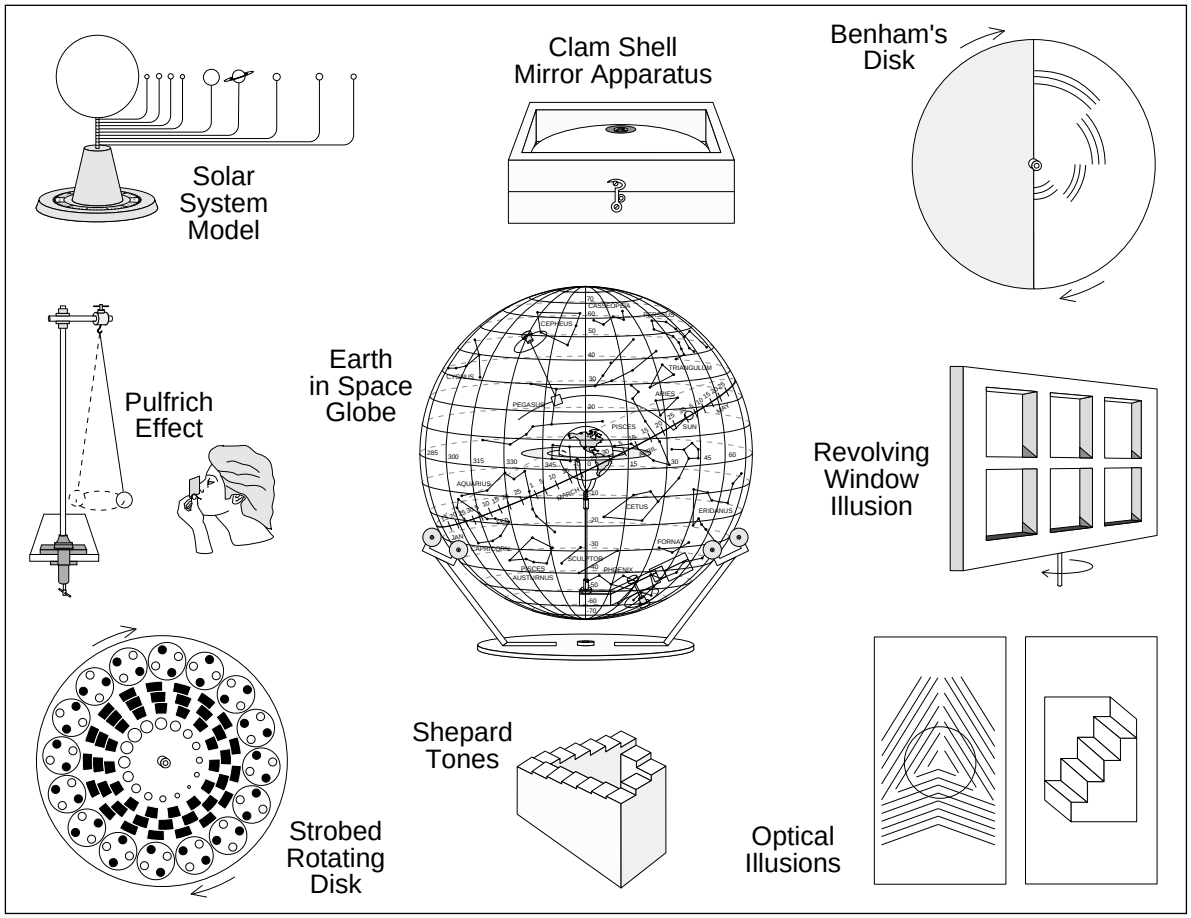
Notebook 'G':
Astronomy and Perception
Lecture Demonstrations



ASTRONOMY SLIDES G+0+0

35 mm slides for astronomy

Three sets of slides:

HPF (Haydn Planetarium)
1) The solar system
2) Formation of the planets
3) The Sun
4) Mercury (Mariner 10 NASA photo)
5) Crescent Venus
6) Clouds of Venus (in UV) (Mariner 10 NASA photo)
7) The Earth (Apollo 17 NASA photo)
8) Full moon
9) Mars
10) Mars: Olympus Mons volcano (Mariner 9 NASA photo)
11) Mars: Grand Canyon (Mariner 9 NASA photo)
12) Mars: Sinuous channel (Mariner 9 NASA photo)
13) Phobos (Mariner 9 NASA photo)
14) Jupiter with moon
15) Jupiter's great red spot (Pioneer 11 NASA photo)
16) Saturn
17) Saturn: rings edge-on
18) Uranus and Neptune (arrows indicate moons)
19) Pluto
20) Comet Ikeya-Seki

V
1) The Sun in total eclipse, June 30, 1973
2) The Sun in annular eclipse, April 19, 1997 (multiple exposure)
3) The moon in total eclipse, May 25, 1975
4) Greenish northern lights (aurora borealis) Finland, Nov. 22, 1975
5) Blue northern lights (aurora borealis) Finland, Jan. 6, 1978
6) Comet West (1976 VI), March 4, 1976
7) 2 Nebulae in Scorpius NGC 6357 (top) & NGC 6334
8) Orion's Belt and Nebulae: Horsehead and Great Nebula
9) Trifid (top) and Lagoon Nebulae in Sagittarius M20 & M8)
10) California Nebula (NGC 1499) in Perseus
11) North American & Pelican Nebulae in Cygnus (NGC 7000 & IC 5067-70)
12) Eta Carinae Nebula (NGC 3372)
13) Veil Nebula in Cygnus (complete loop: NGC 6960 / 95)
14) Open Cluster NGC 6231 and Nebula in Scorpius
15) Praesepe Open Cluster (M44) in Cancer
16) Omega Centauri Globular Cluster (NGC 5139)
17) Milky Way in Sagittarius (looking toward center of galaxy)
18) Milky Way with Southern Cross, Coalsack, and Eta Carinae
19) Large Megellanic Cloud with Tarantula Nebula (NGC 2070)
20) Small Megellanic Cloud and Globular Cluster 47 Tucanae

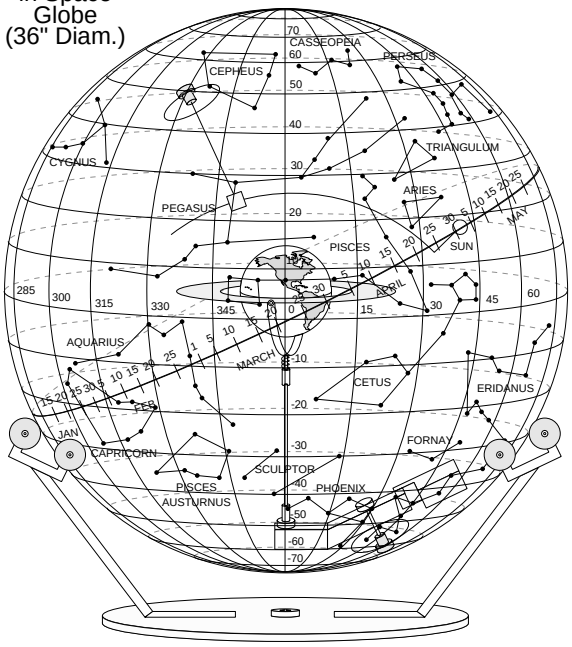
USNO (United States National Observatory)
1) Crab Nebula in Taurus (M1, NGC 1952)
2) Lagoon Nebula in Sagittarius (M8, NGC 6523)
3) Trifid Nebula in Sagittarius (M20, NGC 6514)
4) Dumbbell Nebula in Vulpecula (M27, NGC 6853)
5) Great Nebula in Orion (M42, NGC 1976)
6) Ring Nebula in Lyra (M57, NGC 6720)
7) Veil Nebula in Cygnus (NGC 6992-95)
8) Globular Cluster in Hercules (M13, NGC 6205)
9) Milky Way in Sagittarius
10) Andromeda Galaxy: Nucleus (M31, NGC 224)
11) Elliptical Galaxies (M32, NGC 221, type E2) and (NGC 205 type E6p)
12) Whirlpool Galaxy in Canes Venatici, type SC I / Irr (M51, NGC 5194 / 5)
13) Irregular Galaxy in Ursa Major type SCP? (M82, NGC 3034)
14) Spiral Galaxy in Coma Berenices, type SB (edge-on) (NGC 4565)
15) Spiral Galaxy in Draco, Type SC / SB (edge-on) (NGC5907)
16) Spiral Galaxy in Cygnus, type SC (NGC 6946)
17) Jupiter (great red spot visible)
18) Saturn (rings nearly edge-on)
19) Star trails around the North Star
20) Aurora (the Northern Lights)

Ref.:Teacher's Manual For Farquhar, p.11-18

ASTRONOMY MODELS. G+5+0

Vault of the heavens: Large lucite globe.

Earth in Space Globe (36" Diam.)



Compass

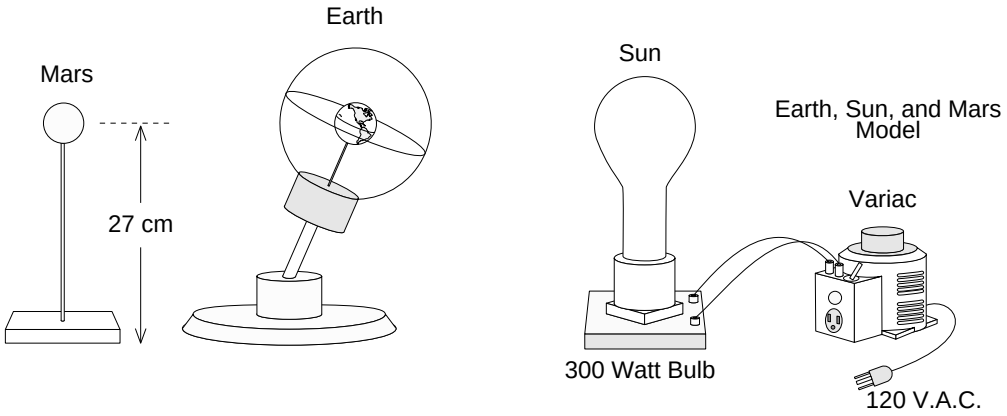
The Earth in Space Globe consists of a number of elements. At the center is a transparent model of the earth mounted on a shaft which can be rotated by hand using a knob at the base of the assembly near the South Celestial Pole. An adjustable plastic 'Horizon Ring' is positioned about the Earth to indicate the visual horizon. Suspended above the Earth is the Sun on a wire that can be adjusted using a knob mounted near the North Celestial Pole. There is also a wire perpendicular to this called the Sunlight Terminator wire, which shows where the Sun is rising and setting.

Surrounding the Earth is a large 36" transparent plastic globe that is printed with a lot of information. The globe has Hour Circle Lines every 15° corresponding to longitude (used to determine Right Ascension) and Lines of Declination every 10°, corresponding to latitude. Inscribed about the globe at an angle of 23.5° is the plane of the ecliptic, printed with Months in 5 day increments, indicating the position of the Sun. Over 1100 stars to magnitude 4.5 are shown with dots of 7 sizes. The more popular stars are named, and distances are given in light years. Eighty constellations are drawn in with lines and named. Also some nebulae, star clusters and galaxies are shown, as well as boundaries of the Milky Way. The precessional path of the North and South Celestial Poles are shown.

A compass is mounted at the base of the entire assembly. Following the procedures outlined in the Farquhar manual, the Earth is oriented in space so that the Sun and stars are at their correct locations for the current date and time.

ASTRONOMY MODELS. **G+5+5**

Earth, Sun and Mars model.

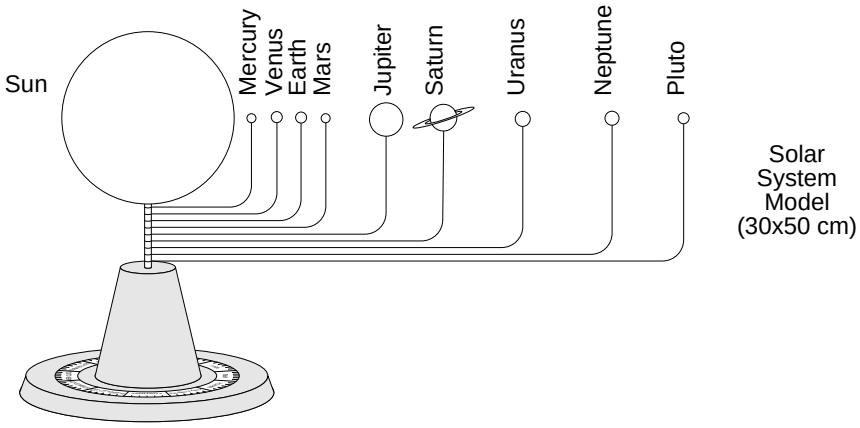


There isn't much to this demo. A variac controls the brightness of a large light bulb that represents the Sun. Small models of the Earth and Mars are set out at selected distances.

Ref.:Hubbard Sci. Co. Manual

ASTRONOMY MODELS. **G+5+10**

Solar system model.



This solar system model is a three-dimensional representation of the Sun and the nine planets. The model is not true to scale. (A real model would have the sun with a 15 cm diameter and Pluto would be a small grain of sand half a mile away...) The model can be used to give the class a sense of the relative sizes, distances, speeds of the planets around the sun, and length of years. Using a planet location table and the degree markings on the base of the model, the position of the planets can be shown for different months and years (the charts we have only go up to year 1990.) This makes it clear why only some planets are seen at certain times of the year. The manual included with the model gives other information about the planets, as well as comments on asteroid swarms, planetary conjunctions, and Kepler's laws of planetary motion.

Ref.:Circularity in Judgments of Relative Pitch, R. Shepard, Journal of the Acoustical Soc. of Amer., Dec. 1964

AUDITORY ILLUSIONS. G+50+5

Shepard tones: illusion of continually rising or falling tones.

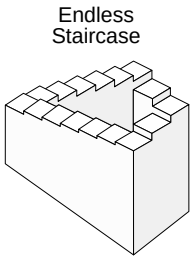


Fig.1

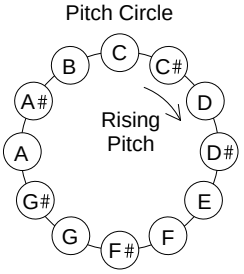


Fig.2

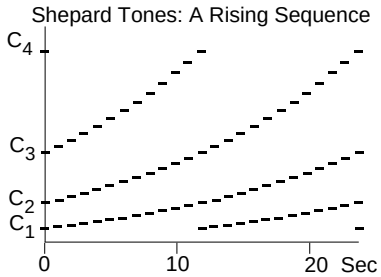


Fig.3

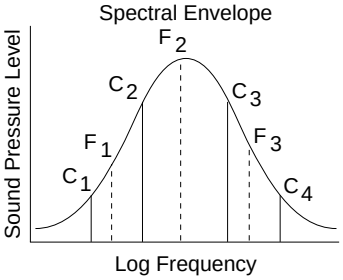


Fig.4

See figure 1. The endless staircase picture (designed by Penrose and made famous by Escher) gives the visual illusion that one can go endlessly up or down. The acoustic counterpart designed by Shepard in 1964 gives the illusion that tones endlessly rise or fall in pitch. Our audio cassette tape has a selection of rising and falling sequences of 'Shepard tones', each about a minute long.

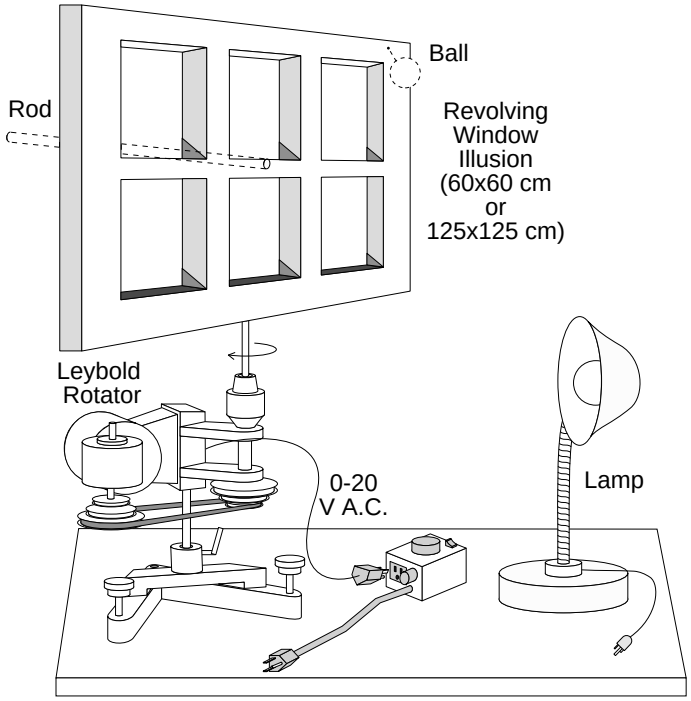
See figure 2. A note that is twice the frequency of another note is said to be an octave above. In the 'equally tempered scale' used in Western music, there are 12 semitones in one octave: C, C-sharp, D, D-sharp and so forth up to C again. The second C is an octave above the first. Thus, all notes can be shown on a 'pitch-circle', with frequency increasing as one goes clockwise. The piano has a keyboard with 7 octaves; the international standard is set so that A4 (note A in the fourth octave) equals 440 Hz; C4 or middle C on the piano is 261.6 Hz, etc.

A note such as F in one octave is 'perceptually similar' to an F in another octave. With the Shepard illusion, it appears that notes are rising (or falling) within an octave, yet the octave containing the notes becomes unclear. Shepard was able to make 'tones' that were created by adding a number of notes in different octaves. See figure 3. The first tone in a simple 'rising sequence' could consist of several notes an octave apart such as C1, C2, C3 and C4. The amplitude of each of the notes in the tone is adjusted using the 'spectral envelope' shown in figure 4. E.G.: the amplitude of C1 is small, C2 and C3 are larger, and C4 is small. Each of the sequential Shepard tones is modified by the envelope so that after 12 increments around the pitch-circle the original tone is encountered again and the cycle repeats.

Ref.:Modern College Physics by Harvey White, 6rd ed., p. 24-25

OPTICAL ILLUSIONS. G+55+0

Revolving window illusion.

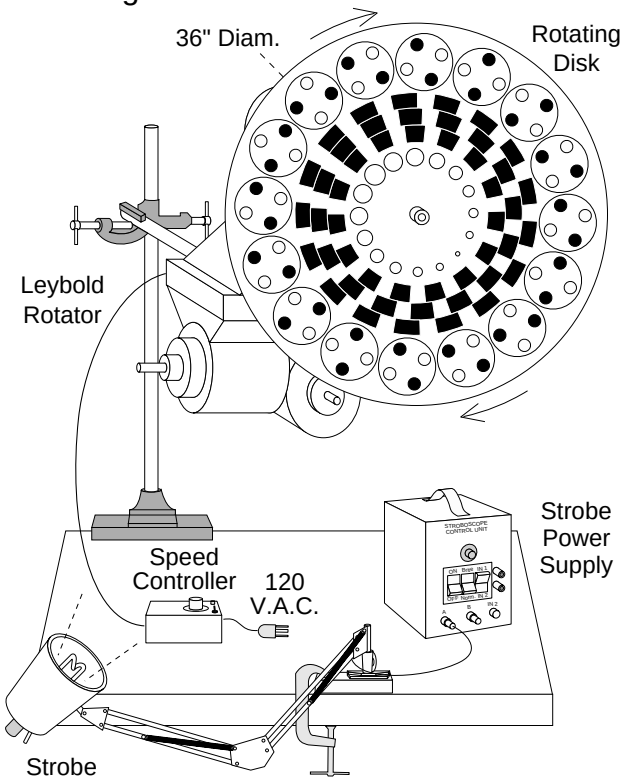


The revolving trapezoidal window is a striking optical illusion in perspective. The window is plywood painted white, black and gray, with rectangles cut out for windows. It is mounted on a slowly rotating motor-driven shaft in a darkened room. (There are light sources from the front and from the side, shielded from the class.) The window appears to rotate first in one direction, and then the other. An additional effect is to hang a brightly colored ball on the upper corner of the small end. The ball appears to keep going in the same direction while the window oscillates back and forth. One other effect is to place a colored rod through the upper center window. As the assembly rotates, the rod's behavior if baffling.

Ref.:Modern College Physics by Harvey White, 6rd ed., p.26

OPTICAL ILLUSIONS. G+55+5

Rotating disk and strobe demonstration.

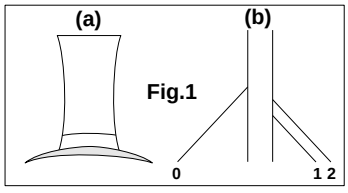


In a dark room, a stroboscope illuminates a rotating disk painted with three concentric sets of designs. The central design consists of circles ranging from small to large. The middle design is three slightly different rings of rectangles. The outer design is a series of dots within circles. The flashing strobe creates the illusion that the main disk is standing still, while the circles in the center ring alternately shrink and grow; the rings of rectangles rotate but at different speeds and directions, and the dots rotate either clockwise or counterclockwise within the outer circles. The strobe must flash at least sixteen times per second for the illusion to appear smooth to the eye. This effect, called 'persistence of vision', is the same mechanism that enables one to watch a motion picture movie composed of a series of individual pictures.

Ref.:Modern College Physics by Harvey White, 6rd ed., p. 18-26

OPTICAL ILLUSIONS. G+55+10

Optical Illusion posters.



Various Optical Illusions (60x120 cm)

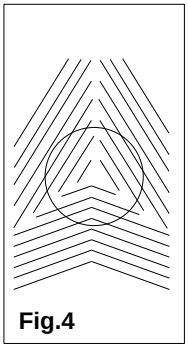


Fig.4

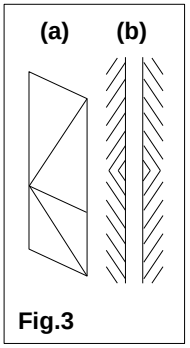


Fig.3

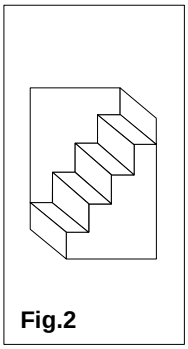


Fig.2

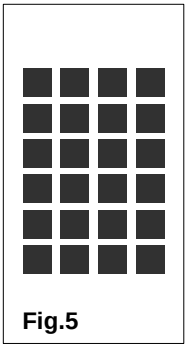


Fig.5

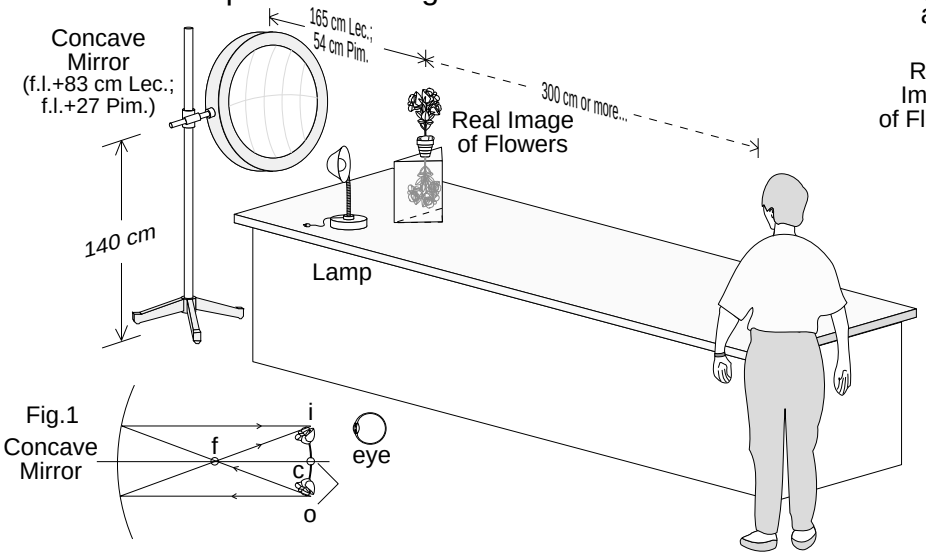
In Fig.1 (a), the length of the brim of the hat is the same as the height of the hat. In Fig.1 (b), the lower right hand slanted line 1, if extended, will intersect the left-hand line 0 where it joins the vertical. However, slanted line 2 actually looks like the one that will intersect with line 0. In Fig.2, the perfect circle appears distorted. In Fig.3 (a), the two diagonal lines are the same length. In Fig.3 (b), the two vertical lines are parallel and straight. These are all 'optical illusions with lines and angles'. In Fig.4 a flight of stairs is seen from above looking down, or from below looking up. This is an 'equivocal figure illusion'. In Fig.5, small gray spots are seen at the intersections of the white lines. The white lines look brighter against the black background, and the place where the white lines intersect seems less bright (or gray) in contrast with the white lines. If you stare at a gray spot, it will become white, while all the other spots remain gray. This is an example of 'irradiation' or 'brightness contrast'.

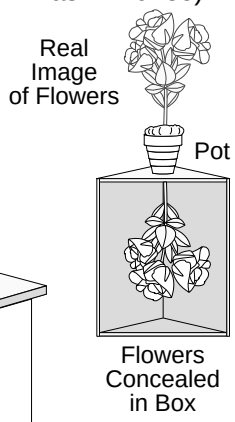
OPTICAL ILLUSIONS.

G+55+15

Phantom bouquet: Real image from a concave mirror.

(Same apparatus as E+40+35)





If an object is placed just below the center of curvature of a concave mirror, a real inverted image is formed just above the center of curvature. This is the secret to the 'phantom bouquet' demo. Artificial flowers are suspended upside-down in a box so that they are concealed to the viewer yet open to the mirror. A real rightside-up image of the flowers appears to be planted in the pot. The image appears solid and real,-yet a hand can pass through it.

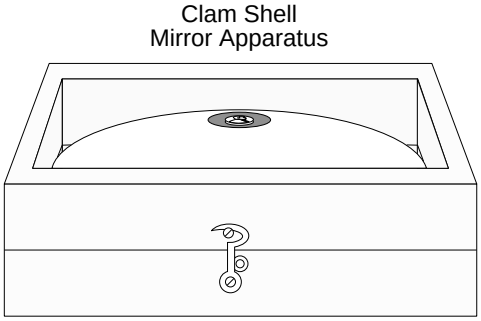
Figure 1 shows the ray diagram for the setup. The inverted flowers are the object at 'o', and the real image of the flowers are at 'i'. A lamp is used to illuminate the flowers, making the image much brighter. In setting up this demo, the distance from the flowers to the mirror must be quite accurate to make the illusion seem real.

OPTICAL ILLUSIONS.

G+55+20

Clam shell mirrors: Floating coin illusion.

(Same apparatus as E+40+40)



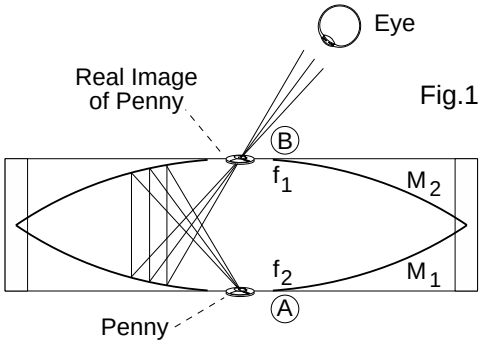


Fig.1

The 'floating-penny' illusion is a clever use of two concave parabolic mirrors. A coin placed on the lecture table in the center of the opening of the lower mirror appears to float within the opening of the upper mirror. The image is so real that people are tempted to touch the coin.

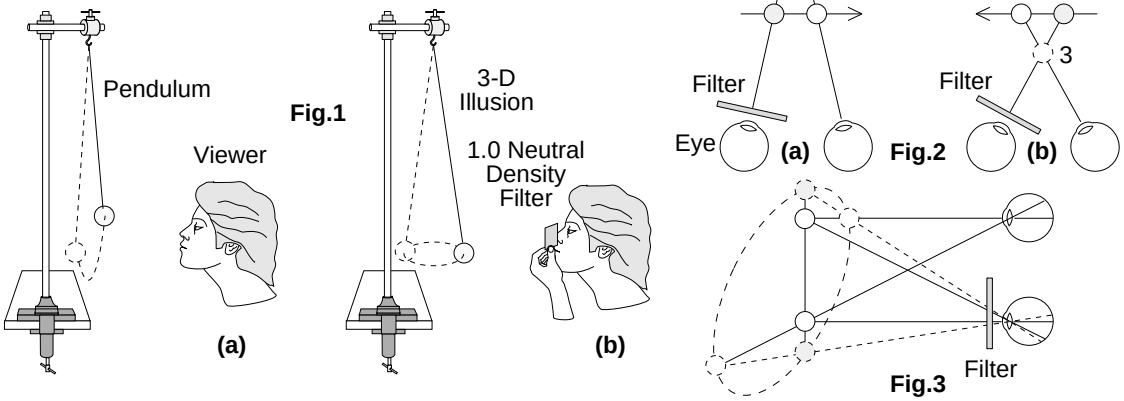
See Figure 1. Front-surface parabolic mirrors M1 and M2 are identical. They both have diameters of 28 cm and focal lengths of 10 cm. Each mirror has a small hole cut in its vertex. The mirrors are arranged so that they face each other. The dimensions of the mirrors have been chosen so that the focal point f1 of mirror M1 is at the vertex of mirror M2, (and f2 is at the vertex of M1). Thus, if a small object such as a penny is placed at 'A' (the focal point of M2), rays of light hitting mirror M2 will all be reflected parallel to each other. These parallel rays will then reflect from mirror M1 and be focused as a real image at 'B' (the focal point of M1).

This device was originally constructed as a 'thermal-imager'. A light bulb placed at 'A' will ignite a piece of paper at 'B'. Sound can also be focused in the same way. A watch ticking at 'A' can be hear loudly at 'B'.

Ref.:A Study of the Pulfrich Phenomenon, William Fleischman (thesis), Univ. of CA, 1948 (QP 495 F5, Optometry library)

PERCEPTION. G+60+5

Pendulum and Filter experiment (Pulfrich effect).



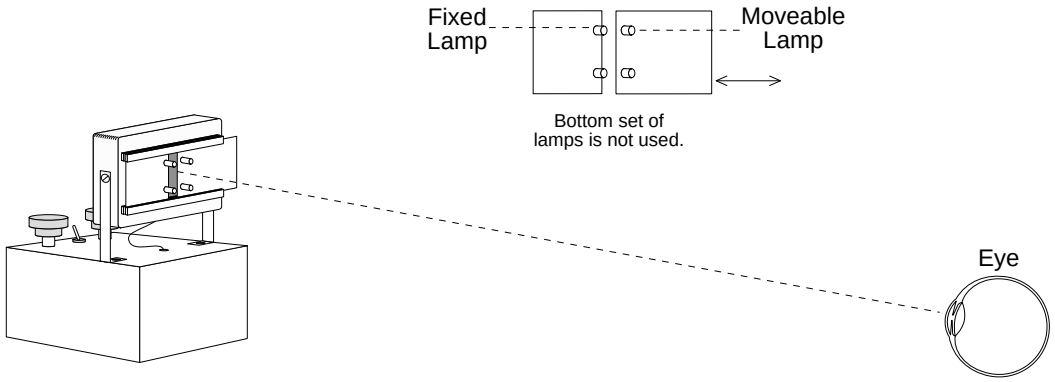
See figure 1a and 1b. In 1922, Pulfrich noted that a pendulum swinging in one plane 'appeared to have' an elliptical path when viewed with a neutral density filter in front of one eye. This startling illusion is due to perceptual mechanisms in the eye and circuits in the brain. See figure 2a. The pendulum ball is swinging left to right. The left eye looking through the neutral density filter sees a dimmer image of the pendulum ball. The rods and cones in the retina of this eye take longer to register and send their image to the brain. This is called a 'latency period'. 1 is the brightly illuminated image seen by the right eye. 2 is the delayed image seen by the left eye. The brain combines these images and the ball appears to be at position 3, further away than expected. In figure 2b, the pendulum is swinging right to left. In this case, applying the same reasoning shows that the image seems closer than expected. Looking at figure 3, one sees how the path of the pendulum appears to be elliptical. Another less obvious effect is that the ball appears larger when farther away, and seems smaller when closer. The perception of the speed of the ball is also distorted. In fact, the greater the speed, the greater the distortion. Thus, the use of a ND filter (1.0-2.5) in front of one eye creates distortions in the perception of depth, size, velocity and position. The Pulfrich effect has been implicated in vehicular crashes when eyes experience conditions of unequal illumination.

Ref.:Physics For Scientists and Engineers by Giancoli, 2nd ed., p. 814

PERCEPTION. G+60+10

Limit of Resolution: Two small lamps on adjustable slide.

(Same apparatus as E+10+45)



Two lamps are mounted on a slide bar so that the spacing between the filaments is variable from 3 to 22 mm. (In addition, the intensity of each filament is individually variable.) The demonstration is pointed at the class and students at different distances from the lamps will experience different limits of resolution dependent upon the conditions set up by the instructor.

The resolution of the human eye is limited by several factors. The resolution is best at the fovea, where cone spacing is the closest. Spherical and chromatic abberation degrade resolution. For an average pupil of about .9 cm, and at λ = 550 nm the eye can resolve objects whose angular separation is about .0005 rad. Thus, at a distance of about 20 m, the eye can resolve the two point lamps at about 1 cm separation.

Ref.:Physics For Scientists and Engineers by Giancoli, 2nd ed., p. 383

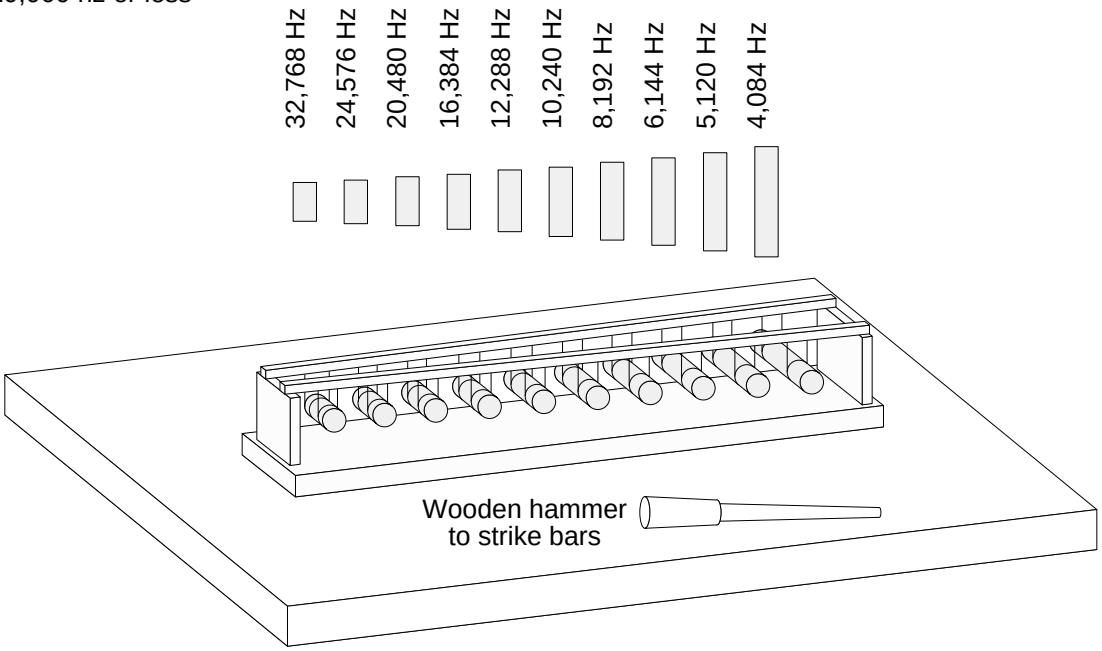
PERCEPTION.

G+60+15

Limit of audibility: Set of rods that ring at different frequencies.

(Same apparatus as B+50+30)

This is a set of 10 solid metal cylinders suspended on strings to resonate from 4084 Hz to 32,768 Hz. A small wooden hammer is used to strike the bars. The audible range for humans is about 20 Hz to 20,000 Hz. With age, the high frequency limit may shrink to 10,000 hz or less

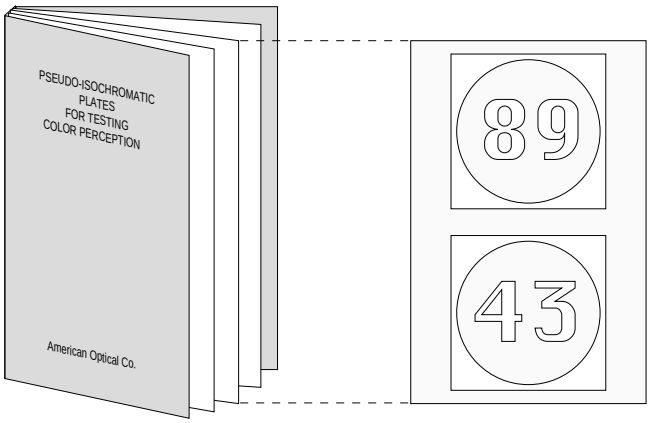


PERCEPTION.

G+60+20

Set of color blindness cards.

(Same apparatus as E+5+0)



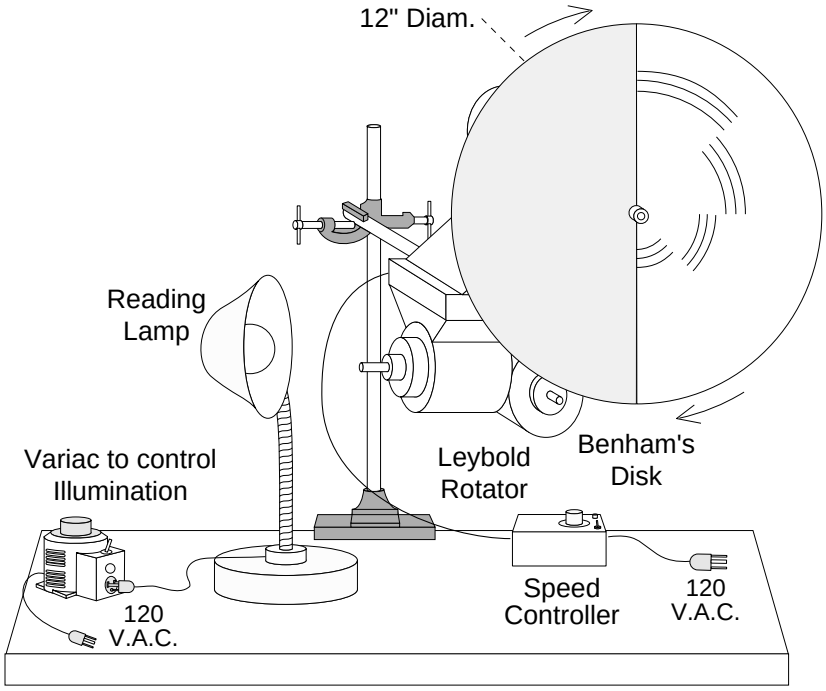
Book of Pseudo-Isochromatic Plates (40 plates)

The Book of Pseudo-Isochromatic Plates has 40 plates. Each plate is composed of grey or green background dots and foreground numbers of red or purple. People with some forms of color blindness can not make out the numbers.

PERCEPTION. **G+60+25**

Rotating disk with black and white lines makes color illusion.

(Same apparatus as E+5+35)



Note: Leybold Rotator pulleys are set for the highest speed

Benham's Disk:

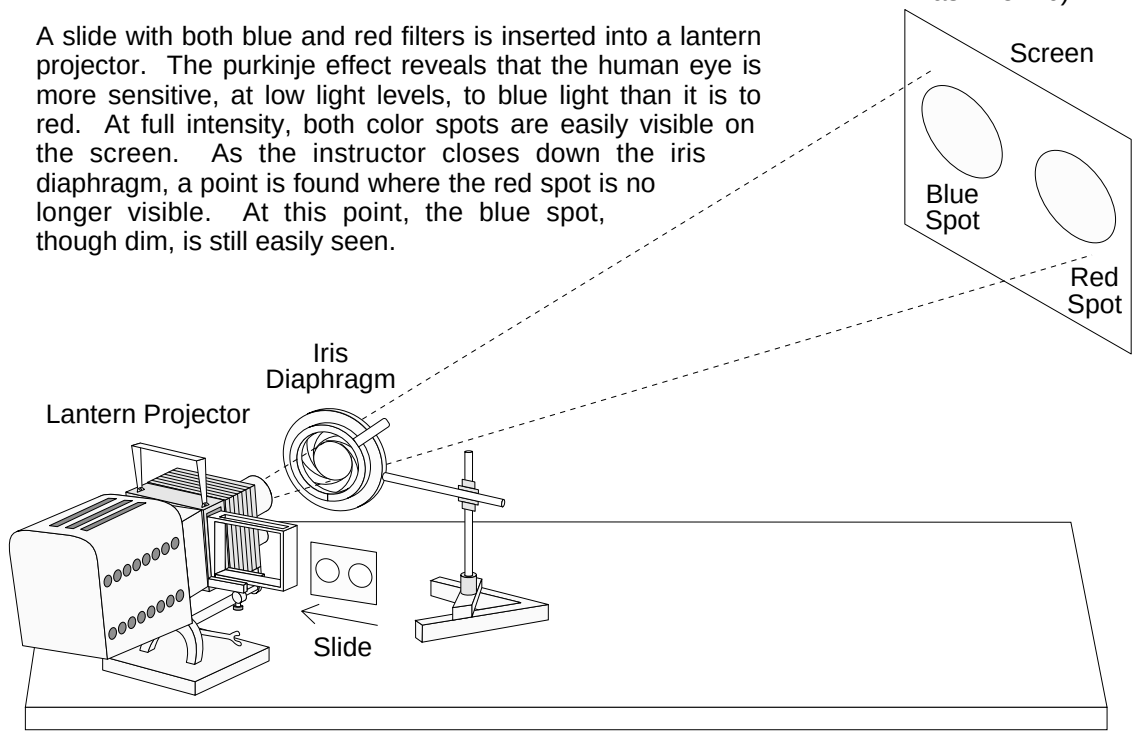
The disk has one half of black, and the other half of white. On the white half, lines of concentric arcs are placed as shown. As the disk is rotated, colors seem to appear. For example: the outer circle may appear light tan, the two inner circles may appear green, and the innermost circle may appear blue. The colors vary with the speed of the disk, and the colors may be perceived differently from person to person. If the disk is stopped, then rotated in the opposite direction, the order of the colors reverses. The explanation is not fully known, but it may be that the rotating arcs cause low frequency stimulation of the color receptors in the retina of the eye.

PERCEPTION. **G+60+30**

Purkinje effect: At low intensity, blue is more visible than red.

(Same apparatus as E+5+40)

A slide with both blue and red filters is inserted into a lantern projector. The purkinje effect reveals that the human eye is more sensitive, at low light levels, to blue light than it is to red. At full intensity, both color spots are easily visible on the screen. As the instructor closes down the iris diaphragm, a point is found where the red spot is no longer visible. At this point, the blue spot, though dim, is still easily seen.



PERCEPTION.

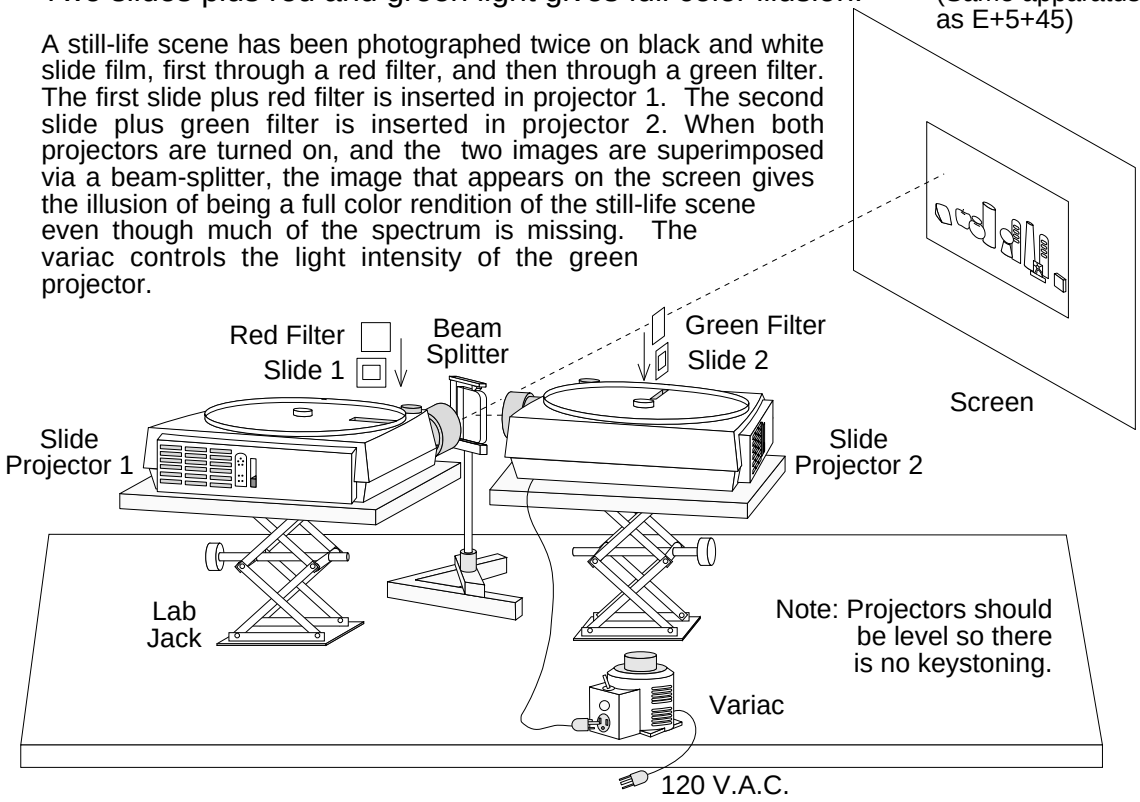
References:
Scientific American, E.H. Land, May 1959, pg.84
and Scientific American, E.H. Land, Dec 1977

G+60+35

(Same apparatus as E+5+45)

Two slides plus red and green light gives full color illusion.

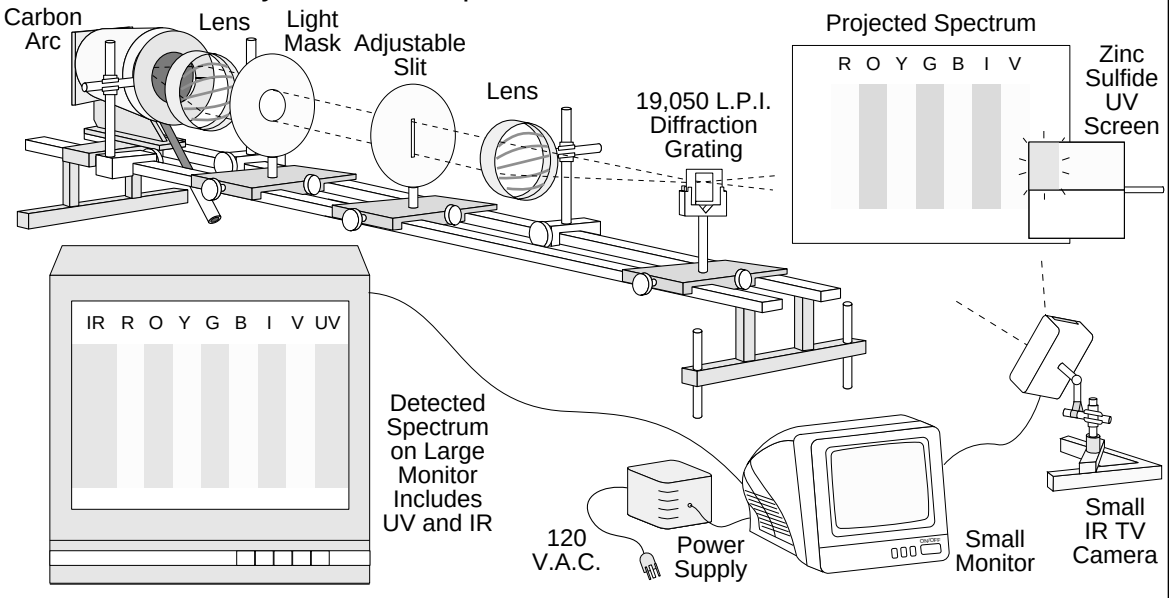
A still-life scene has been photographed twice on black and white slide film, first through a red filter, and then through a green filter. The first slide plus red filter is inserted in projector 1. The second slide plus green filter is inserted in projector 2. When both projectors are turned on, and the two images are superimposed via a beam-splitter, the image that appears on the screen gives the illusion of being a full color rendition of the still-life scene even though much of the spectrum is missing. The variac controls the light intensity of the green projector.



PERCEPTION.

G+60+40

Limits of visibility: the visible spectrum, infrared and ultraviolet.



White light from a carbon arc passes through a slit and is sent through a diffraction grating, creating a full spectrum focused on a white screen. A zinc sulfide screen will phosphoresce when inserted into the dark region of the spectrum beyond violet, showing that there are ultraviolet rays that our eyes do not detect. Also, a small TV camera aimed at the spectrum detects light in the dark region past red, indicating infrared rays that are not visible to our eyes. The small TV camera also shows the visible region and some of the ultraviolet region as well. The instructor can point to the areas that seem dark to our eyes, yet on the monitor they are brightly lit.