Foreword

This manual has evolved from the exercises conducted in the basic astronomy laboratory course taught at the University of North Florida for the past 6 years. It contains 43 lab exercises that are appropriate for a one semester or year long laboratory course. Each exercise contains an introduction that should make it clear to beginning students why the particular topic of that lab is of interest and relevant to astronomy. No mathematics beyond simple high school algebra and trigonometry are required, and an exercise reviewing that is provided (Exercise 37, Astronomy Math Review). About one-third of the exercises are observing exercises, several of which can be repeated with different subjects, for example, Exercise 12, Astrophotography, and Exercise 29, Planetary Observing.

The exercises provided here include variations on standard and popular exercises, and also many exercises which many astronomy instructors will find to be new and innovative. Those which we believe to be innovative are listed below with brief comments. The exercises are organized in this manual into six major topics: Sky, Optics and Spectroscopy, Celestial Mechanics, Solar System, Stellar Properties, and Exploration and Other Topics.

The exercises we believe to be innovative are:

Exercise 5, The Messier List, a pen and paper exercise, which has students discover basic facts about the Milky Way Galaxy by plotting these objects on a star chart.

Exercise 6, About Your Eyes, a lab exercise, which has students measure the time required for their eyes to adapt to the dark. Students also learn to see the light which passes through their eye lids.

Exercise 12, Astrophotography, an observing exercise, which includes a discussion of how photography makes brighter stars appear larger.

Exercise 13, Electronic Imaging, an observing exercise, which explores modern electronic methods of recording images, especially the use of CCD's.

Exercise 15, Motions of Earth, a pen and paper exercise in which students discover just how fast the Earth is moving through space and in which direction is it going.

Exercise 18, Orbiting Earth, a pen and paper exercise in which students learn the basics of space transportation.

Exercise 23, Solar Observing, an observing exercise in which students generate data that they use in a subsequent exercise, to determine the rate of the Sun's rotation, verify the equation of time, and determine the latitude and longitude of the observing site.

Exercise 24, Solar Eclipses, an observing exercise in which students make quantitative and qualitative observations of solar eclipses.

Exercise 27, Lunar Eclipses, an observing exercise in which students make quantitative and qualitative observations of lunar eclipses.

Exercise 28, Observing Comets, an observing exercise for bright comets.

Exercise 30, Occultations, an observing exercise for lunar and planetary occultations.
Exercise 33, Elements and Supernovae, a pen and paper exercise in which students explore the periodic table to learn the properties of elements that are important for differentiation of the Solar System, and radioactive heating and dating of celestial bodies.
Exercise 35, Binary Stars, an observing exercise in which students make quantitative and qualitative observations of binary stars.
Exercise 36, Variable Stars, an observing exercise in which students make quantitative and qualitative observations of variable stars.
Exercise 38, Computer Planetaria, a computer exercise in which students explore these useful tools of astronomy.
Exercise 39, Astronomy on the Internet, a computer exercise in which students explore this enormous source of astronomical information.
Exercise 40, Observatory Visit, an exercise for directing a tour of an observatory.
Exercise 41, Planetarium Visit, an exercise for directing a visit to a planetarium.
Exercise 42, Radioactivity and Time, a lab exercise in which students measure the half-life of a short-lived isotope, and consider radioactive dating and heating of celestial bodies.

The following labs contain observing exercises:

Exercise 3, Sky Patterns
Exercise 4, Dark Sky Observing
Exercise 12, Astrophotography
Exercise 13, Electronic Imaging
Exercise 23, Solar Observing
Exercise 24, Solar Eclipses
Exercise 26, Lunar Observing
Exercise 27, Lunar Eclipses
Exercise 28, Observing Comets
Exercise 29, Planetary Observing
Exercise 30, Occultations
Exercise 35, Binary Stars
Exercise 36, Variable Stars

Foreword
Underline exercises pgs. i, ii?
Virtual Document does not have underline. Text does.

Guide to Astronomical Pronunciation

This is a list of rules for the pronunciation of astronomical names. Most of the astronomical names used today have their origins in Latin, Classical Greek, and Arabic. An effort has been made to preserve as many of the original sounds as possible. Because these languages were unplanned, some letters have more than one sound. A good rule for pronouncing a particular letter is to choose the sound that is easiest to say with the other sounds in the word.

Vowels

a: as in "father" or as in "barn"
e: as in "let" or as 'ay' in "play"
i: as in "machine" or as in "bit"
o: as in "note" or as in "knot"
u: as in "rude" or as in "put"
y: as in the German "über" or as 'i' in "bit."

Dipthongs

h

ae: as 'ai' in "aisle"
au: as 'ou' in "out"
ei: as in "reign"
eu: as "e(h)oo" or as in "neutral"
oe: as 'oi' in "oil"
ui: as in "ruin."

Consonants

Pronounce consonants as in American English with the following specifications:
c: as in "can"
g: as in "go"
i and **j**: as 'y' in "yet"
qu: as 'k' in "kite" or as in "quill"
r: same as in American English, except trilled
s: as in "sea"
t: as in "tired"
v: as 'w' in "wake" or as in "vase"
x: as in "axle"
ch: as in the German "Bach" or as 'ck' in "block"
ph: as in "philosophy"
th: as in "thin"
double consonants are *pronounced double*, that is, they are held longer than single consonants

Emphasis

Words have as many syllables as vowels. Normally, emphasis (accent) falls on the antepenult (last syllable but two). The penult (next to last syllable) gets the accent if there are only two syllables (as in Rigel), the penult contains a long vowel or a dipthong (as in Cassiopeia), or the penult's vowel is followed by two or more consecutive consonants (as in Sagitta).

Examples

Acamar - AK-a-mar
Aldebaran - ahl-DEB-ahr-ahn
Boötes - BOH-oh-tes
Betelgeuse - beh-tel-GEU-seh
Canes Venatici - KAHN-ehs weh-NAH-tee-kee
Canis Major - KAHN-ees MAH-yor
Cassiopeia - kas-see-o-PAY-a
Delphinus - DEHL-fee-nus
Enif - EH-nif
Equuleus - eh-KOO-leh-us
Gemini - GEH-mee-nee
Hyades - HOO-ah-des
Lacerta - lah-KER-ta
Lupus - LOO-pus
Mizar - MEE-zahr
Monoceros - mo-NO-kehr-os
Nunki - NOON-kee
Orion - O-ree-ohn
Pisces - PEES-kehs
Pleiades - PLEH-ah-des
Procyon - PRO-koo-on
Rigel - REE-gehl
Sagitta - sah-GEET-tah
Sagittarius - sah-geet-TAH-ree-us
Taurus - TOU-rus (ou in house)
Ursa Minor - OOR-sa MEE-nor
Vulpecula - wool-PEH-koo-lah
Zubenelgenubi - zoo-beh-nehl-GEH-noo-bee

Guide to the Constellations

Our ancestors gazed up at the night sky, without air and light pollution, and saw great beauty and mystery. They imagined pictures in the sky, formed by the tiny points of light known as stars. These pictures are the constellations. Each culture has had its own set of constellations, depicting the concerns of its people. The early European sailors to the southern hemisphere named the imaginary star patterns after concerns of their time (c.f., Vela (sails), Puppis (ship's stern), Sextans (sextant), Telescopium (telescope), etc.). Had the constellations been named in our modern age, we might have placed computers, digital watches, televisions, and mushroom clouds in the sky.

The constellations are named in Latin, which adds a little confusion but a lot of romance to the heavens. The constellations are also named in the international language, Esperanto. Modern star charts divide the heavens into eighty-eight constellations. Although celestial coordinates are more precise for locating objects, modern astronomers continue to use the constellations as a convenient way to communicate the general region of the sky in which to find an object.

The easiest way to find out which stars will be visible at a particular time and date is to use a star wheel. Just dial the star wheel to the desired date and time. The stars visible through the window are the ones in the sky at that time. For example, at 2100 (or 9:00 PM) on 14 February, Coma Berenices and Leo are rising in the east with Virgo not far behind. Ursa Major is in the northeast. Nearly overhead are Auriga, Gemini, and Cancer. To the south are Taurus, Orion, and Canis Major. In the west are Perseus, Cassiopeia, and Andromeda. In the northwest is Cepheus, and in the southwest is Cetus.

The mythology behind the names of the constellations illustrate the imaginations of some of our ancestors. Most people are familiar with the story of Perseus saving the fair Andromeda from the ravening sea-monster, Cetus. Andromeda's parents, Cepheus, the king and Cassiopeia, the queen, stand by helplessly. Other stories from many cultures are available at your local library or bookstore.

Along with constellations, other sky patterns also have been named. These patterns are called asterisms. An asterism is composed of part of a larger constellation or from parts of more than one constellation. For example, the Big Dipper is part of the larger constellation Ursa Major (The Greater Bear) and the Summer Triangle is composed of the brightest stars from the constellations Lyra, Cygnus, and Aquila. Other famous asterisms are the Little Dipper, the Great Square, the Seven Sisters, and the Winter Pentagon.

Sometimes the sky is shown as a globe with the stars pasted to its surface and Earth resting at its center. As Earth rotates about its axis from west to east, the sky seems to rotate from east to west. Stars move across the sky, some rising, some setting, and some neither rising nor setting. These stars that never fall below the horizon are called circumpolar stars, for they move in circular paths around the celestial poles. In the northern hemisphere, the point in the sky that does not seem to move at all is the north celestial pole. Currently, Polaris, the North Star, is the closest star visible with the naked eye to the north celestial pole. Polaris did not always hold this position.

Due to Earth's axial precession, the celestial poles move over time. When the great pyramids of Giza were being built, Thuban in the constellation of Draco held this position. In thirteen thousand years, Vega in Lyra will be near the north celestial pole. Vega shall make a fine north star, for it is the fifth brightest star in the night sky.

Most of the bright stars have names. But, astronomers need an easier way to label stars. The Bayer Constellation Designation (BCD) names a star based on the constellation in which it appears and its relative brightness compared with other stars in the constellation. The first part of the BCD is a Greek letter. The brightest star of the constellation is labeled Alpha, the second brightest is labeled Beta, and so on. The second part of the designation is the genitive form of the constellation name. Regulus, the brightest star in the constellation of Leo, is given the BCD of Alpha Leonis. The third brightest star in Crux is Gamma Crucis.

Unfortunately, brightnesses have been incorrectly measured or stars have changed their brightnesses since their BCD's were established. So, the BCD ordering may not always accurately reflect the brightnesses of the stars. For example, Betelgeuse is listed as Alpha Orionis, though it is dimmer than Rigel (Beta Orionis). Modern catalogues of stars label the stars with their celestial coordinates (right ascension and declination).

The following table lists for each of the eighty-eight constellations its Latin name, its genitive form, the Latin abbreviation, the Esperanto [1] name, and an English description.

Latin Name	Genitive	Abbr	Esperanto	English Description
Andromeda	Andromedae	And	Andromedo	Chained Princess
Antlia	Antliae	Ant	Pumpilo	Air Pump
Apus	Apodis	Aps	Birdo de Paradiso	Bird of Paradise
Aquarius	Aquarii	Aqr	Akvoportanto	Water Bearer
Aquila	Aquilae	Aql	Aglo	Eagle
Ara	Arae	Ara	Altaro	Altar
Aries	Arietis	Ari	Sxafo	Ram
Auriga	Aurigae	Aur	Cxargvidisto	Charioteer
Boötes	Boötis	Boö	Brutisto	Herdsman
Caelum	Caeli	Cae	Cxizilo	Sculptor's Chisel
Camelopardalis	Camelopardalis	Cam	Gxirafo	Giraffe
Cancer	Cancri	Cnc	Kankro	Crab
Canes Venatici	Canum Venaticorum	CVn	Cxasantoj Hundoj	Hunting Dogs
Canis Major	Canis Majoris	CMa	Hundego	Greater Dog
Canis Minor	Canis Minoris	CMi	Hundeto	Lesser Dog
Capricornus	Capricorni	Cap	Kaprikorno	Sea Goat
Carina	Carinae	Car	Kilo	Ship's Keel
Cassiopeia	Cassiopeiae	Cas	Kasiopejo	Queen in a Chair
Centaurus	Centauri	Cen	Centauro	Centaur
Cepheus	Cephei	Cep	Kefeo (Cefeo)	Monarch
Cetus	Ceti	Cet	Baleno (Ceto)	Whale

Chamaeleon	Chamaeleontis	Cha	Kameleono	Chameleon
Circinus	Circini	Cir	Cirkelo	Pair of Compasses
Columba	Columbae	Col	Kolombo	Dove
Coma Berenices	Comae Berenices	Com	Haroj de Berenico	Berenice's Hair
Corona Australis	Coronae Australis	CrA	Krono Suda	Southern Crown
Corona Borealis	Coronae Borealis	CrB	Krono Norda	Northern Crown
Corvus	Corvi	Cor	Korvo	Crow
Crater	Crateris	Crt	Kratero (Taso)	Cup
Crux	Crucis	Cru	Kruco	Cross (Southern)
Cygnus	Cygni	Cyg	Cigno	Swan (Northern Cross)
Delphinus	Delphini	Del	Delfeno	Dolphin
Dorado	Doradus	Dor	Glavfisxo	Swordfish
Draco	Draconis	Dra	Drako	Dragon
Equuleus	Equulei	Equ	Cxevaleto	Little Horse
Eridanus	Eridani	Eri	Eridano	River Eridanus (Po)
Fornax	Fornacis	For	Forno	Furnace
Gemini	Geminorum	Gem	Gxemeloj	Twins
Grus	Gruis	Gru	Gruo	Crane
Hercules	Herculis	Her	Herkulo	Hercules, son of Zeus
Horologium	Horologii	Hor	Horologxo	Clock
Hydra	Hydrae	Hya	Hidro	Sea Serpent
Hydrus	Hydri	Hyi	Marserpento	Water Snake
Indus	Indi	Ind	Hindo	Indian
Lacerta	Lacertae	Lac	Lacerto	Lizard
Leo	Leonis	Leo	Leono	Lion
Leo Minor	Leo Minoris	LMi	Leoneto	Lesser Lion
Lepus	Leporis	Lep	Leporo	Hare
Libra	Librae	Lib	Skalo	Balance (Scales)
Lupus	Lupi	Lup	Lupo	Wolf
Lynx	Lyncis	Lyn	Linko	Lynx
Lyra	Lyrae	Lyr	Liro	Lyre (Harp)
Mensa	Mensae	Men	Tablo	Table Mountain
Microscopium	Microscopii	Mic	Mikroskopo	Microscope
Monoceros	Monocerotis	Mon	Unukornulo	Unicorn
Musca	Muscae	Mus	Musxo	Fly
Norma	Normae	Nor	Nivelilo	Carpenter's Level
Octans	Octantis	Oct	Oktanto	Octant
Ophiuchus	Ophiuchi	Oph	Ofiuhxo (Ofiuko)	Ophiuchus, the Serpent Bearer
Orion	Orionis	Ori	Oriono	Orion, the Hunter
Pavo	Pavonis	Pav	Pavo	Peacock

Pegasus	Pegasi	Peg	Pegazo	Pegasus, the Winged Horse
Perseus	Persei	Per	Perseo	Perseus, the Hero
Phoenix	Phoenicis	Phe	Fenikso	Phoenix
Pictor	Pictoris	Pic	Stablo	Painter's Easel
Pisces	Piscium	Psc	Fisxoj	Fishes
Piscis Austrinus	Piscis Austrini	PsA	Fisxo Suda	Southern Fish
Puppis	Puppis	Pup	Poupo	Ship's Stern
Pyxis	Pyxidis	Pyx	Kompaso	Mariner's Compass
Reticulum	Reticuli	Ret	Reto	Net
Sagitta	Sagittae	Sge	Sago	Arrow
Sagittarius	Sagittarii	Sgr	Pafarkisto	Archer
Scorpius	Scorpii	Sco	Skorpio	Scorpion
Sculptor	Sculptoris	Scl	Skulptisto	Sculptor
Scutum	Scuti	Sct	Sxildo	Shield
Serpens	Serpentis	Ser	Serpento	Serpent
Sextans	Sextantis	Sex	Sekstanto	Sextant
Taurus	Tauri	Tau	Tauro	Bull
Telescopium	Telescopii	Tel	Teleskopo	Telescope
Triangulum	Trianguli	Tri	Triangulo	Triangle
Triangulum Australe	Trianguli Australis	TrA	Triangulo Suda	Southern Triangle
Tucana	Tucanae	Tuc	Tukano	Toucan
Ursa Major	Ursae Majoris	UMa	Ursego	Greater Bear
Ursa Minor	Ursae Minoris	UMi	Urseto	Lesser Bear
Vela	Velorum	Vel	Velo	Ship's Sails
Virgo	Virginis	Vir	Virgo	Maiden
Volans	Volantis	Vol	Fisxfluganto	Flying Fish
Vulpecula	Vulpeculae	Vul	Vulpeto	Little Fox

(1) Esperanto is a planned language developed by L.L. Zamenhoff in the late 19th century. The alphabet is pronounced similar to American English, except each letter has one sound only; i.e., a as in father, b as in bear, c as 'ts' in bats, d as in dog, e as in terran, f as in fox, g as in garden, h as in hot, i as in machine, j as 'y' in year, k as in kite, l as in light, m as in moon, n as in noon, o as in orbit, p as in Pluto, r as in ray (trilled), s as in sail, t as in torque, u as in rule, v as in vector, z as in zodiac. Consonants followed by an 'x' are softened; i.e., cx = 'ch' in charge, gx = 'g' in gem, hx = 'ch' in Bach, jx = 's' in pleasure, sx = 'sh' in ship. Also, the following dipthongs are available: au = 'ou' in house, aj = 'i' in light, ej = 'ei' in vein, oj = 'oy' in joy, uj = 'ui' in ruin. A word has as many syllables as vowels or dipthongs. Emphasis always falls on the penultimate (next-to-last) syllable.

The International System of Units

Le Système International d'Unités (SI), the International System of Units, is the modern metric system. It is a standard system of measurements established by international agreement. SI has been used in the United States since 1866. In fact, the yard and pound have been based on the meter and the kilogram since 1893. In the 1950's, the inch was redefined to be exactly 2.54 centimeters.

The three most often used base units of SI are the meter (length), the kilogram (mass), and the second (time). Hence, the system is often called the **MKS system**. Other base units are the kelvin (absolute temperature), the ampere (electric current), the mole (amount of a substance), and the candela (luminous intensity). Some supplementary units are the radian (plane angle measure) and the steradian (solid angle measure). Some older texts may use the cgs (centimeter -gram- second) system, but it is a simple matter to convert between these units and the standard MKS units.

All other SI units, called "derived units," are defined in terms of these units. Table 1 contains a listing of some common SI units and their abbreviations. For example, the newton (N) is the SI unit of force and is defined as the force required to accelerate a 1 kilogram mass at a rate of 1 meter per second per second. Another common derived unit is the liter (L), a unit of volume. The liter is equivalent to 1000 cm^3, so the milliliter (mL) is used interchangeably with the cubic centimeter (cm^3 or cc).

Multiples and fractions of these units may be made using standard prefixes. Table 2 lists the standard prefixes and their values. Notice that these multiples and fractions are based on powers of ten. This makes for easy conversion between metric units. For example, 34.5 kilometers is 34,500 meters or 3.45 million centimeters.

Of the industrialized countries, only the United States of America has not completely converted to the metric system. This is causing an increasing number of problems in trade. Some of the archaic U.S. Customary units are still in use and are listed in Table 3 with factors for converting them to SI units. For example, 10 acres is about 4 hectares.

Table 1: Some SI Units

Unit Name	Abbreviation	Derivation	Description
meter	m		length
kilogram	kg		mass
second	s or sec		time
kelvin	K		absolute temperature
ampere or amp	A		electric current
mole	mol		amount of a substance
candela	cd		luminous intensity
radian	rad		plane angle measure
steradian	sr		solid angle measure
degree Celsius	°C	(K - 273.15)·(1°C/K)	temperature
metric ton (tonne)	ton or tonne	1000 kg	mass
are	are	$100\ m^2$	area
liter	L	$1000\ cm^3$	volume
hertz	Hz	1/s	frequency
newton	N	$kg \cdot m/s^2$	force
joule	J	N·m	energy, work, heat
watt	W	J/s	power
pascal	Pa	N/m^2	pressure
volt	V	W/A	electric potential
weber	Wb	V·s	magnetic flux

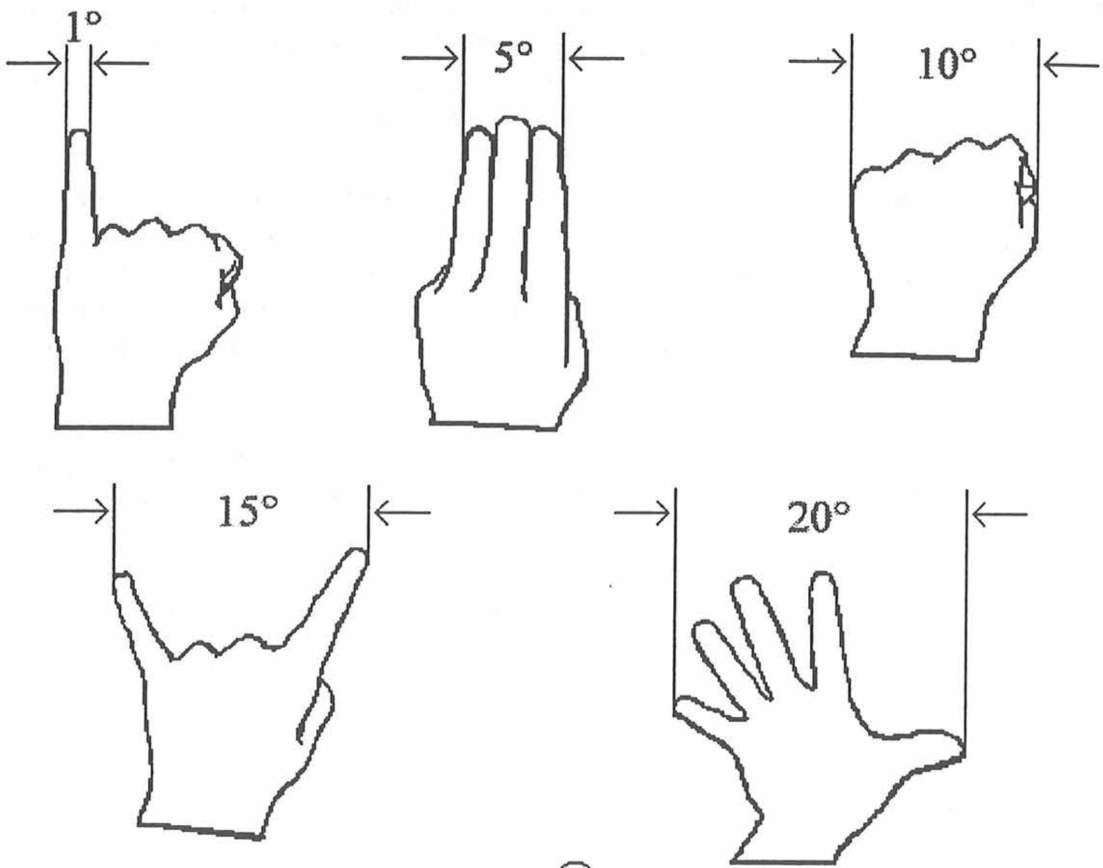
Table 2: Standard Metric Prefixes

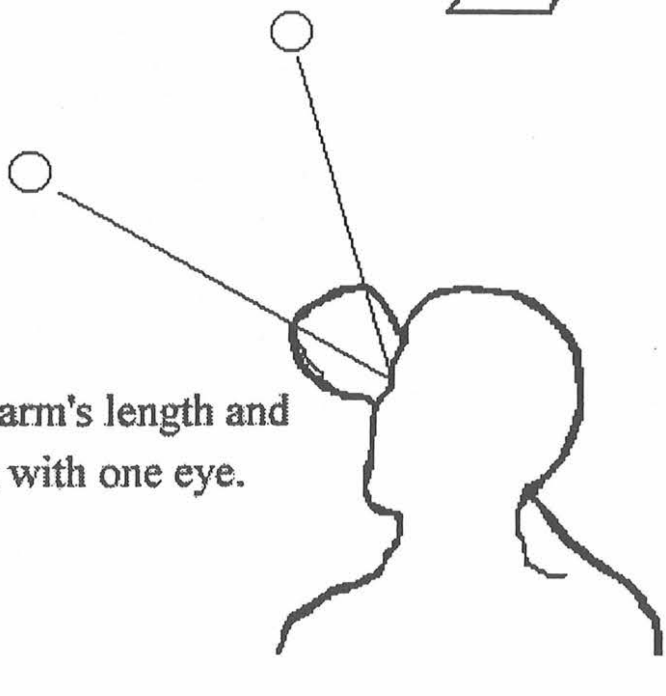
Prefix	Abbreviation	Value	Prefix	Abbreviation	Value
exa	E	$\cdot 10^{18}$	deci	d	$\cdot 10^{-1}$
peta	P	$\cdot 10^{15}$	centi	c	$\cdot 10^{-2}$
tera	T	$\cdot 10^{12}$	milli	m	$\cdot 10^{-3}$
giga	G	$\cdot 10^{9}$	micro	m	$\cdot 10^{-6}$
mega	M	$\cdot 10^{6}$	nano	n	$\cdot 10^{-9}$
kilo	k	$\cdot 10^{3}$	pico	p	$\cdot 10^{-12}$
hecto	h	$\cdot 10^{2}$	femto	f	$\cdot 10^{-15}$
deka	da	$\cdot 10^{1}$	atto	a	$\cdot 10^{-18}$

Table 3: Some Archaic Units and Conversion Factors to SI Units

start with	**multiply by**	**get**
inch	2.54	centimeter
foot	0.3048	meter
cubit	0.4826	meter
fathom	1.8288	meter
rod	5.0292	meter
mile	1.609	kilometer
slug	14.59	kilogram
pound (mass)	0.4536	kilogram
pound (force)	4.448	newton
U.S. short ton	907.2	kilogram
British thermal unit (BTU)	1,055	joule
acre	0.4047	hectare
U.S. gallon	3.7861	liter
pound per square inch (psi)	6,895	Pascal

Hand-Angle Measurements





Hand is held at arm's length and sighted along with one eye.

Spectral Classifications

In the late 1800's and early 1900's, astronomers noticed that stars could be grouped according to their spectra. Edward C. Pickering and Annie J. Cannon developed a method of grouping stars with similar spectral characteristics. This spectral classification scheme is still used today, though it has been expanded somewhat. See Exercise 32, Hertzsprung-Russell Diagram, for some exercises using spectral classes.

Pickering and Cannon originally classified stars according to the number and intensity of the hydrogen absorption lines in their spectra. Stars with the strongest hydrogen lines were called type A, stars with the second strongest hydrogen lines were called type B, and so on. By 1920, the spectra of several hundred thousand stars from both the northern and southern hemispheres had been catalogued. Table 1 lists some properties of the stars in each spectral class.

The 1920's saw the emergence of our modern understanding of atomic structure. See Exercise 11, Atomic Spectra, for more information. Analysis of stellar spectra by astronomers, like Meghnad N. Saha and Cecilia Payne-Gaposchkin, led to the realization that the spectral differences were due to differences in the surface temperatures of the stars. The spectral classes were resorted according to temperature and redundant classes were removed. In the current arrangement, the spectral classes, running from hottest to coolest, are **W**, **O**, **B**, **A**, **F**, **G**, **K**, **M**, **R**, **N**, and **S**. There are several popular mnemonics for remembering this sequence. One is "Wow! Oven Baked Ants, Fried Gently, Kept Moist, Retain Natural Succulence."

The first and last three spectral classes were added more recently than the others. Type W stars (also called Wolf-Rayet stars) are fairly young stars whose outer atmospheres have been blown away by strong stellar winds and, perhaps, by gravitational interaction with companion stars. The spectra of Wolf-Rayet stars differ from those of other classes by exhibiting only emission lines. Stars of types R, N, and S are called carbon stars, for they show absorption lines by carbon molecules. Type S stars seem to be between M- and N-type stars, but with zirconium oxide (ZrO) lines instead of titanium oxide (TiO) lines.

Annie J. Cannon recognized that the simple lettering system was too crude to fully describe the subtleties of the observed spectra. She divided each spectral class into ten temperature subdivisions, numbered 0 through 9. The hottest stars of a given class are assigned 0, the second hottest are assigned 1, and so on through 9.

Finally, a luminosity class is used to note the position of the star on the HR diagram. See Exercise 32, Hertzsprung-Russell Diagram. These classes are Ia (bright supergiants), Ib (supergiants), II (bright giants), III (giants), IV (subgiants), V (main sequence stars/dwarfs), VI (white dwarfs), and VII (subdwarfs). For example, the Sun is classified as G2V, meaning it has a spectral class of G, it is in the third hottest group of that class, and it is on the main sequence. Rigel (Beta Orionis) is a B8Ia star, meaning it is in the ninth hottest group of the B spectral class, and it is a bright supergiant.

Table 1: Some Properties of the Spectral Classes

Class	Characteristics[1]	Approx. Color	Surface Temperature	Examples
W	resemble type O stars but with broad emission features due to their turbulent atmospheres	blue	50,000 - higher	γ Vel
O	ionized He, N, and O; weak H	bluish	28,000 - 50,000	χ Per, λ Ori
B	ionized H, neutral He	blue-white	9,900 - 28,000	Rigel, Regulus
A	strong H, ionized Mg, Si, Fe, Ti, Ca, etc.	white	7,400 - 9,900	Sirius, Altair
F	weaker H, ionized Fe, Cr, Ti, and other metals; some neutral metals	yellow-white	6,000 - 7,400	Canopus, Procyon
G	ionized Ca, ionized and neutral metals	yellow-white	4,900 - 6,000	Sol, α Cen A
K	ionized Ca, hydrocarbon molecules, neutral metals	orange	3,500 - 4,900	Arcturus, Pollux
M	TiO, singly ionized Ca, neutral metals, other molecules	reddish	2,000 - 3,500	Antares, Betelgeuse
R	CN, weak C bands	orange	3,500 - 5,400	S Cam
N	C_2, other carbon molecules	red	1,900 - 3,500	R Lep, S Cep
S	ZrO, other molecules, H emission lines	red	2,000 - 3,500	R Cyg

1. Chemical symbols from the periodic table of the elements are used in this column. See Exercise 33, Elements and Supernovae, for a periodic table.

Quotes on Science

or knowing the Universe through a few sentences

The contemplation of celestial things will make a man both speak and think more sublimely and magnificently when he descends to human affairs.

Marcus Tullius Cicero, 106-43 B.C.

. . . each one of us and all of us, are truly and literally a little bit of stardust.

W. A. Fowler, 1911-

The mind, once expanded to the dimensions of larger ideas never returns to its original size.

Oliver Wendell Holmes, 1809-1894

Knowledge is power.

Francis Bacon, 1561-1626

We know very little, and yet it is astonishing that we know so much, and still more astonishing that so little knowledge can give us so much power.

Bertrand Russell, 1872-1970

The whole of science is nothing more than the refinement of everyday thinking.

Albert Einstein, 1879-1955

It has been said that there is no such thing as a free lunch. But the universe is the ultimate free lunch.

Alan Guth, 1947-

The diversity of the phenomena of nature is so great, and the treasures hidden in the heavens so rich, precisely in order that the human mind shall never be lacking in fresh nourishment.

Johannes Kepler, 1571-1630

In questions of science, the authority of a thousand is not worth the sound reasoning of a single individual.

Galileo Galilei, 1564-1642

The task is not so much to see what no one has yet seen, but to think what nobody has yet thought about that which everybody sees.

Erwin Schroedinger, 1887-1961

People see only what they are prepared to see.

Ralph Waldo Emerson, 1803-1882

We do not see things as they are, we see things as we are.

The Talmud, 1532

Chance favors the prepared mind.

L. Pasteur, 1822-1895

Everything should be as simple as possible, but not simpler.

Albert Einstein, 1879-1955

The house of delusion is cheap to build, but drafty to live in.

A. Housman, 1859-1936

Science, measured against reality, is primitive and childlike - and yet it is the most precious thing we have.

Albert Einstein, 1879-1955

We may now be near the end of the search for the ultimate laws of nature.

Stephen Hawking, 1942-

A scientist is a person who can find out things that nobody else can tell whether he found them out or not. And the more things he can find out that no one else can tell about, why the bigger scientist he is.

Will Rogers, 1879-1935

Space is what keeps everything from happening at the same place.

Jay Huebner, 1939-

Space acts on matter telling it how to move. In turn, matter reacts back on space telling it how to curve.

Charles Misner, 1932-

How inappropriate to call this planet Earth, when clearly it is Ocean.

A. C. Clark, 1917-

Our loyalties are to the species and the planet. Our obligation to survive is owed not just to ourselves, but to that cosmos, ancient and vast, from which we sprang.

Carl Sagan, 1934-

One important, often overlooked fact about the solar system is that the bulk of the real estate is not on planets.

Freeman J. Dyson, 1923-

Time is what prevents everything from happening at once.

John Wheeler, 1911-

... in the beginning was the plasma.

Hannes Alfven, 1908-

Prehistory ended with the Big Bang.

Jay Huebner, 1939-

The world was made, not in time, but simultaneously with time. There was no time before the world.

St. Augustine, 354-430

The world was created on 22 October 4004 BC at 6 o'clock in the evening.

James Ussher, 1581-1656

Space and time are not conditions in which we live, but modes in which we think.

Albert Einstein, 1879-1955

To try to write a grand cosmical drama leads necessarily to myth.

Hannes Alfven, 1908-

Common sense is a particular group of prejudices acquired before the age of 18.

Albert Einstein, 1879-1955

The most incomprehensible thing about the universe is that the universe is so comprehensible.

Albert Einstein, 1879-1955

The universe is not only queerer than we suppose, it is queerer than we can suppose.

J. B. S. Haldane, 1892-1964

The more the universe seems comprehensible, the more it also seems pointless.

Steven Weinberg, 1933-

To many the search for life in the universe is the greatest adventure left to humanity.

Frank Drake, 1930-

Either we are alone in the Universe, or we are not. In either case, it is amazing.

L. Dubridge, 1901-

Geometry provided God with a model for the creation.

Johannes Kepler, 1571-1630

Penetrating so many secrets, we cease to believe in the unknowable. But there it sits never-the-less, calmly licking its chops.

H. L. Mencken, 1880-1956

Why shouldn't truth be stranger than fiction, after all fiction has to make sense.

Mark Twain (S. Clemens), 1835-1910

Science is organized knowledge.

H. Spencer, 1820-1903

Science has to do with ordering complexity.

Jay Huebner, 1939-

Knowledge is one. Its division into (academic) subjects is a concession to human weakness.

H. J. Mackinder, 1861-1947

When I want to read a good book, I write one.

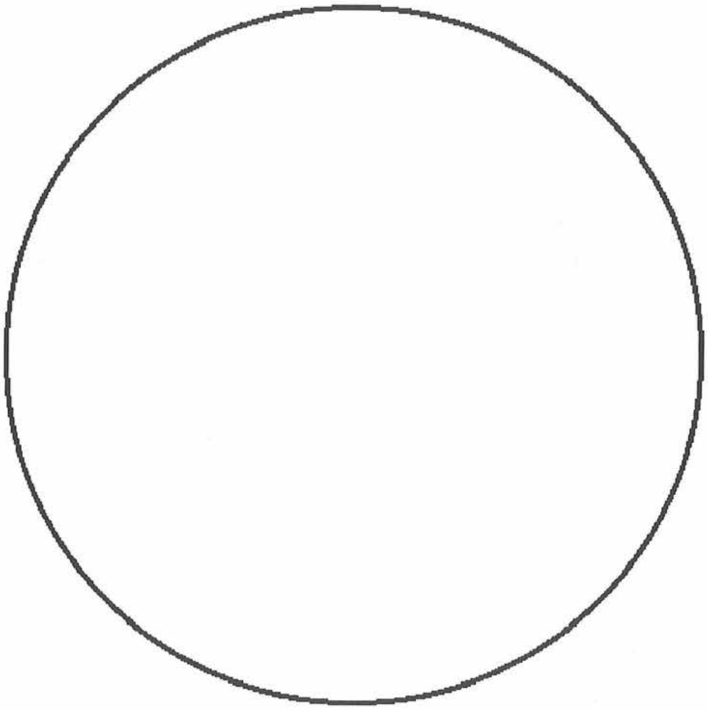
B. Disraeli, 1804-1881

Lots of things are invisible, but we don't know how many because we can't see them.

Dennis the Menace, created by Hank Ketcham, 1920-

Observing Form A

Observer:
Exercise:
Date:
Lab Day:



Observing Form B

Observer:
Exercise:
Date:
Lab Day:

Notes:

Notes:

Observing Form C

Observer:
Exercise:
Date:
Lab Day:

Notes:

Notes:

Notes: