Senior Thesis

An Outline for Teaching a Gemology Course

by

Thomas M. Chapman

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Approved by:

Rodney Tettenhorst

Dr. Rodney T. Tettenhorst

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Contents

Introduction

Purpose: This thesis is intended to serve as a guide for anyone interested in teaching gemology by providing an outline of the subject, suggested labs, lists of resources and references on the subject, and recommendations as to necessary equipment and materials, scheduling, and the costs of teaching such a course. This paper also may serve as a starting point for students who wish to pursue the study of gemology on their own.

Justification: Gemology is a suitable subject for study for several reasons. Most importantly, gemology is a significant branch of mineralogy. The world trade in gem materials amounts to many billions of dollars annually and all of these materials must be identified and graded, both as rough material and as finished goods. In addition, research into the production and identification of synthetics, simulants, and treatments is ongoing, along with the identification of new materials and the pursuit of new information about known species. Because of its economic importance, gemology is a perfect complement to courses in other economically valuable materials such as metals and building materials.

Gemology is one of the few areas of geology that most people have at least a passing interest in. Because of its widespread appeal, it makes an ideal subject for introducing geology to students who might otherwise ignore it. The study of gemology may serve as an introduction to a variety of topics related to crystallography, mineralogy, petrology, and geochemistry. It is an ideal first laboratory course. It also provides an excellent opportunity to emphasize the connection between the study of geology and economics, art and human history, a connection which is sometimes lost in other courses.

Perhaps the strongest argument for the value of a course in Gemology is historical precedent. As A.A. Levinson notes:

> In addition to those at Columbia and Michigan, gemology courses have been taught in the United States at various times since 1920 at: University of Arizona, Brigham

Young University, Colgate University, University of Kansas, Michigan technological University, Ohio State University, Pennsylvania State University, University of Southern California, University of Texas, and University of Wisconsin.

Gemology has been recognized as an important subject, worthy of teaching at the university level, for many years and in all parts of the nation. Dr. Levinson also notes that the University of Wisconsin course is available online, as are a number of relevant and useful web sites.

Assumptions: The outline and labs in this proposal have been prepared with the assumption that students taking this course will have completed an introductory geology course. The requirement of a prerequisite allows for basic material to be covered quickly, as a review. This, in turn, allows for more time to be spent on new material, the volume of which is considerable. It is assumed that contact hours will consist of two two-hour lectures and one two hour lab per week over a ten week quarter for a total of forty hours of lecture and twenty hours of lab oratory. These hours include one midterm on lecture material and a lab midterm. While these hours may seem excessive, as noted above, the course contains a considerable quantity of material.

Enrollment in the course will be limited by the number of students that can be accommodated in the labs. The number of sections taught, expense of equipment, difficulty and expense of obtaining specimens, and security concerns will all serve to limit the size of laboratory classes. Each section should be limited to twelve to fifteen students to make it easier to keep track of specimens. Ideally, one microscope, refractometer, and polariscope should be available for each 4 students, along with various other equipment (for costs see below).

While it is possible to teach a course in gemology without the lab experience, the lab experience will greatly improve student's understanding and retention. The best of photographs cannot replace the experience of manipulating a stone and using lab equipment. In addition, the opportunity to handle a variety of gem materials should serve to attract students to the course. If labs are not included in the course, enrollment is virtually unlimited as exemplified by the University of Wisconsin's online course.

In the event that all of the material cannot be covered, the sections on metals and jewelry design, fabrication, and history may be deleted. It should be noted that many courses in gemology do not discuss grading. Grading occupies much of the effort of professional gemologists and should, in the opinion of the author, be taught.

Contents: The lecture material is divided into ten sections, although these sections are not of equal length: Definitions and Economics, Crystallography, Chemistry and Color, Deposit Types, Equipment, Grading, Diamonds, Colored Stones; Synthetics, Simulants and Treatments, and Miscellaneous Topics.

There are nine labs, the tenth lab period being reserved for a lab midterm: Crystal Systems and Physical Properties, Identification of Rough, Equipment Used in Gemology I, Equipment used in Gemology II, Diamonds, Colored Stones I, Colored Stones II, Simulants, Synthetics, and Treatments, and Review: Identification and Grading of All Stones.

Equipment and Materials: The list of references includes books that would be suitable for use as textbooks. The Hurlburt and Kammerling text is the most comprehensive, but also the most expensive at $110. The book by Read is a good compromise at $35, being complete, if less rigorous, than the Hurlburt and Kammerling. Walter Schumann's book is concise, well organized, thorough, and has excellent photographs of rough and finished materials. It may be used as a textbook and would make an excellent reference in the lab.

Specimens for lab study may be purchased from a variety of dealers. *Lapidary Journal* lists dealers and the dates and locations of gem and mineral shows, which often have dealers. in addition, the names and addresses of local clubs are listed. Club members may be able to assist in obtaining specimens, particularly from amateur cutters. The April "Buyer's Guide" issue of *Lapidary Journal* is the most comprehensive. Stones might also be obtained from local stores. Stores that do repair work may be willing to supply damaged stones that are not worth recutting but are suitable for the lab.

Approximate current costs for equipment in the Gem Instruments Catalog are as follows:

Microscope	$4000
Refractometer	$475
Polariscope	$255
Sodium light	$433
Dichroscope	$120
Chelsea filter	$49
Specific gravity liquids	$175
Methylene Iodide	$45
Ultraviolet light	$280
Stone Tweezers	$29

Given these figures, a set of equipment for four students would cost approximately $6000. Given that some equipment can be shared by more than four students and allowing for the purchase of miscellaneous items such as stone cloths, stones boxes etc., a lab suitable for use by 16 to 20 students would cost approximately $24,000 to equip. It may well be possible to find less expensive equipment from other sources. Consult *Lapidary Journal* for the names of additional equipment dealers. It would be wise to remember that any equipment used in the lab is likely to need occasional repair. Refractometer hemicylinders, in particular, are easily damaged.

Resources: The Gemological Institute of America has an extensive offering of books, equipment, and other resources. Their A and B charts of gemstone characteristics are extremely handy in the lab. The Gemmological Association of Great Britain can supply useful slides for the illustration of lectures. *Gems and Gemology* is the most complete and the most current source for information on research in gemological topics. The U.S.G.S. web site listed allows for the search of all U.S.G.S. sites. Searching for "gemstones" provides a list of all relevant sites. Of particular interest are the figures on gemstone production. The Gem and Lapidary Page References list other useful sources of information and provide links to a wealth of related internet sites.

Course Outline

Definitions

Gemology - The science of gemstones

Gemstone - A mineral that has been finished (shaped and polished) and that is rare, durable, and beautiful Exceptions include amber (organic), opal (amorphous), and diamond (not rare)

Mineral - Historical - not animal or vegetable
Legal - a valuable product extracted from the earth and subject to depletion
Scientific - a crystalline, inorganic, natural, solid with chemical composition that is expressible by a formula

Gem material - Any material that will yield a gemstone when finished

Precious/Semiprecious stones - Traditionally, precious stones included "the big four": diamond, emerald, ruby and sapphire, while semiprecious described all other gemstones. These terms are not used now as they are pejorative and undefinable (bort and a particularly nice red spinel, for example, challenge the traditional definitions)

Economics (Source: United States Geological Survey)

Total annual world trade - Diamond production and reserves as of 1995: 57,700,000 carats. with Botswana and Australia being the leading producers. Production of other species is impossible to estimate owing to the size and disorganization of the market

Annual U.S. production - Includes agates, beryls, freshwater pearls, garnets, jade, jasper, mother-of-pearl, opals, peridot, quartz, sapphire, tourmalines, and turquoise

Primary producers were Tennessee, Alabama, Arkansas, North Carolina, Oregon and Arizona

Lesser producers include Nevada, Maine, California and Montana

Also, 14 U.S. firms produce significant quantities of synthetics: 1 in Massachusetts, Michigan, New Jersey, New Mexico, North Carolina, Ohio, and Washington, 4 in Arizona, and 3 in California

1995 production: natural, 75.5 million dollars
synthetic, 24,4 million dollars

Annual U.S. exports - 1995: 2,510 million dollars
Annual U.S. imports - 1995: 6,520 million dollars
Apparent consumption 1995: 4,110 million dollars

Significance of these numbers: at each stage of production, recovery, sale of rough, cutting, wholesaling of goods (multiple times), and retail sales, the material must be identified, treatments to the material documented, and the material graded. These functions are carried out by gemologists. Also, appraisers are needed at all levels. Appraisers generally are gemologists with extensive knowledge of current markets

Crystallography

Significance in gemology

Crystalline materials have a regular, repeating arrangement of atoms. Many physical properties of gem materials vary and depend on crystallographic direction. These directions must be considered in both cutting and identifying gemstones. The directional dependence of physical properties is intimately related to atomic arrangement and attendant symmetry. Examples include pleochroism, which is a key identifying characteristic of iolite (cordierite) and determines the orientation of rough tourmaline by the cutter, and cleavage, which affects rough orientation of spinel and can be used to identify kunzite (spodumene). Therefore, an understanding of symmetry is important for the gemologist.

Symmetry

Described by planes of symmetry, axes of symmetry and a center of symmetry. Faces (plane surfaces that bound a crystal) commonly are observed on crystals that grow unimpeded by their surroundings. A crystal form is composed of faces all of which have the same relationship to the elements of symmetry of that system

Seven Systems

Described in terms of imaginary axes which allow for a single and uniform description of all crystals. These descriptions represent the highest possible symmetry for the system. Some examples belong to classes with less than the highest symmetry for that system

Isometric (cubic). 3 axes of equal length at right angles to each other. Six two-fold, four three-fold, three four-fold axes, nine planes, one center of symmetry

Common forms include cube, octahedron, dodecahedron, trapezohedron

Examples include diamond, spinel, garnet.

Tetragonal. Two axes of equal length with the third either shorter or longer, all axes at right angles. Four two-fold, one four-fold axes, five planes, and a center of symmetry

Common forms include four sided prism, dipyramid

Examples include zircon, idocrase

Hexagonal. Four axes, three of equal length in the same plane intersecting at 60 degrees, with the fourth axis at right angles to, and usually longer than, these three, six two-fold and one six-fold axes, three planes, and a center of symmetry

Common forms include six sided prism, dipyramid

Examples include beryl, apatite

Trigonal (rhombohedral). Axes similar to the hexagonal system with three two-fold, one three-fold axes, three planes, and a center of symmetry

Common forms include rhombohedron, scalenohedron, three sided prism

Examples include corundum, quartz, tourmaline

Orthorhombic. Three axes of different lengths at right angles to each other. Three two-fold axes, three planes, and a center of symmetry

Common forms include prism, dipyramid, pinacoid

Examples include peridot, topaz, iolite, chrysoberyl

Monoclinic. Three axes of different lengths, two at an oblique angle, the third intersecting these two at a right angle. One two-fold axis, one plane, and a center of symmetry

Common forms include prism, pinacoid

Examples include diopside, epidote, orthoclase

Triclinic. Three axes of different lengths, none at right angles to another. One center of symmetry.

Common forms include pinacoid

Examples include rhodonite, plagioclase, kyanite, microcline

Lattices

August Bravais, 1849, determined that all possible three dimensional atomic arrangements can be described by 14 different space lattices. These lattices can be grouped into seven unit cells based on the symmetry of their basic shape. The seven unit cells are the basis of the seven crystal systems and describe the symmetry of crystalline materials. Specific dimensions and angles of unit cells vary between minerals. Thirty-two point groups or symmetry classes and 230 space groups define the atomic arrangement of a given mineral.

Twins

A twinned crystal is a composite composed of two or more individuals grown together in a definite crystallographic manner. Most often the crystals are related by reflection through a plane or rotation of 180 degrees about an axis. Twins are either penetration twins or contact twins. Repeated twinning with parallel planes produces polysynthetic twins as in plagioclase. Repeated twinning about an axis produces cyclic twins as in chrysoberyl.

Microcrystalline materials

Aggregates of microscopic crystals. Random orientation of crystals causes these materials to differ in their optical properties from single crystals of the same species as in agate and quartz

Chemistry

- Basic Earth Composition
  - 8 minerals make up 95% of crust
    - feldspar (Na,K,Ca,Al,O) 60%
    - quartz (Si,O) 13%
    - pyroxene and amphibole (Mg,Fe,Ca,Na,Al,Ti,Mn,Si,O) 12% and 5% respectively
    - mica (K,Mg,Fe,Al,Si,O) 4%
    - olivine (Mg,Fe,Si,O,) 1%
  - Most common elements include (by weight)
    - Oxygen 46.6%
    - Silicon 27.72%
    - Aluminum 8.13%
    - Iron 5%
    - Calcium 3.63%
    - Sodium 2.83%
    - Potassium 2.59%
    - Magnesium@.09%
    - All other elements < 1%
  - Other elements significant in gemology
    - Cobalt .0025%
    - Lithium .0020%
    - Boron .0010%
    - Beryllium .00028%
- Approximately 50% of gem species are composed of the 8 most common elements, but only rarely do these 8 elements form gem-quality material
- Other gem species include rare elements
  - Beryl - Beryllium
  - Natural Blue Diamond - Boron
  - Kunzite (pink spodumene) - Lithium
- Therefore, gemstones must occur in environments that have a concentration of one or more rare elements and/or environments that have rare conditions of formation.

- Most gem materials are either oxides, carbonates, phosphates, or silicates
    - oxides are metals combined with oxygen
        - Corundum - Al2O3
    - carbonates are metals combined with carbonic acid
        - Rhodochrosite - MnCO3
    - phosphates are metals combined with phosphoric acid
        - Apatite - Ca5(PO4)3(F,Cl,OH)
    - silicates are metals combined with silicic acid
        - Zircon - ZrSiO4
    - exceptions include diamond, which is essentially pure carbon, and the organic gem materials

<u>Color</u>

- Light is electromagnetic radiation composed of different wavelengths
- Different wavelengths or combinations of wavelengths are perceived as different colors

Red	700-630 nm
Orange	630-590 nm
Yellow	590-550 nm
Green	550-490 nm
Blue	490-440 nm
Violet	440-400 nm

- Objects that reflect all wavelengths are perceived as white
- Objects that absorb all wavelengths equally are perceived as gray or black
- Objects that absorb different wavelengths unequally are perceived as having color
- Causes of selective absorption
    - chromophores
        - In some ions, electrons can be moved to a higher orbital by the energy of a photon
        - Different electron jumps require different amounts of energy and absorb selective wavelengths of light

Ions that produce characteristic colors through selective absorption of photons due to electron shifts are called chromophores

The elements titanium, vanadium, chromium, manganese, iron, cobalt, nickel, and copper are common chromophores

The orbitals of chromophores can be affected by neighboring ions, their positions in the crystal structure, and their oxidation state

color centers

Color centers are defects in a crystal that trap electrons

The trapped electrons absorb photons of certain wavelengths

Color centers can be caused by mechanical deformation of the crystal structure, excess or missing ions, or substitution of ions

idiochromatic minerals

Minerals that have a characteristic color (malachite) are idiochromatic

Metallic minerals are often idiochromatic

Idiochromatic minerals owe their color to a primary constituent element, one that is abundant in the mineral, such as copper in malachite

allochromatic minerals

Allochromatic mineralsshow variations in color (agate)The color of allochromatic minerals is the result of the presence of an element which does not constitute its chemical makeup

Treatments to enhance color

heating

can alter the oxidation states of chromophores, dissolve included crystals to provide new chromophores, and repair color center defects

heating is also used to diffuse chromophores into the surface layers of a gem material, producing a colored rind

radiation
- by x-rays, gamma rays (can leave dangerous residual radiation), or electrons creating color centers
- radiation induced color centers are often not stable, being affected by heat and light

heating and radiation sometimes reverse the effects of one another

naturally occurring colors may also be unstable
- (amethyst fades if worn repeatedly in a tanning bed)

treatments often are combined to produce the desired color

Deposit types

- Many species can be found in several different deposit types
  - Corundum is found in dikes in Montana, alluvial deposits in Sri Lanka, metamorphic rocks in Kashmir
- Alluvial
  - definition of alluvial
  - not an environment of formation
  - necessary conditions
    - source material
    - concentrating agent
  - Examples
    - South Africa/Namibia
      - diamond
      - recovered from beach sands in large scale operations involving heavy machinery
    - Sri Lanka
      - garnet, spinel, topaz, zircon, etc.
      - recovery by individuals with no machinery
- Kimberlites (diamonds)
  - definition of kimberlite
  - origin
  - evidence of diamond formation not at depth
  - producing nations
  - Examples
    - South Africa
    - Australia
      - diamonds in lamproite rather than kimberlite
  - Recovery by open pit mining
- Pegmatites
  - definition of pegmatite
  - process of formation
    - intruded magma
    - fractional crystallization
    - necessary rates of cooling

- Examples
  - Brazil
    - beryl, topaz, quartz, tourmaline, etc
    - recovered with open pit and underground techniques

  - Maine
    - tourmaline
      - recovered with underground techniques
- Organic
  - Examples
  - Baltic
    - amber
      - recovered as float on beaches, open pit mining in Russia
  - Japan
    - pearls
      - cultured in farms
- Surface water
  - ability of surface water to dissolve, transport, deposit materials
  - formed by fluctuating water table, chemical reactions, cooling of groundwater
  - Examples
    - Australia
      - opals
        - recovered primarily with small-scale underground mining techniques
    - Russia
      - malachite
        - recovered with underground mining techniques
    - Brazil
      - amethyst
        - recovery with open pit techniques

- Extra-terrestrial
  - limited use in jewelry
  - Examples
    - Moldau valley
      - tektites
        - recovered as alluvial material
    - various meteorites
        - recovered as alluvial material
- Hydrothermal
  - definition of hydrothermal deposits
  - Examples
    - Columbia
      - emeralds
        - recovered with both primitive and highly mechanized surface techniques
    - Brazil/U.S.
      - agates
        - recovered with open pit techniques
- Metamorphic
  - definition of metamorphic environment
  - regional as compared to contact metamorphism
  - Example
    - Burma
      - ruby
        - current information difficult to obtain due to political conditions
- Igneous
  - definition
  - Examples
    - Arizona
      - olivine
        - recovered with open pit mining techniques
    - Montana
      - corundum
        - recovered with open pit mining techniques

Equipment

- design and use
- Gemological equipment is, ideally, small, easy to use, inexpensive, nondestructive, simple
    - Eyes
        - most important
        - diamond color graders work only in the morning, consume no alcohol the night before working
    - Loupe/Microscope
        - grading uses 10x magnification
        - identification uses up to 100x magnification
        - advantages of gemological microscope
            - binocular
            - variable magnification
            - dark field, bright field, or reflected light
            - use of immersion cell
            - stone holder
    - Design
        - loupe
            - should be aplanatic, aspherical
            - three-piece lens
            - black body (reduces reflections in stone)
        - microscope
            - ocular lens
            - objective lens
            - lighting system
            - adjustable diaphragm
            - throat/base assembly
    - Characteristics identified with microscope
        - clarity characteristics or inclusions
            - protogenic
            - syngenetic
            - epigenetic

    - solid
        - included crystals
            - can be variety specific, i.e. byssolite "horsetails" in demantoid garnet
            - give clues to environment of formation
            - negative crystals
    - liquid
        - can indicate environment of formation
    - gas
        - fingerprints
        - feathers
        - bubbles
    - multiphase
        - can be variety specific, i.e. three-phase inclusions in emerald
- double refraction
    - visible as doubled facet junctions
    - gives stone "oily" appearance to unaided eye
    - varies according to orientation of stone
- wear
    - paper wear
    - scratches
    - chips
    - can indicate hardness/toughness
- cleavage/fracture
    - orientation of multiple cleavage planes can be diagnostic
- cut characteristics
    - naturals
    - extra facets
    - polish
    - symmetry

- Refractometer
    - used to determine refractive index (R.I.)
        - refractive index
            - measure of angular change of light path when passing into/out of substance of different density
            - critical angle
            - R.I. = sine of critical angle divided by R.I. of refractometer hemicylinder
    - generally second piece of equipment used
    - used only on polished surfaces
    - R.I. and microscope observations often sufficient to identify stone
        - design
            - hemicylinder
            - scale
            - contact liquid
            - limits R.I. to 1.81
            - shadow edge
        - doubly refractive materials
            - produce two shadow edges
            - rotate stone to find maximum and minimum values
        - cabachons
            - spot method
- Immersion liquids
    - used to estimate refractive index
    - can be used with rough material
    - toxicity
    - potential damage to porous stones
    - composition

methylene iodide	refractive index 1.74,
bromoform	refractive index 1.60
toluene	refractive index 1.49
water	refractive index 1.33

    - method
        - white paper and black card
        - light and dark facet edges and contours
- Sodium light
    - provides single wavelength light source
    - effect on results
        - provides sharpest shadow edge with refractometer
        - provides most accurate reading, refractive index defined with 589 nm. wavelength light
- Dichroscope
    - used to identify pleochroic colors of stone
    - design
        - uses optical calcite to produce doubled image of stone viewed through metal tube
    - pleochroism
        - most pronounced perpendicular to optic axis
        - stone should be checked in several orientations
        - dichroscope should be rotated to observe maximum difference in colors
- Polariscope
    - used to detect pleochroism, determine optical character, separate polycrystalline materials, strain, anomalous double refraction
    - design
        - light source beneath two independently rotating polarizing filters
- Heavy Liquids
    - used to determine approximate specific gravity
    - toxicity
    - potential damage to stone
    - composition
        - methylene iodide, specific gravity 3.32
        - benzyl benzoate, specific gravity 1.11
        - mixed to produce intermediate solutions
    - stone floats in liquid of higher specific gravity

- Spectroscope
    - used to determine absorption spectra
    - requires white light
    - design
        - prism type
            - uses prism to disperse reflected light
            - produces unevenly spaced spectrum
        - diffraction grating type
            - uses diffraction grating to produce spectra
            - not as bright as prism type
            - less expensive than prism type
    - absorption spectra
    - fine line spectra
        - often identify synthetic materials
- UV light
    - used to determine fluorescence strength and color
    - long/shortwave fluorescence
- Chelsea Color filter
    - used to distinguish between some similarly colored stones
- Destructive
    - used only on materials that may be sacrificed
    - acetone
        - used to detect dyes
    - streak
    - hardness
    - x-ray diffraction
    - hot needle
        - used to identify amber, detect plastic impregnation

Grading

- evaluating quality by comparison with standards
    - cut, clarity, color, weight
- Cut
    - shape
        - round brilliant facet names
            - girdle
            - crown
                - table, star, upper girdle
            - pavilion
                - lower girdle, pavilion main, culet
        - common cuts
            - radial cuts
            - step cuts
    - symmetry
    - extra facets
    - polish
        - polish marks
        - finish flaws
    - facet junctions
    - proportions
        - ideal
        - nailheads
            - deep stones
        - fisheyes
            - shallow stones
        - table size percentage
    - mounted stones
        - limitations of evaluating cut

- Color
    - hue
    - tone
    - saturation
    - distribution
        - zoning
        - bicolors
        - pleochroism
        - color change
    - mounted stones
        - limitations of evaluating
- Clarity
        - diagnostic characteristics
        - grade setters
            - characteristics that set grade
                - location
                - size
                - color
    - mounted stones
        - limitations of grading
- Weight
    - estimation
        - by formula
        - scale
    - measurement
        - Leveridge gauge
        - printed scales and microscope
    - mounted stones
        - limitations of grading

Diamonds

- Identification
  - physical properties
  - species with which it may be confused
  - diagnostic properties
- Grading
  - personal limitations
    - alcohol
    - sleep
    - stress
  - environmental limitations
    - north daylight
    - equipment
  - color
    - colorless stone is ideal
    - various scales
    - master color sets
    - colorimeter
    - fancy colors
  - cut
    - typical rough shapes
      - octahedron, macle, cube
      - effect on stone shape
    - industry standards
      - measurements taken
      - ideal proportions
  - clarity
    - various scales
  - weight
    - estimation formulas

- occurrences
    - India
    - Brazil
    - South Africa
    - Russia
    - Australia
    - U.S.
    - Canada
- Famous stones
  - Hope
  - Dresden
  - Tiffany
  - Cullinans, 1-9
- Current range of values
  - sources of information
  - volume of world trade
  - estimated rates of production
  - estimate of stockpiled rough

Colored Stones

- differences in grading compared with diamonds
    - variable standards of cut, clarity
    - intense color generally more valuable
- Corundum
    - varieties
    - physical properties
    - species with which it may be confused
    - diagnostic properties
    - grading standards
        - cut
        - color
        - clarity
        - weight
    - localities
    - famous stones
    - current values
    - availability

Note: The stones listed below should be treated as corundum, above

- agate/chalcedony
- amber
- apatite
- azurite
- beryl
- chrysoberyl
- coral
- diopside
- epidote
- feldspar
- garnet
- ivory
- jadeite
- jet
- lapis
- malachite
- nephrite
- olivine

- quartz
- rhodochrosite
- rhodonite
- shell
- sodalite
- spinel
- spodumene
- topaz
- tourmaline
- turquoise
- zoisite
- zircon
- opal
    - varieties
        - body color
        - fire pattern
        - fire opal
    - physical properties
    - diagnostic properties
    - grading standards
        - cut
        - color
        - clarity
        - weight
    - localities
    - famous stones
    - current values
    - availability

- pearl
    - varieties
        - natural
        - cultured
        - South Sea
        - conch
    - physical properties
    - diagnostic properties
    - grading standards
        - shape
        - color
        - orient
        - luster
        - nacre thickness
        - blemishes
        - size
    - localities
    - famous stones
    - current values
    - availability
- dimension stone used in contemporary jewelry

Synthetics

- definition
- method of production/history
- for each of the following techniques, consider 1) description of the process, 2) history of the process, and 3) key diagnostic features of the product
  - Verneuil
  - Czochralski
  - floating zone
  - hydrothermal
  - flux-melt
  - skull melting
  - diamond synthesis
  - ceramic processes
  - colloidal suspensions
  - species
    - for each species, consider key diagnostic features that separate the synthetic material from the natural
    - beryl
    - corundum
    - diamond
    - opal
    - chrysoberyl
    - quartz
    - spinel
    - jadeite
    - malachite
    - turquoise
  - markets for synthetics

Simulants

- definition
- species
  - for each species, consider key diagnostic features that separate the simulant from the natural material
  - glass
  - plastics
  - cubic zirconia
  - YAG, GGG, strontium titanate, other diamond simulants
  - assembled stones
    - garnet and glass
    - opal doublets and triplets
    - other assembled stones
    - stones with asterism
    - foilbacks
  - reconstitution
    - process
    - stability
    - separation from natural materials
    - species
      - turquoise
      - lapis lazuli
- markets for simulants

Treatments

- irradiation
    - process
        - x-ray
        - electron
        - neutron
        - alpha particles
        - beta particles
        - gamma particles

    - stability and safety
    - evidence of treatment
    - effects
        - color change
    - species
        - beryl
        - topaz
        - corundum
        - diamond
        - quartz
- heating
    - process
        - heat
        - diffusion
    - stability
    - evidence of treatment
    - effects
        - color change
        - alteration of inclusions
    - species
        - beryl
        - quartz
        - corundum
        - amber

- coating
  - process
  - stability
  - evidence of treatment
  - effects
    - color change
  - species
    - emerald
- drilling
  - process
  - stability
  - evidence of treatment
  - effects
  - species
- fracture filling
  - process
    - materials used
      - oils
      - resins
      - glass
      - wax
  - stability
  - evidence of treatment
  - effects
    - reduce visibility of clarity characteristics
  - species
    - emerald
    - diamond
    - opal

- dye
    - process
        - quench crackling
        - smoke treatment
        - sugar treatment
    - stability
    - evidence of treatment
    - effects
    - species
        - emerald
        - ruby
        - quartz
        - chalcedony
        - jadeite
        - lapis lazuli
        - opal
- bleaching

combination of treatments

Miscellaneous topics

- Nomenclature
  - History of gem names
    - diamond
    - morganite
    - emerald
    - sapphire
    - turquoise
  - Misnomers/misidentification
    - ruby and spinel
- Cutting
  - Methods
    - sawing
    - bruting
    - polishing
    - carving
    - jamb peg
    - modern equipment
  - Styles
    - traditional
    - freeform
  - Limitations
    - clarity characteristics
    - crystallographic orientation
    - rough shape
    - color zoning
    - market forces

- Jewelry
  - metals/alloys - platinum
    - colors
    - working characteristics

gold
24k, 18k, 14k, 10k
colors
working characteristics
silver
fine, sterling
colors
working characteristics
pot metal
colors
working characteristics
plating
fabrication
casting
electroforming
setting
repair
History of design
examples from a variety of historical periods
Opportunities
research
identifying new treatments, synthetics, simulants
developing new treatments, synthetics, simulants
determining country of origin
determining origin of color, cataloging clarity characteristics
teaching
sales
appraising
affixing current value to graded stone
requires constantly updated market knowledge
common types
insurance
estate

Labs

Lab 1: Crystal Systems and Physical Properties

Objective: To familiarize the student with the
characteristics and physical properties of minerals that
are useful in identifying gem materials that affect
their use as gemstones.

Equipment and Materials:
hardness needles
low and high temperature light sources
ultraviolet light source
10x hand lens
specimens displaying desired properties (see below)
models of the crystal systems
spectroscope

Procedure: Establish stations using specimens described below. Instruct students to examine the specimens and answer the relevant questions.

Crystal Systems

1. Cubic - pyrite
2. Tetragonal - zircon
3. Hexagonal - apatite
4. Trigonal - quartz
5. Orthorhombic - topaz
6. Monoclinic - orthoclase
7. Triclinic - kyanite
8. None - opal

Using your textbook or other reference material, list the gem species that belong to each system.

For each system, sketch an idealized crystal. Indicate which axes are of equal length and which intersections are ninety degrees.

Can noncrystalline materials be minerals? Gemstones? Why?

Physical Properties

9. Hardness - suite representing the Mohs scale
    Below what hardness on the Mohs scale are materials scratched by a fingernail? Penny? Steel?
    What is your recommended minimum hardness for a gem material? Why?
10. Cleavage - calcite, fluorite
    Define cleavage. Why is cleavage important to gemologists? To gem-cutters?
11. Fracture - obsidian, nephrite
    List the common types of fracture.
12. Specific Gravity - galena, chalcedony
    Define specific gravity. How is S.G. estimated? How can it be measured accurately?
13. Color - malachite, agate, fluorite (zoned)
    List three causes of color in minerals. Which of these specimens is idiochromatic?
14. Color change - garnet
    Explain why this mineral changes color under different light sources.
15. Refractive Index - calcite, fluorite
    Define refractive index.
16. Double refraction- calcite
    Why is calcite doubly refractive while fluorite isn't?
    What other gem materials are doubly refractive?
17. Dispersion - cubic zirconia, quartz
    Define dispersion. Name three gem species with high dispersion.
18. Absorption spectra - garnet, peridot
    Compare the spectra. Are there distinctive lines in the spectra?
19. Luster - sphalerite, opal
    List the common types of luster.
20. Pleochroism - iolite
    Why does pleochroism exist? In minerals of what crystal system is pleochroism absent?

21. Fluorescence - calcite, fluorite
    Explain the cause of fluorescence.
22. Inclusions - any species
    What are the four primary types of inclusions? What can inclusions indicate about a gemstone?
23. Phenomena - tiger's eye, moonstone, opal, star diopside
    List the primary types of phenomena. What causes each type?

Lab 2: Identification of Rough

Objective: To become familiar with the equipment and procedures used to identify unfinished gem materials, including the need for nondestructive tests, to become familiar with unfinished gem materials, to practice identifying unfinished gem materials, review information about environments of formation, chemical composition, crystallographic symmetry, and mineralogical associations that may assist in identifying rough.

Equipment and materials: specimens of unfinished gem species including amber, azurite, beryl, chalcedony, corundum, feldspar, garnet, lapis, malachite, nephrite, olivine, opal, quartz, rhodochrosite, rhodonite, shell, sodalite, spinel, spodumene, topaz, tourmaline, turquoise, zircon
Specimens that illustrate mineralogical associations may be helpful in emphasizing chemical and environmental relationships between various species
hand lens
hardness needles
high and low temperature light sources

Procedures: establish individual stations with one specimen per station. Ask students to identify each specimen and record its chemical formula. Additional questions may be asked where appropriate: What are the gem varieties of this mineral?
What basic symmetry does this mineral exhibit?
With what other species might this mineral be confused and how can the species be separated?
What minerals might be expected to occur with this species based on chemistry? Based on environment of formation?

Lab 3: Equipment used in gemology, part 1.

Objective: To familiarize the student with the equipment used in gemology and its proper use.

Equipment and materials:
- tweezers
- hand lens
- microscope
- refractometer
- sodium light
- specimens suitable for evaluation. Examples of singly and doubly refractive stones should be included. Cabachon-cut stones should be included.

Procedure: Review the proper use and care of each piece of equipment. Explain the proper use of the tweezers, including hard and soft surface pick-ups. Review the proper sequence of examination of specimen: eye, magnification, refractometer. Have students practice using each piece of equipment and answer questions relevant for each piece of equipment:

Examination of specimen with the eye:

What is meant by the term "eye-clean?"
How strong is the dispersion displayed by this stone?
What color is the stone?
Is the stone step-cut or radial-cut?

Examination with a hand lens and the microscope:

List and describe any clarity characteristics observed.
List and describe any observed damage to the surface of the stone.
What type of illumination is best suited for each of the above observations?
When is dark field illumination preferred over light field illumination?

Use of the refractometer:

How does use of a sodium light source influence the reading on the refractometer compared to a white light source?
How are the results obtained different for singly and doubly refractive stones?
Describe the results that indicate uniaxial positive, uniaxial negative, biaxial positive, and biaxial negative stones.
Describe the procedure for determining the refractive index of cabachon-cut stones.
What is the maximum refractive index measurable with the refractometer and what results are obtained for a stone with a refractive index higher than this maximum?

Lab 4: Equipment used in gemology, part 2

Objective: The objectives for this lab are the same as those for lab no.3

Equipment and Materials:

immersion liquids
dichroscope
polariscope
heavy liquids
spectroscope
ultraviolet light (long wave and shortwave)
Chelsea filter
specimens suitable for evaluation

Procedure: Review the proper use and care of each piece of equipment. Discuss when each piece of equipment should be employed. Have students practice using each piece of equipment and answer questions relevant for each piece of equipment:

What features of a stone can be best seen using immersion liquids?
What common gemstones display marked pleochroism?
What are the possible results obtained with the polariscope?
What are disadvantages of the spectroscope?
What information can be obtained only with the spectroscope?
List three stones that commonly show strong fluorescence.
List two separations that can be made with a Chelsea filter.

Lab 5: Diamonds, identification and grading.

Objective: To practice identifying and grading diamonds. To apply the knowledge gained in the preceding labs to the identification and grading of diamonds.

Equipment and materials:

All equipment used in previous labs
A variety of diamonds and stones that might be confused with diamonds, including synthetics and simulants. Stones should represent a range of grades.

Procedure: Students should identify stones using the appropriate equipment in the appropriate order. Students should then grade the stones using the appropriate equipment in the appropriate order. For each stone, students should list the results that justify their identification and grade.

Lab 6: Colored stones, identification and grading

Objective: To practice identifying and grading colored stones. To apply the knowledge gained in the preceding labs to the identification and grading of colored stones.

Equipment and Materials;
All equipment used in previous labs
A variety of colored stones including synthetics and simulants. Stones should represent a range of grades and colors.

Procedure: Students should identify stones using the appropriate equipment in the appropriate order. Students should then grade the stones using the appropriate equipment in the appropriate order. For each stone, students should list the results that justify their identification and grade.

Lab 7: Colored stones, identification and grading

Lab 7 is a continuation of Lab 6. Objectives, equipment and procedures are identical.

Lab 8: Simulants, synthetics, treated stones, identification and grading.

Objective: To practice identifying and grading synthetics, simulants, and treated stones. To apply the knowledge gained in the preceding labs to the identification and grading of synthetics, simulants, and treated stones.

Equipment and Materials;
All equipment used in previous labs
A variety of synthetics, simulants, and treated stones.
Stones should represent a range of grades and colors, and treatments.

Procedure: Students should identify stones using the appropriate equipment in the appropriate order. Students should then grade the stones using the appropriate equipment in the appropriate order. For each stone, students should list the results that justify their identification and grade.

Lab 9: Review, identification and grading of all stones

Objective: To provide additional practice in identifying and grading all of the materials presented in the labs.

Equipment and Materials: All equipment used in previous labs
A representative selection of all stones used in the previous labs.

Procedure: Students should identify stones using the appropriate equipment in the appropriate order. Students should then grade the stones using the appropriate equipment in the appropriate order. For each stone, students should list the results that justify their identification and grade.

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Note: Bold asterisk (*) indicates a book suitable for use as a textbook.

Resources

G.I.A. Gem Instruments
5345 Armada Drive, Suite 300
Carlsbad, Ca 92008
760-603-4200
www.gia.edu/giagem

Gemmological Association and Laboratory of Great Britain
27 Greville St.
London, EC1N 8SU
United Kingdom

Lapidary Journal
60 Chestnut Ave., Suite 201
Devon, PA 19333-1312
610-293-1112
www.lapidaryjournal.com

Gems and Gemology
5345 Armada Drive, Suite 300
Carlsbad, Ca 92008
1-800-421-8161
www.gia.edu/giagem

Gem and Lapidary Page References
http://www.tradeshop.com/gems/moreinfo.html

United States Geological Survey Search Page
http://search.usgs.gov

University of Wisconsin online gemology course
http://www.geology.wisc.edu/^jill/geo306.html