The physical properties of minerals are a direct result of their chemical and structural characteristics. Because they are readily determined (i.e., by examination or simple tests), they are important to the rapid identification of minerals. Other methods for studying minerals involve more elaborate tests (e.g., optical, x-ray, or SEM), and although they provide important information, can be time-consuming.

I. Physical Properties
   A. Color
      1. Color of a mineral is a result of the interaction of electromagnetic radiation (visible light) with the surface of a mineral (primarily the electrons).
      2. Minor amounts of some elements (especially the transition elements) can greatly affect the perceived color of a substance.
      3. Color also produced by defects in crystal structure, structural planes, and by small inclusions.
   B. Luster
      1. Luster refers to the general appearance of a mineral surface in reflected light.
      2. Metallic versus non-metallic; minerals with metallic luster are usually opaque and have a colored streak
      3. Non-metallic Lusters: Vitreous, Resinous, Pearly, Greasy, Silky, Adamantine
   C. Form (Crystal habit and aggregates) see Klein.
   D. Twins and Intergrowths
      Perfectly formed crystals are uncommon, and many have defects. Twinning is a special type of defect wherein two parts of a crystal have different crystallographic orientations that are related by a symmetry operation (usually reflection, rotation, or a inversion).

      Twins are symmetrically intergrown crystals.
      Twin Law - a center, axis, or plane of twinning
      Contact (related by a twin plane) versus interpenetration twins (twinned crystals share a common volume).

      Lowest energy configuration of a crystal is perfectly ordered. Internal energy of a twinned crystal is only slightly higher. That is, during growth, an ion can occupy a
position that has only slightly higher energy, causing the crystal growth to occur in a new direction. This is a **growth twin**.

**Transformation twinning** occur as a result of a polymorphic transformation, usually from a higher-temperature form.

Under deformation, crystals attain a lower energy configuration by **mechanical, or deformation, twins** along a glide axis due to the sliding of atoms within a lattice.

**Multiple (cyclic) and polysynthetic** twins.

**Parallel intergrowths** are common because they are a lower energy configuration than randomly oriented crystals.

E. **Cleavage, Parting, and Fracture**

All manifestations of the way a mineral responds to an applied stress. Strain occurs along planes of weakness in the atomic structure.

**Cleavage** directions (or forms) are described using Miller Index notation. Quality of cleavage is also described (eg. perfect in micas, to poor in beryl or apatite.

**Parting** is used to describe the breakage planes in minerals that occur along structurally weak planes, but that are not cleavages, which are shown by all specimens of a mineral.

**Fracture** is used to describe the way a mineral breaks when the strength of the bonds is approximately the same in all directions.

- Conchoidal
- Fibrous or splintery
- Hackly
- Uneven or irregular.

F. **Magnetism**

1. Some iron-bearing minerals are naturally magnetic (**ferromagnetic**)
2. Others are weakly magnetic when subjected to a strong magnetic field and are termed **paramagnetic**.
G. **Hardness**

While the structure of a crystal depends on the strongest bonds that are present in the crystal structure, the physical properties depend on the weakest bonds. For example, silicate minerals all have Si$^{4+}$ in tetrahedral coordination, and the strength of the Si--O bond in all silicates is approximately the same, their **hardnesses** range from 1 - 7.

Hardness is the resistance of a mineral surface to scratching.

Furthermore, the strength of ionic bonds between divalent ions is stronger than the bonds between monovalent ions. Similarly, ions with larger radii tend to form weaker bonds because electrostatic attraction falls off in proportion to the square of the distance. (eg. Al$_2$O$_3$ [corundum=9] and Fe$_2$O$_3$ [hematite=6]).

**Moh's scale of Hardness**

10. Diamond
9. Corundum
8. Topaz
7. Quartz steel file
6. Orthoclase glass
5. Apatite knife blade
4. Fluorite
3. Calcite copper penny
2. Gypsum fingernail
1. Talc

H. **Streak**

1. Fine-grained powder of a substance a more reliable indicator of color.
2. **Streak** is determined using a streak plate (unglazed porcelain tile).

I. **Effervescence** - gaseous reaction produced by carbonate when dissolved in HCl; some require heating to start reaction.
J. **Specific Gravity**
Specific gravity is the ratio between the weight of a substance and the weight of an equal volume of water. eg. 10 cc of platinum weighs 19 times that of 10 cc of H₂O.
Specific gravity of a mineral depends on the elements that are present, and their packing density.

K. **Tenacity** - Resistance to breaking, crushing, bending, and tearing.
Minerals with metallic bonds yield to stress by deforming plastically (malleable). This is possible because the cations are surrounded by a 'cloud' of mobile electrons. Thus they can slide past another without being repulsed electrostatically.
A sectile mineral can by cut into shavings, and a ductile mineral can be drawn into a wire.
A flexible mineral can be bent, but does not regain its original shape the way an elastic mineral does.
Brittle minerals break and powder easily.

L. **Luminescence**
1. Emission of light by a mineral that is not related to visible light. Similar to color, luminescence is caused by the excitation of electrons. Most common in the transition metals. Shorter wavelengths (UV) have greater energy, and excited electrons give off heat plus light (visible) when they fall back to initial state.
2. **Fluorescence** - luminescence due to exposure to ultraviolet light
3. **Phosphorescence** - luminescence continues after exciting rays are cut off
Also: Thermoluminescence and Triboluminescence

M. **Radioactivity**
1. Some elements are naturally unstable and spontaneously decay by the release of energy.
2. Can be easily measured using a Geiger counter or scintillation counter. Also by using photographic film.

N. **Piezoelectricity, Pyroelectricity**
1. The electrical polarity that develops along a crystal's polar axis in proportion to a mechanical strain along this axis.
2. Same as piezoelectricity, but related to change in temperature.