Ch 4 - Physical Properties: Glass and Soil

- Physical and chemical properties.
- Metric and British systems.
- Celsius (Centigrade) vs Fahrenheit.
- Mass vs Weight.
- Density
- Refractive Index
- Crystalline vs Amorphous solids.
- Double refraction and birefringence.

Physical property: describes the behavior of a substance without having to alter the substance’s composition through a chemical reaction.

Chemical property: describes the behavior of a substance when it reacts or combines with another substance.

Fahrenheit scale: the temperature scale using the melting point of ice as 32°F and the boiling point of water as 212°F, with 180 equal divisions or degrees between them.

Celsius scale: the temperature scale using the melting point of ice as 0°C and the boiling point of water as 100°C, with 100 equal divisions or degrees between.

Weight: a property of matter that depends on the mass of a substance and the effects of gravity on that mass.

Mass: a constant property of matter that reflects the amount of material present.

Density: a physical property of matter that is equivalent to the mass-per-unit volume of a substance.

Refractive index: the ratio of the speed of light in a vacuum to its speed in a given substance.

Crystalline solid: a solid in which the constituent atoms have a regular arrangement.

Refractive index: the bending of a light wave as it passes from one medium to another.

Amorphous solid: a solid in which the constituent atoms or molecules are arranged in random or disordered positions. There is no regular order in amorphous solids.

Birefringence: a difference in the two indices of refraction exhibited by most crystalline materials.

Dispersion: the separation of light into its component wavelengths.

Tempered glass: glass to which strength is added by introducing stress through the rapid heating and cooling of the glass surfaces.

Becke line: a bright halo that is observed near the border of a particle immersed in a liquid of different refractive index.

Radial fracture: a crack in a glass that extends outward like the spoke of a wheel from the point at which the glass was struck.

Concentric fracture: a crack in a glass that forms a rough circle around the point of impact.

Mineral: a naturally occurring crystalline solid.
Density-gradient tube: a glass tube filled from bottom to top with liquids of successively lighter densities; used to determine the density destruction of soil.

### Properties of Matter

- **Chemical Properties**
  - A characteristic of a substance that describes the way the substance undergoes or resists change to form a new substance.

- **Physical Properties**
  - A characteristic of a substance that can be observed without changing the substance into another substance.

### Physical Properties

- **Extensive (extrinsic) Properties**
  - Depend on the amount of sample
    - Volume, mass

- **Intensive (intrinsic) Properties**
  - Do not depend on the amount of sample
    - Melting point, density

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### Metric System

- In 1791, the French Academy of Science devised the simple system of measurement known as the metric system.

- The **metric system has basic** units for length, mass, and volume.
- These units are the **meter**, **gram**, and **liter**.

- Volume can be defined in terms of length.
- A liter by definition is the volume of a cube, each side having a length of 10 centimeters.
- One liter is therefore 10 cm x 10 cm x 10 cm
  - 1 liter = 1,000 cubic centimeters (cc)
  - 1 liter is also 1,000 mL
  - Therefore, **1mL = 1cc**.

These terms are used interchangeably by scientists.
In the Fahrenheit scale, the values are 32 °F and 212 °F.

In the Celsius scale, the values are 0°C and 100°F.

Weight and Mass

✓ What is the difference between weight and mass?

Weight is the force with which gravity attracts a body.

✓ Is your weight on Earth the same as it would be on the Moon?

Mass refers to the amount of matter an object contains.

The mass of an object is determined by comparing it against the known mass of standard objects.

Density

An important physical property of matter with respect to the analysis of certain kinds of physical evidence is density.

An intensive property of matter.

Defined as mass per unit volume.

Density = mass/volume

Density is typically measured in g/mL or g/cm³.

How does the density of solids compare to liquids? Gases?

Varies by temperature

✓ A solid object either sinks, floats, or remains suspended when immersed in a liquid.

✓ If the density of a solid is greater than that of a liquid in which it is immersed, the object sinks.

✓ If the density is less than that of the liquid, it floats.

✓ When the solid and liquid have equal densities, the solid remains suspended in the liquid.

Physical Measurements

Light Facts:

Electromagnetic radiation is composed of waves - like ripples on the surface of a pond, and the waves transport energy as photons - tiny wave-packets.

Wavelength

Frequency

Light Facts:

Travels at 3,000,000 m/s in a vacuum

c = λν

Light travels more slowly in media

The change of wavelength (speed) at the surface between different media causes light passing to be bent - to be refracted

White light is refracted, as when passing through a prism, with waves of different frequencies bent at different angles - the result being that the light is dispersed.
Physical Measurements

Dispersion

Refractive Index (RI or N_D)

- The ratio of the velocity of light in a vacuum to the velocity of light in a given medium
- Refractive index = \( \frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}} \)
- Example: RI (water) = 1.333
  - light travels 1.333 time faster in vacuum than in water
- The refractive index of a substance is measured at a certain temperature, such as 25ºC.
- An intensive property

Refractive Index Table

<table>
<thead>
<tr>
<th>Substance</th>
<th>State</th>
<th>Refractive Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>Gas</td>
<td>1.000293</td>
</tr>
<tr>
<td>Ice</td>
<td>Solid</td>
<td>1.33</td>
</tr>
<tr>
<td>Water</td>
<td>Liquid</td>
<td>1.33</td>
</tr>
<tr>
<td>Ethyl Alcohol</td>
<td>Liquid</td>
<td>1.36</td>
</tr>
<tr>
<td>Quartz</td>
<td>Solid</td>
<td>1.54</td>
</tr>
<tr>
<td>Salt</td>
<td>Solid</td>
<td>1.54</td>
</tr>
<tr>
<td>Tourmaline</td>
<td>Solid</td>
<td>1.62</td>
</tr>
<tr>
<td>Garnet</td>
<td>Solid</td>
<td>1.73-1.89</td>
</tr>
<tr>
<td>Cubic Zirconia</td>
<td>Solid</td>
<td>2.14-2.20</td>
</tr>
<tr>
<td>Diamond</td>
<td>Solid</td>
<td>2.41</td>
</tr>
</tbody>
</table>

- Almost all refractive indices are determined at wavelength of 589.3 nm (predominant wavelength emitted by sodium light)

Refraction

- The bending that occurs when a light wave passes at an angle from one medium to another (ex. air to glass)
- bending occurs because the velocity of the wave decreases

Snell's Law:

\[
\eta_1 \sin \theta_1 = \eta_2 \sin \theta_2
\]

- Refractive index is a highly distinctive property of glass and is useful for evidential value.
- The physical properties of **density and refractive index** are most widely used for characterizing glass particles.

Birefringence

- The difference between the two indices of refraction
  - for calcite: 1.486 & 1.658
  - birefringence for calcite is 0.172
- Use in identifying crystals
Dispersion

- Occurs when
  - an incident parallel beam of light to fans out according to the refractive index of the glass for each of the component wavelengths, or colors.

What is Glass?

- One of the oldest of all manufactured materials
- A simple fusion of sand, soda & lime (all opaque)
  - produces a transparent “solid” when cooled
- An extended, 3D network of atoms which lacks the repeated, orderly arrangement typical of crystalline materials
- The viscosity is such a high value that the amorphous material acts like a solid

Glass

The Basics

Structure of Glass

Physical Properties

- At ordinary temp.
  - internal structure resembles a fluid
    - random molecular orientation
  - external structure displays the hardness & rigidity of a solid
- Does not show a distinct melting point
  - on heating gradually softens
  - on cooling gradually thickens
How Is Glass Made?

- BLOWN OR SPIN GLASS
- FLOAT GLASS PROCESS
- ROLLED GLASS PROCESS

How Is Glass Made?


Types of Glasses

- ~a thousand chemical formulations
  - each has its own combination of properties
- more than 700 compositions in commercial use
- Most common type encountered by the forensic scientist is “flat” glass
  - glass used in windows & doors

Comparing Glass Fragments

Composed of silicon oxides mixed with metal oxides

<table>
<thead>
<tr>
<th>Soda-lime glass</th>
<th>Soda (NaCO₃)</th>
<th>Lime (CaO)</th>
<th>windows bottles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrex Borosilicates</td>
<td>use Boron oxide, Can withstand HIGH heats</td>
<td>Test tubes Headlights</td>
<td></td>
</tr>
<tr>
<td>Tempered Glass:</td>
<td>Rapid heating and cooling does not shatter</td>
<td>Shower doors Side + rear windows</td>
<td></td>
</tr>
<tr>
<td>Laminated Glass</td>
<td>Plastic or Glass and glues and sandwich</td>
<td>windshields</td>
<td></td>
</tr>
</tbody>
</table>

✓ *Float (Plate) glass:* molten glass is cooled on a bed of molten tin, which produces flat glass typically used for windows.

✓ *Tempered glass:* stronger than ordinary window glass by introducing stress through rapid heating and cooling of the glass surfaces.
  - When tempered glass breaks, it does not shatter but rather fragments or dices into small squares with little splintering.
  - Commonly used in side and rear windows of automobiles.

✓ *Laminated glass:* made by sandwiching one layer of plastic between two layers of glass.
  - Found in car windshields.

Plate Glass

Tempered Glass

- Soda-lime glass
- Pyrex Borosilicates
- Tempered Glass
- Laminated Glass

Plate Glass

Tempered Glass

- Soda-lime glass
- Pyrex Borosilicates
- Tempered Glass
- Laminated Glass
Most glass analysis compares the refractive indices, elemental compositions, and densities of two or more samples (class).

Sometimes a fractured glass object can be reconstructed. Due to the vast number of ways such a lens could break, a piece of glass fitting into such a reconstruction would constitute an identification.

**Glass Analysis**

**Glass Fracture Examination**
- Occurs when the limit of its elasticity is reached
- Gives information relating to force and direction of an impact
- Two types:
  -Radial fractures – cracks radiate outward and encircle hole like spokes of a wheel
  -Concentric fractures – circular lines form a rough circle around point of impact

**Glass Fractures Sequence:**
1. Radial cracks are formed on opp. surface
2. Continued force on surface causes concentric cracks on surface side of the force.

- Impact causes a pane of glass to bulge
- Side opposite the impact will stretch more & rupture first
- Radial cracks are rapidly propagated in short segments from the point of impact

**Glass Fractures**

- Radial and concentric fractures
- Heat fracture
- Blunt object fracture
Glass Analysis

- Ridges on radial cracks can be used to determine on which side impact occurred
- Stress marks left on broken edges of glass are perpendicular to one side and curve (run almost parallel) to the other side

Four R Rule

- Ridges on radial cracks are at right angles to the Rear (side opposite the impact)

Four R Rule

- Exceptions
  - Tempered glass
  - “deed” without forming ridges
  - Very small windows held tightly in frame
  - Can’t bend or bulge appreciably
  - Windows broken by heat or explosion
  - No “point of impact”

Heat Fractures

- Typical crack is curved
- Has a smooth edge (“mirror edge”)
- No indication of point of impact

Fractures Caused by Projectiles

- Close Range shot
  - Leaves a round, crater-shaped hole surrounded by a nearly symmetrical pattern of radial and concentric cracks
  - Hole is wider at exit side providing a means of determining direction of impact
- High-velocity projectiles
  - Crater-like hole surrounded by a nearly symmetrical pattern of radial and concentric cracks
Fractures Caused by Projectiles

Bullet Analysis
- If a window is broken by a bullet, it is possible to determine the bullet's direction by noting the side of the cone-shaped hole left by the bullet. The small opening is on the entrance side and the large opening is on the exit side.
- A determination of the sequence of bullet holes can be made by noting the radial fractures. Radial fractures caused by the passage of a bullet will stop at any pre-existing fracture.

Comparing Glass Fragments
Using Physical Properties

Glass as Forensic Evidence
- Films of breaking glass show that glass flies backward from all parts of the window where cracks appear
- Glass fragments recovered from clothing: number & distribution are important
- Glass must be classified: window glass vs broken bottle glass
- Individualization may be possible

Classification Tests
- Physical properties can be used to place glass into a class
  - Density
  - Refractive Index (RI)
- Individualization can’t be determined from these properties alone
**Flotation Test**
- Based on density comparison
- A control glass chip (known density)
  - Immersed in a liquid (mixture of bromoform & bromobenzene)
  - Composition altered until the chip remains suspended
- The crime object (glass of unknown density)
  - Immersed in the liquid mixture
  - Remains suspended: liquid, control & unknown have same density
  - Sinks: unknown is more dense than control
  - Different origins

**Refractive Index By Immersion**
- Entails finding the temp. at which a glass particle & a liquid have identical refractive indices
- Refractive index of glass is relatively unaffected by changing temp
- Reason why the eye unable to distinguish between the solid-liquid boundary.

**Refractive Index By Immersion**
1. Hot stage microscope used
2. Glass is immersed in RI liquid which is higher RI than glass. Temperature is raised at rate of 0.2 °C/min until Becke line disappears. Rate of change of RI in liquid is known (3x10^(-4)/degree) so the RI of the unknown can be determined
3. The point where the Becke line disappears:
   - RI of the sample = the RI of the liquid
- If all glass fragments have similar match points, they have comparable RI

**Becke Line**
- A bright halo that is observed near the border of a particle immersed in a liquid of a different refractive index
- When Becke line and glass disappears, index of refraction has been reached
- Glass has higher refractive index
  - Becke line seen inside
  - Rays converge
- Glass has lower refractive index
  - Becke line seen outside
  - Rays diverge

**Elemental Analysis**
- Many trace elements enter glass via trace impurities in the raw materials
- Comparison of elemental analysis of crime glass & reference glass
  - If ranges of elements overlap for every element
    - Indistinguishable
  - If ranges of one or more elements are different
    - Samples are distinguishable
GRIM 2

- Glass Refractive Index Measurement
- Instrument used for measuring refractive index of glass fragments

Soil Analysis

Forensic Characteristics of Soil

- Soil includes any disintegrated surface material, that lies on or near the earth’s surface
- Value based on prevalence at crime scenes and ability to transfer between scene and criminal
- Most soils can be differentiated and distinguished by appearance
  - visual comparison

What Is Soil?

- Mixture of organic and inorganic material
- May range from 100% inorganic (sand) to nearly 100% organic (peat)
- Inorganic part is minerals
- Organic part is decayed plant and animal material and is sometimes called humus

Soil Analysis

Soil is darker when wet. Therefore, color comparisons must always be made when all the samples are dried under identical laboratory conditions.
- There are an estimated 1,100 distinguishable soil colors.
- Low-power microscopic examination reveals the presence of plant and animal materials as well as artificial debris.
Soil comparison:

Density Gradient tube used to compare soil samples

- 1.0 g/ml
- 1.5 g/ml

Soil Analysis

- Soil is frequently found on clothing, shoes, or tools and in the wheel wells of vehicles.
- Most soil analysis consists of comparing two or more samples by their mineral content, color, and density. The presence of pesticides and herbicides have also been used in soil comparison.

Soil Analysis

- Hit and Run: - Under-fender dirt/soil deposited at impact with the victim was used to locate the car/driver; also, matching the grease on the victim with the grease under the car provided supporting evidence.
- Rape: - Soil on clothing of a suspected rapist was used to place the suspect at the crime scene and to eliminate the suspect’s alibi.
- Murder: - Soil found on murder victims used to determine the location of homicides, especially when the murder occurs in one location and the body is then moved. Using water-current measurements, bodies/objects thrown into water can be located and where a discovered body/object originally entered the water determined.
- Assault: - Identifying the type of rocks used as weapons led to the source of the rocks and helped locate suspects.