

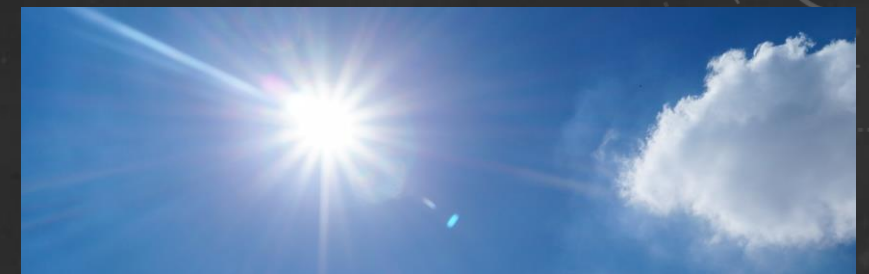
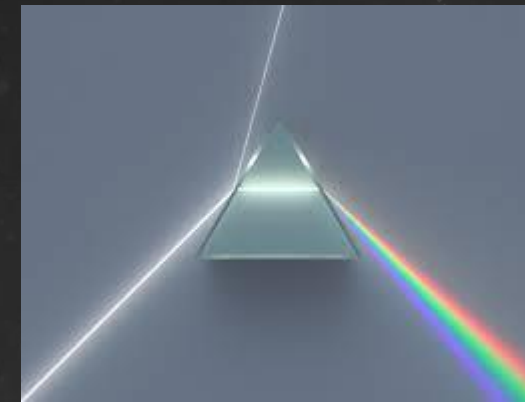
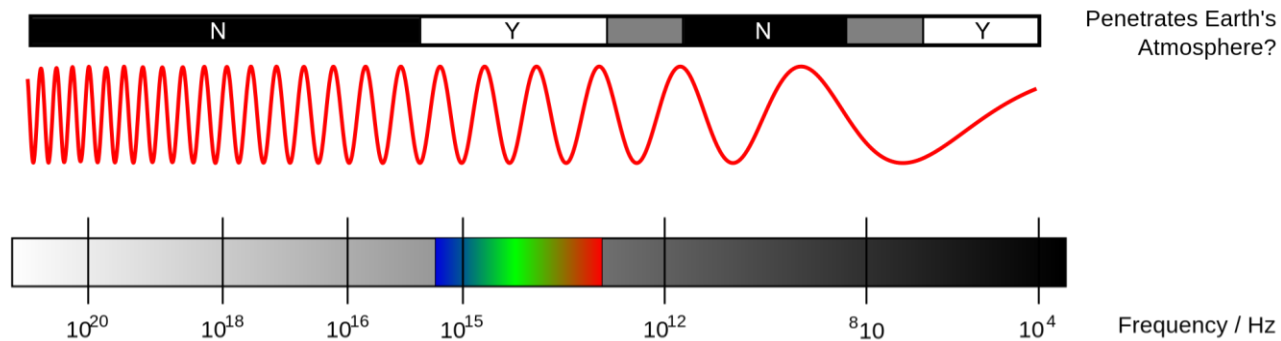
The background features a dark, textured surface with several faint, light-colored circular patterns. On the left side, there is a large, semi-circular scale with numerical markings from 140 to 260 in increments of 10. The scale is oriented vertically, with 140 at the top and 260 at the bottom. Several circular diagrams with arrows are scattered across the background, some appearing to represent orbits or paths. The overall aesthetic is technical and scientific.

LIGHT AND COLOR

PES 1000 – PHYSICS IN EVERYDAY LIFE

WHITE LIGHT

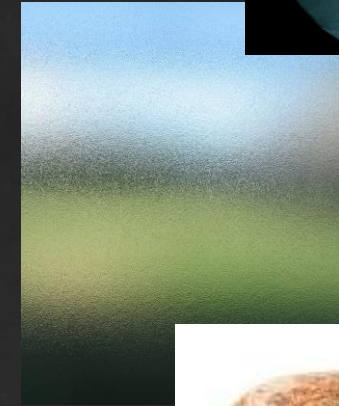
- **Natural sunlight** consists of all the colors of the rainbow.
- We see this '**visible**' light as **white** because it stimulates equally the color receptors in our eyes.
- Sunlight is 'visible' because it is able to pass through the **atmosphere** (along with radio and a little infra-red).
- Visible light is really just a **tiny sliver** of the entire electromagnetic spectrum.



TRANSMISSION, ABSORPTION, REFLECTION

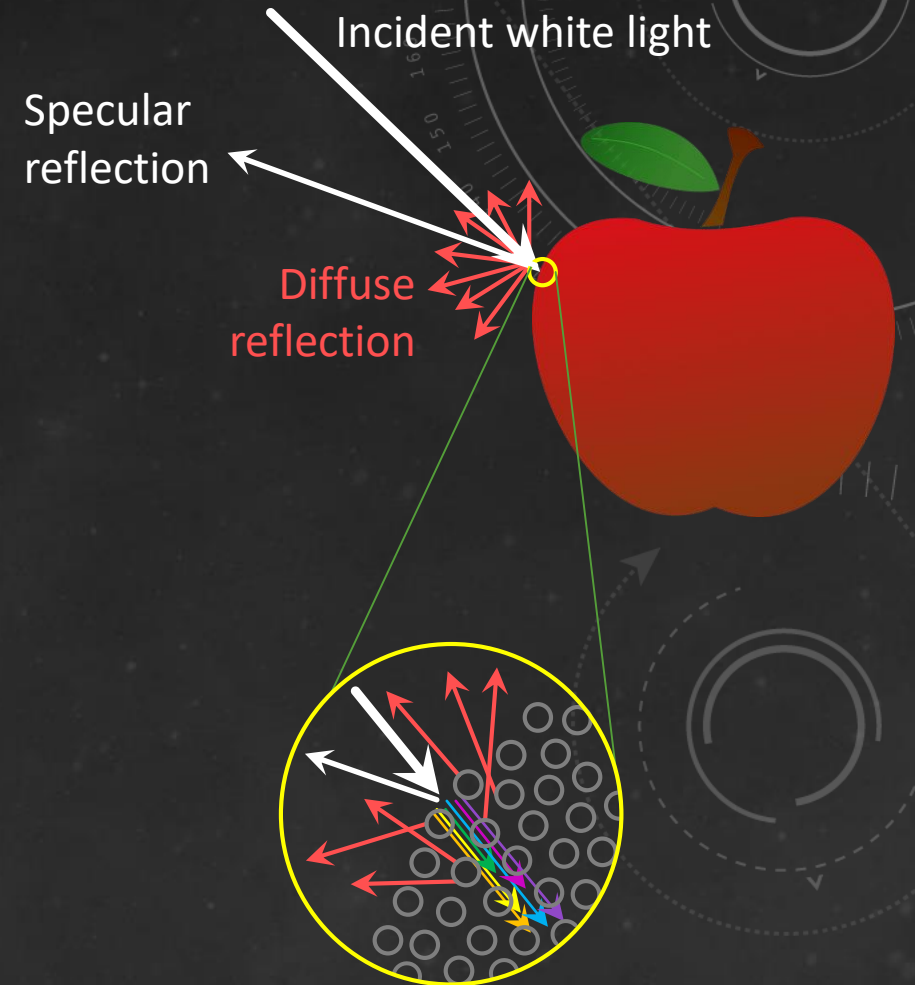
Light interacts with different materials in different ways:

- **Transparent materials:** Light rays pass straight through these materials. Parallel rays remain parallel. The material may absorb or scatter some wavelengths. Includes: glass, air and other gases, pure water.
- **Translucent materials:** Light passes through these materials, but rays do not remain parallel. They are absorbed and re-emitted randomly. Images cannot be formed through this type of material. Includes: frosted glass, dirty water, very thin slices of rock, skin.
- **Opaque materials:** Light cannot pass through these materials. It is either reflected or absorbed. Includes most room-temperature solids we see every day. Opaque objects can exhibit color by the way the light interacts with their surface atoms.



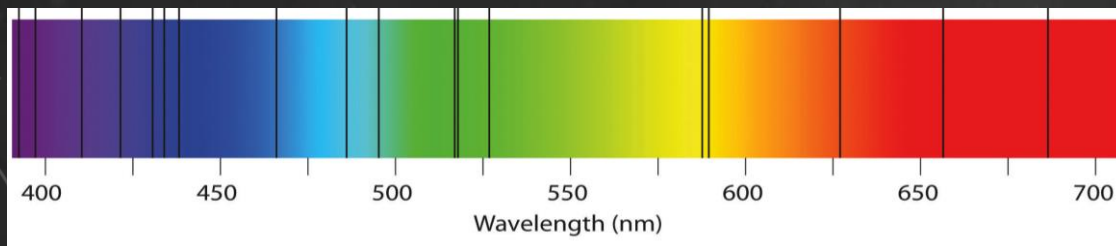
REFLECTED LIGHT FROM AN OBJECT

- Imagine white light falling upon a polished apple.
- A part of the light will **reflect** from the outer atomic layers, remaining white. (The 'glint' we notice on shiny objects).
 - This is called *specular reflection*.
- The **red** wavelengths in the light are **absorbed and re-emitted** by the outer layer of atoms. They are re-emitted in all different directions.
 - This is called *diffuse reflection*.
- The remaining colors are **not re-emitted**. They are absorbed and converted to **heat**.



ABSORPTION OF LIGHT AND SUBTRACTIVE COLOR

- **Pigments** form color from white light by **subtracting** all but one color.
- In subtractive color, the primary pigments are **Red**, **Yellow**, and **Blue**.
- If **no color is subtracted** from the light, it reflects as **white** (as from white paper).
- If **all color is subtracted** from the light, no light reflects, and the object appears **black**.
- **Mixing** all subtractive primary colors usually results, not in perfect black, but shades of **brown**.
 - Many substances in nature are a mix of many molecules which absorb a variety of colors, leaving the substance a shade of brown.
- Shining white light through a gas and then through a prism produces an **absorption spectrum**: a **rainbow background with black absorption lines**.
 - The missing lines are **unique** to each molecule, and would correspond to the emission lines in the emission spectrum for this molecule.

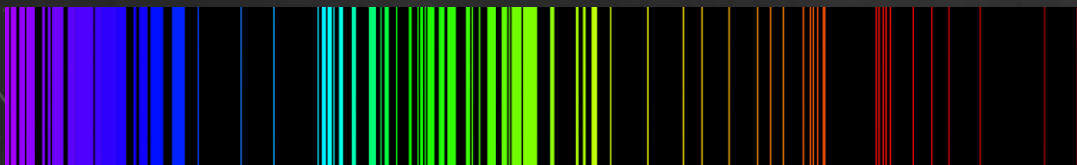


Absorption spectrum

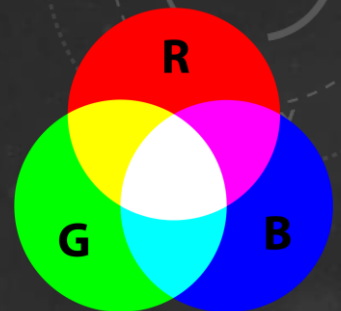


EMISSION OF LIGHT AND ADDITIVE COLOR

- When an object is **hot**, the atoms hit each other, knocking **electrons into higher levels**, which then spontaneously drop back down, **re-emitting** the energy as light.
- In **additive color**, the primary colors are **Red**, **Green**, and **Blue**.
- If **no light** is present, **black** is the result. (That's why space is black.)
- **All primary colors** mixed produces **white** light. (Sunlight is white.)
- Emission televisions work by combining Red, Green, and Blue (RGB) in different fractions to produce a variety of colors.
- **Heating** a gas to incandescence and passing the light through a prism results in an **emission spectrum**, which is **bright, colored lines on a black background**.
 - The colored lines are **unique** to each molecule, and would fill in the absorption lines in the absorption spectrum for this molecule.



Emission spectrum



BLACKBODY RADIATION

- If an object is made of a variety of substances and is heated to the point of emitting light, that light is often a **mixture of all wavelengths**.
- There will be **one dominant wavelength** that is emitted most strongly.
- Other wavelengths will have decreasing intensity the farther they are from the brightest color.
- Which wavelength is the **dominant color** is entirely dependent on the **surface temperature**.



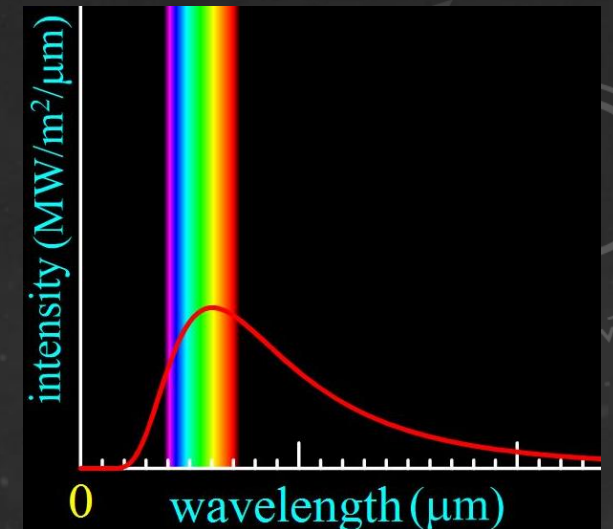
2500 K



3500 K

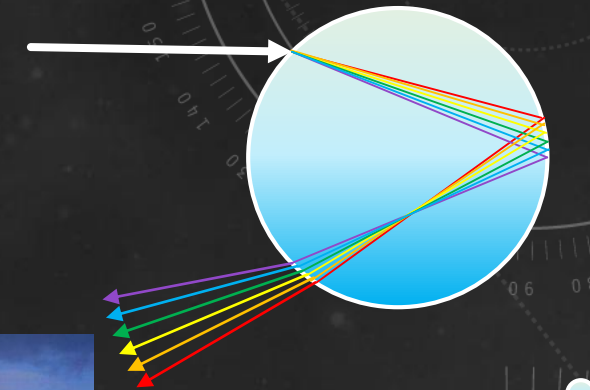
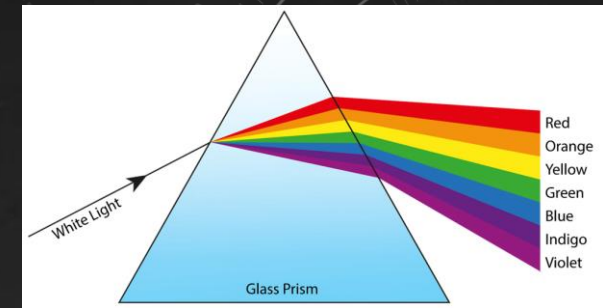


6300 K



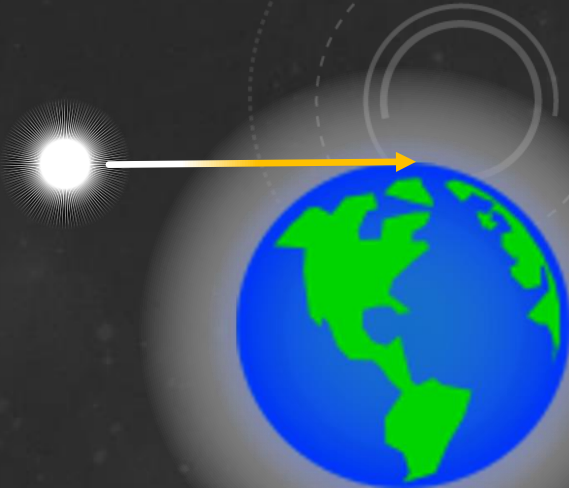
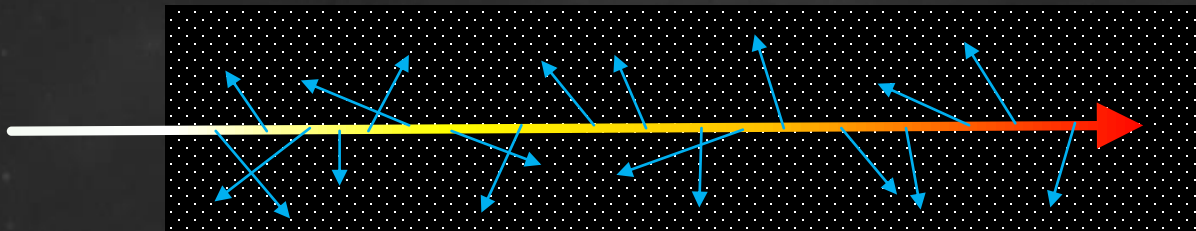
DISPERSION

- When **light enters glass at an angle**, the **light ray will bend**. Different wavelengths of light (i.e. **colors**) will **bend different amounts**. **Red** bends the least, and **violet** bends the most.
 - This is how a triangular prism splits white light into its component colors.
- A **spherical prism** works similarly. Raindrops act as spherical prisms.
- A sheet of raindrops illuminated by white sunlight will form a **rainbow**.
 - The observer sees **red light** from the **upper drops**, **violet** from the **lower drops**, and all colors in between.
 - There is only **one angle** relative to the sun that the observer can see the colors. That is why **rainbows are circles** or arcs.
 - **Double rainbows** are formed when light reflects many times inside droplets.
 - Secondary rainbows are dimmer: multiple reflections remove most of the light.



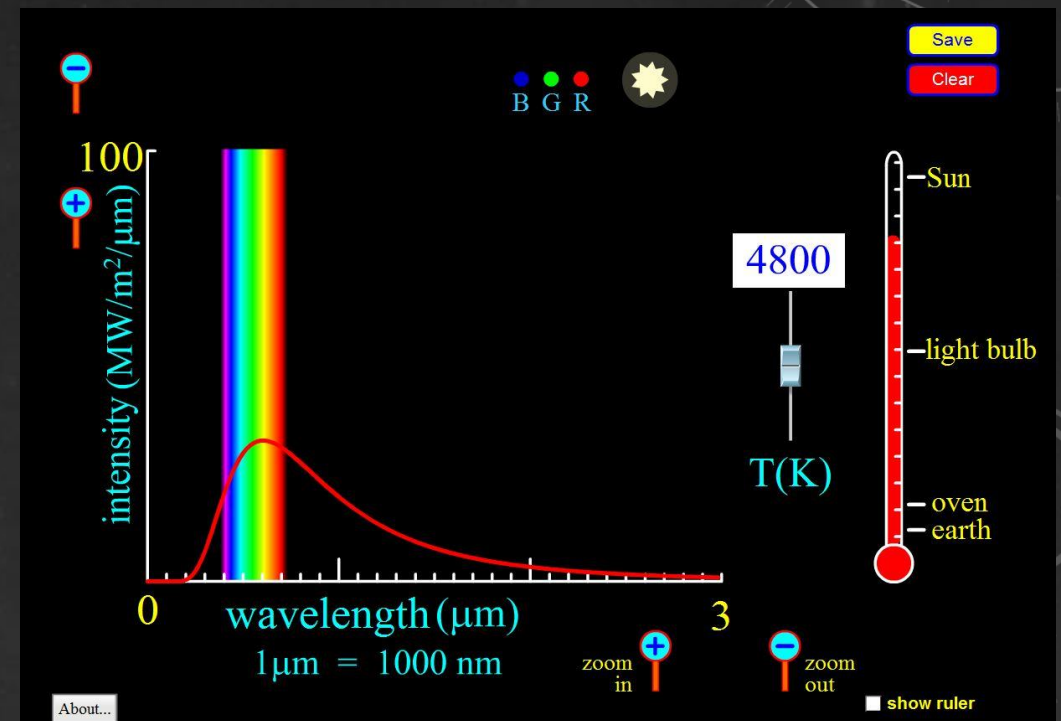
SCATTERING

- **White light** from the sun **interacts with molecules** in the atmosphere.
- Shorter wavelengths (**blue, green**) are **scattered** (absorbed and re-emitted in a random direction.)
- Longer wavelengths (**red, orange, yellow**) are less affected by the molecules.
- Looking at any angle, you see scattered blue, causing the sky to be blue.
- At **sunrise** and **sunset**, the light has passed through more atmosphere than normal to reach the observer. More **blue light** has been **scattered** out, causing sunrise and sunset to be filled with **reds, oranges, and yellows**.
- Dust and moisture in the air can cause more scattering. Sunrises/sunsets after volcanic eruptions tend to be more red than usual.



SIMULATION – BLACKBODY RADIATION

- Link to simulation: https://phet.colorado.edu/sims/blackbody-spectrum/blackbody-spectrum_en.html
- Things to do:
 - Click 'zoom in' a couple of times.
 - Notice how **all wavelengths** are represented in the emitted light.
 - Slide the **temperature** up and down.
 - **Observe** how the **peak intensity shifts** toward the red end for low temperatures, and toward the violet end for high temperatures.



SIMULATION – BENDING LIGHT

- Link to simulation: https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html

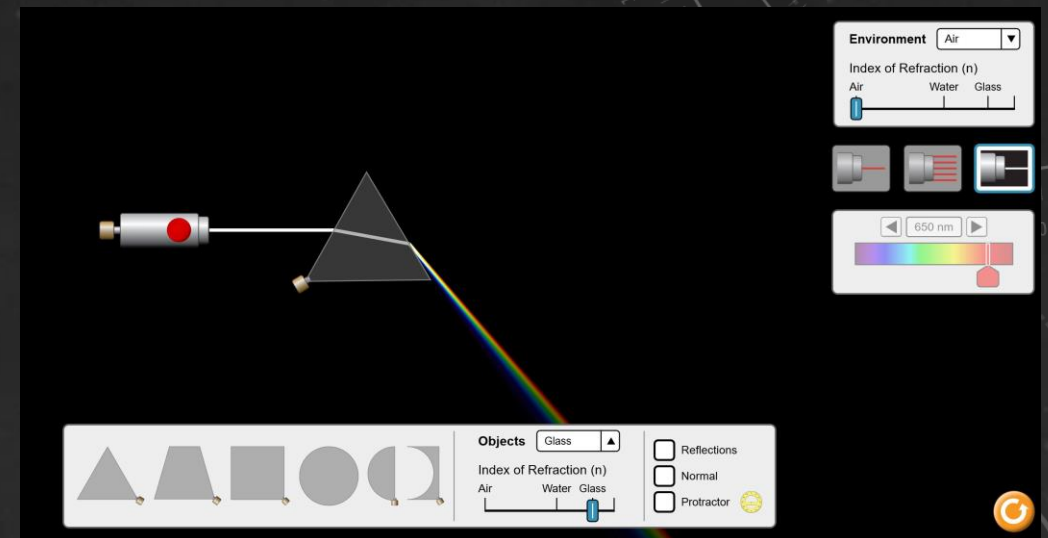
- Things to do:

- **Triangular prism**

- Select the 'Prisms' at the start.
 - Choose the **white light source** (at the right).
 - Press the **red button** on the source to turn on the light.
 - Drag a **glass triangle** in front of the light.
 - Observe the **dispersion**.

- **Raindrop**

- Drag the triangle back to the bottom, then **drag a sphere** in front of the light.
 - Change the sphere to '**water**' with the controls at the bottom.
 - Check the '**Reflections**' box at the bottom.
 - **Move the sphere** to create the '**double rainbow**' effect. (Hint: beam should enter just at the top of the drop. You should get two dispersed beams leftward.)



CONCLUSION

- **Sunlight**, which is **white**, consists of **all the colors** of the rainbow.
- **Absorption** of some light **and reflection** of other light is responsible for the **color** we see in room-temperature objects.
- **Heated objects** can **emit** their own light.
- **Atoms and molecules absorb and emit a unique spectrum** of wavelengths due to their unique atomic structure.
- **Transparent** materials will **bend different colors of light differently**, causing them to split apart (dispersion).
- Some wavelengths of light can be **scattered** (absorbed and randomly re-emitted) when light passes through gases and other transparent materials.

Image attributions:

- Molecular motion: <https://en.wikipedia.org/wiki/Harmonic>
- LASER: <https://pixabay.com/en/photos/laser/?cat=science>
- LASER: <https://commons.wikimedia.org/wiki/File:Laser.svg>
- Apple: <http://www.clipartpanda.com/categories/teacher-apple-clipart>
- Stovetop burner: <https://www.flickr.com/photos/lemasney/4428709126>
- Acetylene torch: <https://www.flickr.com/photos/aspis7/5340375681>
- Campfire: https://commons.wikimedia.org/wiki/File:Campfire_Pinecone.png
- Additive color: https://en.wikipedia.org/wiki/Color_theory
- Subtractive color: https://commons.wikimedia.org/wiki/File:Color_mixture.svg
- Rainbow: <https://www.pinterest.com/pin/212372938648590266/>
- Earth: <http://www.clipartfree.net/clipart/1503-earth-nice-colored-clipart.html>
- Sun: <https://openclipart.org/detail/172455/sun-abstract-design>
- Sunset: <https://www.pexels.com/search/sunset/>
- Sky: <https://www.pexels.com/search/sky/>
- Round Window: <https://www.flickr.com/photos/56832361@N00/15053739916>
- Frosted Glass: <https://www.flickr.com/photos/pinkmoose/3818168174>