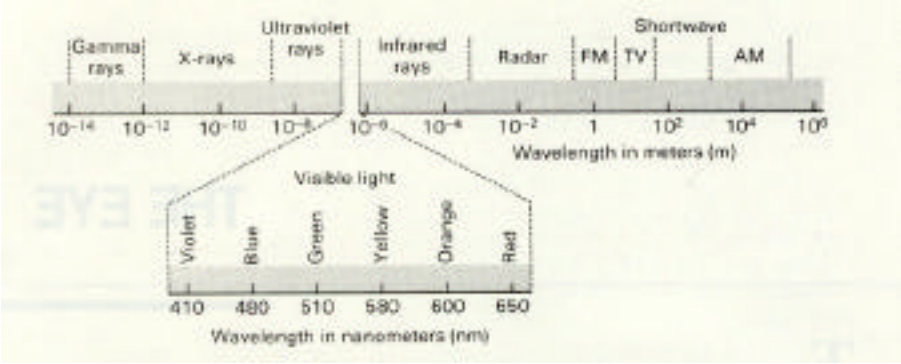
CPSC 532E — Week 4: Lecture

Environment, Eyes, and Displays

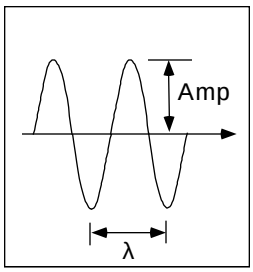
- The Terrestrial Environment; Optics; Vision
- Physiology & Abilities of Human Eyes
- Monitor Characteristics

The Terrestrial Environment; Optics; Vision

Light is a form electromagnetic radiation
- only wavelengths between 380-700 nm are visible to humans



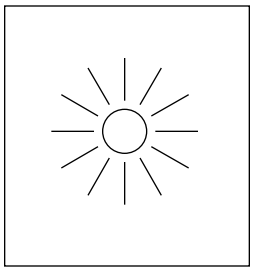
0. Intensity of EM radiation in free space



Property: **intensity**
= (amplitude)^2
= energy/sec
= power

Units: **watts**

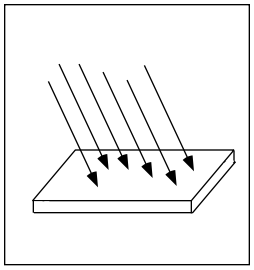
1. Light **sent from** object (light source)



Property: **radiance**
= total energy / sec
(i.e., energy of all EM radiation being sent out)

Units: **watts**

2. Light **received by** object (incoming light)



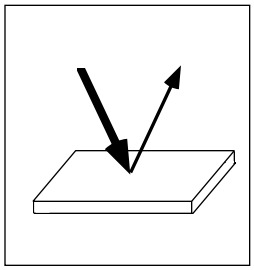
Property: **irradiance**

= power / area

(total falling on surface from all directions)

Units: **watts / m^2**

3. Light **reflected by** object surface



Property: **reflectance (albedo)**

$$= \frac{\text{outgoing light}}{\text{incoming light}}$$

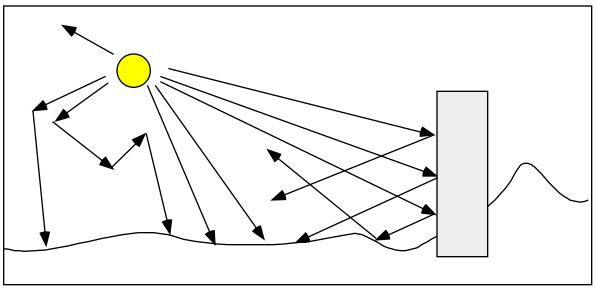
Units: **fraction (between 0 and 1)**

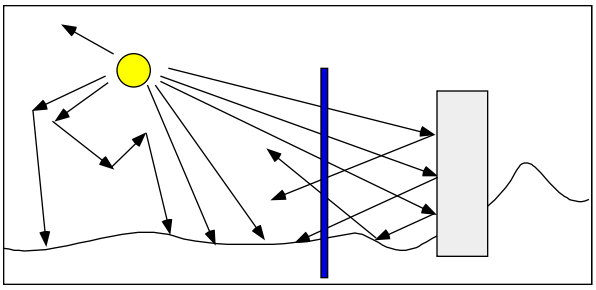
- 0 = total absorption (black)
- 1 = total reflection (white)

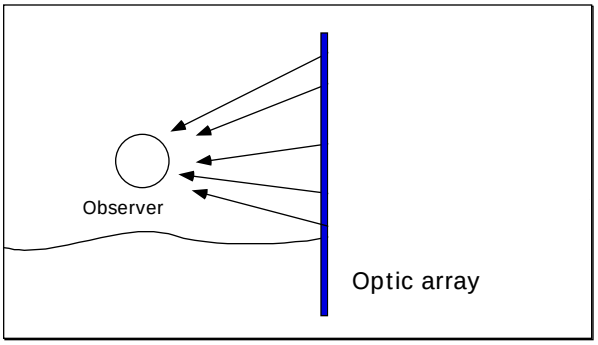
4. Terrestrial Optics

Light originates (largely) from sun. Then it:

- gets scattered by sky (nitrogen, oxygen)
- falls on surfaces of objects
- reflected from surfaces onto other surfaces







Optic array is what a monitor is trying to simulate...

Perception of Brightness & Lightness

- psychological measures

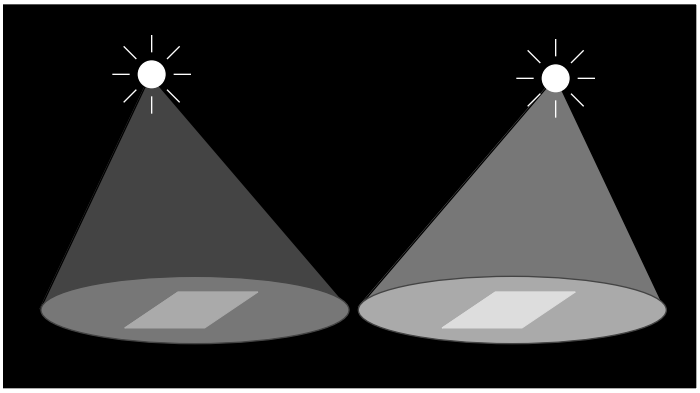
1. **Brightness**: subjective estimate of **intensity** (radiance) of light from a light source, or from a reflected surface

2. **Lightness**: subjective estimate of **whiteness** (reflectance) of a surface

Note: Surface can be considered either as a light source (brightness) or as a reflector (lightness)

How **lightness** is separated from **illumination**:

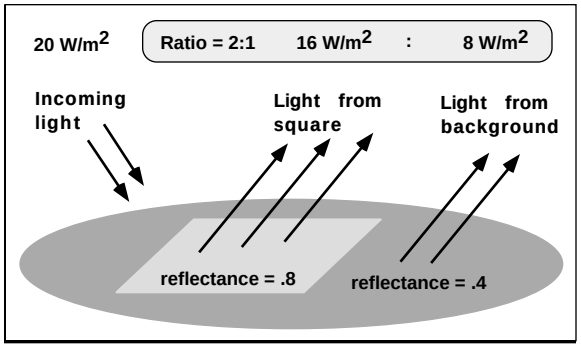
- one patch (on a simple background)
- estimate lightness of patch when different illumination is used



Result: **Lightness is unaffected by illumination**
-> Lightness constancy

Lightness computed as a

$$\text{ratio} = \frac{\text{intensity of light from square}}{\text{intensity of light from background}}$$



Ratio is completely unaffected by illumination level... it's a relative measure

-> **invariant**

Thus, vision provides an estimate of a property of

the **world** (object surface)

- doesn't change with lighting

rather than

the **image** (light on retina)

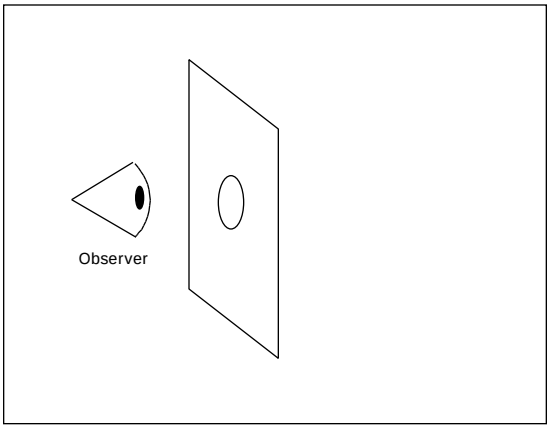
- does change with lighting

More generally, vision provides an estimate of various properties of the world

- does this by making inferences about scene structure, based on
  - incoming information (eyes)
  - stored knowledge (brain)

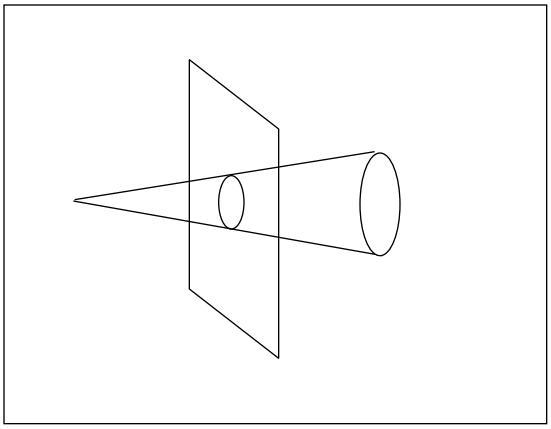
This is usually takes the form of choosing the most likely hypothesis

- likelihood depends on knowledge of many factors...

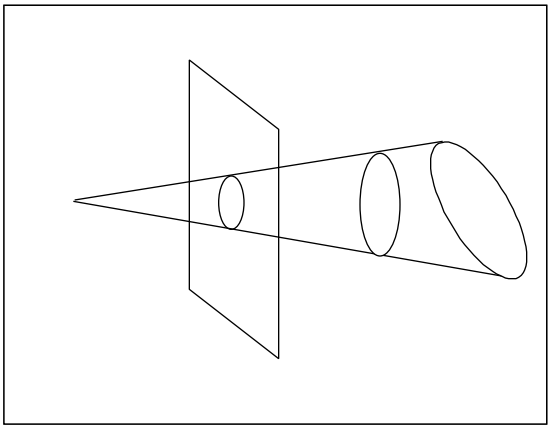


For example,

Consider an observer that sees an oval...



-The oval could be due to a circle straight ahead...



-Or an ellipse at an angle.

(Or many other possibilities...)

Ecological Optics (Gibson)

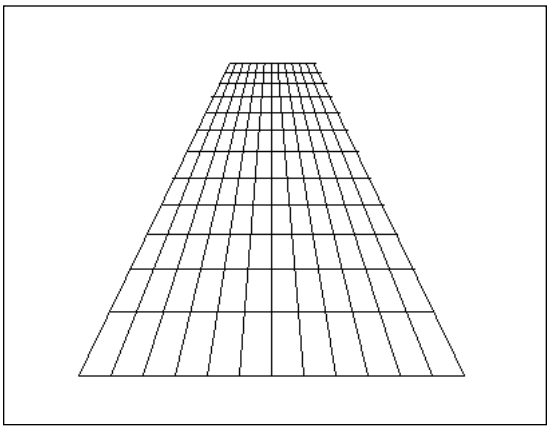
What aspects of the world are picked up? How?

- Gibson: perception is not “for fun”, but is intended for particular tasks
  - (e.g., walking, grasping)

-information that is picked up is

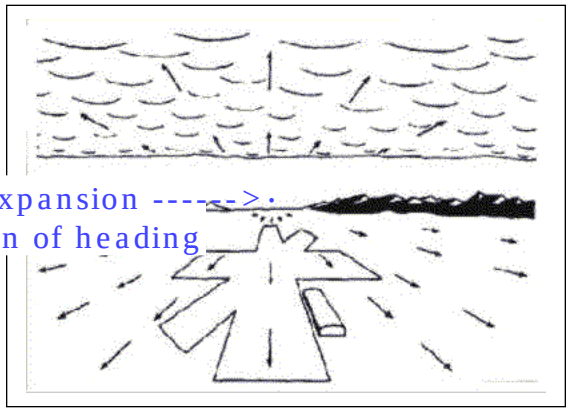
(e.g., perception of ground plane;
-Perception of optic flow).

-Simple patterns are no good.



-perception of ground plane via
- texture denser with increasing distance

Optic flow - pattern of motion in image
when observer moves



Focus of expansion ------>
= direction of heading

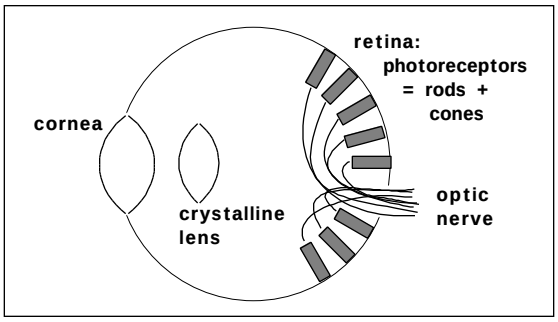
But...

How do we know **what** information is important?
- importance is obvious for some tasks
(e.g., landing an airplane)
- but not for others (e.g., Web surfing)

Thus, the ecological approach has it limits.

Need to step back and consider problem again...

Physiology of the Human Eye

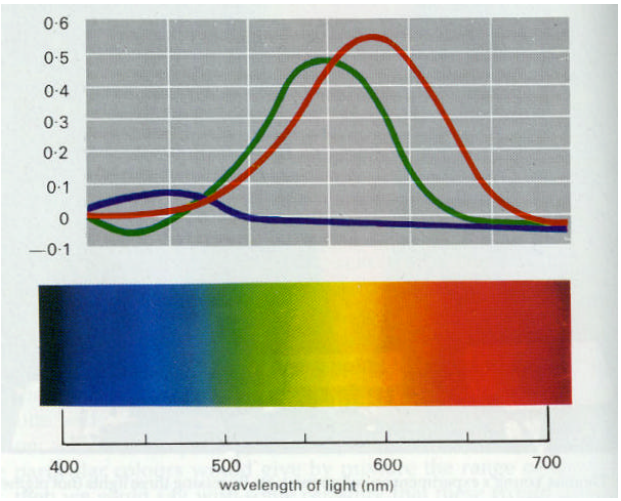


Photoreceptors are either

rods (120 million) - black & white vision; motion

cones (5 million) - color vision; high resolution

Relative efficiency of R, G, and B cones



Because rods and cones only capture part of the incoming energy, need to separate the idea of “energy” and “visible light”

Radiance -> Luminance

Irradiance -> Illuminance

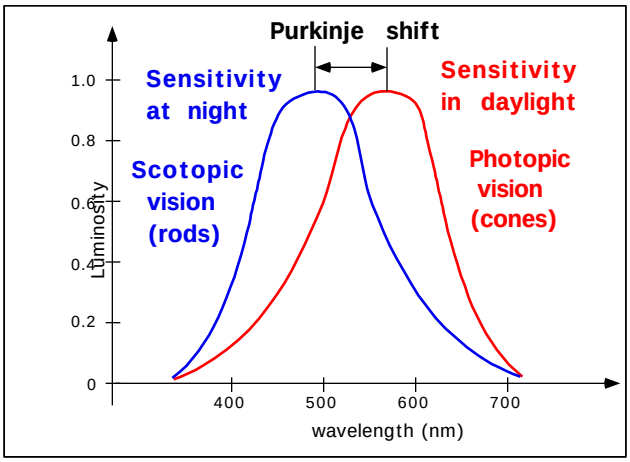
Reflectance -> Reflectance

(since it’s a ratio, it stays the same)

Because rods and cones have different sensitivities

-Different wavelengths have different luminosities

(some wavelengths are brighter than others)



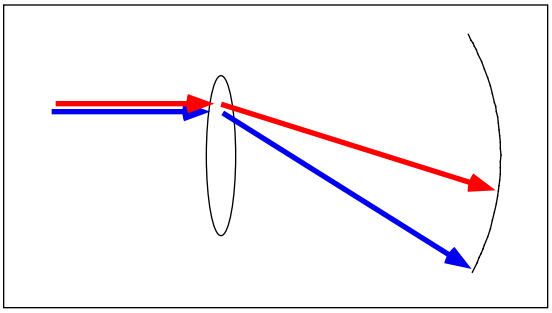
Chromatic Aberration

Another characteristic of the eye is that different wavelengths have different physical characteristics

-> blue is bent more by the lens

-> red is bent less

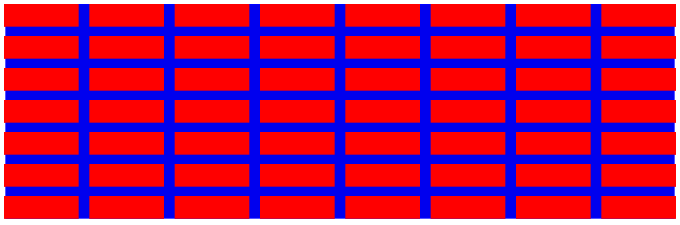
This is ***chromatic aberration***



This has several implications for displays.

1. Can lead to blurring of either red or blue signal
   - can only focus on one color

2. Can get a “jazzy” effect as eye tries to compensate
   - shifts back and forth between the two

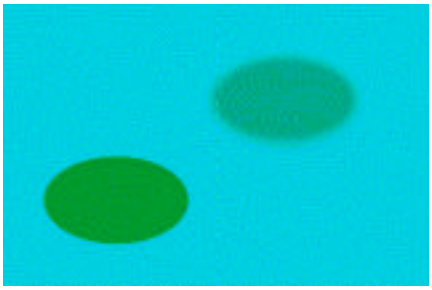


3. Can lead to perception of depth
   - red usually seen as closer to observer
   - blue is further away

Why?

Aerial perspective (da Vinci)

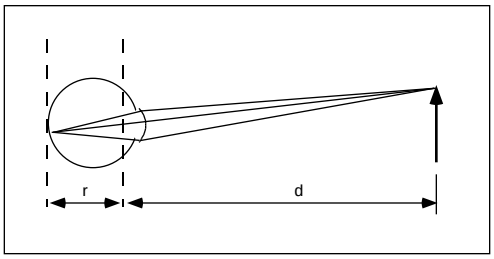
Smog, haze, etc. scatter light
- objects farther away -> more scattering
-> more bluish



<-- Object with bluish haze seen as further away

Focus

Another characteristic of the eye is that it can only focus on one given depth at a time



Range of depths that can simultaneously be in focus (***depth of focus***) is [3d/(d+3), 3d/(d-3]

Note: In displays, everything is presented in focus
- because display is at constant depth,
there is no blurring because objects are out of focus

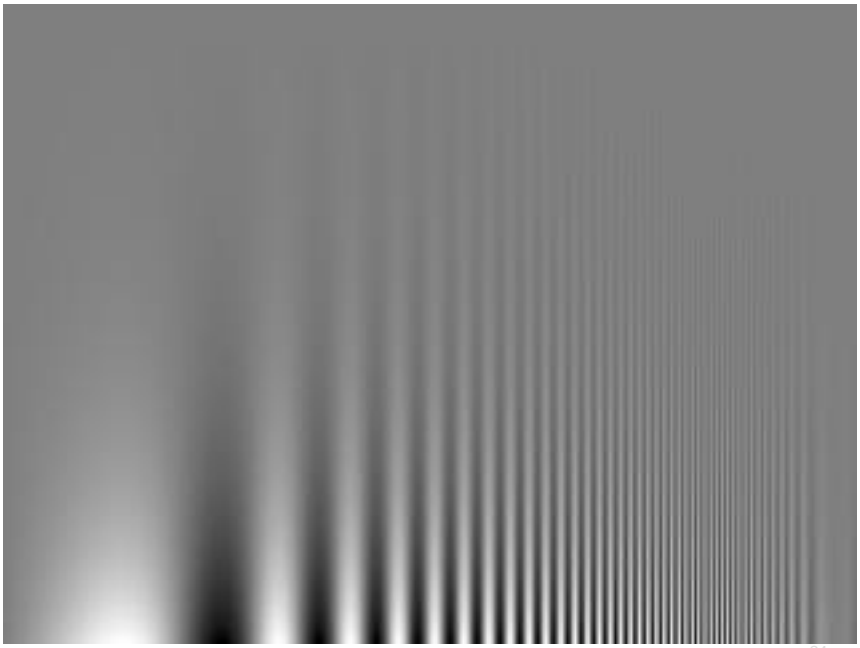
-> May lead to unrealistic-appearing displays

-> In augmented-reality systems (e.g. HUDs), computer imagery may need to have similar out-of-focus component to be integrated into a single image. If not:
- good: can easily create separation
- bad: can cause crashes
(apparent size <-> focus distance)

Acuity

Another characteristic of the eye is that
- highest acuity is in the central few degrees (fovea)
- more generally, acuity drops off steeply with distance from fovea

Vision is differentially sensitive to spatial frequencies
- most sensitive to c.2-3 cycles/degree
- changes with age
  - higher frequencies get harder to see



Temporal Characteristics

Sensitivity to image flicker
- ranges between 0.1 Hz - 50 Hz
- most sensitive to 2-10 Hz

Monitor Characteristics

Monitors designed to match sensitivity
of human visual system

Television
- 525 lines (10 degrees)
-> approx. 30 cycles / degree; 30 Hz
(reasonable close to human range)

Hi-Res Monitors
- complete image (no loss) would require
4000 x 4000 pixels