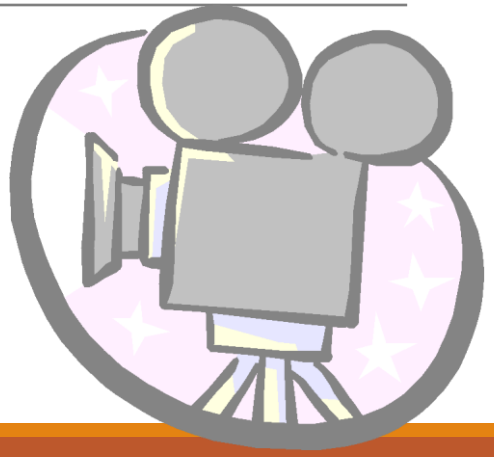
Image Processing

CS-317/CS-341



Outline

- Elements of Visual Perception
  - Image Formation in the Eye
  - Brightness Adaptation and Discrimination

Image Formation in the Eye

- Lens is flexible
- Refraction of lens is controlled by its thickness.
- Radius of curvature of the anterior surface of lens is greater than the radius of posterior surface.
- Thickness / shape is controlled by the tension of muscles (ciliary body) connected to the lens.
- ***Focus on distance objects***: lens is relatively flattened, ***refractive power is minimum.***
- ***Focus on near objects***: lens is thicker, ***refractive power is maximum.***
- The distance between the center and the retina (focal length) varies from 17 mm (minimum refractive index)~ 14 mm(maximum refractive index).
- Object farther away 3 m from eye , eye exhibit maximum focal length (17 mm) and lowest refractive power.

Image Formation in the Eye

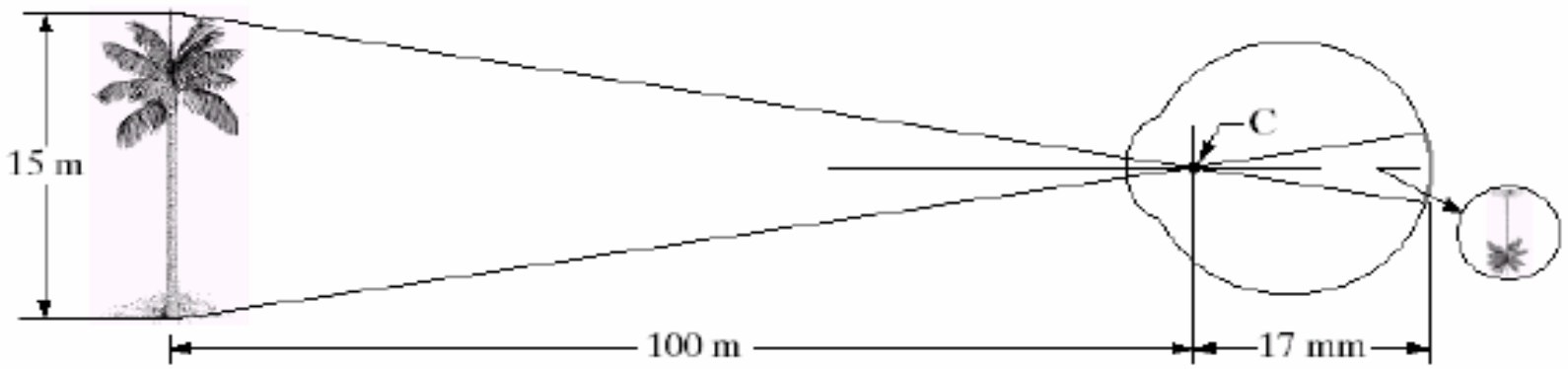


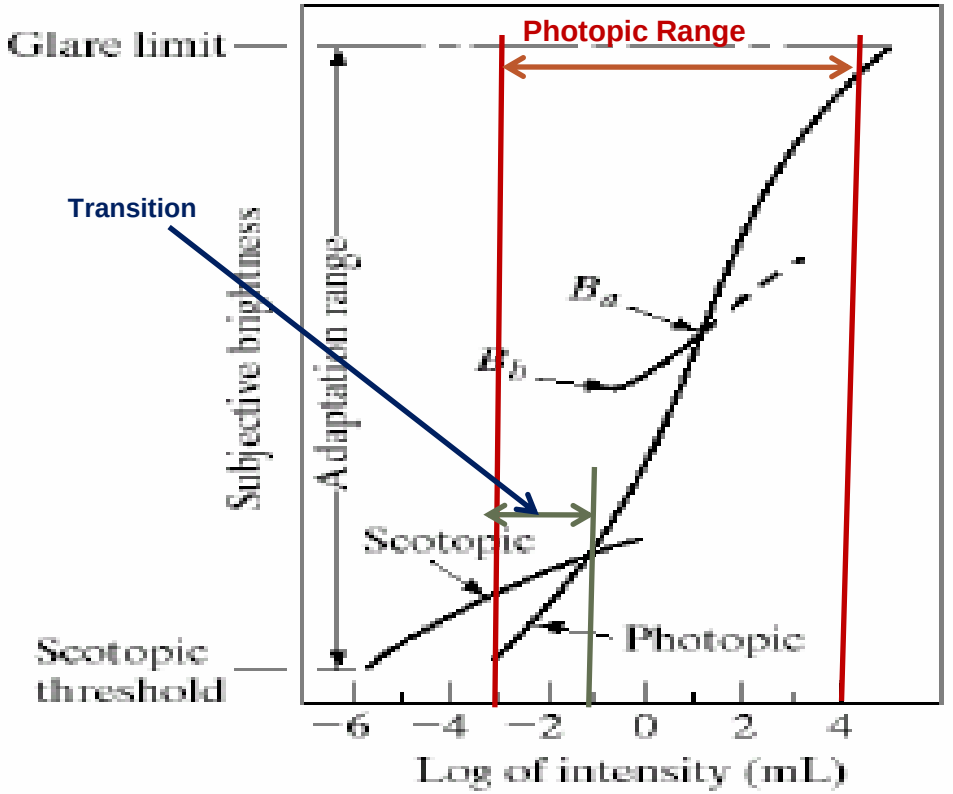
FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

Object size 15 m at distance 100 m form an image of size 2.55 mm at retina.

- Retinal image is reflected primarily in the area of Fovea.
- Perception takes place by the relative excitation of light receptors.
- Light receptors transform the radiant energy into electrical impulses.
- Electrical impulses are decoded by the Brain.

Brightness Adaptation

- The range of light intensity levels to which human visual system can adapt .
- This range is of the order of 10^{10} : ***scotopic threshold*** to the ***glare limit***.
- Experimental evidence shows that the subjective brightness (light intensity as perceived by human visual system) is a logarithmic function of light intensity incident on the eye.



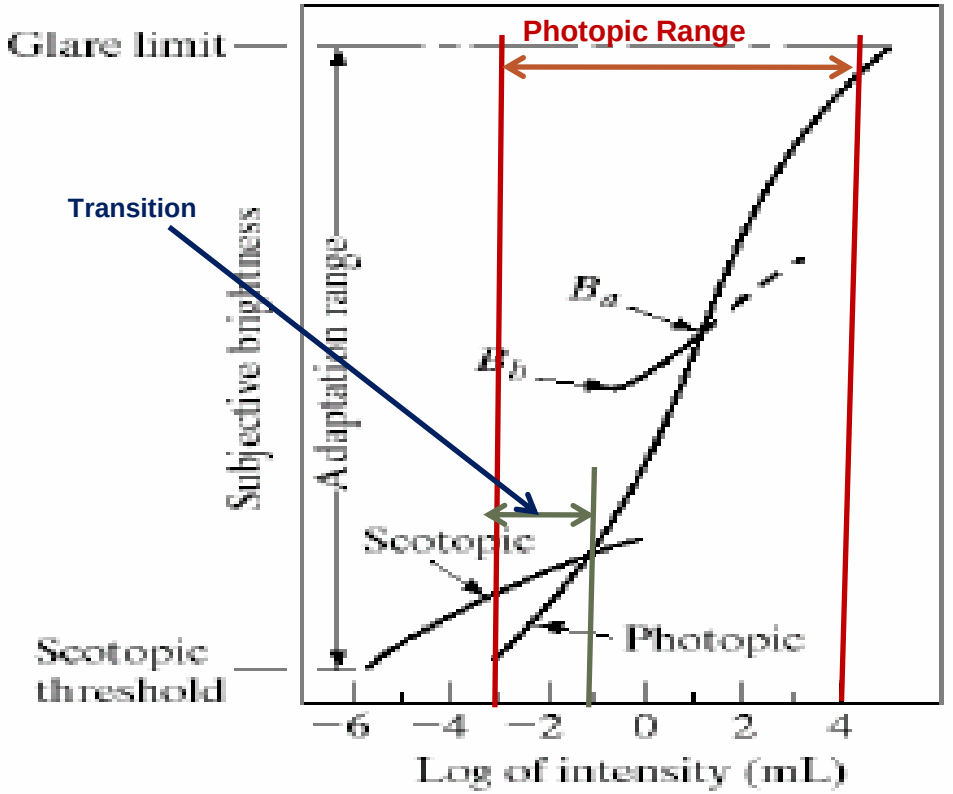
Brightness Adaptation

➢This range is of the order of 10^{10} : ***scotopic threshold***

to the ***glare limit***.

➢ Glare limit: The maximum brightness under which the object is just visible. If brightness level is increased further we can not see the object.

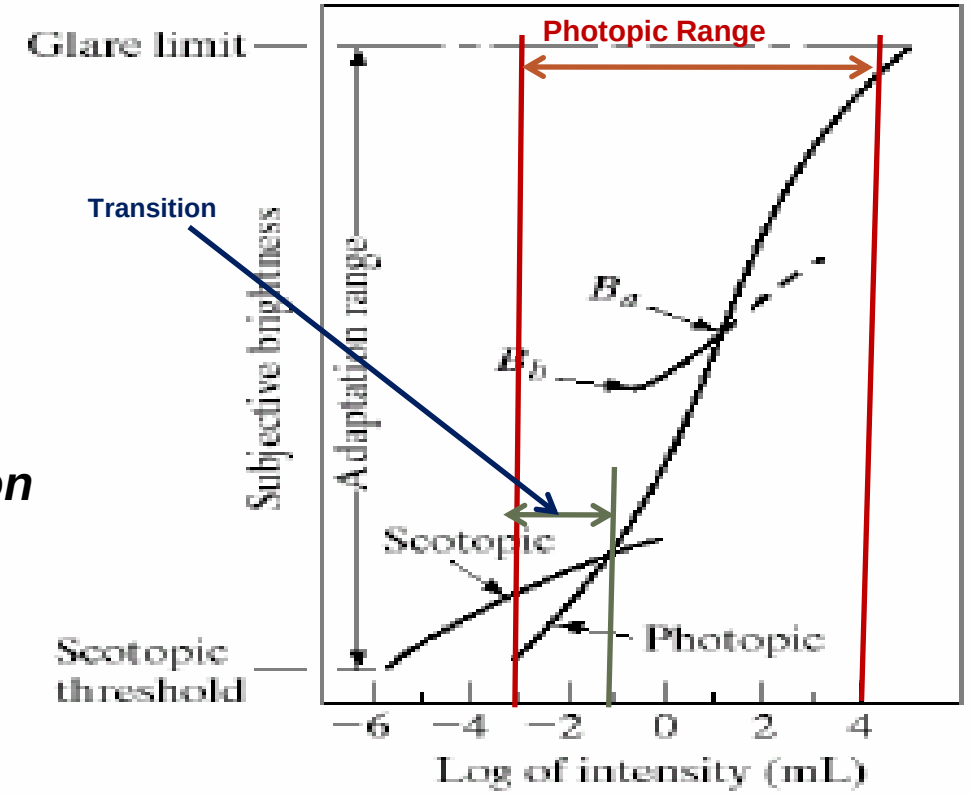
➢Scotopic threshold: The minimum brightness under which the object is just visible. If brightness level is decreased further we can not see the object.



Brightness Adaptation

Long solid curve : HVS adaption range

- Photopic range ~ 10^6
- Transition from scotopic to photopic is gardual over approximate range from 0.001 to 0.1
- millilambert (- 3 to -1 mL on the log scale)



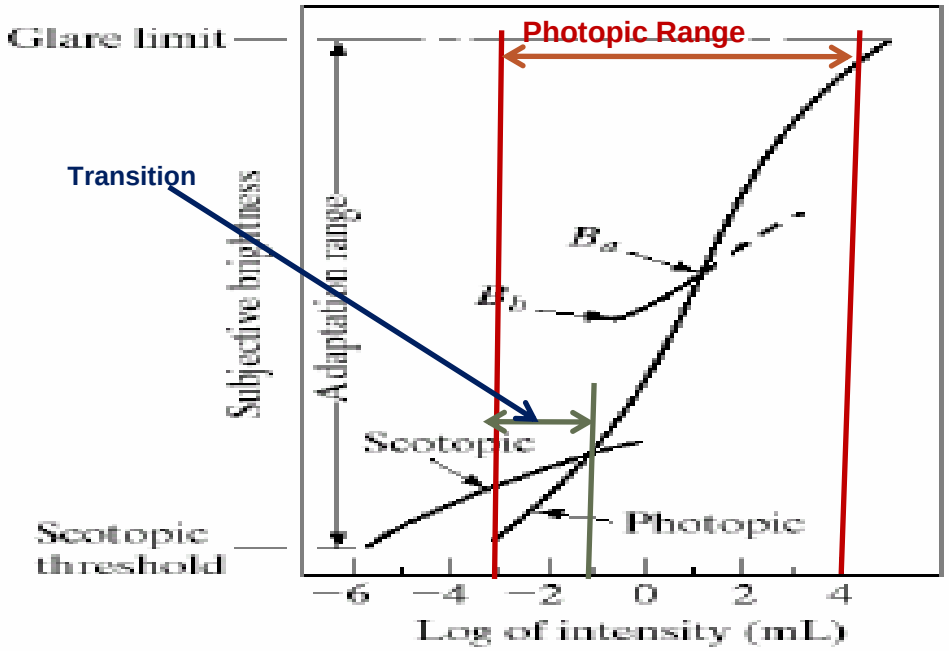
- ***Note:***HVS can not operate over the entire range simultaneously.
- It accomplishes large variations by change in its overall ***sensitivity***, a phenomenon known as ***brightness adaptation***

Photopic : color

Scotopic : Gray

Brightness Adaptation

- Total range of intensity level simultaneously distinguishable <<< total adaption range.
- For any given set of conditions, the sensitivity level of visual system is called ***Brightness Adaption Level.*** Example B_a .
- Short intersecting curve: Subjective brightness perceived by Eye when adapted to this level.
- B_b is level below which all stimuli are perceived as indistinguisha



- The upper (- - -) is not restricted, but extended to for, loses the meaning because much higher intensity would simply raise the adaption level higher than B_a .

Brightness Discrimination

Digital Image Displayed as Discrete Set of Intensity

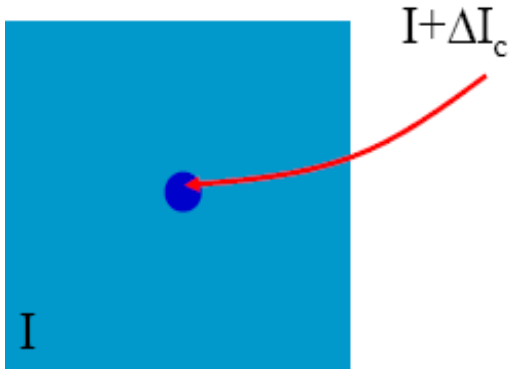
Eye Ability to discriminate between different intensity level is an important consideration in presenting image processing result.

Weber Experiments – *brightness discrimination of HVS*

- Having a subject look at flat, uniformly illuminated area large enough to occupy entire field of view

Opaque glass illuminated from behind by light source whose intensity, I, can be varied. (work as diffuser).

This field is added an increment of illumination, ΔI, in the form of a short – duration flash that appears as a circle in the centre of the uniformly illuminated field.



- If ΔI is not enough, the subject says no : Indicating that no perceivable change.
- As ΔI get stronger, the subject may give positive response of “yes,”: Indicate perceived changes.

Brightness Discrimination

Weber ratio:

The quantity $\Delta I/I$, where ΔI, is the increment of the illumination discriminable 50 % of the time with background illumination I, is called the ***Weber ratio***.

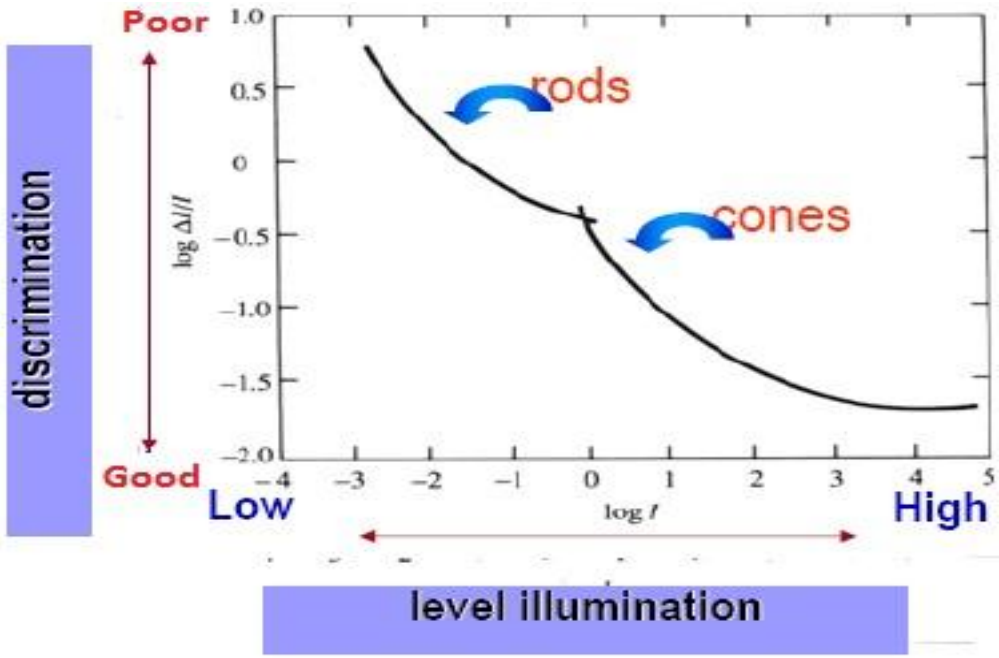
Small $\Delta I/I$ → Small percentage change in intensity is discrimanable → Good brightness discrimaination

Large $\Delta I/I$ → Large percentage change in intensity is discrimanable → Poor brightness discrimaination

Brightness Discrimination

Weber Ratio as Function of Intensity :

- Brightness discrimination is poor (the Weber ratio is large) at low levels of illumination and improves significantly (the ratio decreases) as background illumination increases.
- Hard to distinguish the discrimination when it is bright area but easier when the discrimination on a dark area.
- At low levels of illumination, vision is carried out by activity of **rods**, at high levels by **cones**.



Brightness Discrimination

Digital Image Displayed as Discrete Set of Intensity

How many different intensity level could be discriminate

Weber Experiments – *no of intensity level HVS*

- Background illumination is held constant and the intensity of other source, instead of flashing, is allowed to vary incrementally, from never being perceived to always being perceived.
- Typical observer can discriminate 1 -2 dozen different intensity changes.
- This number of different intensities a person can see at any one point in a monochrome image.
- But as eye roam about image / scene the average background changes, thus allowing a different set of incremental changes to be detected at each new adaption level.

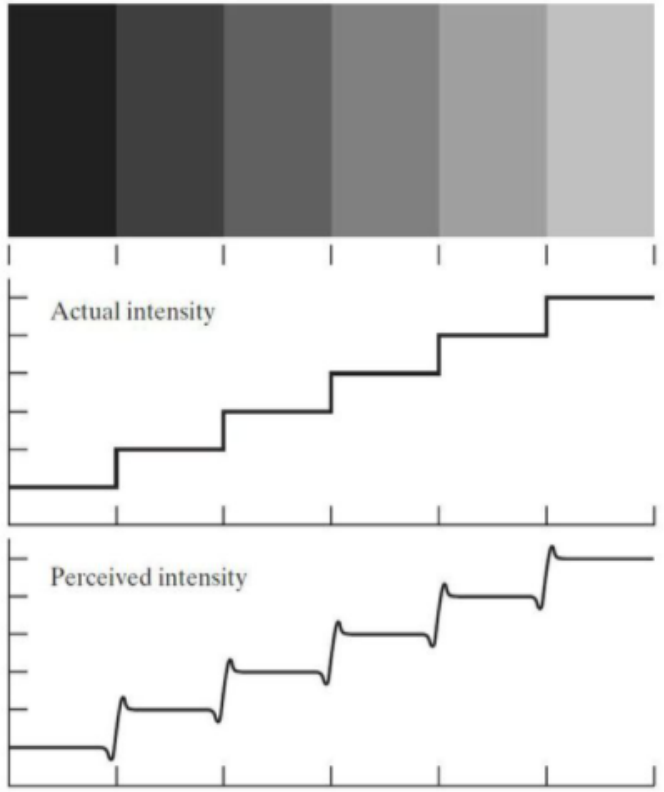
Eye is capable of much broader of over all intensity discrimination

Brightness Discrimination

- **the perceived brightness is not a simple function of intensity.**
- Visual system tends to undershoot or overshoot around the boundary of regions of different intensities.
- The intensity of the stripes is constant but we actually perceive a brightness pattern is strongly scalloped near the boundaries.

a
b
c

FIGURE 2.7
Illustration of the Mach band effect. Perceived intensity is not a simple function of actual intensity.



Simultaneous Contrast Effect

- Which small square is the darkest one ?

a b c

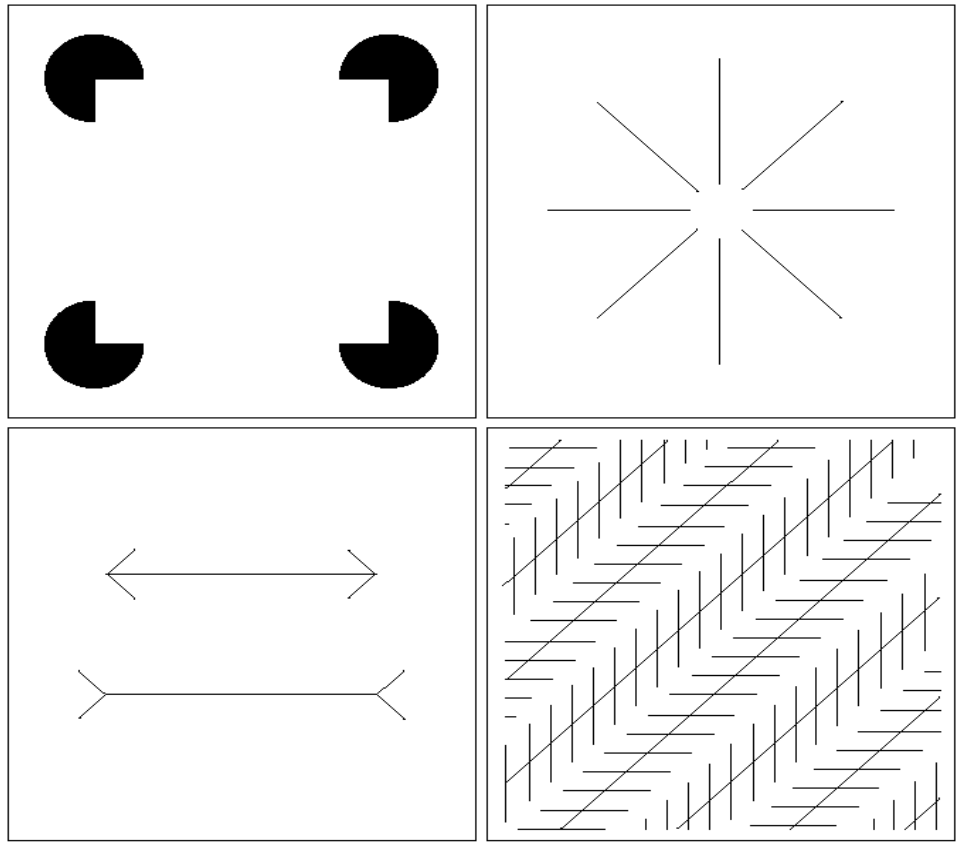
FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

- All the small squares have exactly the same intensity, but they appear to the eye progressively darker as the background becomes brighter.
- Region's perceived brightness does not depend simply on its intensity.

Optical Illusion

The eye fills in non existing information or wrongly perceives geometrical properties of objects

- Outline of square is seen, in spite of the fact that no line defining a such figure.
- Illusion of a complete circle.
- Line are same length but one appears shorter than other.
- All line are oriented at 45^{o} are equidistant and parallel. Crossing creates illusion that those lines are far from being parallel.



a b
c d

FIGURE 2.9 Some well-known optical illusions.

Suggested Readings

- **Digital Image Processing by Rafel Gonzalez, Richard Woods, Pearson Education India, 2017.**

- **Fundamental of Digital image processing by A. K Jain, Pearson Education India, 2015.**

Thank you