General Elective – II

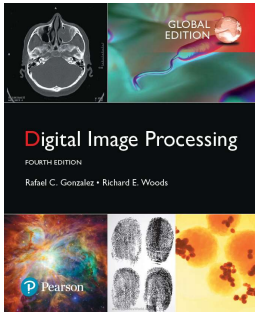
Digital Image Processing

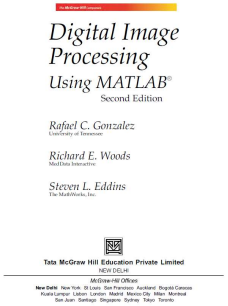
BSc (Data Science)

Second Year

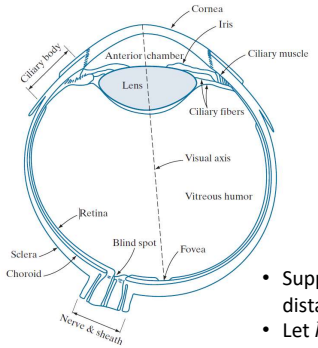
Semester - 4

Reference books

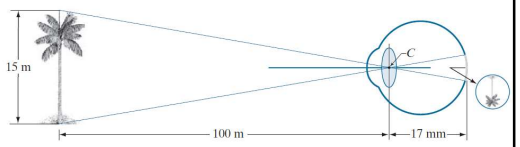




How image is formed in eyes?



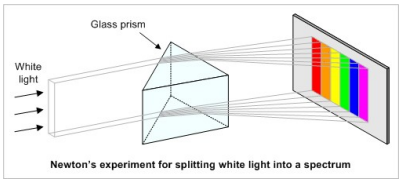
- Distance between the center of the lens and retina is fixed
- Proper focus is obtained by flattening or thickening the lens



- Suppose that a person is looking at a tree 15 m high at a distance of 100 m.
- Let h be the height of that object in the retina.
- Then geometry of figure gives $\frac{15}{100} = \frac{h}{17}$ i.e $h = 2.5$ mm.

Some physics behind image

- In 1666, Sir Isaac Newton discovered that when a beam of sunlight passes through a glass prism, the emerging beam of light is not white.
- It consists of a continuous spectrum of colors ranging from violet to red.

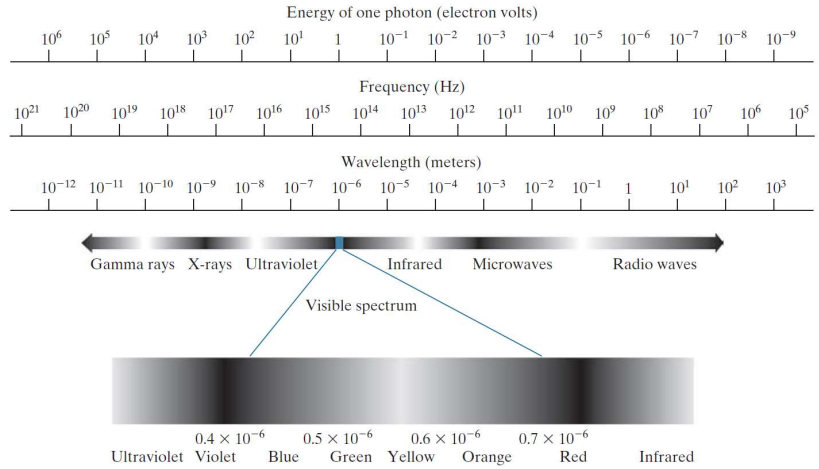


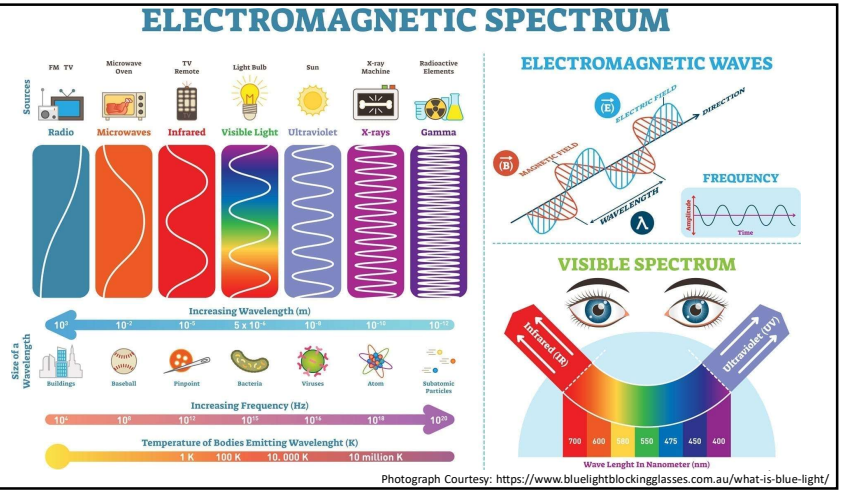
Photograph Courtesy: https://in.pinterest.com/pin/518195500845272363/

Photograph Courtesy: https://munsell.com/color-blog/sir-isaac-newton-color-wheel/

Electromagnetic spectrum

- The range of colors we perceive in visible light is a small portion of the electromagnetic spectrum.
- On one end of the spectrum are radio waves with wavelengths longer than those of visible light.
- On the other end of the spectrum are gamma rays with wavelengths smaller than those of visible light.
- The electromagnetic spectrum can be expressed in terms of wavelength, frequency, or energy.





Photograph Courtesy: https://www.bluelightblockingglasses.com.au/what-is-blue-light/

- Light is a type of electromagnetic radiation that can be sensed by the eye.
- The color spectrum is divided into six broad regions: violet, blue, green, yellow, orange, and red.
- No color ends abruptly but each range blends smoothly into the next.
- The colors perceived in an object are determined by the nature of the light reflected by the object.
- A body that reflects light relatively balanced in all visible wavelengths appears white to the observer.
- Green objects reflect light with wavelengths primarily in the 500 to 570 nm range, while absorbing most of the energy at other wavelengths.

Monochromatic light

- Light that is void of color is called monochromatic light.
- The only attribute of monochromatic light is its intensity (graylevel).
- Intensity (gray level) of monochromatic light is perceived to vary from black to grays and finally to white.
- The range of values of monochromatic light from black to white is called the gray scale.
- The monochromatic images are known as grayscale images.

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Chromatic light

- Chromatic (color) light spans the electromagnetic energy spectrum from approximately 0.43 micrometer to 0.79 micrometer.
- Chromatic light is described by frequency, radiance, luminance, and brightness.
- Radiance is the total amount of energy that flows from the light source.
- Luminance gives a measure of the amount of energy an observer perceives from a light source.
- Brightness is a subjective descriptor of light perception.

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Sources of images

- Imaging is not just based on energy from electromagnetic wave radiation
- Sound reflected from objects can be used to form ultrasonic images.
- Other sources of digital images are electron beams for electron microscopy, and software for generating synthetic images used in graphics and visualization.

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- Human eyes are limited to the visual band of the electromagnetic (EM) spectrum.
- On the other hand, imaging machines cover almost the entire EM spectrum, ranging from gamma to radio waves.
- They can operate on images generated by sources that humans are not accustomed to associating with images.
- These include ultrasound, electron microscopy, and computer-generated images.
- Thus, digital image processing encompasses a wide and varied field of applications.

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What is an image?

- An image is defined as a two-dimensional function $f(x, y)$.
- Here x and y are plane coordinates.
- f is the amplitude at any pair of coordinates (x, y).
- f is also called the intensity or gray level of the image at that point.
- The darkest color corresponds to minimum intensity (0).
- The lightest color corresponds to maximum intensity (1).
- Values between 0 and 1 represents various grey levels.

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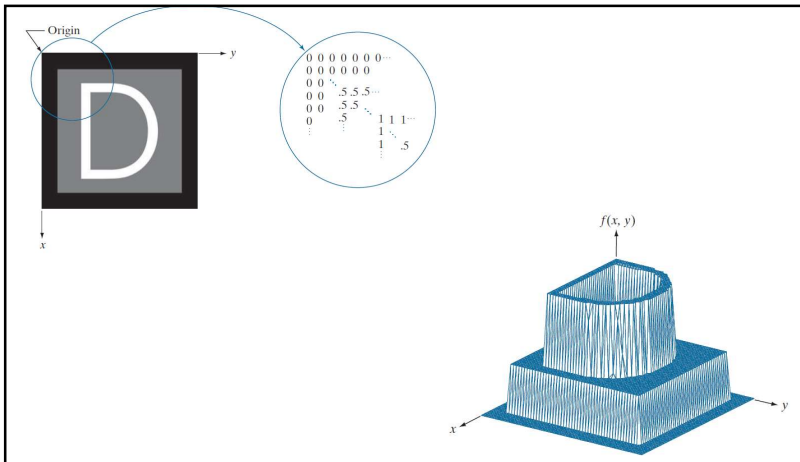

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Digital image and Digital image processing

- When x, y, and the intensity values of f are all finite, discrete quantities, we call the image a **digital image**.
- **Digital image processing** refers to processing digital images with help of a digital computer.
- A digital image is composed of a finite number of tiny elements, called **pixels**.
- Each pixel has a particular location and an intensity value.

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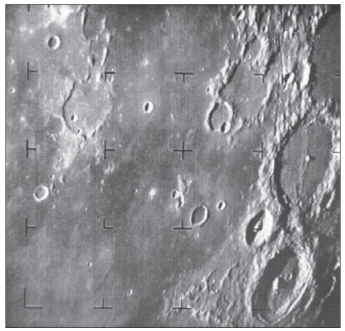

The first picture of the moon by a U.S. spacecraft. Ranger 7 took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface.

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Uses of Digital image processing

- From the 1960s until the present, the field of image processing has grown vigorously.
- In addition to applications in **medicine** and the **space program**, digital image processing techniques are now used in a broad range of applications.
- Computer procedures are used to enhance the contrast or code the intensity levels into color for easier interpretation of X-rays and other images used in **industry**, medicine, and the **biological sciences**.

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- **Geographers** use the same or similar techniques to study pollution patterns from aerial and satellite imagery.
- In **archeology**, image processing methods have successfully restored blurred pictures that were the only available records of rare artifacts lost or damaged after being photographed.
- Image enhancement and restoration procedures are used to process **degraded images**.
- In **physics** and related fields, computer techniques routinely enhance images of experiments in areas such as high-energy plasmas and electron microscopy.
- Image processing has successful applications in **astronomy**, **biology**, **nuclear medicine**, **law enforcement**, **defense**, and **industry**.

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- Another major area of application of digital image processing techniques is **machine perception**.
- In machine perception, information is extracted from an image.
- Such information are statistical moments, Fourier transform coefficients, and multidimensional distance measures.
- Machine perception has following applications:

1. Automatic character recognition
2. Industrial machine vision for product assembly and inspection,
3. Military recognizance,
4. Automatic processing of fingerprints,
5. Screening of X-rays and blood samples
6. Machine processing of aerial and satellite imagery for weather prediction and environmental assessment

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- The continuing decline in the ratio of computer price to performance, and the expansion of networking and communication bandwidth via the internet, have created unprecedented opportunities for continued growth of digital image processing.
- Today, there is almost no area of technical endeavor that is not impacted in some way by digital image processing.
- These applications are categorized according to source of images (e.g., X-ray, visual, infrared, and so on).
- The principal energy source for images in use today is the electromagnetic energy spectrum.
- Other important sources of energy include acoustic, ultrasonic, and electronic etc.

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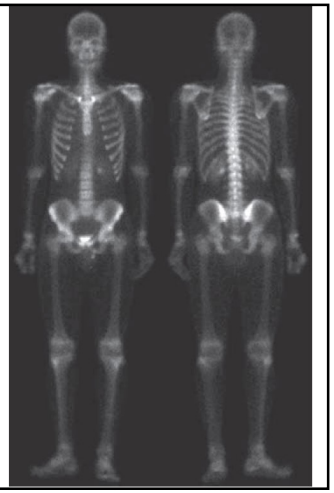
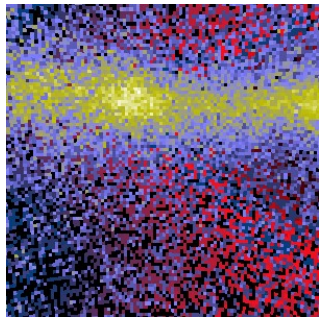
Gamma-ray imaging

- Major uses of imaging based on gamma rays include **nuclear medicine** and **astronomical observations**.
- In nuclear medicine, the approach is to inject a patient with a radioactive element that emits gamma rays.
- Images are produced from the emissions collected by gamma-ray detectors.
- Such images are useful to locate sites of bone pathology, such as infections or tumors.



- A star in the Cygnus constellation exploded about 15,000 years ago.
- This generated a superheated, stationary gas cloud.
- The cloud glows in a spectacular array of colors.
- Figure shows an image of such cloud in the gamma-ray band.
- This Gamma-ray image was obtained using the natural radiation of the object being imaged.



Photograph courtesy: https://skyview.gsfc.nasa.gov/current/help/skv_images_cygnus.html

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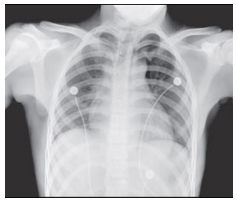
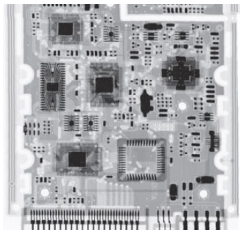
X-ray imaging

- The best known use of X-rays is **medical diagnostics** as shown in first figure.
- Higher energy X-rays are applicable in **industrial processes**. Second figure shows an X-ray image of an electronic circuit board.





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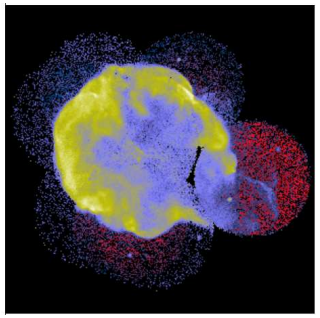
- X-rays are also used extensively in other areas, such as **astronomy**.
- Figure shows X-ray of cloud that is generated by explosion in Cygnus constellation.



Photograph courtesy: https://skyview.gsfc.nasa.gov/current/help/skv_images_cygnus.html

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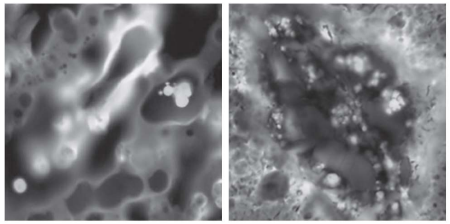
Imaging in the ultraviolet band

- Applications of ultraviolet "light" are **lithography**, **industrial inspection**, **microscopy**, **lasers**, **biological imaging**, and **astronomical observations**.



Ultraviolet imaging: (a) Normal corn. (b) Corn infected by smut.

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Imaging in the visible and infrared bands

- This band is most widely used for applications.
- Applications includes **light microscope** which is useful in **pharmaceuticals** and **micro-inspection** to materials characterization.
- Another major area of visual processing is **remote sensing**, which usually includes several bands in the visual and infrared regions.
- It is also useful for **satellite imaging**, **weather observation** and **prediction**, **automated visual inspection**.

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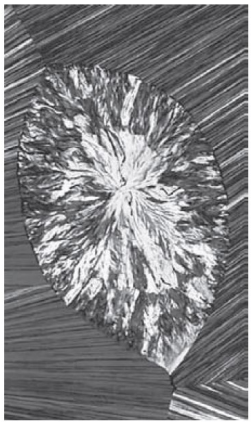
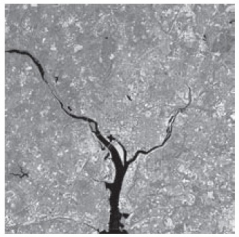


Light microscopy image of Cholesterol



LANDSAT satellite images of the Washington, D.C. area.

Satellite image of Hurricane Katrina taken on August 29, 2005.

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Imaging in the microwave band

- The principal application of imaging in the microwave band is **radar**.
- In a radar image, one can see only the microwave energy that was reflected back toward the radar antenna.

Spaceborne radar image of mountainous region in southeast Tibet.

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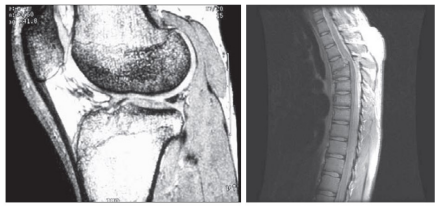
Imaging in the radio band

- Applications of imaging in the radio band are in **medicine** and **astronomy**.
- In medicine, radio waves are used in **magnetic resonance imaging** (MRI).



MRI images of a human (a) knee, and (b) spine

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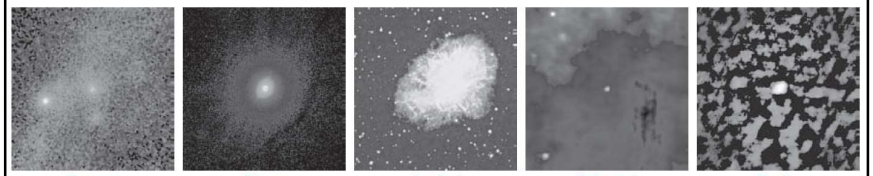
- Following are images of "crab nebula" using various imaging.



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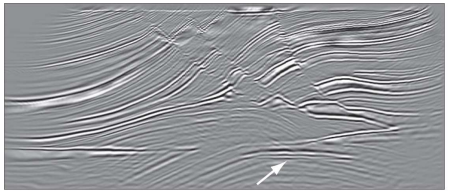
Other imaging techniques

- Imaging using "sound" finds application in **geological exploration**, **industry**, **mineral** and **oil exploration**, and **medicine**.



Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap.

Ultrasound imaging of a fetus.

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