IMAGE PROCESSING (CS40019) 10-August-2021

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Dept. of CSE

IIT Kharagpur

COURSE DETAILS

- Course Name: Image Processing
- Course Code: CS40019
- Number of Credits: 3-0-0
- Course Time Table:
  - ➢Mon (11-12 Noon)
  - ➢Tue (8-10 AM)

- Applications of DIP

  – Remote sensing (tracking of earth resources, geographical mapping, prediction of agricultural crops, urban growth, flood control, weather and environmental conditions)

  – Image transmission and storage (compression)

  – Medical image processing

  – Military applications

  – Industrial machine vision

  – Document image processing

  – Social applications

- Course Contents
  - Image fundamentals
  - Imaging geometry
  - Image transforms
  - Image enhancement and filtering
  - Image restoration
  - Image segmentation
  - Image representation, description, recognition
  - Image compression

- Text/Reference Books
  - R C Gonzalez & R E Woods, Digital Image Processing, 3rd/4th Ed, PHI
  - A. K. Jain, Fundamentals of DIP, PHI
  - Wiliam K Pratt, DIP, Wiley Student Publishers, 3ed.
  - R C Ganzalez, R E Woods & S L Eddins, DIP using MATLAB, 2nd Ed.

Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 1
Introduction

Source: Chapter 01 of DIP, 3E: Introduction

CHAPTER CONTENTS:

- What is Digital Image Processing

- The Origins of Digital Image Processing

- Examples of Fields that use Digital Image Processing
  - Gamma-Ray Imaging
  - X-Ray Imaging
  - Imaging in UV Band
  - Imaging in Visible & IR Bands
  - Imaging in Microwave Band
  - Imaging in Radio Band
  - Examples where other Imaging Methods are used

- Fundamental Steps in Digital Image Processing

- Components of an Image Processing System

IMAGE REPRESENTATION

- An image is a 2-D function f(x,y):
  - x, y: spatial coordinates
  - f: intensity / grey level
  - f(x,y): Pixel

- If x, y and f are discrete: Digital Image
  - Digitization of (x, y): Spatial Sampling
  - Digitization of f(x, y): Quantization

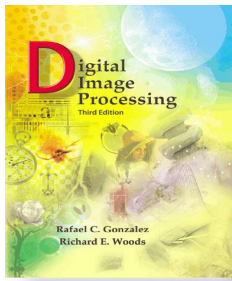# IMAGE REPRESENTATION (Cont..)

- If f(x, y) is:
  - 0 / 1: Binary Image
  - [0, 255]: Gray Scale B/W Image
  - <[0, 255], [0, 255], [0, 255]>: Color or Multi-spectral Image
    - RGB: Red-Green-Blue
    - HSV: Hue-Saturation-Value
    - HSL: Hue-Saturation-Lightness
    - CMYK: Cyan-Magenta-Yellow-Black

- ## What is Digital Image Processing ?

  ❑ Processing of digital images by digital computers

HUMAN VISION & DIP

- Vision: Most important human perception
  - Limited to Visual Band of EM Spectrum
- DIP applies beyond visual:
  - Gamma Rays to Radio Waves
  - Ultra-sound, Electron Microscopy, …
  - Synthetic Images
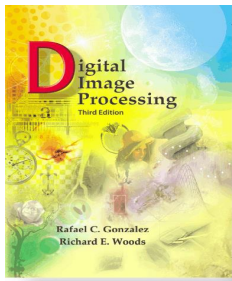
- DIP relates deeply to other areas
  - Pattern Recognition
  - Computer Vision
  - Artificial Intelligence
  - Machine Learning
  - Computer Graphics

- Three types of Computer Processes:
  - Low-level (Image Processing)
    - Noise reduction, Contrast enhancement, Image sharpening
    - I/P & O/P: Both images
  - Mid-level (Image Analysis/Understanding)
    - Segmentation / Object Description / Recognition
    - I/P: Images, O/P: Attributed entities
  - High-level (Computer Vision)
    - Interpretation, 'Making Sense', …

- **Example: Automated Analysis of Document**
  - Acquiring the image of the area containing the text
  - Preprocessing
  - Extraction of individual characters (Segmentation)
  - Describing the characters suitable for computer processing (deriving the attributes/features)
  - Recognition of individual characters
  - Making sense of the content of the page

Chapter 1
Introduction

- ## Human interpretation

  - Enhance the contrast or code the intensity into appropriate color for easy interpretation

  - Study of pollution patterns from satellite images

  - Image enhancement and restoration

  - Archeology (blurred, degraded)

  - Physics (high energy plasma & electron microscopy

  - Astronomy, biology, nuclear medicine, law enforcement, defense, industry

- ## Machine perception

  - Extract information from images for computer processing (statistical moments, Fourier transform coeff and distance measures)

  - Automatic char rec, industrial machine vision for product assembly and inspection, military, automatic processing of fingerprints

Digital Image Processing, 3rd ed.

Gonzalez & Woods

www.ImageProcessingPlace.com

Chapter 1
Introduction

Source: Chapter 01 of DIP, 3E: Introduction

- History of Digital Image Processing

- Examples of Fields that use Digital Image Processing
  - Gamma-Ray Imaging
  - X-Ray Imaging
  - Imaging in UV Band
  - Imaging in Visible & IR Bands
  - Imaging in Microwave Band
  - Imaging in Radio Band
  - Examples where other Imaging Methods are used

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.[†])
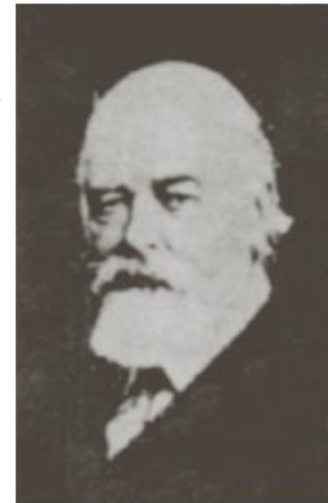
FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)

Bartlane System, 1920

Trans-Atlantic Transmission

1921: Five gray levels
1929: Fifteen gray levels

Chapter 1
Introduction

FIGURE 1.3 Unretouched cable picture of Generals Pershing and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

Bartlane System, 1920

Fifteen gray levels here

Image Processing for Space Application

Jet Propulsion Laboratory (JPL)

FIGURE 1.4 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. (Courtesy of NASA.)

- ## Digital Computers

  - 1948: Transistor, Bell Labs

  - 1950's, 1960's: High-Level Languages

  - 1958: ICs by Texas Instruments

  - Early 1960's: OS

  - Early 1970's: Microprocessors, Intel

  - 1980's /1990's: VLSI / ULSI

  - Advances in Mass Storage / Display System

- ## Digital Image Processing

  – 1964: Space Probe, Jet Propulsion Laboratory

  – 1960's / 1970's:

    - Medical Imaging

    - Remote Sensing

    - Astronomy

  – Early 1970's: CAT (Computerized Axial Tomography) or CT
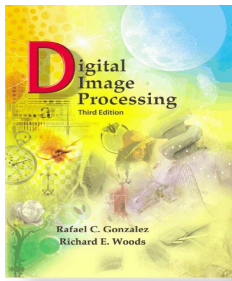
- # Energy Sources for Images
  - EM Energy Spectrum
  - Acoustic
  - Ultrasound
  - Electronic
  - Synthetic
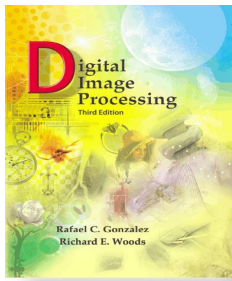
Chapter 1
Introduction

- EM
  - Gamma Ray Imaging
  - X-Ray Imaging
  - Imaging in Ultra-Violet Band
  - Imaging in the Visible and Infrared Bands
  - Imaging in the Microwave Bands
  - Imaging in the Radio Bands

- Non EM
  - Acoustic
  - Ultrasound
  - Electronic
  - Synthetic
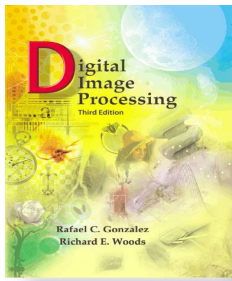
ELECTRO MAGNETIC (EM) SPECTRUM

EM Spectrum based energy per photon

Energy of one photon (electron volts)

| 10^6 | 10^5 | 10^4 | 10^3 | 10^2 | 10^1 | 10^0 | 10^{-1} | 10^{-2} | 10^{-3} | 10^{-4} | 10^{-5} | 10^{-6} | 10^{-7} | 10^{-8} | 10^{-9} |

Gamma rays   X-rays   Ultraviolet Visible Infrared   Microwaves   Radio waves
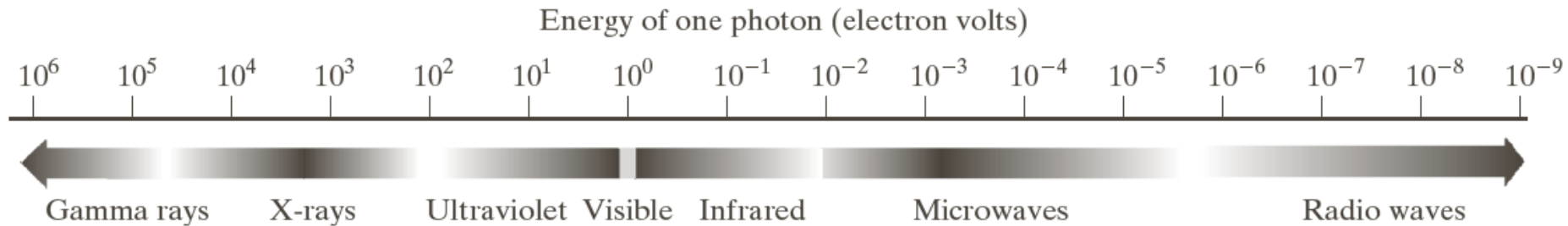
FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.
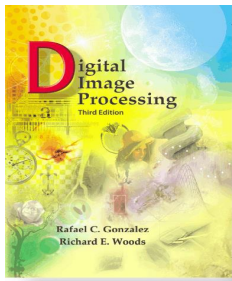
1eV = 1.602176565·10⁻¹⁹ J

Chapter 1
Introduction

E = hv = hc/λ, h is Planck's constant (h = 6.625 × 10⁻³⁴ Joule-seconds or J-s)

EM SPECTRUM (Cont..)
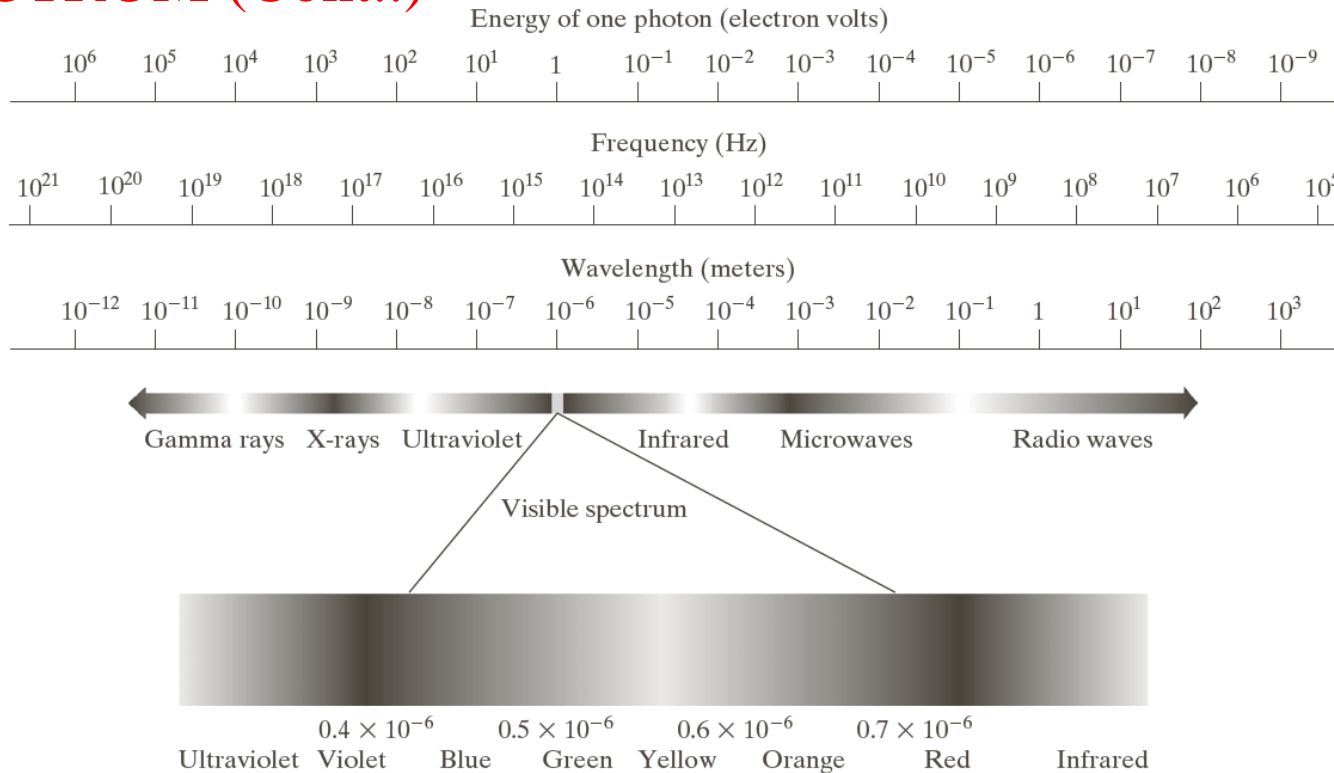
FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

λv=c, λ is the **wavelength**, v is the **frequency** and c is the speed of light.

Chapter 1
Introduction
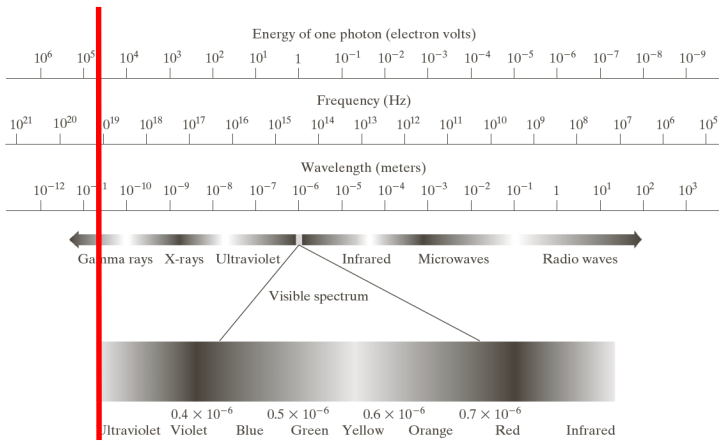
- # Gamma Ray Imaging
  - Nuclear Medicine (Bone Scan, PET)
  - Astronomical Observations

Chapter 1
Introduction
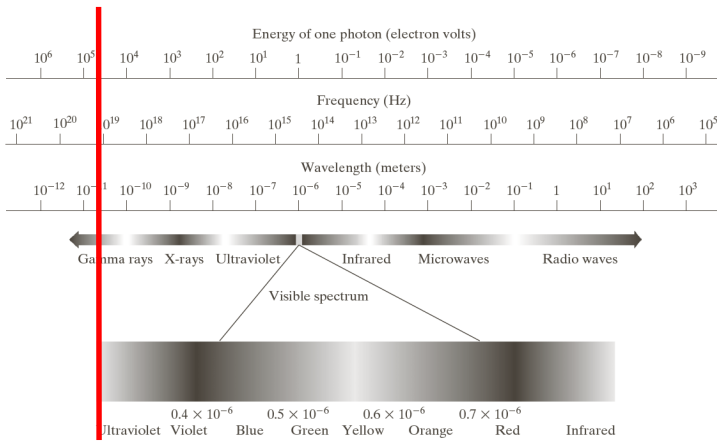
Radioactive isotope injected into patient's body for emitting gamma rays
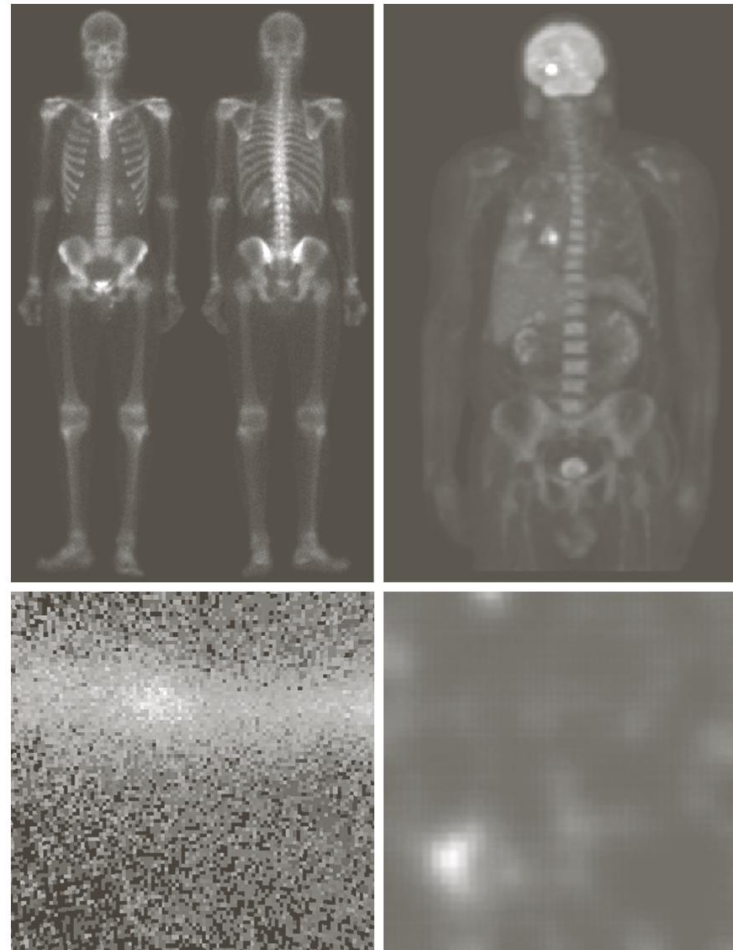
FIGURE 1.6 Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)

Chapter 1
Introduction
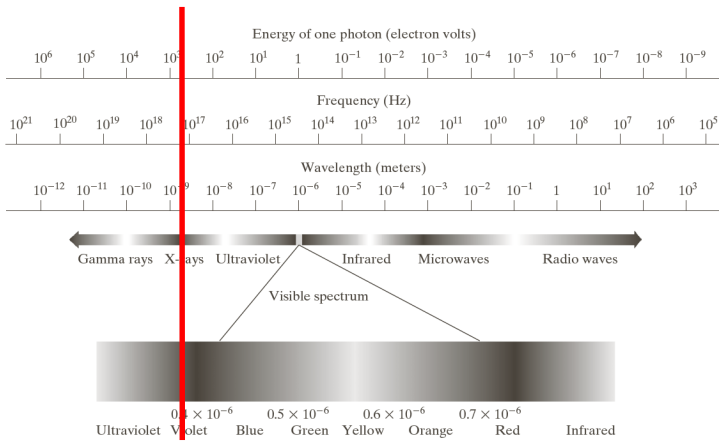
- **X-Ray Imaging**
  - Medical Diagnosis
    - Bone X-Ray
    - Angiography
    - CAT
  - Industrial Scanning & Testing
  - Astronomy
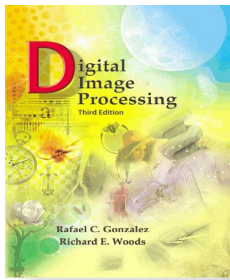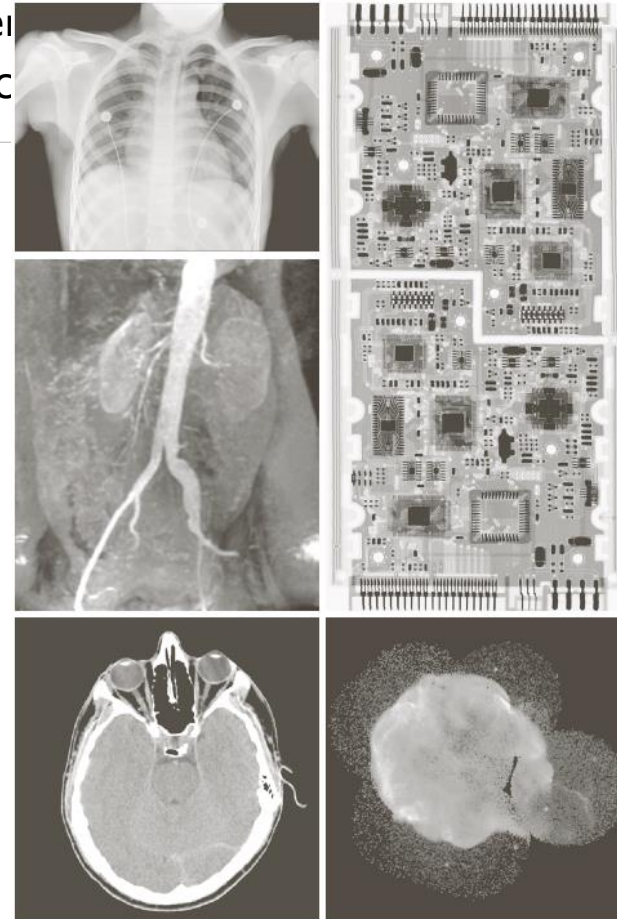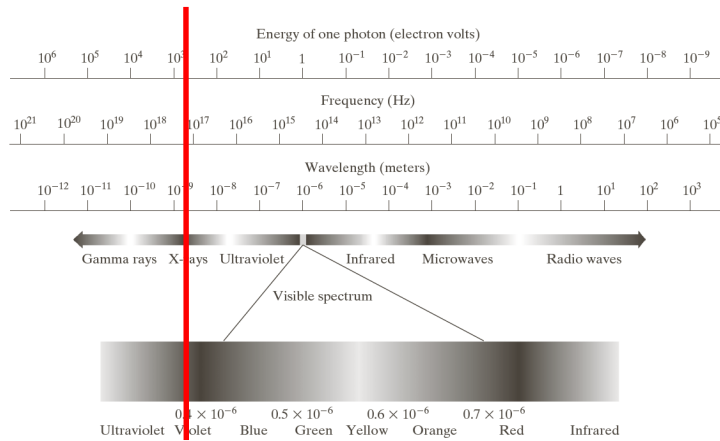
FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School; (d) Mr. Joseph E. Pascente, Lixi, Inc.; and (e) NASA.)

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Chapter 1
Introduction
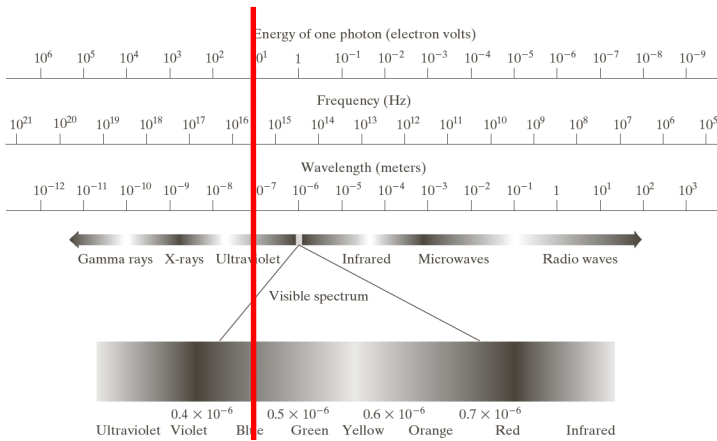
- **Imaging in Ultra-Violet Band**
  - Industrial Inspection
  - Lithography
  - Microscopy (Fluorescence)
  - Lasers
  - Biological Imaging
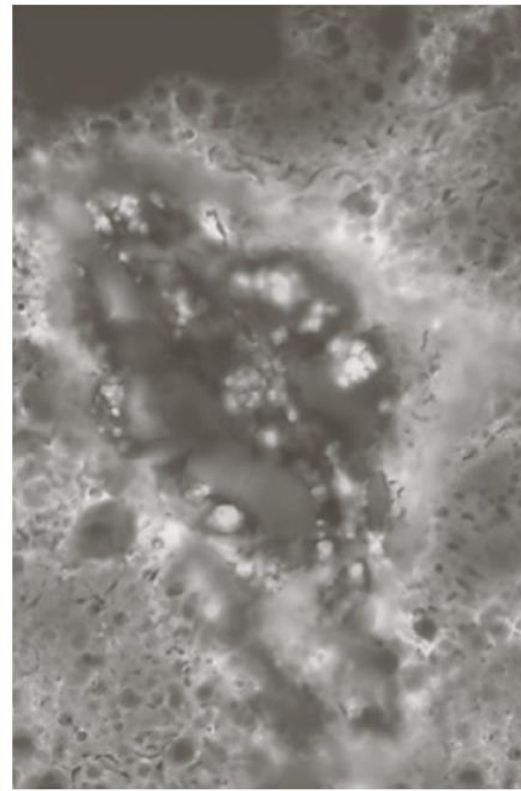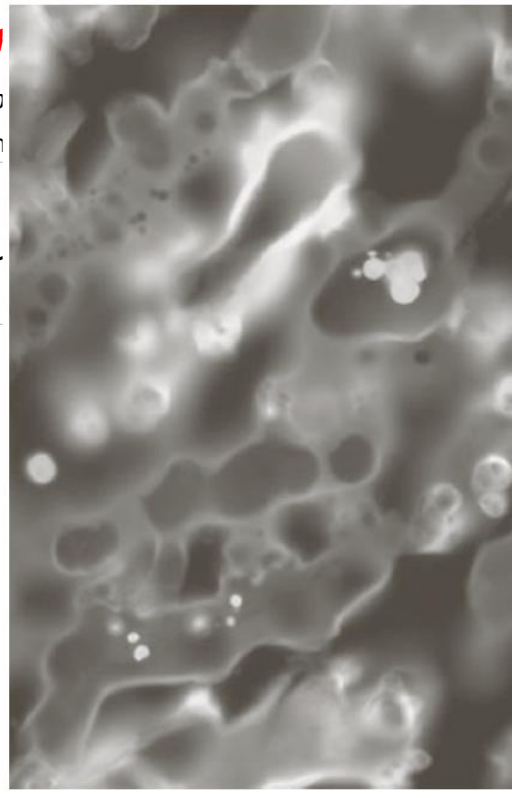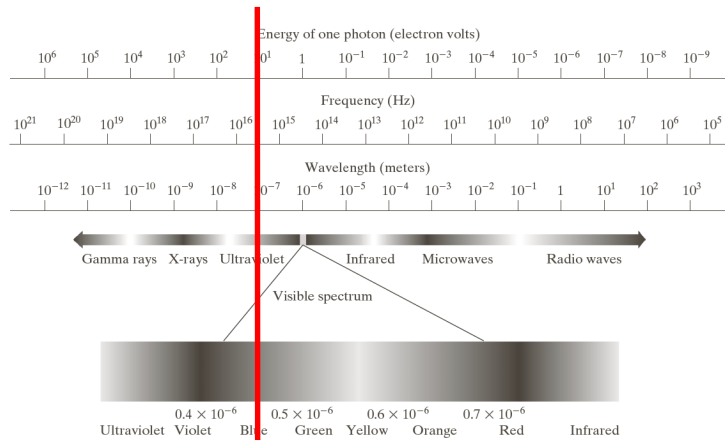 - Astronomical Observations

Ir

Energy of one photon (electron volts)

| 10^6 | 10^5 | 10^4 | 10^3 | 10^2 | 10^1 | 1 | 10^{-1} | 10^{-2} | 10^{-3} | 10^{-4} | 10^{-5} | 10^{-6} | 10^{-7} | 10^{-8} | 10^{-9} |

Frequency (Hz)

| 10^{21} | 10^{20} | 10^{19} | 10^{18} | 10^{17} | 10^{16} | 10^{15} | 10^{14} | 10^{13} | 10^{12} | 10^{11} | 10^{10} | 10^9 | 10^8 | 10^7 | 10^6 | 10^5 |

Wavelength (meters)

| 10^{-12} | 10^{-11} | 10^{-10} | 10^{-9} | 10^{-8} | 10^{-7} | 10^{-6} | 10^{-5} | 10^{-4} | 10^{-3} | 10^{-2} | 10^{-1} | 1 | 10^1 | 10^2 | 10^3 |

Gamma rays X-rays Ultraviolet Infrared Microwaves Radio waves

Visible spectrum

| 0.4×10^{-6} | 0.5×10^{-6} | 0.6×10^{-6} | 0.7×10^{-6} |
Ultraviolet Violet Blue Green Yellow Orange Red Infrared

FIGURE 1.8
Examples of
ultraviolet
imaging.
(a) Normal corn
(b) Smut corn.
(c) Cygnus Loop
(Images courtes
of (a) and
(b) Dr. Michael
W. Davidson,
Florida State
University,
(c) NASA.)
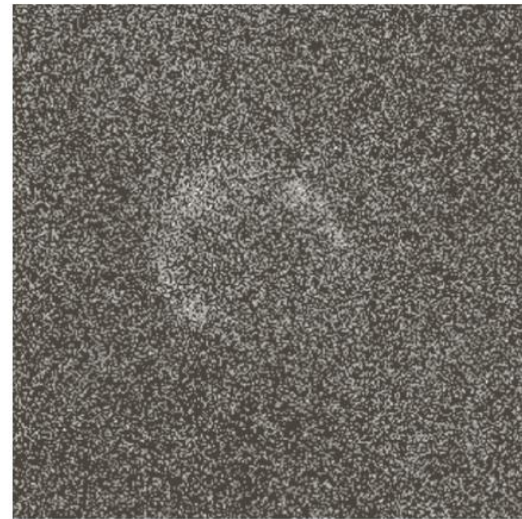
Chapter 1
Introduction
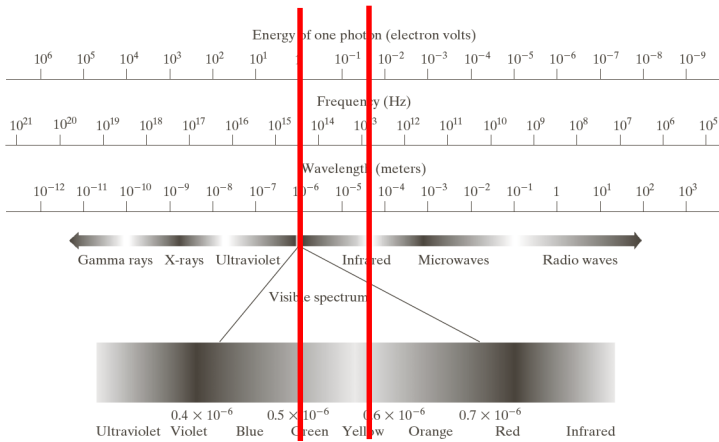
- **Imaging in the Visible and Infrared Bands**
  - Light Microscopy
  - Remote Sensing
  - Weather Observation / Prediction
  - Automated Visual Inspection
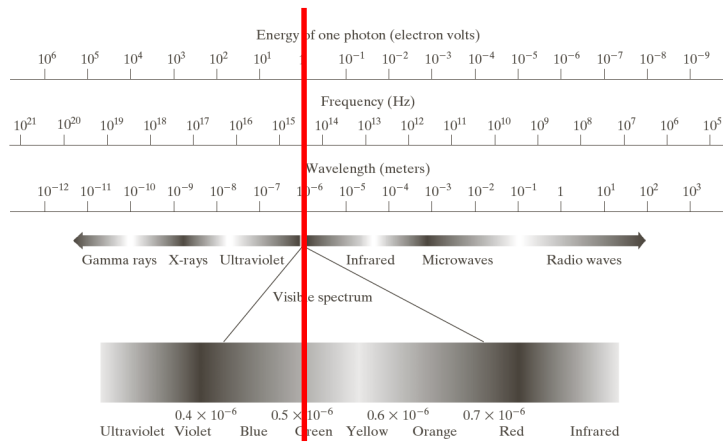 - Finger Printing
  - Iris Recognition

Chapter 1
Introduction
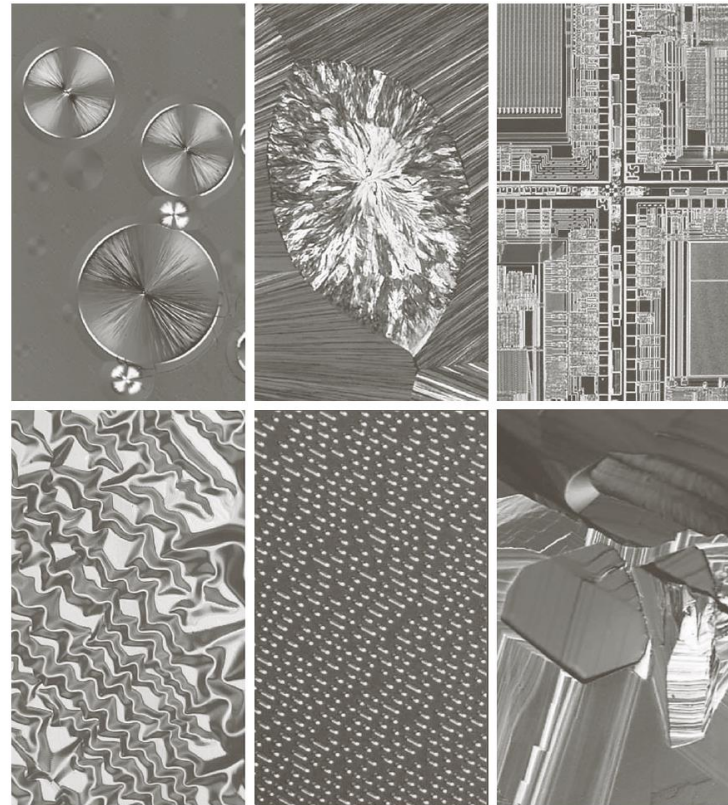

a b c
d e f

FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)
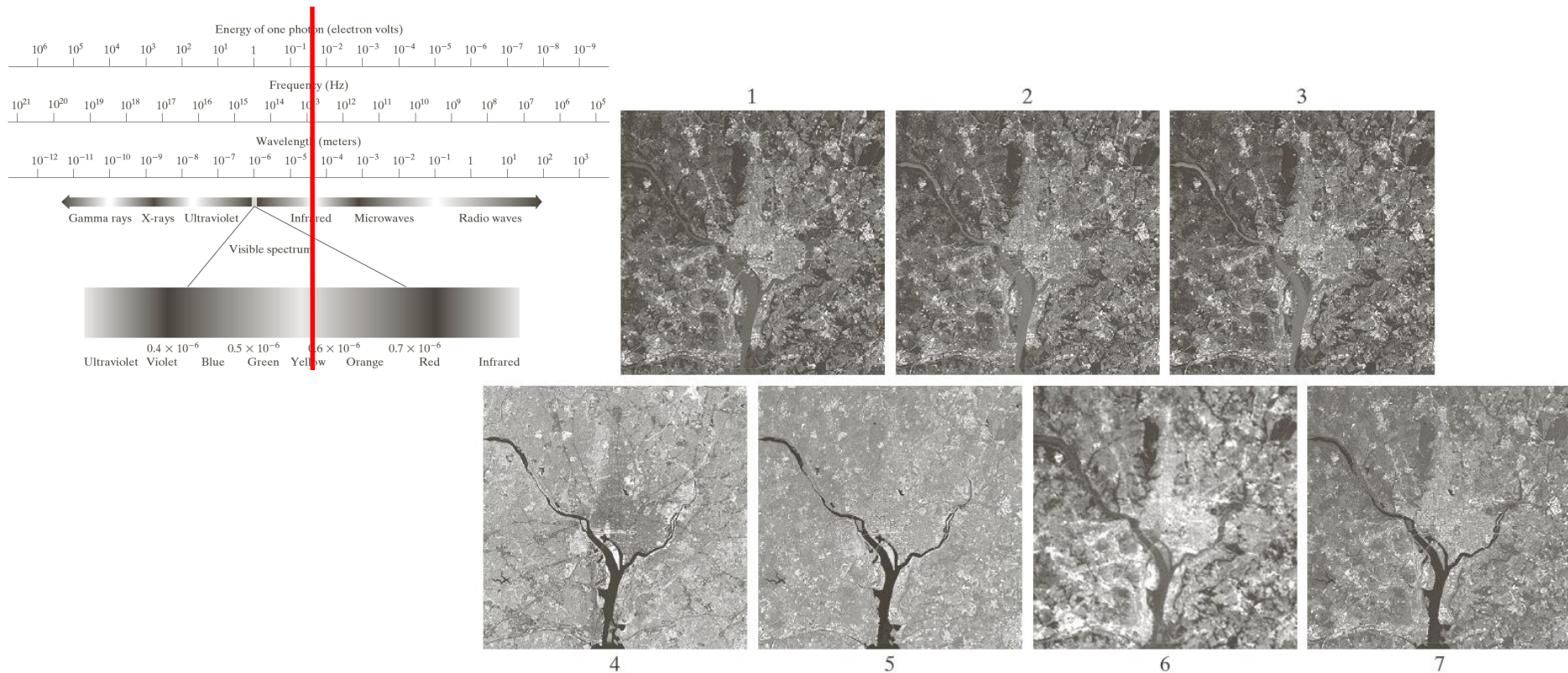
FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)
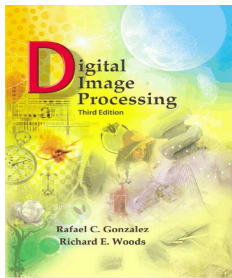
Chapter 1
Introduction

Energy of one photon (electron volts)

10^6 10^5 10^4 10^3 10^2 10^1 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9}

Frequency (Hz)

10^{21} 10^{20} 10^{19} 10^{18} 10^{17} 10^{16} 10^{15} 10^{14} 10^{13} 10^{12} 10^{11} 10^{10} 10^9 10^8 10^7 10^6 10^5

Wavelength (meters)

10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10^1 10^2 10^3

Gamma rays   X-rays   Ultraviolet   Infrared   Microwaves   Radio waves

Visible spectrum

0.4×10^{-6} 0.5×10^{-6} 0.6×10^{-6} 0.7×10^{-6}

Ultraviolet   Violet   Blue   Green   Yellow   Orange   Red   Infrared
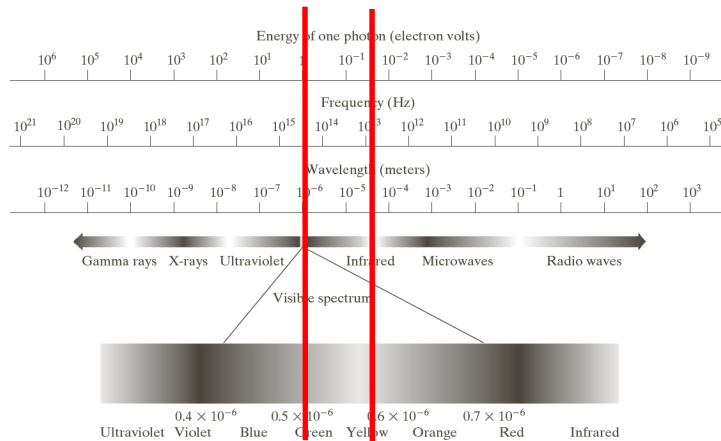
TABLE 1.1
Thematic bands in NASA's LANDSAT satellite.

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

Chapter 1

Introduction

FIGURE 1.11
Satellite image of Hurricane Katrina taken on August 29, 2005. (Courtesy of NOAA.)
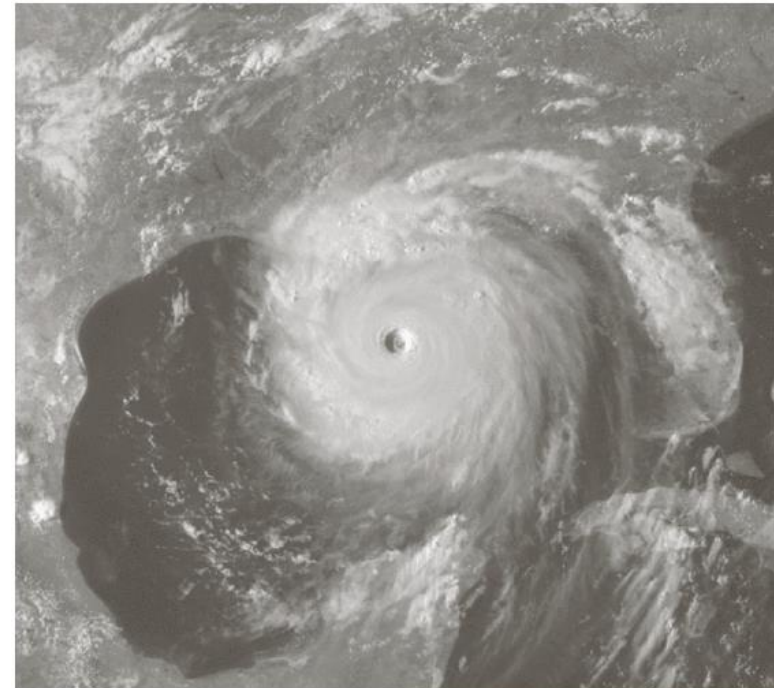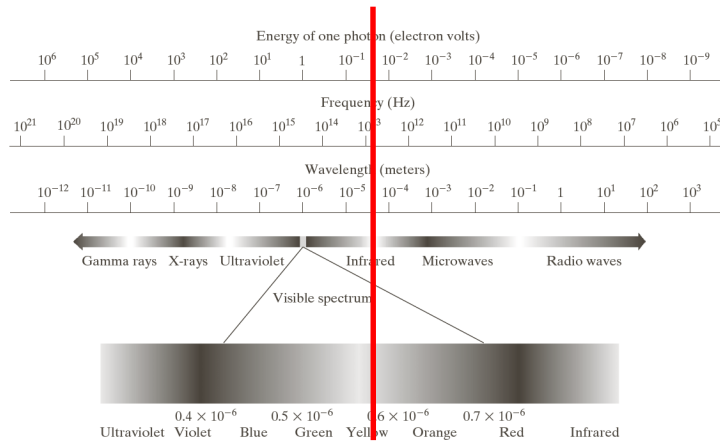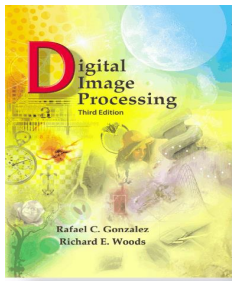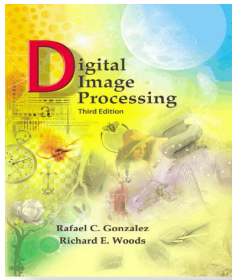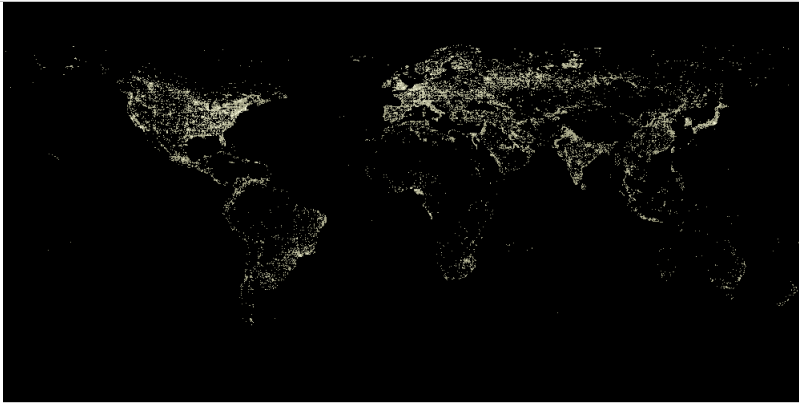
Chapter 1

Introduction

Chapter 1
Introduction

1993

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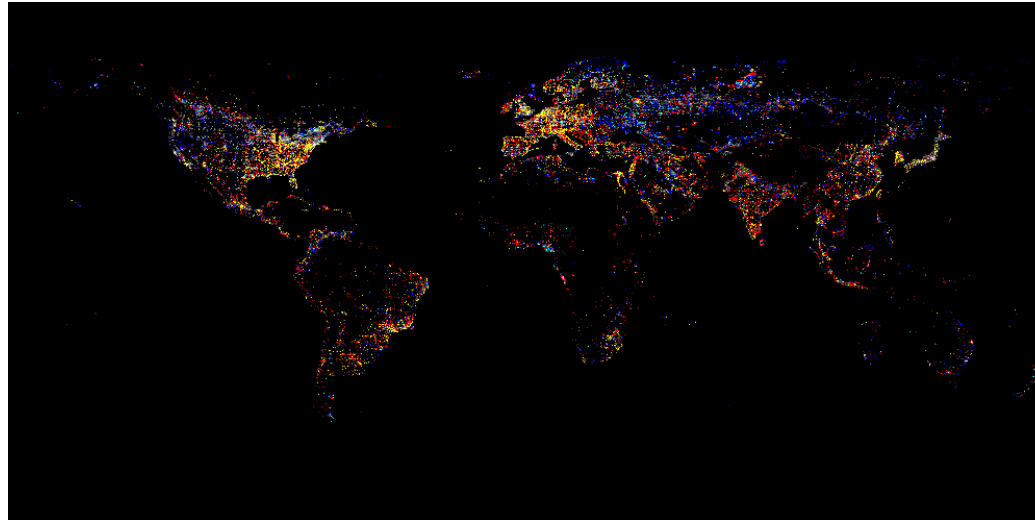
Chapter 1

Introduction

FIGURE 1.12
Infrared satellite images of the Americas. The small gray map is provided for reference. (Courtesy of NOAA.)
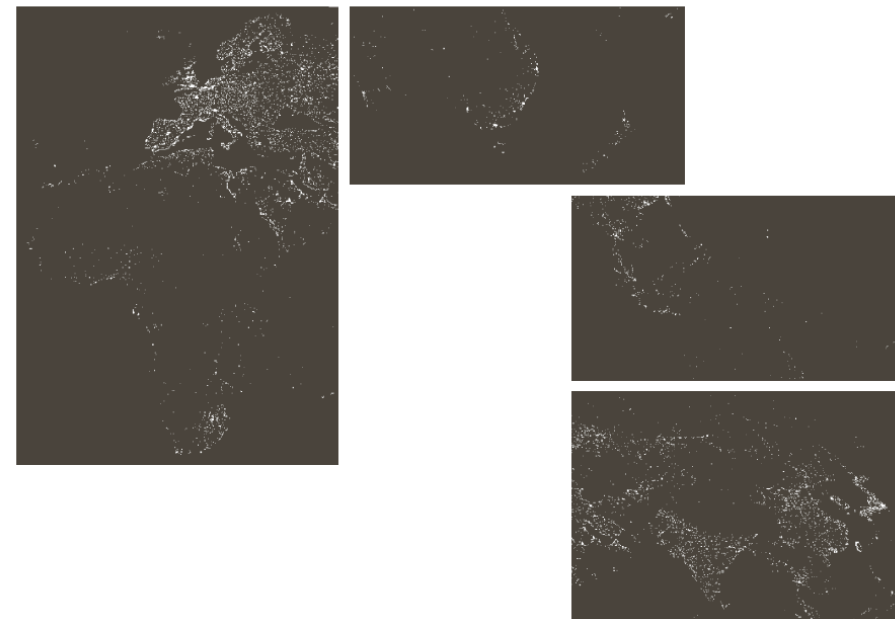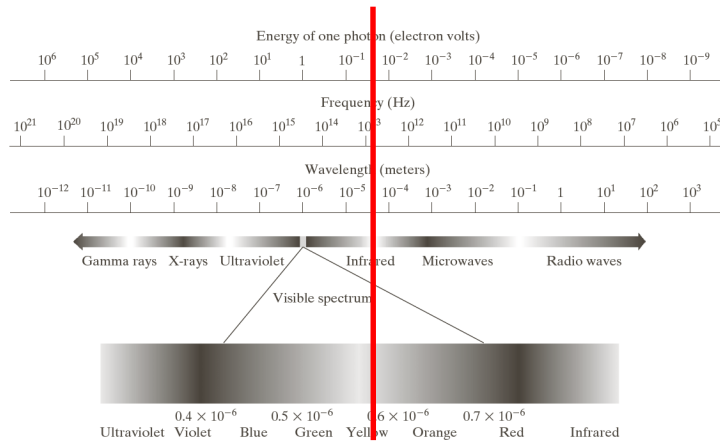
Chapter 1

Introduction

FIGURE 1.13
Infrared satellite images of the remaining populated part of the world. The small gray map is provided for reference. (Courtesy of NOAA.)

Chapter 1
Introduction
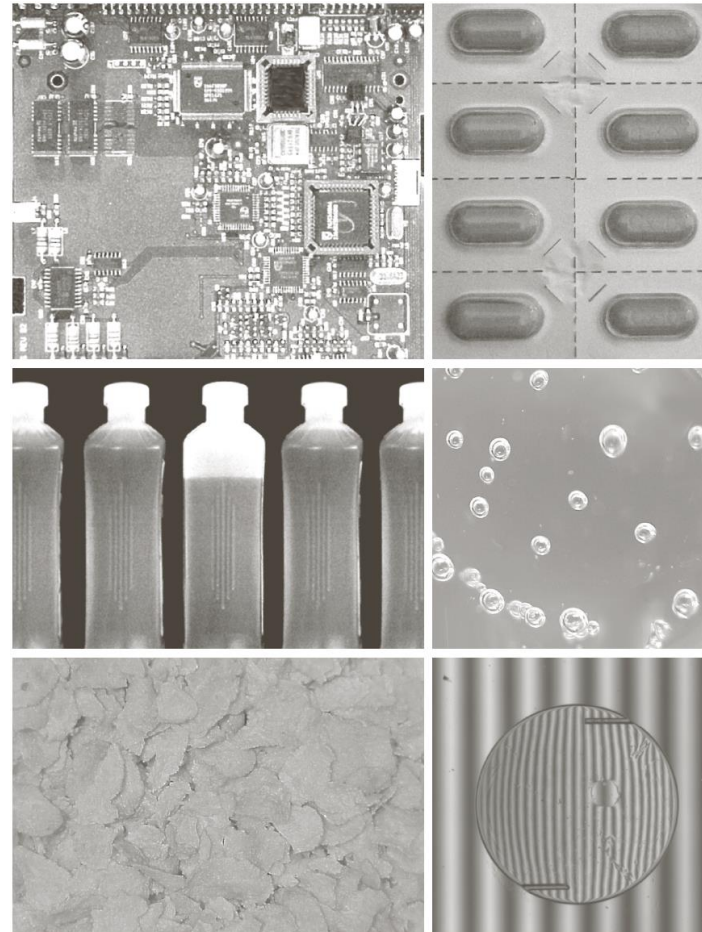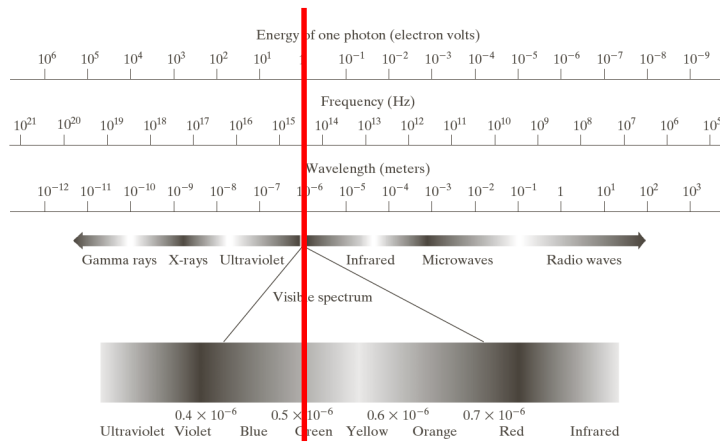
a b
c d
e f

FIGURE 1.14
Some examples of manufactured goods often checked using digital image processing.
(a) A circuit board controller.
(b) Packaged pills.
(c) Bottles.
(d) Air bubbles in a clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.
(Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

Chapter 1
Introduction
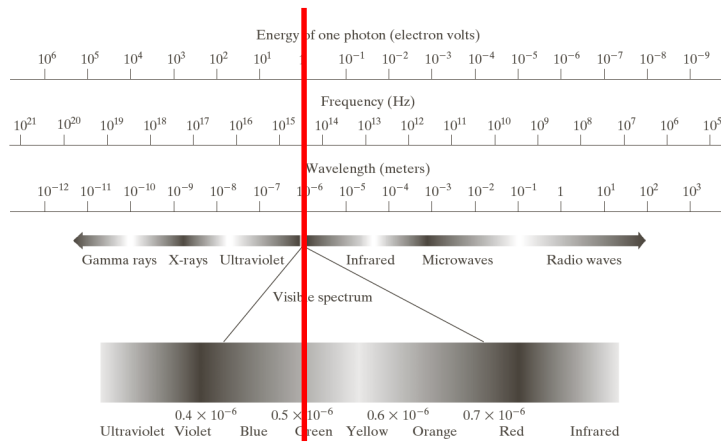
a b
c d

FIGURE 1.15
Some additional examples of imaging in the visual spectrum. (a) Thumb print. (b) Paper currency. (c) and (d) Automated license plate reading. (Figure (a) courtesy of the National Institute of Standards and Technology. Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)
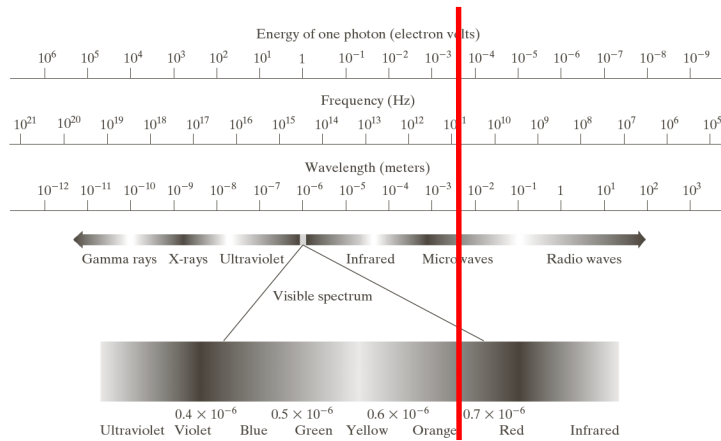
- **Imaging in the Microwave Bands**
  – Radar

Chapter 1
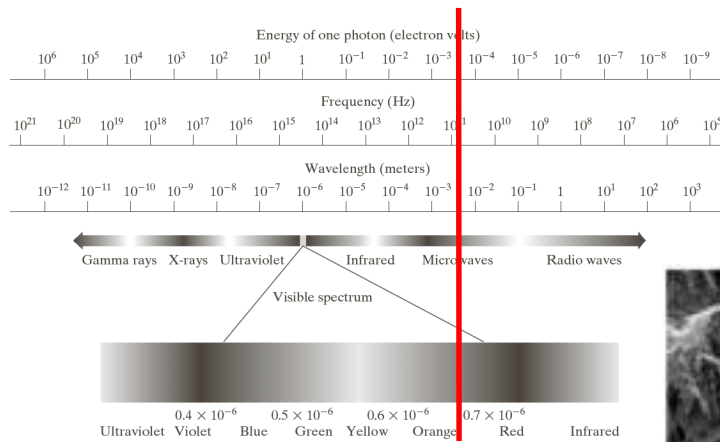
Introduction

FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)
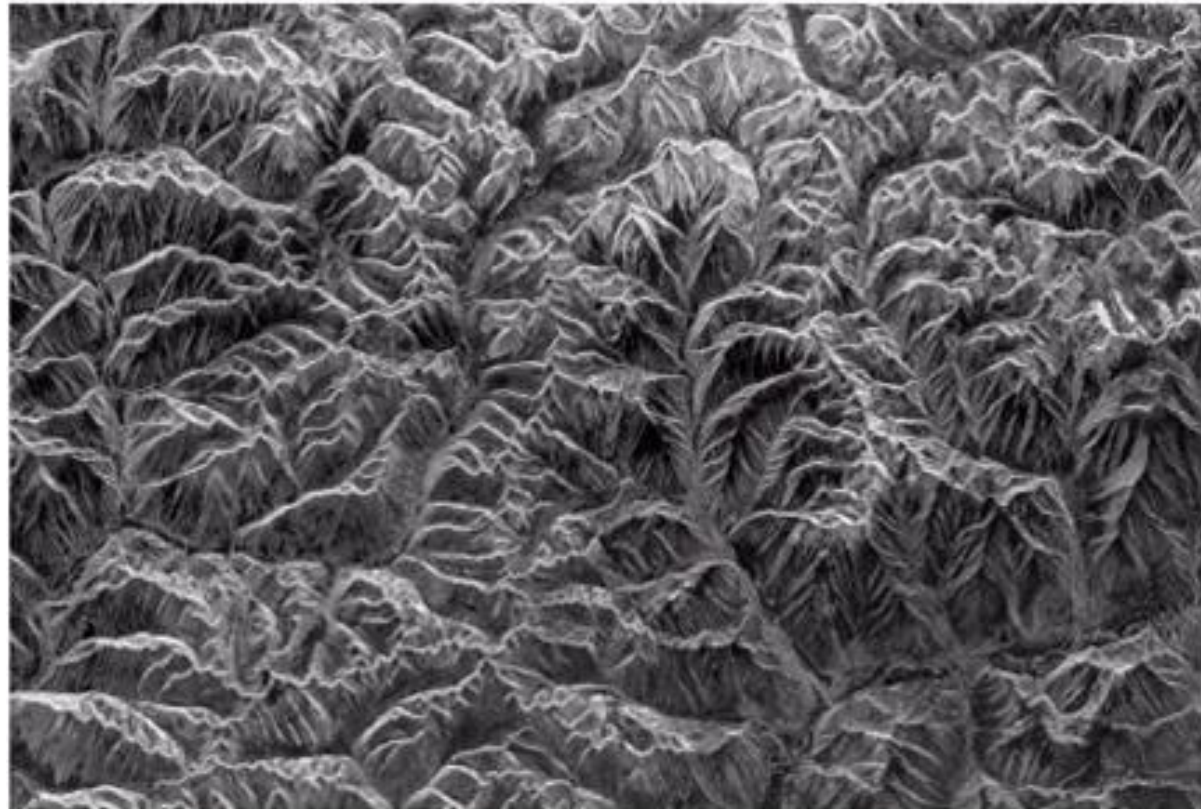
- ## Imaging in the Radio Bands
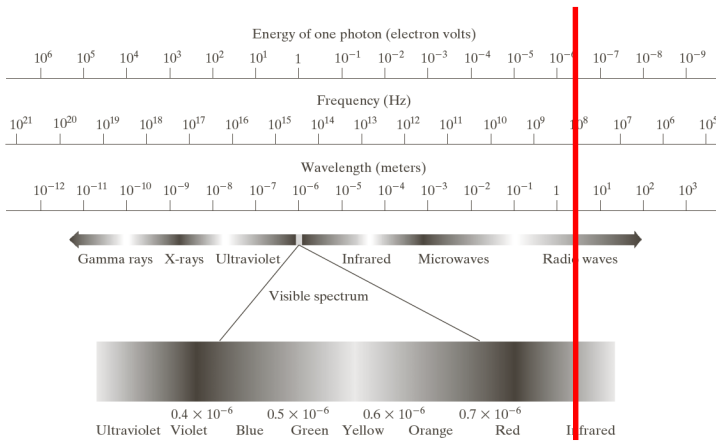
  – Medicine: MRI

  – Astronomy

FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)
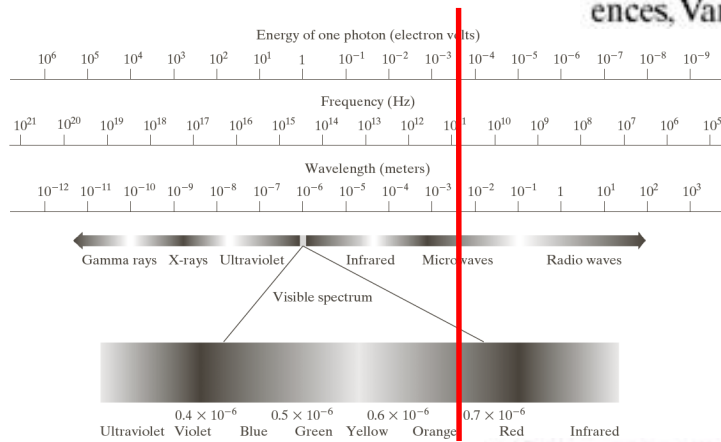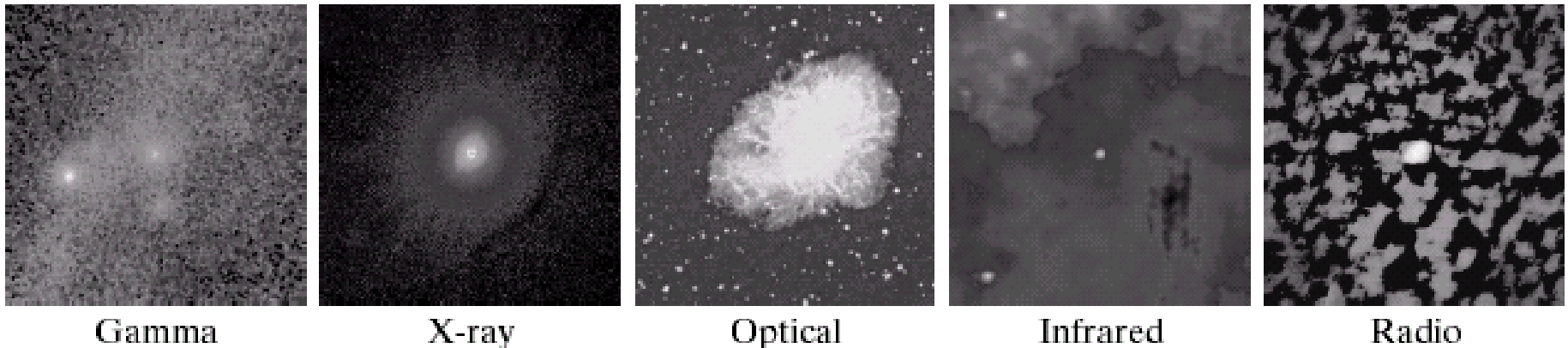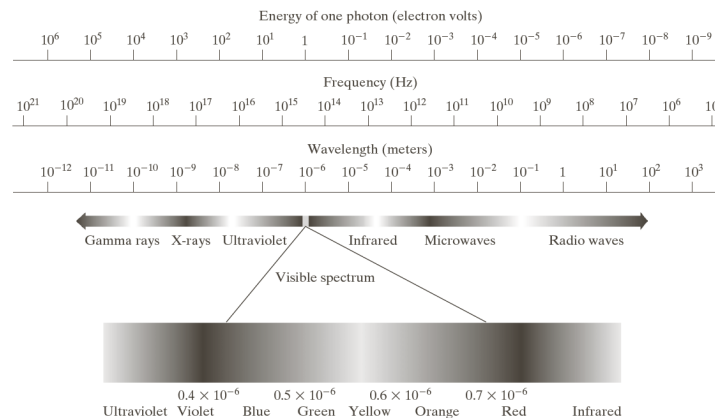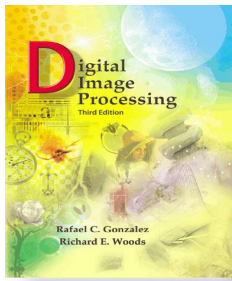
Chapter 1
Introduction

FIGURE 1.18 Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)
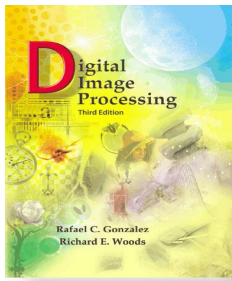
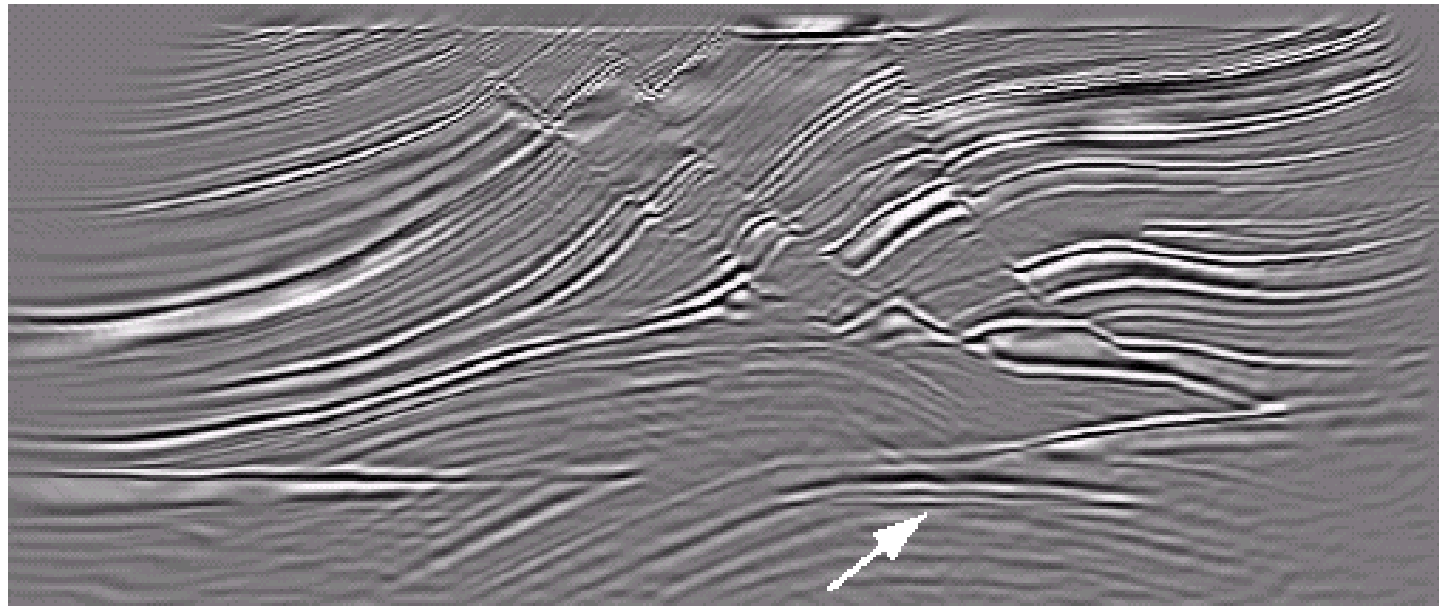Chapter 1
Introduction

- **Non EM**
  - ➢ Acoustic
  - ➢ Ultrasound
  - ➢ Electronic
  - ➢ Synthetic

Chapter 1

Introduction

FIGURE 1.19
Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)
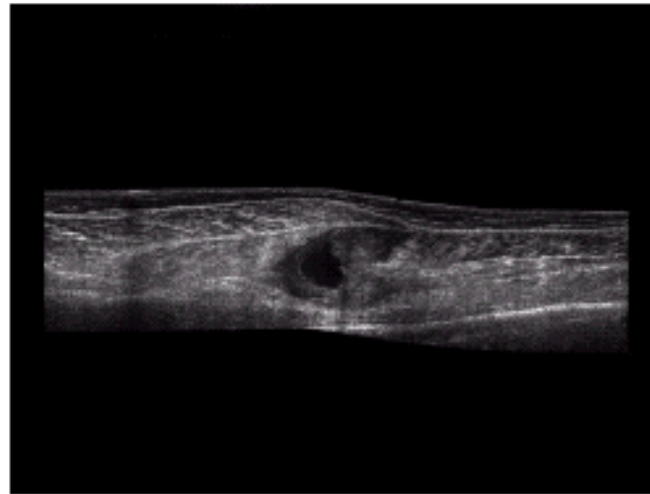

Seismic Image

Chapter 1
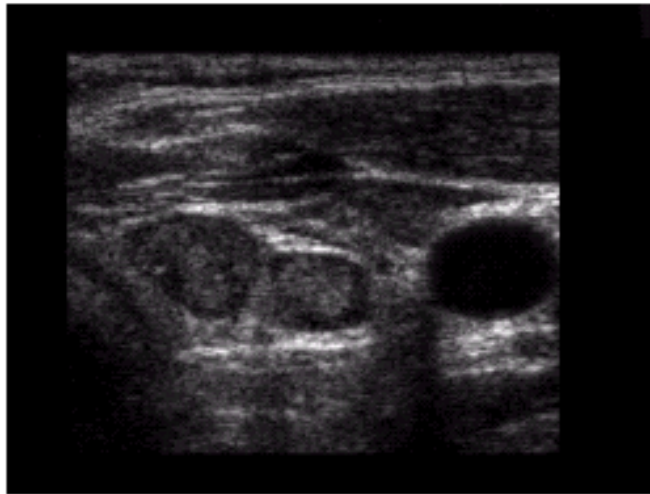## Introduction

a b
c d

FIGURE 1.20
Examples of
ultrasound
imaging. (a) Baby.
(2) Another view
of baby.
(c) Thyroids.
(d) Muscle layers
showing lesion.
(Courtesy of
Siemens Medical
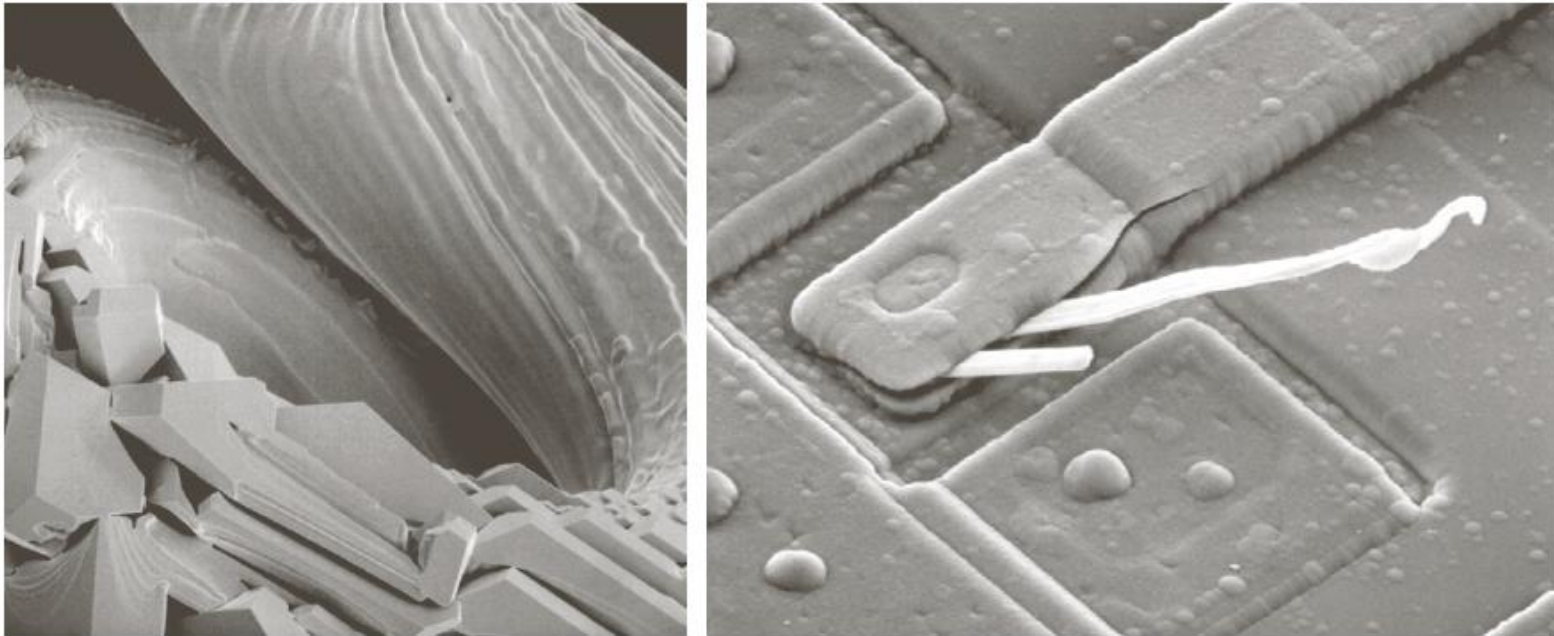Systems, Inc.,
Ultrasound
Group.)

Ultra Sound Image

Chapter 1

Introduction

Thermal

Image

a b

FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure (note the shattered pieces on the lower left). (b) 2500× SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)
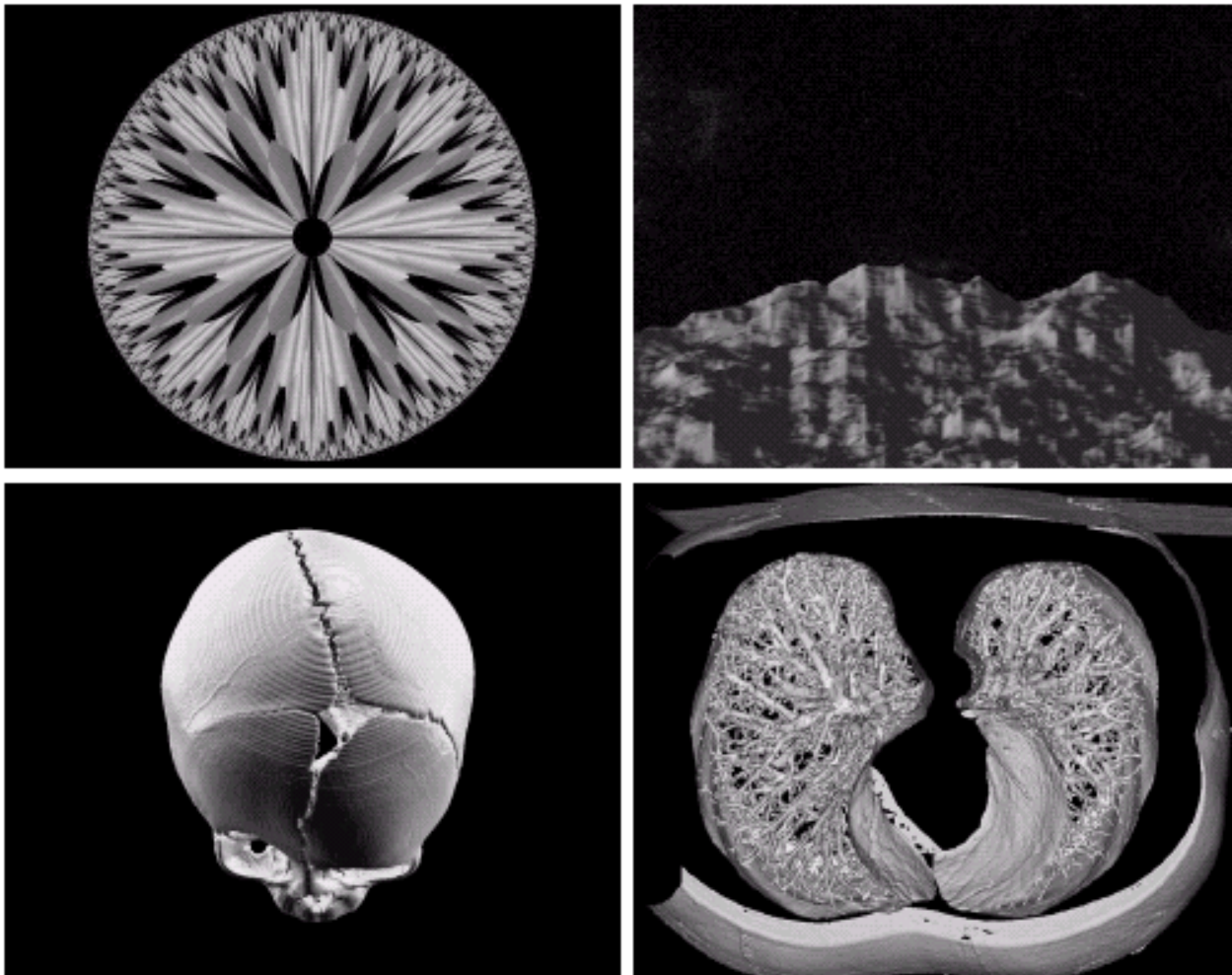
Chapter 1
Introduction

a b
c d

FIGURE 1.22
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College, (c) and (d) courtesy of NASA.)
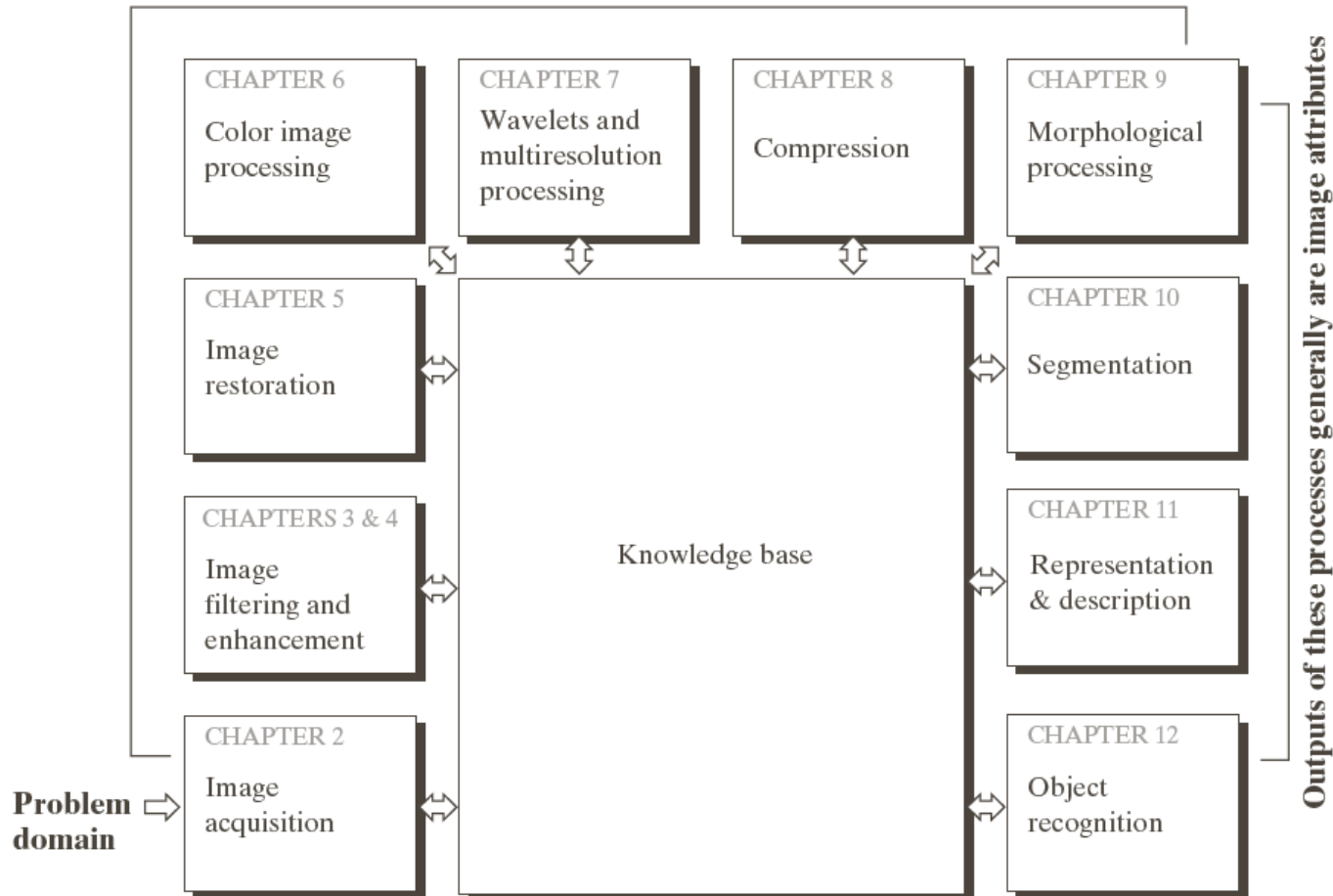
Graphics Image

Chapter 1
Introduction

Outputs of these processes generally are images

FIGURE 1.23 Fundamental steps in digital image processing. The chapter(s) indicated in the boxes is where the material described in the box is discussed.
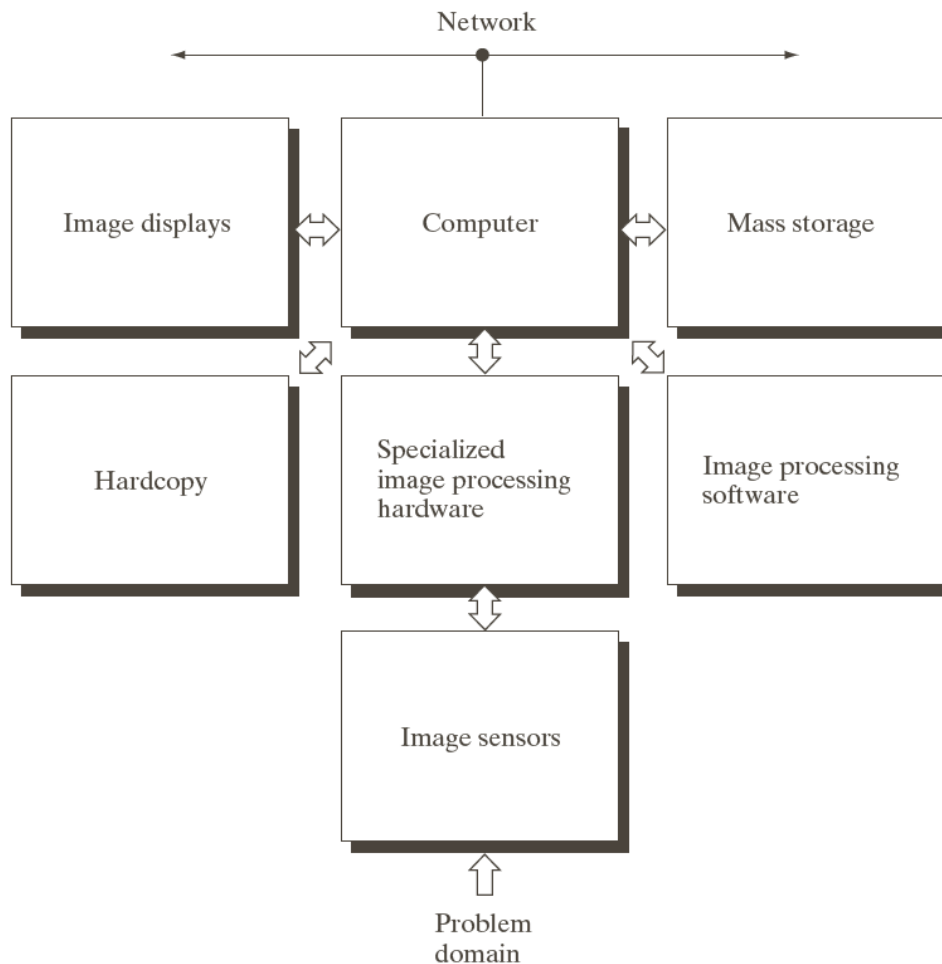
CHAPTER 6 — Color image processing

CHAPTER 7 — Wavelets and multiresolution processing

CHAPTER 8 — Compression

CHAPTER 9 — Morphological processing

CHAPTER 5 — Image restoration

CHAPTER 10 — Segmentation

CHAPTERS 3 & 4 — Image filtering and enhancement

CHAPTER 11 — Representation & description

CHAPTER 2 — Image acquisition

CHAPTER 12 — Object recognition

Knowledge base

Problem domain

Outputs of these processes generally are image attributes

Chapter 1
Introduction

FIGURE 1.24
Components of a general-purpose image processing system.