

Canadian Board of Examiners for Professional Surveyors
Core Syllabus Item
E 4: ADVANCED REMOTE SENSING

Study Guide:

Numerical answers and specific references to the Essential Reference Materials to assist in non-numerical answers are provided for each section of this study guide.

1. With reference to Principles of Remote Sensing:

- Electromagnetic radiation principles (black body radiation, interaction of the EM radiation with the atmosphere, interaction of the EM radiation with the surface of the Earth)
- Remote sensing platforms
- Operational principles of remote sensing systems (active and passive)
- Photogrammetric mapping
- Relationship of remote sensing to other mapping sciences (e.g., photogrammetry, surveying, GPS, cartography, GIS)

Sample Questions:

- Q1.1. What are the main differences between remote sensing and photogrammetry?
- Q1.2. Discuss the different types of resolutions that are used to describe the characteristics of a remote sensing system (give some examples/illustrations whenever possible).
- Q1.3. Explain how can you use the spectral reflectance curve to identify the moisture content in vegetation and soil?
- Q1.4. Why do we see blue sky in mid-day and reddish/yellowish sky at sunset?
- Q1.5. What are the differences between active and passive remote sensing systems? Give one example for each system. Discuss the pros and cons of these systems.
- Q1.6. What are the main differences between geosynchronous and Sun-synchronous satellite orbits? List the advantages and disadvantages of these types of orbits.
- Q1.7. Hyper-spectral and multi-spectral scanners detect and record radiation in several (perhaps hundreds) of very narrow spectral bands. What would be the advantages of these types of sensors? What would be the disadvantages of such sensors?
- Q1.8. What is meant by specular reflectance? What is the surface roughness relative to the radiation wavelength criterion that would lead to specular reflectance?
- Q1.9. What is meant by diffuse reflectance? What is the surface roughness relative to the radiation wavelength criterion that would lead to diffuse reflectance?
- Q1.10. What are the advantages and disadvantages of airborne remote sensing platforms?
- Q1.11. What are the advantages and disadvantages of satellite remote sensing platforms?

(See Essential Reference Materials ENGO 435, Chapter 2; Remote Sensing of the Environment: An Earth Resource Perspective, Chapters 1 and 2; Introductory Digital Image Processing: A Remote Sensing Perspective, Chapter 2)

2. With reference to Radiometric Corrections of Remote Sensing data:

- Radiometric calibration of remote sensing data: motivation
- Sensor calibration: Recovery of the at-sensor-radiance from the recorded digital numbers
- Atmospheric correction: Recovery of the surface radiance from the at-sensor-radiance
- Solar and topographic correction: Recovery of the surface reflectance from the surface radiance

Sample Questions:

- Q2.1. What are the three main processes needed to satisfy the objectives of radiometric calibration of remote sensing systems?
- Q2.2. Recorded grey value (digital number) at any pixel location in an image is not a record of the true ground leaving radiance. Explain why?
- Q2.3. What are the factors affecting the recorded energy by the sensor?
- Q2.4. Atmospheric correction is an important step during radiometric calibration of remote sensing imagery. State and discuss three major fields of applications where atmospheric correction is needed.
- Q2.5. What is the optimal solar zenith angle, which will produce largest atmospheric transmittance? Support your answer by discussing the relevant formula(s).

Answer:

0°

- Q2.6. The removal of the atmospheric path radiance (LP) can be established by observing recorded digital numbers from dark objects. What are the various factors that would give rise to dark objects?
- Q2.7. Briefly explain the procedure for transforming the at-sensor radiance (LS) into target leaving radiance (LT).
- Q2.8. What is meant by atmospheric path radiance (LP)? How does (LP) affect the quality of the recorded image?
- Q2.9. What are the factors affecting the magnitude of the target radiance (LT)?

(See Essential Reference Materials ENGO 435, Chapter 4; Remote Sensing of the Environment: An Earth Resource Perspective, Chapters 1 and 2; Introductory Digital Image Processing: A Remote Sensing Perspective, Chapters 2 and 6)

3. With reference to Geometric Corrections of Remote Sensing Imagery:

- Registration, geo-coding, and ortho-rectification
- Necessary tools:
 - Image-to-image transformation (direct and indirect transformation)
 - Image resampling techniques (nearest neighbour, bilinear, bi-cubic resampling)
- Registration paradigm: registration primitives, transformation parameters, and similarity function
- Polynomial rectification

- Rigorous rectification

Sample Questions:

- Q3.1. What is meant by data registration? Why is it an important issue?
- Q3.2. Briefly explain the conceptual basis of the implemented procedure for the co-registration of two remotely-sensed images.
- Q3.3. What are the characteristics and possible applications of an orthophoto?
- Q3.4. What are the different strategies of rectifying images? Tabulate the advantages and disadvantages of each method?
- Q3.5. What are the differences between direct and indirect transformation during image-to-image transformation? Tabulate the advantages and disadvantages of each method?
- Q3.6. What is the objective of image resampling? What are the possible alternatives for image resampling?
- Q3.7. What are the main characteristics of nearest neighbour, bilinear, and bi-cubic convolution resampling techniques?
- Q3.8. What are the advantages and disadvantages of nearest neighbour, bilinear, and bi-cubic convolution resampling techniques?
- Q3.9. List all the necessary steps required to produce an orthophoto using differential rectification?
- Q3.10. What is the required input for orthophoto generation using differential rectification?
- Q3.11. What is the required input for orthophoto generation using polynomial rectification?
- Q3.12. What are the controlling factors for selecting the order of the transformation function in polynomial rectification?

(See Essential Reference Materials ENGO 435, Chapter 5; ENGO 531, Chapters 1, 2, and 5; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 6; Introductory Digital Image Processing: A Remote Sensing Perspective, Chapter 6)

4. With reference to Image Classification:

- Image classification: Objective
- Image classification techniques:
 - Supervised classification (parllelpiped classifier, minimum distance classifier, maximum likelihood classifier)
 - Unsupervised classification (K-means classification, ISODATA classification, Expectation Maximization – EM – classification)
- Accuracy assessment

Sample Questions:

- Q4.1. What is the difference between spectral and information classes from image classification point of view?
- Q4.2. List and briefly explain the basic assumptions behind image classification techniques.
- Q4.3. Briefly explain the conceptual basis of supervised and unsupervised image classification methodologies.

- Q4.4. What are the main characteristics/differences between supervised and unsupervised classification strategies? Tabulate your answer.
- Q4.5. What is the main function of the training set in a supervised image classification procedure?
- Q4.6. Briefly explain the implemented procedure in the parallelepiped classifier. What are the advantages and disadvantages of this classification technique?
- Q4.7. Briefly discuss the implemented procedure in the k-means unsupervised classification technique. What are the drawbacks of such procedure?
- Q4.8. Briefly explain how the ISODATA classifier circumvents some of the drawbacks of the k-means classifier.
- Q4.9. Given the following confusion matrix:

	A	B	C
A	120	12	8
B	21	212	9
C	16	11	89

Estimate the following quantities:

- The overall accuracy of the classification outcome
- The producer's accuracy for the three classes
- The user's accuracy for the three classes

Answer:

84.54% - 76.43%, 90.21%, 83.96% - 85.71%, 87.60%, 76.72%

(See Essential Reference Materials ENGO 435, Chapter 6; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 12; Introductory Digital Image Processing: A Remote Sensing Perspective, Chapter 8)

5. With reference to Thermal and Multi/Hyper-Spectral Scanning:
- Blackbody radiation
 - Thermal scanners
 - Geometric characteristics of thermal scanners
 - Radiometric calibration of thermal scanners
 - Temperature mapping with thermal scanner data
 - Multi-spectral scanners: operation and design considerations
 - Principal Component Analysis (PCA)

Sample Questions:

- Q5.1. What is meant by a “Blackbody”? What are the factors that affect its conversion of absorbed heat into radiant energy? Give an example of a blackbody under certain conditions.
- Q5.2. List some applications of an infrared passive sensor.
- Q5.3. Explain the operation mechanism of a line thermal scanner.
- Q5.4. Explain the operation mechanism of an opto-mechanical thermal scanner.
- Q5.5. What is the difference between qualitative and quantitative thermal scanning?
- Q5.6. What are the main characteristics of the diurnal temperature variation of soil and rocks (you can use a sketch to illustrate your answer)?
- Q5.7. What are the main characteristics of the diurnal temperature variation of water (you can use a sketch to illustrate your answer)?
- Q5.8. Briefly explain the geometric distortions introduced by the scanning mechanism of a thermal scanner.
- Q5.9. Briefly explain two of the commonly used radiometric calibration techniques of thermal scanners.
- Q5.10. What is the difference between multi-spectral and hyper-spectral remote sensing systems?
- Q5.11. What is main motivation of PCA?
- Q5.12. Briefly explain the conceptual basis of PCA?

(See Essential Reference Materials Remote Sensing of the Environment: An Earth Resource Perspective, Chapters 7 and 8)

6. With reference to Digital Image Processing:

- Image enhancement: introduction
- Contrast manipulation: linear contrast stretch, histogram equalization, Gaussian stretch)
- Noise removal
- Convolution
- Texture analysis
- Image processing in the frequency domain: Fourier Transform

Sample Questions:

- Q6.1. Briefly explain the conceptual basis of the linear contrast stretch.
- Q6.2. Briefly explain the conceptual basis of the histogram equalization.
- Q6.3. Briefly explain the conceptual basis of the Gaussian stretch.
- Q6.4. Briefly explain the different alternatives for image smoothing
- Q6.5. What is the conceptual basis of Fourier series/Transform?
- Q6.6. List some of the applications of Fourier transform in image processing.
- Q6.7. Describe the conceptual basics of image smoothing in the frequency domain.

Q6.8. Describe the conceptual basics of image sharpening (enhancement) in the frequency domain.

Q6.9. The following is a 3x3 sub-image of a remote sensing scene:

95	94	84
86	27	96
100	97	87

Derive the smoothed value at the central pixel using the following filters:

3x3 moving average,

3x3 median filter, and

The following smoothing mask:

$$\frac{1}{12} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 4 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Answer:

85.11, 94, 70.58

(See Essential Reference Materials ENGO 435, Chapter 4; Introductory Digital Image Processing: A Remote Sensing Perspective, Chapter 7)

7. With reference to Microwave Sensing:

- Advantages of microwave sensing
- Side Looking Airborne RADAR (SLAR) system operation
- Geometric characteristics of SLAR imagery
- Earth surface feature characteristics affecting RADAR returns
- Interpretation of SLAR imagery

Sample Questions:

Q7.1. What are the advantages of Radar remote sensing systems?

Q7.2. Tabulate the advantages and disadvantages of the systems using the following parts of the EMR: visible, infrared, and microwave (passive & active).

Q7.3. Briefly explain the basic operating principle of Side Looking Airborne Radar (SLAR) systems.

Q7.4. Briefly explain what is meant by range resolution and azimuth resolution of SLAR systems.

Q7.5. Briefly explain the slant-range distortion of SLAR systems.

Q7.6. Briefly explain the relief-displacement distortion of SLAR systems.

Q7.7. Briefly explain the impact of sensor/terrain geometry on SLAR imagery.

Q7.8. Briefly explain the soil response in SLAR imagery.

Q7.9. Briefly explain the vegetation response in SLAR imagery.

Q7.10. Briefly explain the water and ice response in SLAR imagery.

(See Essential Reference Materials ENGO 435, Chapter 3; ENGO 531, Chapter 6; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 9)

8. With reference to LiDAR mapping:

- LASER principles
- LiDAR principles
- LiDAR equation
- Error sources (systematic and random errors)
- LiDAR data segmentation and feature extraction
- LiDAR versus photogrammetric systems

Sample Questions:

Q8.1. What are the main components of a LiDAR system?

Q8.2. What are the main factors affecting the size of the laser footprint?

Q8.3. What is meant by the following specifications and their typical values for commercial LiDAR systems:

- a. Scan rate/frequency,
- b. Pulse rate/frequency,
- c. Ground spacing,
- d. Wavelength,
- e. Scan pattern, and
- f. Beam divergence?

Q8.4. What are the systematic errors that might be present in a LiDAR system? How can you mitigate the impact of these errors?

Q8.5. What is the conceptual basis of point positioning using a LiDAR system?

Q8.6. What is the main objective of LiDAR data segmentation?

Q8.7. What are the alternative segmentation approaches of LiDAR data? Comment on the advantages and disadvantages of these approaches.

Q8.8. How would you compare the intensity image generated from a LiDAR system to an optical image?

Q8.9. What are the main differences between photogrammetric and LiDAR systems?

Q8.10. What are the main advantages of LiDAR when compared to a photogrammetric system?

Q8.11. What are the main advantages of a photogrammetric system when compared to LiDAR?

Q8.12. For a photogrammetric system, the horizontal accuracy is superior to the vertical accuracy. Do you agree with this statement? Why?

Q8.13. For a LiDAR system, the vertical accuracy is superior to the horizontal accuracy. Do you agree with this statement? Why?

(See Essential Reference Materials ENGO 435, Chapter 3; ENGO 531, Chapters 4 and 5; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 9)

9. With reference to Remote Sensing Applications:

- Land use/land cover mapping
- Agricultural applications: vegetation indices extraction
- Urban and regional mapping applications
- Environmental assessment
- Water resource applications
- Change detection

Sample Questions:

Q9.1. Use a sketch to illustrate the spectral reflectance curves for healthy and stressed vegetation.

Q9.2. Explain what is meant by vegetation indices.

Q9.3. What are the key characteristics of an optimum vegetation index?

Q9.4. How is the Simple Ratio (SR) vegetation index defined?

Q9.5. How is the generic Normalized Difference Vegetation Index (NDVI) defined?

Q9.6. How is the Soil Adjusted Vegetation Index (SAVI) defined?

Q9.7. What is the best wavelength for discriminating land from pure water?

Q9.8. Explain the basic cues that can be used for the discrimination of single family from multi-family residential in airborne imagery.

Q9.9. What are the necessary steps for a change detection application using temporal remote sensing data?

Q9.10. Briefly explain the conceptual basis of two change detection algorithms (e.g., post classification comparison, image algebra change detection, or spectral change vector analysis).

(See Essential Reference Materials ENGO 435, Chapters 2, 3, 4 and 6; Remote Sensing of the Environment: An Earth Resource Perspective, Chapters 10 – 13; Introductory Digital Image Processing: A Remote Sensing Perspective, Chapters 8 and 9)