Canadian Board of Examiners for Professional Surveyors
Core Syllabus Item
C 7: REMOTE SENSING AND PHOTOGRAMMETRY

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 electromagnetic radiation:
   - Terminology (Energy, radiant energy, radiant flux, radiant flux density)
   - EM radiation principles (black body radiation, interaction of EM radiation with the atmosphere, atmospheric windows)
   - Active versus passive remote sensing systems (optical imaging, LiDAR, and RADAR)
   - Bands of the electro-magnetic radiation (characteristics, advantages, limitations):
     - Radio waves
     - Microwaves
     - Infrared radiation
     - Visible light
     - Ultraviolet rays
     - X-rays
     - Gamma rays

Sample Questions:

Q1.1. List the major wavebands of the EM radiation. Which one is used in Photogrammetry?

Q1.2. In a tabular form, briefly define and list the units of measurements of the following EM radiation relevant terms: Radiant energy, radiant flux, radiant flux density, irradiance, radiant existence, spectral existence.

Q1.3. The shorter the wavelength, the higher the energy carried by the radiation. Support this statement by quoting an example of such radiation.

Q1.4. Explain why active microwave systems are more suited for high resolution remote sensing when compared to passive microwave systems.

Q1.5. What are the advantages of RADAR remote sensing systems?

Q1.6. List some applications of an infrared passive sensor.

Q1.7. What is the EM radiation used in LiDAR systems? Are they active or passive systems?

Q1.8. Satellite remote sensing systems avoid detecting and recording wavelengths in the Ultraviolet portion of the spectrum. Why? What about Gamma rays?

Q1.9. Tabulate the advantages and disadvantages of the systems using the following parts of the EMR: visible, infrared, and microwave (passive & active).

See Essential Reference Materials ENGO 431, Chapter 2; ENGO 435, Chapters 1 – 3; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 2

2. With reference to basic optics:
   - Geometric and physical optics
   - Basic camera components (lens, shutter, aperture, body, light-sensitive medium)
   - Reflection and refraction
   - Lenses (optical axis, principal planes, lateral magnification, nodal points, focal points, focal length)
   - Lens equation, aberrations, distortions (radial and de-centering lens distortions), and diffraction
   - Depth of field, depth of focus, motion blur, resolving power of imaging systems
   - Geometric, radiometric, and spectral resolutions

Sample Questions:

Q2.1. Reducing the effect of aberrations and diffraction as well as improving the depth of field and depth of focus of the imaging system have conflicting requirements. Do you agree with this statement? Why?

Q2.2. Why is it important to reduce the aberration and distortion effects?

Q2.3. What is the function of each of the major camera components?

Q2.4. What is the conceptual difference between physical and geometric optics?

Q2.5. Explain the issues addressed by the law of reflection.

Q2.6. Explain the issues addressed by the law of refraction.

Q2.7. What is meant by the depth of field? What are the factors that affect the depth of field of a digital imaging system?

Q2.8. What is meant by the depth of focus? What are the factors that affect the depth of focus of a digital imaging system?

Q2.9. What is meant by the geometric resolution of remote sensing system? What are the factors that affect the geometric resolution of a digital imaging system?

Q2.10. What is meant by the radiometric resolution of remote sensing system? What are the factors that affect the radiometric resolution of a digital imaging system?

Q2.11. What is meant by the spectral resolution of remote sensing system? What are the factors that affect the spectral resolution of a digital imaging system?

See Essential Reference Materials ENGO 431, Chapter 3

3. With reference to film development and digital cameras:
   - Photographic film components
   - Processing of Black and White (B/W) film (negative film, inverse film)
   - Nature of colour
   - Processing of colour film (negative film, inverse film)

- Sensitometric properties of the emulsion
- Analogue versus digital cameras
- Frame versus line cameras

Sample Questions:

Q3.1. What are the basic differences between negative, inverse, and positive films?

Q3.2. What are the parts and the function of each part of a photographic film? Use a sketch to explain your answer.

Q3.3. What is the difference between negative and diapositive B/W films?

Q3.4. Explain with sketches the steps for developing a B/W negative film.

Q3.5. Explain the steps for developing a B/W inverse film.

Q3.6. Explain with sketches the steps for developing a color negative film.

Q3.7. Briefly explain the image acquisition process for a line camera.

Q3.8. What are the different alternatives for stereo-coverage using line cameras?

See Essential Reference Materials ENGO 431, Chapter 4; ENGO 435, Chapter 3; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 4

4. With reference to vertical photography:

- Image versus map characteristics
- Vertical photography: definitions and characteristics
- Image scale
- Mathematical relationship between corresponding image and ground coordinates
- Relief displacement

Sample Questions:

Q4.1. At the bottom of a valley, the scale of a particular vertical photograph is 1:8000. The focal length of the lens used to make the photograph is 6". A road intersection on the same photograph is 495′ above the valley floor and 3.99" from the principal point. What is the relief displacement of the road intersection with respect to the bottom of the valley?

Answer:

0.4938"

Q4.2. What is meant by a vertical photograph? What is meant by a nearly vertical photograph?

Q4.3. Give a brief definition of the following entities: Nadir point, principal point, principal distance, flying height, as well as X and Y -axes of the image coordinate system.

Q4.4. Use the lens equation to argue for the fact that one can use the principal distance and focal length interchangeably when working with aerial photography.

Q4.5. In photography, images have varying scale. Use a sketch to illustrate this fact. Sketch a special case where the scale in a photograph is considered constant.

Q4.6. What are the sources of digital imagery? Which do you prefer if the same quality can be attained? Why?

See Essential Reference Materials ENGO 431, Chapter 5; Elements of Photogrammetry (with Applications in GIS), Chapter 6; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 6

5. With reference to image coordinate measurements and refinements:

- Image coordinates measurements in analogue, analytical, and digital environments
- Comparators: mono and stereo-comparators
- Automatic comparators
- Machine-to-image coordinates transformation
- Reduction/refinement of image coordinate measurements:
    - Radial and de-centering lens distortions
    - Atmospheric refraction
    - Earth curvature

Sample Questions:

Q5.1. Compare the different generations of photogrammetry according to the input and output formats as well as the stereo-viewing methodologies.

Q5.2. What are the comparators used for?

Q5.3. What is the difference between mono and stereo comparators? Which device do you think is more accurate and less susceptible to blunders? Why?

Q5.4. What are the conditions for stereo viewing in stereo comparators? Is this an advantage or disadvantage?

Q5.5. What is the purpose of image coordinate refinement?

Q5.6. Using an auxiliary sketch, explain Abbe's rule.

See Essential Reference Materials ENGO 431, Chapter 6; Elements of Photogrammetry (with Applications in GIS), Chapter 4

6. With reference to photogrammetric mathematics:

- Mathematical model: Objectives
- Mathematical model: Alternatives
- Rotation matrices (2-D and 3-D)
    - Derivation and characteristics
- Collinearity equations
    - Concept and derivation
- Coplanarity condition
    - Concept and derivation
- Bundle block adjustment

    - Concept and objectives
- Least-squares adjustment in photogrammetry
- Special cases: single photo resection, photogrammetric intersection, bundle adjustment with self-calibration
- Quality Assurance (QA) of photogrammetric mapping:
    - flight mission planning
    - camera calibration
    - system calibration
- Quality Control (QC) of photogrammetric products: Accuracy and precision evaluation

Sample Questions:

Q6.1. What is the objective of the mathematical model in photogrammetry?

Q6.2. What is the conceptual basis of the Collinearity equations?

Q6.3. What is the conceptual basis of the Coplanarity condition?

Q6.4. What is the assumed perspective geometry in photogrammetry?

Q6.5. What is the function of rotation matrices?

Q6.6. List and describe the parameters involved in the Collinearity equations.

Q6.7. What is meant by the interior orientation parameters and how are they determined?

Q6.8. What is meant by the exterior orientation parameters and how are they estimated?

Q6.9. What is the conceptual basis, target function, of a bundle adjustment procedure involving an image block with ground control and tie points?

See Essential Reference Materials ENGO 431, Chapters 5 – 8; Elements of Photogrammetry (with Applications in GIS), Chapters 11 and 17; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 6

7. With reference to theory of orientation and photogrammetric triangulation:

- Concept of transforming centrally projected images into a three-dimensional model to generate an orthogonal map
- Interior orientation: distortions, camera calibration (laboratory, indoor, and in-situ)
- Exterior orientation: (Relative Orientation, x versus y-parallax, Absolute Orientation, direct orientation/geo-referencing, indirect orientation/geo-referencing)
- Aerial Triangulation: strip triangulation, block triangulation, and bundle adjustment
- Photogrammetric resection and intersection

Sample Questions:

Q7.1. What are the causes and characteristics of radial lens distortions? Use a representative sketch to explain two different types of radial lens distortion.

Q7.2. What causes de-centering lens distortion? Use a representative sketch to explain a standard pattern of such distortion.

Q7.3. How are affine deformations manifested? Use a sketch to clarify such distortion.

Q7.4. Which digital camera characteristics would lead to affine deformations?

Q7.5. Briefly discuss the main objectives of a camera calibration exercise.

Q7.6. Briefly explain the different alternatives for camera calibration? Which method would you prefer? Why?

Q7.7. Briefly explain the different alternatives for establishing the Exterior Orientation Parameters of an image block?

Q7.8. What is the conceptual basis of the bundle adjustment procedure?

See Essential Reference Materials ENGO 431, Chapter 8; Elements of Photogrammetry (with Applications in GIS), Chapter 17

8. With reference to radiometric processing of remote sensing data:

- Radiometric calibration
  - Sensor calibration
    - DN/grey values → At-sensor radiance.
  - Atmospheric correction
    - At-sensor radiance → Surface radiance.
  - Solar and topographic correction
    - Surface radiance → Surface reflectance.
- Radiometric image processing:
  - Spatial/image domain processing
    - Noise removal
    - Point and edge detection
  - Frequency domain processing

Sample Questions:

Q8.1. What are the factors affecting the recorded energy by a remote sensing system?

Q8.2. 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.

Q8.3. 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

$$\frac{1}{10}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Answer:

85.11, 94, 79.30

Q8.4. Briefly explain the concept behind the involved procedure in the transformation from recorded digital numbers into at-sensor radiance (LS).

Q8.5. How will the scattering and absorption affect the at-sensor radiance (LS) for different wave bands of the EM spectrum? Discuss the resulting relative relationship between the magnitudes of the at-sensor radiance (LS) and the target leaving radiance (LT) for different EM wave bands as a result of these effects.

Q8.6. What is the conceptual basis of Fourier series/Transform? List some of the applications of Fourier transform in image processing.

Q8.7. Describe the conceptual basics of image smoothing in the frequency domain.

Q8.8. Describe the conceptual basics of image sharpening (enhancement) in the frequency domain.

See Essential Reference Materials ENGO 435, Chapter 4; Elements of Photogrammetry (with Applications in GIS), Chapter 14; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 2

9. With reference to image classification:

- Image classification: objective
- Image classification techniques:
    - Supervised classification
    - Unsupervised classification
- Accuracy assessment

Sample Questions:

Q9.1. What is the difference between spectral and information classes from image classification point of view?

Q9.2. List and briefly explain the basic assumptions behind image classification techniques.

Q9.3. Briefly explain the conceptual basis of supervised and unsupervised image classification methodologies.

Q9.4. What are the main characteristics/differences between supervised and unsupervised classification strategies? Tabulate your answer

Q9.5. What is the main function of the training set in a supervised image classification procedure?

Q9.6. Briefly explain the utilized procedure for evaluating the accuracy of a classification procedure?

See Essential Reference Materials ENGO 435, Chapter 6; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 12

10. With reference to orthophoto generation:
    - Registration, geo-coding, and ortho-rectification
    - Necessary tools:
        - Image-to-image transformation
        - Image resampling
    - Polynomial rectification
    - Rigorous rectification

Sample Questions:

Q10.1. What is meant by data registration? Why is it an important issue?

Q10.2. What are the characteristics and possible applications of an orthophoto?

Q10.3. What are the different strategies for image rectification? Tabulate the advantages and disadvantages of each method?

Q10.4. What are the differences between direct and indirect transformation during image rectification? Tabulate the advantages and disadvantages of each method?

Q10.5. List all the necessary steps required to produce an orthophoto using differential rectification?

Q10.6. What is the required input for orthophoto generation using differential rectification?

Q10.7. What is the required input for orthophoto generation using polynomial rectification?

See Essential Reference Materials ENGO 435, Chapter 5; Elements of Photogrammetry (with Applications in GIS), Chapters 10 and 13; Remote Sensing of the Environment: An Earth Resource Perspective, Chapter 6