

Exercise 1: Spectral Reflectance and Resolution

72 Points scaled to 20 Points

Introduction

In this exercise, you will explore some key characteristics of spectral reflectance curves and spatial, spectral, radiometric, and temporal resolutions relating to different sensors and data. You will not use any geospatial software or data in this first lab; however, you will use Microsoft Excel or Google Sheets, whichever you prefer. You will also use web resources.

Objectives

- *Use web resources to discover key characteristics associated with spatial, spectral, radiometric, and temporal resolutions of sensors*
- *Compare the spectral reflectance of different land cover types and surface materials*
- *Understand and describe patterns in spectral reflectance curves*

Prerequisite Materials

- ❖ Modules: Spectral Signatures
- ❖ Videos
 - Lab 1 Intro: https://youtu.be/GqvTzacuI_4

Background Questions

Question 1. List the following electromagnetic radiation ranges/types in order of increasing wavelength: visible light, microwave, near infrared, thermal infrared, shortwave infrared, and ultraviolet. (2 Points)

Question 2. List the following electromagnetic radiation ranges/types in order of increasing frequency: visible light, microwave, near infrared, thermal infrared, shortwave infrared, and ultraviolet. (2 Points)

Question 3. List the following electromagnetic radiation ranges/types in order of increasing energy: visible light, microwave, near infrared, thermal infrared, shortwave infrared, and ultraviolet. (2 Points)

Question 4. Convert 0.7 nm to the following units. Report your answers in scientific notation: μm , mm, cm, and m. (2 Points)

Question 5. Calculate the dominant wavelength in nm of emitted radiation for an object with a surface temperature of 1500 K using Wien's Law. (2 Points)

Question 6. Calculate the dominant wavelength in nm of emitted radiation for an object with a surface temperature of 500 K using Wien's Law. (2 Points)

Question 7. Find the total radiant exitance from a surface for an object with a surface temperature of 1500 K using the Stefan-Boltzmann Law. Units should be Watts/(steradian $m^2 \mu m$). (2 Points)

Question 8. Find the total radiant exitance from a surface for an object with a surface temperature of 500 K using the Stefan-Boltzmann Law. Units should be Watts/(steradian $m^2 \mu m$). (2 Points)

Question 9. Using your answers for Questions 5 and 6 and Wien's Law, state the relationship between an object's temperature and the wavelength and frequency of dominantly emitted radiation. (2 Points)

Question 10. Using your answers for Questions 7 and 8 and the Stefan-Boltzmann Law, state the relationship between an object's temperature and total radiant exitance from its surface. (2 Points)

Question 11. Explain the difference between radiance and surface reflectance. (2 Points)

Question 12. Explain the units of measurement of radiance: Watts/(steradian $m^2 \mu m$). What does each term mean/represent? (2 Points)

Question 13. How many unique values or brightness levels can be differentiated using the following radiometric resolutions: 2-bit, 4-bit, 8-bit, 12-bit, and 16-bit? (2 Points)

Question 14. Explain why leaves are green based on spectral reflectance properties in the visible spectrum. (2 Points)

Question 15. Explain why the sky is blue based on the interaction of electromagnetic radiation with the atmosphere. (2 Points)

Resolution Comparisons of Different Sensors

Use web resources to fill out the following tables for the Landsat 8 OLI/TIRS sensors (first table) and the Sentinel-2 MSI sensor (second table).

Band	Wavelength Range	Spatial Resolution
Band 1 (Coastal Aerosol)		
Band 2 (Blue)		
Band 3 (Green)		
Band 4 (Red)		
Band 5 (NIR)		
Band 6 (SWIR 1)		
Band 7 (SWIR 2)		
Band 8 (Panchromatic)		
Band 9 (Cirrus)		
Band 10 (Thermal Infrared 1)		
Band 11 (Thermal Infrared 2)		

Band	Central Wavelength	Spatial Resolution
Band 1 (Coastal Aerosol)		
Band 2 (Blue)		
Band 3 (Green)		
Band 4 (Red)		
Band 5 (Red Edge 1)		
Band 6 (Red Edge 2)		
Band 7 (Red Edge 3)		
Band 8 (NIR)		
Band 8A (Narrow NIR)		
Band 9 (Water Vapor)		
Band 10 (Cirrus Cloud)		
Band 11 (SWIR 1)		
Band 12 (SWIR 2))		

Question 16. Provide a comparison of the two sensors in regards to spatial resolution. (2 Points)

Question 17. Provide a comparison of the two sensors in regards to spectral resolution. (2 Points)

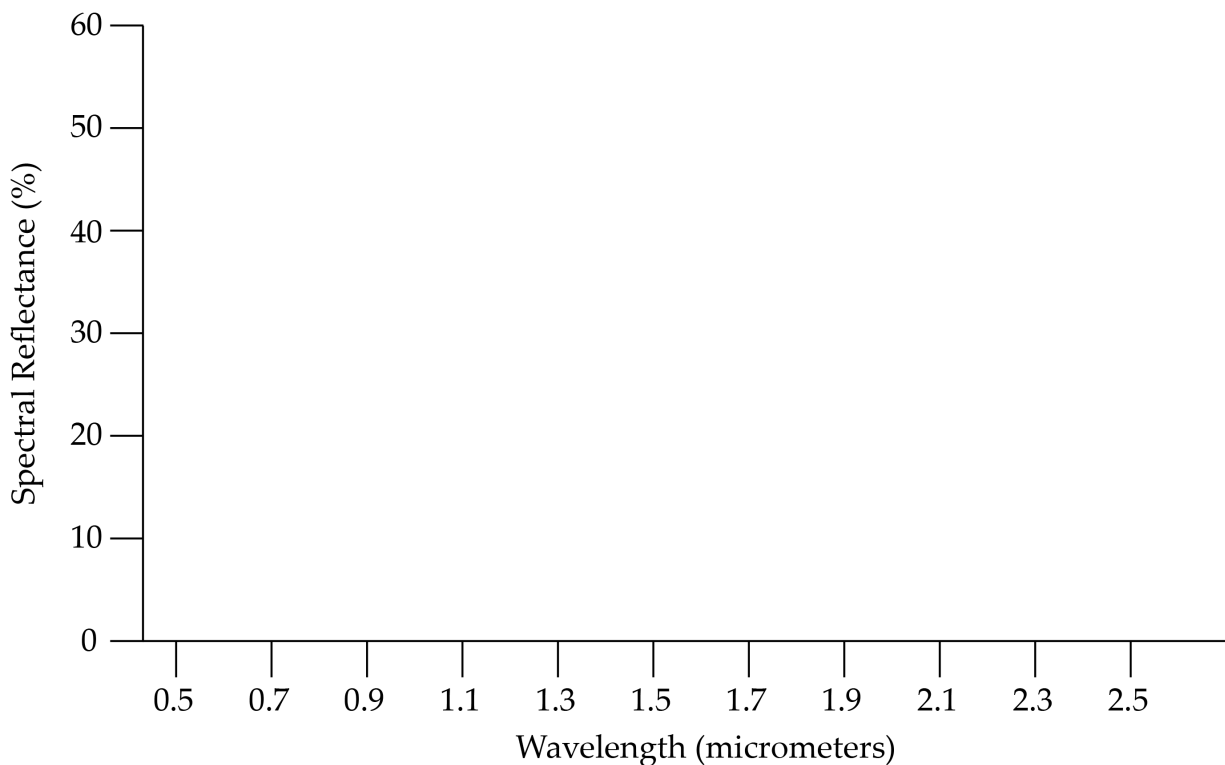
Question 18. Using web resources, find the return interval for Landsat 8 OLI/TIRS. (2 Points)

Question 19. Using web resources, find the return interval for Sentinel-2 MSI. (2 Points)

Question 20. Using web resources, find the range of available dates for Landsat 8 OLI/TIRS and Sentinel-2 MSI. (2 Points)

Spectral Reflectance Curves

Question 21: In the provided graph space, draw a generic spectral reflectance curve for green, healthy, photosynthetically active vegetation. Draw the generic spectral reflectance curve and also delineate the red, green, blue, NIR, and SWIR ranges. (2 Points)



Question 22. Explain the spectral reflectance pattern for green, healthy, photosynthetically active vegetation in the visible spectrum. (2 Points)

Question 23. Explain the spectral reflectance pattern for green, healthy, photosynthetically active vegetation in the NIR spectrum. (2 Points)

Question 24. Explain the spectral reflectance pattern for green, healthy, photosynthetically active vegetation in the SWIR spectrum. (2 Points)

You have been provided with a set of spectral data obtained from the USGS Spectral Library Version 7 (https://www.usgs.gov/centers/gggsc/science/usgs-high-resolution-spectral-library?qt-science_center_objects=0#qt-science_center_objects). The data have been provided in an Excel file with each feature in a separate sheet (**usgs_spectral_library_7_examples.xlsx**). The following data have been provided:

- ❖ Maple Leaf: Maple_Leaves DW92-1 DESCRIPT
- ❖ Blue Spruce: Blue_Spruce DW92-5 needles DESCRIPT
- ❖ Brick: Brick GDS348 Pave DkBrwngrey DESCRIPT
- ❖ Kaolinite (a clay mineral): Kaolinite CM9 DESCRIPT
- ❖ Concrete: Concrete GDS375 Lt Gry Road DESCRIPT

Wavelengths are reported in μm and surface reflectance is reported as a proportion (multiply by 100 to get a percentage).

Question 25: Use Excel or Google Sheets to create a single plot that shows all spectral reflectance curves. Reflectance should be plotted to the y-axis and wavelength should be plotted to the x-axis. (2 Points)

Use the graph to answer the following questions.

Question 26: Which of the five materials generally has the highest reflectance across the visible, NIR, and SWIR regions collectively? (2 Points)

Question 27: Based on the maple (deciduous) and blue spruce (conifer) examples, which group of trees, deciduous or conifer, tends to have the highest NIR surface reflectance. (2 Points)

Question 28: What is the reason for the absorption feature in the kaolinite spectral curve occurring around $2.2 \mu\text{m}$? (2 Points)

Question 29: Based on the concrete and brick curves, explain why the brick would appear red while the concrete would be grayer in color. (2 Points)

Question 30: What is the reason for the two SWIR absorption features in the maple leaf and blue spruce spectral reflectance curves? (2 Points)

Convert OLI Data to Reflectance

You will now convert Landsat 8 OLI data to top of atmosphere (TOA) reflectance. The equations below are used to estimate TOA reflectance. Note that this does not require a conversion to radiance.

$$\varphi_{\lambda}' = M_p Q_{cal} + A_p$$

φ_{λ}' = TOA planetary reflectance, without correction for solar angle

M_p = Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where x is the band number)

A_p = Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel value (DN)

To correct for solar angle:

$$\varphi_{\lambda} = \frac{\varphi_{\lambda}'}{\cos(\theta_{SE})}$$

φ_{λ} = TOA planetary reflectance

θ_{SE} = Local sun elevation angle (at scene center) (SUN_ELEVATION in metadata).

The needed values to perform the conversion can be found in the example Landsat 8 metadata file provided (LC08_L1TP_016033_20210112_20210308_02_T1_MTL.txt). Fill out the table below with the values needed.

Band	MULT
1	
2	
3	
4	
5	
6	
7	
8	
9	

Band	ADD
1	
2	
3	
4	
5	
6	
7	
8	
9	

Sun Elevation

Question 31: A cell in an image has a DN value of 25398 in the NIR band (Band 5). Calculate the reflectance at this cell location. Show your work. (2 Points)

Question 32: A cell in an image has a DN value of 11438 in the Red band (Band 4). Calculate the reflectance at this cell location. Show your work. (2 Points)

You will now convert TIRS data to TOA brightness temperature. This requires a conversion to radiance first. The equation below is used to estimate TOA radiance.

$$L_{\lambda} = M_L Q_{\text{cal}} + A_L$$

L_{λ} = TOA spectral radiance (Watts/(m² * srad * μm))

M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel value (DN)

Next, use the following equation to convert TOA radiance to TOA brightness temperature.

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_{\lambda}} + 1\right)}$$

T = Top of atmosphere brightness temperature (K)

L_{λ} = TOA spectral radiance (Watts/(m² * srad * μm))

K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number)

K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

Please fill out the table below with the values from the provided Landsat 8 TIRS metadata file (LC08_L1TP_016033_20210112_20210308_02_T1_MTL.txt).

Band	MULT	ADD	K1	K2
1				
2				

Question 33: A cell in an image has a DN value of 31470 in Band 10. Calculate the radiance at this cell location. Show your work. (2 Points)

Question 34: A cell in an image has a DN value of 31470 in Band 10. Calculate the TOA brightness temperature in Kelvin at this cell location. Show your work. (2 Points)

Question 35: Convert the temperature obtained above to Celsius. Show your work. (2 Points)

Question 36: Convert the temperature obtained above to Fahrenheit. Show your work. (2 Points)