## (Typical Answers)

## Q1.

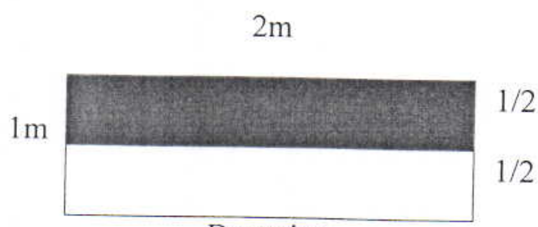
**A.** A thermal rectangular target, the temperature difference between this target and its background **3°K**. It is required to calculate the range for FLIR system with the specifications as follows: For system: $MRT_{\circ} = \mathbf{0.0254\ °K}$; $\beta_{sys.} = \mathbf{0.996\ mrad/cycle}$ Task level factor for the thermal target with height (width) **1.0 m** and length **2.0 m** for probability of **90%** detection and recognition at dry condition, where the molecular plus $H_2O$ cont. at $T_a = \mathbf{10°C}$ and $T_{dp} = \mathbf{0°C}$ is **0.093 $Km^{-1}$** while the $\beta_{aer.}$ equals to $\frac{0.95}{vis.}$ where the visibility **3.0 Km**.

$$\beta_{aer.} = \frac{0.95}{vis.} = \frac{0.95}{3\ Km} = 0.3167\ Km^{-1}$$

$$\beta_{atm} = \beta_{mol} + \beta_{H_2O\ cont.} + \beta_{aer.}$$

$$= 0.093 + 0.3167 = 0.4097\ Km^{-1}$$

$$R_\rho = \frac{\ln\left\{\frac{1}{k_\rho} \cdot \frac{\Delta T\sqrt{\varepsilon/7}}{MRT_{\circ}}\right\}}{\beta_{atm} + \frac{\gamma}{s} \cdot \beta_{sys.}}$$



Detection

For detection

$$\rho = 0.9 \rightarrow k_\rho = 1.5$$

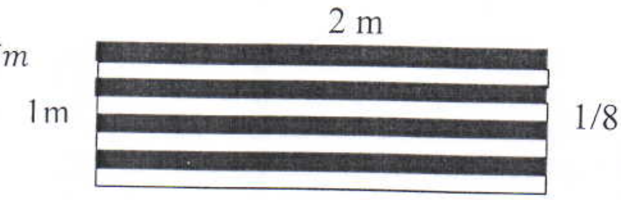
$$R_{0.9} = \frac{\ln\left\{\frac{1}{1.5} \cdot \frac{3\sqrt{4/7}}{0.0254}\right\}}{0.4097 + \frac{1}{1} \cdot 0.996} = \frac{\ln 59.5219}{1.4057} = \frac{4.0863}{1.4057}$$

$$= 2.907\ Km$$

For recognition

$$\rho = 0.9 \rightarrow k_\rho = 1.5;\ \varepsilon = \frac{length}{width} = \frac{2}{1/8} = \frac{16}{1};\ \gamma = 4\ pairs$$

$$R_{0.9} = \frac{\ln\left\{\frac{1}{1.5} \cdot \frac{3\sqrt{16/7}}{0.0254}\right\}}{0.4097 + \frac{4}{1} \cdot (0.996)} = \frac{\ln 119.044}{4.3937} = \frac{4.78}{4.3937} = 1.088\ Km$$



Recognition

**B. Answer the following items:**

**1.** Show the difference between laser ranging and laser profiling.

All laser methods are used to measure the distance to a high degree of accuracy.

**In Laser ranging:** the measurement of distance or range, which is always based on the precise measurement of time, can be carried out using one of the two main methods. The first of these involves the accurate measurement of the Time-Of-Flight TOF of a very short but intense pulse of laser radiation to travel from the laser ranger to the object and back being measured Thus, the laser ranging instrument measures the precise time interval that has elapsed between the pulse being emitted by the laser ranger and its return after reflection from a ground object In the second (alternative) method, the laser transmits a continuous beam of laser radiation instead of a pulse.

**Laser Profiling**: The use of a reflectorless laser ranger to measure the distances to a series of closely spaced points located adjacent to one another along a line on the terrain results in a two-dimensional (vertical) profile or vertical cross section of the ground showing the elevations of the ground along that line.

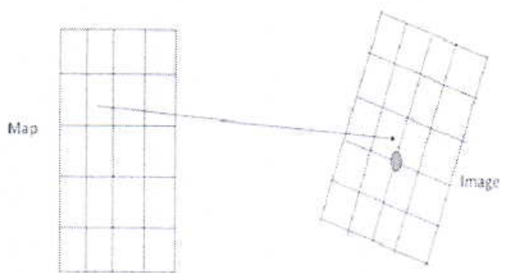
**2.** Define resampling method and its uses. Then list the common approaches used in resampling methods in geometric correction and explain one of them.

**Resampling**: It is used for geometric correction of the original distorted image, to determine the digital values to place in the new pixel locations of the corrected output image. The resampling process calculates the new pixel values from the original digital pixel values in the uncorrected image. There are three common methods for resampling: nearest neighbor, bilinear interpolation, and cubic convolution.

**Resampling Methods**:

1. Nearest Neighbor 2. Bilinear Interpolation 3. Cubic Convolution

**Nearest Neighbor:** This approach uses the digital value from the pixel in the original image which is nearest to the new pixel location in the corrected image. This is the simplest method and does not alter the original values, but may result in some pixel values being duplicated while others are lost. This method also tends to result in a disjointed or blocky image appearance, as shown in figure.




## Q2.

**A.** A Maximum Likelihood supervised classification was run to classify an image. Five categories have been indicated assigned to Residential, Commercial, Wetland, Forest and Water. With the class identities in the image as the standard, the number of pixels correctly assigned to each class and those miss assigned to other classes were arranged in the confusion matrix (Error matrix) used to produce the summary information shown in the following table. (15 Marks)

1. Compute the overall accuracy?
2. Compute the Producers' and user' accuracy?
3. Compute of $K_{hat}$ Coefficient?

| | | Reference or Ground truth classes | | | | |
|---|---|---|---|---|---|---|
| | | Residential | Commercial | Wetland | Forest | Water |
| Classification | Residential | 70 | 5 | 0 | 13 | 0 |
| | Commercial | 3 | 55 | 0 | 0 | 0 |
| | Wetland | 0 | 0 | 99 | 0 | 5 |
| | Forest | 0 | 0 | 4 | 37 | 0 |
| | Water | 0 | 0 | 0 | 0 | 121 |

**Answer:**

| | | Reference or Ground truth classes | | | | | Total Row |
|---|---|---|---|---|---|---|---|
| | | Residential | Commercial | Wetland | Forest | Water | |
| Classification | Residential | 70 | 5 | 0 | 13 | 0 | 88 |
| | Commercial | 3 | 55 | 0 | 0 | 0 | 58 |
| | Wetland | 0 | 0 | 99 | 0 | 5 | 104 |
| | Forest | 0 | 0 | 4 | 37 | 0 | 41 |
| | Water | 0 | 0 | 0 | 0 | 121 | 121 |
| Total Column | | 73 | 60 | 103 | 50 | 126 | 412 |

1. **Overall Landsat classification Accuracy**=(70+55+99+37+121)/ 407=382/ 407= 93.85%
2. **Producers' Accuracy**
   Residential = 70/73= 95.89%
   Commercial = 55/60=91.66%
   Wetland = 99/103= 96.11%
   Forest =37/50= 74%
   Water=121/126=96.03 %

**Producers' Accuracy**
Residential =70/88= 79.54%
Commercial =55/58=94.83 %
Wetland =99/104 =95.19 %
Forest =37/41=90.24%
Water=121/121=100%

$$K_{hat} = \left[ N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} x_{i+}\, x_{+i} \right] / \left[ \left( N^2 - \sum_{i=1}^{r} x_{i+}\ x_{i+1} \right) \right]$$

$N = 412$

$$\sum_{i=1}^{r} x_{ii} = (70 + 55 + 99 + 37 + 121) = 382$$

$$\sum_{i=1}^{r} x_{i+}\ x_{i+1} = (88 \times 73) + (58 \times 60) + (104 \times 103) + (41 \times 50) + (121 \times 126) = 37912$$

$$K_{hat} = \frac{[(412 \times 382) - 37912]}{[(412^2\ - 37912)]} = \frac{157384 - 37912}{169744 - 37912} = \frac{119472}{131832} = 90.6\ \%$$

$K_{hat} > 75\%$ Strong agreement (accuracy) between classification map and the ground reference information

$75\% > K_{hat} > 40\%$ Fair to good agreement (accuracy) between classification map and the ground reference information

$K_{hat} < 40\%$ Poor agreement (accuracy) between classification map and the ground reference information

**As $K_{hat} > 75\%$, So Strong agreement (accuracy) between classification map and the ground reference information**

**B. Answer the following items:**

1. Define the following terms: Atmospheric windows; Scattering; Digital Number; Nadir line.
2. Differentiate between Active and passive remote sensing system

**1. Define the following terms:**

**Atmospheric Windows; Scattering; Digital Number; Nadir line , Thermal crossover**

**Atmospheric Windows:** Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called atmospheric windows.

**Scattering** occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere. There are three (3) types of scattering which take place. **Rayleigh scattering** occurs when particles are very small compared to the wavelength of the radiation. **Mie scattering** occurs when the particles are just about the same size as the wavelength of the radiation.

**Digital Number:** An image or photo can be represented and displayed in a **digital** format by subdividing the image into small equal-sized and shaped areas, called picture elements or **pixels**, and representing the brightness of each area with a numeric value or **digital number**.

**Nadir line** is the plumb (vertical) line passing through photo and ground nadir points. While, **Nadir point** $N$ also called photo nadir point is the intersection of vertical (plumb line) from perspective center with photograph.

**Thermal crossover:** At the thermal crossover times, most of the materials have the almost same radiant temperature; it is not wise to do thermal remote sensing.

Water and vegetation have higher thermal capacity. In different time of thermal images, there are different performances even the materials.

**2. Differentiate between Active and passive remote sensing system.**

A ***passive*** **Remote sensing system** records the energy naturally radiated or reflected from an object

An ***active*** **Remote sensing system** supplies its own source of energy, which is directed at the object in order to measure the returned energy. Flash photography is active Remote Sensing in contrast to available light photography, which is passive. Another common form of active Remote Sensing is radar, which provides its own source of Electromagnetic energy in the microwave region. Airborne laser scanning is a relatively new form of active Remote Sensing, operating the in the visible and Near Infra Red wavelength bands.

## Q3.

**A.** An aerial photo was taken with camera focal length **152 mm**, format dimension **(23×23)** $cm^2$, longitudinal overlap **60%**, the distance between successive flight lines **2100 m** and the average terrain of the pictured area was **600 m** above mean sea level. A railway line (AB) with length **10.16 cm** was appeared in this photo. In the same time this railway was appeared with a length of **2.54 cm** in a map with scale **1/50000**. If you known the x-coordinates for the two ends of the railway in photo coordinate ($\boldsymbol{x_a = +50.01\ mm;\ x_b = -52.6\ mm}$)

Find:

1- The average altitude of the plane from mean sea level.
2- The ground coordinates for the two ends of the railway.
3- The length of the appeared railway in the pictured scene.
4- The baseline **B** and the lateral overlap sidelap **V%**.

**Solution:**

**1)**

$$photo\ scale = \frac{dis.on\ photo}{dis.on\ map} \times map\ scale \Rightarrow photo\ scale = \frac{10.16\ cm}{2.54\ cm} \times \frac{1}{50000} = \frac{1}{12500}$$

$$Scale = \frac{C}{H_{av.} - h_{av.}} \quad \Rightarrow \quad \frac{1}{12500} = \frac{0.152\ m}{H_{av.} - 600\ m}$$

$H_{av.} = 2500\ m$ The average altitude of the plane from mean sea level

**2)**

$$X_A = x_a\left(\frac{Hav. - h_{av.}}{c}\right) = +50.01\left(\frac{2500-600}{152}\right) = +\ 625.125\ m$$

$$X_B = x_b\left(\frac{Hav. - h_{av.}}{c}\right) = -52.6\ \left(\frac{2500-600}{152}\right) = -\ 657.5\ m$$

**3)** To solve railway line (AB length), either use photo scale or map scale

$$Photo\ Scale = \frac{ab}{AB}$$

$$\frac{1}{12500} = \frac{10.16}{AB} \Rightarrow AB = 1270\ m$$

$$Map\ Scale = \frac{ab}{AB} \quad \Rightarrow \quad \frac{1}{50000} = \frac{2.54}{AB} \qquad \Rightarrow \quad AB = 1270\ m$$

**4)** $B = S \times E\ (1 - U\ \%) \Rightarrow \quad B = 0.23 \times 12500\ (1 - 0.6) =$ **1150 m** the base line length

A=S×E (1−V %) ⇒ 2100= 0.23×12500(1−V %) ⇒ $0.730 = (1 - V\%)$

$$\Rightarrow V\% = 0.269 \approx 27\%\ \ Lateral\ Overlap\ (Sidelap)$$

**B.** Show the difference between the SAR and RAR Techniques?

**SAR & RAR**— Both SLAR and SAR systems use side-looking geometry. SAR sensors are mounted on satellites and the NASA Space Shuttle. The sensor transmits and receives as it is moving. The signals received over a time interval are combined to create the image.

For the **RAR**, the cross-range spatial resolution (Azimuth resolution) is a direct function of radar wavelength (λ) and target range (R) and inverse function of antenna length along track ($D_{AT}$), see Figure.

$\delta_{AT}=\lambda.R/D_{AT}$

While; For the **SAR**, the cross-range spatial resolution (Azimuth resolution) is a direct function of antenna length along track (*DAT*), $\delta_{AT}=D_{AT}/2$

## Q4.

**A.** Satellite Altitude is **800 km** mounted SAR radar system has the following characteristics: a wavelength of **23cm**, antenna length is **2.0 m,** antenna width is **0.5 m,** and pulse length (duration) of **1** $\mu sec$.

If the targets were imaged in the **far range** with a depression angle of **30°** and however, the same targets were imaged in the **near range** with a depression angle of **60°**.

1) Compute the ground range resolution and the azimuth resolution for both cases [Far and near Range]?
2) Compute of the swath width?
3) Will these targets be resolved in the far range and near range? If you known that the two targets appeared on flat terrain and separated in the range direction by a distance along the ground by **200 m**.

**1.** Compute Resolution

In the far range:

$$The\ ground-range\ resolution\ \ \delta_R = R_{gr} = \frac{c.\tau}{2\cos\gamma}$$

$$\delta_R = R_{gr} = \frac{3*10^8\ m/\sec\ *\ 1*10^{-6}\,sec}{2\cos 30°} = 173.2\,m$$

$$The\ azimuth\ resolution\ \ \delta_{AT} = R_a = \frac{\lambda}{L_a}\cdot\frac{(c\tau\cos\gamma)}{2}$$

$$\delta_{AT} = R_a = \frac{0.23\,m}{2}\cdot\frac{3*10^8\ m/\sec\ *\ 1*10^{-6}\,sec\ \cos 30°}{2}$$

$$\delta_{AT} = R_a = 14.94 \approx 15\,m$$

In the near range:

$$The\ ground-range\ resolution\ \ \delta_R = R_{gr} = \frac{c.\tau}{2\cos\gamma}$$

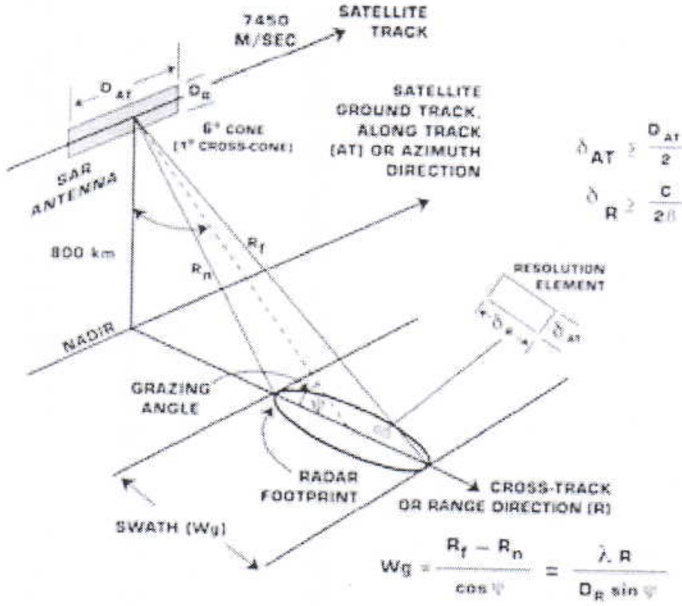
$$\delta_R = R_{gr} = \frac{3*10^8\ m/\sec\ *\ 1*10^{-6}\,sec}{2\cos 60°} = 300\,m$$

$$The\ azimuth\ resolution\ \ \delta_{AT} = R_a = \frac{\lambda}{L_a}\cdot\frac{(c\tau\cos\gamma)}{2}$$

$$= \frac{0.23\,m}{2}\cdot\frac{3*10^8\ m/\sec\ *\ 1*10^{-6}\,sec\ \cos 60°}{2}$$

$$\delta_{AT} = R_a = 8.625\,m$$

**2.** Compute swath width




$\psi = 60^{\circ} - 30^{0} = \left({30^{\circ}}/{2}\right) + 30^{0} = 45^{\circ}$

$\phi$ look angle in the far range $= \left(90^{\circ} - 30^{\circ}\right) = 60^{\circ}$

$$\cos\phi = \frac{H}{R_f}$$

$$R_f = \frac{H}{\cos\phi} = \frac{800\ \text{km}}{\cos 60} = 1600\ \text{km}$$

$\phi$ look angle in the near range $= \left(90^{\circ} - 60^{\circ}\right) = 30^{\circ}$

$$R_n = \frac{H}{\cos\phi} = \frac{800\ \text{km}}{\cos 30} = 923.76\ \text{km}$$

$$W_g = \frac{R_f - R_n}{\cos\psi} = \frac{1600 - 923.76}{\cos 45^{\circ}} = 956.348\ km$$

3. In the far range, the two targets would be resolved. Whereas, in the near range the two targets would not be resolved in ground – range resolution. But they are resolved in the azimuth resolution. Thus, the range resolution is better in the far range, and azimuth resolution is better in the near range.

**B.** Explain why data from the Landsat TM sensor might be considered more useful than data from the original MSS sensor. Hint: Think about their spatial, spectral, and radiometric resolutions.

**Answer**

There are several reasons why TM data may be considered more useful than MSS data. Although the areal coverage of a TM scene is virtually the same as a MSS scene, TM offers higher spatial, spectral, and radiometric resolution. The spatial resolution is 30 m compared to 80 m (except for the TM thermal channels, which are 120 m to 240 m). Thus, the level of spatial detail detectable in TM data is better. TM has more spectral channels which are narrower and better placed in the spectrum for certain applications, particularly vegetation discrimination. In addition, the increase from 6 bits to 8 bits for data recording represents a four-fold increase in the radiometric resolution of the data. (Remember, 6 bits = $2^6$ = 64, and 8 bits = $2^8$ = 256 - therefore, 256/64 = 4). However, this does not mean that TM data are "better" than MSS data. Indeed, MSS data are still used to this day and provide an excellent data source for many applications. If the desired information cannot be extracted from MSS data, then perhaps the higher spatial, spectral, and radiometric resolution of TM data may be more useful.

## Q5.

**A.** A vertical aerial photo has been taken over a flat terrain; it is required to be corrected geometrically by using ground control points (GCPs) with 1st order polynomial model. If a total

number of 3 GCPs were used to perform this order of polynomial model for geometric correction of satellite image with spatial resolution 0.6 m. Where, the X residual and Y residual measured in pixels for the GCPs are shown in the table below. Find:

1. The minimum number of GCPs that are required to perform this transformation.
2. The RMS error for each GCP.
3. The total RMS error.

| GCP No. | X residual | Y residual |
|---|---|---|
| 1 | -0.441 | 0.388 |
| 2 | 0.451 | -0.406 |
| 3 | 0.436 | -0.503 |

**Solution:**

1) The RMS error for GCP1

$$RMS\ error = \sqrt{XR_i^{\ 2} + YR_i^{\ 2}}$$

$$RMS\ error = \sqrt{XR_1^{\ 2} + YR_1^{\ 2}}$$

$$RMS\ error = \sqrt{(-0.441)^2 + (0.388)^2}$$

$$= \sqrt{0.1944 + 0.1505}$$

$$= 0.5872\ pixel$$

The RMS error for GCP2

$$RMS\ error = \sqrt{XR_2^{\ 2} + YR_2^{\ 2}}$$

$$RMS\ error = \sqrt{(0.451)^2 + (-0.406)^2}$$

$$= \sqrt{0.2034 + 0.1648}$$

$$= 0.6067\ pixel$$

The RMS error for GCP3

$$RMS\ error = \sqrt{XR_3^{\ 2} + YR_3^{\ 2}}$$

$$RMS\ error = \sqrt{(0.436)^2 + (-0.503)^2}$$

$$= \sqrt{0.1900 + 0.2530}$$

$$= 0.6655\ pixel$$

2) The total RMS error

$$R_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n} XR_i^{\ 2}}$$

$$R_x = \sqrt{\frac{1}{3}\ [(-0.441)^2 + (0.451)^2 + (0.436)^2]}$$

$$R_x = \sqrt{\frac{1}{3}\ [0.1944 + 0.2034 + 0.1900]}$$

$$= \sqrt{\frac{1}{3}\ [0.5878]}$$

$$= 0.4426\ pixel$$

$$R_y = \sqrt{\frac{1}{n}\sum_{i=1}^{n} {YR_i}^2}$$

$$R_y = \sqrt{\frac{1}{3}\ [(0.388)^2 + (-0.406)^2 + (-0.503)^2]}$$

$$R_y = \sqrt{\frac{1}{3}\ [0.1505 + 0.1648 + 0.2530]}$$

$$= \sqrt{\frac{1}{3}\ [0.5683]}$$

$$= 0.4352\ pixel$$

$$T = \sqrt{{R_x}^2 + {R_y}^2}$$

$$T = \sqrt{(0.4426)^2 + (0.4352)^2}$$

$$= \sqrt{0.3852}$$

$$= 0.6206\ pixel$$

**B.** The forset ambient temperature is a bout 15 °C in normal situation when disaster took place an average surface fire on the forest floor can reach temperatures of 800°C. In wich thermal window (3-5μm or 8-14 μm) should analyst use to sense in both cases before and after disaster.if you know emissivity of forest is about $\varepsilon$ =0.98 calculate the total energy in both cases if you know forest area is 10 $km^2$. Knowing that Stefan- Boltzman constant is $5.67\times10^{-12}$ W. $cm^{-2}$.

**Solution:**

**Before disaster**

$\lambda_{max} = 2898/T$

Temp $°_K$ = Temp $°_c$ + 273 =15 +273 = 288 $°_K$

$\lambda_{max} = a/T = 2898/288°_K = 10.0625\ \mu m$ ;which is inside window $(8-14)\mu m$

$W = \sigma\varepsilon T^4 = 5.67 \times 10^{-12} \times 10^{-4} \times 0.98 \times (288)^4 = 3.83 \times 10^{-6}$ $w.m^{-2}.k^{-4}$

**Total energy**= $3.83 \times 10^{-6} \times 10 \times 10^{6} = 38.3$ $w.K^{-4}$

**After disaster**

Temp $°_K$ = Temp $°_c$ + 273 = $800°_c$ + 273 = 1073 $°_K$

$\lambda_{max} = a/T = 2898/1073°_K = 2.7\ \mu m$ ; which is inside $(3-5)\ \mu m$ window

$W = \sigma\varepsilon T^4 = 5.67 \times 10^{-12} \times 10^{-4} \times 0.98 \times (1073)^4 = 7.365 \times 10^4$ $w.m^{-2}.k^{-4}$

**Total energy**=$7.365 \times 10^4 \times 10 \times 10^6 = 73.65 \times 10^{10}$ $w.K^{-4}$