

Although programmable calculators may be used, candidates must show all formulae used, the substitution of values into them, and any intermediate values to 2 more significant figures than warranted for the answer. Otherwise, full marks may not be awarded even though the answer is numerically correct. Please, make sure that your answer is legible and easy to follow.

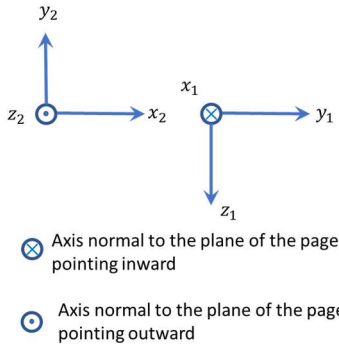
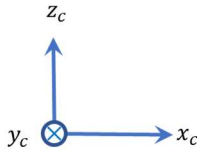
Note: This examination consists of 10 questions on 3 pages.

Marks

Q. No

Time: 3 hours

Value Earned

1.	a) For direct georeferencing of a LiDAR system, accurate estimation of the rotational relationship between the IMU-body frame and laser unit coordinate system is more critical than the translational relationship (shift). Do you agree with this statement? Why? b) For a given flight mission, the overlap percentage would change depending on the flying height above ground. Do you agree with this statement? Why? c) What is the rotation matrix ($R_{x_2y_2z_2}^{x_1y_1z_1}$) relating the two coordinate systems $x_1y_1z_1$ and $x_2y_2z_2$ in the figure below? Please, justify your answer.  d) Does the figure below represent a right-handed coordinate system? Why or why not? 	3 2 5 2	
2.	a) Starting from the Collinearity equations derive the mathematical model associated with vertical photography. In other words, starting from the equations below for a general image orientation: $x_a = x_p - c \frac{r_{11}(X_A - X_o) + r_{21}(Y_A - Y_o) + r_{31}(Z_A - Z_o)}{r_{13}(X_A - X_o) + r_{23}(Y_A - Y_o) + r_{33}(Z_A - Z_o)} + distortion_{x_a}$ $y_a = y_p - c \frac{r_{12}(X_A - X_o) + r_{22}(Y_A - Y_o) + r_{32}(Z_A - Z_o)}{r_{13}(X_A - X_o) + r_{23}(Y_A - Y_o) + r_{33}(Z_A - Z_o)} + distortion_{y_a}$ Derive the equations below for vertical photography (In your derivation, clearly state the assumptions you are making) : $x_a = c * \frac{X_A}{H-h_A} \text{ and } y_a = c * \frac{Y_A}{H-h_A}$ b) The side lap percentage between neighboring flight lines does not change with above ground flying height variation. Do you agree with this statement? Why? c) One needs a minimum of four GNSS satellites for single point positioning using pseudo ranges. Do you agree with this statement? Why?	8 2 2	

3.	a) What are the image formation principles used in deriving the lens equation ($1/\text{image distance} + 1/\text{object distance} = 1/\text{focal length}$)? b) How far is the principal point from the nadir point for a vertical image? Why? c) List three advantages of increasing the overlap/side lap in an image block. d) List three reasons for GNSS/INS integration for direct geo-referencing of an imaging system.	2 1 3 3	
4.	a) A GNSS receiver is better than a GPS receiver. Do you agree with this statement? Why or why not? b) What is meant by x-parallax and y-parallax in stereo-images? c) Could the following matrix be considered a rotation matrix? Why or why not? $\begin{bmatrix} -0.7071 & 0.7071 & 0 \\ 0.7071 & 0.7071 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	2 2 2	
5.	a) What is the difference between metric and non-metric digital cameras? b) Briefly explain the following terms and how they are evaluated for a digital camera: 1) Geometric resolution, 2) Radiometric resolution, 3) Spectral resolution, and 4) Temporal resolution. c) Where in the image is there no Radial Lens Distortion? Why? – list any assumptions made. d) Why do we use the term “Pseudo Range” to denote the measured range by a GPS/GNSS receiver?	2 4 3 2	
6.	What is the minimum number and optimal configuration of Ground Control Points that are needed for (justify your answer) : • Dependent relative orientation of a stereo-pair, • Independent relative orientation of a stereo-pair, • Single photo resection, • Indirect geo-referencing of an image stereo-pair, and • Indirect geo-referencing of an image block with 70% overlap and 70% side lap?	5	
7.	a) How is the perspective center defined for the lens assembly of a digital camera system? b) The light ray from an object point to its corresponding image point follows a straight line. Do you agree with this statement? Why? c) What is the objective of establishing the interior orientation for a given camera? List the interior orientation parameters that we usually solve for. What are the alternative methodologies for deriving the interior orientation parameters of a photogrammetric camera? Which one would you prefer to adopt? Why? d) What is the objective of establishing the exterior orientation for a given image? List the exterior orientation parameters that we usually solve for. What are the alternative methodologies for deriving the exterior orientation parameters of an imaging system? Which one would you prefer to adopt? Why or why not?	2 2 5 5	
8.	a) Height estimation using relief displacement measurements of objects closer to the nadir point is more precise than those that are farther. Do you agree with this statement? Why or why not? b) How many collinearity equations can be established for an object point that has been observed in five images? What is the redundancy when estimating the ground coordinates of the object point? State any assumptions made in this calculation. c) What are the main characteristics/differences between supervised and unsupervised classification strategies? Tabulate your answer. d) Image residuals from a bundle adjustment procedure are always very small. Do you agree with this statement? Why or why not?	2 2 3 2	

9.	a) Explain how you can use the spectral reflectance curve to identify the moisture content in vegetation and soil.	1	
	b) One can argue that digital cameras can see through shadow. Do you agree with this statement? Why or why not?	2	
	c) What is the dynamic range of a color (RGB) digital camera that has 10 bits/pixel?	2	
	d) What are the parameters that are solved for (you should explain what these parameters represent – individual parameters should be listed) in the following photogrammetric problems: 1) Single photo resection; 2) Photogrammetric intersection; 3) Bundle adjustment; 4) Bundle adjustment with self-calibration; 5) Dependent relative orientation for a stereo-pair; and 6) Independent relative orientation for a stereo-pair)?	6	
10.	a) What are the key requirements for using an integrated Global Navigation Satellite System/Inertial Navigation System (GNSS/INS) to derive the direct georeferencing parameters for a digital camera?	3	
	b) A wide-angle camera is expected to have significant radial lens distortion. Do you agree with this statement? Why or why not?	2	
	c) What is the variance of the scale number (i.e., the ratio between an object distance D and image distance d) given that σ_D and σ_d are the standard deviations of the object distance and image distance, respectively? You should show the derivation of the final expression.	6	
	Total Marks:	100	