Time: 15 minutes. Max marks: 10

Name: **Roll No.:**

Instructions:
- Do not plagiarize. Do not assist your classmates in plagiarism.
- Show your full solution for the questions to get full credit.
- Attempt all questions that you can.
- A statement is true if it is *always* true. MCQs may have multiple correct answers.
- In the unlikely case a question is not clear, discuss it with an invigilator. Please ensure that you clearly include any assumptions you make, even after clarification from the invigilator.

1. ($5 \times 1 = 5$ points) Answer True or False and provide the justification.

   (a) For a 3D point $\mathbf{X}$, let $\mathbf{x}$ and $\mathbf{x}'$ be the corresponding image points in the two images. Let ℓ and ℓ' are the respective epipolar lines passing through them, i.e., $\ell^\top \mathbf{x} = \ell'^\top \mathbf{x}' = 0$, then $\ell \times \ell' = \mathbf{X}$.
   Solution: False. ℓ and ℓ' are in two different cameras and therefore in different co-ordinate spaces. It does not make sense to take their cross-product.

   (b) If $\mathbf{S}_{3\times3}$ and $\mathbf{S}'_{3\times3}$ are similarity transformation matrices, then the Fundamental matrices $\mathbf{F}$ and $\mathbf{F}' = \mathbf{S}'^{-\top}\mathbf{F}\mathbf{S}^{-1}$ indicate the same camera motion.
   Solution: True. Since the matrices $\mathbf{S}$ and $\mathbf{S}'$ are similarity matrices, they are only scaling the image points, and can be completely absorbed into the intrinsic matrices. They have no bearing on the extrinsic parameters, i.e., the camera motion parameters $\mathbf{R}$ and $\mathbf{t}$.

   (c) The planar homography relationship between corresponding points is given by $\mathbf{x}'_{3\times1} = \mathbf{H}_{3\times3}\mathbf{x}_{3\times1}$. When estimating the homography using the direct linear transform (DLT), each correspondence generate three independent constraints.
   Solution: False. There are be 3 equations generated for each corresponding point during DLT, however, only two are independent and the third is a linear combination of the two.

   (d) The solution for the Fundamental matrix obtained by solving the $\mathbf{Af} = 0$ system of equations always has rank 2.
   Solution: False. The solution is obtained via SVD and there is no way to guarantee that the resulting vector when reshaped to a 3×3 matrix will have rank 2.

   (e) There is no relationship between the Fundamental and the Essential matrix.
   Solution: False. They are related via the intrinsic matrices of the two cameras, i.e., $\mathbf{F} = \mathbf{K}'^{-\top}\mathbf{E}\mathbf{K}^{-1}$ where $\mathbf{F}$ is the fundamental matrix, $\mathbf{E}$ is the Essential matrix, and $\mathbf{K}'$ and $\mathbf{K}$ are the intrinsic matrices of the two cameras such that $\mathbf{x}'\mathbf{F}\mathbf{x} = 0$ is the epipolar constraint.

2. ($5 \times 1 = 5$ points) Check ***all*** the correct answers. Partial grading if a subset of the correct answers are provided. Zero if *any* provided answer is incorrect.

(a) In a stereo setup, if the image planes are parallel, i.e., if they lie in the same plane in the 3D world, select all that are always true
(A) The epipoles will have their third coordinate as zero.
(B) The epipolar lines will be parallel.
(C) The camera centers will lie on the baseline.
(D) None of the above.

Solution: (A), (B), (C). (A) because the epipoles will be at infinity as the baseline is parallel to the image planes. (B) because the epipoles are at infinity, then the epipolar lines will intersect at a point at infinity, therefore will be parallel to each other. (C) because of the definition of baseline as the line containing the two camera centers.

(b) If the essential matrix has the form

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}$$

, then the motion between the two cameras is given by
(A) a horizontal translation.
(B) a vertical translation.
(C) no rotation.
(D) a 90° rotation about the X-axis.
(E) None of the above
Solution: (A), (C) This is a product of the cross-product matrix of $\mathbf{t} = [1, 0, 0]^\top$ and an identity rotation matrix.

(c) If the essential matrix has the form

$$\begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & 0 & 0 \end{bmatrix}$$

, then the motion between the two cameras is given by
(A) a horizontal translation.
(B) a vertical translation.
(C) no rotation.
(D) a 90° rotation about the X-axis.
(E) None of the above
Solution: (B), (C) This is a product of the cross-product matrix of $\mathbf{t} = [0, 1, 0]^\top$ and an identity rotation matrix.

(d) The smallest singular value of an Essential matrix is
(A) 0 (B) 1 (C) 2 (D) 3 (E) None of the above
Solution: (A) - The Essential matrix has a 1-D null space in the same direction as the translation vector.

(e) If the epipoles for two images coincide with the principal point, i.e., the projection of the camera center on the image plane, the the camera motion is given by
(A) rotation about X-axis
(B) translation along Z-axis
(C) pure rotation about Y-axis
(D) translation along Y-axis
(E) None of the above
Solution: (B) - If the epipoles coincide with the principal point, the camera has moved in the same direction as the optical axis (Z-axis), i.e., the axis connecting the camera center and the principal point.