Graphics (INFOGR) **Midterm Exam**

Duration: 2 hrs; Total points: 100

No documents allowed. Use of electronic devices, such as calculators, smartphones, smartwatches is forbidden.

Question 1 **[5 points]** Equation of the plane given that the vector

$$\vec{v} = \begin{pmatrix} 1 \\ 2 \\ 2 \end{pmatrix}$$

is a normal to it at point $(1, 1, 1)$ is

(A) $x + 2y + z - 4 = 0$	(C) $x + y + 2z - 4 = 0$	● $x + 2y + 2z - 5 = 0$
(B) $2x + y + z - 4 = 0$	(D) $x + y + z - 3 = 0$	(F) $2x + y + 2z - 5 = 0$

Question 2 **[4 points]** Compared to primary ray queries, shadow ray queries are faster on average for almost all scenes. In the following list, there is one scene for which shadow rays are not faster. Select this scene.

(A) A camera and a grid of $4 \times 4 \times 4$ point illuminating a banana.

(B) A cube with in it a point light, and outside the cube a second point light plus the camera.

(C) A grid of $4 \times 4 \times 4$ cubes with a distant point light and a camera.

● A cube with in it a camera and a point light.

(E) A cube with in it a point light. The camera is outside the cube.

Question 3 **[4 points]** Consider a scene with two point light sources, a diffuse sphere, a (purely) reflective sphere and a (pure dielectric) glass ball. For a particular pixel, we trace a single primary ray. What is the maximum number of rays traced in the subsequent recursive process, if we cap recursion depth to eight?

(A) 256 ● 16 (C) 6561 (D) 8 (E) 65536

Question 4 **[12 points]** Consider the surface of the sphere given by the equation $(x-3)^2 + (y-4)^2 + z^2 = 25$. You shoot a ray from the point $(8, 4, 0)$ along the vector

$$\vec{v} = \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}.$$

The *outward* unit vectors normal to the surface of the sphere at the intersection points of the ray and the sphere are

(A) $\begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}$ and $\begin{pmatrix} 1/\sqrt{2} \\ 0 \\ 1/\sqrt{2} \end{pmatrix}$

(B) $\begin{pmatrix} 2/3 \\ 2/3 \\ 1/3 \end{pmatrix}$ and $\begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}$

(C) $\begin{pmatrix} 1/\sqrt{2} \\ 0 \\ 1/\sqrt{2} \end{pmatrix}$ and $\begin{pmatrix} 0 \\ 1/\sqrt{2} \\ 1/\sqrt{2} \end{pmatrix}$

(D) $\begin{pmatrix} 1/3 \\ 2/3 \\ 2/3 \end{pmatrix}$ and $\begin{pmatrix} 1/\sqrt{2} \\ 0 \\ 1/\sqrt{2} \end{pmatrix}$

(E) $\begin{pmatrix} 2/3 \\ 2/3 \\ 1/3 \end{pmatrix}$ and $\begin{pmatrix} 2/3 \\ 1/3 \\ 2/3 \end{pmatrix}$

● $\begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$ and $\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$

Question 5 **[4 points]** What are the lower and upper bounds of the response time for a game running at a constant 50 frames per second?

(A) Lower bound is 10ms, upper bound is 20ms.

● Lower bound is 20ms, upper bound is 40ms.

(C) Lower bound is 0 ms, upper bound is 40ms.

(D) Lower bound is 10ms, upper bound is 40ms.

(E) Lower bound is 0ms, upper bound is 20ms.

Question 6 **[3 points]** There are two vectors

$$\vec{v} = \begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix} \quad \text{and} \quad \vec{w} = \begin{pmatrix} 1 \\ 0 \\ -2 \end{pmatrix}.$$

The quantity $u = \vec{v} \cdot (\vec{v} \times \vec{w})$ equals

(A) -1 ● 0 (C) -2 (D) 3 (E) 2 (F) 1

Question 7 **[4 points]** Which of the following options best describes the color of a bathroom mirror?

(A) Transparent (B) Grey (C) Black (D) Silver ● White

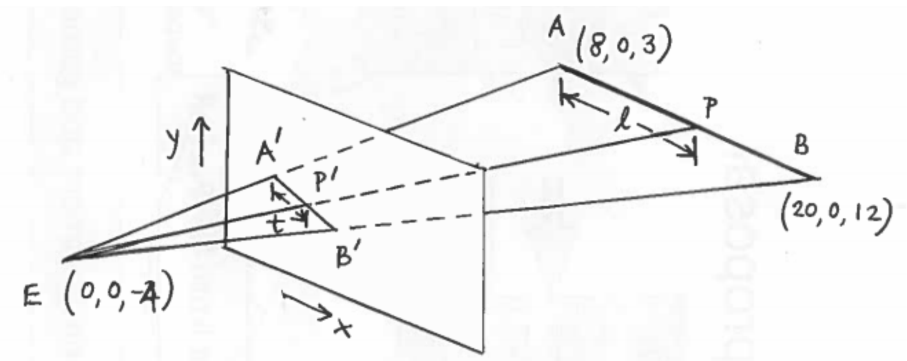
Question 8 **[4 points]** What does 'HDR' stand for?

- (A) High Density Resolution
- (B) High Definition Resolution
- (C) High Discrete Range
- (D) High Depth Range
- ● High Dynamic Range

Question 9 **[4 points]** One of the following statements is incorrect. Select this statement.

- ● Discretization is a form of rasterization.
- (B) Discretization turns an analog signal into a digital signal.
- (C) Screen resolution is analogous to sampling rate on a CD.
- (D) Rasterization turns an analog signal into a digital signal.
- (E) HDR color representation is a form of discretization.

Question 10 **[19 points]** As shown in the picture below, a bar AB is placed in three dimensions, with the locations of A = $(8, 0, 3)$ and B = $(20, 0, 12)$. The bar is being viewed by the eye located at E = $(0, 0, -4)$, and the view is being projected on the two-dimensional screen, which is simply the xy-plane. On the screen, A$'$ is the projection of A, P$'$ is the projection of P and so on. The distance AP is given by l and the distance A$'$P$'$ is given by t. The quantity t relates to l as

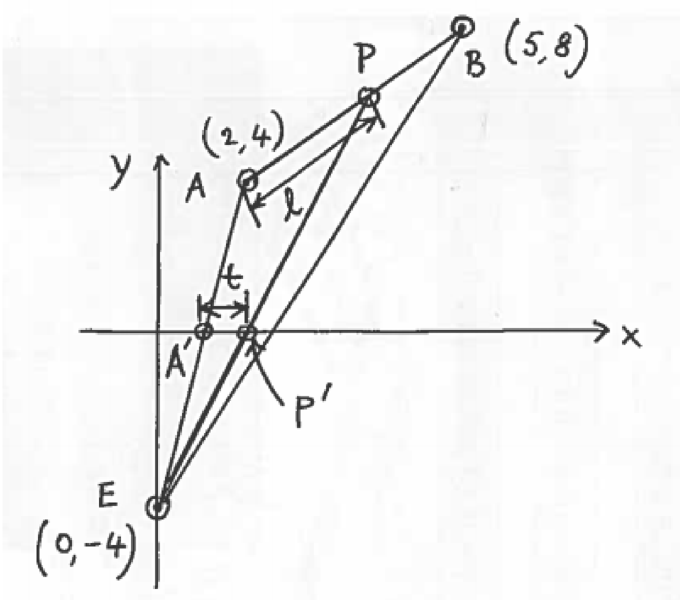


- ● $t = \dfrac{16l}{3l+35}$
- (B) $t = \dfrac{9l}{l+14}$
- (C) $t = \dfrac{2l}{2l+15}$
- (D) $t = \dfrac{15l}{3l+21}$
- (E) $t = \dfrac{8l}{l+3}$
- (F) $t = \dfrac{15l}{2l+11}$
- (G) $t = \dfrac{5l}{3l+4}$
- (H) $t = \dfrac{8l}{l+17}$

Question 11 **[8 points]** The unit vectors perpendicular to the triangular plane formed by A = $(4, -1, -3)$, B = $(5, -5, -2)$ and C = $(3, -3, -3)$ is

- (A) $\pm\begin{pmatrix} -3/13 \\ 4/13 \\ 12/13 \end{pmatrix}$
- ● $\pm\begin{pmatrix} 2/3 \\ 1/3 \\ 2/3 \end{pmatrix}$
- (C) $\pm\begin{pmatrix} -2/3 \\ 1/3 \\ 2/3 \end{pmatrix}$
- (D) $\pm\begin{pmatrix} 3/13 \\ -4/13 \\ 12/13 \end{pmatrix}$
- (E) $\pm\begin{pmatrix} 3/13 \\ 4/13 \\ 12/13 \end{pmatrix}$
- (F) $\pm\begin{pmatrix} 2/3 \\ -1/3 \\ 2/3 \end{pmatrix}$

Question 12 **[15 points]** As shown in the picture below, a bar AB is placed on the two-dimensional plane, with the locations of A = $(2, 4)$ and B = $(5, 8)$. The bar is being viewed by the eye located at E = $(0, -4)$, and the view is being projected on the one-dimensional "screen", which is simply the x-axis. On the x-axis, A′ is the projection of A, P′ is the projection of P and so on. The distance AP is given by l and the distance A′P′ is given by t. The quantity t relates to l as



(A) $t = 2l/(l+5)$ (C) $t = l/(l+7)$ (E) $t = l/(l+2)$ (G) $t = 2l/(l+5)$
(B) $t = l/(l+4)$ (D) $t = 3l/(l+8)$ (F) $t = 3l/(l+9)$ ● $t = 2l/(l+10)$

Question 13 **[4 points]** Why is the factor we use for distance attenuation $1/r^2$?

(A) The volume of a sphere is proportional to $1/r^2$.

(B) The volume of a sphere is proportional to r^2.

(C) The photon density on the surface of a sphere is proportional to r^2.

(D) The area of a sphere is proportional to $1/r^2$.

● The area of a sphere is proportional to r^2.

Question 14 **[6 points]** Take two points on the two-dimensional (x, y) plane: A = $(1, 2)$ and B = $(2, 3)$. Also consider a third point P = $(1, 5)$, from which you drop a perpendicular on to the line AB, intersecting it at point S. The co-ordinates of S and the *implicit form* equation for the line AB are respectively given by

(A) $(3, 7/2)$ and $3x - y - 1 = 0$
(B) $(5/2, 4)$ and $x - y + 1 = 0$
(C) $(7/2, 5/2)$ and $x + y - 1 = 0$
● $(5/2, 7/2)$ and $x - y + 1 = 0$
(E) $(3, 4)$ and $2x - y + 1 = 0$
(F) $(3, 7/2)$ and $x - y - 1 = 0$

Question 15 **[4 points]** Consider a scene with one point light source and two reflective surfaces (without a diffuse component). For a particular pixel, we trace a single primary ray. What is the maximum number of rays traced in the subsequent recursive process, if we cap recursion depth to eight?

⬤ 8 (B) 65536 (C) 16 (D) 256 (E) 24

Answer sheet:

0	0	0	0	0	0	0
1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7
8	8	8	8	8	8	8
9	9	9	9	9	9	9

⟵ please encode your student number to the left, and write your first and last name in the box below.

first and last name:

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Answers must be given exclusively on this sheet: answers given on the other sheets will be ignored. **Please fill the boxes completely.**

QUESTION 1: (A) (B) (C) (D) (■) (F)
QUESTION 2: (A) (B) (C) (■) (E)
QUESTION 3: (A) (■) (C) (D) (E)
QUESTION 4: (A) (B) (C) (D) (E) (■)
QUESTION 5: (A) (■) (C) (D) (E)
QUESTION 6: (A) (■) (C) (D) (E) (F)
QUESTION 7: (A) (B) (C) (D) (■)
QUESTION 8: (A) (B) (C) (D) (■)
QUESTION 9: (■) (B) (C) (D) (E)
QUESTION 10: (■) (B) (C) (D) (E) (F) (G) (H)
QUESTION 11: (A) (■) (C) (D) (E) (F)
QUESTION 12: (A) (B) (C) (D) (E) (F) (G) (■)
QUESTION 13: (A) (B) (C) (D) (■)
QUESTION 14: (A) (B) (C) (■) (E) (F)
QUESTION 15: (■) (B) (C) (D) (E)