University of California San Diego
Department of Computer Science
CSE190: Virtual Reality Technology
Spring Quarter 2018
Midterm Examination
Thursday, May 24th, 2018

Name:_____

This is closed book exam. You may not use electronic devices, notes, books or other written materials.

Good luck!

*Do not write below this line*

| Exercise | Max. | Points |
|---|---|---|
| 1 | 10 | |
| 2 | 10 | |
| 3 | 10 | |
| 4 | 10 | |
| 5 | 10 | |
| 6 | 10 | |
| 7 | 10 | |
| 8 | 10 | |
| **Total** | 80 | |

**1. The VR/AR Spectrum (10 Points)**

a) Put the following VR technologies in the order of **increasing** immersion by assigning them the numbers 1, 2, 3 and 4. 1 being the least immersive, 4 the most immersive. (4 points)

_____ 360 degree stereoscopic video on Merge VR viewer

_____ VR application on Oculus Rift

_____ 360 degree monoscopic video on smart phone

_____ VR application on Oculus Go

b) Name **and** explain **two** differences between **Virtual** Reality and **Augmented** Reality devices. (4 points)

c) What is the difference between **Augmented** Reality and **Mixed** Reality? (2 points)

**2. Human Color Vision (10 Points)**

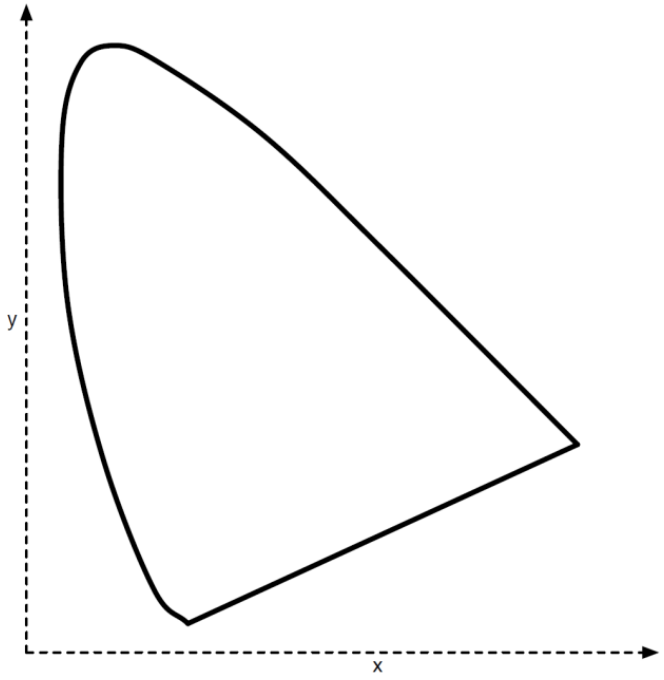
a) How many different **types** of rods and cones are in the retina? (2 points)

b) Describe **one** difference between rods and cones (besides that there are different amounts of types). (2 points)

c) What is the **tristimulus** theory, and how does it help us in Computer Graphics? (2 points)

d) Can a computer monitor produce **all** the colors our eyes can distinguish? Why/why not? (2 points)

e) The diagram below shows the the x-y plane of the CIE color space. Mark and label one plausible location each for the red, green, and blue basis colors. Indicate the color gamut for the color basis you have shown. (2 points)



**3. Stereo Imaging Techniques (10 Points)**

a) The owner of a movie theater wants to start showing 3D movies and is torn between **anaglyphic**, **active** and **passive** stereo. Name one advantage **and** one disadvantage for **each** of them which it has compared to the other two. (6 points)

Anaglyphic:

Active Stereo:

Passive Stereo

b) Briefly describe how an **autostereoscopic** display with a **barrier** screen works. Additionally, draw a sketch with a few light paths from screen pixels to right and left eyes, and where they pass through the barrier screen. (2 points)

c) Many stereo imaging techniques suffer from **ghosting**. Briefly describe what ghosting is. (1 point)

d) Name an example for a 3D display which completely **avoids** ghosting? (1 point)

**4. VR Display Characteristics (10 Points)**

Briefly **define** the following terms in the context of VR displays and **estimate** the values for the Oculus Rift. (2 points each)

a) Field of View (FOV):

b) Field of Regard (FOR):

c) Spatial Resolution:

d) Total number of pixels per eye:

e) Refresh Rate:

**5. Interior Design (10 Points)**

You have been hired as a consultant by a successful furniture company to help them design an application for interior design (i.e., to help people lay out new furniture in their house) using VR or AR. During this process you need to make the following decisions.

a) Name **two** benefits that VR has over AR for this application. (2 points)

b) Name **two** benefits that AR has over VR for this application. (2 points)

c) Of all the existing and currently available VR and AR devices, which one would you recommend that the company design their application for initially? Give **three** reasons for your decision. (3 points)

d) What are the **three** most important features you recommend that the interior design application that runs on the device you recommended in part c) needs to have? (3 points)

**6. CAVE vs HMD (10 Points)**

a) Name **three** advantages of CAVEs over HMDs (0.5 points each)

b) Name **three** advantages of HMDs over CAVEs (0.5 points each)

c) Write down the **sequence** of matrix transformations from object space to canonical view volume and briefly describe each one for HMDs and CAVEs: (6 points)

HMDs:

CAVEs:

**7. VR Rendering Optimization (10 Points)**

a) Describe the Asynchronous **Time** Warp (ATW) by answering the following questions.

Why is it done? (2 points)

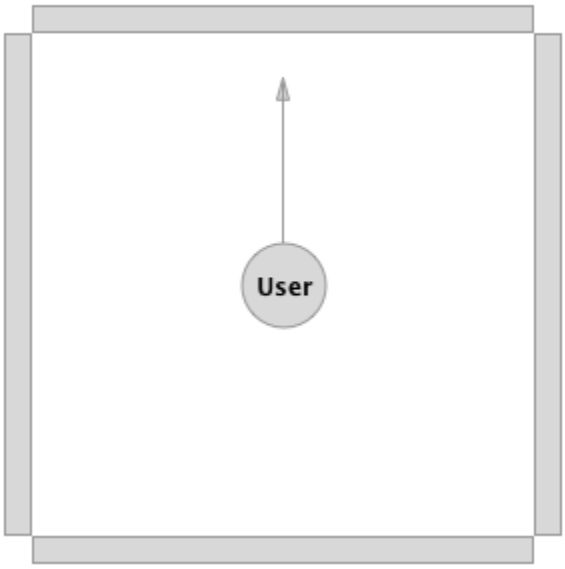
At what rendering stage is it done? (1 point)

How does it work? (3 points)

b) Describe two ways in which the Asynchronous **Space** Warp (ASW) differs from ATW. (4 points)

**8. Virtual CAVE System (10 points)**

Bob is trying to simulate a 360-degree CAVE system on an Oculus Rift HMD using OpenGL. He created four virtual CAVE screens, where user will stand in the center surrounded by four textured quads, as shown in the figure below:




The virtual cave scene in top-down view

Bob wants to render a skybox of the CSE courtyard to the CAVE screens in stereo, but he encounters some problems and asks you for help.

a) Render to Texture: Bob understands that custom frame buffer objects would be a good way to render the skybox to the CAVE screens, but he cannot figure out how to use FBOs correctly. He wrote down this pseudocode with place holders: (4 points)

```
for_each_eye {
        For_each_screen {
                                ____
                                ____
                                ____
                                ____
                                ____
                        }
                }
```

What is missing is the five function calls needed for the core loop above. Put the function calls below in the correct order and fill in the letters A through E (i.e., the abbreviations of the function calls as given below) in the above pseudo code.

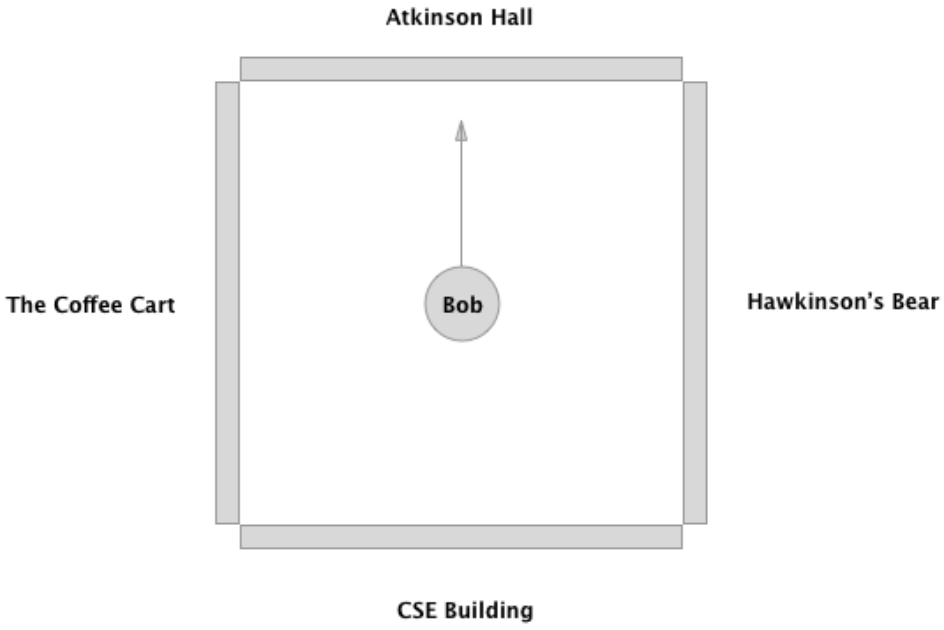
A. P = GetOffAxisProjectionMatrix();
B. BindFrameBufferToDefault();
C. BindMyFrameBuffer();
D. DrawQuad();
E. DrawSkybox(P);

b) Now Bob is implementing the GetOffAxisProjectionMatrix() function. The off-axis perspective matrix is constructed from the formula below. Explain the role of each matrix in this formula. (3 points)

$$P' = PM^T T$$

c) Bob notices that the images rendered on the four screens are roughly correct but not aligned to each other. Name **two** things Bob might be doing wrong, and briefly explain how they would cause alignment problems. (2 points)

d) Finally, Bob is able to render the skybox correctly on the CAVE screens. However, he now has the problem that the skybox rotates when he turns his head. For example: when he starts out looking straight ahead where he sees Atkinson Hall (see figure below), and then rotates his head by 90 degrees to the left, he sees the CSE building.




What could he be doing wrong? (1 point)