PRIFYSGOL ABERYSTWYTH UNIVERSITY

SEMESTER ONE 2025

COMPUTER SCIENCE

CS32420 : COMPUTER GRAPHICS AND GAMES

Time allowed: **2 HOURS**

Answer **THREE** from **SIX** questions.

Answer **TWO** questions from Section A, **ONE** question from Section B.

All questions carry equal marks.

YOU MAY BRING THE FOLLOWING INTO THE EXAMINATION:
UP TO 3 SHEETS OF NOTES ON A4 PAPER (WHICH MAY BE DOUBLE-SIDED). THERE ARE NO ADDITIONAL RESTRICTIONS ON CONTENT OR FORMATTING OF THESE NOTES.
NO ELECTRONIC DEVICES.

CALCULATORS ARE PERMITTED (CASIO FX991, FX83 OR FX85 MODELS ONLY)

STUDENTS MAY SUBMIT ANSWERS TO THIS PAPER IN EITHER WELSH OR ENGLISH

Dan Jo
15.12.25

Once seated, students may complete the front cover of the answer book(s) and the attendance slip ONLY.

DO NOT TURN THE EXAMINATION QUESTION PAPER OVER UNTIL INSTRUCTED TO DO SO.

SECTION A

Answer **TWO** from **THREE** questions

1. This question is on Software Engineering.

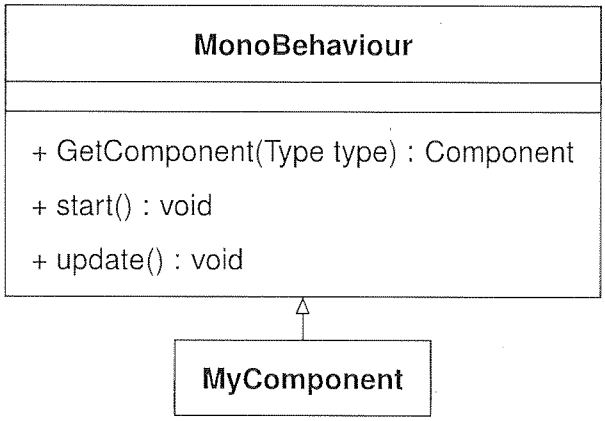


Figure 1: UML class diagram showing a simplified version of Unity's MonoBehaviour class.

Figure 1 shows partial UML diagram of the MonoBehaviour class in Unity.

a) What functions would you add to the MyComponent class to add behaviour:

(i) When the GameObject is created. [1 mark]

(ii) On every frame. [1 mark]

(iii) To detect the first frame of a collision. [1 mark]

b) What functions already exist in MonoBehaviour (and its base classes) that allow you to:

(i) To find other components on the same GameObject? [1 mark]

(ii) Remove a GameObject, component, or asset. [1 mark]

(iii) Clone an object and return the clone. [1 mark]

c) With reference to figure 1 describe the composite design pattern and how Unity implements it. In your answer refer to the 3 functions shown in figure 1, describe what they do and how they are used in the pattern. [12 marks]

d) Discuss three principal advantages of composition compared to inheritance? [12 marks]

2. This question is on lighting, shading and shadows.

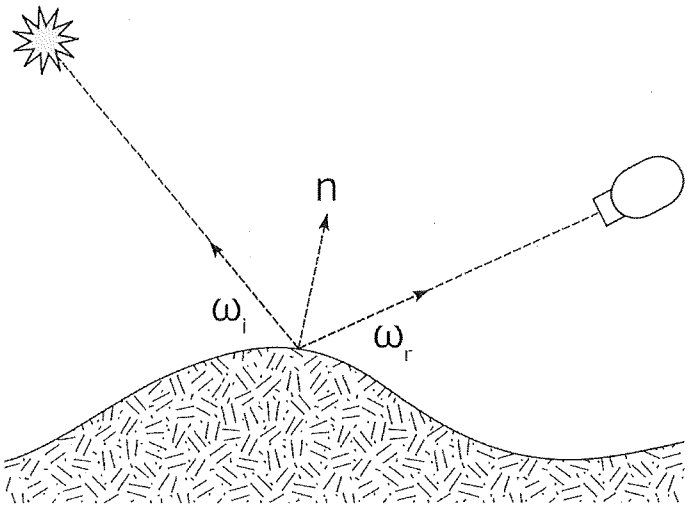


Figure 2: Simplified view of a bidirectional reflectance distribution function, showing a light source interacting with a surface from the point of view of a camera. The vectors are labelled as follows: ω_r - the Vector from surface to view point. ω_l - Vector from surface to light. n - surface normal.

a) A Bidirectional Reflectance Distribution Function (BRDF) describes how light is reflected from a surface. With reference to the BRDF and micro-facets describe:

- Lambertain diffuse reflection. [6 marks]
- Specular reflection. [6 marks]
- Roughness. [6 marks]

b) Describe how the photon-mapping algorithm simulates caustics (lighting). [12 marks]

3. This question is on matrix and vector mathematics.

Figure 3: Vector Addition $\overrightarrow{a+b}$ where $\overrightarrow{a} = \begin{bmatrix} -1.0 & 1.0 \end{bmatrix}$ $\overrightarrow{b} = \begin{bmatrix} 1.0 & 1.0 \end{bmatrix}$

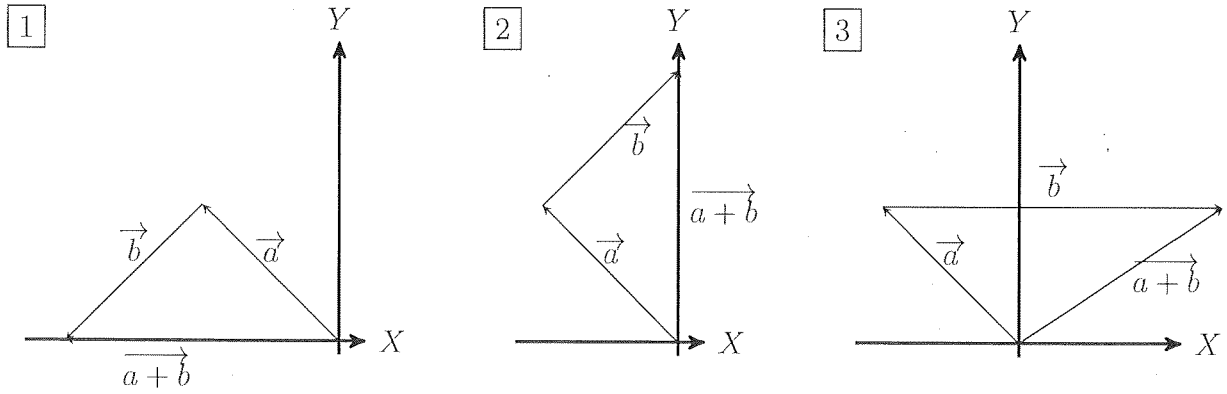
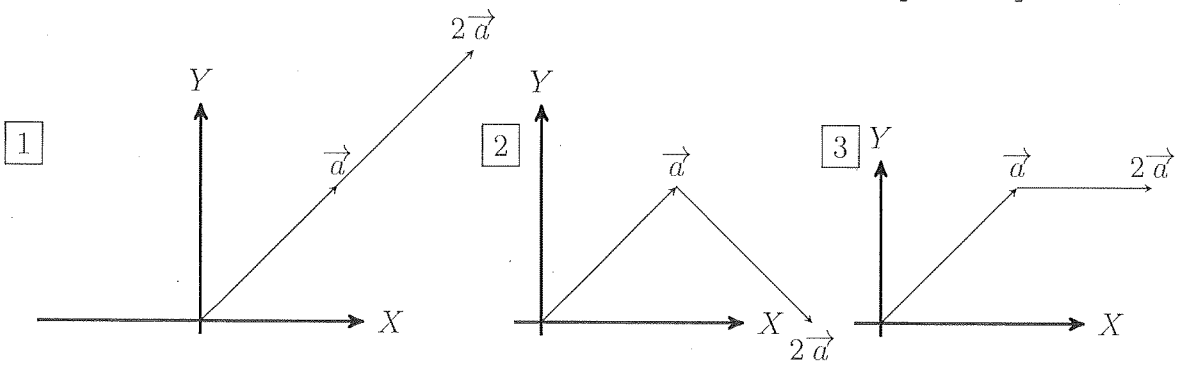


Figure 4: Vector Scaling $\overrightarrow{2a}$ where $\overrightarrow{a} = \begin{bmatrix} 1.0 & 1.0 \end{bmatrix}$



a) Which of the three diagrams in figure 3 correctly illustrates vector addition (in each case, $\vec{a}$ and $\vec{b}$ are position vectors)? [1 mark]

b) Which of the three diagrams in figure 3 correctly illustrates vector scaling? [1 mark]

Question continues on next page.

c) For each of the following equations supply the missing matrix.

An example is:

$$\begin{bmatrix} 1.5 & 2.0 \end{bmatrix} \mathbf{X} = \begin{bmatrix} 1.5 & -2.0 \end{bmatrix}$$

where X is **Reflection about the y-axis.**

Answer

$$\begin{bmatrix} 1.5 & 2.0 \end{bmatrix} \begin{bmatrix} 1.0 & 0.0 \\ 0.0 & -1.0 \end{bmatrix} = \begin{bmatrix} 1.5 & -2.0 \end{bmatrix}$$

(i)

$$\begin{bmatrix} 0.25 & 1.0 \end{bmatrix} \mathbf{X} = \begin{bmatrix} 0.25 & 1.0 \end{bmatrix}$$

where X is the **Identity matrix.**

[3 marks]

(ii)

$$\begin{bmatrix} 1.5 & 2.0 \end{bmatrix} \mathbf{X} = \begin{bmatrix} 0.75 & 1.0 \end{bmatrix}$$

where X **scales by 0.5 in both axes.**

[3 marks]

(iii)

$$\begin{bmatrix} 1.5 & 2.0 \end{bmatrix} \mathbf{X} = \begin{bmatrix} 0.0 & 2.0 \end{bmatrix}$$

where X **sets the x-axis value to zero, keeps y-axis value.**

[3 marks]

(iv)

$$\begin{bmatrix} 1.5 & 2.0 \end{bmatrix} \mathbf{X} = \begin{bmatrix} 2.0 & 1.5 \end{bmatrix}$$

where X **swaps x and y values.**

[3 marks]

(v) Give a 2 by 2 matrix that **rotates a vector by an arbitrary angle** θ.

[4 marks]

d) Write a pseudocode algorithm to determine the distance between two points.

[5 marks]

e) Write a pseudocode algorithm to determine if one line (3D) is at 90 degree (orthogonal) to another line (3D) in any direction [7 marks]

Turn over for Section B.

SECTION B

Answer **ONE** from **THREE** questions

4. Write a professional and technical blog-post on "How the 3D Rendering pipeline transforms 3D geometry into 2D images". As part of your answer identify the various stages of the pipeline and describe their operation. By the end of your blog post the reader should be able to understand:

   - The core problem the topic/algorithm is trying to address.
   - How this problem is addressed.
   - How well this problem is addressed.
   - What issues arise from this solution.
   - What alternatives exist. [40 marks]

5. Write a report describing a design for the following problem. Your solution should include at least one appropriate UML diagram.

   You have been asked to create a tile based rule sub-system for a puzzle game in Unity. The game consists of tiles on a grid. Some tiles can move but only from grid cell to grid cell (not stopping in between). Each tile has different properties that affect how the tile reacts to player actions or other moving tiles. There can be multiple tiles per grid cell, unless otherwise specified by the properties.

   The properties are:

   - Slide. If pushed by another tile the tile will slide in the direction of the push unless blocked.
   - Block. If pushed by another tile the tile will not slide and will block motion.
   - Player. The block is controlled by the player and will respond to left, right, up, down command input by moving 1 tile in the appropriate direction (unless blocked by a 'Block' tile).
   - Sink. Any tile that occupies the same grid cell as a sink tile is destroyed and the sink animation played, unless the tile has the property 'float'.

Question continues on next page.

- Float. Should the tile occupy the same grid cell as a sink tile, the tile will not Sink, no other behaviour is altered.
- Win. Any 'Player' tile that occupies the same grid cell as the win tile causes the level to be won.
- Defeat. Any 'Player' tile that occupies the same grid cell as the defeat tile causes the level to be lost.

A tile may have any number of these properties. A tile may have no properties.

Design a flexible and extensible solution for this design. [40 marks]

6. This question is on Artificial Intelligence in Video games.

You have been asked to design the AI for a box packing bot. In order for the items to fit, the bot needs to place items into the boxes according to a recipe. There are three box shapes with a recipe each (3 total). The boxes are cuboid, triangular prism and cylindrical.
The recipes are:

- Cuboid: green thing, green thing, blue thing.
- Triangular prism: green thing
- Cylindrical: blue thing, blue thing.

The bot collects the boxes one at a time (the type is random but can be sensed by the bot) and must place the things inside. It does this by either picking up a blue thing or picking up a green thing, and putting the thing in its hand in the box. The bot can sense if it cannot pickup an item (e.g. if there are none left) and can sense it the item was successfully placed in the box. If the bot successfully places the required things in the box it places the box in the success pile. If the bot fails to pack the box (e.g. a thing doesn't fit) it places the box in the fail pile.

Three design patterns for artificial intelligence were given in class; state-machines, decision trees and behavior trees. Choose an appropriate design pattern and justify your decision. Describe how you will implement a solution for creating the bot AI and discuss the advantages and disadvantages of the chosen algorithm. Your solution should include at least one diagram. [40 marks]

END OF PAPER