CRT03

UNIVERSITY OF BOLTON

CREATIVE TECHNOLOGIES

BSc (Hons) Games Programming

SEMESTER 2 EXAMINATION 2022/2023

GAME DYNAMICS

MODULE NO: GAP5006

Date: Tuesday 9th May 2023 **Time: 2:00pm – 4:00pm**

INSTRUCTIONS TO CANDIDATES:

There are FOUR questions on this examination. You MUST answer ALL questions.

Calculators may be used for this examination.

Note: Formula sheets are attached at the rear of the examination.

Where necessary, assume that acceleration due to gravity = 9.8 m/s^2.

Unless stated otherwise, round to two decimal places where appropriate.

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Question 1

A car with a mass of 1.4 tonnes is moving at 17.5 m/s and collides with another car with a mass of 1.1 tonnes, which is also moving in the same direction at 11 m/s.

a) Calculate the velocity of each car after a perfectly elastic collision. [9 marks]

b) Calculate the velocity of each car after a perfectly inelastic collision. [3 marks]

c) Calculate the kinetic energy lost during the perfectly inelastic collision, in Joules. [9 marks]

d) Highlight and explain, with examples, the key differences between a perfectly elastic collision, perfectly inelastic collision, and partially elastic collision. [4 marks]

Total 25 marks

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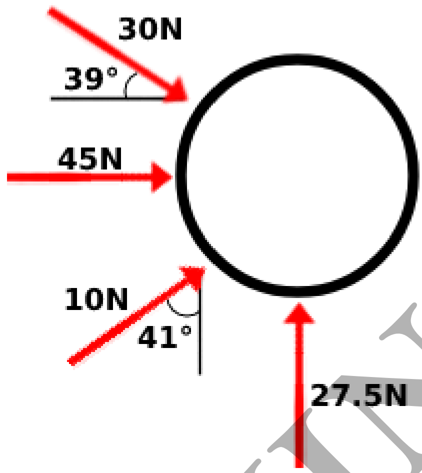
Question 2

A body has a number of forces acting on it – all acting through the body's centre of mass – as shown below.



a) Calculate the magnitude of the resultant force on the body to one decimal place. [15 marks]

b) Calculate the direction of the resultant force on the body to one decimal place, in degrees. [4 marks]

c) After the forces in part a) are applied, the body is found to accelerate by 2.63 m/s^2. Assuming no losses, calculate the mass of the body. [3 marks]

d) If the body was initially at rest, and the resultant force was applied through the centre of mass, and assuming constant acceleration and no losses, how far would the body move in 1.5 seconds? [3 marks]

Total 25 marks

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Question 3

a) In game development, it is often useful to normalize our vectors into unit vectors. In a game, the player is moving in a direction that is inclined 76 degrees to the positive x-axis and is travelling at 5 meters per second. What is the normalized/unit vector? Write your answer in cartesian notation. [6 marks]

b) Object A is located at position [4, 8, -3] and Object B is located at [1, -5.3, 6]. Calculate the distance between these two points in meters. [4 marks]

c) Express the dot product of Vector A [5,-3,5] and Vector B [1, 0, -3]. [4 marks]

d) Express the cross product of Vector A [5,-3,5] and Vector B [1, 0, -3] using cartesian notation. [5 marks]

e) In a game, the Enemy fires at the Player if its position is *in front* of the enemy position. Outline how to calculate whether the Player position is in front of the Enemy position, when the Enemy is facing a specified direction, using vectors. [6 marks]

Total 25 marks

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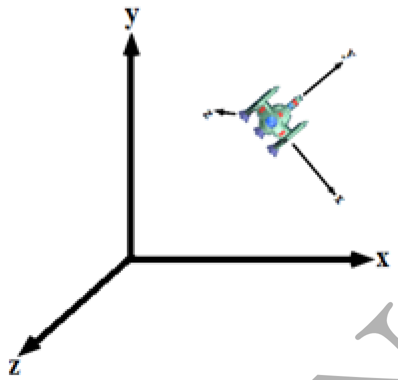
Question 4

An object's vertices are specified in object coordinates and the object is translated and rotated from the world space / coordinates, as shown below.



The object above has a vertex at (2, 3.5, -4.1), in object space, and the object was translated by (4, -2.5, 3.3) in world space, and then rotated counterclockwise 53° about the z-axis, and scaled by 3 along the x and z axes.

a) Specify the translation matrix as a 4x4 matrix. [4 marks]

b) Specify the rotation matrix as a 4x4 matrix. [4 marks]

c) Specify the scale matrix as a 4x4 matrix. [4 marks]

d) Transformation matrices often include a *homogenous* coordinate. Explain why a *homogenous* coordinate is added and give an example of where such a coordinate value may not be equal to 1. [5 marks]

e) For rotation, rather than directly calculating a rotation matrix, the rotation is to be specified using quaternions. Specify the above rotation as a *unit* quaternion. [5 marks]

f) For rotation, rather than directly calculating a rotation matrix, the rotation is to be specified using quaternions. Briefly outline why quaternions are often used for rotations in game engines. [3 marks]

END OF QUESTIONS

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FORMULA SHEET FOR GAME DYNAMICS

Vectors

Dot product: $\bar{a} \cdot \bar{b} = |a||b| \cos\theta$

Cross product: $\bar{a} \times \bar{b} = (|a||b| \sin\theta)\,\hat{n}$ where $\hat{n}$ is a vector at 90° to vectors $\bar{a}$ and $\bar{b}$

Quaternions

Unit quaternion, $q = \cos\frac{\theta}{2} + (ai + bj + ck)\sin\frac{\theta}{2}$

Equations of motion

Linear equation of motion
$v_{avg} = s / t$
$v = u + at$
$s = ut + ½at^2$
$v^2 = u^2 + 2as$

Forces

Resultant force, F = ma; where m = mass and a = acceleration

Conservation of momentum

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ where m_1/m_2 are the masses of body 1 / 2
u_1 / u_2 are the velocities before impact of bodies 1 / 2
v_1 / v_2 are the velocities after impact of bodies 1 / 2
$v_1 – v_2 = -e(u_1 - u_2)$ where e is the coefficient of restitution

Energy

Kinetic energy, KE = $½mv^2$ where v = velocity

END OF PAPER