[CRT09]

UNIVERSITY OF GREATER MANCHESTER

SCHOOL OF CREATIVE TECHNOLOGIES

GAMES PROGRAMMING

SEMESTER TWO EXAMINATIONS 2024/2025

GAME DYNAMICS

MODULE NO: GAP5006

Date: Thursday 15 MAY 2025 **Time: 14:00 – 16:00**

INSTRUCTIONS TO CANDIDATES:

There are 4 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.

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Question 1:

Vectors

a) Consider a player located at point **P** (2, 5, -3) and an enemy located at the point **E** (-4, 3, 6) in a 3D space. Compute the Euclidean distance between these two points in meters, rounding your result to two decimal places.

[4 Marks]

b) In game development, it is common to normalize vectors to unit vectors for consistent movement direction. If a player is moving at a speed of 6 meters per second in a direction that forms an angle of 30 degrees with the positive x-axis, what is the normalized / unit vector in Cartesian coordinates.

[6 Marks]

c) 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]

d) Express the dot product of the Vector A [2, -2, 5] and Vector B [-4, 6, 1].

[4 Marks]

e) Express the cross product of the Vector A [3, 5, -2] and Vector B [5, 6, 7] using cartesian notation.

[5 Marks]

Total: 25 Marks

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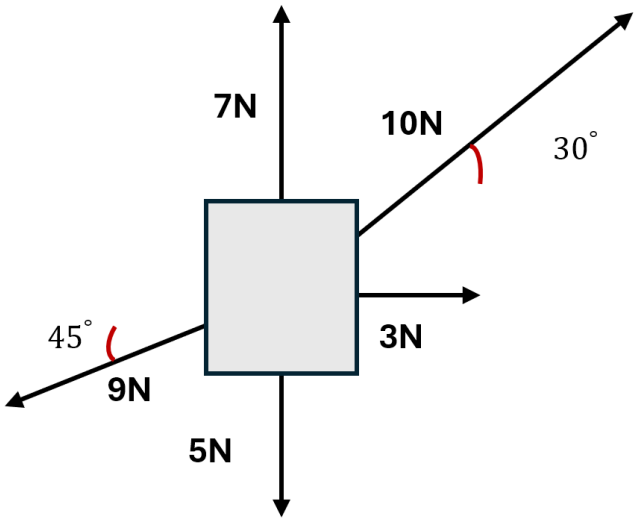
Question 2:

Newtonian Dynamics

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



a) Calculate the magnitude of the resultant force on the body to one decimal place. Show your work.

[15 Marks]

b) Calculate the direction of the resultant force on the body to one decimal place, in degrees. Show your work.

[4 Marks]

c) After the forces in part a) are applied, the body is found to accelerate by 4.5 **m/s²**. Assuming no losses, calculate the mass of the body.
Show your work.

[3 Marks]

Question 2 Continues Over the Page…

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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 3.2 seconds, to two decimal places?
Show your work.

[3 Marks]

Total: 25 Marks

Question 3:

Collision Physics

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

A car with a mass of 1.2 tonnes is moving at 15 **m/s** and collides with another car with a mass of 1.5 tonnes, which is also moving in the same direction at 18 **m/s**. Calculate the velocities of the cars.

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 perfectly elastic collision, inelastic collision, and partially or nearly elastic collision.

[4 Marks]

Total: 25 Marks

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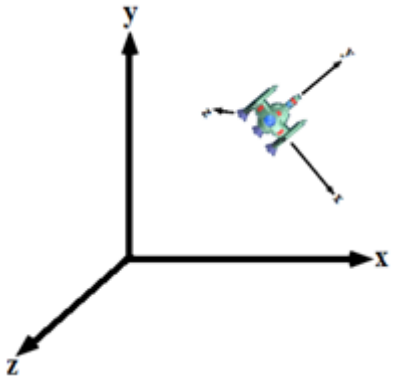
Question 4:

Matrices & Transformations

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



The object above has a vertex at (5, 2.5, 3), in object space, and the object was translated by (6, 2.5, 8.2) in world space, and then rotated counterclockwise 50° about the y-axis, and scaled by 1.25 along the x and y 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]

Question 4 Continues Over the Page…

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]

Total: 25 Marks

End of Questions

Please Turn the Page for the Formula Sheet

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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 EXAM