[CRT12]

UNIVERSITY OF BOLTON

CREATIVE TECHNOLOGIES

BSC (HONS) GAMES PROGRAMMING

SEMESTER TWO EXAMINATION 2018/2019

APPLIED PHYSICS

MODULE NO: GAP5003

Date: Wednesday 22nd May 2019 **Time: 14:00 – 16:00**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions on this examination.

Answer FOUR questions

Calculators may be used for this examination.

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

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Creative Technologies
BSc (Hons) Games Programming
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Applied Physics
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Where necessary, assume acceleration due to gravity = 9.8 m/s^2.

Question 1

a) Within a game, an Enemy object is positioned at coordinates of (1.6, 1.8, -2.8) and is facing in the x-direction. A Player object is currently at position (2.5, 1.5, -2.8). What angle would the Enemy need to be rotated by, to face the Player position? **[11 marks]**

b) Using appropriate calculations, what would be the required rotation axis, for the rotation in a)? As such, state whether this would be a clockwise or anti-clockwise rotation. **[5 marks]**

c) Whilst the Enemy is rotating, a thin bullet is fired in direction: 0.7i - 0.5j – 0.3k. What would be the shortest distance of the bullet to the Player's position? **[9 marks]**

Question 2

a) It is found that an obstacle within a game has the following 3 points on a face: (5, 3, 2.5), (8, 5, 7) and (-2, 1, -8). What would the Cartesian equation of the plane, representing the obstacle, be? **[8 marks]**

b) What is the shortest distance of the obstacle specified in a) from the origin? **[4 marks]**

c) The vertex of a game object is at point (1.8, 1.1, -2.5). What is the shortest distance between the vertex and the obstacle in a)? **[5 marks]**

d) During a game, a ray cast is made given by the line, $\bar{r} = 0.5i + 2j - 3k + \lambda(4i + 2j - 8k)$. At what point would the ray cast intersect with the obstacle specified in a)? **[6 marks]**

e) If it was required to know which 'side' of a plane a point was, in relation to a plane, how could this most 'easily' be calculated? **[2 marks]**

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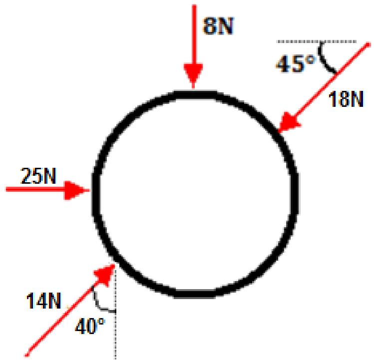
<u>Question 3</u>

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. **[13 marks]**

b) Calculate the direction of the resultant force on the body. **[4 marks]**

c) If the body has a mass of 3.2kg, and the same <u>magnitude</u> of force calculated in a) was applied, whilst the body is moving horizontally, and in contact with another surface, what would be the dynamic coefficient of friction between the surface and body, if the body accelerates by $0.5 m/s^2$, assuming no other losses?

[8 marks]

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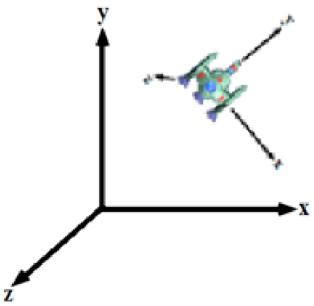
<u>Question 4</u>

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



The object above has a vertex at (1.1, 1.9, -0.4), in object space, and the object was translated by (3.6, 4.7, -1.3) in world space, and then rotated 32° <u>clockwise</u> about the z-axis, and scaled by 1.2 in the x-axis, and by 1.5 in the y 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) Calculate the object's vertex in world space coordinates, using the matrices specified in a), b) and c). **[8 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]**

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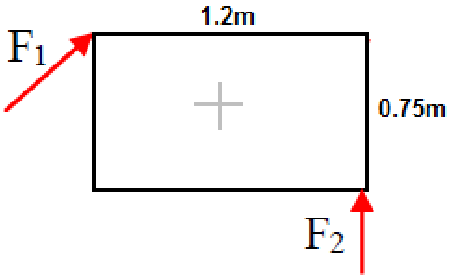
Question 5

A game object is modelled as a cuboid. The cuboid has two forces acting on it, away from its centre of mass in the x and z directions, as shown below.



The cuboid is free to rotate about its centre of mass.

a) The Force $\overline{F1}$ is given by the vector 120i-100k and Force $\overline{F2}$ is given by the vector -80k. Assuming that the forces reduce to a single force, calculate the overall torque vector and specify the overall magnitude and rotation axis of the torque. **[12 marks]**

b) The moment of inertia for a cuboid rotating about its centre of mass, about a principal axis, is given by: $= \frac{m(l^2+w^2)}{12}$. If the mass of the cube is 900kg, assuming no losses, what would the angular acceleration of the cuboid be? **[6 marks]**

c) If the cube was initially at rest before the forces were applied, and assuming no losses and constant torque throughout, what angle, in degrees, would the cube rotate by in 0.6 seconds? **[7 marks]**

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Question 6

A lorry of mass 4.1 tonnes, travelling at 20km/hr, collides into a car, of mass 1.3 tonnes, travelling in the opposite direction at 35km/hr. After collision, the vehicles travel at the same velocity.

a) What type of collision is this said to be? **[1 mark]**

b) At what velocities, in standard SI units, would the vehicles be travelling after the collision? **[9 marks]**

c) If the vehicles, in the scenario above, before collision, were involved in a collision where it was found that, rather than travelling at the same velocity afterwards, a coefficient of restitution of 0.4 applied, at what velocities would the vehicles be travelling after collision? **[14 marks]**

d) What type of collision is that in c) said to be? **[1 mark]**

END OF PAPER

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FORMULA SHEET FOR APPLIED PHYSICS

Vector equations

Vector equation of a 3D line:	$\bar{\boldsymbol{r}} = \bar{\boldsymbol{a}} + \boldsymbol{\lambda}\bar{\boldsymbol{b}}$
Distance of a point from a 3D line:	$\boldsymbol{d} = \dfrac{\lvert \bar{\boldsymbol{b}} \times (\bar{\boldsymbol{p}} - \bar{\boldsymbol{a}})\rvert}{\lvert\bar{\boldsymbol{b}}\rvert}$
Shortest distance between 2 skew 3D lines:	$\boldsymbol{d} = \left\lvert \dfrac{(\boldsymbol{a_1} - \boldsymbol{a_2}) \cdot (\boldsymbol{b_1} \times \boldsymbol{b_2})}{\lvert \boldsymbol{b_1} \times \boldsymbol{b_2}\rvert} \right\rvert$
Cartesian Equation of a plane:	$\boldsymbol{ax} + \boldsymbol{by} + \boldsymbol{cz} = \boldsymbol{D}$
Distance of a plane from the origin:	$\boldsymbol{d} = \dfrac{\boldsymbol{D}}{\lvert\bar{\boldsymbol{n}}\rvert}$
Distance of a point from a plane	$\boldsymbol{d} = \dfrac{\bar{\boldsymbol{p}} \cdot \bar{\boldsymbol{n}} - \boldsymbol{D}}{\lvert\bar{\boldsymbol{n}}\rvert}$
Intersection of a 3D line on a plane:	$\boldsymbol{\lambda} = \dfrac{\boldsymbol{D} - \bar{\boldsymbol{a}} \cdot \bar{\boldsymbol{n}}}{\bar{\boldsymbol{b}} \cdot \bar{\boldsymbol{n}}}$

Rotation using matrices

For a rotation of θ about the **x-axis**: R = $\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$

For a rotation of θ about the **y-axis**: R = $\begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$

For a rotation of θ about the **z-axis**: R = $\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$

Quaternions

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

Equations of motion

Linear equation of motion	Angular equation of motion
$v_{avg} = s / t$	$\omega_{avg} = \theta / t$
$v = u + at$	$\omega = \omega_0 + \alpha t$
$s = ut + ½at^2$	$\theta = \omega_0 t + ½\alpha t^2$
$v^2 = u^2 + 2as$	$\omega^2 = \omega_0^2 + 2\alpha\theta$

ω_0 = initial angular velocity

$v = \omega r$ and $a = \alpha r$

Angular motion

Torque, T = Fr   where F is the resultant force applied and r is the radius at which it acts.

T=Iα where I is the moment of Inertia about the rotation axis and α is the angular acceleration

Forces

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

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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
$v_1 – v_2 = -e(u_1 - u_2)$ for collisions, where e = coefficient of restitution

Energy

Kinetic energy, KE = $\frac{1}{2}mv^2$ where v = velocity

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