On admission to the examination room, you should acquaint yourself with the instructions below. You <u>must</u> listen carefully to all instructions given by the invigilators. You may read the question paper, but must <u>not</u> write anything until the invigilator informs you that you may start the examination.

You will be given five minutes at the end of the examination to complete the front of any answer books used.

May/June 2014   SE3VR11 2013/14 A 001

3 Answer Books & Treasury Tag
Any calculator (including programmable calculator) permitted
Open Book (Notes and books permitted)

UNIVERSITY OF READING

VIRTUAL REALITY (SE3VR11)

Two hours

Answer any **THREE** out of FOUR questions.

Use a separate Answer Book for **EACH** Question.

EACH Question is 20 marks.

1. (a) Three points $A = (3, 2, -2)$, $B = (-2, 2, -0.5)$ and $C = (1, 4, 3)$ make up the vertices of a polygon.
Assuming a clockwise winding, calculate the normal vector for the front face of the polygon to 2 decimal places. (6 marks)

(b) The polygon shown in Figure 1 is defined by the points:
$P_0 = (1, 1.2, 0)$ and $P_1 = (3, 2.5, 0)$.
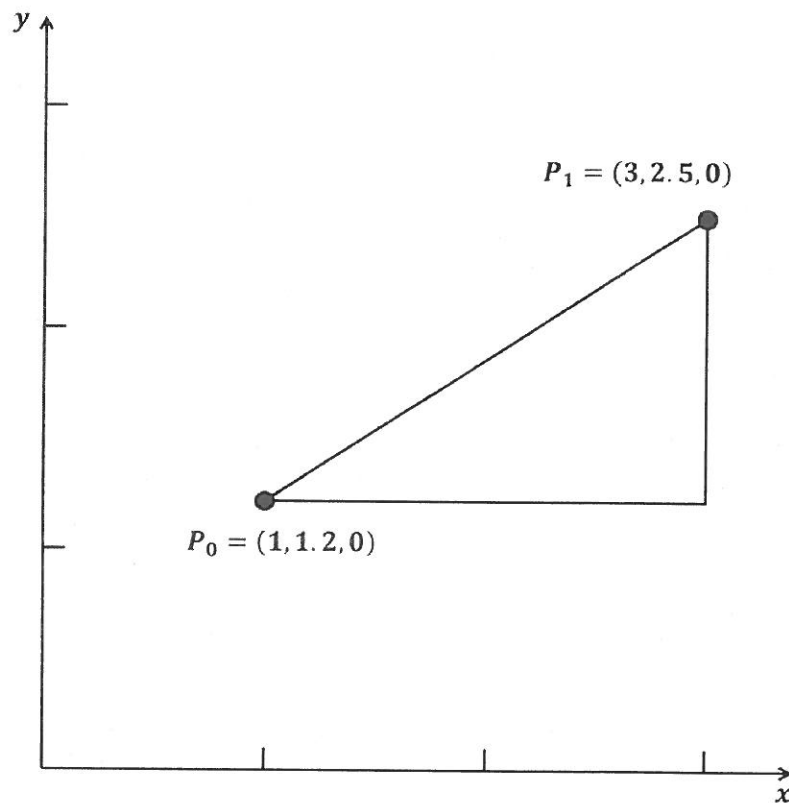The polygon needs to be scaled to double its current size, but P_0 must remain in the same location.

$P_1 = (3, 2.5, 0)$

$P_0 = (1, 1.2, 0)$

Figure Q1

(i) Write down EACH of the matrices needed to perform this operation. (2 marks)

(ii) Calculate a single matrix that would perform the same transformation of the object. (4 marks)

(iii) What is the new coordinate of point P_1 after the transformation? (2 marks)

(iv) Calculate a single matrix that will rotate the polygon 45 degrees around the direction of the z-axis about the point P_0. (6 marks)

2. (a) One of the methods for rendering a 3D environment, which contains objects and light sources, is ray casting.

(i) Basing your answer on the environment shown in Figure Q2, which coordinate system is being used. Explain your answer.
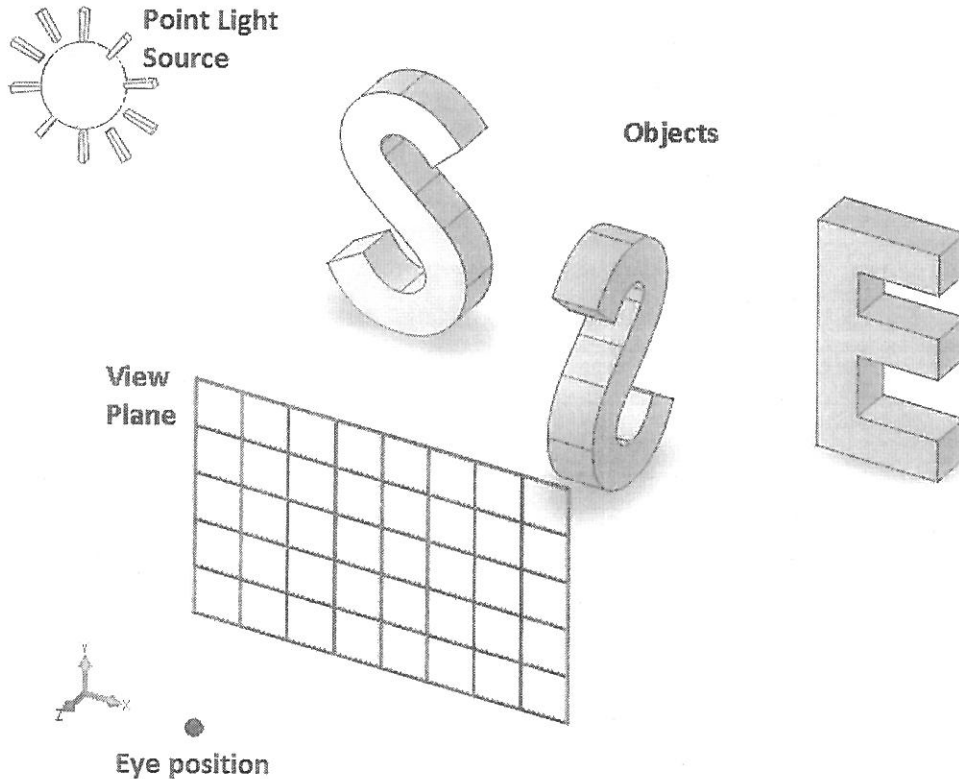
(1 mark)

Figure Q2

(ii) The 'View Plane' in Figure Q2 is used in Ray Casting. Describe two methods to increase accuracy of rendered images when using the Ray Casting process.　(3 marks)

(iii) Describe THREE common systems of Colour Representation and detail how they differ from each other. Which colour system do you feel is best suited to modern computer graphics?　(4 marks)

(iv) In the OpenGL Reflectance Model, describe how the shininess value, or 'n', in Specular Reflection would affect the rendering and perception of an object.　(2 marks)

(Question continues over page)

(b) The following questions are based on Constructive Solid Geometry.

   (i) Constructive Solid Geometry is a form of Solid Modelling. Describe what the term Solid Modelling means and how it differs to 3D Modelling.   (2 marks)

   (ii) State and describe two advantages and two disadvantages of using Constructive Solid Geometry.   (2 marks)

   (iii) The object in Figure Q2-2 was created using Constructive Solid Geometry.
   Describe how this object could be created by drawing a hierarchy of Boolean operations, using the Solid Geometries shown in Figure Q2-3, noting any intermediate objects created by these operations.   (6 marks)
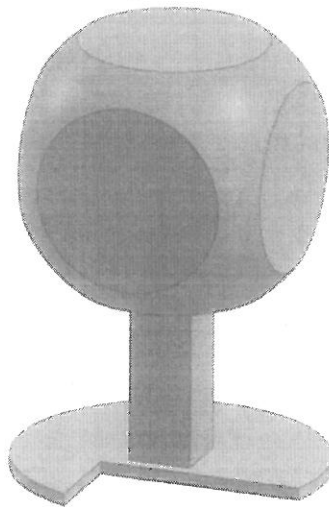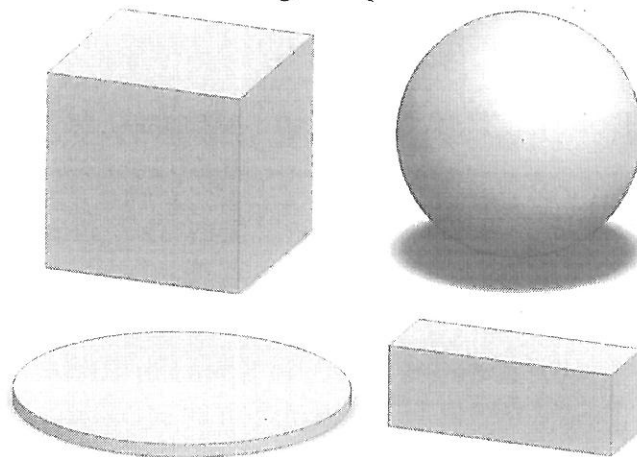
Figure Q2-2

Figure 2-3

3. A military technology contractor has been commissioned to design a Virtual Reality system for training medics to perform surgery under battlefield conditions. The Virtual Reality solution is to replace the current training method which involved role play with actors.

   (a) Give TWO advantages and TWO disadvantages of using Virtual Reality technology for training the medics over the current method.
   (4 marks)

   (b) When selecting the visual display technology it was desired to give the trainee both a highly immersive experience and also a clear and detailed view of the anatomy they are operating on. With reference to two common visual display technologies explain why these might be conflicting requirements and which would best suit each requirement.
   (4 marks)

   (c) A realistic audio display was added to improve the feeling of presence when using the simulator. For one scenario, the virtual environment consists of an operating table in a tent close to soldiers firing weapons.

      (i) Explain why it is possible for a human to distinguish sounds originating inside the tent and outside the tent and how the auditory rendering engine would treat sounds differently to recreate the environment believably.
      (4 marks)

      (ii) Compare the use of headphones and a multi-speaker solution for recreating an audio environment with directional sound requirements.
      (4 marks)

(d) The final training simulator prototype combined a head mounted display with a 6 degree of freedom head tracker, a set of high quality stereo headphones and two force feedback haptic devices to represent the surgical tools.

    (i)   Unfortunately when the system was trialled a number of the users felt sick. Give two reasons why this might be occurring. (2 marks)

    (ii)   The same technologies used in the Virtual Reality training simulator are to be used for performing remote surgery by controlling a robot in the battlefield rather than putting trained surgeons at risk. Is this still a Virtual Reality system? Explain. (2 marks)

4. (a) For each of the following, explain if there are any conditions where it might be considered a haptic interface.

    (i)   A standard computer mouse; (1 mark)

    (ii) A mobile phone with vibrate functionality. (1 mark)

    (b) (i)   Why are the design requirements of a tactile display for the finger tips different from one for the forearm? (2 marks)

    (ii) Why are the mechanical properties of skin as important as those of a surface being touched in the perception of texture? (2 marks)

    (iii) Give an example of how a change in skin elasticity could affect the perceived roughness of a surface. (2 marks)

    (iv) Two solid cubes, one made of steel, the other of rigid plastic are fixed to a table. They have identical dimensions and are at room temperature, measured as 20°C.
    Is it possible to distinguish between them using touch alone, why? (2 marks)

    (c) Compare a typical back-drivable, desk attached force feedback haptic interface such as the Sensable/Geomagic Premium 1.5 and a multi-finger haptic glove such as the CyberGrasp by Immersion/CyberGloveSystems for the following scenarios:

    (i)   A virtual drum kit; (2 marks)

    (ii) CAVE interaction. (2 marks)

    (d) It is common for a haptic rendering algorithm to use a penalty method (virtual spring) to calculate the forces arising due to the depth of penetration into a virtual surface. Explain why the discrete (sampled) time nature of a simulation incorporating a back-drivable force feedback haptic device can cause instability and therefore why having a faster update rate for the haptic device increases the achievable virtual surface stiffness. (6 marks)

(End of Question Paper)