THE UNIVERSITY OF AUCKLAND

FIRST SEMESTER, 2016
Campus: City

COMPUTER SCIENCE

TEST

Computer Graphics and Image Processing

(Time Allowed: 50 minutes)

Note:

- The use of calculators is NOT permitted.
- Compare the exam version number on the Teleform sheet supplied with the version number above. If they do not match, ask the exam supervisor for a new sheet.
- Enter your name and student ID on the Teleform sheet. Your name should be entered left aligned. If your name is longer than the number of boxes provided, truncate it.
- Answer ALL **Multiple-choice** questions on the Teleform answer sheet provided.
- Use a dark pencil to mark your answers in the multiple choice answer boxes on the Teleform sheet. Check that the question number on the sheet corresponds to the question number in this question/answer book. If you spoil your sheet, ask the supervisor for a replacement.

Question 1

[1 marks] The dot product of the vectors $\mathbf{u} = \begin{pmatrix} -1 \\ -2 \\ 3 \end{pmatrix}$ and $\mathbf{v} = \begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$ is equal to:

(a) 0
(b) -4
(c) $\begin{pmatrix} 1 \\ 4 \\ 3 \end{pmatrix}$
(d) 4
(e) None of the others

Question 2

[1 marks] The cross product, $\mathbf{u} \times \mathbf{v}$, of the vectors $\mathbf{u} = \begin{pmatrix} -1 \\ -2 \\ 3 \end{pmatrix}$ and $\mathbf{v} = \begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$ is equal to:

(a) $\begin{pmatrix} 1 \\ -4 \\ 3 \end{pmatrix}$
(b) $\begin{pmatrix} 1 \\ 4 \\ 3 \end{pmatrix}$
(c) 4
(d) $\begin{pmatrix} -1 \\ -2 \\ 3 \end{pmatrix}$
(e) None of the others

Question 3

[1 marks] The orthogonal projection $\mathbf{u}_v$, of the vector $\mathbf{u} = \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$ onto the vector $\mathbf{v} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$, is equal to:

(a) $\frac{2}{3}\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$

(b) $\frac{2}{3}\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$

(c) $2\begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix}$

(d) $\frac{2}{7}\begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}$

(e) None of the others

Question 4

[1 marks] The magnitude of $\mathbf{u}_v$, the orthogonal projection of the vector $\mathbf{u} = \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$ onto the vector $\mathbf{v} = \begin{pmatrix} 1 \\ 0 \\ -1 \end{pmatrix}$, is equal to:

(a) $\frac{2}{7}\begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}$

(b) $\frac{1}{\sqrt{2}}$

(c) 0

(d) $\sqrt{2}$

(e) None of the others

Question 5

[1 marks] Assume a square matrix M = $\begin{pmatrix} 1 & 2 \\ 2 & 1 \end{pmatrix}$.

Which of the following statements about the inverse matrix, M^{-1}, of the matrix M, is *true*?

(a) $M^{-1} = \frac{1}{3}\begin{pmatrix} -1 & -2 \\ -2 & -1 \end{pmatrix}$
(b) M has no inverse
(c) $M^{-1} = \begin{pmatrix} 1 & 1 \\ -2 & 1 \end{pmatrix}$
(d) $M^{-1} = \frac{1}{3}\begin{pmatrix} -1 & 2 \\ 2 & -1 \end{pmatrix}$
(e) None of the others

Question 6

[1 marks] Assume a square matrix M = $\begin{pmatrix} 1 & 2 \\ 1 & 2 \end{pmatrix}$ and a vector $\mathbf{u} = \begin{pmatrix} 1 \\ -1 \end{pmatrix}$.

Which of the following statements about the product M**u**, of matrix M and vector **u**, is *true*?

(a) $M\mathbf{u} = \begin{pmatrix} -1 \\ -1 \end{pmatrix}$
(b) $M\mathbf{u} = 3\begin{pmatrix} 1 \\ -1 \end{pmatrix}$
(c) $M\mathbf{u} = 0$
(d) $M\mathbf{u} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$
(e) None of the others

Question 7

[1 marks] Assume a square matrix M = $\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$.

Which of the following statements about the determinant, det(M), of the matrix M, is true?

(a) det(M) = 2
(b) det(M) = $-\frac{1}{2}$
(c) det(M) = 10
(d) det(M) = 14
(e) None of the others

Question 8
[1 marks] Which of the following statements about the absolute distance, d, between a plane P defined by equation 2x + 2y + z = 1, and the point Q = $\begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix}$, is *true*?

(a) d = 3
(b) d = 0 (the point Q lies on the plane P)
(c) d = $\frac{1}{3}$
(d) d = $\frac{1}{\sqrt{3}}$
(e) None of the others

Question 9
[1 marks] Consider the plane π, orthogonal to the vector **n** = $\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$ and containing the point P = $\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$.

Which of the following statements about the equation of the plane π is *true*?

(a) $x + z = \sqrt{2}$
(b) $x + z = 2$
(c) $x + y + z = 3$
(d) $x + z = 0$ (The origin is on the plane)
(e) None of the others

Question 10
[1 marks] Which of the following statements about the equation of the plane, π, being orthogonal to the vector **n** = $\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$ and at a distance $d = 2$ from the origin is *true*?

(a) $x + z = \sqrt{2}$
(b) $x + z = \frac{1}{2\sqrt{2}}$
(c) $x + z = 2\sqrt{2}$
(d) $x + z = \frac{1}{\sqrt{2}}$
(e) None of the others

Question 11

[1 marks] Consider the triangle ABC the with the vertices A = $\begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$, B = $\begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}$ and C = $\begin{pmatrix} 1 \\ 2 \\ 1 \end{pmatrix}$ listed in counter clockwise order with respect to its normal **n**. Which of the following statements about the coordinates of the normal **n** is *true*?

(a) $n = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$

(b) $n = \frac{1}{\sqrt{3}}\begin{pmatrix} 1 \\ -1 \\ 1 \end{pmatrix}$

(c) $n = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$

(d) $n = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ -1 \\ 1 \end{pmatrix}$

(e) None of the others

Question 12

[1 marks] Consider the plane, π, containing the line of intersection between the planes $x + y + z = 1$ and $y + z = 0$, as well as the point P = $\begin{pmatrix} 2 \\ 1 \\ 0 \end{pmatrix}$. Which of the following statements about the equation of the plane, π, is *true*?

(a) $x - y + z = 1$

(b) $2x + z = 1$

(c) $x + y + z = 0$

(d) $x - y - z = 1$

(e) None of the others

Question 13

[1 marks] Consider the matrix $M = \begin{pmatrix} 2 & 0 & 2 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{pmatrix}$ representing a set of planar (2D) geometric transformations in homogeneous coordinates. Which of the following statements about the matrix M is *true*?

(a) M represents first, a scaling of vector (2, 1) followed by translation of vector (1, 1)
(b) M represents first, a translation by vector (1, 1) followed by scaling of vector (2, 1)
(c) M represents first, a scaling of vector (3, 1) followed by shearing of parameters (-1, 1)
(d) M represents first, a shearing of parameters (-1,1) followed by scaling of vector (3, 1)
(e) None of the others

Question 14

[1 marks] Consider the 2D Cartesian coordinates P' of the point P = $\begin{pmatrix} 1 \\ 2 \end{pmatrix}$ after performing first translation by vector t = $\begin{pmatrix} -1 \\ 1 \end{pmatrix}$; then rotation through 90 degrees; and finally scaling by 1 along the *x*-axis and -2 along the *y*-axis. Which statement about the 2D Cartesian coordinates P' is *true*?

(a) $P' = \begin{pmatrix} -3 \\ 0 \end{pmatrix}$

(b) $P' = \begin{pmatrix} -3 \\ -2 \end{pmatrix}$

(c) $P' = \begin{pmatrix} 3 \\ 0 \end{pmatrix}$

(d) $P' = \begin{pmatrix} 0 \\ -6 \end{pmatrix}$

(e) None of the others

Question 15

[1 marks] Consider the point P = $\begin{pmatrix} 3 \\ 2 \\ 1 \end{pmatrix}$**.** Which of the following statements about the coordinates P' of the point P in a new coordinate system with location E = $\begin{pmatrix} 2 \\ 1 \\ 0 \end{pmatrix}$ and axis unit vectors u = $\frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}$, v = $\frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ -1 \\ 0 \end{pmatrix}$, n= $\begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix}$ is *true*?

(a) P'= $\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$

(b) P'= $\frac{1}{\sqrt{2}}\begin{pmatrix} 2 \\ 0 \\ -\sqrt{2} \end{pmatrix}$

(c) P'= $\frac{1}{\sqrt{14}}\begin{pmatrix} 3 \\ 2 \\ 1 \end{pmatrix}$

(d) P'= $\begin{pmatrix} 3 \\ 2 \\ 1 \end{pmatrix}$

(e) None of the others

Question 16

[1 marks] Which of the following drawing modes for OpenGL primitives does **not** exist in OpenGL?

(a) GL_LINE_LOOP
(b) GL_QUAD_STRIP
(c) GL_TRIANGLES
(d) GL_SQUARES
(e) GL_POINTS

Question 17

[1 marks] Given is a window in world coordinates with the coordinates w.left=0, w.right=3, w.bottom=0, and w.top=2. The world window is mapped to a window on the display. The resulting window on the display has a width of 600 pixels, height of 400 pixels, and it is aligned with the top left corner of the display, i.e. its position is (0, 0). What is the world-to-viewport transformation for mapping a point in world coordinates into the corresponding point in screen coordinates?
NOTE: Making yourself an illustration helps with finding the correct answer.

(a) $\begin{pmatrix} A & 0 & C \\ 0 & B & D \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 200 & 0 & 0 \\ 0 & 200 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

(b) $\begin{pmatrix} A & 0 & C \\ 0 & B & D \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 200 & 0 & 0 \\ 0 & 200 & 400 \\ 0 & 0 & 1 \end{pmatrix}$

(c) $\begin{pmatrix} A & 0 & C \\ 0 & B & D \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 200 & 0 & 0 \\ 0 & -200 & 400 \\ 0 & 0 & 1 \end{pmatrix}$

(d) $\begin{pmatrix} A & 0 & C \\ 0 & B & D \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 200 & 0 & 0 \\ 0 & -200 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

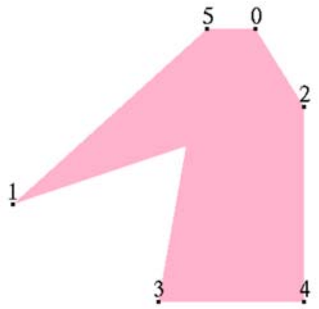
(e) None of the others

Question 18
[1 marks] Given are the vertices

```
const int numVertices=6;
const float vertices[numVertices][2] =

{{300,380},{50,200},{350,300},{200,100},{350,100},{250,380}}
```

Which calling sequence of these vertices (using `glVertex2fv`) results in the shape below if we use the OpenGL commands `glBegin(GL_QUADS)` and `glEnd()`?

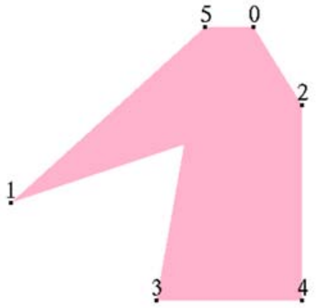


(a) 1, 5, 2, 0, 2, 0, 4, 3
(b) 1, 5, 0, 2, 4, 3, 2, 1
(c) 0, 1, 2, 3, 2, 3, 4, 5
(d) 1, 2, 5, 0, 3, 4, 0, 5
(e) 1, 2, 0, 5, 3, 4, 2, 5

Question 19
[1 marks] Given are the vertices

```
const int numVertices=6;
const float vertices[numVertices][2] =
      {{300,380},{50,200},{350,300},{200,100},{350,100},{250,380}}
```

Which calling sequence of these vertices (using `glVertex2fv`) results in the shape below if we use the OpenGL commands `glBegin(GL_TRIANGLE_FAN)` and `glEnd()`?



(a) 0, 5, 1, 2, 3, 4
(b) 2, 1, 5, 0, 4, 3
(c) 5, 1, 3, 4, 2, 0
(d) 1, 5, 0, 2, 4, 3
(e) None of the others

Question 20
[1 marks] Using Phong illumination, if you want to make the highlight on a surface *smaller*, you have to

(a) Increase the intensity of the specular light
(b) Increase the shininess α
(c) Decrease the shininess α
(d) Increase the intensity of the ambient light
(e) None of the others

Question 21
[1 marks] Which of the following statements about shading algorithms is *false*?

(a) Phong shading interpolates the normal between the vertices of a face
(b) Gouraud shading cannot represent highly localised effects, such as small highlights in the middle of a polygon.
(c) Flat shading is faster than Gouraud shading
(d) Flat shading produces stronger Mach bands than Gouraud shading
(e) None of the others

Question 22

[1 marks] Given is a scene containing an illuminated object. The scene contains a single light source with ambient intensity $I_a=0.7$ and $I_d=1.0$. The illuminated object has the ambient reflection coefficient $\rho_a=0.5$ and $\rho_d=0.6$. Given is a point $\mathbf{p}=(0,0,0)^T$ on the surface of the object. The surface normal at $\mathbf{p}$ is $(0,0,1)^T$, the light position is $(0,3,4)^T$, and the viewpoint is $(2,0,0)^T$.
Using the (achromatic) Phong Illumination equation discussed in the lecture and assignment, what is the **ambient component** of the reflected light at **p**?
NOTE 1: Please assume that there is no distance dependency, i.e. $k_c=1.0$ and $k_l=k_q=0.0$.
NOTE 2: In order to work out your answer you may not need all of the parameters specified above.

(a) 0.35
(b) 0.95
(c) 0.42
(d) 0.5
(e) 0.7

Question 23

[1 marks] Given is a scene containing an illuminated object. The scene contains a single light source with ambient intensity $I_a=0.7$ and $I_d=1.0$. The illuminated object has the ambient reflection coefficient $\rho_a=0.5$ and $\rho_d=0.6$. Given is a point $\mathbf{p}=(0,0,0)^T$ on the surface of the object. The surface normal at $\mathbf{p}$ is $(0,0,1)^T$, the light position is $(0,3,4)^T$, and the viewpoint is $(2,0,0)^T$.
Using the (achromatic) Phong Illumination equation discussed in the lecture and assignment, what is the **diffuse component** of the reflected light at **p**?
NOTE 1: Please assume that there is no distance dependency, i.e. $k_c=1.0$ and $k_l=k_q=0.0$.
NOTE 2: In order to work out your answer you may not need all of the parameters specified above.

(a) 0.6
(b) 0.35
(c) 0.48
(d) 0.42
(e) 0.95

Question 24

[1 marks] In order to determine which parts of a surface are visible when rendering 3D scenes, OpenGL uses the

(a) Depth buffer
(b) Accumulation buffer
(c) Frame buffer
(d) Stencil buffer
(e) Double buffer

Question 25

[1 marks] Given is a triangle with the vertices A=(-1,0,0), B=(1,0,0), C=(0,1,0). The triangle is rendered in OpenGL using fully saturated red for vertex A (C_A=(1,0,0)), fully saturated green for vertex B (C_B=(0,1,0)), and fully saturated blue for vertex C (C_C=(0,0,1)). What is the colour C_P at the point P=(0, 0, 0)?

(a) C_P=(1/4, 1/4, 1/2)
(b) C_P=(1/6, 1/6, 2/3)
(c) C_P=(0, 0, 1)
(d) C_P=(1/3, 1/3, 1/3)
(e) C_P=(0.5, 0.5, 0)

Question 26

[1 marks] Given is an object consisting of intersecting spheres and cuboids with cylindrical holes. You want to model and render this object. What modelling technique is most appropriate for this task (i.e. is easy to implement and gives precise results).

(a) Subdivision Surfaces
(b) Constructive Solid Geometry (CSG)
(c) Manually defined polygon mesh
(d) Implicit Surfaces
(e) Parametric Surfaces

Question 27

[1 marks] What is the model view matrix after executing the following code?

```
glMatrixMode(GL_MODELVIEW);
glLoadIdentity();
glRotatef(φ, 0, 0, 1);
glTranslatef(1, 2, 0);
```

(a) $\begin{pmatrix} \cos\varphi & -\sin\varphi & 0 & \cos\varphi \\ \sin\varphi & \cos\varphi & 0 & -2\cos\varphi \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

(b) $\begin{pmatrix} \cos\varphi & -\sin\varphi & 0 & -2\sin\varphi \\ \sin\varphi & \cos\varphi & 0 & -2\cos\varphi \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

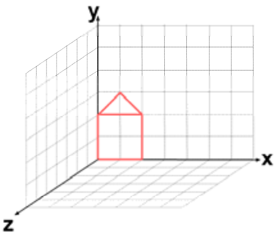
(c) $\begin{pmatrix} \cos\varphi & -\sin\varphi & 0 & 1 \\ \sin\varphi & \cos\varphi & 0 & 2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

(d) $\begin{pmatrix} \cos\varphi & -\sin\varphi & 0 & \cos\varphi - 2\sin\varphi \\ \sin\varphi & \cos\varphi & 0 & \sin\varphi + 2\cos\varphi \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$

(e) None of the above

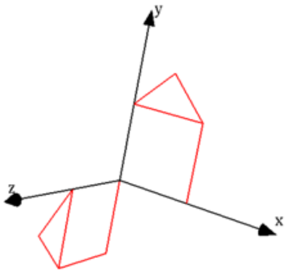
Question 28

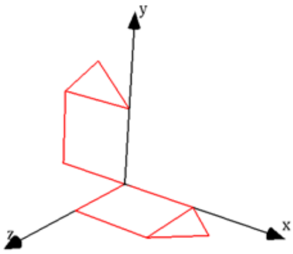
[1 marks] Given is a function *drawHouse()* which draws a wire frame house in the xy-plane as shown in the image below.

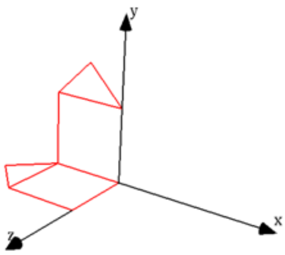


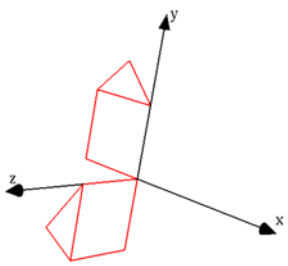
Which scene is produced by executing the following OpenGL code:

```
glPushMatrix();
glScalef(-1, 1, 1);
drawHouse();
glPopMatrix();
glRotatef(-90, 0, 0, 1);
glRotatef(-90, 0, 1, 0);
drawHouse();
```

(a) 

(b) 

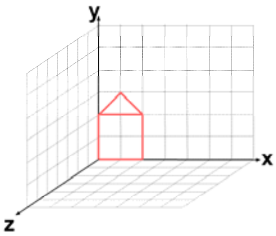
(c) 

(d) 

(e) None of the others

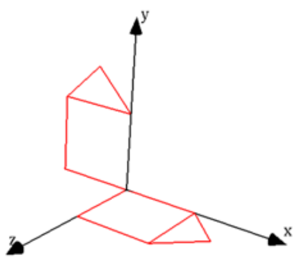
Question 29

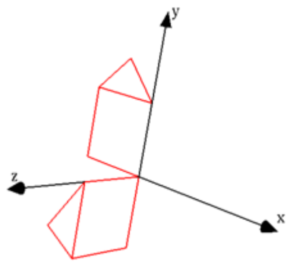
[1 marks] Given is a function *drawHouse()* which draws a wire frame house in the xy-plane as shown in the image below.

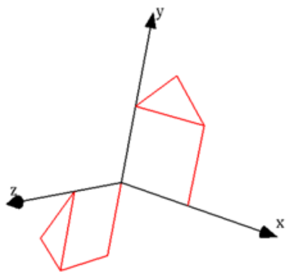


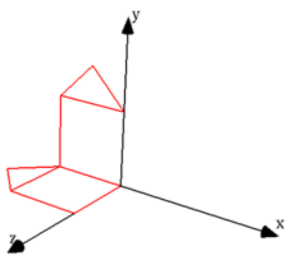
Which scene is produced by executing the following OpenGL code:

```
glScalef(-1, 1, 1);
drawHouse();
glRotatef(-90, 0, 0, 1);
glRotatef(-90, 0, 1, 0);
drawHouse();
```

(a) 

(b) 

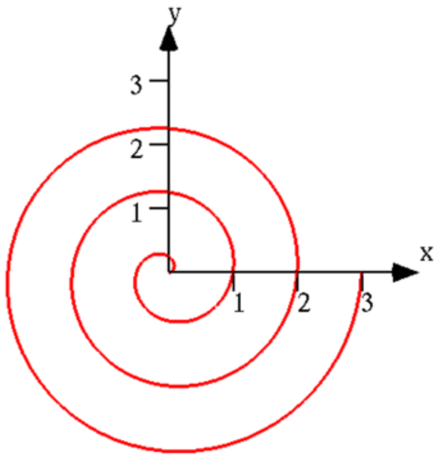
(c) 

(d) 

(e) None of the others

Question 30

[1 marks] Given is a parametric curve $\mathbf{c}(t)=(x(t),y(t))$ $(0 \le t \le 1)$, which defines a spiral with n revolutions and linearly increasing radius. The radius increases by 1 unit with each revolution. The image below shows the curve for n=3.



Which of the following equations defines this parametric curve?

(a) $\begin{pmatrix} t\cos(2\pi\, n\, t) \\ t\sin(2\pi\, n\, t) \end{pmatrix}$

(b) $\begin{pmatrix} n\, t\cos(2\pi\, n\, t) \\ n\, t\sin(2\pi\, n\, t) \end{pmatrix}$

(c) $\begin{pmatrix} n\, t\cos(2\pi\, t) \\ n\, t\sin(2\pi\, t) \end{pmatrix}$

(d) $\begin{pmatrix} n\, t^n\cos(2\pi\, n\, t) \\ n\, t^n\sin(2\pi\, n\, t) \end{pmatrix}$

(e) None of the others

Rough Working – This page will not be marked