CompSci.372.FC 2002
Computer Graphics

Surname (Family Name):

First Name(s):

ID Number:

Login Name:

Instructions:

1. Attempt **ALL** questions.
2. The exam is for two (2) hours.
3. This is a closed book test.
4. Calculators are **NOT** permitted.
5. Write your answers in the spaces provided. There is space at the back for answers that overflow the allotted space.
6. **Questions total 100 Marks**.
7. This exam is worth 65% of your final marks for CompSci372FC

Section	Marks	Maximum Marks
Q.1		6
Q.2		7
Q.3		10
Q.4		12
Q.5		8
Q.6		12
Q.7		12
Q.8		12
Q.9		11
Q.10		10
Total		100

Question 1 – Short answer test [6 marks]

Complete each of the following statements by filling in the underlined blank spaces. Each blank space is worth 1 mark.

[6 marks]

(a) A video card (graphics card) consist of three main components: Graphics commands are send to the video processor which processes them and writes the resulting pixel data into the _____ which is a region of memory sufficiently large to hold all pixels of the display. The _____ continuously scans this memory and displays the corresponding pixels on the monitor.

(b) The cross product (0,1,2) × (0,-1,4) is equal to _____.

(c) The area A of a triangle in 3D with the edges **u** and **v** can be computed by A=_____ (you are not allowed to use *sin*, *cos* or any other trigonometric functions).

(d) The command `gluLookAt` computes the _____ Matrix.

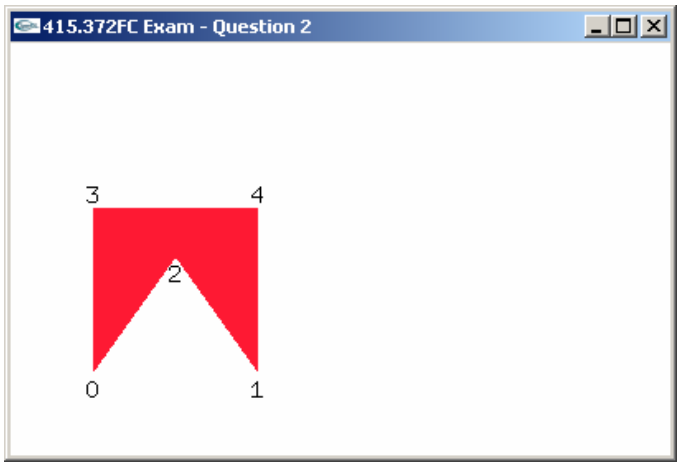
(e) The last transformation step in the rendering pipeline is the _____.

Question 2 – OpenGL [7 marks]

Given is an OpenGL program, which defines a global array of five 2D vertices as follows

```
const int numVertices=5;
const float v[numVertices][2] = {{-50,0},{50,0},{0,70},{-50,100},{50,100}};
```

Write a display function, which uses these vertices to draw the shape shown below (the vertex numbers have been inserted afterwards for clarity).
For each of the three parts of this question you have to draw the shape using different geometric primitives.



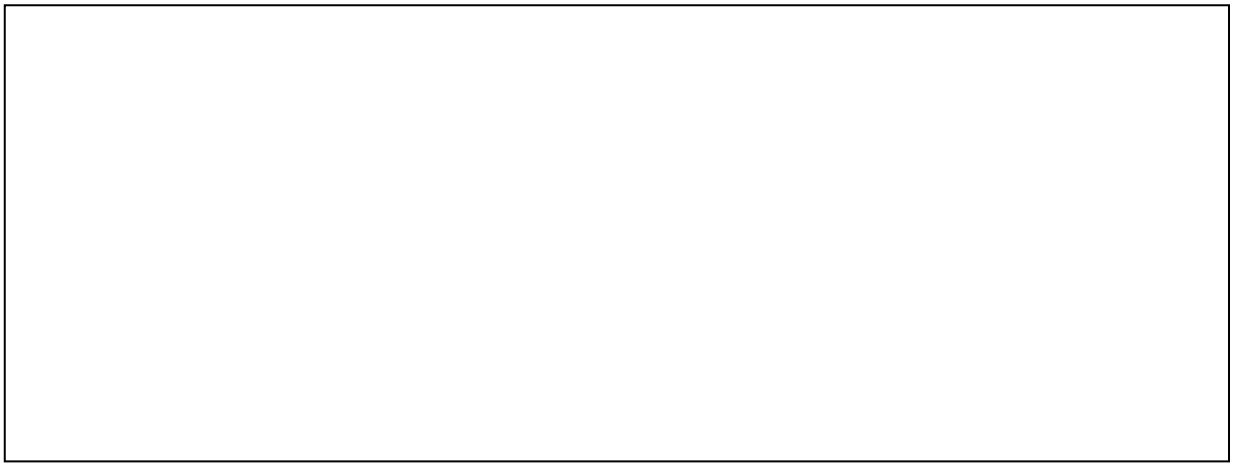
A. Draw the shape using triangles [3 marks].

```
void display(void)
{
    // clear all pixels in frame buffer
    glClear(GL_COLOR_BUFFER_BIT);
    glColor3f(1.0, 0.1, 0.2);    // reddish colour
    glBegin(GL_TRIANGLES);
```

```
    glEnd();
    glFlush();
}
```

B. Draw the shape using a triangle strip [2 marks].

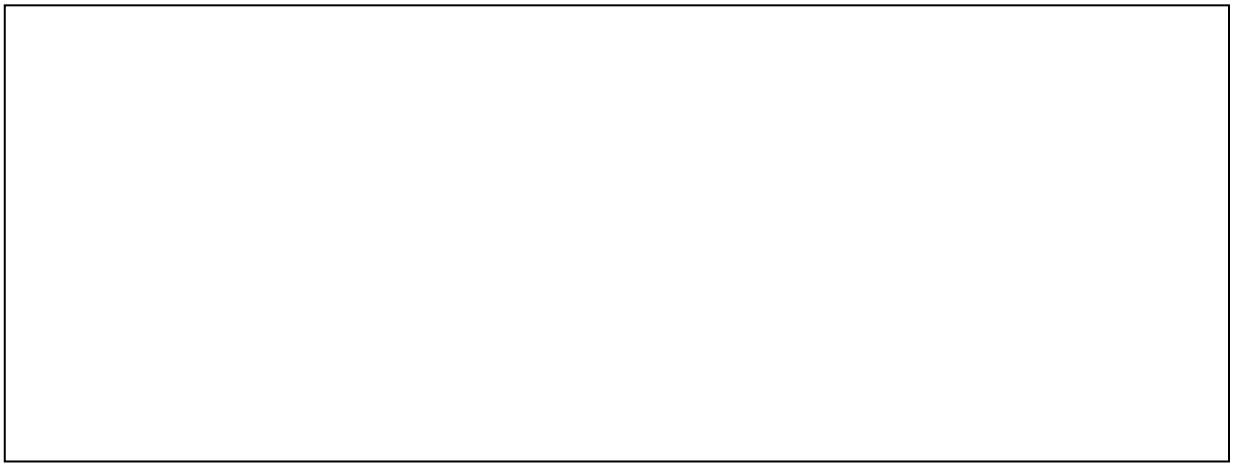
```
void display(void)
{
    // clear all pixels in frame buffer
    glClear(GL_COLOR_BUFFER_BIT);
    glColor3f(1.0, 0.1, 0.2);  // reddish colour
    glBegin(GL_TRIANGLE_STRIP);
```



```
    glEnd();
    glFlush();
}
```

C. Draw the shape using a triangle fan [2 marks].

```
void display(void)
{
    // clear all pixels in frame buffer
    glClear(GL_COLOR_BUFFER_BIT);
    glColor3f(1.0, 0.1, 0.2);  // reddish colour
    glBegin(GL_TRIANGLE_FAN);
```

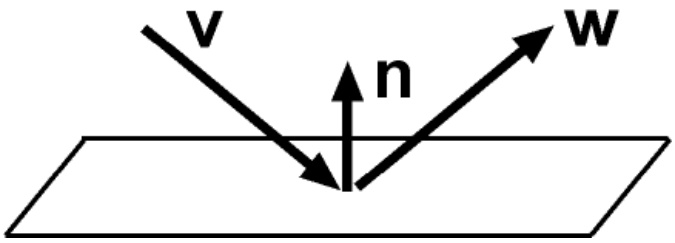


```
    glEnd();
    glFlush();
}
```

Question 3 – 3D Geometry [10 marks]

A. Compute the distance of the point (4,1,2) to the plane given by the point (1,0,0) and the normal (1,2,2). Show your working [5 marks].

B. A 3D vector **v** is reflected on a surface with a unit normal **n**. Given the reflected vector **w** derive a formula to compute the original vector **v**. [5 marks].

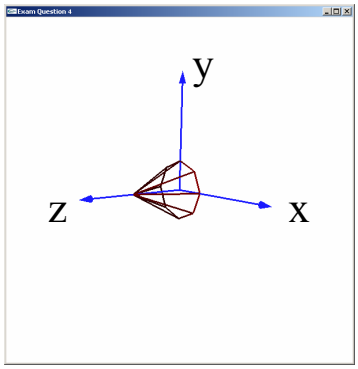


Question 4 – Transformations [12 marks]

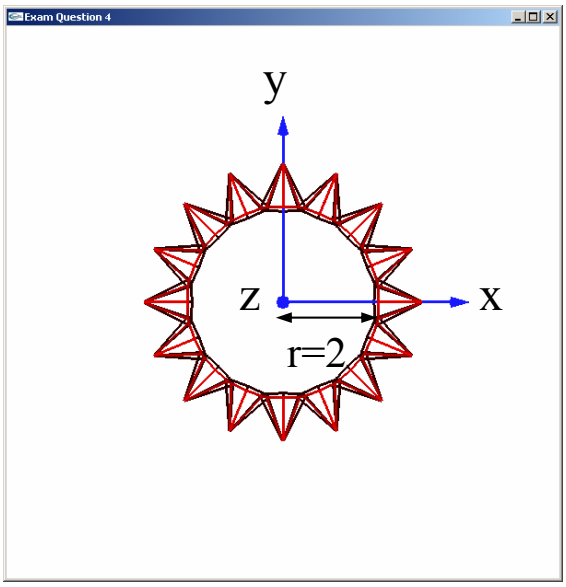
A. Given is a function

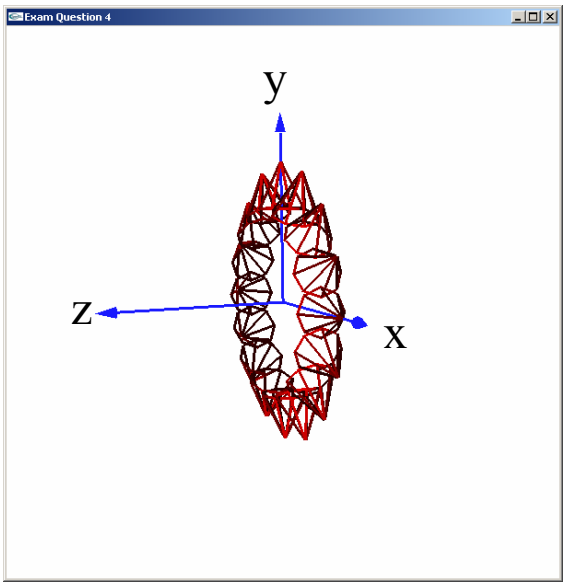
```
myCone()
```

which draws a wireframe cone of length 2 and radius 0.5, which is aligned with the z-axis and has the origin as the centre of its circular base. The output of this function is shown in the image on the right (the axes and their labels have been added for clarity).



Use this function to draw the scene shown in the images below. The scene consists of 16 wireframe cones with length 2 and radius 0.5., which are arranged in equidistant steps around a circle with radius r=2 (i.e. the distances and the angles between the axes of two adjacent cones are constant). The coordinate axes and their labels have been added for clarity and you don't have to draw them.



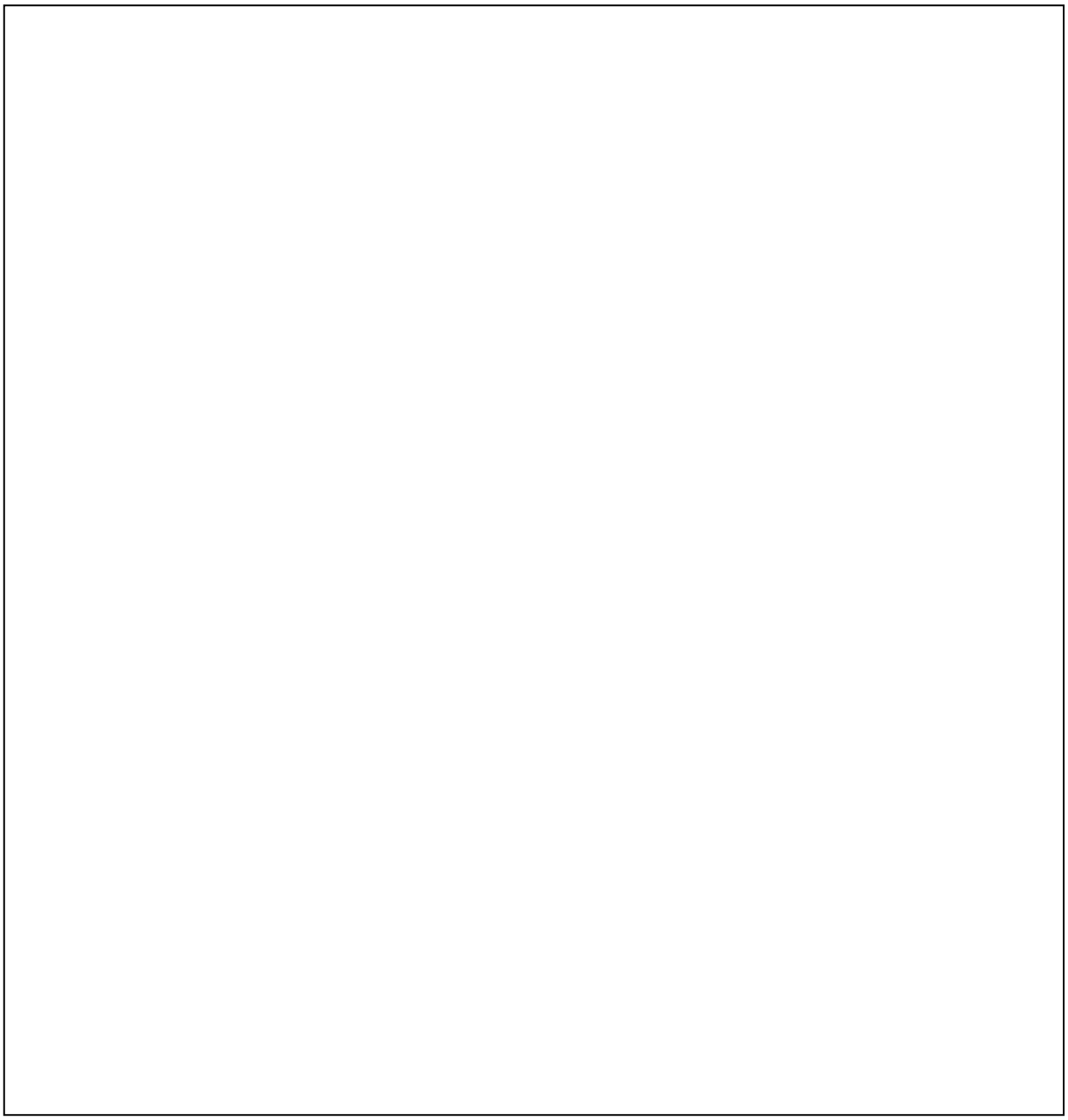


Here are the function prototypes of some OpenGL commands you might want to use:

```
glTranslatef(float tx, float ty, float tz);
glRotatef(float angle, float vx, float vx, float vz);
glPushMatrix();
glPopMatrix();
```

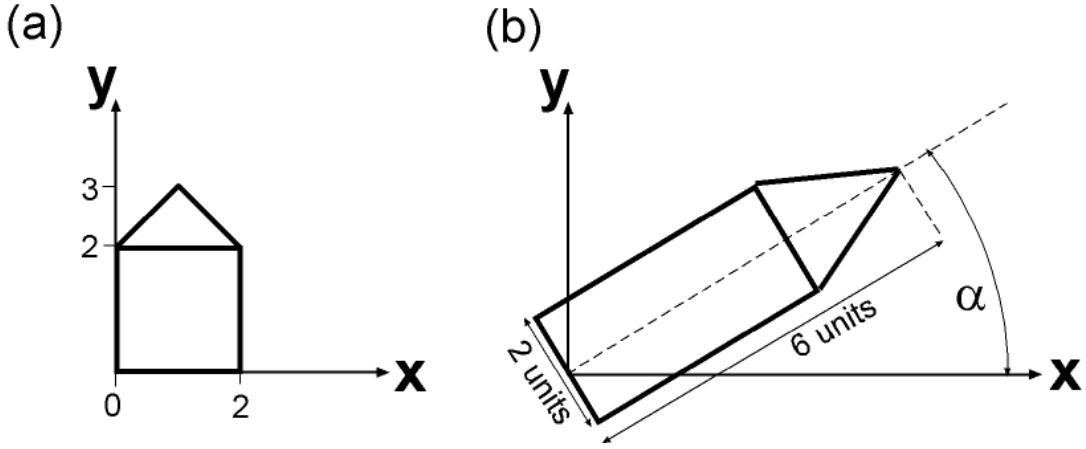
Please complete the code on the following page [7 marks].

```
void display(void)
{
    glMatrixMode( GL_MODELVIEW ); // Set the view matrix ...
    glLoadIdentity();             // ... to identity.
    gluLookAt(0,0,8, 0,0,0, 0,1,0);   // camera is on the z-axis
    trackball.tbMatrix();         // rotate the object using the trackball ...

    glClear( GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);

    // Draw the scene
    int numCones=16;
```



```
    glFlush ();
    glutSwapBuffers();
}
```

B. Given is the 2D scene in the part (a) of the image below. Write down the homogeneous 2D transformation matrix **M**, which transforms the scene in (a) into the scene in part (b) of the image. You are allowed to write the transformation matrix as a product of simpler matrices (i.e. you are not required to multiply the matrices) [5 marks].



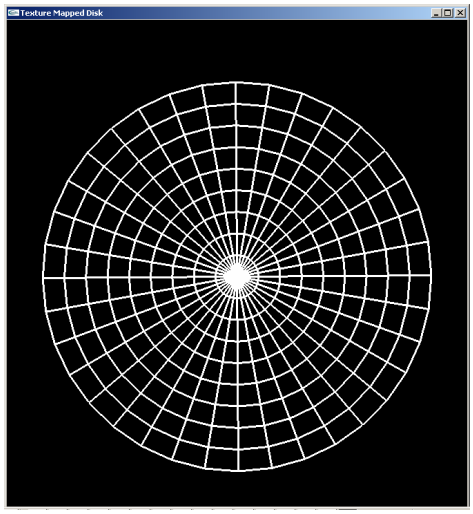
Question 5 – Modelling and Texture Mapping [8 marks]

A disk with radius 1 can be described by the parametric equation $\mathbf{p}(s,t) = \begin{pmatrix} s\sin t \\ s\cos t \\ 0 \end{pmatrix}$

where the parameters s lies within the interval [0,1] and the parameter t lies within the interval [0,2π]. Implement the function

```
void drawTexturedDisk(int nStacks, int nSegments)
```

which draws such a unit disk by subdividing the surface into `nSegments` segments in circumferential direction and into `nStacks` segments in radial direction. An example with nStacks=9 and nSlices=36 is shown on the right.



You should define texture coordinates such that the disk is texture mapped and the texture image is tiled 3 times in radial direction and 6 times in circumferential direction.
Using the texture image shown below on the left the function should draw a textured disk as shown below on the right.

The texture image

The texture mapped disk

The function prototype of the OpenGL command for specifying a texture coordinate is

```
glTexCoord2f(float s, float t);
```

Please complete the code on the following page [9 marks].

```
#include <math.h>
const float Pi = 3.14159265358979323846264338327f;

void drawTexturedDisk(int nStacks, int nSegments)
{
    // Create texture and set texture parameters
    glBindTexture(GL_TEXTURE_2D, texName);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_REPEAT);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T, GL_REPEAT);
    glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, textureWidth, textureHeight,
                0, GL_RGBA, GL_UNSIGNED_BYTE, texture);
    glBindTexture(GL_TEXTURE_2D, texName);
    glTexEnvf(GL_TEXTURE_ENV, GL_TEXTURE_ENV_MODE, GL_REPLACE);
    glEnable(GL_TEXTURE_2D);
```

```
    // Draw the disk with appropriate texture coordinates
```

```
    glDisable(GL_TEXTURE_2D);
}
```

Question 6 – Ray Tracing and Illumination [12 marks]

Consider ray tracing a scene with only one object: a sphere centered at (0, 0, 5) with radius 5. There is a single point light source at (0, 5, -5) with intensity 1.0. The background has intensity 1.0. There is no ambient light.

The following questions refer to the intensity of the ray $(0, 0, -5 + t)$ in this scene.

A. What is the diffuse component of the illumination at the point of intersection of the ray with the object if the diffuse reflection coefficient of the object is 1.0? [4 marks]

B. What is the Phong component of the illumination at the point of intersection if the specular reflection coefficient is 1.0 and the Phong exponent is 1.0? Use the mirror reflection direction method of computing Phong Illumination. [4 marks]

C. What is the mirror reflection component of the illumination at the point of intersection if the mirror reflection coefficient of the object is .4? [4 marks]

Question 7 – Ray Intersection [12 marks]

Consider intersecting a ray with a generic object whose surface is defined by the equation

$$x^2 + y^2 = z^2.$$

A. Derive the fact that the intersection of this surface with a ray, $s + dt$, can be found by solving a quadratic equation of the form $At^2 + Bt + C = 0$. What are A, B, and C? [6 marks]

B. Derive a formula for the normal to this surface at the point (x,y,z). (Assume that (x,y,z) is on the surface). [6 marks]

Question 8 – Parametric Curves [12 marks]

The two parts to this question apply to a curve defined by the four control points (0,0), (0,0), (0,1), and (1,1). (The first control point is repeated.)

A. Suppose a Bezier curve is fitted to the control points. What are the (x,y) coordinates of the curve at t=.25 and t=.5? Graph the control points and sketch the curve. [6 Marks]

B. Suppose a Quadratic spline curve is fitted to the control points. What are the (x,y) coordinates of the curve at t=2.5 and t=3? Graph the control points and sketch the curve. [6 Marks]

Question 9 – Color Theory [11 marks]

A. What is saturation? [1 Mark]

B. What is the CIE chromaticity diagram, and what is its relation to the *X*, *Y*, *Z* primaries? [10 Marks]

Question 10 – Hidden Surface Removal [10 marks]

What are the advantages and disadvantages of using a BSP tree to solve the hidden surface problem, compared to solving the problem using a depth buffer?

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