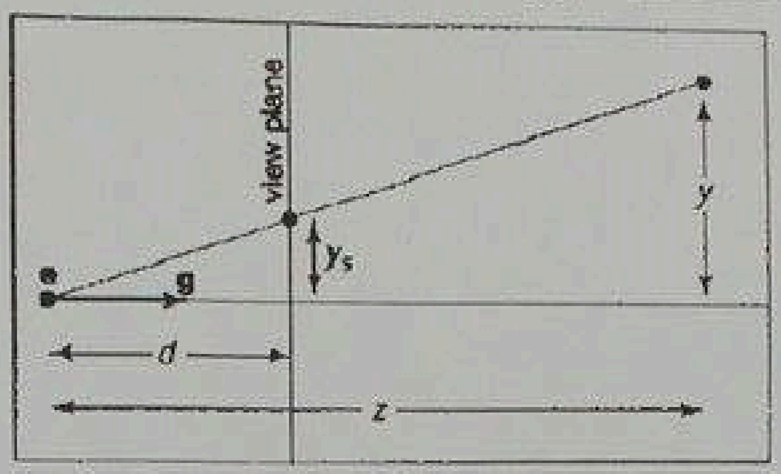
8. The specular component of the shading model depends on the angle between the viewing direction and the ______________________________________.

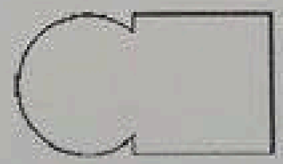
9. In the figure below which describes perspective projection, $y_s =$ ____________________.



10. To represent a material that has perfect red diffuse component (i.e. reflects all incoming red light, and nothing else), we set the diffuse coefficient k_d = [_______ , _______ , _______].

11. The three surface rendering methods discussed in the course are flat shading, __________________________________, and ______________________________________.

12. Environment mapping is used to approximate ______________________________________ in the rasterization pipeline.



13. In Constructive Solid Geometry, the ray intersection with the object above can be found by computing the ray intersection with a ______________________ and a _______________________ and then taking their ______________________________.

14. Bounding Volume Hierarchies reduces the time required for ray tracing by ____.

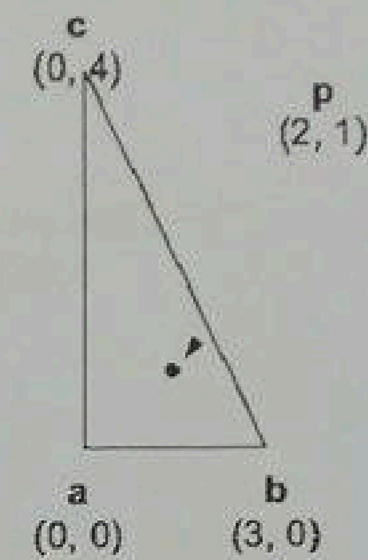
15. An ellipse can be modeled by transforming a __________________________, and this is an example of ____________________________.

Question 3 [5 points]

Given a 4x4 transformation matrix M that is used to transform points, show that to transform *normal vectors* correctly you should use the transformation matrix $(M^{-1})^T$

Question 4 [5 points]

Compute the Barycentric Coordinates (α, β, γ) of the point p on the right such that $p = \alpha a + \beta b + \gamma c$



Question 5 [10 points]

Given a ray with starting point e and direction vector d:

1. [4 points] Show that the barycentric coordinates of the point of intersection of that ray with a triangle with vertices a, b, and c can be found by solving the linear system of equation

$$\begin{bmatrix} x_a - x_b & x_a - x_c & x_d \\ y_a - y_b & y_a - y_c & y_d \\ z_a - z_b & z_a - z_c & z_d \end{bmatrix} \begin{bmatrix} \beta \\ \gamma \\ t \end{bmatrix} = \begin{bmatrix} x_a - x_e \\ y_a - y_e \\ z_a - z_e \end{bmatrix}$$

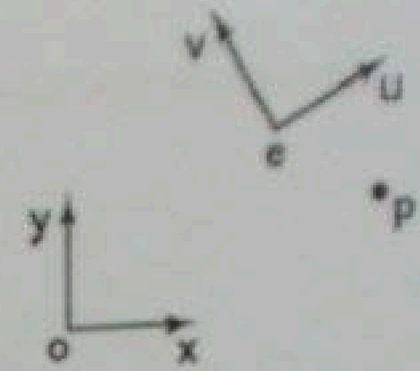
where $a = [x_a, y_a, z_a]^T$ and similarly for e, d, b, and c.

2. [3 points] Show also how to solve this system of equations and find the coordinates of the intersection point.

3. [3 points] Find the point of intersection of the ray $e = [1, 2, 1]^T$ and $d = [1,2,1]^T/\sqrt{6}$ with the triangle $a = [6, 0, 0]^T$, $b = [0, 6, 0]^T$ and $c = [0, 0, 6]^T$.

[Hint: find the parametric equation of the line and the barycentric representation of the triangle.]

Question 6 [10 points]



You are given two 2D coordinate frames xy (with origin at o) and uv (with origin at e) such that the frame uv is obtained from the frame xy by applying a 2x2 rotation matrix R followed by a translation by a 2D vector e.

1. [3 points] In terms of R and e, what is the 3x3 transformation matrix that can be used to convert coordinates of a point p from the uv frame to the xy frame i.e. $p_{xy}=T_1 p_{uv}$

$$T_1=\begin{bmatrix} & \\ & \end{bmatrix}$$

2. [3 points] In terms of R and e, what is the 3x3 transformation matrix that can be used to convert coordinates of a point p from the xy frame to the uv frame i.e. $p_{uv}=T_2 p_{xy}$

$$T_2=\begin{bmatrix} & \\ & \end{bmatrix}$$

3. [4 points] Let $R=\begin{bmatrix}\sqrt{3}/2 & -1/2\\ 1/2 & \sqrt{3}/2\end{bmatrix}$, $e=\begin{bmatrix}1\\2\end{bmatrix}$, and $p_{xy}=\begin{bmatrix}3\\1\end{bmatrix}$, find p_{uv} i.e. the point p in the uv frame.

Question 7 [10 points]

1. [5 points] Describe briefly the different transformations in the pipeline to transform points from the 3D model and project them onto the screen:

2. [5 points] Briefly describe one advantage and one disadvantage for the rasterization pipeline and ray tracing.

Rasterization Pipeline	Ray Tracing

Question 8 [5 points]

Assume a material with ambient coefficient $k_a=[0.5,0.5,0.5]$, diffuse coefficient $k_d=[1.0,1.0,0.5]$, specular coefficient $k_s=[1.0,0,0]$, and specular exponent $p=0.25$.

Assume the ambient light is $I_a=[1.0,1.0,1.0]$ and there are two light sources $I_1=[1.0,0.0,0.0]$ at position $[2,3,5]$ and $I_2=[0.0,1.0,0.0]$ at position $[-2,3,5]$.

Compute the lighting at the point $[0,0,0]$ with surface normal $n=[0,0,1]^T$ as seen by a camera at position $[0,0,10]$

[Recall: the lighting at a point is computed as $R=k_a I_a+\sum_i \left[k_d I_i max(0,l_i\cdot n)+k_s I_i max(0,e\cdot r_i)^p\right]$ where l_i is the direction of light i, e is the direction of the eye, and $r_i=-l_i+2(l_i\cdot n)n$ is the reflection direction.]