INDIAN INSTITUTE OF INFORMATION TECHNOLOGY, ALLAHABAD

C3 Assessment, 30 November 2023. Graphics & Visual Computing (GVC)

B.Tech - IT: V - Semester

Full Marks - 12+20+5+3+10+10 = 60 Which will be Scaled to 25. **Time – 2.0 hrs.**

Answers should be brief and to the point. Marks will be deducted for unnecessary writing. Calculators are allowed.

1. a) Write the generalized empirical formula for illumination for multiple light sources. Explain each term of the equation and graphically show the angular dependence of the intensity of each term.

Identify the terms of the equation with "**a**", "**b**", "**c**" and "**d**" in Fig. 1 and determine which of them is i) "**diffuse reflection**", ii) "**specular reflection**", iii) "**ambient**" and iv) "**emission**".

b) Is the above derived generalized empirical formula applicable if the object/surface is transparent? If not what are the modifications. If $I_{background}$ is the illumination of a background object, Will that have an effect?

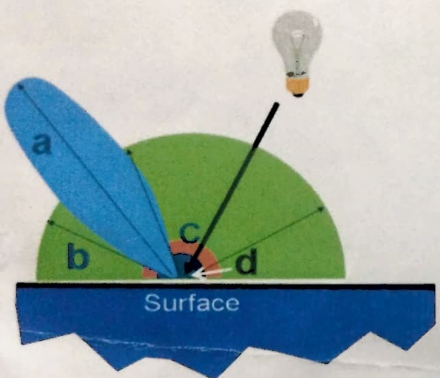


Fig. 1

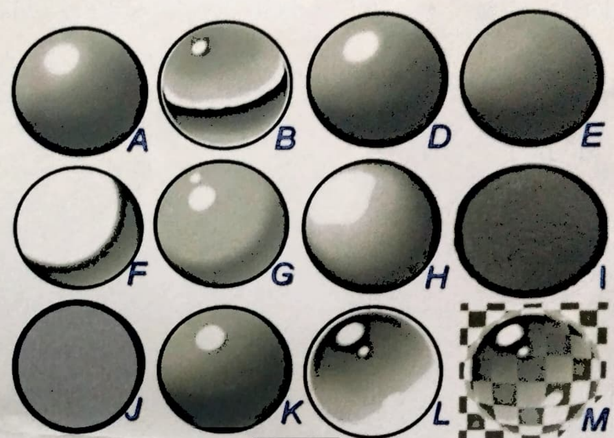


Fig. 2

c) Discuss the illumination of the spheres (A, .. to .., M) shown in Fig. 2 with respect to the generalized illumination equation derived in (a) and (b). **[4+2+12X0.5=12]**

2. Assume that you will have to design a well-polished sphere of radius R=10. This sphere is illuminated from the top (y-axis) in the world frame by sunlight. The camera capturing the image of the sphere is placed at ***x_c=30, y_c=50, z_c=40***, (30,50,40) with respect to the center of the sphere. The camera is looking at the center of the sphere and the up vector of the camera is (0,1,0).

a) Draw neatly a diagram showing the sphere with respect to the camera in the world frame. Mark the coordinates and the angles properly. Indicate the camera Look-at vector and the up vector. Indicate the direction of light $\vec{L}$ at 3 points on the sphere. Make a projection diagram choosing appropriate coordinates which illustrates the above points the best (Indicate the projection axis on the above diagram). If the light source was not the sun but a point source place at (0, 20,0) in the world space, then what deference would it make.

b) Write the equation (Cartesian coordinates ***[x,y,z]***) of the sphere in the **Camera Space** (Origin at the camera). Redraw the diagram in **Camera Space**. In the same camera space, write the vector $\hat{L}$ (Direction of Sunlight), $\hat{V}$ (Viewing Vector), $\hat{N}$ (Normal to the surface) for the point ***(x, y, z)*** on the sphere. [Note that the vectors are normalized. Derive the vector $\vec{R}$ (Reflected light) with the help of **snell's law**.

c) Relate the illumination equation derived above to this example. Eliminate the terms which are not required in the above example with proper justification.

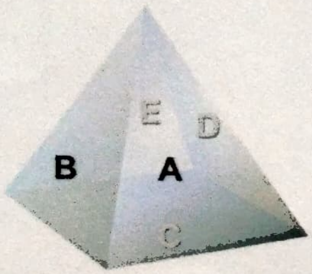
d) From symmetry we can say that the specular lighting maximum will be at $x_{cam} = 0$. How will you determine y of the specular lighting maximum even if $\vec{R}$ is not normalized?

[(2+2+1) + (1+1+1+1+4) + (2) + (5) = 20]

3. The illumination equation does not show the effect of shadow. Knowing the position of all the Light sources $L_i(x_i^l, y_i^l, z_i^l)$ and using the ray-tracing method explain with a pseudo code how one could determine if the particular point on the object is the shadow or not. What will you change in the illumination equation if the particular point is in the shadow?

[5]

4.



The pyramid prism shown in the figure has 5 facete **A,B,C,D** and **E**. If the prism was not transparent which are the facete which will be visible? Each facete **A**, **B**, **D** and **E** make an angle of 45^0w.r.t to the Base **C**. Looking at the shading of the prism in the figure can you guess the direction of the light source knowing that surface **C** looks the darkest? Compare the angles θ_A, θ_B, θ_C, θ_D and θ_E; that the direction of illumination $\vec{L}$ makes with the normal of each facete ($\vec{n_A}$, $\vec{n_B}$, $\vec{n_C}$, $\vec{n_D}$ and $\vec{n_E}$). **[3]**

5. a) Derive and formulate the **Hermite Cubical Spline.** Determine all the terms of the equation

$$p(u) = U \bullet M_{spline} \bullet M_{geom}$$

After formulating the constraints of **Bézier spline**, derive it from the **Hermite Spline.** Determine the 4 **Hermite** $H_i(u)$ and **Bézier** $B_i(u)$ blending functions and roughly plot and compare them.

$$H_i(u) \rightarrow B_i(u) \rightarrow U \cdot M_{spline}$$

b) Assume an equilateral triangle **ABC** of a side **AB=*a*=*10***. The coordinates of the vertex **A** is **(5,3)**. The slope of the segment **AB** is $(1/\sqrt{3})$. If the coordinate of **B** and **C** are (x_B, y_B) and (x_C, y_C), then $(y_B > y_C)$

This triangle controls a smooth curve. This smooth curve is tangent at 2 vertices on the segments **AB** and **AC** at **1/4a** from **B** and **C**. Draw the figure properly and mark and determine the coordinates of the 2 knots (**B'** and **C'**) and 2 control points (**B** and **C**) of the spline and determine the equations for the smooth spline curve using **Bézier** blending functions.

c) Assume the triangle **ABC** described in **(b)** in 3-dimensions. The **Z** coordinates for each point is zero (**Z=0**) to start with. This triangle is rotated by an angle **θ** about the axis formed by the median of the triangle emanating from the vertex **A.** Determine the required transformations to rotate the triangle. What changes will there be in the spline equation when $\theta = 3\pi/2$.

[(3 + 2) + (2+1) +2 = 10]

6. Write a pseudo code for Cohen-Sutherland Line Clipping algorithm. Assume a rectangular window having the delimiters $[x_{min}, x_{max};\ y_{min}, y_{max}]$.

a) To help with the code, first make the diagram with the region codes and mark. the delimiters.
b) Write the pseudo code to code the vertices.
c) Write the pseudo code trivial accept, trivial reject, Clip against one side, Computations of new vertices and assigning of code ....

{Assume Clip(V_i, V_j) is given which clips against one side $[x_{min}, x_{max};\ y_{min}, y_{max}]$ *(where code V_k is non-zero)* and assign new code to V_i or V_j based on the side clipped*}*

[2 + 3 + 5 = 10]