

# CS2401-COMPUTER GRAPHICS

## UNIT I 2D PRIMITIVES

### PART - A

#### 1. Define persistence.

Persistence is defined as the time it takes the emitted light from the screen to decay to one tenth of its original intensity.

#### 2. Define resolution.

The maximum number of points that can be displayed without overlap on a CRT is referred to as the resolution.

#### 3. Define aspect ratio.

Aspect ratio is the ratio of the vertical points to horizontal points necessary to produce equal length lines in both directions on the screen.

#### 4. What is horizontal and vertical retrace?

The return to the left of the screen after refreshing each scan line is called as the horizontal retrace.

Vertical retrace: At the end of each frame the electron beam returns to the top left corner of the screen to the beginning the next frame.

#### 5. What is interlaced refresh?

Each frame is refreshed using two passes. In the first pass, the beam sweeps across every other scan line from top to bottom. Then after the vertical retrace, the beam traces out the remaining scan lines.

#### 6. What is a raster scan system?

In a raster scan system the electron beam is swept across the screen, one row at a time top to bottom. As the electron beam moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots. Picture information is stored in a memory area called refresh buffer or frame buffer. Most suited for scenes with subtle shading and color patterns.

#### 7. What is a random scan system?

In random scan display unit, a CRT has the electron beam directed only to the parts of the screen where a picture is to be drawn. This display is also called as vector displays. Picture definition is stored as asset of line drawing commands in a memory referred to the refresh display file or display list or display program.

#### 8. What are beam penetration method color monitors?

Two layers of phosphor red and green are coated onto the inside of the CRT screen, and the displayed color depends on how far the electron beam penetrates into the phosphor layers. A beam of slow electrons excites only the outer red layer. A beam of very fast electrons penetrates through the red layer and excites the inner green layer.

#### 9. What are shadow mask method color monitors?

A shadow mask CRT has three phosphor color dots (red, blue and green) at each pixel position. There are three electron gun one for each color dot and a shadow mask grid behind the screen. The three electron beams are deflected and focused as a group through the hole in the shadow mask onto the screen. The electron beam activates a dot triangle which appears as a small color spot on the screen.

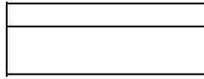
#### 10. What is scan conversion?

Digitizing a picture definition given in an application program into a set of pixel intensity values for storage in the frame buffer by the display processor is called scan conversion.

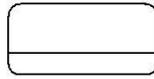
### 11. What are line caps?

The shape of the line ends are adjusted to give a better appearance by adding line caps. Butt cap: obtained by adjusting the end positions of the component parallel lines so that the thick line is displayed with square ends that is perpendicular to the line path.

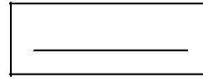
Round cap: obtained by adding a filled semicircle to each butt cap.



Butt cap



round cap



projecting square cap

### 12. What are different methods of smoothly joining two line segments?

Miter joins: Accomplished by extending the outer boundaries of each of the two lines until they meet.

Round join: produced by capping the connection between the two segments with a circular boundary whose diameter is equal to the line width.

Bevel join: generated by displaying the line segments with butt caps and filling in the triangular gap where the segments meet.

### 13. State some of the character attributes.

Text attributes:

Font: set of characters with a particular design style. Eg. Times roman, courier. Underlining

style: solid, dotted, double Boldface, *italics* **ou t l i n e**, *shadow*

### 14. Compare unbundled and bundled attributes.

Unbundled attributes: how exactly the primitive is to be displayed is determined by its attribute setting. These attributes are meant to be used with an o/p device capable of displaying primitives the way specified.

Bundled attributes: when several kinds of o/p devices are available at a graphics installation, it is convenient for a user to be able to say how attributes are to be interpreted on different o/p devices. This is accomplished by setting up tables for each o/p device that lists sets of attribute value that are to be used on that device to display each primitive type. A particular set of attribute values for a primitive on each o/p device is then chosen by specifying the appropriate table index. Attributes specified in this manner is called as bundled attribute.

### 15. Define aliasing.

Displayed primitives generated by the raster algorithms have a jagged, stair step appearance because the sampling process digitizes coordinate points on an object to discrete integer pixel positions. This distortion of information due to low frequency sampling is called aliasing.

### 16. What is antialiasing?

Appearance of displayed raster lines by applying antialiasing methods that compensate for the under sampling process. Nyquist sampling frequency: to avoid losing information, the sampling frequency to at least twice that of the highest frequency occurring in the object.  $F_s = 2 * f_{max}$ .

### 17. What is antialiasing by super sampling or post filtering?

This is a technique of sampling object characteristics at a high resolution and displaying results at a lower resolution.

### 18. What is antialiasing by area sampling or prefiltering?

An alternative to super sampling is to determine pixel intensity by calculating areas of overlap of each pixel with the objects to be displayed. antialiasing by computing overlaps areas is referred to as area sampling or prefiltering.

### 19. What is antialiasing by pixel phasing?

Raster objects can be antialiased by shifting the display location of pixel areas. This is applied by "micro positioning" the electron beam in relation to object geometry.

## 20. What are the basic transformations?

Translation : translation is applied to an object by repositioning it along a straight plane.

Rotation:

$$P1=R.P$$

$$R = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \quad \theta - \text{rotation angle}$$

Scaling: a scaling transformation alters the size of an object .

$$x1=x.Sx \quad y1=y.Sy$$

$Sx$  and  $Sy$  are scaling factors.

## 21. What is uniform and differential scaling?

Uniform scaling:  $Sx$  and  $Sy$  are assigned the same value.

Differential scaling: unequal values for  $Sx$  and  $Sy$ .

## 22. Define reflection.

A reflection is a transformation that produces a mirror image of an object.

By line  $y=0$ (x-axis)

$$\text{Transformation Matrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

by the x axis

$$\text{Transformation Matrix} = \begin{pmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

## 23. Define shearing.

A transformation that distorts the shape of an object such that the transformed shape appears as if the object is composed of internal layers that had been caused to slide over each other is called shear.

x-direction shear relative to x axis

$$\text{shear matrix} = \begin{pmatrix} 1 & shx & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

x-direction shear relative to other reference lines

$$\text{shear matrix} = \begin{pmatrix} 1 & shx & -shx * yref \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

## 24. What is a window and a viewport?

A world coordinate area selected for display is called a window. An area on a display device to which a window is mapped is called a viewport.

## 25. What is cell array?

The cell array is a primitive that allows users to display an arbitrary shape defined as a two dimensional grid pattern.

## PART B

1. Explain in detail about Bresenham's line generating algorithm. Give example.
2. Explain in detail about Bresenham's circle generating algorithm. Give example.
3. Explain in detail about Bresenham's ellipse generating algorithm. Give example.
4. Explain in detail about window to viewport coordinate transformation.
5. Write a detailed note on the basic two dimensional transformations.
6. Explain with an example the Cohen-Sutherland line clipping algorithm.
7. Compare Cohen-Sutherland line clipping algorithm and Liang-Barsky line clipping algorithm. Write note on any one polygon clipping algorithm.
8. Explain in detail about video display devices.
9. Explain in detail about raster and random scan systems.
10. Explain in detail about graphics input devices.

## UNIT II 3D CONCEPTS

### PART - A

#### 1. What are the representation schemes for solid objects?

Boundary representations: they describe a 3D object as a set of surfaces that separate the object interior from environment. Example: polygon facets

Space partitioning representations: they are used to describe interior properties, by partitioning the spatial region containing an object into a set of small, non overlapping, contiguous solids. Example: octree

#### 2. What is parallel projection?

One method for generating a view of a solid object is to project points on the object surface along parallel lines onto the display plane. By selecting different viewing positions, can project visible points on the object onto the display plane.

#### 3. What is perspective projection?

Project points to the display plane along converging points.

#### 4. What are blobby objects?

Some objects do not maintain a fixed shape, but change their surface characteristics in certain motions or when in proximity with other objects. These objects are referred to as blobby objects, since their shapes show a certain degree of fluidness.

#### 5. What is depth cueing?

Depth information is important so that easily identify for a particular viewing direction, which is the front and which is the back of displayed objects.

#### 6. What is an ellipsoid?

An ellipsoid surface can be described as an extension of a spherical surface, where the radii in three mutually perpendicular directions can have different values.

#### 7. Define spline curve.

The term spline is a flexible strip used to produce a smooth curve through a designated set of points. In computer graphics, the term spline curve refers to any composite curve formed with polynomial sections satisfying specified continuity conditions at the boundary of the pieces.

#### 8. How to generate a spline curve?

A spline curve is specified by giving a set of coordinate positions called as control points. These control points are then fitted with piece wise continuous parametric polynomial functions in one of the two ways. When polynomial sections are fitted so that the curve passes through each control point, the resulting curve is said to interpolate the set of control points. When the polynomials are fitted to the general control point path without necessarily passing through any control point the resulting curve is said to approximate the set control points.

### 9. Define Bezier curves.

This is a spline approximation method. A Bezier curve section can be fitted to any number of control points. The number of control points to be approximated and their relative position determine the degree of the Bezier polynomial. As with the interpolation splines, a Bezier curve can be specified with boundary conditions, with a characterization matrix, or with blending functions.

### 10. List the features of representations.

Sweep representations are useful for constructing three-dimensional objects that possess translational, rotational or other symmetries. One can represent such objects by specifying a 2D shape and a sweep that moves the shape through a region of space. A set of 2D primitives such as circles and rectangles, can be provided for sweep representations as menu options.

### 11. What do you mean by constructive solid geometry?

CSG creates a new volume by applying the union, intersection or difference of two specified volumes.

### 12. How ray casting is implemented?

- Ray casting methods are commonly used to implement constructive solid geometry operations when objects are described with boundary representations.
- Ray casting is applied by constructing composite objects in world coordinates with the xy plane corresponding to the pixel plane of a video monitor.
- This plane is referred to as “firing plane”, since each pixel emits a ray through the objects that are combined.
- Then the surface intersections along each ray path, and they are sorted according to the distance from the firing plane. The surface limits for the composite objects are determined by specified set operations.

### 13. Define Octree.

Hierarchical tree structures called octrees are used to represent solid objects in some graphics system. The tree structure is organized so that each node corresponds to a region of 3D space. This representation for solids takes advantage of spatial coherence to reduce storage requirements for 3D objects.

### 14. What are the two types of projections?

Parallel projection: coordinate positions are transformed to the view plane along parallel lines.

Perspective projection: object positions are transformed to the view plane along lines that converge to a point called projection reference point.

### 15. What are the two types of parallel projection?

Orthographic parallel projection: projection is perpendicular to the view plane.

Oblique parallel projection: projection is not perpendicular to the view plane.

### 16. Define axonometric projection.

Orthogonal projections that display more than one face of an object are axonometric projection.

### 17. Define isometric projection.

Isometric projection is obtained by aligning the projection plane so that it intersects each coordinate axis in which the object is defined at the same distance from the origin.

### 18. What is cavalier projections.

Point  $(x,y,z)$  is projected to position  $(x_p,y_p)$  on the view plane. The projection line from  $(x,y,z)$  and  $(x_p,y_p)$  makes an angle  $\alpha$  with the line on the projection plane that joins  $(x_p,y_p)$  and  $(x,y)$ . When  $\alpha = 45^\circ$  the views obtained are cavalier projections. All lines perpendicular to the projection plane are projected with no change in length.

### 19. Define depth cueing.

Depth cueing is a technique for choosing maximum and minimum intensity (or color) values and a range of distances over which the intensities are to vary.

**20. State the use of exploded views.**

Exploded and cutaway views of such objects can then be used to show the internal structure and relationship of the object parts.

**21. What are called control points?**

The spline curve is specified by giving a set of coordinate positions, called controlpoints, which indicates the general shape of the curve.

**22. When is the curve said to interpolate the set of control points?**

When polynomial sections are fitted so that the curve passes through each control point, the resulting curve is said to interpolate the set of control points.

**23. When is the curve said to approximate the set of control points?**

When the polynomials are fitted to the general control-point path without necessarily passing through any control point, the resulting curve is said to approximate the set of control points.

**24. What is called a convex hull?**

The convex polygon boundary that encloses a set of control points is called the convex hull.

**25. Mention some surface detection methods.**

Back-face detection, depth-buffer method, A-buffer method, scan-line method, depth-sorting method, BSP-tree method, area subdivision, octree method, ray casting.

**PART B**

1. Explain about the spline representation of three dimensional objects.
2. Explain about the octree representation of three dimensional objects.
3. Write short notes on fractal geometry method of representing three dimensional objects.
4. Briefly explain about the basic transformations performed on three dimensional objects.
5. Write short notes on parallel and perspective projections.
6. Explain in detail about three dimensional display methods.
7. Explain in detail about the boundary representation of three dimensional objects.
8. Explain in detail about the three dimensional transformations.
9. Explain in detail about depth buffer method.
10. Explain in detail about BSP tree method of determining object visibility.

**UNIT III GRAPHICS PROGRAMMING**

**PART – A**

**1. What is a color model?**

A color model is a method for explaining the properties or behavior of color within some particular context. Example: XYZ model, RGB model.

**2. Define intensity of light.**

Intensity is the radiant energy emitted per unit time, per unit solid angle, and per unit projected area of source.

**3. What is hue?**

The perceived light has a dominant frequency (or dominant wavelength). The dominant frequency is also called as hue or simply as color.

**4. What is purity of light?**

Purity describes how washed out or how “pure” the color of the light appears. pastels and pale colors are described as less pure.

**5. Define the term chromacity.**

The term chromacity is used to refer collectively to the two properties describing color characteristics: purity and dominant frequency.

**6. Write about CMY model.**

A color model defined with the primary colors cyan, magenta and yellow is useful for describing color output to hard copy devices.

**7. Define computer animation.**

Computer animation generally refers to any time sequence of visual changes in a scene.

**8. What do you mean by frame-by-frame animation?**

Frame-by-frame animation, each frame of the scene is separately generated and stored. Later the frames can be recorded on film or they can be consecutively displayed in "real time playback" mode.

**9. Define story board.**

The storyboard is an outline of the action. It defines the motion sequence as a set of basic events that are to take place. Depending on the type of animation to be produced, the storyboard could consist of a set of rough sketches or it could be a list of the basic ideas for the motion.

**10. Define key frame.**

A key frame is a detailed drawing of the scene at a certain time in the animation sequence. Within each key frame, each object is positioned according to the time for that frame. Some key frames are chosen at extreme positions in action; others are spaced so that the time interval between key frames is not too great.

**11. What is morphing?**

Transformation of object shape from one form to another is called morphing.

**12. Mention some input graphics primitives.**

String, choice, valuator, locator and pick.

**13. Mention some physical input devices.**

Keyboard, buttons, mouse, tablet, joystick and trackball, knobs, space ball and data glove.

**14. What are OpenGL datatypes?**

Glbyte, Glshort, Glint, Glsizei, Glfloat, Glclampf, Gldouble, Glboolean

**15. How is the color of an object determined?**

When white light is incident upon an object, some frequencies are reflected and some are absorbed by the object. The combination of frequencies present in the reflected light determines what we perceive as the color of the object.

**16. Define brightness.**

Brightness is defined as the perceived intensity of the light.

**17. Write Window to viewport transformation.**

$s_x = Ax + C$  and  $s_y = By + D$  with  $A = \frac{V.r - V.l}{W.r - W.l}$ ,  $C = \frac{V.l - AW.l}{W.r - W.l}$  and  $B = \frac{V.t - V.b}{W.t - W.b}$ ,  $D = \frac{V.b - BW.b}{W.t - W.b}$

**18. List some functions to draw some 3D objects.**

Cube, sphere, torus, teapot.

**19. Define intensity.**

Intensity is the radiant energy emitted per unit time, per unit solid angle, and p:r unit projected area of the source.

**20. Define purity or saturation.**

Purity describes how washed out or how "pure" the color of the light appears.

**21. Define complementary colors.**

If the two color sources combine to produce white light, they are referred to as 'complementary colors. Examples of complementary color pairs are red and cyan, green and magenta, and blue and yellow.

## **22. Define primary colors.**

The two or three colors used to produce other colors in a color model are referred to as primary colors.

## **23. State the use of chromaticity diagram.**

Comparing color gamuts for different sets of primaries. Identifying complementary colors. Determining dominant wavelength and purity of a given color.

## **24. Mention the steps in animation sequence.**

Storyboard layout, Object definitions, Key-frame specifications, Generation of in-between frame

## **25. What are in between frames?**

In-betweens are the intermediate frames between the key frames. The number of in-betweens needed is determined by the media to be used to display the animation. Film requires 24 frames per second, and graphics terminals are refreshed at the rate of 30 to 60 frames per second.

## **PART B**

1. Explain in detail about XYZ color model.
2. Explain in detail about RGB color model.
3. Explain in detail about YIQ color model.
4. Explain in detail about CMY color model.
5. Explain in detail about HSV color model.
6. Compare and contrast RGB and CMY.
7. Explain in detail about the conversion between HSV and RGB color models.
8. Explain in detail about HLS color model.
9. Explain in detail about the steps in computer animation.
10. Explain in detail about the approaches for object motion specifications.
11. Explain in detail about morphing.

## **UNIT IV RENDERING**

### **PART – A**

#### **1. What is a shading model?**

It attempts to model how light that emanates from light sources would interact with objects in a scene. Usually it does not try to simulate all of the physical principles having to do with the scattering and reflection of light.

#### **2. Define flat shading.**

A calculation of how much light is scattered from each face is computed at a single point, so all points on a face are rendered with the same gray level.

#### **3. Define Gouraud shading.**

Different points of a face are drawn with different gray levels found through an interpolation scheme.

#### **4. What is Achromatic light?**

It has brightness, but no color. Achromatic light is only a shade of gray; hence it is described by a single value: its intensity.

#### **5. What are the two types of light sources that illuminate the objects in a scene?**

The two light sources are point light source and ambient light.

#### **6. What are the different ways by which the incident light interacts with the surface?**

The three different ways are: some is absorbed by the surface and is converted to heat, some is reflected from the surface and some is transmitted into the interior of the object, as in the case of a piece of glass.

**7. Define blackbody.**

If all the incident light is absorbed, the object appears black and is known as blackbody.

**8. What are the two types of reflection of incident light?**

The two types are diffuse scattering and specular reflections.

**9. What are the three vectors to be found, to compute the diffuse and specular components of light?**

The three vectors are: the normal vector  $m$  to the surface at  $P$ , the vector  $v$  from  $P$  to the viewer's eye, the vector  $s$  is from  $P$  to the light source.

**10. What is specular reflection?**

Real objects do not scatter light uniformly in all directions, so a specular component is added to the shading model. Specular reflection causes highlights, which can add significantly to the realism of a picture when objects are shiny.

**11. What is tiler?**

A polygon filling routine is sometimes called a tiler, because it moves over the polygon pixel by pixel, coloring each pixel appropriately. The pixels are visited in regular order, usually scan line by scan line from bottom to top and across each scan line left to right.

**12. What is smooth shading?**

Smooth shading attempts to de-emphasize edges between faces by computing colors at more points on each face.

**13. What are the principal types of smooth shading?**

The two principal types of smooth shading are Gouraud shading and Phong shading.

**14. What are the most common sources of textures?**

The most common sources of textures are bitmap textures and procedural textures.

**15. What is reflection mapping?**

The class of techniques known as reflection mapping can significantly improve the realism of pictures, particularly animation. The basic idea is to see reflection in an object that suggest the "world" surrounding that object.

**16. What are the types of reflection mapping?**

The types are: chrome mapping and environment mapping.

**17. Define chrome mapping.**

A rough and usually blurry image that suggests that surrounding environment is reflected in the object, as a surface coated with chrome.

**18. Define environment mapping.**

A recognizable image of the surrounding environment is seen reflected in the object. We get valuable visual cues from such reflections, particularly when the object moves about.

**19. What are the stages of rendering in creating shadows?**

The stages are: loading shadow buffer and rendering the scene.

**20. What is Bump mapping?**

It is a technique to give a surface a wrinkled or dimpled appearance without struggling to model the dimple itself.

**21. How to create a glowing object?**

The visible intensity  $I$  is set equal to the texture value at each spot:  $I = \text{texture}(s,t)$ . The object then appears to emit light or glow. Lower texture values emit less light and higher texture values emit more light.

**22. What are bitmap textures?**

Textures are often formed by bitmap representation of images. Such representation consists of an array of color values, often called as texels.

### 23. What are procedural textures?

Defining texture by a mathematical function or procedure.

### 24. Define texture space.

Texture space is traditionally marked off by parameters named  $s$  and  $t$ . The function of texture( $s,t$ ) produces a color or intensity value for each value of  $s$  and  $t$  between 0 and 1.

### 25. What is Phong shading?

Phong shading finds a normal vector at each point on the face of the object and then apply the shading model there to find the color. Compute the normal vector at each pixel by interpolating the normal vectors at the vertices of the polygon.

## PART B

1. Explain in detail about shading models.
2. Give an account about specular reflection.
3. Explain about shading and graphics pipeline.
4. How can light sources be used in OpenGL?
5. Give a detailed account about Flat shading.
6. Explain in detail about smooth shading.
7. Give an account on removing hidden surfaces.
8. Explain how texture can be added to faces.
9. Explain in detail how texture can be rendered.
10. Explain Gouraud shading and Phong shading.

## UNIT V FRACTALS

### PART A

#### 1. Define self-similar.

Most of the curves and pictures have a particularly important property: they are self-similar. This means that they appear “the same” at every scale. No matter how much one enlarges a picture of the curve, it has the same level of detail.

#### 2. Mention the types of self-similar.

The types are: exactly self-similar and statistically self-similar.

#### 3. What is Koch curve?

Very complex curves can be fashioned recursively by repeatedly “refining” a simple curve. The simplest is the Koch curve. This curve stirred great interest in the mathematical world because it produces a infinitely long line within a region of finite area.

#### 4. What are Peano curves?

A fractal curve can in fact “fill the plane” and therefore have a dimension of 2. Such curves are called Peano curves.

#### 5. What is a L-System?

A large number of interesting curves can be generated by refining line segments. A particularly simple approach to generating these curves uses so called L-Systems to draw complex curves based on simple set of rules.

#### 6. Mention the dragon rules.

The dragon rules are ‘F’‘F’, ‘X’“X+YF+”, ‘Y’ “-FX-Y”, atom=”FX”

#### 7. What is space-filling?

Such curves have a fractal dimension of 2 and they completely fill a region of space.

#### 8. What are the two famous Peano curves?

The two famous Peano curves are: Hilbert and Sierpinski curves.

### 9. Define fractal trees.

Fractal trees provide an interesting family of shapes that resemble actual trees. Such shrubbery can be used to ornament various drawings.

### 10. What is periodic tiling?

The notion is to take many copies of some shape such as polygon and to fit them together as a jigsaw puzzle so that they cover the entire plane with no gaps.

### 11. What is dihedral tiling?

They permit the use of two prototiles and therefore offer many more possibilities.

### 12. How can a black and white image be described?

A black and white image  $I$  can be described simply as the set of its black points:  $I = \text{set of all black points} = \{(x,y) \text{ such that } (x,y) \text{ is coloured black}\}$ .

### 13. What is the "Chaos Game"?

It is also known as the random iteration algorithm which offers a simple nonrecursive way to produce a picture of the attractor of an IFS.

### 14. What is fractal image compression?

The original image is processed to create the list of affine maps, resulting in a greatly compressed representation of the image.

### 15. What is Mandelbrot set?

It is the black inner portion, which appears to consist of a cardioid along with a number of wart like circles glued to it. Its border is complicated and this complexity can be explored by zooming in on a portion of the border.

### 16. Define Julia sets.

Julia sets are extremely complicated sets of points in the complex plane. There is a different Julia set  $J_c$  for each value of  $c$ .

### 17. What are the steps in ray tracing process?

The steps are: build the ray, find the intersections with the object, identify intersections that lie close to and in front of the eye, compute the hit point, find the color of the light and place the color in the pixel.

### 18. How to incorporate texture into a ray tracer?

Two principal kinds of texture are used: with image texture a 2D image is pasted onto each surface of the object, with solid texture the object is considered to be carved out of a block of some material.

### 19. What is wood grain texture?

As the distance of points from some axis varies, the function jumps back and forth between two values. This effect can be simulated with the modulo function  $\text{rings}(r) = ((\text{int})r) \% 2$  where rings about the z-axis, the radius  $r = \sqrt{x^2 + y^2}$ .

### 20. Define refraction of light.

When a ray of light strikes a transparent object, a portion of the ray penetrates the object. The ray change direction from  $d_i$  to  $t$  if the speed of light is different in medium 1 than in medium 2.

### 21. State Snell's law.

If the angle of incidence of the ray is  $\theta_1$ , Snell's law states that the angle of refraction  $\theta_2$  will be  $\sin(\theta_2)/c_2 = \sin(\theta_1)/c_1$ .

### 22. What is total internal reflection?

When the smaller angle gets larger enough, it forces the larger angle to  $90^\circ$ . A larger value is impossible, so no light is transmitted into the second medium. This is called total internal reflection.

**23. What are CSG objects?**

Objects such as lenses and hollow fishbowls, as well as objects with holes are easily formed by combining the generic shapes treated thus far. They are called compound, Boolean or CSG objects.

**24. What are the Boolean operators used on objects?**

Some Boolean operators used on objects are: union, intersection and difference.

**25. What is the motivation of using projection extends?**

There is a strong motivation for using projection extends for CSG objects, due to the cost of ray tracing them.

**PART B**

1. Explain about fractals and self-similarity.
2. Give an account about Peano curves.
3. Explain the methods for crating images by means of iterated function systems.
4. Explain about the Mandelbrot set.
5. Explain about Julia sets.
6. Give a detailed account of random fractals.
7. Explain how to find the intersection of a ray with an object.
8. Give an account on adding surface texture.
9. Explain about reflections and transparency.
10. Explain the Boolean operations that can be performed on objects.