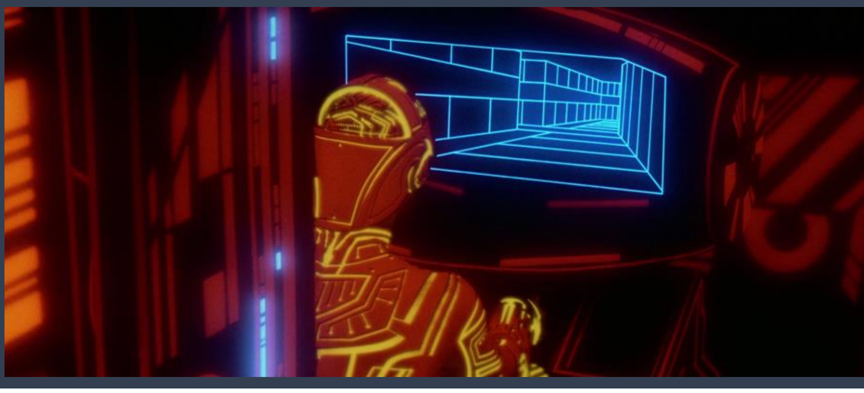
CGA

MODULE: COMPUTER GRAPHICS & ANIMATION



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Certificate

This is to certify that the e-book titled <u>"Computer Graphics and Animation"</u> comprises all elementary learning tools for a better understating of the relevant concepts. This e-book is comprehensively compiled as per the predefined eight parameters and guidelines.

madhavi

Signature **Date: 25-03-2021**

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Unit 3: Viewing in 3D

Contents

Viewing in 3D

Stages in 3D viewing, Canonical View Volume (CVV), Specifying an Arbitrary 3D View, Examples of 3D Viewing, The Mathematics of Planar Geometric Projections, Combined transformation matrices for projections and viewing, Coordinate Systems and matrices, camera model and viewing pyramid. Light: Radiometry, Transport, Equation, Photometry Color: Colorimetry, Color Spaces, Chromatic Adaptation, Color Appearance

References:

Sr. No	Reference Book Titles	Author/s	Publisher	Edition	Module Nos.
1	Computer Graphics - Principles and Practice	J. D. Foley, A. Van Dam, S. K. Feiner and J. F. Hughes	Pearson	2nd	Unit 1
2	Fundamentals of Computer Graphics	Steve Marschner, Peter Shirley	CRC Press	4th	Unit 2, 3 & 5
3	Computer Graphics	Hearn, Baker	Pearson	2nd	All
4	Principles of Interactive Computer Graphics	William M. Newman and Robert F. Sproull	TMH	2nd	Unit 5
5	Mathematical Elements for CG	D. F. Rogers, J. A. Adams	TMH	2nd	Unit 2 & 3
6	Basics of Computer Graphics	Atul.P. Godse	Technical	1st	Unit 1 & 2

Prerequisites and Linking

Unit I	Pre-Requisites	Sem. II	Sem. III	Sem. IV	Sem. V	Sem. VI
Introduction	-	OOPS	-	-	-	Project

1. Three-Dimensional Viewing

Viewing in 3D involves the following considerations:

- We can view an object from any spatial position,

eg.

In front of an object,
Behind the object,
In the middle of a group of objects,
Inside an object, etc.

- 3D descriptions of objects must be projected onto the flat viewing surface of the output device.
- The clipping boundaries enclose a volume of space.

2. Viewing Pipeline

Modelling Coordinates
⇓
[Modelling Transformations]
⇓
World Coordinates
⇓
[Viewing Transformation]
⇓
Viewing Coordinates
⇓
[Projection Transformation]
⇓
Projection Coordinates
⇓
[Workstation Transformation]
⇓
Device Coordinates

Explanation:

Modelling Transformation and Viewing Transformation can be done by 3D transformations.

The viewing-coordinate system is used in graphics packages as a reference for specifying the observer viewing position and the position of the projection plane.

Projection operations convert the viewing-coordinate description (3D) to coordinate positions on the projection plane (2D). (Usually combined with clipping, visual-surface identification, and surface-rendering)

Workstation transformation maps the coordinate positions on the projection plane to the output device.

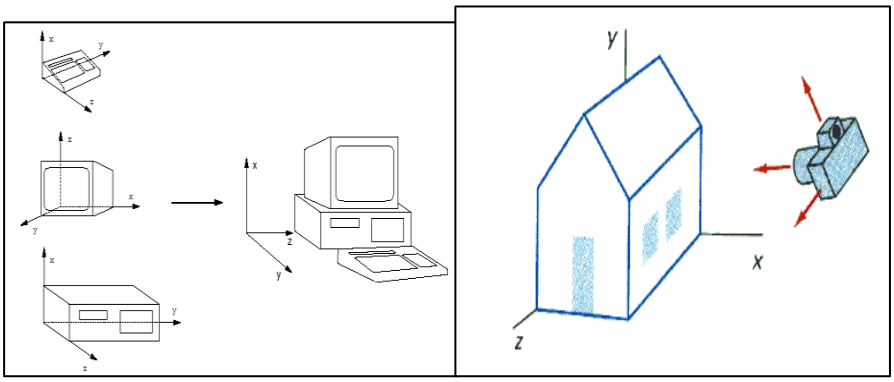


Fig 1: Viewing Pipeline

3. Viewing Transformation

Conversion of objection descriptions from world to viewing coordinates is equivalent to a transformation that superimposes the viewing reference frame onto the world frame using the basic geometric translate-rotate operations:

1. Translate the view reference point to the origin of the world-coordinate system.
2. Apply rotations to align the x_v, y_v, and z_v axes (viewing coordinate system) with the world x_w, y_w, z_w axes, respectively.

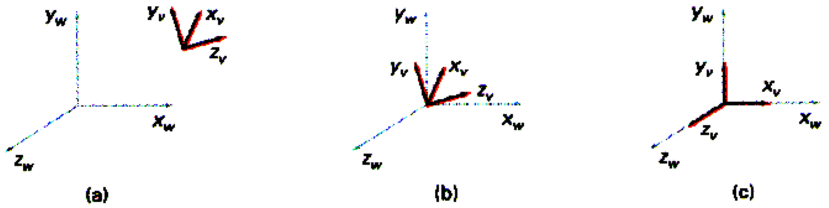


Fig 2: Viewing Transformation

View Volume:
View window - A rectangular area in the view plane which controls how much of the scene is viewed. The edges of the view window are parallel to the x_v and y_v viewing axes.

View volume - formed by the view window and the type of projection to be used. Only those objects within the view volume will appear in the generated display. So, we can exclude objects that are beyond the view volume when we render the objects in the scene.

A finite view volume is obtained by bounding with front plane and back plane (or the near plane and the far plane). Hence a view volume is bounded by 6 planes => rectangular parallelepiped or a frustum, for parallel projection and perspective projection respectively.

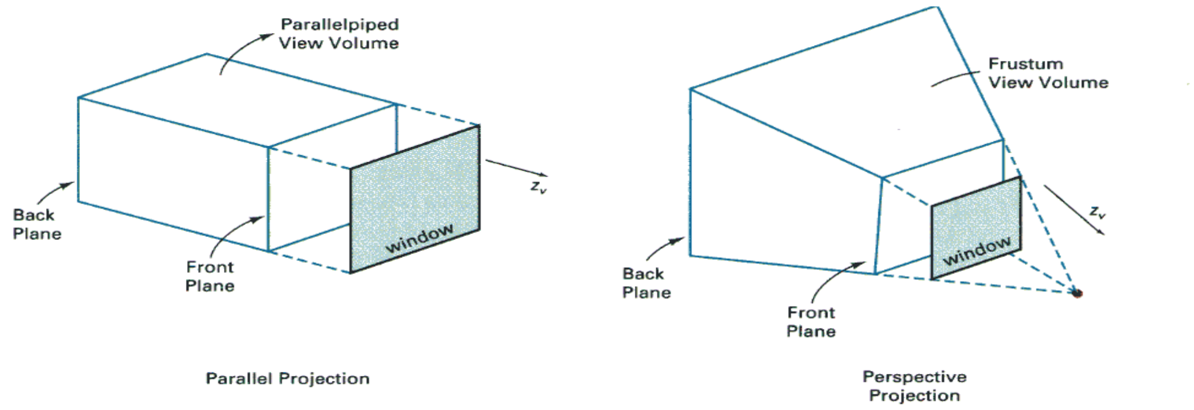


Fig 3: View Volume

<u>Some facts:</u>
Perspective effects depend on the positioning of the center point of projection. If it is close to the view plane, perspective effects are emphasized, ie. closer objects will appear larger than more distant objects of the same size.
The projected size of an object is also affected by the relative position of the object and the view plane.

<u>'Viewing' a static view:</u>

The view plane is usually placed at the viewing-coordinate origin and the center of projection is positioned to obtain the amount of perspective desired.

'Viewing' an animation sequence:

Usually the center of projection point is placed at the viewing-coordinate origin and the view plane is placed in front of the scene. The size of the view window is adjusted to obtain the amount of scene desired. We move through the scene by moving the viewing reference frame (ie. the viewing coordinate system.

Canonical View Volume (CVV):
After the projection matrix is applied to the view space, the view space is "normalized" so that all the points lie within the range [-1, 1]. This is generally referred to as the "canonical view volume" or "normalized device coordinates".

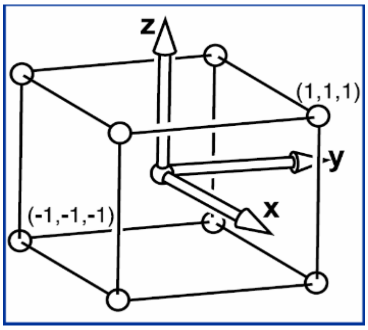


Fig 4: CVV

Light:
Radiometry is the science of measuring light in any portion of the electromagnetic spectrum. In practice, the term is usually limited to the measurement of infrared, visible, and ultraviolet light using optical instruments. Irradiance is the intensity of light and is measured in watts per square meter.

Photometry is the science of measuring visible light in units that are weighted according to the sensitivity of the human eye. It is a quantitative science based on a statistical model of the human visual response to light - that is, our perception of light - under carefully controlled conditions. The photometric equivalent of Radiance is called Illuminance and is measured in Lumens per square meter (Lux).

Color:
Colorimetry: In physical and analytical chemistry, colorimetry or colorimetry is a technique "used to determine the concentration of colored compounds in solution." A colorimeter is a device used to test the concentration of a solution by measuring its absorbance of a specific wavelength of light (not to be confused with the tristimulus colorimeter used to measure colors in general).
To use the colorimeter, different solutions must be made, including a control or reference of known concentration. With a visual colorimeter, for example the Duboscq colorimeter illustrated, the length of the light path through the solutions can be varied while filtered light transmitted through them is compared for a visual match. The concentration times path length is taken to be equal when the colors match, so the concentration of the unknown can be determined by simple proportions. Nessler tubes work on the same principle.

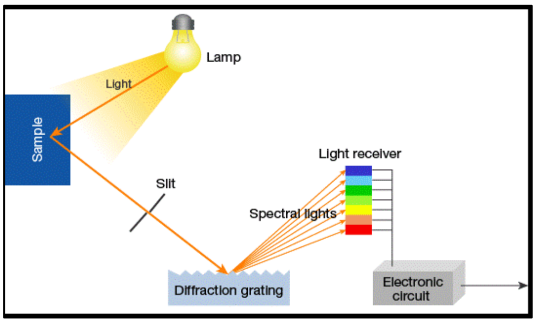


Fig 5: Colorimetry

Color Spaces: HSV is a transformation of an RGB **color space**, and its components and colorimetry are relative to the RGB **color space** from which it was derived. HSL (hue, saturation, lightness/luminance), also known as HLS or HSI (hue, saturation, intensity) is quite similar to HSV, with "lightness" replacing "brightness".

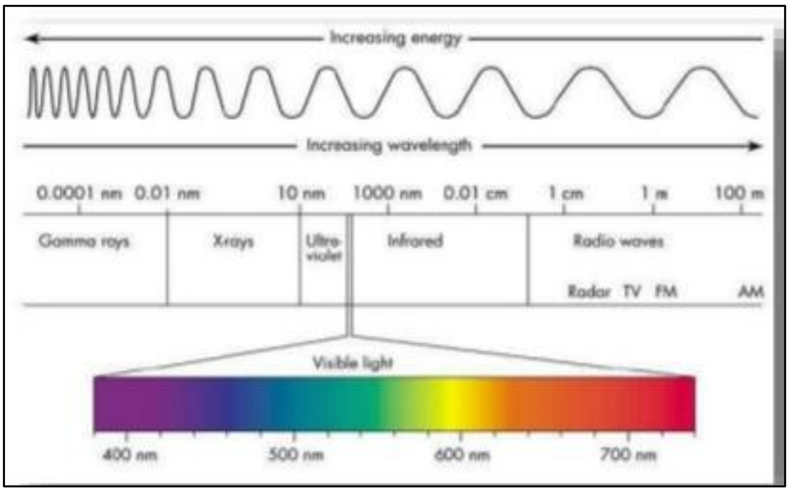


Fig 6: Color Space

Chromatic Adaptation: It is the human visual system's ability to adjust to changes in illumination in order to preserve the appearance of object colors. It is responsible for the stable appearance of object colors despite the wide variation of light which might be reflected from an object and observed by our eyes. A **Chromatic Adaptation Transform** (CAT) function emulates this important aspect of color perception in Color Appearance Model.

Color Appearance:

- Color originates in the mind of the observer; "objectively", there is only the spectral power distribution of the light that meets the eye. In this sense, any color perception is subjective.
- However, successful attempts have been made to map the spectral power distribution of light to human sensory response in a quantifiable way.
- In 1931, using psychophysical measurements, the International Commission on Illumination (CIE) created the XYZ color space which successfully models human color vision on this basic sensory level.

RGB Model:

- Based on the tristimulus theory of vision, our eyes perceive color through the stimulation of three visual pigments in the cones of the retina.
- These visual pigments have a peak sensitivity at wavelengths of about 630 run (red), 530 nm (green), and 450 nm (blue).
- By comparing intensities in a light source, we perceive the color of the light.
- This theory of vision is the basis for displaying color output on a video monitor using the three color primitives, red, green, and blue, referred to as the RGB color model.
- We can represent this model with the unit cube defined on R, C, and B axes. The origin represents black, and the vertex with coordinates (1,1,l) is white.
- Vertices of the cube on the axes represent the primary colors, and the remaining vertices represent the complementary color for each of the primary colors.
- As with the XYZ color system, the RGB color scheme is an additive model.
- Intensities of the primary colors are added to produce other colors.
- Each color point within the bounds of the cube can be represented as the triple (R, G, B), where values for R, G, and B are assigned in the range from 0 to 1.
- Thus, a color C, is expressed in RGB components as

$$C_\lambda = R\mathbf{R} + G\mathbf{G} + B\mathbf{B}$$

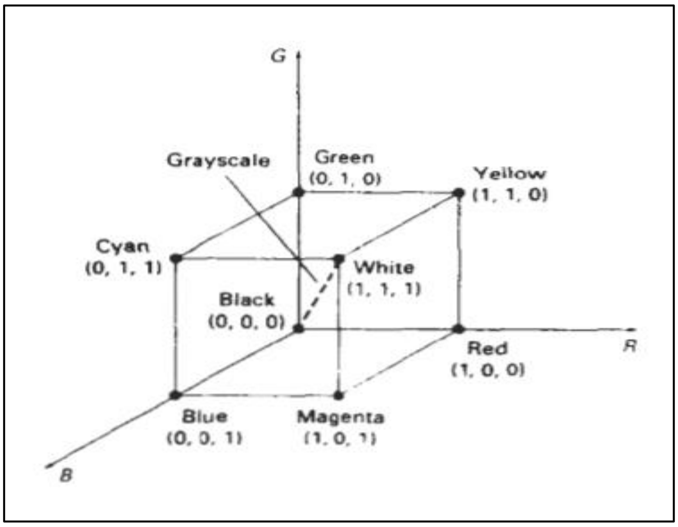


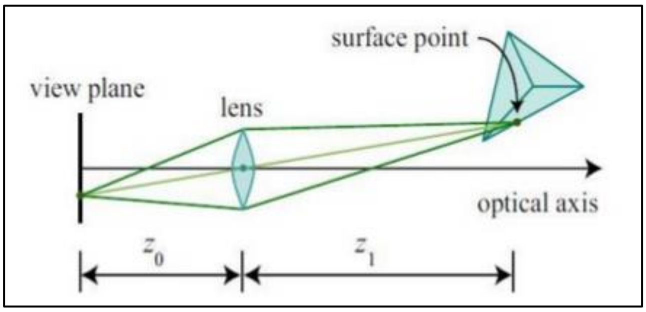
Fig.: RGB Model

Various parameters used in Color appearance:

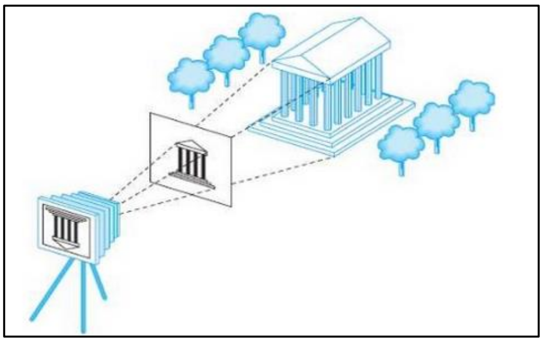
1. Color originates in the mind of the observer; "objectively", there is only the spectral power distribution of the light that meets the eye. In this sense, any color perception is subjective.
2. Following are the parameters used in Color appearance:
   a. Hue: An area appears to be similar to one of the perceived colors: Red, Yellow, Green, Blue.
   b. Lightness: The brightness of an area judged relative to brightness of a similarly illuminated white area.
   c. Brightness: It is an attribute of visual perception in which a source appears to be radiating or reflecting light.
   d. Chroma: The colorfulness of an area judged as a proportion of the brightness of similarly illuminated white.
   e. Colourfulness: It is the attribute of a visual perception according to which the perceived color of an area appears to be more or less chromatic.
   f. Saturation: is the colorfulness of an area judged in proportion to its brightness, which in effect is the perceived freedom from whitishness of the light coming from the area.

Camera Model:

- The Camera model simulates the capture of light from a three-dimensional scene in object space onto a two dimensional image, or image space.
- Most models contain or approximate a system of parallel lenses such as that of a camera or the eye.
- Thin Lens Model:



- Most modern cameras use a lens to focus light onto the view plane. this is done so that one can capture enough light in a sufficiently short period of time that the objects do not move appreciably, and the image is bright enough to show significant detail over a wide range of intensities and contrasts.
- Synthetic Camera model:



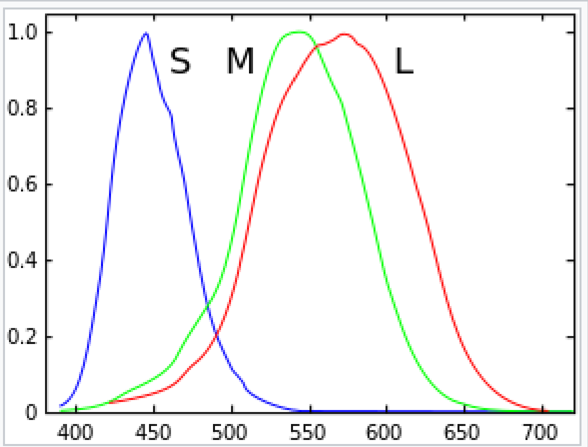
- In computer Graphics we use a synthetic camera model to mimic the behaviour of a real camera.
- In the synthetic camera model, we avoid the inversion by placing the film plane, called the projection plane, in front of the lens.
- The clipping rectangle or clipping window determines the size of the image.
- Each point in the 3D model is projected onto the image plane using the pin-hole camera model.

Photometry:

- Photometry is the science of measuring visible light in units that are weighted according to the sensitivity of the human eye.
- It is a quantitative science based on a statistical model of the human visual response to light -- that is, our perception of light -- under carefully controlled conditions.
- The human visual system is a marvellously complex and highly nonlinear detector of electromagnetic radiation with wavelengths ranging from 380 to 770 nanometres (nm).
- We see light of different wavelengths as a continuum of color ranging through the visible spectrum: 650 nm is red, 540 nm is green, 450 nm is blue, and so on.
- The sensitivity of the human eye to light varies with wavelength.
- A light source with a radiance of one watt/m2 -steradian of green light, for example, appears much brighter than the same source with a radiance of one watt/m2 -steradian of red or blue light. In photometry, we do not measure watts of radiant energy.
- Rather, we attempt to measure the subjective impression produced by stimulating the human eye-brain visual system with radiant energy.
- This task is complicated immensely by the eye’s nonlinear response to light.
- It varies not only with wavelength but also with the amount of radiant flux, whether the light is constant or flickering, the spatial complexity of the scene being perceived, the adaptation of the iris and retina, the psychological and physiological state of the observer, and a host of other variables.

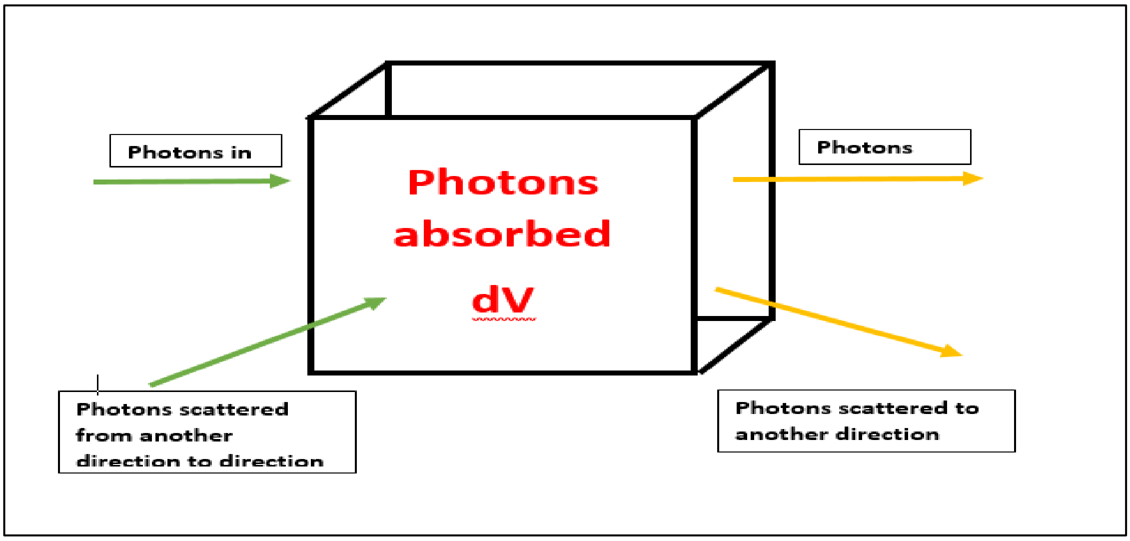
LMS color space:

- LMS is a color space represented by the response of the three types of cones of the human eye, named for their responsivity (sensitivity) peaks at long, medium, and short wavelengths.
- It is common to use the LMS color space when performing chromatic adaptation.
- It's also useful in the study of color blindness, when one or more cone types are defective.
- Since the LMS color space is supposed to model the complex human color perception, no single, “objective” transformation matrix between XYZ and LMS exists.



Normalized responsivity spectra of human cone cells, S, M, and L types

Transport equation of light:
Light is considered as an electromagnetic wave modelled by the Maxwell equations.
Light is considered as a stream of energetic particles-photons and modelled by energy conservation which is 'the transport equation'.
Examples of Transport equations:
1) Heat conduction
2) Diffusion
3) neutrons in nuclear reactions
4) Light propagation in turbid media
The Transport Equation:
1) Assume a small volume dV & a direction S.
2) Conservation of energy yields that photons can only be added or subtracted from the photon distribution function in specific interactions.



Questions:
1) What are the stages in 3D viewing?
2) Explain the Canonical View Volume (CVV)?
3) What is a Camera model?
4) What is a Viewing Pyramid?
5) Specifying an Arbitrary 3D View,
6) Explain 3D Viewing with an Example.
7) What is mathematics of Planar Geometric Projections?
8) Combined transformation matrices for projections and viewing,
9) Coordinate Systems and matrices,
10) Explain the following terms: Radiometry, Photometry
11) Explain the following terms: Colorimetry, Color Spaces, Chromatic Adaptation, Color Appearance

Multiple Choice Questions:
1) Viewing in 3D involves the following considerations:

   a) In front of an object,
   b) Behind the object,
   c) In the middle of a group of objects
   d) All of the above

2) The __________ system is used in graphics packages as a reference for specifying the observer viewing position and the position of the projection plane.
   a) viewing-coordinate system
   b) CVV
   c) Viewing Transformation
   d) None of the above

3) _________ A rectangular area in the view plane which controls how much of the scene is viewed.

   a) View window
   b) Co-ordinate Window
   c) Rectangular window
   d) Horizontal window

4) _____________ It is the human visual system's ability to adjust to changes in illumination in order to preserve the appearance of object colors.
   a) Colorimetry
   b) Color space
   c) Chromatic Adaptation
   d) None of the above

5) _____________ is a technique "used to determine the concentration of colored compounds in solution.
   a) Colorimetry
   b) Color space
   c) Chromatic Adaptation
   d) None of the above

6) __________ is the science of measuring visible light in units that are weighted according to the sensitivity of the human eye
   a) Colorimetry
   b) Photometry
   c) Chromatic Adaptation
   d) None of the above

7) _________ is the science of measuring light in any portion of the electromagnetic spectrum.
   a) Colorimetry
   b) Photometry
   c) Chromatic Adaptation
   d) Radiometry

8) After the projection matrix is applied to the view space, the view space is "normalized" so that all the points lie within the range [-1, 1]. This is generally referred to as the "__________" or "normalized device coordinates".
   a) Colorimetry
   b) Photometry
   c) Viewing Window
   d) Canonical view volume

9) The _ _ _ _ _ _ _ _ _ is usually placed at the viewing-coordinate origin and the center of projection is positioned to obtain the amount of perspective desired.
   a) view plane
   b) CVV
   c) Viewing Window
   d) None of the above

10) __________ formed by the view window and the type of projection to be used.
   a) view plane
   b) CVV
   c) Viewing Window
   d) View Volume