Student ID:								

CS-112: Introduction to Computer Graphics
Final - Winter 2020
3/19/2020

Total Time: 120 min **Total Points:** 120

Name: ____

Pledge: I neither received nor gave any help from or to anyone in this exam.

Signature: ____

<u>Useful Tips</u>

1. All questions are multiple choice questions --- please indicate your answers very clearly. **Please circle your choice clearly**.
2. **Some questions have more than one answer. Full credit is given for marking all the correct answers.**
3. Use the blank pages as your worksheet. Put the question number when working out the steps in the worksheet. Also, do your work clearly. This will help us give partial credit.
4. If you need more work sheets, feel free to ask for extra sheets.
5. Staple all your worksheets together with the paper at the end of the exam. If pages of your exam are missing since you took them apart, we are not responsible for putting them together.
6. **The number of minutes you should spend on each question is roughly equal to the number of points assigned to the question.**

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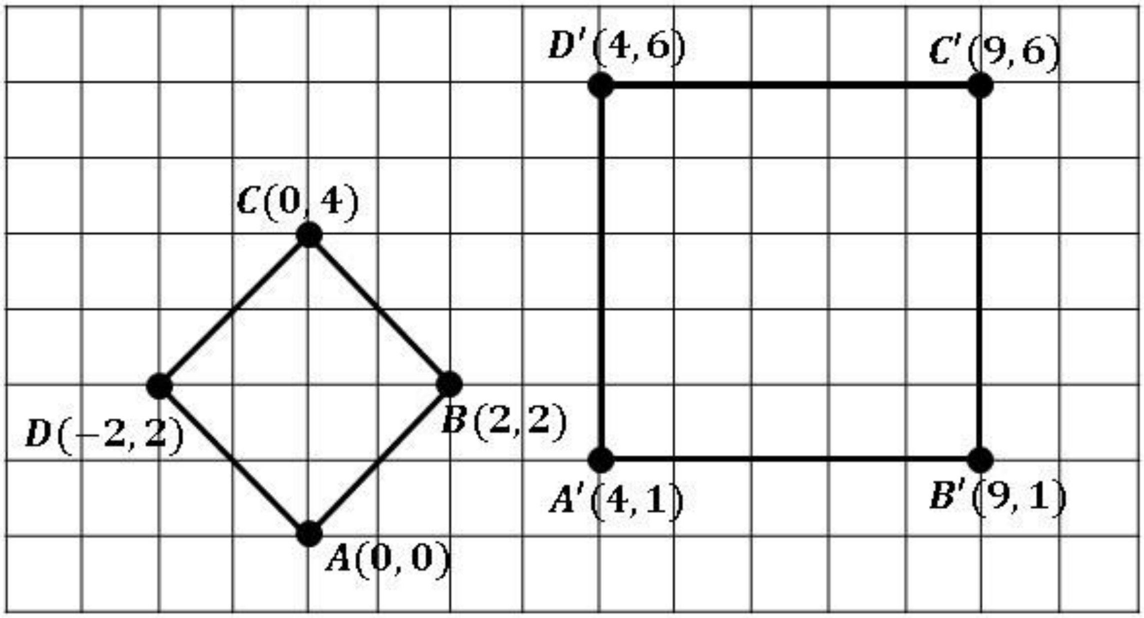
TRANSFORMATIONS = 13



1) **[2+3+3+2+3=13]** Please refer to the above figure. Consider a transformation ***T_2SRT_1*** that takes ABCD to A'B'C'D'? ***T***, ***S***, ***R*** and ***Sh*** denote translation, scaling, rotation and shear.

a. The parameter for T_1 is: **i.** (2,0) **ii.** (-2, 0) **iii.** (0, -2) **iv.** (0, 2)	**b.** The parameter for rotation will be: **i.** Y axis and 45 degrees **ii.** Z axis and 90 degrees **iii.** Z axis and 45 degrees **iv.** Y axis and 90 degrees
c. The parameter for scaling will be: **i.** 5/2 **ii.** 5/2√2 **iii.** 5 **iv.** 2√2	**d.** The parameter for T_2 will be: **i.** *(6.5, 3.5)* **ii.** *(5.5, 2.5)* **iii.** *(6, 3)* **iv.** *(6.5, 1.5)*
e. When considering local coordinate systems, the order of the transformation will be: **i.** T_1 followed by R followed by S and then by T_2 **ii.** T_2 followed by S followed by R and then by T_1	

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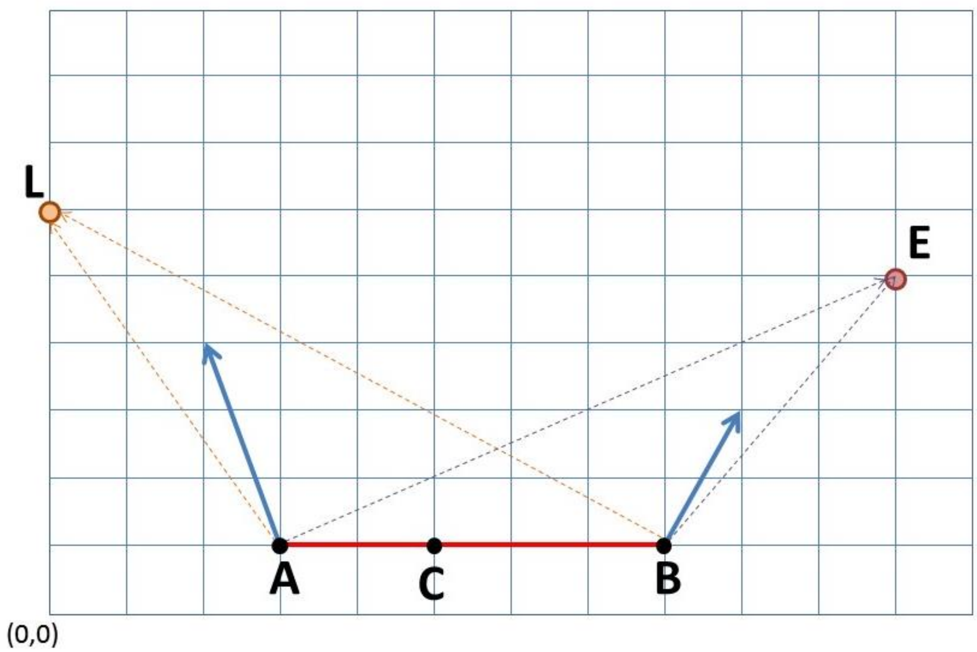
ILLUMINATION AND SHADING = 23



2) **[2+2+2+3+3+3+4+4=23]** Consider the above 2D gray world and the primitive AB in it (shown by the red line). The blue vectors show the normal at A and B. L and E are the position of the light and the eye respectively. Let the coefficient of diffused illumination be 0.5 respectively. Let the intensity of light be 0.5. **Note: (a) No need to normalize vectors; (b) Treat negative dot products as 0.**

   a. The coefficients of A and B respectively for bilinear interpolation at C are:
      i. 3/5, 2/5
      ii. 2/5, 3/5
      iii. 1/4, 3/4
      iv. 3/4, 1/4
      v. 1/2, 1/2

   b. The normal at A is:
      i. (1,3)
      ii. (-1,3)
      iii. (1,-3)

   c. The normal at B is:
      i. (1,2)
      ii. (-1,2)
      iii. (1,-2)

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d. The interpolated normal at C is:
  i. (1/5,12/5)
  ii. (1,13/5)
  iii. (-1/5,13/5)
  iv. (0,5/2)

e. The diffused illumination at A is:
  i. 0
  ii. 3.6
  iii. 4.5
  iv. 4.0

f. The diffused illumination at B is:
  i. 0
  ii. 0.8
  iii. 0.4
  iv. 0.5

g. The diffused illumination at C using Gouraud shading is:
  i. 4.6
  ii. 2.9
  iii. 0
  iv. 5.6

h. The diffused illumination at C using Phong shading is:
  i. 4.5
  ii. 3.5
  iii. 0
  iv. 5.6

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SAMPLING AND ALIASING =11

3) [2+2+2=6] You are given an image which is made of sine waves that make 0-200 cycles within the span of the screen.

a. What is the minimum resolution a display should have to display this image free of any artifacts?

i. 100x100
ii. 200x200
iii. 400x400
iv. 150x150

b. If a display of resolution 200x200 is used to display this image, what kind of artifacts would you see?

i. Compression of Contrast
ii. Aliasing
iii. Blurring

c. You want to apply a filtering technique to make it suitable for display on a 200x200 resolution display. What will be the maximum frequency of sine wave (in cycles within the span of the screen) that this processed image can have in order to be rendered free of artifacts in the 200x200 display?

i. 50 **ii.** 200 **iii.** 100 **iv.** 400

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4) **[2+1+2=5]** Consider an image of spatial resolution 600x400 and color resolution of 4. We would like to increase the color resolution to 28 using dithering over (**n** x **n**) blocks of pixels.

a. The value of n is:
  i. 2
  ii. 3
  iii. 4

b. We would reduce the spatial resolution by a factor of:
  i. 2
  ii. 4
  iii. 3
  iv. 9

c. The most likely artifact the dithering will create is:
  i. Contouring
  ii. Aliasing
  iii. Gamut Compression

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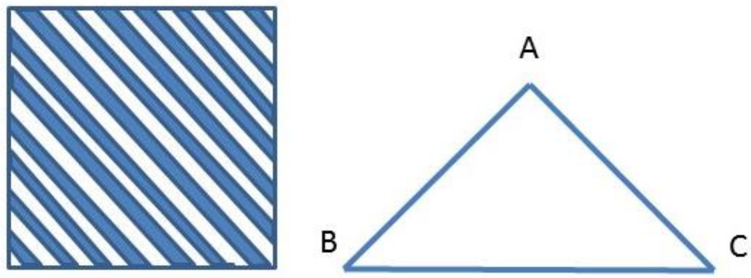
TEXTURE MAPPING=20



5) **[2+2+2+2=8]** Consider the above striped texture on the left and the triangle ABC which we would like to texture map using this texture. Consider the bottom left corner of the texture to be (0,0) and the top right to be (1,1).

a. To create the appearance of **horizontal** stripes on the triangle, the vertices A, B and C should be respectively assigned the coordinates:
   i. (0,1), (0,0), (1,0)
   ii. (1,1), (0,1), (1,0)
   iii. (0,1), (0,0), (1,1)
   iv. (1/2,1), (0,0), (1,0)
   v. (1/2,0), (1,1), (0,1)

b. To create the appearance of **vertical** stripes on the triangle, the vertices A, B and C should be respectively assigned the coordinates:
   i. (0,1), (0,0), (1,0)
   ii. (1,1), (0,1), (1,0)
   iii. (0,1), (0,0), (1,1)
   iv. (1/2,1), (0,0), (1,0)
   v. (1/2,0), (1,1), (0,1)

c. To create the appearance of stripes in the same orientation as the texture, the vertices A, B and C should be respectively assigned the coordinates:
   i. (0,1), (0,0), (1,0)
   ii. (1,1), (0,1), (1,0)
   iii. (0,1), (0,0), (1,1)
   iv. (1/2,1), (0,0), (1,0)
   v. (1/2,0), (1,1), (0,1)

Student ID:								

d. To create the appearance of stripes in an orientation perpendicular to that in the texture, the vertices A, B and C should be respectively assigned the coordinates:

i. (0,1), (0,0), (1,0)
ii. (1,1), (0,1), (1,0)
iii. (0,1), (0,0), (1,1)
iv. (1/2,1), (0,0), (1,0)
v. (1/2,0), (1,1), (0,1)

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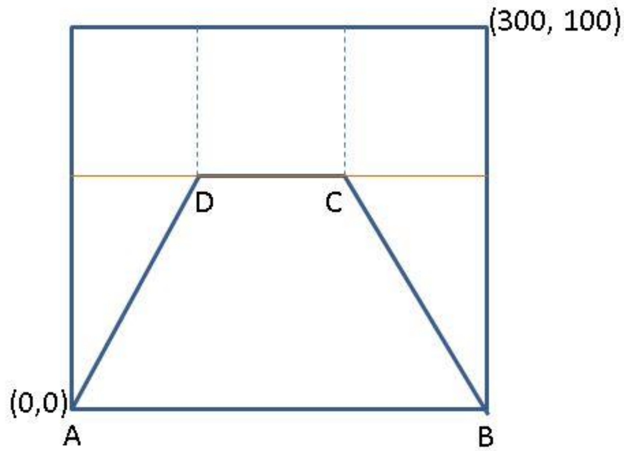

6) [2+4+2+2+2+2=12] Consider the above framebuffer of size 300x100. ABCD is a rectangle in 3D space which has been projected as a trapezium in the 2D. AB is projected on the bottom scanline. CD is projected on a scanline (shown in brown) that is 3/5 way above and has a projection length 1/3 of AB. The depth of side AB is 60 and that of CD is 30. Consider a 512x512 checkerboard texture T that will be used to texture map ABCD. T is stored in different resolutions using mipmapping.

a. The scanline on which CD is projected is:

i. 20
ii. 40
iii. 60
iv. 80

b. Consider a scanline S that is half-way in screen space between AB and CD. The depth of S in 3D is:

i. 30
ii. 40
iii. 45
iv. 50

c. The length of S contained in the trapezium is:

i. 100
ii. 200
iii. 300

d. The level of T that will be used to texture map AB is:

i. 256x256
ii. 128x128
iii. 64x64
iv. 32x32

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e. The level of T that will be used to texture map CD is:

- **i.** 256x256
- **ii.** 128x128
- **iii.** 64x64
- **iv.** 32x32

f. The level of T that will be used to texture map the part of S contained in the trapezium is:

- **i.** 256x256
- **ii.** 128x128
- **iii.** 64x64
- **iv.** 32x32

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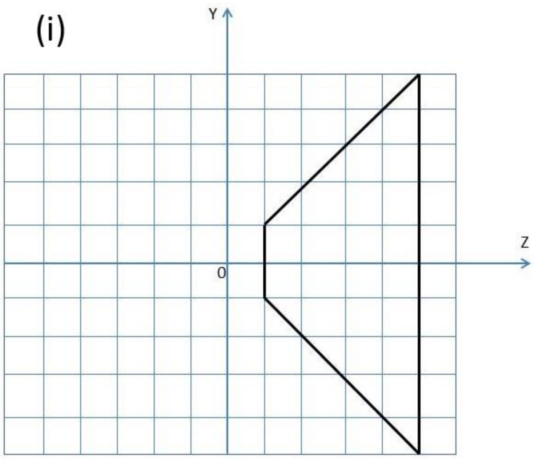
CLIPPING AND CULLING = 11

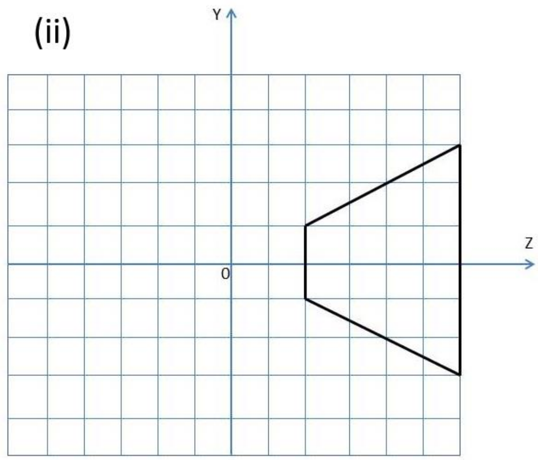
7) [1+2+2+2+4=11] Consider the following view setup. The eye is at (0, 0, 0). The six planes of the view frustum are given by near=2, far=6, top=1, bottom=-1, left=-1, right=1. Consider the line PQ given by P=(0, 4, -2) and Q=(1, 1, -6). **Hint: OpenGL considers –Z to be the view direction.**

a. Which of the following pictures show this view frustum?

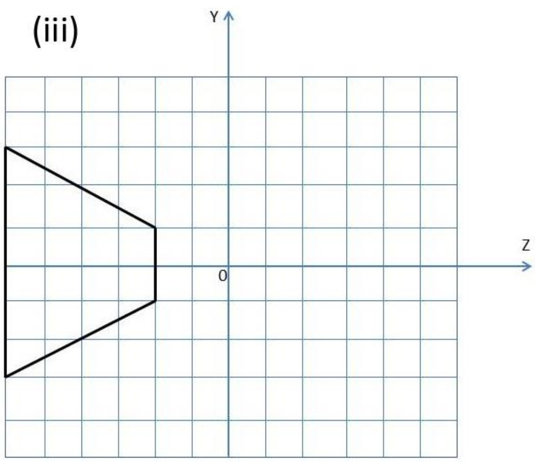
(i)



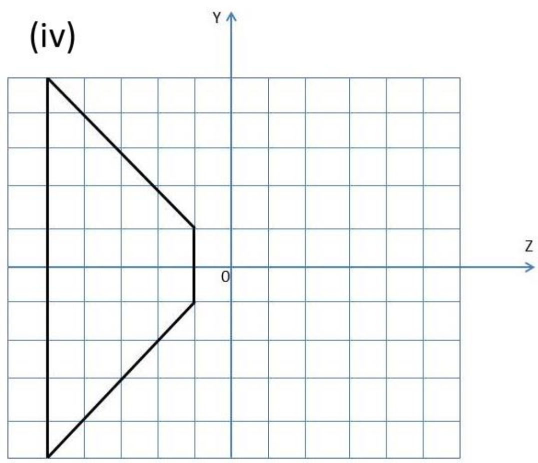
(ii)



(iii)



(iv)



b. The general form for an implicit plane equation is:

i. $y = ax + b$

ii. $(y_2 - y_1) / (x_2 - x_1) = (y_1 - y) / (x_1 - x)$

iii. $(x_2 - x_1)(x_1 - x) + (y_2 - y_1)(y_1 - y) + (z_2 - z_1)(z_1 - z) = 0$

iv. $ax + by + cz + d = 0$

Student ID:								

c. For the given view frustum, the plane equation for the top plane is:

i. $2y + z = 0$
ii. $y + 2z = 0$
iii. $y - 2z = 0$
iv. $2y - z = 0$

d. The parametric equation for line PQ is:

i. $(x, y, z) = (0, 4, -2) + (1, -3, -4)\, t$
ii. $(x, y, z) = (1, 1, -6) + (1, -3, -4)\, t$
iii. $(x, y, z) = (0, 4, -2) + (-1, 3, 4)\, t$
iv. $(x, y, z) = (1, 1, -6) + (-1, 3, 4)\, t$

e. PQ is clipped to generate a clipped line P′Q′. The coordinates of points P′ and Q′ are:

i. P′ = (0, 4, -2), Q′ = (0.4, 2.2, -4.4)
ii. P′ = (0.6, 2.2, -4.4), Q′ = (1, 1, -6)
iii. P′ = (0, 4, -2), Q′ = (1, 1, -6)

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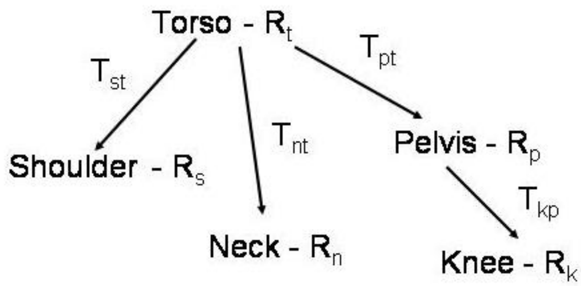
MISCELLENEOUS TECHNIQUES = 20

8) [3+3=6] The tree data structure below is used to represent an object in animation.



a. In what order will the different parts (represented as the nodes of the tree) be drawn while rendering this object following a depth-first traversal of the tree?

i. Torso – Shoulder – Neck – Pelvis - Knee
ii. Knee – Pelvis – Neck – Shoulder - Torso
iii. Shoulder –Neck – Knee – Pelvis - Torso
iv. Shoulder – Torso – Neck – Pelvis – Knee

b. What is the transformation that the knee will go through when it is being rendered?

i. $T_{st}R_nT_{nt}T_{kp}R_tT_{pt}R_p$
ii. $R_tT_{pt}R_pT_{kp}R_k$
iii. $R_tT_{kp}R_kT_{pt}R_p$

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9) [1+1+2=4] Consider rendering effects of transparent where *s* denotes the translucency of a triangle (*s=1* for an opaque primitive and *s=0* for a completely transparent primitive).

a. The source (the triangle you are rendering) color and the color (the pixel residing in the framebuffer) should be combined using respectively:
  i. *s* and *s/2*
  ii. *s* and *(1-s)*
  iii. *s* and *1*

b. The above would not yield correct results unless you consider the:
  i. Connectivity of the triangles
  ii. Depth order of the triangles
  iii. Texture of the triangles

c. If we desire to reduce the effect of opaque objects in the amalgam of colors created by overlapping opaque and translucent primitives at any pixel, which of the following functions should be used?
  i. If *s<1,* then *s* and *(1-s);* else *s/2* and *(1-s/2)*
  ii. If *s<0.5,* then *s* and *(1-s);* else *s*2* and *(1-s*2)*
  iii. If *s=1,* then *s* and *(1-s);* else *s/2* and *(1-s/2)*

10) [3+3+1+2+1=10] Consider two rectangles, A and B. A is a square with center at (5,5) and each side of length 2. B is a rectangle whose center is (8,8) with sides of length 6 (in Y direction) and 8 (in X direction) respectively.

a) What is the center and radius of a circular bounding geometry of A?
  i. (5,5) and 2
  ii. (5,5) and $\sqrt{2}$
  iii. (0,0) and 5
  iv. (0,0) and $5\sqrt{2}$

b) What is the center and radius of a circular bounding geometry of B?
  i. (8,8) and 5
  ii. (5,5) and 5
  iii. (8,8) and $5\sqrt{2}$
  iv. (0,0) and 8

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c) B is now rotated by 90 degrees. The new bounding box is:

- **i.** (-8,8) and 5
- **ii.** (5,5) and 5
- **iii.** ($0,16/\sqrt{2}$) and 5
- **iv.** (0,0) and 8

d) Is the addition of the radius of the bounding circle:

- **i.** Greater than the distance between the centers of A and B
- **ii.** Lesser than the distance between the centers of A and B
- **iii.** Equal to the distance between the centers of A and B

e) Do A and B collide?

- **i.** Yes
- **ii.** No

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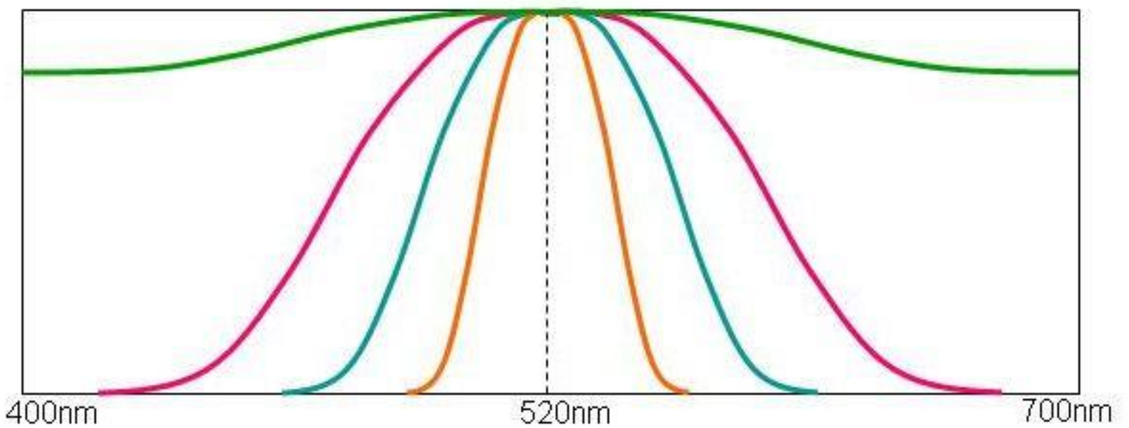
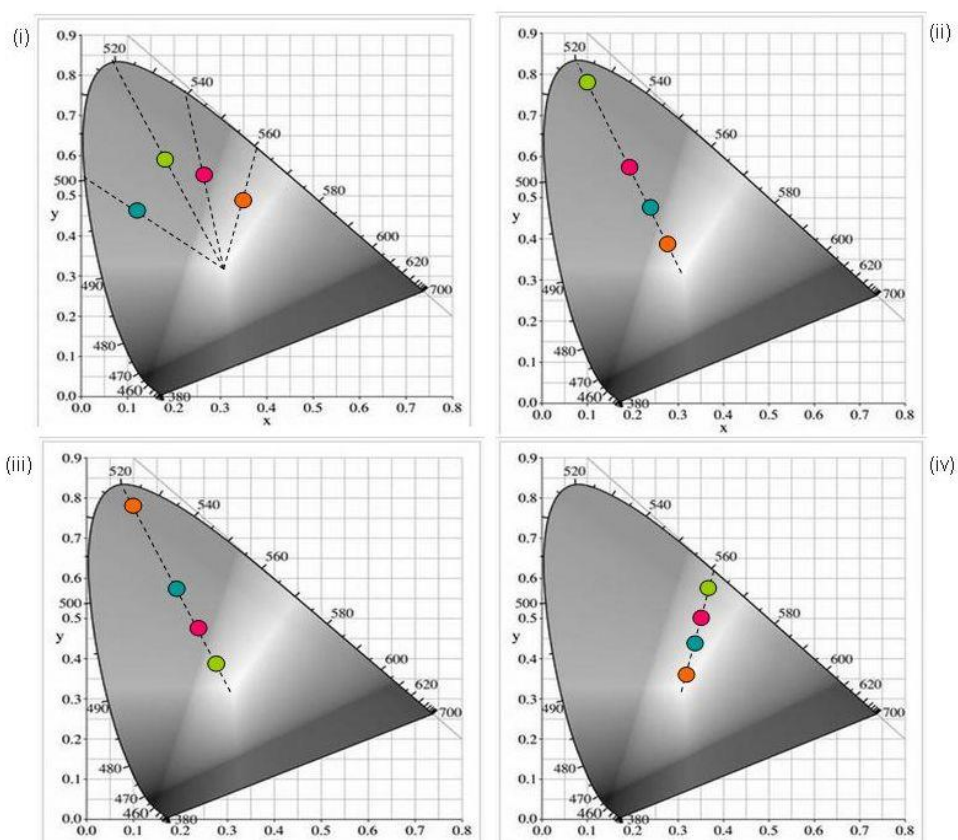
COLOR = 24

11) **[3+2+2+2=9]** Consider the following four spectrums, their color not related to their visible colors, but used for visualization.



a) Which one of the following is most accurate representation of where these spectrums will fall on the chromaticity chart?



b) The dominant wavelength of all these colors are most likely:

- **i.** Same
- **ii.** Entirely different
- **iii.** Clustered together

c) The intensity (X+Y+Z) of these colors are most likely related by the following:

- **i.** Not related at all
- **ii.** Orange < Blue < Pink < Green
- **iii.** Green < Pink < Blue < Orange
- **iv.** Blue < Pink < Orange < Green

d) The most likely position of these colors in the CIE-XYZ 3D space is:

- **i.** On the same ray from the origin
- **ii.** On four different rays from the origin
- **iii.** On two different rays from the origin
- **iv.** On three different rays from the origin

12) [2+2+2+5+2+2=15] Consider two colors C1=(X1,Y1,Z1) and C2=(X2,Y2,Z2) in the CIE XYZ space. Let their chromaticity coordinates be (x1,y1) and (x2,y2) respectively.

a. If C1 is a pure achromatic color, which of the following are true?

- **i.** X1=Y1=Z1
- **ii.** (x1,y1) = (1/3,1/3)
- **iii.** Black lies on the ray connecting the origin to C1 in XYZ space
- **iv.** White lies on the ray connecting the origin to C1 in XYZ space

b. If C2=(100,100,50), then (x2,y2) is:

- **i.** (1/5,2/5)
- **ii.** (2/5,2/5)
- **iii.** (1/2,1/2)
- **iv.** (1/4,1/2)

c. The dominant wavelength of C2 is:

- **i.** 550nm
- **ii.** 575nm
- **iii.** 490nm
- **iv.** 610nm

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d. To create a color of chromaticity coordinates (7/20,7/20), in what proportions should be C1 and C2 be mixed?

- **i.** (1/4,3/4)
- **ii.** (3/4, 1/4)
- **iii.** (3/10, 7/10)
- **iv.** (1/2,1/2)
- **v.** (2/5,3/5)

e. The intensity of C1 required for this mixture is:

- **i.** 500
- **ii.** 250
- **iii.** 1000
- **iv.** 750

f. The luminance of C1 required for this mixture is:

- **i.** 500
- **ii.** 250
- **iii.** 1000
- **iv.** 750