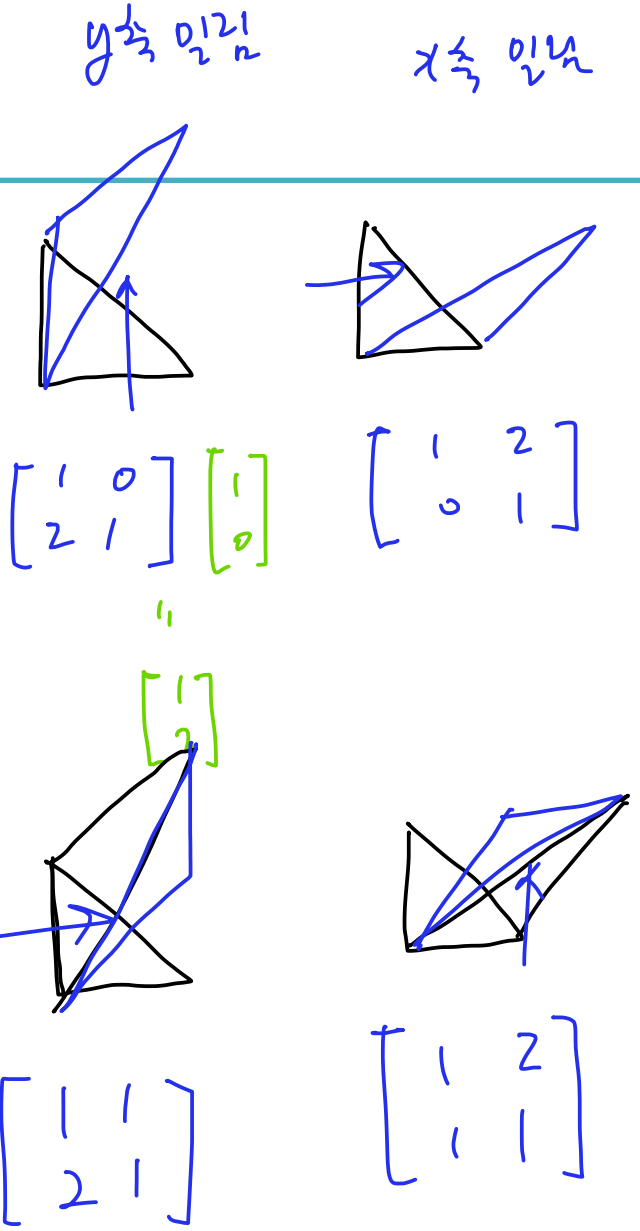
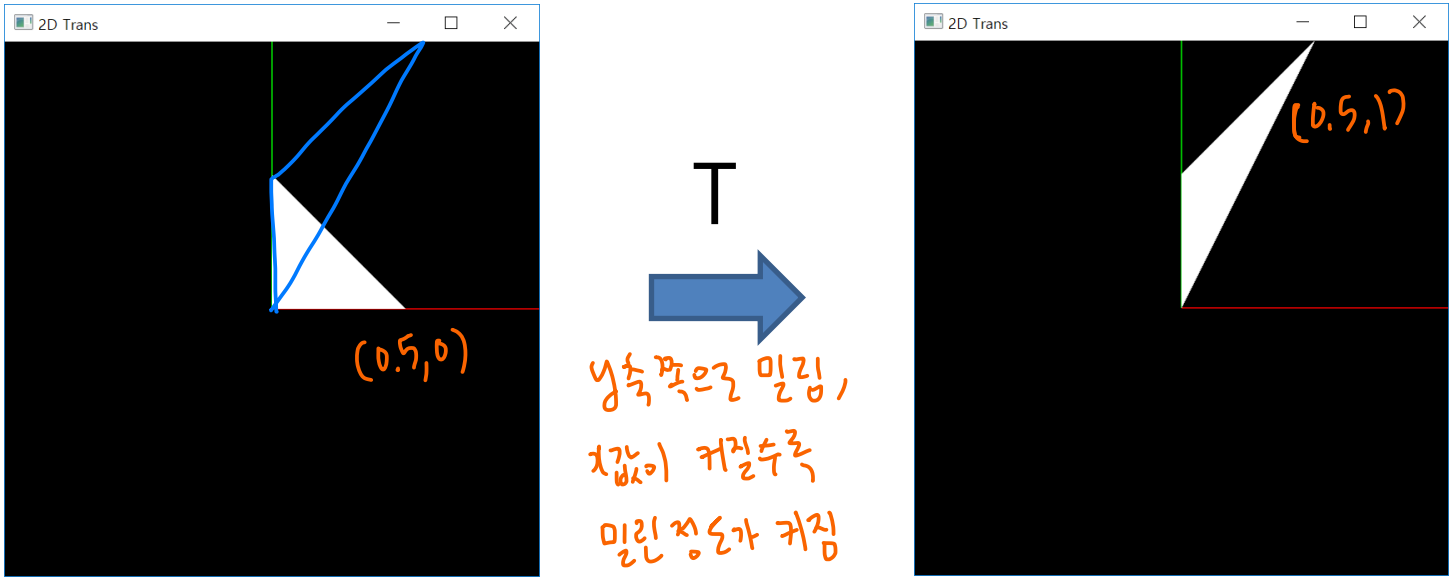
3 - Quiz



#1

$$\begin{bmatrix} 1 & 0 \\ a & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \Rightarrow \begin{bmatrix} x \\ ax+y \end{bmatrix}$$

- What is the 2x2 transformation matrix T?



1) `[1.,0.]` `[2.,1.]`

2) `[1.,0.]` `[1.,1.]`

3) `[-1.,0.]` `[0.,-1.]`

reflexion

4) `[1.,2.]` `[0.,1.]`

x축 쪽으로 밀림

#2

- Which pair of the blank (a) and (b) render this image?

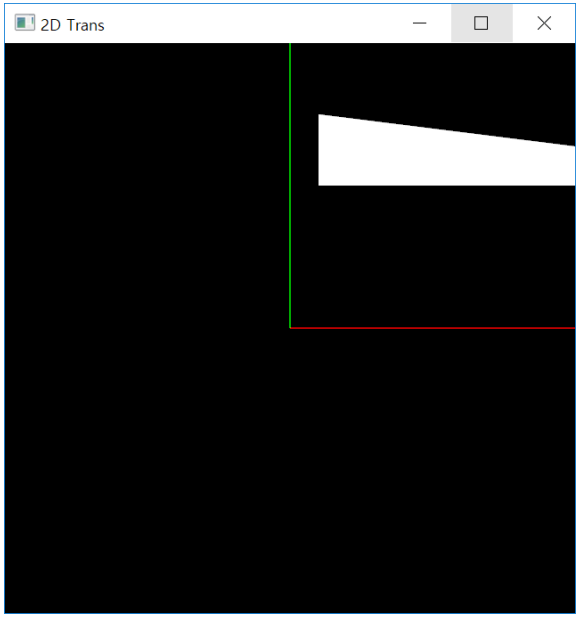
1)
```
(a)
[[.5,0]
 [0,4]]
(b)
[.5,.1]
```

2)
```
(a)
[[2,0]
 [0,2]]
(b)
[.5,.1]
```

3)
```
(a)
[[4,0]
 [0,.5]]
(b)
[.1,.5]
```

4)
```
(a)
[[4,0]
 [0,.5]]
(b)
[.5,.5]
```

5)
```
(a)
[[4,1]
 [0,.5]]
(b)
[.1,.5]
```
x shear




```python
def render(M, u):
    # ...
    glBegin(GL_TRIANGLES)
    glColor3ub(255, 255, 255)
    glVertex2fv(M @ np.array([0.0,0.5]) + u)
    glVertex2fv(M @ np.array([0.0,0.0]) + u)
    glVertex2fv(M @ np.array([0.5,0.0]) + u)
    glEnd()
def main():
    # ...
    while not glfw.window_should_close(window):
        # ...
        M = np.array(__(a)__)
        u = np.array(__(b)__)
        render(M, u)
```

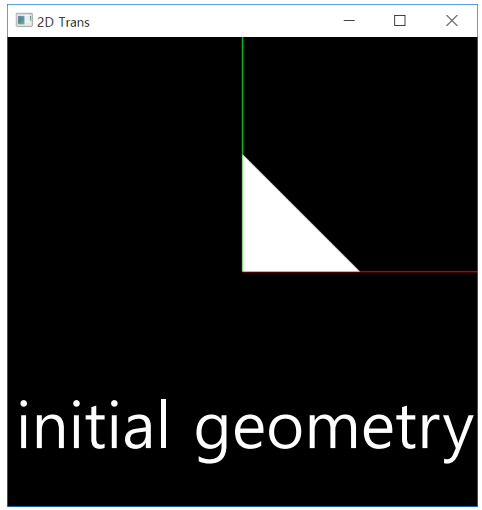
x축으로 늘어나고, y축으로 줄어듦

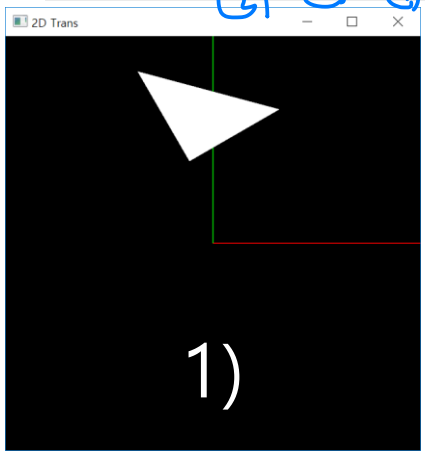
x축으로 줄고 y축으로 많이 translation

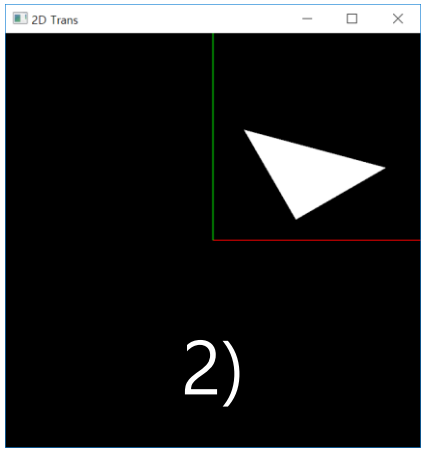
#3

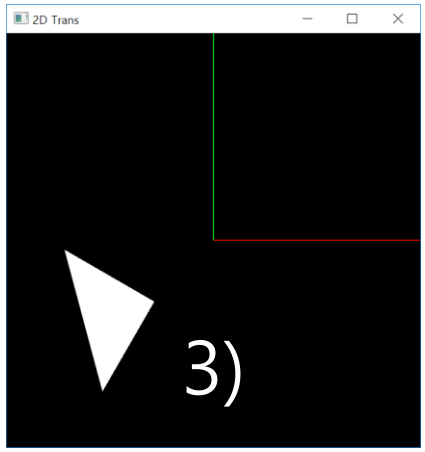
- What is the result of the following code?

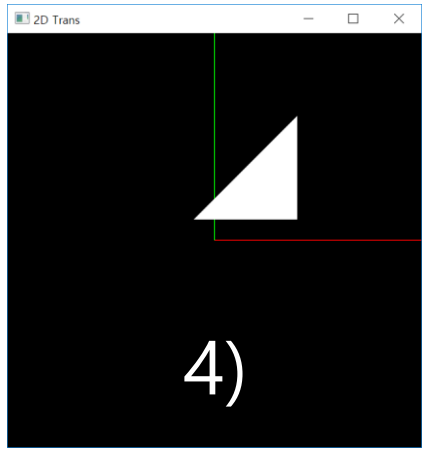
```
# rotate 60 deg about z axis
th = np.radians(60)
R = np.array([[np.cos(th), -np.sin(th),0.],
              [np.sin(th), np.cos(th),0.],
              [0.,         0.,        1.]])

# reflect about y axis
F = np.array([[-1.,0.,0.],
              [0.,1.,0.],
              [0.,0.,1.]])

# translate by (.4, .1)
T = np.array([[1.,0.,.4],
              [0.,1.,.1],
              [0.,0.,1.]])

render(R @ F @ T)
```











4 - Quiz

#1

- What kind of transformation matrix is this?

```
T = np.identity(4)
T *= 3
T[3,3] = 1.
```

  - 1) A rotation matrix in 3D space
  - 2) A nonuniform scale matrix in 3D space
  - 3) A uniform scale matrix in 3D space
  - 4) A translation matrix in 2D space
  - 5) None of the above

#2

$p' = CTSRp$

- Let's say you want some object to be
  - first, translated by (1,0,2)
  - then, scaled by (-2, 2, 4)
  - lastly, rotated PI/2 about y axis
- (w.r.t. global coordinates)
- Choose ALL correct code to be inserted between glLoadIdentity() and drawing code for the object.

1)
```
glTranslatef(1, 0, 2)
glScalef(-2, 2, 4)
glRotatef(np.pi/2, 0, 1, 0)
```

2)
```
glRotatef(90, 0, 1, 0)
glScalef(-2, 2, 4)
glTranslatef(1, 0, 2)
```

3)
```
glTranslatef(1, 0, 2)
glScalef(-2, 2, 4)
glRotatef(90, 1, 0, 0)
```

4)
```
glRotatef(np.pi/2, 0, 1, 0)
glScalef(-2, 2, 4)
glTranslatef(1, 0, 2)
```

5)
```
glRotatef(90, 0, 1, 0)
glScalef(-2, 2, 4)
T = np.identity(4)
T[:3,3] = [1, 0, 2]
glMultiMatrixf(T.T)
```

#3

point : w=1 , vector : w=0

- Choose ALL undefined operations in terms of coordinate-free geometric programming.

  - 1) (x1, y1, z1, 1) + (x2, y2, z2, 1) — 2
  - 2) (x1, y1, z1, 0) + (x2, y2, z2, 0) — 0
  - 3) (x1, y1, z1, 1) - (x2, y2, z2, 0) — 1
  - 4) (x1, y1, z1, 0) - (x2, y2, z2, 0) — 0
  - 5) (x1, y1, z1, 1) - (x2, y2, z2, 1) — 0
  - 6) 2.5 * (x1, y1, z1, 1) — 2.5

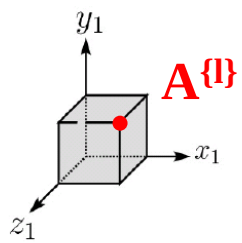
5 - Quiz

#1

- The vertex "A" is one of the vertices of the grey box object. A's position w.r.t. the box's own local frame ($\mathbf{A}^{\{l\}}$) is $(1,1,1)^T$ and the modeling transformation matrix is:

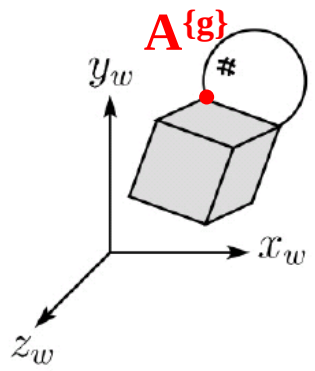
```
[[1,0,0,1],
 [0,1,0,2],
 [0,0,1,3],
 [0,0,0,1]]
```

- What is the position of the vertex "A" w.r.t. global frame ($\mathbf{A}^{\{g\}}$)?



$\mathbf{A}^{\{l\}} = [1,1,1]$

$$\begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ 3 \\ 4 \\ 1 \end{bmatrix}$$



$(2,3,4)^T$

Object space

World space

#2

- Fill in the blank (a) so that the left render() produces the same rendering result as the right render().

```
def render():
    glClear(GL_COLOR_BUFFER_BIT)
    glLoadIdentity()
    gluLookAt(______(a)______)

    glBegin(GL_TRIANGLES)
    glVertex2f(0.0,1.0)
    glVertex2f(0.0,0.0)
    glVertex2f(1.0,0.0)
    glEnd()
```

```
def render():
    glClear(GL_COLOR_BUFFER_BIT)
    glLoadIdentity()

    glBegin(GL_TRIANGLES)
    glVertex2f(0.0,1.0)
    glVertex2f(0.0,0.0)
    glVertex2f(1.0,0.0)
    glEnd()
```

gluLookAt(0,0,0, 0,0,-1, 0,1,0)

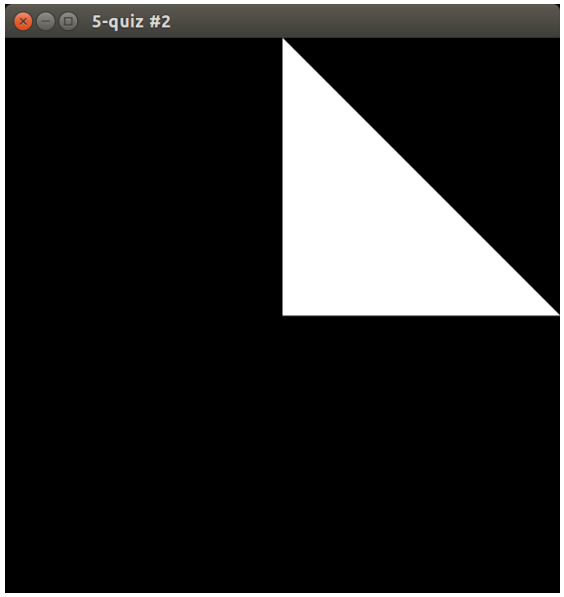
-1을 0으로 하면 W벡터가 0벡터가 돼버려서 안그려짐

negative z-direction 상의 임의의 점을 지정해야 함

#3

- Fill in the blank (a) to render the following image.

```
def render():
    glClear(GL_COLOR_BUFFER_BIT)
    glLoadIdentity()

    glOrtho(_____(a)_____)

    glBegin(GL_TRIANGLES)
    glVertex2f(0.0,1.0)
    glVertex2f(0.0,0.0)
    glVertex2f(1.0,0.0)
    glEnd()
```



canonical view volume의 size

glOrtho(1, -1, 1, -1, 1, -1)

left right bottom top near far

2차원이기때문에 생략해버림

default camera 상태

default NDC space 즉,

canonical view volume에서

xy plane에 projection하게

그려짐

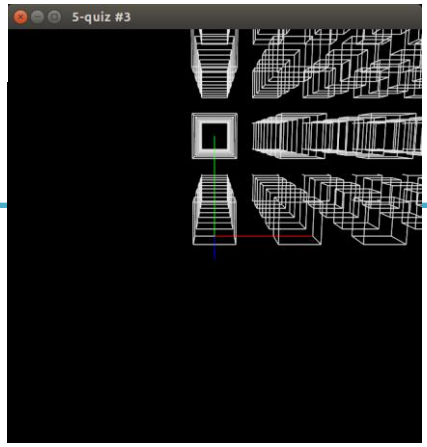
6 - Quiz

#1

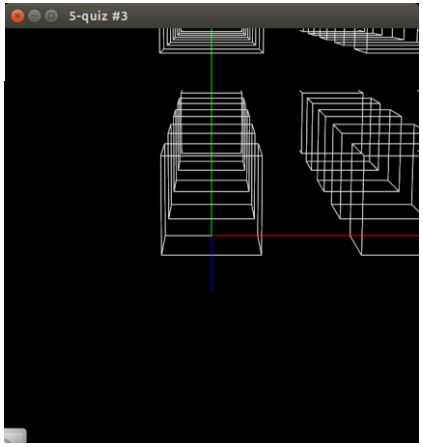
- Choose the correct gluPerspective() call for the following rendered images 1), 2), 3).

```
def render():
    glClear(GL_COLOR_BUFFER_BIT|GL_DEPTH_BUFFER_BIT)
    glEnable(GL_DEPTH_TEST)
    glPolygonMode( GL_FRONT_AND_BACK, GL_LINE )
    glLoadIdentity()

    gluPerspective(20, 1, 1,10) # a)   2
    gluPerspective(45, 1, 1,10) # b)   1
    gluPerspective(90, 1, 1,10) # c)   3

gluLookAt(5.*np.sin(gCamAng),gCamHeight,5.*np.cos(gCa
mAng), 0,0,0, 0,1,0)

    drawFrame()

    glColor3ub(255, 255, 255)
    drawCubeArray()
```

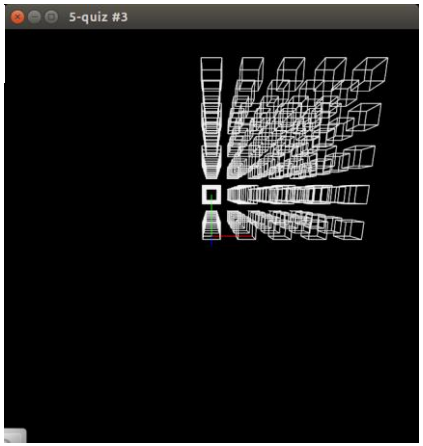
1)



2)



3)



#2

- Fill in the blank (a), (b), and (c) to render a quad polygon using the vertex array `varr`. Write down your answers only using scalar number (not python expression).

```
varr = np.array([
                ( 0 , 0 ), # v0
                ( .5 , 0 ), # v1
                ( .5 , .5 ), # v2
                ( 0 , .5 ), # v3
                ], 'float32')

glVertexPointer((a), GL_FLOAT, (b), varr)
glDrawArrays(GL_QUADS, 0, (c))
```

dimension

stride (한 vertex의 크기)

그려질 vertex의 개수

#3

- Fill in the blank (a), (b), (c) , and (d) to render a quad polygon using the vertex array `varr` and the index array `iarr`. Write down your answers only using scalar number (not python expression).

```
varr = np.array([
                ( 0 , 0 ), # v0
                ( .5 , 0 ), # v1
                ( .5 , .5 ), # v2
                ( 0 , .5 ), # v3
                ], 'float32')
iarr = np.array([
              (0,1,2,3),
              ])

glVertexPointer((a), GL_FLOAT, (b), varr)
glDrawElements(GL_QUADS, (c), GL_UNSIGNED_INT, (d))
```

index array의 index들의 개수

(a) 2
(b) 8
(c) 4
(d) iarr

7 - Quiz

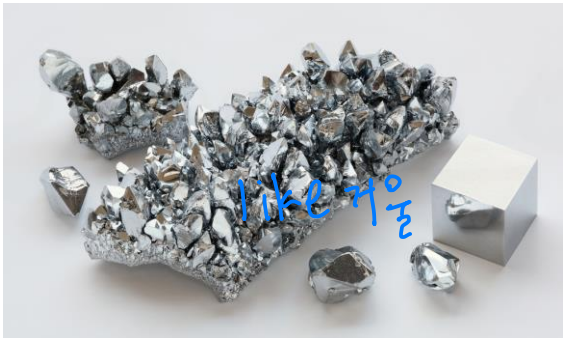
#1

- Which type of reflection is dominant on the following objects?

1)

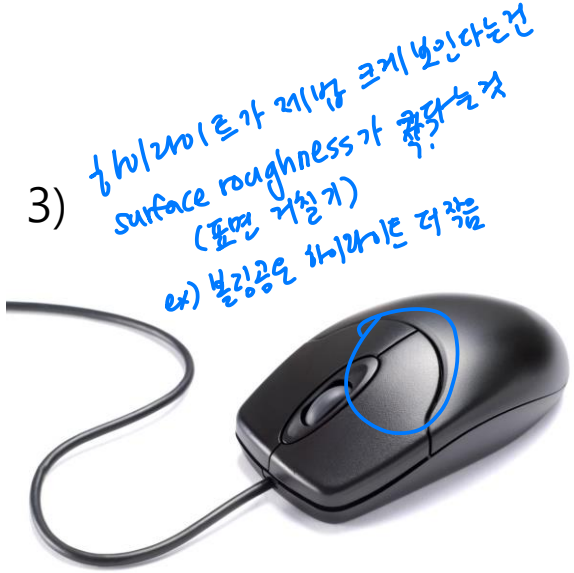
Diffuse

2)



Ideal

3)



Non-Ideal

#2

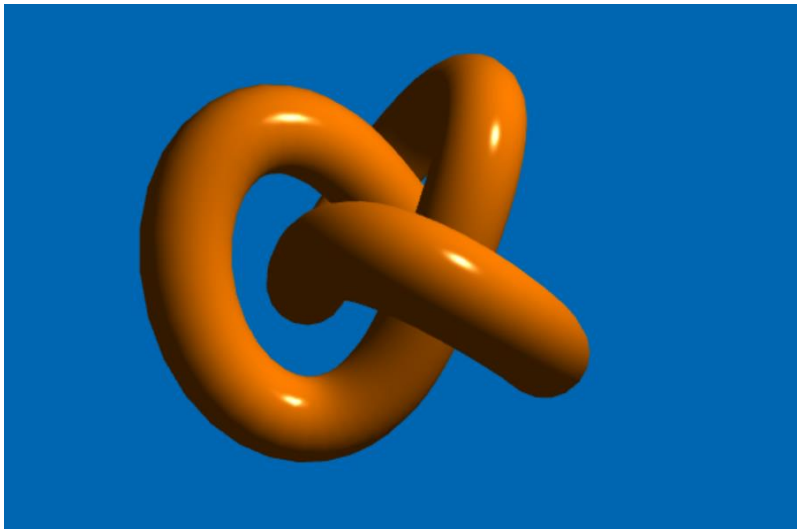
- Choose ALL correct statements about a) and b). Assume that ambient, diffuse, specular colors for both images are the same.
  - 1) a) has a higher diffuse reflection coefficient than b).
  - 2) a) has a lower specular reflection coefficient than b).
  - 3) a) has a higher shininess coefficient than b).

색의 밝기 intensity

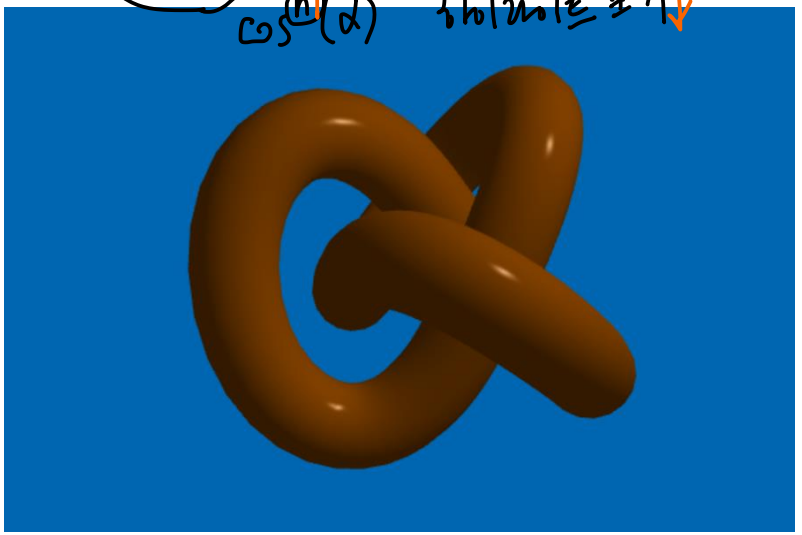
하이라이트의 밝기

$\cos^{n}(\alpha)$ n: 하이라이트 크기

a)



b)



#3

- What the rendered color of the cube in the following code?

- 1) Red
- 2) Blue
- 3) Black
- 4) None of the above

```
def render():
    global gCamAng, gCamHeight
    glClear(GL_COLOR_BUFFER_BIT|GL_DEPTH_BUFFER_BIT)
    glEnable(GL_DEPTH_TEST)
    glDisable(GL_LIGHTING)

    glMatrixMode(GL_PROJECTION)
    glLoadIdentity()
    gluPerspective(45, 1, 1,10)

    glMatrixMode(GL_MODELVIEW)
    glLoadIdentity()

gluLookAt(5*np.sin(gCamAng),gCamHeight,5*np.cos(gCam
Ang), 0,0,0, 0,1,0)

    lightPos = (3.,4.,5.,1.)
    glLightfv(GL_LIGHT0, GL_POSITION, lightPos)

    lightColor = (1.,0.,0.,1.)
    glLightfv(GL_LIGHT0, GL_DIFFUSE, lightColor)

    objectColor = (1.,0.,0.,1.)
    glMaterialfv(GL_FRONT, GL_DIFFUSE, objectColor)

    glColor3f(0, 0, 1)
    drawCube_glDrawArray()
```

8 - Quiz

#1

- The position of point **p** is (1,2,3) w.r.t. the affine frame T_1 :
  - T_1's x-axis=(-1,0,0),
  - y-axis=(0,1,0),
  - z-axis=(0,0,1),
  - origin=(10,20,30) (w.r.t. global frame)
- Write down the position of **p** w.r.t. global frame.

$$T_1 p = \begin{bmatrix} -1 & 0 & 0 & 10 \\ 0 & 1 & 0 & 20 \\ 0 & 0 & 1 & 30 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ 3 \\ 1 \end{bmatrix} = \begin{bmatrix} 9 \\ 22 \\ 33 \\ 1 \end{bmatrix} \quad (9, 22, 33)^T$$

frame을 affine matrix로 표현

#2

- Let’s say we have a 3D point $p=(x,y,z,1)^T$ on an object (initially, object's local frame == global frame).
- The object is transformed as follows w.r.t. the object's local frame:
  - first, transformed by 4x4 matrix A,
  - then, transformed by 4x4 matrix B,
  - finally, transformed by 4x4 matrix C,
- What is the position of the point p w.r.t. global frame after these transformations? ABCp

#3

- What is the current transformation matrix used to render box4?


```
glLoadIdentity()

glPushMatrix()
glTranslate(T1)
Draw box1

glPushMatrix()
glRotate(R1)
Draw box2

glPushMatrix()
glRotate(R2)
Draw box3
glPopMatrix()

glPopMatrix()

glPushMatrix()
glRotate(R3)
Draw box4
glPopMatrix()

glPopMatrix()
```

I

T1

T1R1

T1R1R2

T1R3

9 - Quiz

#1

- Let's say that $R_x(\theta)$, $R_y(\theta)$, $R_z(\theta)$ represent rotation matrices about x, y, z axes, respectively, by θ rad.

- What is the rotation matrix for ZXY Euler angles with rotation angles of 0.2 rad about x axis, 0.5 rad about y axis, 1.0 rad about z axis?

- Use the symbols in the problem to write down the answer.

$R_z(1.0)\,R_x(0.2)\,R_y(0.5)$

#2

- Write down the 9 elements of the rotation matrix for rotation about axis v = (1,2,3)/sqrt(14) by angle 0 rad.
  - In this order: R[0,0], R[0,1], R[0,2], R[1,0], R[1,1], R[1,2], R[2,0], R[2,1], R[2,2]

rotation을 안하면 Identity matrix $\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

Rodrigues' rotation formula에 적용하면 identity 나옴

#3

- $\mathbf{R}_1$ and $\mathbf{R}_2$ are rotation matrices. Write down a rotation matrix that rotate a frame defined by $\mathbf{R}_1$ to be coincident with the frame defined by $\mathbf{R}_2$ when applied w.r.t. the frame $\mathbf{R}_1$.

만약 X가 global frame에 대해 적용된다고 하면

$$R_1 \times X = R_2$$

X = G(rotation matrix)

$$X \times R_1 = R_2$$

$$X = R_1.T \,@\, R_2$$

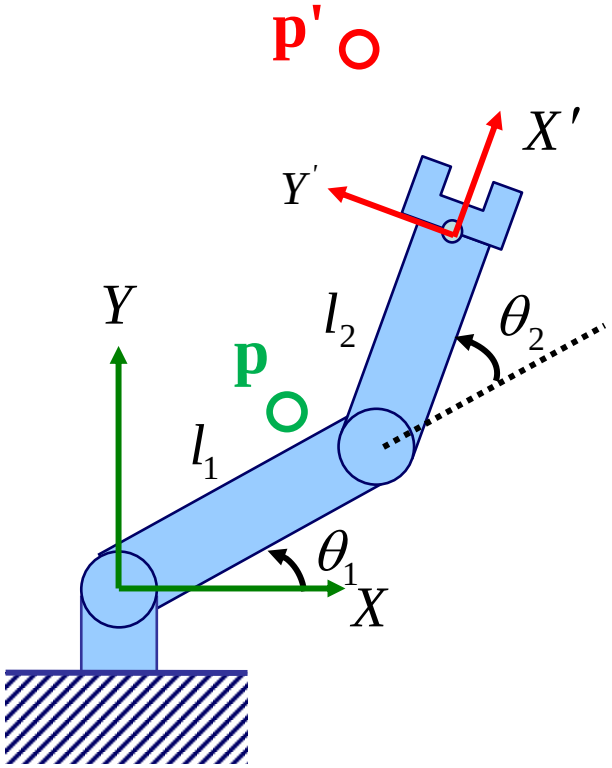
(rotation matrix의 특성인 $R^{-1} = R^T$ 때문에 $R_1^{-1} @ R_2$ 도 맞음)

역행렬 = 전치행렬

10 - Quiz

#1

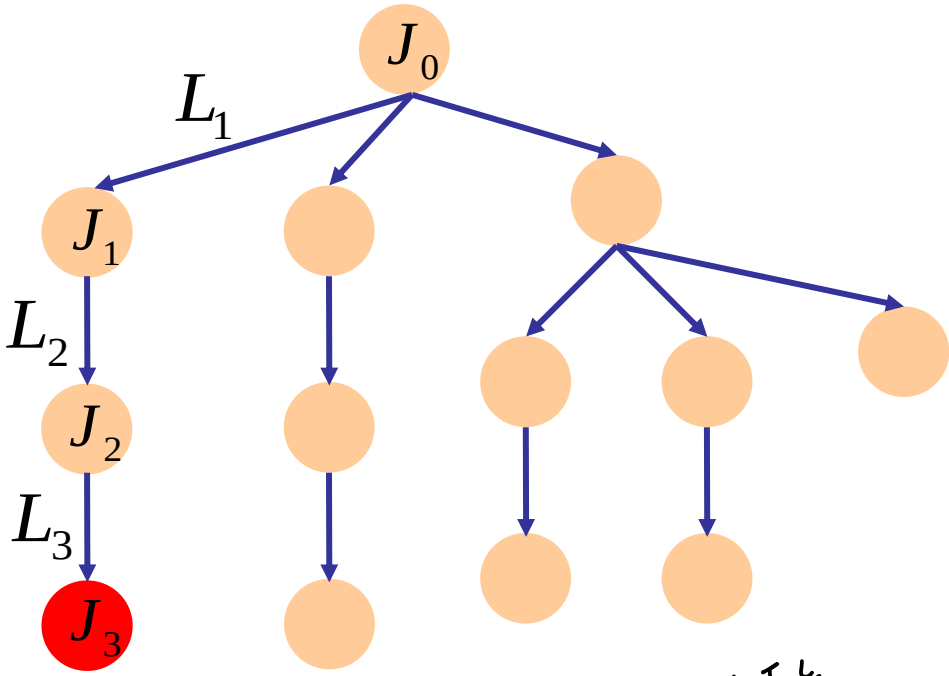
- p=(1,1) w.r.t. the frame XY, p'=(1,1) w.r.t. the frame X'Y'.
- What is the position of p' w.r.t. the frame XY?
- Use this notation:
  - R(θ): matrix representing rotation by x rad
  - $T_x(l)$: matrix representing translation matrix by l along the positive X direction



$$\begin{bmatrix} p' \\ 1 \end{bmatrix} = R(\theta_1)T_x(l_1)R(\theta_2)T_x(l_2)\begin{bmatrix} p \\ 1 \end{bmatrix}$$

#2

- The following figure describes the hierarchical structure of a model.
  - Jn: Joint transformations, pure rotations
  - Ln: Link transformations, pure translations
- What is the position of the red joint (specified by J_3) w.r.t global frame?



J_3까지 가는 forward kinematics map

원점 좌표이며 J_3는 없어도 똑같음

$J_0 L_1 J_1 L_2 J_2 L_3 (J_3) \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \vec{0}$ 3D

2D $\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$

(joint 의 위치는 joint frame 의 원점에 있다고 가정한다)

#3

$T((3,2,1))\,R_x(30)\,R_y(20)\,R_z(10)\,T((1,0,0))\,R_z(40)\,R_x(50)\,R_y(60)\,T((0,1,0))\,(0,0,0,1)^T$

- What is the position of "link2" joint w.r.t. global frame at the first frame?

- Use T(v) for translation (v is a vector), Rx(θ), Ry(θ), Rz(θ) for rotation (θ in degrees).

```
HIERARCHY
ROOT link0
{
  OFFSET  0  0  0
  CHANNELS 6 Xposition Yposition Zposition
Xrotation Yrotation Zrotation
  JOINT link1
  {
    OFFSET   1  0  0
    CHANNELS 3 Zrotation Xrotation Yrotation
    JOINT link2
    {
      OFFSET   0  1  0
      CHANNELS 3 Zrotation Xrotation Yrotation
      End Site
      {
        OFFSET   0  0  1
}}}}
MOTION
Frames:    1
Frame Time: 0.033333
3 2 1 30 20 10 40 50 60 0 0 0
```

11 - Quiz

#1

- Write down the lowest-degree polynomial x(t) that passes through two data points p_0=1 (when t=0) and p_1=-2 (when t=1).

* data point 두 개를 지나는 가장 낮은 차수의 다항식은 1차 다항식이다

$$x(t) = (1-t)\,1 + t\,(-2)$$

$$= -3t + 1$$

#2

- What is the position of a 2D point on a Hermite curve with p0=(0,0), p1=(1,1), v0=(0,0), v1=(0,0) when t=0.1?

$$\begin{bmatrix} t^3 & t^2 & t^1 & 1 \end{bmatrix} \begin{bmatrix} 2 & -2 & 1 & 1 \\ -3 & 3 & -2 & -1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} P_0 \\ P_1 \\ V_0 \\ V_1 \end{bmatrix} \begin{matrix} 0,0 \\ 1,1 \\ 0,0 \\ 0,0 \end{matrix}$$

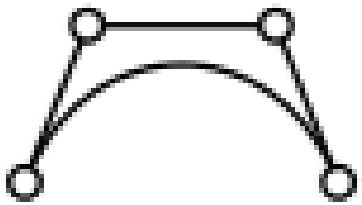
$$-0.002 + 0.03 = 0.028$$

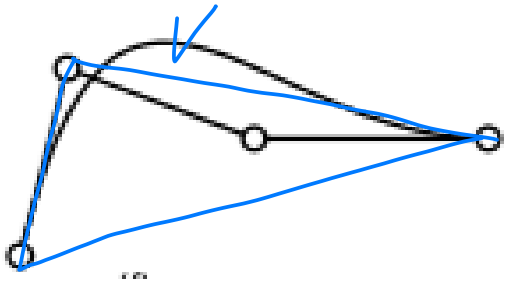
$$x(0.1) = 0.028 \times 1$$
$$y(0.1) = 0.028 \times 1$$

$$\therefore (0.028, 0.028)$$

#3

- Which one is not a Bezier curve?





  - 1) Left one
  - 2) Right one
  - 3) Both
  - 4) None of these