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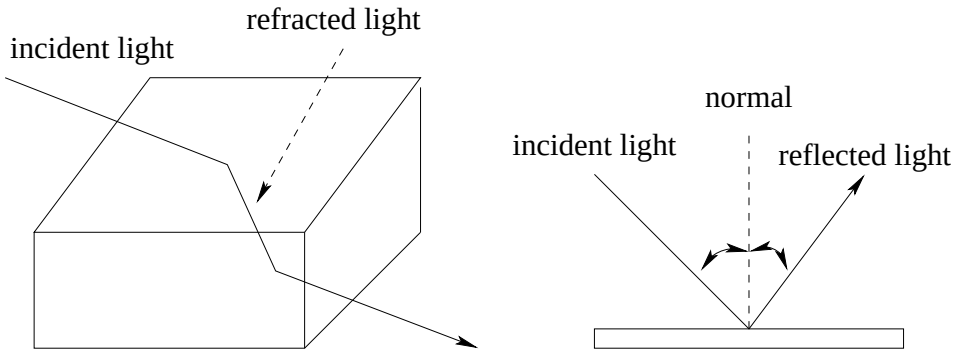

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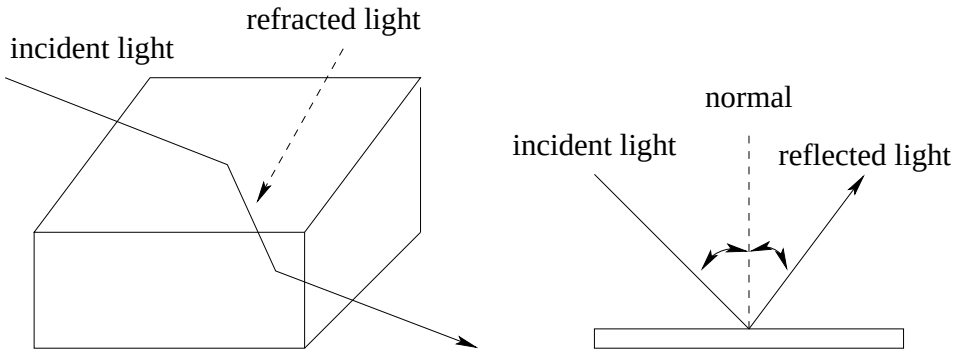

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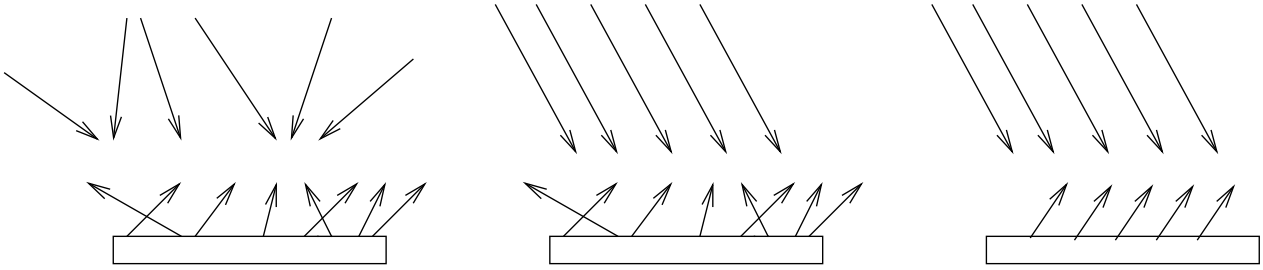
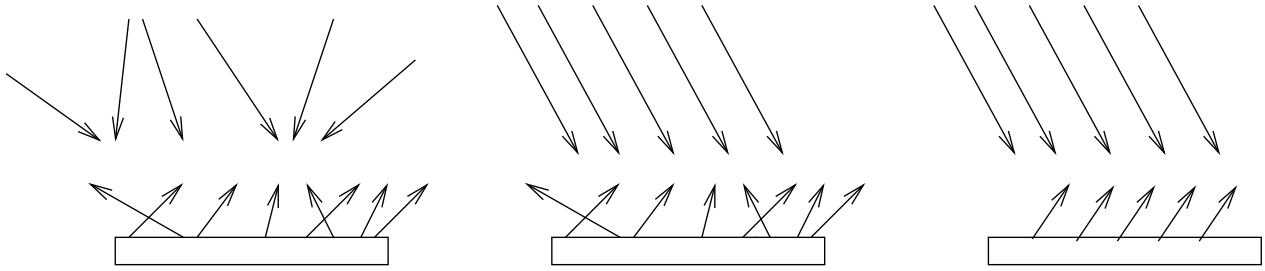


Ambient Diffuse Specular



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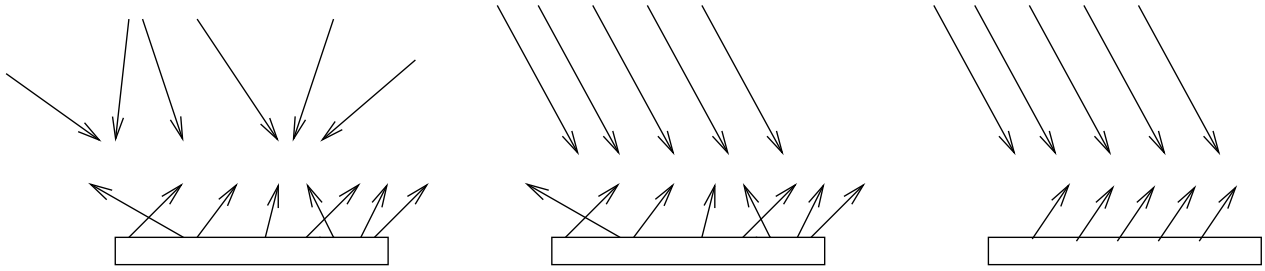

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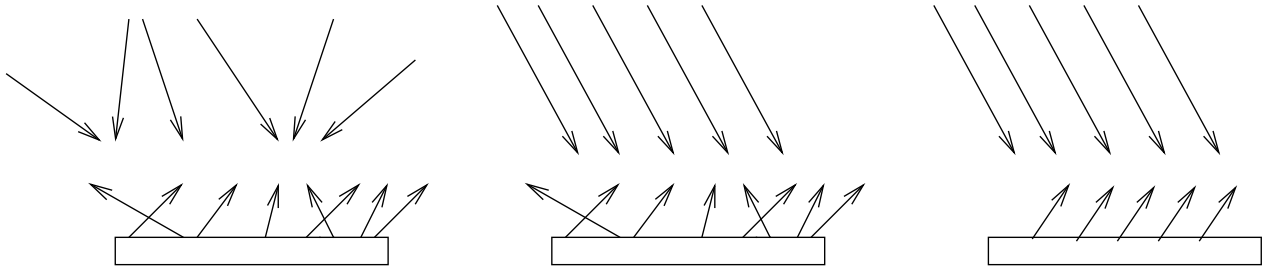

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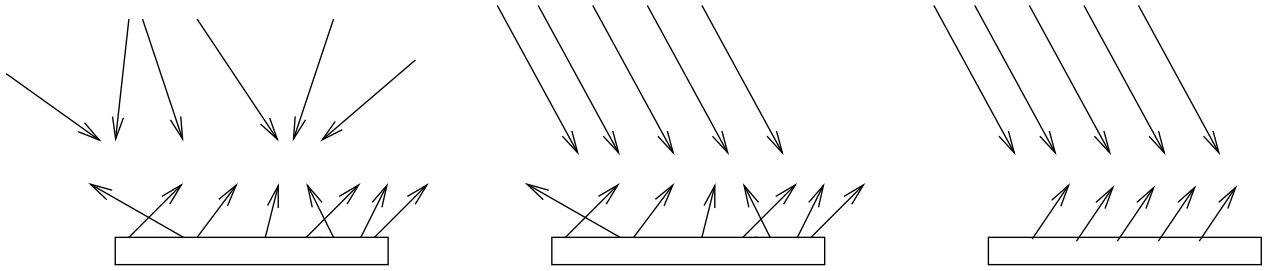

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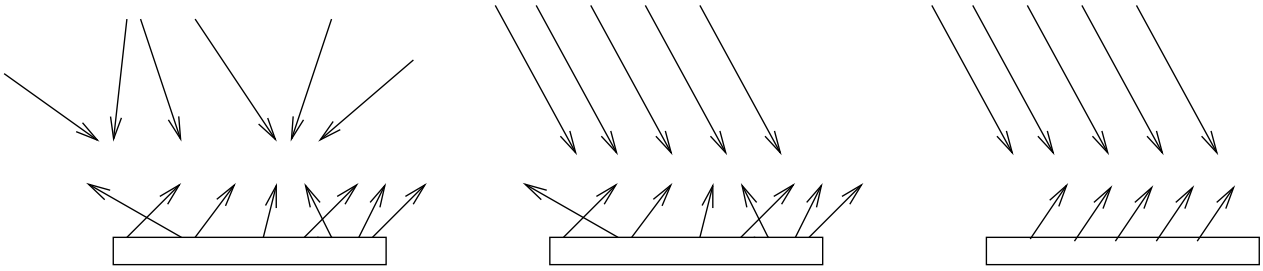

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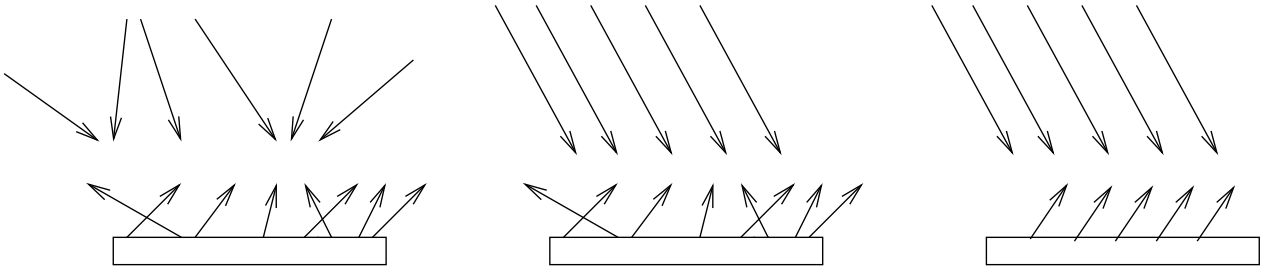

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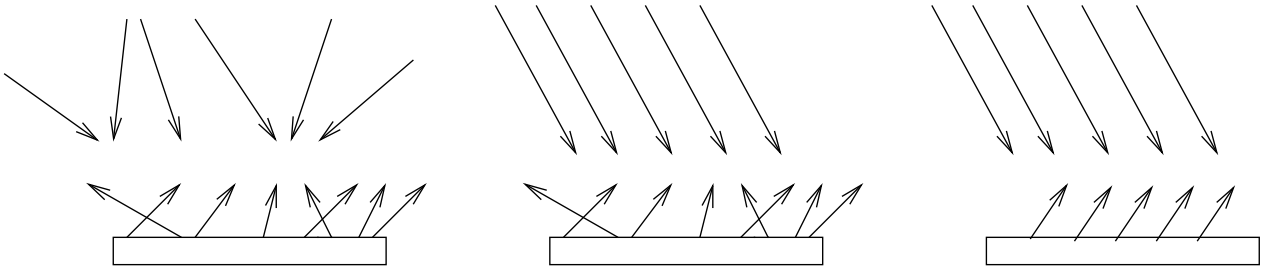

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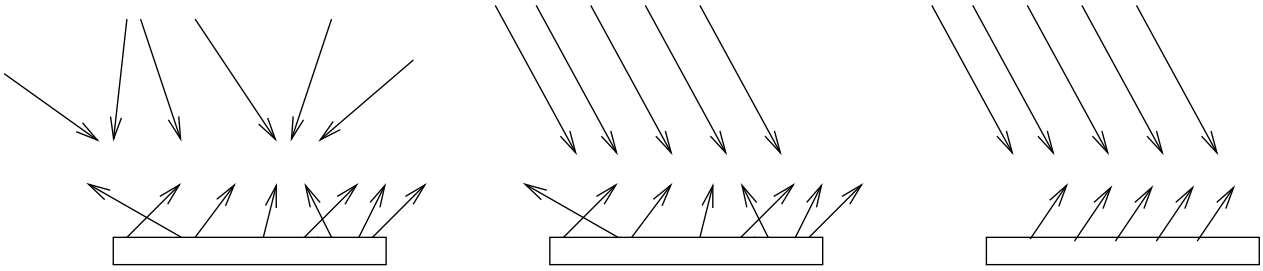

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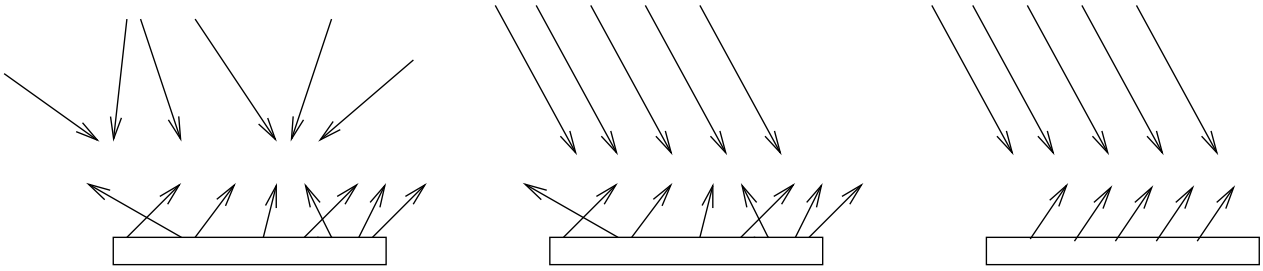

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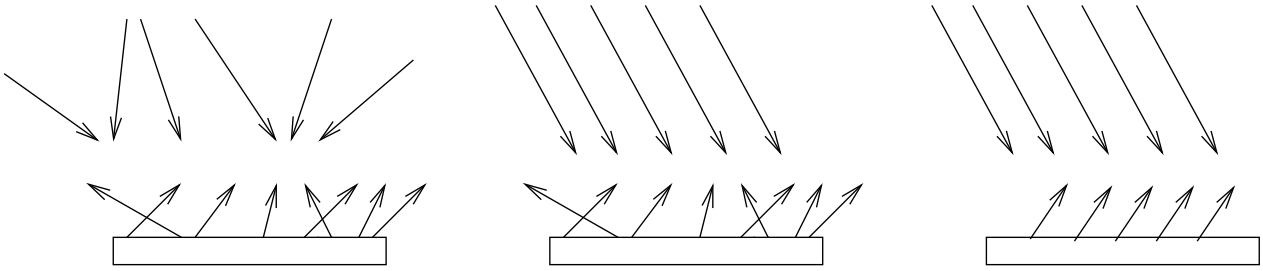

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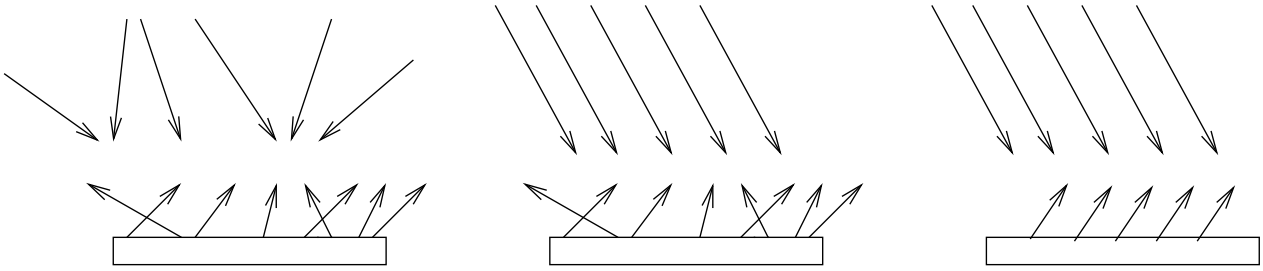

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- Create and position one or more light sources with `glLight*()`. (OpenGL supports at least 8 light sources).
- Select a lighting model; with `glLightModel*()`. This defines the level of (global) ambient light, and the effective location of the viewpoint (for the lighting calculations).
- Define the material properties for each object in the scene with `glMaterial*()`.

```
void glLight{if}(GLenum light, GLenum pname,
TYPE param);
```

```
void glLight{if}v(GLenum light, GLenum pname,
TYPE *param);
```

create the light specified by `GL_LIGHT0`, `GL_LIGHT1`, ... with properties given by `pname`; `param` specifies the set of parameters for the properties `pname`. The vector version (suffix '`v`') is used to specify an array of parameters.

Lighting models in OpenGL

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TYPE *param);
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create the light specified by `GL_LIGHT0`, `GL_LIGHT1`, ... with properties given by `pname`; `param` specifies the set of parameters for the properties `pname`. The vector version (suffix '`v`') is used to specify an array of parameters.

Parameter name	Default Value	Meaning
GL_AMBIENT	(0.0, 0.0, 0.0, 1.0)	ambient color
GL_DIFFUSE	(1.0, 1.0, 1.0, 1.0)	diffuse color
GL_SPECULAR	(1.0, 1.0, 1.0, 1.0)	specular color
GL_POSITION	(0.0, 0.0, 1.0, 0.0)	(x, y, z, w): position or direction
GL_CONSTANT_ATTENUATION	1.0	see equation following
GL_LINEAR_ATTENUATION	0.0	
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There are also other parameters which restrict a light to be a spotlight.

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These four-dimensional quantities specify the colors of the ambient, diffuse, and specular light emitted from a light source.

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The fourth value specified for `GL_POSITION` controls whether the light is directional or positional.

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Light position: `GL_POSITION`

The fourth value specified for `GL_POSITION` controls whether the light is directional or positional. A directional light is infinitely far away, such that the rays of light it emanates are

parallel (e.g. like the rays of light from the sun striking a small area on Earth).

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where d is the distance from the light source, and k_c, k_l, and k_q are the constant, linear, and quadratic attenuation terms.

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  glEnable(GL_LIGHTING);
  glEnable(GL_LIGHT0);
  glEnable(GL_DEPTH_TEST);
}
```

```
void display(void)
{
  glClear (GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
  glutSolidSphere (1.0, 20, 16);
  glFlush ();
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This example, `movelight.c`, illustrates how the position of a light is transformed by the MODELVIEW matrix:

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   glClear (GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
   glPushMatrix ();

   glPushMatrix ();
   glRotated ((GLdouble) spin, 1.0, 0.0, 0.0);
   glLightfv (GL_LIGHT0, GL_POSITION, position);
   glTranslated (0.0, 0.0, 1.5);
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   glDisable (GL_LIGHTING);   /* Draw an unlit wire cube at
   glColor3f (0.0, 1.0, 1.0); /* the position of the light.
   glutWireCube (0.1);
   glEnable (GL_LIGHTING);
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   glLightfv (GL_LIGHT0, GL_POSITION, position);
   glTranslated (0.0, 0.0, 1.5);

   glDisable (GL_LIGHTING);   /* Draw an unlit wire cube at
   glColor3f (0.0, 1.0, 1.0); /* the position of the light.
   glutWireCube (0.1);
   glEnable (GL_LIGHTING);
   glPopMatrix ();

   glutSolidTorus (0.275, 0.85, 8, 15);
```

```
void display(void)
{
   GLfloat position[] = { 0.0, 0.0, 1.5, 1.0 };

   glClear (GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
   glPushMatrix ();

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   glRotated ((GLdouble) spin, 1.0, 0.0, 0.0);
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```
void reshape (int w, int h)
{
   glViewport (0, 0, (GLsizei) w, (GLsizei) h);
   glMatrixMode (GL_PROJECTION);
   glLoadIdentity();
   gluPerspective(40.0, (GLfloat) w/(GLfloat) h, 1.0, 20.0)
   glMatrixMode(GL_MODELVIEW);
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   gluLookAt (0.0, 0.0, 5.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0);
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}


void mouse(int button, int state, int x, int y) {
   switch (button) {
      case GLUT_LEFT_BUTTON:
         if (state == GLUT_DOWN) {
            spin = (spin + 30) % 360;
            glutPostRedisplay();
         }
         break;
      default:
         break;
   }
}
```

```
void keyboard(unsigned char key, int x, int y) {
   switch (key) {
      case 27:
         exit(0);
         break;
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int main(int argc, char** argv)
{
   glutInit(&argc, argv);
   glutInitDisplayMode (GLUT_SINGLE | GLUT_RGB | GLUT_DEPTH
   glutInitWindowSize (500, 500);
   glutInitWindowPosition (100, 100);
   glutCreateWindow (argv[0]);
   init ();
   glutDisplayFunc(display);
   glutReshapeFunc(reshape);
   glutMouseFunc(mouse);
   glutKeyboardFunc(keyboard);
   glutMainLoop();
   return 0;
}
```

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In the following, `GL_LIGHT_MODEL` precedes the parameter name:

Parameter name	Default Value	Meaning
`_AMBIENT`	(0.2, 0.2, 0.2, 1.0)	ambient intensity for scene
`_LOCAL_VIEWER`	0.0	how specular reflection angles are calculated
`_TWO_SIDE`	0.0	one sides or two sided lighting
`_COLOR_CONTROL`	`GL_SINGLE_COLOR`	whether specular color is calculated separately

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Shading — what happens between vertices

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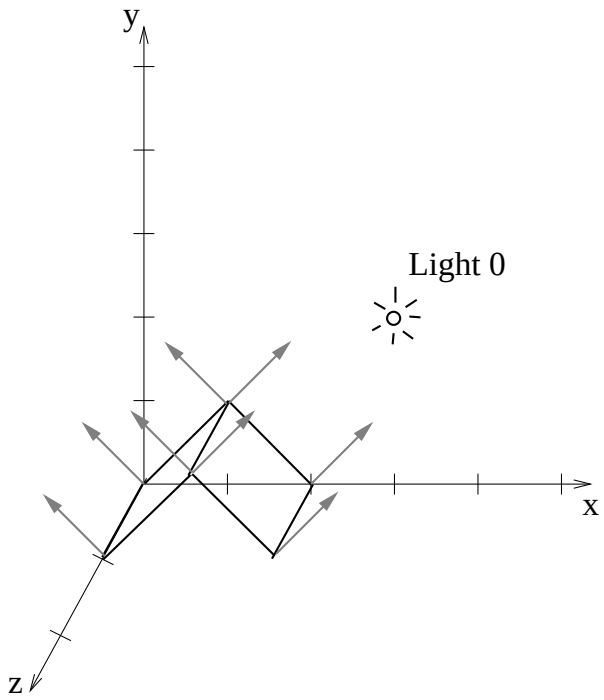

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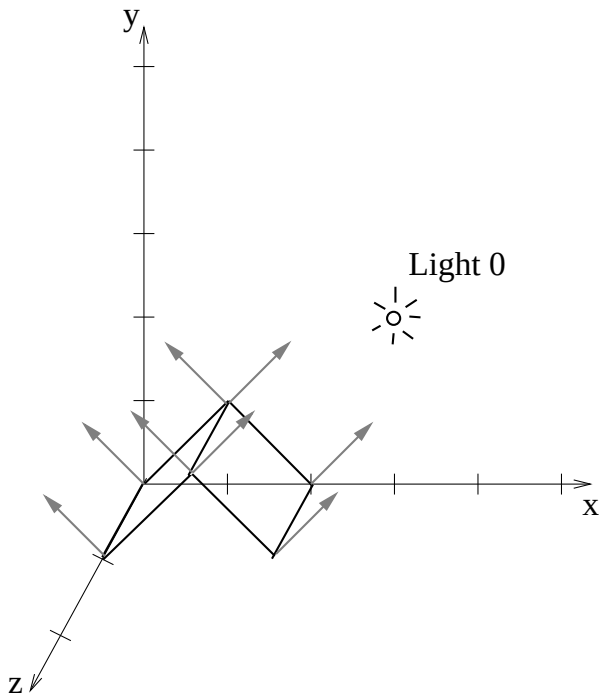

The diffuse light source illuminates the right polygon much more than the left, and the transition in illumination is abrupt.

A more gentle transition in illumination can be enabled by specifying normal vectors as follows:

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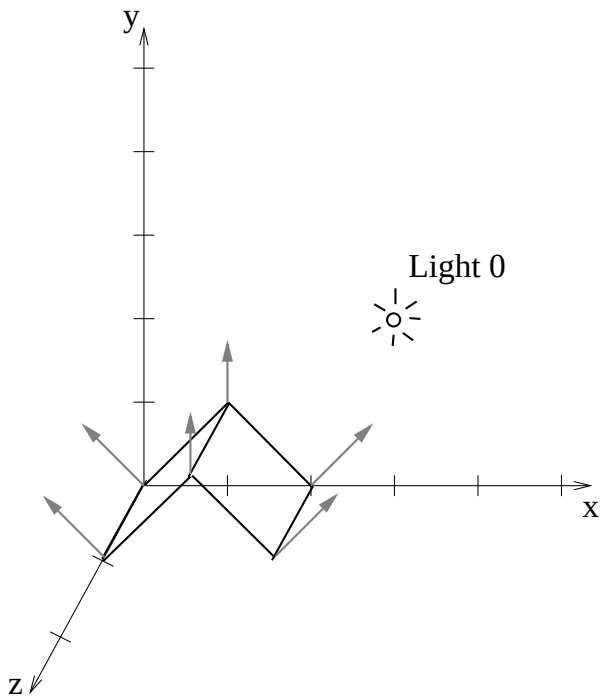

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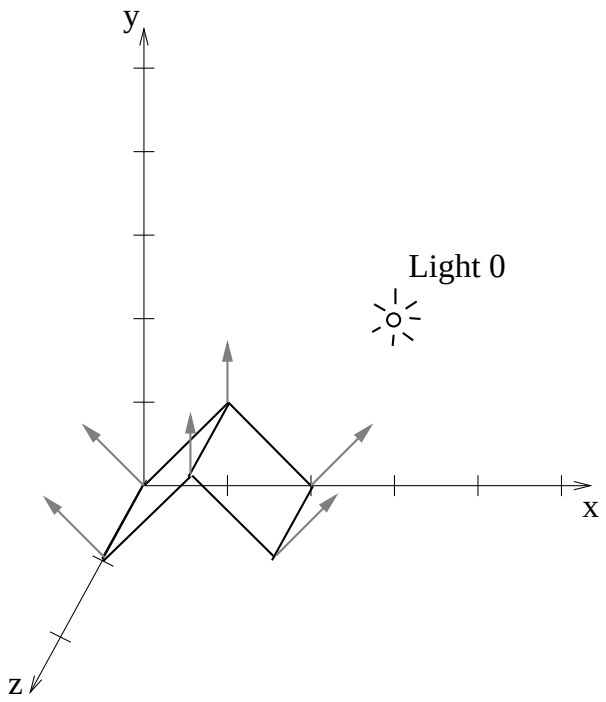

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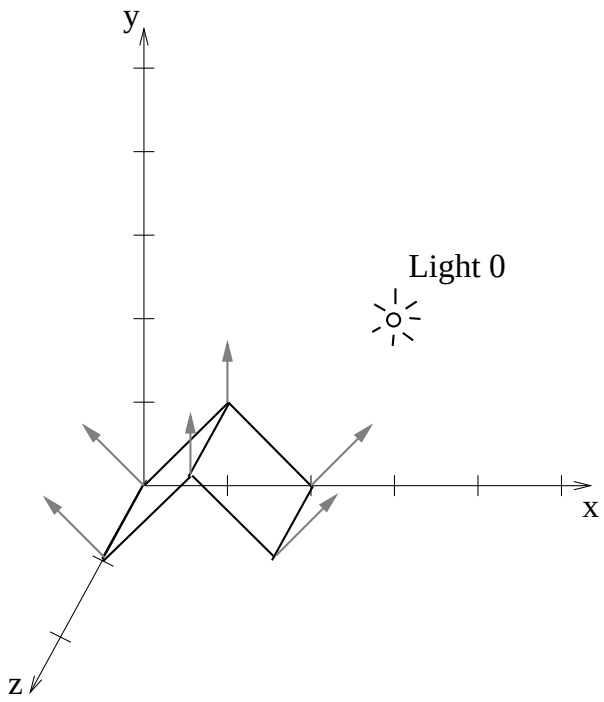

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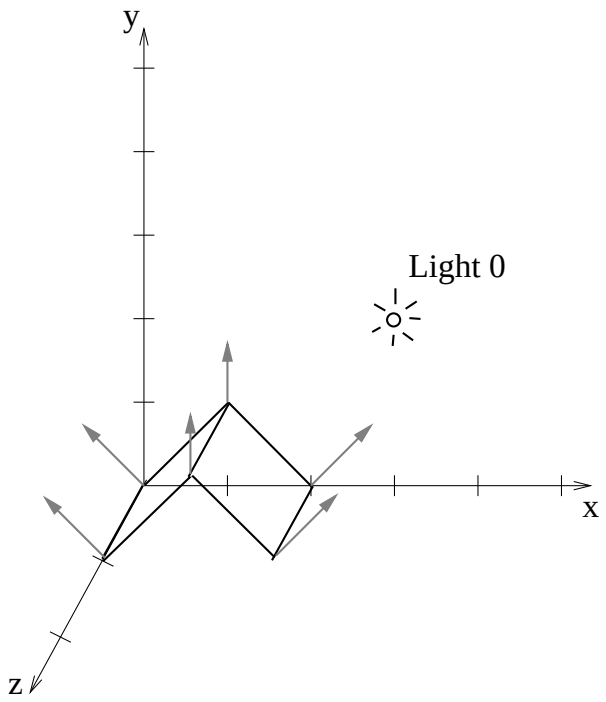

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The following is the most relevant code from `tent.c`...

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void display(void) {
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 /* We require unit length normal vectors.  For a vector with 2 non-zero
  * elements of equal magnitude, the magnitude of both elements should be equal
  * to 1 / sqrt(2) = 0.7071 for the vector to be of unit length. */
   double l = 0.7071;
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 /* Set up the light in a position perpendicular to the right polygon. */
   GLfloat light_position[] = { 3.0, 2.0, 0.0, 1.0 };
   glLightfv(GL_LIGHT0, GL_POSITION, light_position);
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 /* Draw the tent. */
   glBegin(GL_QUADS);
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   glBegin(GL_QUADS);
    /* Left side. */
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  * to 1 / sqrt(2) = 0.7071 for the vector to be of unit length. */
   double l = 0.7071;

 /* Set up the light in a position perpendicular to the right polygon. */
   GLfloat light_position[] = { 3.0, 2.0, 0.0, 1.0 };
   glLightfv(GL_LIGHT0, GL_POSITION, light_position);
      .
      .
      .
 /* Draw the tent. */
   glBegin(GL_QUADS);
    /* Left side. */
      glNormal3f(-l, l, 0);
      glVertex3f(0, 0, 0);
      glVertex3f(0, 0, 1);
      if ( topUp ) glNormal3f(0, 1, 0);
      glVertex3f(1, 1, 1);
      glVertex3f(1, 1, 0);

    /* Right side. */
      glNormal3f(l, l, 0);
      glVertex3f(2, 0, 1);
      glVertex3f(2, 0, 0);
      if ( topUp ) glNormal3f(0, 1, 0);
      glVertex3f(1, 1, 0);
      glVertex3f(1, 1, 1);
   glEnd();
```

```
void display(void) {
      .
      .
      .
 /* We require unit length normal vectors.  For a vector with 2 non-zero
  * elements of equal magnitude, the magnitude of both elements should be equal
  * to 1 / sqrt(2) = 0.7071 for the vector to be of unit length. */
   double l = 0.7071;

 /* Set up the light in a position perpendicular to the right polygon. */
   GLfloat light_position[] = { 3.0, 2.0, 0.0, 1.0 };
   glLightfv(GL_LIGHT0, GL_POSITION, light_position);
      .
      .
      .
 /* Draw the tent. */
   glBegin(GL_QUADS);
    /* Left side. */
      glNormal3f(-l, l, 0);
      glVertex3f(0, 0, 0);
      glVertex3f(0, 0, 1);
      if ( topUp ) glNormal3f(0, 1, 0);
      glVertex3f(1, 1, 1);
      glVertex3f(1, 1, 0);

    /* Right side. */
      glNormal3f(l, l, 0);
      glVertex3f(2, 0, 1);
      glVertex3f(2, 0, 0);
      if ( topUp ) glNormal3f(0, 1, 0);
      glVertex3f(1, 1, 0);
      glVertex3f(1, 1, 1);
   glEnd();
      .
      .
      .
}
```

```
void init (void)
{
   glClearColor (0.0, 0.0, 0.0, 0.0);
   glShadeModel (GL_SMOOTH);

 /* Set up material properties. */
   GLfloat mat_ambient[] = { 1.0, 0.0, 0.0, 1.0 };
   GLfloat mat_diffuse[] = { 0.0, 1.0, 0.0, 1.0 };
   glMaterialfv(GL_FRONT, GL_AMBIENT, mat_ambient);
   glMaterialfv(GL_FRONT, GL_DIFFUSE, mat_diffuse);
   glMaterialf(GL_FRONT, GL_SHININESS, 50.0 ); /* No effect if specular == 0 */
   glEnable(GL_LIGHTING);
   glEnable(GL_LIGHT0);
   glEnable(GL_DEPTH_TEST);
}
```

```
void key( unsigned char k, int x, int y )
{
   switch (k) {
   case 27:  /* Escape */
     exit(0);
     break;
   case 's':
     specular = !specular;
     if ( specular ) {
        GLfloat mat_specular[] = { 0.0, 0.0, 1.0, 1.0 };
        glMaterialfv(GL_FRONT, GL_SPECULAR, mat_specular);
     } else {
        GLfloat mat_specular[] = { 0.0, 0.0, 0.0, 1.0 };
        glMaterialfv(GL_FRONT, GL_SPECULAR, mat_specular);
     }
     break;
   case 't':
     topUp = !topUp;
     break;
   default:
     return;
   }
   glutPostRedisplay();
}
```